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**Conseil suisse de la science CSS**

# Appréciation de l'impact du programme national d'encouragement Nano-Tera.ch

Rapport et recommandations du Conseil suisse de la science CSS sur mandat du Secrétariat d'Etat à la formation, à la recherche et à l'innovation SEFRI

Rapport final accepté à la séance plénière des 4-5 juin 2018.

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**Table**

## Résumé

En septembre 2016, le Secrétariat d'Etat à la formation, à la recherche et à l'innovation (SEFRI) a confié au Conseil suisse de la science (CSS) le mandat d'apprécier les effets de Nano-Tera.ch, programme de recherche soutenu de 2008 à 2016 par un financement fédéral à hauteur de 120 Mio CHF. Le mandat comportait également un volet consacré à l'appréciation des effets du programme SystemsX.ch, traité séparément par le CSS. Conformément au mandat, l'appréciation porte sur les impacts scientifique, éducationnel, économique, sociétal et institutionnel. A quoi s'ajoute la mise en perspective de Nano-Tera.ch dans le système de la formation, de la recherche, et de l'innovation (FRI). L'appréciation du CSS se fonde sur un rapport d'auto-évaluation établi par le consortium de Nano-Tera.ch, sur une appréciation indépendante par un panel d'experts internationaux, sur une étude externe du transfert de savoir et de technologies (TST) dans Nano-Tera.ch, sur une série d'entretiens du CSS avec les acteurs-clé, ainsi que sur la documentation reçue et disponible.

Il ressort de l'analyse menée par le CSS que Nano-Tera.ch a produit une recherche d'excellente qualité. La communauté de recherche en sciences de l'ingénieur, principalement issue des écoles polytechniques fédérales, a été orientée vers davantage de collaborations interdisciplinaire et interinstitutionnelle, et vers l'application. La formation de plus de 360 doctorants dans des domaines-clé pour la recherche scientifique et pour l'économie témoigne de l'impact éducationnel. Au niveau économique, Nano-Tera.ch a créé plusieurs start-ups prometteuses ou déjà confirmées, ainsi que des démonstrateurs et prototypes. Ces résultats sont dus à la qualité intrinsèque des projets soutenus, à la dotation financière globale importante, et au rôle du panel du Fonds national suisse pour l'encouragement de la recherche scientifique (FNS) dans la sélection des projets et dans leur suivi, en particulier lors du passage de la phase I (2008-2012) à la phase II (2013-2016).

L'initiative Nano-Tera.ch a rencontré différentes difficultés dans la formulation des objectifs stratégiques et dans leur mise en œuvre, marquée par la prise plutôt tardive de mesures d'encouragement ciblé. Par exemple, le TST n'a pas fait l'objet d'une définition explicite et était laissé à l'appréciation des chercheurs. Le programme de soutien au TST (Gateway) n'a été lancé qu'en 2015, de même que le soutien ciblé à la formation doctorale (NextSteps). Dans les deux cas, l'introduction tardive et la dotation financière réduite ont limité le potentiel d'efficacité. Les impacts sociétal et institutionnel ne comptaient pas parmi les objectifs stratégiques initiaux de Nano-Tera.ch, ce qui explique l'absence de mesures spécifiques prises dans ces dimensions. Des impacts indirects sont constatés, sans qu'un lien de causalité ne puisse être démontré. Par exemple, Nano-Tera.ch a contribué à la formulation du programme «Bridge», lequel se fonde aussi sur d'autres expériences nationales et internationales.

Suite aux prises de position de différents acteurs du domaine FRI, la base légale pour de telles initiatives se situe depuis 2014 dans la Loi sur l'encouragement de la recherche et de l'innovation (LERI). Compte tenu de ce changement législatif et suite à l'appréciation de Nano-Tera.ch, le CSS recommande au SEFRI d'examiner dans quelle mesure les dispositions légales actuelles (art. 41, al. 5 et 6 LERI) garantissent le respect de principes clairs quant à la formulation, au choix et à l'organisation interne des initiatives financées à ce titre. Considérant que Nano-Tera.ch est marqué par une forte orientation vers l'application socio-économique, le CSS recommande en outre, dans la mise en œuvre de telle initiatives, de veiller à :

- Encourager l'ensemble de la chaîne de création de valeur de manière à créer une valeur ajoutée par rapport aux dispositifs d'encouragement existants;
- Formuler les objectifs stratégiques en accord avec les parties prenantes, le cas échéant en associant le secteur privé et/ou des utilisateurs finaux à la sélection des projets et au suivi de la mise en œuvre;
- Etablir dès le début de l'initiative des concepts de mesures opérationnelles en accord avec les objectifs, en particulier sous l'angle scientifique, éducationnel, socio-économique, institutionnel et international;
- Disposer d'une gouvernance, d'un pilotage et de règles de monitoring en accord avec les parties prenantes et correspondant aux standards en vigueur;
- Prévoir un dispositif de nature structurelle pour s'assurer que la valeur ajoutée de l'initiative se perpétue au sein des partenaires institutionnels et disciplinaires après la fin du financement fédéral.

## Zusammenfassung

Im September 2016 hat das Staatssekretariat für Bildung, Forschung und Innovation (SBFI) dem Schweizerischen Wissenschaftsrat (SWR) den Auftrag erteilt, die Auswirkungen des Forschungsprojekts Nano-Tera.ch zu beurteilen. Dieses Projekt wurde von 2008 bis 2016 mit einem Bundesbeitrag in der Höhe von 120 Mio. CHF unterstützt. Teil des Auftrags war es auch, die Auswirkungen des vom SWR separat behandelten Programms SystemsX.ch zu untersuchen. Evaluiert werden sollten gemäss dem Auftrag die wissenschaftlichen, pädagogischen, wirtschaftlichen, gesellschaftlichen und institutionellen Auswirkungen. Ausserdem ging es darum, Nano-Tera.ch in das Bildungs-, Forschungs- und Innovationssystem (BFI-System) einzuordnen. Die Beurteilung des SWR stützt sich auf einen Selbstbeurteilungsbericht des Konsortiums von Nano-Tera.ch, eine unabhängige Evaluation eines internationalen Expertenpanels, eine externe Studie zum Wissens- und Technologietransfer (WTT) im Rahmen von Nano-Tera.ch, eine Reihe von Gesprächen des SWR mit den Hauptakteuren sowie die erhaltene und verfügbare Dokumentation.

Die Analyse des SWR zeigt, dass die Forschung von Nano-Tera.ch qualitativ hervorragend ist. Die Forschungsgemeinschaft der Ingenieurwissenschaften, die hauptsächlich aus den Eidgenössischen Technischen Hochschulen stammt, wurde dadurch stärker auf die interdisziplinäre und interinstitutionelle Zusammenarbeit und auf die Anwendung ausgerichtet. Die Ausbildung von mehr als 360 Doktorandinnen und Doktoranden in Bereichen, die für die wissenschaftliche Forschung und die Wirtschaft von zentraler Bedeutung sind, verdeutlicht die pädagogische Wirkung des Projekts. Auf wirtschaftlicher Ebene hat Nano-Tera.ch mehrere vielversprechende oder mittlerweile etablierte Start-ups sowie Demonstratoren und Prototypen hervorgebracht. Zu verdanken sind diese Ergebnisse der Qualität der unterstützten Projekte an sich, der grosszügigen Mittelausstattung und der Rolle des Panels des Schweizerischen Nationalfonds (SNF) bei der Auswahl und Begleitung der Projekte, insbesondere beim Übergang von der Phase I (2008−2012) zur Phase II (2013−2016).

Bei der Formulierung der strategischen Ziele und deren Umsetzung bekundete die Initiative Nano-Tera.ch verschiedene Schwierigkeiten, wobei eher spät gezielte Unterstützungsmassnahmen getroffen wurden. So wurde der WTT beispielsweise nicht explizit definiert und vielmehr der Einschätzung der Forschenden überlassen. Das Programm zur Unterstützung des WTT (Gateway) wurde erst 2015 lanciert, ebenso die gezielte Unterstützung der Doktoratsausbildung (NextSteps). In beiden Fällen schränkten die späte Einführung und die begrenzten finanziellen Mittel das Effizienzpotenzial ein. Die gesellschaftlichen und institutionellen Auswirkungen gehörten ursprünglich nicht zu den strategischen Zielen von Nano-Tera.ch, weshalb in diesen Bereichen keine spezifischen Massnahmen getroffen wurden. Es gab indirekte Auswirkungen, ohne dass sich jedoch eine kausale Beziehung aufzeigen liess. So trug Nano-Tera.ch beispielsweise zur Erarbeitung des Programms «Bridge» bei, das auch auf anderen nationalen und internationalen Erfahrungen beruht.

Aufgrund der Stellungnahmen von verschiedenen Akteure des BFI-Bereichs ist die gesetzliche Grundlage für solche Initiativen seit 2014 im Forschungs- und Innovationsförderungsgesetz (FIFG) zu finden. Angesichts dieser rechtlichen Änderung und nach der Evaluation von Nano-Tera.ch empfiehlt der SWR dem SBFI zu prüfen, inwieweit die aktuellen Gesetzesbestimmungen (Art. 41 Abs. 5 und 6 FIFG) die Einhaltung klarer Grundsätze betreffend Formulierung, Wahl und interne Organisation der zu diesem Zweck finanzierten Initiativen sicherstellt. Zumal Nano-Tera.ch stark auf die sozioökonomische Anwendung ausgerichtet ist, empfiehlt der SWR überdies, bei der Umsetzung solcher Initiativen auf folgende Punkte zu achten:

- Unterstützung der gesamten Wertschöpfungskette, um gegenüber den bestehenden Förderinstrumenten einen Mehrwert zu schaffen;
- Formulierung der strategischen Ziele im Einklang mit den beteiligten Akteuren, gegebenenfalls unter Einbezug des Privatsektors und/oder der Endnutzerinnen und -nutzer in die Auswahl der Projekte und die Begleitung der Umsetzung;
- Erarbeiten von Konzepten für operative Massnahmen ab Beginn der Initiative, im Einklang mit den Zielen, insbesondere in wissenschaftlicher, pädagogischer, sozioökonomischer, institutioneller und internationaler Hinsicht;

- Festlegen einer Governance-Struktur, von Steuerung und Monitoring im Einvernehmen mit den beteiligten Akteuren und entsprechend den geltenden Standards;
- Einführen von strukturellen Vorkehrungen, um sicherzustellen, dass der Mehrwert der Initiative bei den institutionellen und disziplinären Partnern nach dem Auslaufen der Bundesfinanzierung weiterbesteht.

## A. Recommandations du Conseil suisse de la science

### 1. Garantir l'efficacité de la mise en œuvre de l'art. 41, al. 5 et 6 LERI

Parce qu'elles dépassent, sur le plan financier et organisationnel, les tâches ordinaires d'encouragement des institutions chargées d'encourager la recherche, les initiatives planifiées et coordonnées par le Conseil fédéral au titre de l'art. 41, al. 5 et 6 LERI, doivent être exceptionnelles. Il n'en reste pas moins qu'elles doivent aussi reposer sur des principes clairs, en particulier quant à la formulation et au choix de telles initiatives, et quant aux règles d'organisation interne, en particulier la procédure de sélection des projets soutenus. Le CSS recommande au SEFRI d'examiner l'efficacité des dispositions légales actuelles (art. 41, al. 5 et 6 LERI) pour garantir une telle mise en œuvre.

### 2. Encourager l'ensemble de la chaîne de création de valeur

Les initiatives orientées vers l'application socio-économique et financées au titre de l'art. 41, al. 5 LERI doivent mobiliser une vision claire de l'encouragement couvrant l'ensemble de la chaîne de création de valeur, de la recherche et développement jusqu'à la valorisation sur le marché. L'encouragement doit favoriser les synergies entre les critères de sélection des projets soutenus au sein de l'initiative et les mesures ciblées (p. ex. TST, formation doctorale, encouragement de l'interdisciplinarité, mesures structurelles, etc.), de manière à créer une valeur ajoutée par rapport aux dispositifs d'encouragement existants.

### 3. Formuler les objectifs stratégiques en accord avec les parties prenantes

Les objectifs stratégiques, le concept de mise en œuvre, l'organisation et la procédure de sélection des projets soutenus au sein de l'initiative doivent reposer sur un consensus entre les parties prenantes telles que définies dans la LERI (art. 41, al. 6), à savoir les organes de recherche, la CSHE et le CEPF. En cas de prédominance de l'orientation appliquée et/ou sociétale, le secteur privé et/ou des utilisateurs finaux doivent participer à la définition des objectifs stratégiques, à la sélection des projets soutenus, ainsi qu'au suivi de la mise en œuvre, par exemple en intégrant un *Scientific and economic advisory board*.

### 4. Etablir des concepts de mesures opérationnelles en accord avec les objectifs

Pour les initiatives orientées vers l'application socio-économique, les mesures opérationnelles aux plans scientifiques, socio-économiques et structurels, ainsi qu'en matière de positionnement international, d'encouragement de la formation doctorale et du TST, doivent être définies par les porteurs de l'initiative en accord avec les objectifs correspondants. Les projets soutenus doivent disposer d'un concept de TST explicite, intégrant le cas échéant des partenaires industriels resp. des utilisateurs finaux. La mobilisation d'*Industrial mentors* pour tous les doctorants et les post-docs, y compris les PIs et Co-PIs, doit être examinée. Des mesures propres à favoriser l'interdisciplinarité durant la réalisation du programme et lors de la publication doivent être envisagées.

### 5. Gouvernance, pilotage et monitoring

La gouvernance, le pilotage et le monitoring doivent refléter le consensus préalable entre les parties prenantes et correspondre aux standards en vigueur, y compris en matière de règlement des conflits d'intérêt. Les mesures ciblées, en particulier dans les domaines de la formation doctorale et du TST (pour les initiatives orientées vers l'application socio-économique), doivent bénéficier d'une dotation budgétaire suffisante pour favoriser la prise de mesures dès le début de l'initiative. Le monitoring sert au pilotage stratégique de l'initiative; il peut, le cas échéant, reposer sur des indicateurs spécifiques. La qualité du monitoring détermine non seulement la mise en œuvre d'un programme, mais aussi son appréciation *ex post*.

### 6. Favoriser la durabilité des effets à moyen et long terme

Le caractère exceptionnel des initiatives financées au titre de l'art. 41 al. 5 et 6 LERI doit s'accompagner d'une exigence de durabilité des effets à moyen et long terme. L'initiative doit prévoir un dispositif de nature structurelle pour s'assurer que la valeur ajoutée de l'initiative se perpétue au sein des partenaires institutionnels et disciplinaires après la fin du financement fédéral.

# B. Rapport du Conseil suisse de la science

## 1. Introduction

### *1.1 Mandat*

En septembre 2016, le Secrétariat d'Etat à la formation, à la recherche et à l'innovation (SEFRI) a confié au Conseil suisse de la science (CSS) le mandat d'apprécier les effets (*Wirkungsprüfung*) de Nano-Tera.ch[1], «l'initiative suisse pour les sciences de l'ingénieur et de l'information»[2]. Ce programme de recherche de portée nationale a bénéficié de 2008 à 2016 d'un financement fédéral à hauteur de 120 Mio CHF. Le mandat du SEFRI comportait également un volet consacré à l'appréciation des effets du programme SystemsX.ch[3]. La procédure générale est la même pour chacun des deux programmes sous revue, mais le calendrier et les dimensions à apprécier sont différents.

Selon le cadre de mise en œuvre du mandat du SEFRI[4], la procédure consiste en l'établissement d'un rapport d'auto-évaluation par le consortium constitutif de Nano-Tera.ch, suivi d'une appréciation externe menée par le CSS. Celle-ci fait intervenir une appréciation indépendante par un panel d'experts internationaux (désormais: panel d'experts CSS). L'appréciation porte sur les cinq dimensions d'impact suivantes: scientifique, éducationnel, économique, sociétal et institutionnel. A quoi s'ajoute une vue plus large, que le CSS a conduite par la mise en perspective de l'appréciation globale de Nano-Tera.ch dans le système FRI.

### *1.2 Démarche*

L'analyse CSS a été conduite par un groupe de travail réunissant les Prof. Dr Fariba Moghaddam et Jean-Marc Triscone, membres du Conseil. Le secrétariat les a assistés dans leur travail. Conformément au mandat du SEFRI, le CSS a mis sur pied en avril 2017 le panel d'experts CSS selon un processus de sélection en concertation avec Nano-Tera.ch et le Fonds national suisse de la recherche scientifique (FNS)[5]. Les membres du panel d'experts CSS sont:

- Prof. Dr Jeremy Baumberg, Director of the Nanophotonics Centre, University of Cambridge;
- Prof. Dr Rudy Lauwereins, Vice-President IMEC;
- Prof. Dr Mark Lundstrom, Professor of Electrical and Computer Engineering, Purdue University.

Après la remise du rapport d'auto-évaluation de Nano-Tera.ch fin octobre 2017[6], le CSS a organisé une rencontre à Berne (*Site Visit*) les 13-14 novembre 2017 entre le groupe de travail CSS, le panel d'experts CSS, une délégation de Nano-Tera.ch et une délégation du FNS[7]. Cette rencontre a permis au panel d'experts CSS d'échanger de manière directe avec les représentants de Nano-Tera.ch et du FNS, afin de répondre aux questions posées par le CSS, sur la base du mandat du SEFRI[8]. Pour rappel, le FNS n'est pas objet de l'appréciation de Nano-Tera.ch, mais sa participation à la mise en œuvre de l'initiative requérait qu'il soit représenté auprès du panel d'experts CSS. Le rapport final du panel d'experts CSS se fonde sur ces échanges, sur le rapport d'auto-évaluation de Nano-Tera.ch et sur différents

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* Toutes les adresses de liens internet ont été vérifiées le 21 août 2018.

[1] Annexe A.

[2] Selon la formule utilisée par le Conseil des écoles polytechniques fédérales (CEPF) en 2007: CEPF, Informations de la séance du Conseil des EPF, Berne, le 3 octobre 2007. Cf. https://www.ethrat.ch/sites/default/files/F-Informations_de_la_seance_du_CEPF_02031007.pdf. Entre 2008 et 2016, Nano-Tera.ch est qualifié tantôt d'initiative, tantôt de projet national de coopération. Depuis 2014, la base légale de tels projets se situe dans l'art. 41, al. 5 et 6, de la Loi fédérale sur l'encouragement de la recherche et de l'innovation (LERI) du 14 décembre 2012, RS 420.1, https://www.admin.ch/opc/fr/classified-compilation/20091419/index.html, et la désignation varie, selon les langues nationales, entre «initiative» et «projet». Afin de faciliter la lecture dans le cadre du présent rapport, Nano-Tera.ch est qualifié d'initiative ou de programme, sans que ces formulations n'aient de valeur normative.

[3] Le rapport final du CSS sur SystemsX.ch (SWR 2018) a été adressé au SEFRI.

[4] Annexe A.

[5] Les membres du panel d'experts CSS ont tous pris connaissance des «Terms of reference» reproduits en Annexe C1.

[6] Annexe B.

[7] Annexe G.

[8] Annexe C2.

documents additionnels[9]; le FNS et Nano-Tera.ch ont pris position sur le rapport du panel d'experts CSS[10].

Ces différents documents et échanges ont servi au CSS pour sa propre analyse. De plus, une étude externe a été réalisée sur mandat du CSS par le bureau d'études Interface de Lucerne[11], afin d'approfondir l'appréciation de la mise en œuvre et de l'impact de Nano-Tera.ch en matière de transfert de savoir et de technologies (TST). Pour des questions de calendrier, cette étude a été réalisée avant la remise du rapport d'auto-évaluation par Nano-Tera.ch. Le CSS a procédé à quinze entretiens semi-directifs destinés à apprécier Nano-Tera.ch dans une perspective générale et selon les différentes dimensions sous revue[12]. Enfin, le CSS s'est aussi fondé sur une base extensive de documents confidentiels transmis par l'état-major du Conseil des écoles polytechniques fédérales (CEPF), par Nano-Tera.ch, et par le FNS.

Le groupe de travail CSS a régulièrement informé le plenum de l'avancée des travaux. Une coordination avec le groupe de travail en charge de l'appréciation de SystemsX.ch et au sein du secrétariat a été organisée. En avril 2018, les résultats de l'analyse consacrée à Nano-Tera.ch ont été discutés par le CSS. Le présent rapport et les recommandations ont été acceptés par le CSS lors de la séance plénière des 4-5 juin 2018.

Bien que, selon le mandat du SEFRI, l'analyse consiste en une appréciation des effets de Nano-Tera.ch (*Wirkungsprüfung*) le présent rapport du CSS n'a pas pour but de démontrer un lien de causalité entre le programme et ses effets attendus (*outcomes, impact*). Les méthodologies existantes, notamment en sciences économiques et sociales[13], susceptibles d'isoler par des méthodes quantitatives les effets d'une action publique ne sont pas applicables dans le cas d'un programme de grande échelle comme Nano-Tera.ch. En effet, Nano-Tera.ch se compose de plusieurs communautés scientifiques et niveaux d'action publique qui constituent un système complexe d'interrelations dont le programme n'est que l'un des déterminants. De même, les données de monitoring disponibles ne sont pas suffisamment détaillées et précises pour informer sur l'ensemble des processus à l'œuvre[14]. Enfin, le caractère exceptionnel de Nano-Tera.ch[15] limite le recours à une comparaison ou à un groupe contrôle. Dès lors, le principal point de référence (*benchmark*) de Nano-Tera.ch se situe dans ses objectifs initiaux resp. dans les attentes qu'il a suscitées et qui ont motivé son existence. Les informations issues d'autres programmes de recherche et instruments ou dispositifs de financement de la recherche en Suisse sont utilisées à titre d'ordres de grandeur. En outre, le CSS considère que, sur le plan des contenus, les objectifs propres à SystemsX.ch et à Nano-Tera.ch sont trop différenciés pour justifier une comparaison entre les deux programmes. Ainsi, le CSS contribue, par l'analyse qualitative de différents types de sources et par la triangulation des informations, à identifier et à apprécier les résultats du programme à l'aune de ses objectifs et de sa mise en œuvre, afin de nourrir la réflexion et le débat au sein des bénéficiaires du programme comme des responsables politiques.

### *1.3 Structure*

Le chapitre 2 présente un aperçu introductif à l'initiative Nano-Tera.ch. Il se fonde principalement sur la documentation librement accessible et sur la documentation confidentielle reçue. Dans le chapitre 3, après mention des *Key Statements* relatifs à chaque dimension selon le mandat du SEFRI, l'analyse récapitule les principales observations et conclusions du CSS pour chaque dimension sous revue. Les sources reposent ici principalement sur les documents produits pour le présent rapport, et sur l'analyse propre du CSS.

[9] Annexe C3.
[10] Annexes C31 et C32.
[11] Meyer et Rieder 2017 (Annexe D).
[12] Annexe F.
[13] Voir Givord 2010, Link et al. 2013.
[14] Voir l'analyse CSS, chapitre 3.
[15] Voir le chapitre 2.

## 2. L’initiative Nano-Tera.ch: un aperçu

Ce chapitre est un commentaire introductif au contexte général, à la mise sur pied et aux principaux objectifs et processus de Nano-Tera.ch. Il se fonde sur les documents librement accessibles, sur la documentation reçue du CEPF, de Nano-Tera.ch, et du FNS, sur les discussions approfondies menées durant la *Site Visit* de novembre 2017, et sur les entretiens réalisés par le CSS.

### *2.1 Contexte scientifique et institutionnel*

Nano-Tera.ch intervient dans un paysage marqué depuis les années 1990 à la fois par la convergence des disciplines[16], notamment dans les micro- et nanosystèmes électromécaniques (MEMS et NEMS), par un positionnement stratégique des institutions universitaires sur ces domaines, et par une certaine diversité des possibilités de soutien public. En effet, la Confédération encourage de longue date le domaine des nanosciences/nanotechnologies et des microsystèmes/microélectronique, souvent en partenariat avec l’industrie privée[17]. Par exemple, on compte durant les années 1990 dans ce domaine au moins trois Programmes nationaux de recherche (PNR)[18] au FNS et quatre Programmes prioritaires de recherche (PPR)[19], gérés par le CEPF. D’autres instruments, comme le programme d’action en microélectronique *Microswiss* géré par la Commission pour la technologie et l’innovation (CTI) de 1992 à 1997 sont centrés sur les futures Hautes écoles spécialisées (HES) et sur le soutien aux petites et moyennes entreprises (PME). A partir de 2004, à l’issue du programme commun CTI-CEPF *Top-Nano 21* (2001-2003), la CTI reprend le soutien aux nanotechnologies et aux microsystèmes dans son domaine «Nouvelles technologies». Dès 2001, le PRN *Nanoscale Science – Impact on Life Sciences, Sustainability, Information and Communication Technologies* hébergé par l’Université de Bâle (Unibas) accompagne la création d’un *Swiss nanoscience institute* en Argovie (2005) et introduit de nouveaux cursus de formations interdisciplinaires à Bâle. D’autres PRN couvrent des champs voisins[20]. Dès 2004, la Conférence universitaire suisse (CUS) soutient l’élargissement des formations bâloises à l’Université de Neuchâtel (Unine), ainsi que le rapprochement entre l’Ecole polytechnique fédérale de Lausanne (EPFL) et l’Institut de microtechnique (IMT) de l’Unine[21]. A partir de 2009, l’IMT est intégré à l’EPFL et le partenariat avec l’Unine est confirmé. Durant toute cette période, le domaine des nanosciences et/ou microsystèmes est une priorité stratégique pour plusieurs institutions, en particulier l’Unibas, l’Ecole polytechnique fédérale de Zurich (EPFZ), l’EPFL, l’Unine, l’Université de la Suisse italienne (USI) et le Centre suisse d’électronique et de microtechnique (CSEM). Quasiment tous ces programmes resp. projets reposent sur un cofinancement bilatéral (*matching funds*), avec parfois une participation privée. La coopération interinstitutionnelle et l’interdisciplinarité, de même que la création de centres de compétences, la formation et le TST sont des buts déclarés.

La création formelle de Nano-Tera.ch est liée à celle de SystemsX.ch[22]. Pour rappel, SystemsX a d’abord été financé par la CUS et le CEPF de 2005 à 2007, afin de soutenir des projets communs en biologie systémique à l’Unibas, à l’EPFZ et à l’Université de Zurich (Unizh). Lorsqu’en 2006, le Secrétariat d’Etat à la recherche (SER) reçoit une demande de financement émanant du projet SystemsX, celui-ci pose comme condition l’élargissement de SystemsX, caractérisé par l’axe Bâle-Zurich, à la communauté de la recherche nationale – l’extension «.ch» symbolisant le principe d’un partenariat national. Parallèlement, le CEPF apprend en été 2006 que l’EPFL prépare une initiative intitulée alors «Nano-

[16] Cf. la notion de «convergence technologique» diffusée par Mihail C. Roco aux Etats-Unis: Roco 2002, Roco et Bainsbridge 2003. Pour une approche critique: Vinck et Robles 2012.

[17] Sur le développement de la recherche en micro- et nanosciences resp. -technologies en Suisse, voir en part. Harayama et al. 2004, Biniok 2013 et Merz 2015.

[18] PNR 13 Microélectronique et optoélectronique, 1980-1991; PNR 24 Chimie et physique des surfaces, 1987-1995; PNR 36 Nanosciences, 1996-2000.

[19] PPR Electronique de puissance, technologie des systèmes informatiques (LESIT, 1992-1995); PPR Optique I (1993-1995) et Optique II (1996-1999); PPR Micro and nanosystems technology (MINAST, 1996-1999).

[20] En particulier: PRN MICS – Systèmes Mobiles d'Information et de Communication (Institution hôte: EPFL); PRN Photonique quantique (EPFL); PRN "CO-ME – Médecine et interventions chirurgicales assistées par ordinateur" (EPFZ); PRN "IM2 – Gestion interactive et multimodale de systèmes d‘information" (IDIAP).

[21] Cf. Projet de coopération et d’innovation «Etudes en Nanosciences», financé au titre des Contributions liées à des projets. Projet de coopération et d’innovation «Centre interuniversitaire de recherche en microsystèmes et nanotechnologie, CIMENT». cf. CUS 2005. A noter qu’après avoir soutenu la création d’une faculté des sciences informatiques à l’USI (2000-2003), la CUS poursuit le développement en 2004-2007, notamment par l’introduction d’un Master of science in embedded systems design.

[22] Sur l’origine de SystemsX.ch, voir SWR 2018.

Giga». Ce projet est vraisemblablement issu des avancées réalisées grâce aux précédents développements en microtechnique et en nanosciences entre Bâle et Lausanne. Citant l'exemple du rapprochement entre l'Unine, le CSEM et l'EPFL dans la microtechnique, le Conseiller national D. Burkhalter demande d'ailleurs en juin 2006 au Conseil fédéral de placer le domaine parmi les priorités stratégiques à soutenir dans le prochain Message sur la formation, la recherche et l'innovation (FRI) 2008-2011[23]. Le Conseil fédéral accepte le postulat en septembre, tout en précisant que la réalisation et le financement d'un éventuel projet dans cette catégorie sera du ressort de la CUS et du domaine des Ecoles polytechniques fédérales (EPF).

En décembre 2006, deux projets sont discutés en séance du CEPF: l'un issu de l'EPFL, porté par G. De Micheli, intitulé «Nano-Giga-Systems»; l'autre issu de l'EPFZ, porté par R. Vahldieck, intitulé «Quantum Tera-Scale Systems Informationstechnologie für das 21. Jahrhundert: Nationales Netzwerkprogramm». Les deux projets se situent dans la convergence technologique entre la recherche en sciences de l'ingénieur à l'échelon nano ou micro et les applications dans le domaine des technologies de l'information et de la communication, caractérisées par le traitement de grands ensembles de données («giga-scale» / «tera-scale»)[24]. Le CEPF juge que le premier est plutôt orienté vers l'application, et le second vers la recherche fondamentale. Le CEPF décide de fusionner les deux approches pour proposer un projet de portée nationale, sur le modèle de SystemsX.ch. La proposition doit être faite pour le 21 janvier 2007 à l'intention du SER[25]. Ce délai est extrêmement court, car le SER finalise alors le Message FRI 2008-2011, qui sera adopté par le Conseil fédéral le 24 janvier 2007[26]. Dans ce document, le Conseil fédéral demande au parlement l'ouverture de crédits au titre des Contributions liées à des projets pour différentes initiatives, dont SystemsX.ch, et un nouveau «projet national de coopération», intitulé «Nano-Tera.ch»[27]. La formalisation de Nano-Tera.ch se calque alors sur celle de SystemsX.ch, notamment avec la volonté du SER de confier au FNS l'évaluation scientifique des projets de recherche soutenus par Nano-Tera.ch[28]. Fin janvier 2008 paraît le premier Appel à propositions et Nano-Tera.ch démarre officiellement début février.

### *2.2 Bases légales, financement et organisation générale*

Le financement de Nano-Tera.ch repose sur les bases légales en vigueur, en particulier l'instrument Contributions liées à des projets[29]. Cet instrument est alors le seul disponible, bien qu'il ne soit pas destiné à financer de grands projets de recherche. Lors de la consultation sur la révision de la Loi fédérale sur l'encouragement de la recherche et de l'innovation (LERI) en 2010, la CUS, le CEPF et le FNS demandèrent d'ancrer le principe de financement de grands projets de recherche comme SystemsX.ch et Nano-Tera.ch dans la nouvelle LERI, et non pas les conserver dans la future Loi sur l'encouragement et la coordination des hautes écoles (LEHE) au titre des Contributions liées à des projets[30].

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[23] 06.3263, Postulat D. Burkhalter Didier. Microtechnique et nanosciences. Projet stratégique d'intérêt national, déposé le 13.06.2006, https://www.parlament.ch/fr/ratsbetrieb/suche-curia-vista/geschaeft?AffairId=20063263.

[24] Pour une présentation plus détaillée, voir: «ETH-Debatte: nationale Projekte. Engineering-Grossprojekt der beiden ETH“. *ETH-Life*, 18.12.2006, http://www.ethlife.ethz.ch/archive_articles/061218-debattevahldieck/index.html.

[25] 154ème séance de l'Assemblée d'Ecole de l'EPFL, 09.01.2007, https://ae.epfl.ch/page-28438-fr.html#4.

[26] Conseil fédéral, Message relatif à l'encouragement de la formation, de la recherche et de l'innovation pendant les années 2008 à 2011 du 24 janvier 2007, FF 2007 1149. https://www.admin.ch/opc/fr/federal-gazette/2007/1149.pdf.

[27] Idem. Le Message sera accepté par les Chambres fédérales le 5 octobre 2007.

[28] Le FNS avait toutefois envisagé de transmettre cette responsabilité à la CTI, eu égard à l'orientation fortement appliquée de l'initiative. Rappelons qu'en 2007, la CTI se situe au sein de l'Office fédéral de la formation professionnelle et de la technologie (OFFT), rattaché au Département fédéral de l'économie (DFE). Ses bases légales sont revues afin de lui donner un nouveau statut dans la Loi fédérale sur la recherche (LR), à partir de 2011. Il faudra attendre septembre 2013 pour que la CTI puisse se voir confier la mise en œuvre de programmes de recherche sur mandat du Conseil fédéral.

[29] Loi fédérale sur l'aide aux universités et la coopération dans le domaine des hautes écoles (Loi sur l'aide aux universités, LAU) du 8 octobre 1999 (Etat le 1er janvier 2008), art. 20-21, aRS 414.20.

[30] «[…] CUS, CEPF et FNS font des observations sur le cadre juridique des grands projets tels que SystemsX.ch et NanoTera.ch. Plutôt que de les considérer comme projets de coopération au sens de l'art. 59 du projet LAHE, il conviendrait de les placer sous le régime de la LERI.» Département fédéral de l'intérieur (DFI), Révision totale de la loi fédérale sur l'encouragement de la recherche et de l'innovation (LERI). Rapport sur les résultats de la consultation, Berne, 1er septembre 2010, p. 14. https://www.admin.ch/ch/f/gg/pc/documents/1764/Ergebnis.pdf

Pour ces organes, de telles initiatives devraient faire l'objet d'un processus de coordination et de décision explicitement réglé dans la LERI. La nouvelle LERI, entrée en vigueur en 2014, fut modifiée en conséquence, avec l'ajout d'un nouvel art. 41, al. 5 et 6[31].

A l'instar de SystemsX.ch, Nano-Tera.ch est constitué en société simple[32]. Le consortium des institutions partenaires fondatrices se compose de l'EPFL (institution-hôte), l'EPFZ, l'Unibas, l'Unine, l'USI et le CSEM[33]. Les chercheurs rattachés à une HES peuvent participer aux projets de Nano-Tera.ch, mais ils ne peuvent être *Principal Investigator* (PI)[34]. Les directions des institutions partenaires composent le *Steering committee.* L'*Executive committee* (ExCom) est responsable de la direction opérationnelle, notamment la planification scientifique et stratégique de Nano-Tera.ch. Présidé par G. De Micheli (EPFL), il réunit les chercheurs issus des différentes institutions partenaires et couvre les disciplines de Nano-Tera.ch. Il est assisté par un *International scientific advisory board*. Chaque membre de l'ExCom peut déposer des demandes pour un financement Nano-Tera.ch[35]. L'administration générale est assurée par le *Management office*, hébergé par l'EPFL. Enfin, le FNS met sur pied un panel propre, dédié à l'évaluation scientifique de certains projets (*Panel FNS*).

Les deux phases de développement de Nano-Tera.ch (2008-2011(-2012); 2013-2016[36]) ont été financées par la Confédération, par les institutions partenaires (*matching funds*) et par les fonds de tiers. Le financement fédéral s'élève à 120 Mio CHF, assuré par les Contributions liées à des projets de la CUS et par la participation du CEPF à des projets d'importance nationale[37]. Au final, Nano-Tera.ch aura bénéficié d'un financement global de près de 260 Mio CHF[38].

Les principaux instruments d'encouragement de Nano-Tera.ch sont les *Research, Technology and Development Projects* (RTD), les *Nano-Tera.ch Focused* (NTF), et les *Education and Dissemination* (ED)[39]. Les buts, conditions, procédures et critères relatifs à l'acceptation des requêtes pour ces trois instruments sont spécifiés dans les Appels à proposition publiés dès 2008 et formulés par Nano-Tera.ch, avec l'aval du FNS pour ce qui est des RTD[40]. Les RTD sont le principal mode d'encouragement de Nano-Tera.ch. Ils regroupent environ 80% des montants accordés. Seuls les RTD sont soumis à l'évaluation par le panel FNS; la gestion du crédit échoit au FNS[41]. La plupart de ces caractéristiques formelles sont dérivées de celles élaborées pour SystemsX.ch.

### *2.3 Objectifs et procédure de sélection*

Selon le Message FRI 2008-2011, Nano-Tera.ch consiste à: «développer des technologies clés ayant recours à des composantes à l'échelle microscopique et nanoscopique dans le but de mettre en place un réseau de données dans les domaines de la sécurité, de l'environnement et de la médecine et

[31] «[5] Le Conseil fédéral coordonne la planification et l'exécution de projets d'encouragement nationaux dans le domaine de la recherche et de l'innovation qui ne peuvent pas être réalisés dans le cadre des tâches ordinaires d'encouragement des institutions chargées d'encourager la recherche et de la CTI en raison de leur dimension organisationnelle et financière.»
«[6] Le Conseil fédéral veille ce faisant à ce que les organes de recherche, la Conférence suisse des hautes écoles et le Conseil des EPF soient associés à la planification. Les propositions à l'Assemblée fédérale concernant des mesures d'encouragement au sens de l'al. 5 sont élaborées en accord avec la Conférence suisse des hautes écoles, y compris en ce qui concerne les modalités de financement et d'exécution». Loi fédérale sur l'encouragement de la recherche et de l'innovation (LERI), art. 41, al. 5 et 6, RS 420.1.

[32] Nano-Tera.ch. Ordinary Partnership Contract, January 2008. Les rapports scientifiques annuels de Nano-Tera.ch informent sur la composition détaillée des différents organes.

[33] A partir de 2010, l'Unige rejoint le consortium, suite à l'acceptation d'un projet porté par un PI rattaché à cette institution. Voir Nano-Tera.ch Scientific Report 2010, December 1st 2010.

[34] Nano-Tera.ch. Ordinary Partnership Contract, January 2008, art. 4.

[35] Nano-Tera.ch. Ordinary Partnership Contract, January 2008, art. 20, al. 1: «In case an issue is discussed in which an Executive Committee member has conflict of interests, she/he may be asked to leave. In any case, if attending, she/he will not take part to the discussion and decisions.» Des règles plus contraignantes visant à limiter les montants alloués aux membres de l'ExCom en tant que PIs de projets RTD seront mises en place à partir de la phase II.

[36] Formellement, la phase II prend fin au 30 juin 2018.

[37] 2008-2011: 20 Mio CHF CUS + 40 Mio CHF CEPF; 2012: 5 Mio CHF CUS + 10 Mio CHF CEPF; 2013-2016: 15.5 Mio CHF CUS + 32 Mio CHF CEPF. La contribution CEPF comprend une contribution de l'OFFT pour soutenir la participation des HES à hauteur de 1.8 Mio CHF (phase I) resp. 2 Mio CHF (phase II).

[38] Voir Annexe B.

[39] L'Annexe B délivre un aperçu complet des différents instruments d'encouragement et de leur dotation financière.

[40] Cf. http://www.nano-tera.ch/news/textes/nano-tera_call_for_proposals2008.pdf

[41] Voir ci-dessous, 2.3.

santé[42].» Cette formulation correspond à la vision qui prévaut dans la demande de financement adressée à la CUS en juin 2007 ou dans le *business plan* de novembre 2007[43], bien qu'aucune partie de ces documents ne soit spécifiquement dédiée aux objectifs de l'initiative. Une analyse réalisée en 2007 par le FNS et fondée sur quatre rapports d'experts indépendants, dont deux sont issus de l'industrie, considère que la vision générale de Nano-Tera.ch est bonne, mais qu'elle n'est pas suffisamment concrète quant à sa stratégie de mise en œuvre et d'opérationnalisation pour être pleinement appréciable et garantir le succès de l'initiative. Lors d'un échange avec le SER, le FNS propose la constitution d'un groupe de travail commun pour formuler des objectifs stratégiques concrets. Tout en réaffirmant que le principe d'une évaluation scientifique des projets financés par Nano-Tera.ch réalisée par le FNS sur le modèle de SystemsX.ch doit être respecté, le SER invite alors le FNS et Nano-Tera.ch à collaborer davantage. Dans un premier temps, la procédure d'évaluation des projets annoncée dans la demande à la CUS est révisée dans le *business plan*[44]. Puis le FNS et Nano-Tera.ch formulent le premier Appel à propositions[45]. Selon ce document, paru fin janvier 2008[46], les objectifs généraux du programme sont[47]:

- «to improve quality of life and security of people across different levels of education, wealth and age and to create innovative products, technologies and manufacturing methods, thus resulting in job and revenue creation.»
- «to bridge traditional disciplines, including but not limited to electrical engineering, micro/nano-mechanical systems engineering, biomedical sciences and computer/communication sciences, with the objective of (i) deepening the understanding of enabling technologies and reducing scientific concepts to practice, and (ii) mastering the novel challenges of engineering tera-scale complex systems.»

Les objectifs spécifiques sont:
- «pursuing excellence in collaborative scientific research in the aforementioned disciplines»
- «creating and expanding educational programs»
- «constructing demonstrators of the technologies being studied and transferring the results to Swiss industry.»

Les axes stratégiques de recherche couverts par Nano-Tera.ch sont:
- «Research and development of advanced technologies, such as i) micro/nanoelectronics, -electromechanical systems (MEMS/NEMS) and -manufacturing processes; ii) (bio)-sensors, actuators and their system-level integration; iii) information and communication sciences as well as systems and software engineering.»
- «Integration of these technologies into application fields, such as wearable systems (e.g., for monitoring of patients, sportsmen, and the elderly), ambient systems (e.g., for environmental intelligence, building monitoring and virtual world) and remote systems (e.g., space applications such as pico-satellites, remote sensing).»

Nano-Tera.ch se distingue des autres financements disponibles par les caractéristiques suivantes:

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[42] Conseil fédéral, Message relatif à l'encouragement de la formation, de la recherche et de l'innovation pendant les années 2008 à 2011 du 24 janvier 2007, FF 2007 1203. https://www.admin.ch/opc/fr/federal-gazette/2007/1149.pdf

[43] CUS, Proposition d'un projet ou d'un programme de coopération et d'innovation, Contributions liées à des projets 2008-2011, Titre du projet: «Nano-Tera.ch», juin 2007. Nano-Tera.ch. The Swiss Initiative Engineering and information technology for health and security of the human being, and the environment. Business Plan, 19 November 2007.

[44] Dans la demande à la CUS (juin 2007), le rôle du FNS se limite à une revue technique internationale, tandis que l'ExCom est responsable de l'évaluation scientifique et stratégique. Dans le *Business plan* (novembre 2007), la procédure est revue dans le sens de ce qui sera arrêté par le FNS en mars 2008 (voir ci-après note 65).

[45] Cette collaboration nécessitera encore des interventions du SER pour rappeler aux porteurs de Nano-Tera.ch le respect des conditions-cadre établies sur le modèle de SystemsX.ch. Par exemple, le SER expliquera en décembre 2007 que l'Appel à propositions ne peut pas être restreint *ex ante* aux *Principal Investigators* rattachés aux institutions fondatrices de Nano-Tera.ch. Outre l'absence de base légale, une telle restriction s'opposerait à la dimension nationale et ouverte de Nano-Tera.ch. Dans le même courrier, le SER souligne que l'absence d'objectifs stratégiques opérationnalisés servant de critères d'évaluation des requêtes présentées au titre du programme Nano-Tera.ch semble être un déficit sérieux, raison pour laquelle le SER appuie la proposition du FNS pour revoir et compléter l'Appel.

[46] Nano-Tera.ch. The Swiss Initiative in Engineering and information technology for health and security of the human being, and the environment. Call for Proposals [28.01.2008]. http://www.nano-tera.ch/news/textes/nano-tera_call_for_proposals2008.pdf

[47] Ces objectifs sont repris dans l'Annexe B, pp. 20-21.

- «Engineering of complex (tera) systems out of small (nano/micro) components, by leveraging scientific and technological discoveries, with the objective of developing technology demonstrators that can be transformed into products in the medium term.»
- «Synergy of various disciplines through well-coordinated research efforts, to explore topics at the boundary of traditional scientific domains.»
- «Collaborative nature and significant funding size of the average research projects (and specifically RTDs) which would not be otherwise available through usual channels (e.g. SNSF projects).»
- «Social relevance, in terms of projected benefits to health, security and the environment.»

En outre, les partenaires institutionnels membres du consortium de Nano-Tera.ch disposent eux aussi d'objectifs spécifiques, qui sont précisés dans le contrat de société simple conclu en janvier 2008[48]:

a) «Coordinate the national and international collaboration of the Partners in the field of Health-Security-Environment Systems Engineering;»
b) «Carry out scientific and complex multidisciplinary engineering projects establishing highly specialised development and technology platforms with demonstrators in the field of Health-Security-Environment Systems Engineering;»
c) «Coordinate the financial contributions for research projects in the field of Health-Security-Environment Systems Engineering;»
d) «Coordinate the presentation of the Partnership under the name "nano-tera.ch" and establish this name as a mark of quality in the field of Health-Security-Environment Systems Engineering;
e) «Develop and implement common training programmes targeted to young researchers in the field of Health-Security-Environment Systems Engineering;»
f) «Coordinate and intensify the cooperation with the private sector;»
g) «Promote a dialogue in and with the public on Health-Security-Environment Systems Engineering;»
h) «Secure additional external funding.»

Ces objectifs de Nano-Tera.ch ne connaîtront pas de changements majeurs, à quelques détails près. Dès 2009, l'Appel à propositions précise que les projets RTD doivent se conformer aux objectifs stratégiques du financement Nano-Tera.ch pour être soutenus[49]. Dès l'Appel de 2011[50], Nano-Tera.ch couvre le domaine de l'énergie en plus de la santé, de la sécurité et de l'environnement[51]. A partir de 2012[52], chaque projet RTD doit intégrer des utilisateurs finaux (*end user*), et non plus seulement un partenaire industriel, comme c'était le cas durant la phase I[53].

Pour rappel, le rôle du FNS dans la mise en œuvre de Nano-Tera.ch a été établi dans les grandes lignes en 2007 dans un «Schéma de mise en œuvre». Les principes directeurs et la procédure générale de l'évaluation scientifique par le FNS ont été formulés dans le contrat de société simple conclu en janvier 2008[54]. Selon ce document, le FNS se prononce sur l'initiative en général et sur la qualité scientifique des projets RTD, tandis que l'ExCom se prononce sur leur conformité avec les buts stratégiques. La décision finale revient au Conseil national de la recherche du FNS. Suite à une séance tenue début janvier 2008 entre Nano-Tera.ch et le FNS, il est décidé de renoncer à préciser, dans l'Appel à propositions en cours de formulation, quelle partie est responsable de quels critères scientifiques resp. stratégiques, au motif que leur appréciation est *de facto* interdépendante.

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[48] Nano-Tera.ch. Ordinary Partnership Contract, January 2008, art. 1, lit. 2.
[49] Nano-Tera.ch. The Swiss Initiative in Engineering and information technology for health and security of the human being, and the environment. Call for Proposals 2009. http://www.nano-tera.ch/news/textes/nano-tera_call_for_proposals_2009.pdf
[50] Nano-Tera.ch. The Swiss Initiative in Engineering and information technology for health and security of the human being, and the environment. Call for Proposals 2011. http://www.nano-tera.ch/pdf/Nano-TeraCall_2011.pdf.
[51] Cette décision fait suite à une recommandation du panel FNS. Une version antérieure de l'Appel à propositions 2011, émise de manière unilatérale par Nano-Tera.ch ne comportait pas cette dimension.
[52] Nano-Tera.ch. The Swiss Initiative in Engineering and information technology for health and security of the human being, energy and the environment. Call for Proposals 2012. http://www.nano-tera.ch/pdf/NT_Call_2012Final.pdf
[53] Outre l'introduction des utilisateurs finaux, le panel FNS suggère aussi de mettre en place un instrument spécifique pour le TST au sein des projets RTD.
[54] Nano-Tera.ch. Ordinary Partnership Contract, January 2008.

En mars 2008, le Conseil national de la recherche du FNS entérine la régulation officielle de l'évaluation FNS des projets RTD Nano-Tera.ch[55]. Ce document, disponible en ligne sur le site internet de Nano-Tera.ch, détaille les principes, procédures et critères. En particulier, l'évaluation scientifique des requêtes RTD échoit au panel FNS. L'avis de Nano-Tera.ch sur la conformité de chaque requête avec le programme général doit être transmis au préalable par écrit au panel FNS (art. 4). En cas de divergence entre les avis, la décision finale revient au panel FNS (art. 6, al. 2). Enfin, le panel FNS reçoit les rapports scientifiques annuels de Nano-Tera.ch et peut se prononcer sur l'avancement général du programme (art. 15, al. 2). Les recommandations du panel FNS concernant l'ensemble des projets et des rapports sont prises en compte par le SER lors des décisions sur la poursuite du programme (art. 15, al. 3).

La plupart des changements qui apparaissent dans les différents Appels à propositions de Nano-Tera.ch résultent de recommandations du panel FNS. Leur mise en œuvre a parfois nécessité des clarifications, comme lorsqu'il s'est agi de veiller à ce que la direction de Nano-Tera.ch tienne compte des recommandations du panel FNS sur la phase I lors de la formulation de la demande de financement auprès de la CUS pour la phase II. Ces difficultés de collaboration paraissent toutefois se résorber à partir de la phase II, alors que le panel FNS constate que les résultats scientifiques sont excellents. En mai 2012, le FNS confirme dans un courrier à la CUS que la collaboration avec Nano-Tera.ch se poursuit désormais sans frictions. Toutefois, la présidence du Conseil national de la recherche constate que, le cas échéant, la conception de telles initiatives de recherche devrait être fondamentalement repensée.

[55] SNSF, Regulation of Nano-Tera.ch applications (Approved by the Swiss National Research Council on March 12th 2008), http://www.nano-tera.ch/news/textes/nano_tera_regulation.pdf

# 3. Analyse du CSS

## *3.1 Impact scientifique*

<u>*Key statements*</u>[56]

- *Nano-Tera.ch has promoted excellence in research in various domains of engineering sciences.*
- *Nano-Tera.ch has fostered strongly collaborative research.*
- *Nano-Tera.ch has fostered strongly interdisciplinary research.*
- *Nano-Tera.ch has triggered inter-institutional collaborations among very diverse players at the national level.*
- *Nano-Tera.ch has fostered strongly applications-oriented research in various domains of engineering sciences.*
- *Nano-Tera.ch has funded ambitious projects.*
- *Nano-Tera.ch has an almost exhaustive coverage of the Swiss scientific community in the program's fields.*

### 3.1.1 Analyse

Les résultats de Nano-Tera.ch sur le plan scientifique sont globalement excellents. Le panel FNS l'a constaté dès la fin de la phase I, soulignant combien la collaboration interdisciplinaire et interinstitutionnelle ont favorisé l'orientation des chercheurs vers l'application. Bien que Nano-Tera.ch prît place dans un contexte marqué par un important financement public[57], l'ampleur financière, la durée et le caractère à la fois interdisciplinaire et interinstitutionnel des projets ont contribué à faire de l'initiative une occasion unique de développer le domaine des sciences de l'ingénieur. Le rapport d'auto-évaluation expose ces différents aspects de manière détaillée[58]. Toutefois, l'absence d'un programme comparable dans le même domaine scientifique (*benchmark*) limite l'appréciation des résultats[59], même si, dans l'absolu, les nombreuses publications et conférences illustrent la qualité et l'intensité de la recherche produite.

La qualité scientifique générale de Nano-Tera.ch est également relevée par le rapport du panel d'experts CSS, en particulier sous l'angle de la collaboration interinstitutionnelle[60]. Les experts internationaux regrettent toutefois que la démonstration de l'interdisciplinarité dans le rapport d'auto-évaluation et lors de la Site Visit ne soit pas entièrement convaincante[61]. En effet, un peu moins d'un tiers des publications de Nano-Tera.ch sont issues de deux auteurs partenaires au même projet (PI et Co-PI), la grande majorité (plus de 70%) restant l'œuvre d'un seul PI ou Co-PI[62]. Ce résultat tranche avec le fait que, durant la réalisation des projets, l'esprit collaboratif s'est manifesté par le fait qu'en moyenne 2.4 partenaires (PI ou Co-PI) étaient en charge d'un même axe de recherche[63]. De même, le rapport d'auto-évaluation fait état d'une moyenne générale de 2.73 disciplines différentes par projet RTD[64]. Mesurer la performance de la recherche interdisciplinaire est complexe, car la publication d'un article procède d'une stratégie qui répond à des critères réputationnels en lien avec la carrière académique (*reward system*), et les revues interdisciplinaires correspondantes font parfois défaut[65]. Toutefois, cette asymétrie entre la phase de réalisation de la recherche et celle de publication des résultats suggère que l'interdisciplinarité aurait pu faire l'objet d'une attention plus soutenue.

Pour le panel d'experts CSS, l'ampleur et la durée du financement RTD ont favorisé l'atteinte d'un seuil critique nécessaire à l'ambition des projets et des objectifs. Nano-Tera.ch paraît se distinguer moins par l'originalité des projets que par le renforcement d'une communauté de recherche en sciences de l'ingé-

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[56] Selon le mandat du SEFRI, Annexe A.

[57] Cf. Section 2.1.

[58] Annexe B, pp. 49-60. Soulignons en particulier (p. 56) la moyenne générale pour les 44 projets RTD de 2.7 institutions de différents types (i.e.: domaine EPF, université cantonale, haute école spécialisée, hôpital universitaire, institut de recherche public ou privé, etc.).

[59] SystemsX.ch ne peut être pris en compte à titre de comparaison en raison des importantes différences quant aux objectifs poursuivis.

[60] Annexe C3.

[61] Annexe C3, p. 3, question I/2.

[62] Annexe B, p. 53, graphique «Amount of joint publications».

[63] Annexe B, pp. 52-53, graphique «Number of Research Group per Research Task».

[64] Annexe B, p. 55. La méthode et les critères utilisés pour définir les disciplines considérées ne sont toutefois pas précisés.

[65] Ce problème n'est pas propre à Nano-Tera.ch: «ID [interdisciplinary research] tends to struggle to get published in high impact factor journals. More broadly, limitations of research metrics for ID work have been well-documented, so funders are more likely to retreat from metrics-use in this domain.» Kolarz 2017, p. 34.

nieur issue en majorité des EPF à la fois vers l'excellence scientifique et vers l'application. Selon l'analyse du CSS, environ 80% des PIs des 44 projets RTD sont rattachés au domaine des EPF, soit à l'EPFL (22 PIs) ou à l'EPFZ (13 PIs). Le reste se répartit entre le CSEM (3 PIs, ca. 7%) et les universités cantonales (6 PIs, ca. 14%), à savoir 3 à l'Unibas, et 1 respectivement à l'Unige, à l'Unil et à l'Unibe. La communauté de recherche de Nano-Tera.ch est en grande partie issue des PRN, avec lesquels elle partage plusieurs des PIs et Co-PIs. Par exemple, 23 PIs de Nano-Tera.ch sont issus des PRN de la série 1[66]. Par la suite, plusieurs des PIs de Nano-Tera.ch rejoindront d'autres PRN des séries 3 et 4[67].

Il faut en outre rappeler que les chercheurs financés par Nano-Tera.ch en tant que PI ou co-PI ont aussi bénéficié d'un soutien FNS pour d'autres requêtes déposées durant la même période. Selon une analyse interne du FNS transmise au CSS, les PI ou co-PI de Nano-Tera.ch ont reçu plus de 1077 subsides FNS, pour un total de 401.7 Mio CHF. Le détail se présente comme suit[68]:

| SNSF Funding Category | # Grants | MCHF | % total SNSF funding |
|---|---|---|---|
| Project funding | 728 | 225.5 | 7.4 |
| Programmes[69] | 179 | 133.3 | 13.7 |
| Infrastructure | 122 | 31.5 | 10.7 |
| Science communication | 33 | 1.2 | 2.7 |
| Careers | 15 | 10.3 | 0.9 |

Ce résultat témoigne du succès des chercheurs soutenus par Nano-Tera.ch dans la recherche de fonds. Il suggère aussi que Nano-Tera.ch n'était pas la seule possibilité de financement pour les chercheurs concernés. Par contre, la dotation financière moyenne par projet RTD (2.1 MCHF[70]) était dans Nano-Tera.ch beaucoup plus importante que celle accordée en moyenne par projet FNS de recherche libre (ca. 310'000 CHF[71]), même si le nombre de bénéficiaires est plus réduit (44 projets RTD). Le soutien financier de Nano-Tera.ch a donc été complémentaire à celui du FNS[72].

Le panel d'experts CSS déplore le manque de Nano-Tera.ch en matière de stratégie internationale[73]. Le CSS constate également que l'articulation des différentes mesures internationales prises par l'ExCom avec les buts scientifiques stratégiques de l'initiative ne reposait pas sur une analyse initiale approfondie. Par exemple, les centres de référence à l'étranger cités dans le *business plan* de 2007 se situent aux Etats-Unis, aux Pays-Bas, en Belgique et au Japon[74]. Or, l'ExCom financera sur ses fonds stratégiques la participation de Nano-Tera.ch à un programme de coopération scientifique sino-suisse de 2011 à 2013[75], puis aux *4th Switzerland-Korea Joint Workshops* tenus à l'EPFL en mai 2013. Dans le cadre d'un *International Exchange Program*, Nano-Tera.ch organisera de 2013 à 2017 quatre symposiums internationaux. Seuls trois conférenciers individuels seront invités sur l'ensemble du programme[76].

Le rôle du panel FNS a été déterminant pour la qualité générale de Nano-Tera.ch. Par exemple, les recommandations transmises aux PIs à l'issue des *Midterm Evaluation Meetings* font régulièrement état du souci de transférabilité des résultats, ce qui confirme l'orientation du panel FNS vers l'application.

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66 PRN MICS, Quantum Photonics, Nanoscale Science, CO-ME, Neuro, Molecular Oncology, MaNEP, Structural Biology, IM2.

67 PRN série 3: Robotics; QSIT; MUST; chembio; TransCure. PRN série 4: MSE, MARVEL.

68 Source: Annexe E.

69 Sans les PRN.

70 Annexe B, p. 14, tableau «Funded projects».

71 225.5 MCHF / 728 = ca. 310 000 CHF.

72 Pour rappel, l'une des caractéristiques de Nano-Tera.ch, annoncée dans le premier Appel à propositions de 2008, est: "Collaborative nature and significant funding size of the average research projects (and specifically RTDs) which would not be otherwise available through usual channels (e.g. SNSF projects)." Nano-Tera.ch. The Swiss Initiative in Engineering and information technology for health and security of the human being, and the environment. Call for Proposals [28.01.2008]. http://www.nano-tera.ch/news/textes/nano-tera_call_for_proposals2008.pdf

73 Annexe C3, pp. 7-8.

74 A savoir: Aux Etats-Unis: Wireless Research Center (BWRC) (University of California, Berkeley), High Performance Wireless Research and Education Network (HPWREN) (University of California, San Diego); aux Pays-Bas: Holst Centre (Human++ research program); en Belgique: IMEC; au Japon: Ambient SoC Center of Excellence (University of Waseda).

75 6 projets financés à hauteur de ca. 530'000 CHF (Annexe B, p. 13), dans le cadre du Sino-Swiss Science and Technology Cooperation (SSSTC) program, démarré en 2008 après une phase pilote (2004-2007).

76 Annexe B, pp. 51, 89-92.

Dans son appréciation délivrée en 2011, avant le passage à la phase II, le panel FNS a souligné l'excellence générale de Nano-Tera.ch, en particulier en tant que dispositif d'encouragement de la recherche en sciences de l'ingénieur orientées vers l'application. La poursuite du programme est fortement recommandée. Toutefois, le panel FNS considère nécessaire de renforcer le potentiel d'application. Il suggère ainsi l'introduction d'un programme spécifique pour soutenir le TST, afin de favoriser le transfert des résultats vers l'industrie. Le panel FNS recommande aussi d'intégrer, dans tous les projets RTD de la seconde phase et de manière obligatoire, des spécialistes en application dans le domaine considéré, comme des utilisateurs finaux potentiels (*end-user*, p. ex. des médecins dans les projets en santé publique). En favorisant la collaboration avec les chercheurs dès la formulation des buts de recherche, une telle mesure renforcera le souci d'applicabilité des résultats dans la pratique. Cette demande sera mise en œuvre dans l'appel à propositions de 2012 par l'ajout du critère d'utilisateurs finaux dans les requêtes pour des projets RTD[77].

Ces recommandations témoignent du souci du panel FNS de prendre des mesures adaptées à la mise en œuvre des objectifs stratégiques de Nano-Tera.ch. En 2016, le panel FNS considère que: «The program is on the path to success. Several projects are already able to show both significant innovations as well as very good scientific output. They have already produced a demonstrator or will have demonstrators ready by the end of the grant duration. They show significant potential to have a real impact on innovation in their respective domains. The collaboration between the research groups of different institutions, background and disciplines seems to work quite well for most projects. In the panel's opinion, the Nano-Tera.ch program therefore showed the usefulness of a new and complementary type of funding scheme in Switzerland promoting application-driven projects, where interactions between scientific, engineering, and innovation-based activities are enabled[78].»

### 3.1.2 Conclusions

- D'une manière générale, Nano-Tera.ch a produit une recherche d'excellente qualité, orientant la communauté de recherche en sciences de l'ingénieur vers la collaboration interdisciplinaire et interinstitutionnelle et vers l'application. Ces résultats paraissent davantage liés à la qualité intrinsèque des chercheurs de Nano-Tera.ch et aux critères retenus pour l'allocation des projets RTD qu'à la mise en œuvre du programme par l'ExCom.
- Le panel FNS a largement contribué à l'orientation des projets RTD vers l'application, que cela soit durant les évaluations annuelles ou à l'issue de la phase I. La critique d'une sélection strictement scientifique («SNSF-only selection») par le panel FNS ne paraît donc pas justifiée[79]. Par contre, certains choix stratégiques de l'ExCom, en particulier au niveau international, ne s'accordent guère avec les objectifs initiaux, ou n'ont simplement pas fait l'objet d'une analyse initiale approfondie. Des mesures complémentaires aux critères de sélection des projets RTD, par exemple afin de renforcer l'interdisciplinarité, ne paraissent pas avoir été prises.
- Les prises de position du FNS et de Nano-Tera.ch sur le rapport du panel d'experts CSS[80] reflètent les divergences rencontrées dans la conduite du programme, en particulier sur le processus de sélection des projets RTD[81]. Le manque en matière d'objectifs scientifique stratégiques concrets a freiné la prise de mesures propres à assurer l'efficacité de l'initiative. Par exemple, le programme Gateway de soutien au TST n'a été introduit qu'en 2015 et s'est limité à 8 projets[82].

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[77] Voir Nano-Tera.ch. The Swiss Initiative in Engineering and information technology for health and security of the human being, energy and the environment. Call for Proposals 2012. http://www.nano-tera.ch/pdf/NT_Call_2012Final.pdf. Le premier appel à propositions de la phase II, ouvert en automne 2011, n'intégrait pas encore la demande du panel FNS relative aux utilisateurs finaux (cf. Nano-Tera.ch. The Swiss Initiative in Engineering and information technology for health and security of the human being, and the environment. Call for Proposals 2011. http://www.nano-tera.ch/pdf/Nano-TeraCall_2011.pdf). La mise en œuvre du programme de TST surviendra en 2015 avec le lancement du programme Gateway. Voir section 3.3.
[78] SNF, RC Presiding Board, 502. meeting, 12 July 2016, agenda item 7.1 (Nano-Tera.ch: Mid-term evaluation).
[79] Contrairement à l'analyse du panel d'experts CSS, cf. Annexe C3, p. 5.
[80] Annexes C31 et C32.
[81] Voir chapitre 2.
[82] Voir section 3.3.

### 3.2 *Impact éducationnel*

<u>*Key statements*</u>

- *Nano-Tera.ch has substantially contributed to the training of next generation researchers (PhD students, Post Docs).*
- *Nano-Tera.ch has encouraged stronger collaborative spirit in the community of PhD students involved in the program and increased their autonomy by giving them the opportunity to submit their own collaborative research proposals.*
- *Nano-Tera.ch has encouraged stronger entrepreneurial spirit in the community of PhD students involved in the program.*

#### 3.2.1 Analyse

Le principal résultat de Nano-Tera.ch au niveau éducationnel réside dans les 366 doctorants soutenus sur l'ensemble de la durée du programme. Les doctorants Nano-Tera.ch ont bénéficié de l'orientation interdisciplinaire et de l'approche holistique propre à l'initiative «Nano»-«Tera» qui renforcent leur valeur ajoutée tant sur les plans scientifique qu'économique[83]. Il ressort d'une enquête réalisée auprès des doctorants Nano-Tera.ch soutenus de 2009 à 2013 (308 réponses) que 208 avaient trouvé un emploi: 39% dans la carrière académique (dont 57% en Suisse), et 61% dans l'industrie (dont 75% en Suisse)[84].

L'encouragement des doctorants et des post-doctorants (post-docs) au sein de Nano-Tera.ch s'est fait principalement par le biais des projets RTD, qui concentraient environ 80% des ressources financières. Une autre source de financement, beaucoup plus réduite[85], se situait dans les projets *Education and Dissemination* (ED), dont la gestion et l'allocation dépendaient uniquement de l'ExCom[86]. C'est par ce biais, à savoir essentiellement 61 actions ED pour un financement total de 1.4 MCHF, que des mesures de soutien ponctuel aux doctorants ont été prises (cours brefs, ateliers, mini-conférences, etc.)[87].

A partir de la phase II, quelques mesures plus ciblées sont prises, comme l'organisation à la veille de la réunion annuelle de Nano-Tera.ch en 2014 d'une rencontre entre les doctorants et d'une information sur la valorisation de leurs résultats, notamment au plan industriel[88]. Mais le principal soutien à la formation doctorale hors des projets RTD reste le programme NextSteps, lancé en 2015 et doté d'un coordinateur propre. Ce programme, qui se fonde sur les résultats de l'enquête réalisée sur les doctorants soutenus de 2009 à 2013, est destiné à renforcer la collaboration interdisciplinaire des doctorants (*track 1 Scientific collaboration*), à favoriser leur entrée sur le marché du travail (*track 2 Entrepreneurship*) et à renforcer leur capacité de communication (*track 3 "My Thesis in 180 Seconds"*).

A l'instar de l'appréciation délivrée par le panel d'experts CSS[89], le CSS considère que ce programme correspond aux standards de l'encouragement ciblé des doctorants dans un programme de cette envergure[90]. Toutefois, son introduction tardive a limité la participation (7 projets pour le track 1 et 4 pour le track 2)[91], et a réduit son impact potentiel. De même, NextSteps a été financé dans le cadre des projets ED, donc la dotation financière était assez réduite[92]. Ainsi que le souligne le panel d'experts

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[83] Ce point a été confirmé par les entretiens menés par le CSS.

[84] Source: Annexe B, p. 72. La date de l'enquête n'est pas précisée, mais elle a vraisemblablement eu lieu en 2014-2015. Les 100 personnes non employées se répartissent comme suit: 93 doctorats encore en cours, 7 au chômage. Les taux de 39% (académie) et 61% (industrie) se réfèrent donc à un total de 208 doctorants, et non aux 366 doctorants soutenus sur les phases I et II. Voir aussi section 3.3.

[85] 1.2% du budget total, selon Annexe B, p. 13. La catégorie «PhD Projects» (1.3 Mio CHF) ne fait pas l'objet de précisions claires dans le rapport d'auto-évaluation.

[86] Selon le contrat de société simple, ces projets devaient prendre la forme de cours brefs, d'ateliers, de mini-conférences (etc.) et visaient notamment à développer de nouveaux cursus d'enseignement dans des domaines non couverts par les Hautes écoles partenaires. Cf. Nano-Tera.ch. Ordinary Partnership Contract, January 2008, art. 32.

[87] Le rapport d'auto-évaluation (Annexe B) ne présente pas ces activités en détail. La participation des femmes, qui se monte à 21% (77 doctorantes), ne paraît pas avoir fait l'objet d'un soutien particulier.

[88] Nano-Tera.ch, Scientific Report 2014, June 1st, 2013 – May 31st, 2014, pp. 22-23.

[89] Annexe C3, p. 5.

[90] Cette appréciation s'applique aux tracks 1 et 2. Le concours "My Thesis in 180 Seconds" (track 3) est une reprise, pour la communauté Nano-Tera.ch, d'un concours introduit pour la première en Suisse par l'EPFL en 2015, sur le modèle original (2008) de l'Université de Queensland en Australie, cf. https://mediacom.epfl.ch/mt180-en, et https://threeminutethesis.uq.edu.au/about.

[91] L'Annexe B ne précise pas le nombre total de personnes soutenues dans NextSteps.

[92] L'Annexe B ne précise pas le montant exact accordé à NextSteps.

CSS[93], Nano-Tera.ch n'a pas pris de mesures spécifiques à l'attention des post-doctorants, en particulier les PIs et co-PIs, même si celles-ci auraient pu davantage renforcer l'orientation de ces derniers envers l'application et la translation.

### 3.2.2 Conclusions

- Le principal impact de Nano-Tera.ch en termes éducationnels réside dans les 366 doctorants soutenus. La qualité de la formation doctorale est reconnue, tant pour les besoins de l'académie que de l'industrie.
- L'essentiel du soutien de Nano-Tera.ch aux doctorants et post-docs a été le fait du financement ordinaire des projets RTD. Il n'existait pas de concept stratégique pour la formation doctorale émanant de la direction du programme, et les soutiens ponctuels (projets ED) constituaient une part minimale du budget alloué. Les mesures ED ne paraissent pas avoir débouché sur la création de nouveaux cursus d'enseignement dans les institutions partenaires[94]. Aucune mesure spécifique pour encourager la participation des femmes à la formation doctorale ou pour soutenir les post-doctorants ne paraît avoir été prise.
- NextSteps (tracks 1 et 2) traduit une formulation convaincante mais tardive d'un concept transversal dans ce domaine, toutefois concentré sur les seuls doctorants et limité à un nombre restreint de projets, la plupart étant couronnés de succès, par exemple avec la création de 3 start-ups à l'issue du track 2. La reprise du track 3 de NextSteps (*"My Thesis in 180 Seconds"*) n'a pas été adaptée spécifiquement à Nano-Tera.ch.
- Il n'est pas fait mention d'une éventuelle poursuite des mesures éducationnelles, telles que NextSteps, au sein des institutions partenaires après la fin de Nano-Tera.ch.
- Le monitoring sur l'impact éducationnel est peu détaillé.

## *3.3 Impact économique*

*Key statements*

- *Nano-Tera.ch has fostered research with high economic potential.*
- *Nano-Tera.ch has deployed a novel pilot funding instrument (the Gateway program) efficiently combining support for research and innovation and integrating an appropriate monitoring mechanism.*
- *Nano-Tera.ch has fostered user-centric research with an early involvement of field practitioners through field tests, clinical studies, etc.*
- *Nano-Tera.ch has contributed to the dissemination of the scientific results achieved to the Swiss industry.*

### 3.3.1 Analyse

L'impact économique de Nano-Tera.ch présente un fort potentiel. Outre la formation de doctorants adaptés aux besoins des acteurs industriels, la plupart des projets ont débouché, dans les deux phases, sur la production de démonstrateurs, de plateformes, voire de prototypes, de start-ups et autres indicateurs usuels de succès potentiels en matière d'impact économique (brevets, licences, financements CTI, etc.)[95]. La majorité de ces résultats a été obtenue par les projets RTD, mobilisant une grande diversité d'instruments de transfert à l'économie et à la société[96]. L'apport financier des partenaires industriels resp. utilisateurs finaux aux projets RTD ne dépasse pas 20% du financement RTD total[97].

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[93] Annexe C3, p. 5.

[94] Ce point n'est pas renseigné dans le rapport d'auto-évaluation (Annexe B), alors que, par exemple, l'*Advanced Learning and Research Institute* (ALaRI) de l'*Università della Svizzera italiana* (USI) a ouvert en 2017 un *Master Program on Cyber-Physical and Embedded Systems*, dans lequel interviennent plusieurs des PIs de Nano-Tera.ch, cf. http://www.alari.ch/education/master-science.

[95] Selon l'Annexe B (p. 71), le nombre de start-up créées dans le cadre de projets soutenus par Nano-Tera.ch est de 10 (6 créées, 4 en cours de création). A quoi s'ajoutent 3 start-up issues des travaux de doctorants soutenus par NextSteps (Annexe B, p. 69). Durant la Site Visit des 13-14 novembre 2017, les représentants de Nano-Tera.ch ont fait état non pas de 10 start-ups, mais de 40. Une liste a été transmise au secrétariat du CSS. Cette variation reflète certes la difficulté d'établir un clair lien de causalité entre un programme de recherche et la création d'une start-up, mais elle démontre aussi la faiblesse du monitoring.

[96] Voir l'étude externe réalisée sur mandat du CSS, Annexe D, p. 29.

[97] La contribution financière issue de fonds de tiers privés et de partenaires industriels s'élève au total à 18 Mio CHF (cf. Annexe B, p. 72), soit environ 19% du financement RTD total alloué (95 Mio CHF: Annexe B, p. 13).

Mais le nombre de partenaires industriels resp. d'utilisateurs finaux (103 pour 44 projets RTD) a favorisé la diffusion des résultats de Nano-Tera.ch.

La conception et la mise en œuvre du TST dans Nano-Tera.ch ont fait l'objet d'une étude externe sur mandat du CSS[98]. Se fondant sur une analyse documentaire approfondie, sur 15 entretiens et sur trois études de cas, cette étude considère que la conception du TST dans Nano-Tera.ch procède d'un modèle réflexif[99]. Le TST de Nano-Tera.ch se caractérise par l'esprit collaboratif de la recherche, par la participation de partenaires tiers issus des secteurs privé et public, et par la formation d'un personnel hautement qualifié[100]. Toutefois, le TST ne fait pas l'objet d'une définition explicite quant à sa conception et à sa mise en œuvre dans les projets[101]; il est implicitement dérivé des buts généraux de Nano-Tera.ch[102]. La mise en œuvre du TST est donc fonction de l'appréciation de son importance au sein de chaque projet. De plus, tous les projets RTD ne procèdent pas de la même compréhension du TST, lequel dépend de plusieurs facteurs, tels les cultures disciplinaires, les buts du projet de recherche, ou la capacité des partenaires à collaborer. Plusieurs des projets RTD se caractérisent par une orientation de recherche plus fondamentale qu'appliquée, de sorte que le TST est aussi marqué par une conception linéaire plus classique[103]. Dans ce sens, Nano-Tera.ch ne se distingue pas fondamentalement d'autres programmes de recherche contemporains, comme les PRN de la série 1 (lancée en 2001)[104]. Mais cette approche dispersée du TST a été critiquée par le panel d'experts CSS comme par l'étude externe sur mandat du CSS. Une étude des bonnes pratiques aurait pu être faite en Europe et au-delà au début du programme pour mettre sur pied un TST performant. Rappelons enfin que, depuis 2011, le FNS demande à chaque PRN de formuler un document stratégique en matière de TST. Ce changement a été introduit à partir de la série 3 des PRN (2010); dès la série 4 (2014), un plan d'action détaillé est exigé[105].

La conception du TST a évolué durant la réalisation de Nano-Tera.ch. Durant la phase I, les projets RTD devaient avoir un partenaire industriel. Cette obligation s'est modifiée à partir de 2012 (phase II), avec le passage du partenaire industriel, toujours recommandé mais non obligatoire, vers l'obligation d'intégrer un utilisateur final (*end user*). Cette évolution traduit une réflexion sur les moyens à mobiliser pour renforcer l'impact économique des projets et mieux articuler les résultats sur les buts stratégiques de l'initiative. Initiée par les recommandations du panel FNS à l'issue de la phase I[106], cette réflexion a aussi été nourrie par une étude interne à Nano-Tera.ch, réalisée auprès de 15 des 19 projets RTD financés durant la phase I[107]. Le passage du partenaire industriel à l'utilisateur final entre la phase I et II change donc les critères de sélection des projets RTD. Cette modification était une nécessaire amélioration du dispositif d'encouragement, et sans doute la plus efficace en raison de la concentration du financement sur les projets RTD. Les autres mesures prises par la direction de Nano-Tera.ch, qui ne relevaient pas du budget RTD, ne pouvaient de fait pas avoir une ampleur comparable. En 2014 démarre ainsi une collaboration avec le *Tech transfer office* de l'EPFL, sous la forme d'un *Industrial Valorization Fund* (IVF), qui permettra à 4 initiatives issues de projets RTD de trouver des partenaires privés durables[108]. En 2015 démarrent l'un des volets du programme NextSteps (*track 2 Entrepreneurship*), et le programme Gateway.

Après une première phase pilote en novembre 2015 (4 projets), le programme Gateway a officiellement été lancé en novembre 2016 (4 projets également). Le coordinateur du programme assurait notamment une fonction de coaching des projets soutenus. La conception et l'organisation interne du programme

[98] Voir Annexe D.
[99] Sur la définition des modèles de TST, voir Annexe D, pp. 21 et sq.
[100] Annexe D, p. 25.
[101] Annexe D, pp. 8-9.
[102] En particulier du *business plan* de 2007, cf. Annexe D, pp. 24-25.
[103] Voir les études de cas présentées dans l'Annexe D, chapitre 4.
[104] Annexe D, pp. 41 et sq.
[105] CSSI 2015, p. 75 et p. 96. En 2016, une appréciation de la première phase des Swiss competence centers for energy research (SCCER) soulignait le manque de définition des objectifs stratégiques et l'absence d'outils permettant d'en assurer le pilotage de manière efficace (monitoring). La CTI a alors demandé aux SCCER de formuler une «Top Innovation Chart», de manière à opérationnaliser les objectifs. Voir Hammer et Iten 2016 (synthèse), Ott et al. 2016, Ess et al. 2016, Buser et al. 2016, Good et Ohler 2016, et CTI 2016 (prise de position de la CTI).
[106] Cf. Section 3.1.2.
[107] Cf. Annexe D, pp. 23-25.
[108] Annexe B, p. 74.

n'appellent pas de remarques particulières, le CSS considérant qu'il correspond aux standards de qualité, en particulier en ce qui concerne le processus de sélection et le monitoring des projets. Par sa fonction d'interface avec l'industrie et l'augmentation du *Technology Readiness Level* (TRL) des projets soutenus, Gateway a renforcé l'impact économique des résultats de Nano-Tera.ch. Le programme a fonctionné comme un complément bienvenu à l'introduction des utilisateurs finaux durant la phase II, dont l'intégration dans les projets était parfois complexe[109]. Selon le panel d'experts CSS, Gateway est une excellente mesure, mais trop modeste dans sa dotation financière (1.6 Mio CHF) et elle a été introduite trop tardivement pour être efficace[110]. Les experts mettent surtout l'accent sur la fonction de conseil que des industriels auraient pu davantage jouer, tant dans Gateway que dans les projets RTD, avec la constitution d'un *Industrial Advisory Board* au niveau de la direction et dans chacun des projets RTD, par exemple avec des *Industrial Mentors* pour la formation doctorale.

Le modèle implicite réflexif du TST, couplé aux mesures prises durant la phase II, a contribué à l'atteinte des objectifs ambitieux de Nano-Tera.ch sur le plan économique[111]. La mixité des conceptions a permis aux groupes de recherche d'adapter de manière autonome la mise en œuvre du TST à leurs besoins, i.e. à leurs rythmes et modes de travail. Cela se traduit par la grande diversité des canaux de TST employés par les différents projets[112]. De même, la collaboration avec un partenaire industriel n'est rentable qu'à partir d'un certain seuil de développement et cela peut varier selon les disciplines. A l'inverse, l'intégration d'un utilisateur final dès la formulation des objectifs de recherche favorise la prise en compte de l'applicabilité des résultats attendus. Tout cela se traduit par la bonne qualité générale du TST, du moins pour ce qui est des études de cas réalisées par l'analyse externe[113].

Mais ce modèle implicite a aussi ses limites. Le manque d'une conception claire du TST au niveau stratégique rend le TST davantage dépendant de la sensibilité des chercheurs individuels quant à la priorisation des objectifs scientifiques vs économiques. La modification des critères de sélection des projets RTD dans la phase II a certes renforcé la transférabilité des résultats, mais elle n'a pas impliqué un changement fondamental de la mise en œuvre du TST au sein des projets RTD. Enfin, contrairement à Gateway, le monitoring du TST dans les projets RTD était peu développé[114]. Pourtant, les porteurs de Nano-Tera.ch avaient annoncé dans le *business plan* de 2007[115] vouloir développer un monitoring systématique sur le modèle de la *Microelectronics Advanced Research Corporation* (MARCO), qui a géré le programme de recherche américain *Focus Center Research Program* de 1997 à 2013[116].

### 3.3.2 Conclusions

- D'une manière générale, Nano-Tera.ch présente un fort potentiel d'impact économique, par la formation d'un personnel qualifié dans un domaine clé de l'industrie, par la création de start-ups prometteuses ou déjà confirmées, et par l'achèvement de plusieurs démonstrateurs et prototypes. Les projets RTD ont recouru à une grande diversité de modes de TST, reflétant l'arc couvert par Nano-Tera.ch, de la recherche fondamentale à l'application. Toutefois, le fait que ces résultats proviennent moins d'une conception claire de la stratégie de mise en œuvre du programme que de mesures d'amélioration prises durant la réalisation a considérablement limité le potentiel d'impact économique.
- L'introduction des utilisateurs finaux comme critère de sélection des projets RTD dans la phase II reflète la réflexion commune à la direction de Nano-Tera.ch et au panel FNS sur les moyens d'améliorer le TST dans les projets. Un tel changement du dispositif d'encouragement d'origine était nécessaire pour mieux articuler les critères de sélection aux objectifs stratégiques de Nano-Tera.ch.

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[109] Annexe D, p. 9.
[110] Annexe C3, pp. 6-8.
[111] Annexe D, pp. 38-39.
[112] Annexe D, p. 37, tableau D 4.3.
[113] Annexe D. Dans les trois études de cas sous revue, toutes les collaborations avec le secteur public ou privé paraissent se poursuivre après la fin du financement Nano-Tera.ch.
[114] Annexe D, p. 10, 40.
[115] Nano-Tera.ch. The Swiss Initiative Engineering and information technology for health and security of the human being, and the environment. Business Plan, 19 November 2007, pp. 32-33.
[116] Voir NRC 2003 et https://www.src.org/program/fcrp/

Dans la seconde moitié de la phase II, la direction de Nano-Tera.ch a pris des mesures complémentaires, en particulier le programme Gateway. Mais leur efficacité a été limitée en raison de la dotation financière modeste et d'une introduction tardive.

- La conception du TST au sein des projets RTD reposait sur un modèle implicite réflexif. La dimension implicite de cette conception a favorisé une mise en œuvre du TST de manière autonome et selon les besoins et capacités propres à chaque projet. Toutefois, cette même flexibilité a limité le pilotage stratégique du TST sur l'ensemble de l'exercice, en raison de la faiblesse du monitoring et de l'absence d'une conception explicite émanant de la direction de Nano-Tera.ch. Le rôle consultatif des industriels au niveau de la direction du programme comme des projets semble n'avoir pas été suffisamment pris en compte. Enfin, la contribution financière privée reste très basse pour une initiative explicitement orientée vers l'application.

## *3.4 Impact sociétal*

*Key statements*

- *Nano-Tera.ch has contributed to steering the research funded toward current social needs (health, environment, energy, etc.).*
- *Nano-Tera.ch has contributed to disseminating the results achieved within and beyond the Nano-Tera.ch community.*
- *Nano-Tera.ch has implemented efficient pilot actions to promote the activities of the programs in high school and towards younger children.*

### 3.4.1 Analyse

Formuler les objectifs sociétaux et mesurer l'impact sociétal d'un programme de recherche sont un défi complexe, où le choix des méthodes et la qualité des données sont déterminants[117]. Dans le cas de Nano-Tera.ch, l'impact sociétal ne constituait pas une priorité des objectifs stratégiques[118]. La contribution de Nano-Tera.ch à la société était plutôt conçue comme un effet indirect, destiné à renforcer la prise de conscience du potentiel d'impact sociétal des sciences de l'ingénieur.

Les résultats présentés par Nano-Tera.ch dans son rapport d'auto-évaluation témoignent d'une convergence entre les domaines couverts par les projets scientifiques de Nano-Tera.ch et les préoccupations de la population resp. des responsables politiques[119]. Toutefois, il ne s'agit pas à proprement parler d'un impact sociétal lié à l'activité déployée par Nano-Tera.ch sur la période 2008 à 2016. Le panel d'experts CSS de même que le CSS considèrent que la présentation de l'effet sociétal du programme par Nano-Tera.ch ne repose pas sur une méthode convaincante. Des mesures ponctuelles ciblées auprès des jeunes ont été prises en 2015 et 2016 en présentant les résultats de certains projets dans le cadre d'activités de l'EPFL[120]. Mais l'essentiel de la mise en œuvre de la dimension sociétale semble avoir été faite par le biais de la communication institutionnelle plus classique, comme le site internet, les publications grand public, et de nombreuses interviews données dans la presse suisse[121].

Pour le panel d'experts CSS, ces différentes mesures, et en particulier la présence dans la presse suisse, ont renforcé le potentiel d'impact des projets financés[122]. Pour le panel FNS, la contribution de Nano-Tera.ch s'exerce d'abord par la prise de conscience des chercheurs envers la nécessité de la

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[117] Pour un aperçu voir en particulier: Bornmann 2012, Bornmann & Marx 2014, de Jong et al. 2014.

[118] Cette dimension est quasiment absente des documents initiaux: aucune mention dans le business plan de 2007; seul le résumé de la requête à la CUS y fait référence (CUS, Proposition d'un projet ou d'un programme de coopération et d'innovation, Contributions liées à des projets 2008-2011, Titre du projet: «Nano-Tera.ch», juin 2007, p. 36): «The scientific outcome is expected to (...) promote a vision of engineering with social objectives.» On retrouve une référence à la dimension sociétale dans l'Appel à propositions de 2008, qui souligne que le programme se distingue par sa «Social relevance, in terms of projected benefits to health, security and the environment.» Nano-Tera.ch. The Swiss Initiative in Engineering and information technology for health and security of the human being, and the environment. Call for Proposals [28.01.2008]. http://www.nano-tera.ch/news/textes/nano-tera_call_for_proposals2008.pdf

[119] Annexe B, pp. 80-84.

[120] Annexe B, p. 93.

[121] 1 à 2 interviews par mois sur Nano-Tera.ch de 2008 à 2016. Annexe B, p. 86.

[122] Annexe C3, p. 8.

collaboration interdisciplinaire pour adresser des enjeux sociétaux[123]. La participation d'utilisateurs finaux aux projets RTD dans la phase II a aussi renforcé l'impact sociétal des projets RTD[124]. Par exemple, les senseurs et capteurs mobiles individuels développés par le projet OpenSense I et II ont permis, grâce à la collaboration avec les utilisateurs finaux à Zurich et à Lausanne, d'améliorer la qualité de la mesure de la pollution atmosphérique en milieu urbain[125]. L'Institut universitaire de médecine sociale et préventive de Lausanne (IUMSP) étudie actuellement comment traiter ces nouvelles données tout en respectant la vie privée des porteurs de capteurs[126].

#### 3.4.2 Conclusions

- Nano-Tera.ch a contribué à promouvoir une vision des sciences de l'ingénieur orientée vers les besoins de la société. Un impact sociétal propre aux projets financés se situe dans la prise de conscience, au niveau des groupes de recherche, de l'importance d'adresser ces problématiques par le biais de collaborations interdisciplinaires incluant des utilisateurs finaux.
- L'impact sociétal ne constituait pas une priorité stratégique de Nano-Tera.ch. Les mesures spécifiques développées consistaient surtout à renforcer la présence de Nano-Tera.ch auprès du grand public (communication générale) et des jeunes (en 2015 et 2016). Les résultats présentés ne sont toutefois pas suffisamment étayés sur le plan méthodologique pour attester d'une causalité entre les mesures prises par Nano-Tera.ch et les effets observés.
- A l'exception de la rencontre annuelle du programme, la plupart des mesures citées au titre de l'impact sociétal par Nano-Tera.ch étaient occasionnelles, limitées à l'EPFL ou introduites durant la phase II.

### *3.5 Impact institutionnel*

*Key statements*

- *Nano-Tera.ch has substantially contributed to the setup of the joint SNSF-CTI program Bridge, a novel funding instrument aiming at better exploiting the economic and societal potential of scientific research by promoting the transfer from scientific knowledge to innovation.*
- *The operational procedures deployed and tested during the Nano-Tera.ch program represent an interesting example of innovative mechanisms for financing and monitoring research with high economic potential.*

#### 3.5.1 Analyse

Les *key statements* du mandat du SEFRI se concentrent sur le programme «Bridge»[127]. Ce programme s'inscrit dans le cadre des efforts du Conseil fédéral en faveur du renforcement du système d'encouragement de la chaîne de création de valeur; il a été présenté aux Chambres fédérales dans le Message FRI 2017-2020[128]. La dotation financière totale s'élève à 70 Mio CHF, avec une allocation annuelle croissante de 2017 à 2020[129]. Géré en commun par le FNS et Innosuisse et réalisé au titre de mandat spécial de la Confédération, le programme Bridge a été lancé en décembre 2016; il est encore en phase expérimentale[130]. Un premier bilan de son introduction est prévu pour 2019[131].

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[123] Cet aspect a été confirmé dans les entretiens CSS.
[124] Cet aspect a été confirmé dans les entretiens CSS.
[125] Voir Annexe B, pp. 30 et 38 ainsi que http://www.opensense.ethz.ch/ et http://opensense.epfl.ch/wiki/index.php/OpenSense_2.html
[126] Entretien CSS.
[127] http://bridge.ch/fr/
[128] Conseil fédéral (2016), Message relatif à l'encouragement de la formation, de la recherche et de l'innovation pendant les années 2017 à 2020 du 24 février 2016, FF 2016 2917-3178. Outre le programme Bridge, le Conseil fédéral mentionne la réforme de la CTI en InnoSuisse, et annonce que la sélection de la prochaine série des PRN prévoit (p. 2971) «de retenir des pôles promettant une recherche fondamentale de très grande qualité assortie d'un gros potentiel d'application à l'innovation réalisable à moyen et à long terme».
[129] Idem, figure 19 p. 3020 et figure 21 p. 3036. Le principe d'une gestion commune par deux institutions chargées d'encourager la recherche (à savoir Innosuisse et le FNS) a été ancrée dans la LERI (nouvelle teneur de l'art. 7, al. 3).
[130] Conseil fédéral (2016), Message relatif à l'encouragement de la formation, de la recherche et de l'innovation pendant les années 2017 à 2020 du 24 février 2016, FF 2016, p. 3016.
[131] Convention de prestations 2017-2020 [entre le SEFRI et le FNS], 31.05.2017. Annexe, pp. 4-5. http://www.snf.ch/SiteCollectionDocuments/Convention_de_prestations_FNS_2017-2020_F_incl_annexe.pdf

Comme pour l'ensemble des dimensions sous revue, le CSS apprécie l'impact institutionnel de Nano-Tera.ch en tenant compte, en premier lieu, des objectifs stratégiques originaux de l'initiative[132]. Or, de ce point de vue, le programme Bridge ne peut être considéré comme un impact institutionnel direct de Nano-Tera.ch, puisque la prise de mesures de nature structurelle n'entrait pas dans les objectifs stratégiques originaux du programme[133]. Cet aspect est d'ailleurs souligné par la direction de Nano-Tera.ch dans sa prise de position sur le rapport du panel d'experts CSS[134]. On peut toutefois se demander, au vu de l'ampleur financière de Nano-Tera.ch et de ses ambitions, s'il est recevable de ne pas intégrer une dimension structurelle aux objectifs initiaux.

Cela n'exclut toutefois pas que Nano-Tera.ch ait pu avoir un effet structurel, en particulier au niveau des institutions partenaires. Mais il convient de rester prudent quant à l'appréciation de cet aspect. Par exemple, la dimension interinstitutionnelle de chaque projet RTD a favorisé un accès, certes modeste, d'institutions comme le CSEM, les universités cantonales, les HES et les hôpitaux aux EPF, tant au niveau du financement que du mode d'organisation de la recherche[135]. Le fait que certaines collaborations interinstitutionnelles et interdisciplinaires se poursuivent après la fin du financement Nano-Tera.ch est un résultat positif[136]. Certaines initiatives stratégiques prises par des membres du consortium témoignent d'une proximité avec Nano-Tera.ch. Citons par exemple le grand axe stratégique de recherche «Systèmes de fabrication de pointe (Advanced Manufacturing)» du domaine des EPF (20 Mio CHF, 2016-2020[137]), dont plusieurs bénéficiaires ou responsables sont d'anciens PIs ou co-PIs de Nano-Tera.ch[138]. Le rapport d'auto-évaluation de Nano-Tera.ch ne renseigne toutefois ni sur ces différents aspects, ni sur l'éventuelle poursuite, au sein des institutions partenaires, de mesures prises durant la mise en œuvre de Nano-Tera.ch, comme le programme NextSteps.

Entre fin 2013 et début 2014, la direction de Nano-Tera.ch a participé à l'élaboration d'un projet de nouvel instrument de financement commun à la CTI et au FNS dans le domaine des sciences de l'ingénieur. Se fondant sur l'expérience de Nano-Tera.ch et du programme du FNS precoR[139], ce nouvel instrument a pour objectif de renforcer le soutien à la translation de la recherche en sciences de l'ingénieur du fondamental à l'appliqué, avec une participation de l'industrie[140]. L'instrument doit se distinguer de l'organisation interne de Nano-Tera.ch, qui ne peut être reprise; le financement doit émarger aux budgets ordinaires de la CTI et du FNS[141]. En 2015, le FNS annonce dans sa planification pluriannuelle le lancement du programme Bridge comme mesure conjointe avec la CTI pour renforcer le transfert de savoir et l'innovation[142]. Outre Nano-Tera.ch et precoR, le FNS motive Bridge en citant sa collaboration avec la CTI sur certains PNR ainsi que des expériences à l'étranger.

La contribution de Nano-Tera.ch à la formulation de Bridge est ainsi avérée, et le CSS considère que Bridge reprend plusieurs aspects jusqu'alors propres à Nano-Tera.ch dans le domaine des sciences de l'ingénieur, en particulier l'interdisciplinarité, l'interinstitutionnalité et le soutien ciblé aux jeunes chercheurs. Bien que la conception de Bridge soit liée à l'expérience de la mise en œuvre de Nano-Tera.ch en tant que programme, et en particulier aux mesures prises durant la phase II pour renforcer le TST (programmes Gateway et NextSteps), il ne paraît pas pertinent de faire une comparaison systématique de ces deux programmes, sans compter que le programme Bridge est en cours de mise en

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[132] Cf. Section 1.2.

[133] A l'exception de la création de nouveaux cursus de formation dans le cadre de projets ED, cf. Nano-Tera.ch. Ordinary Partnership Contract, January 2008.

[134] Cf. Annexe C32, p. 2: «the specific legal status of Nano-Tera.ch ("National Joint Action") did not provision for any potential legacy of the program. In particular, it did not require from the involved institutions any commitment in terms of long-term structural investment (such as the creation of permanent chairs, or institutionalized entities), while this is the case for other funding instruments such as the SNF's NCCRs.»

[135] Entretiens CSS.

[136] Voir Annexe B, pp. 28-41, et Entretiens CSS.

[137] CEPF Conseil des EPF (2014), Plan stratégique 2017–2020 pour le Domaine des EPF. p. 52 et suiv.

[138] Notamment: Christofer Hierold, Christian Enz (membres du Steering Committee); Jürgen Brugger (PI projet Ceramic X.0), Kristina Shea (PI projet SD4D), etc., cf. https://www.sfa-am.ch/research-projects.html.

[139] Initiative for funding precompetitive research (2014), cf. http://www.snf.ch/en/funding/programmes/precor/Pages/default.aspx,

[140] Un entretien CSS a confirmé la nécessité d'un encouragement à collaborer qui soit plus soutenu dans Bridge que cela n'a été le cas dans Nano-Tera.ch.

[141] Ces deux points ont été confirmés par les entretiens CSS.

[142] FNS (2015), Programme pluriannuel 2017–2020. Planification à l'attention des autorités fédérales, Berne, FNS, p. 16.

œuvre. Sans se prononcer sur les critiques adressées à l'égard de Bridge quant à sa dotation financière restreinte ou à son taux de succès relativement bas[143], le CSS considère que le programme Bridge clarifie le rôle des parties prenantes dans la mise en œuvre, dans l'organisation de la procédure de sélection, et précise les attentes en matière de TST[144]. Dans ce sens, Bridge peut être considéré comme un impact indirect de Nano-Tera.ch à la fois sur les plans institutionnel et organisationnel.

### 3.5.2 Conclusions

- Dès lors que l'impact institutionnel ne comptait pas parmi les objectifs stratégiques initiaux de Nano-Tera.ch, il est logique qu'aucune mesure spécifique n'ait été prise dans ce sens par la direction du programme. Ce point n'est d'ailleurs pas documenté en tant que tel dans le rapport d'auto-évaluation de Nano-Tera.ch[145]. Cette absence est d'autant plus regrettable que Nano-Tera.ch disposait de moyens financiers considérables et que la concrétisation de son ambitieuse vision n'aurait sans doute pas été desservie par l'introduction d'objectifs structurels.
- Le programme Bridge est un impact institutionnel indirect de Nano-Tera.ch. Nano-Tera.ch a été associé à la conception du programme Bridge, qui se fonde aussi sur d'autres expériences nationales et internationales. Les aspects positifs de Nano-Tera.ch ont été repris dans Bridge. Mais l'organisation interne de Bridge témoigne aussi des enseignements tirés de l'expérience Nano-Tera.ch sur le plan de la gouvernance.
- Nano-Tera.ch a mis en lumière les difficultés liées à l'encouragement, dans le domaine des sciences de l'ingénieur, de la recherche fondamentale à la recherche appliquée. L'introduction des programmes NextStep et Gateway durant la phase II a permis d'expérimenter des modes d'encouragement ciblé pour améliorer la translation des résultats dans l'industrie et la collaboration avec le secteur privé, y compris au niveau de la formation doctorale (promotion de l'esprit d'entreprise). La poursuite de ces mesures au sein des institutions partenaires n'est toutefois pas documentée.

## *3.6 Perspective systémique*

Cette section propose une mise en perspective de deux aspects fondamentaux de Nano-Tera.ch qui ressortent de l'appréciation des différentes dimensions du mandat du SEFRI. Il s'agit, d'une part, de la question de la valeur ajoutée de l'encouragement déployé par Nano-Tera.ch pour le système FRI, et, d'autre part, des principales leçons que l'on peut tirer de l'expérience de mise en œuvre de Nano-Tera.ch.

### 3.6.1 L'impact global de Nano-Tera.ch: quelle valeur ajoutée pour le système FRI?

Les projets de recherche soutenus par Nano-Tera.ch (RTD) se caractérisent de la manière suivante:

- Des groupes de recherche interdisciplinaires et interinstitutionnels, avec une communauté en majorité issue des sciences de l'ingénieur et des EPF, mais intégrant aussi d'autres disciplines et ressources issues des HEU, des HES, des centres de compétences technologiques collaborant avec des hautes écoles, des hôpitaux universitaires et du secteur privé;
- Une dotation financière par projet plus élevée que la recherche libre du FNS et une durée moyenne de 4 ans;
- Une orientation socio-économique, avec la participation à chaque projet d'un partenaire industriel et/ou d'un utilisateur final;
- Un modèle de TST implicite, plutôt réflexif que linéaire[146], la production de plusieurs démonstrateurs resp. prototypes ainsi que la création de *starts-up*.

Durant la réalisation de Nano-Tera.ch (2008-2017), différents dispositifs ou instruments d'encouragement de la recherche et de la formation contribuent à l'interdisciplinarité, à l'interinstitutionnalité, au TST

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[143] Entretiens CSS.
[144] Voir les différents documents sur le site internet de Bridge, et en particulier les «Terms of Reference», disponibles à l'adresse: http://www.snf.ch/SiteCollectionDocuments/Bridge_Terms_of_Reference.pdf
[145] Annexe B.
[146] Sur la définition des modèles de TST, voir Annexe D, pp. 21 et sq.

ou à l'orientation des résultats vers des buts sociétaux, selon des modalités d'organisation et des intensités de financement qui varient[147]. Ces différents dispositifs permettent de couvrir l'ensemble du spectre d'encouragement de la recherche, de la formation supérieure et de l'innovation, afin d'atteindre les objectifs stratégiques du Conseil fédéral dans le domaine FRI. De plus, la priorité donnée à l'approche de type *bottom-up* s'accorde avec la structure fédéraliste et avec le principe de subsidiarité du financement fédéral.

Mais, sur l'ensemble de la période 2008-2016, seul Nano-Tera.ch (et SystemsX.ch) semble réunir toutes ces propriétés d'encouragement en un seul dispositif et au sein du même projet scientifique. Dès lors, la principale valeur ajoutée de Nano-Tera.ch se situe moins dans la nouveauté que dans la concentration des modes d'encouragement au sein d'une même initiative de recherche. La mobilisation de telles propriétés d'encouragement, qui relèvent de la recherche à la fois fondamentale et appliquée, était indispensable pour tenter de répondre à la très ambitieuse vision initiale.

En déployant une palette d'encouragement couvrant l'ensemble de la chaîne de création de valeur, l'initiative Nano-Tera.ch a répondu aux problèmes posés, dans les sciences de l'ingénieur, par la translation de la recherche fondamentale vers la recherche appliquée. L'introduction des programmes Gateway et NextSteps a renforcé ce mouvement, mais ces mesures ciblées n'ont concerné qu'une part minimale des projets resp. des doctorants[148]. La valeur ajoutée de Nano-Tera.ch est globalement positive, mais il faut souligner qu'elle s'est concentrée sur les sciences de l'ingénieur et sur le domaine des EPF, qui réunit presque 80% des PIs[149]. La participation d'autres disciplines et d'autres institutions a été importante, mais déterminée par cette réalité. Enfin, Nano-Tera.ch n'avait pas d'objectifs structurels resp. institutionnels, ce qui limite son impact à moyen et long terme[150].

L'expérience de Nano-Tera.ch a rendu un peu plus visible la nécessité de compléter l'encouragement de la recherche tout au long de la chaîne de création de valeur, et en particulier au niveau de la recherche précompétitive. L'introduction des utilisateurs finaux comme critère de sélection des projets RTD dans la phase II témoigne d'une capacité de réflexion bienvenue. Il n'a pas fallu attendre la fin de Nano-Tera.ch pour voir la reprise dans l'encouragement ordinaire du système FRI de certains aspects de l'encouragement de Nano-Tera.ch, en premier lieu desquels le programme Bridge[151]. Sur le plan de l'orientation scientifique, l'émergence de nouveaux PRN dans des domaines voisins[152], ou le lancement de l'axe stratégique de recherche «Systèmes de fabrication de pointe» du domaine des EPF, participent d'un élan similaire. Toutefois, le CSS considère qu'il est encore prématuré de procéder à une analyse comparée de ces programmes et de Nano-Tera.ch. Il conviendrait d'attendre au moins la fin de la phase pilote du programme Bridge (2020). De plus, la réflexion devrait tenir compte de la nouvelle LERI, entrée en vigueur en 2014, et intégrer les Pôles de compétence en recherche énergétique (SCCER)[153], qui se poursuivent jusqu'à 2020.

### 3.6.2 Réflexions sur la mise en œuvre de Nano-Tera.ch

Nano-Tera.ch a vu le jour grâce à la fenêtre d'opportunité créée par le passage de SystemsX (2004-2007) à SystemsX**.ch** (2008-2016). Les deux initiatives ont été présentées au parlement dans le même Message FRI 2008-2011. Le soutien apporté par le Conseil fédéral et par les Chambres à SystemsX.ch et à Nano-Tera.ch légitimait leur inscription dans le paysage d'encouragement du domaine FRI. Il pouvait dès lors apparaître logique au législateur d'élaborer le schéma de mise en œuvre de Nano-Tera.ch selon les mêmes principes que celui développé pour SystemsX.ch. Mais alors que SystemsX.ch est

[147] Il s'agit en particulier des dispositifs suivants: l'instrument sinergia, les PRN et les PNR; l'encouragement de la CTI (soutien à l'innovation, soutien à la création de starts-up, réseaux thématiques nationaux); les Pôles de compétence en recherche énergétique (SCCER) lancés en 2013; l'instrument CUS «Contributions liées à des projets».
[148] Voir section 3.3.
[149] Voir section 3.1.
[150] Voir section 3.5.
[151] Voir section 3.5.
[152] En particulier les PRN Robotics, QSIT, MUST chembio, TransCure (série 3); MSE, MARVEL (série 4).
[153] Les Swiss competence centers for energy research (SCCER) ont été lancés en 2013 dans le cadre du plan d'action «Recherche énergétique suisse coordonnée». Ils sont contrôlés et financés par Innosuisse, en collaboration avec le FNS et l'Office fédéral de l'énergie (OFEN). Cf. https://www.innosuisse.ch/inno/fr/home/thematische-programme/foerderprogramm-energie.html. Voir aussi: Message relatif au plan d'action «Recherche énergétique suisse coordonnée» – Mesures pour les années 2013 à 2016 du 17 octobre 2012, FF 2012 8331.

bâti sur une précédente coopération d'au moins trois ans entre les universités de Bâle et de Zurich et l'EPFZ, le projet scientifique de Nano-Tera.ch a vu le jour en moins de six mois et le programme a été formalisé en moins d'un an[154].

Une telle rapidité dans la conception et la mise sur pied d'un programme de cette ampleur est un tour de force. Mais cette phase de conception et de formalisation a aussi été l'occasion d'importantes divergences entre les parties prenantes, illustrant un manque de vision commune des objectifs, des rôles et des compétences[155]. Deux points centraux sont à retenir. D'une part, le manque d'objectifs stratégiques clairs susceptibles d'opérationnaliser la vision scientifique initiale a été souligné par le FNS dès 2007, soit avant le démarrage officiel de Nano-Tera.ch; cette faiblesse a impacté le processus de sélection des projets RTD, la formulation des appels à propositions[156], ainsi que l'ensemble de la mise en œuvre de l'initiative. D'autre part, la concentration de l'essentiel des ressources financières dans les projets RTD, soumis à la sélection du panel FNS, a été interprété par l'ExCom comme une limitation à sa marge de manœuvre dans la mise en œuvre de Nano-Tera.ch[157]. L'analyse CSS a démontré que certaines appréciations étaient injustifiées, en particulier celle selon laquelle le panel FNS aurait procédé à une sélection des projets RTD qui ne prenait pas suffisamment en compte les aspects industriels[158]. Certaines mesures ciblées prises sur l'initiative de l'ExCom, telles les programmes Gateway et NextSteps, ont certes renforcé le potentiel d'impact de Nano-Tera.ch, mais leur effet a été réduit du fait de leur introduction tardive, dans la seconde moitié de la phase II, et de leur dotation financière réduite. Enfin, il faut rappeler que la faiblesse générale du monitoring, relevée notamment par l'étude externe mandatée par le CSS[159], limite l'appréciation globale des résultats.

Les leçons de Nano-Tera.ch pour le système FRI ont en partie déjà été tirées. Deux ans après le début de Nano-Tera.ch, les prises de positions de la CUS, de la Conférence des recteurs des universités suisses (CRUS), du CEPF et du FNS lors de la révision totale de la LERI se fondaient directement sur l'expérience de Nano-Tera.ch et de SystemsX.ch pour demander que des initiatives de ce type «fassent l'objet d'un processus de coordination et de décision explicitement réglé dans la LERI[160].» Les al. 5 et 6 de l'art. 41 de la nouvelle LERI, entrée en vigueur en 2014[161], stipulent que le Conseil fédéral est responsable de la planification et de la coordination de ce type d'initiatives, en concertation avec les acteurs du domaine FRI, en particulier la Conférence suisse des hautes écoles (CSHE). Ce changement devrait permettre de clarifier la définition des objectifs stratégiques de tels programmes exceptionnels par leur portée et par leur organisation. Une attention soutenue devra cependant aussi être portée à différents points que l'expérience Nano-Tera.ch a mis en lumière:

- Les objectifs scientifiques et socio-économiques de l'initiative devraient être clairement définis, de même que les effets structurels attendus du programme. La valeur ajoutée de l'initiative, notamment aux plans de l'organisation et des effets attendus, devrait faire l'objet d'un document initial;
- Les objectifs stratégiques, le concept de mise en œuvre et la procédure de sélection des projets soutenus au sein de l'initiative devraient reposer sur un consensus entre les parties prenantes et faire l'objet d'une documentation détaillée;

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[154] Soit de la décision du CEPF de fusionner les deux propositions issues de l'EPFL et de l'EPFZ (décembre 2006) au dépôt de la proposition de programme à la CUS (juin 2007), puis la création de Nano-Tera.ch en société simple et la parution du premier appel à propositions (janvier 2008), cf. Chapitre 2.

[155] La prise de position de Nano-Tera.ch sur le rapport des experts internationaux mandatés par le CSS témoigne de la persistance de ces divergences, cf. Annexe C32.

[156] Voir Chapitre 2.

[157] Ce point ressort en particulier sous l'angle de la mise en œuvre du TST: «The nature and extent of Nano-Tera's KTT-related measures have been strongly constrained by the imposition to work under SNF's umbrella, while typically projects involving industry are run by CTI/KTI which was not involved in Nano-Tera.ch», cf. Annexe C32, p. 1.

[158] Voir les sections 3.1 Impact scientifique et 3.3 Impact économique.

[159] Voir Annexe D, ainsi que les variations dans le nombre de starts-up créées grâce à Nano-Tera.ch (entre 10 et 40), cf. section 3.3.1.

[160] Message relatif à la révision totale de la loi sur l'encouragement de la recherche et de l'innovation du 9 novembre 2011, FF 2011, p. 8124. Cf. https://www.admin.ch/opc/fr/federal-gazette/2011/8089.pdf. Voir également: DFI, Révision totale de la loi fédérale sur l'encouragement de la recherche et de l'innovation (LERI). Rapport sur les résultats de la consultation, Berne, 1er septembre 2010, p. 14. https://www.admin.ch/ch/f/gg/pc/documents/1764/Ergebnis.pdf

[161] Loi fédérale sur l'encouragement de la recherche et de l'innovation (LERI) du 14 décembre 2012 (Etat le 1er janvier 2018), RS 420.1. https://www.admin.ch/opc/fr/classified-compilation/20091419/index.html

- L'organisation interne et la gouvernance devraient s'accorder aux objectifs stratégiques poursuivis; elles devraient refléter un consensus préalable entre les parties prenantes et correspondre aux standards en vigueur, en particulier sous l'angle de la gestion des conflits d'intérêt et du monitoring;
- En cas de prédominance de l'orientation appliquée, le secteur privé devrait participer à la définition des objectifs stratégiques ainsi qu'à la mise en œuvre, par exemple en intégrant un *Scientific and economic advisory board;*
- Les dispositions légales en vigueur devraient être examinées de manière à s'assurer de leur efficacité quant à la formulation de telles initiatives, quant à la procédure de sélection des projets soutenus et quant aux règles d'organisation interne.

## Abréviations

| | |
|---|---|
| CEPF | Conseil des Ecoles polytechniques fédérales |
| Co-PI | Co-Principal investigator |
| CRUS | Conférence des recteurs des universités suisses |
| CSEM | Centre suisse d'électronique et de microtechnique |
| CSHE | Conférence suisse des hautes écoles |
| CSS | Conseil suisse de la science |
| CSSI | Conseil suisse de la science et de l'innovation |
| CTI | Commission pour la technologie et l'innovation |
| CUS | Conférence universitaire suisse |
| DEFR | Département fédéral de l'économie, de la formation et de la recherche |
| DFI | Département fédéral de l'intérieur |
| ED | Education and Dissemination |
| EPF | Ecoles polytechniques fédérales |
| EPFL | Ecole polytechnique fédérale de Lausanne |
| EPFZ | Ecole polytechnique fédérale de Zurich |
| ExCom | Executive committee (Nano-Tera.ch) |
| FNS | Fonds national suisse pour l'encouragement de la recherche scientifique |
| FRI | Formation, recherche et innovation |
| HES | Hautes écoles spécialisées |
| IMT | Institut de microtechnique |
| Innosuisse | Agence suisse pour l'encouragement de l'innovation |
| IVF | Industrial valorization fund |
| KTT | Knowledge and technology transfer |
| LEHE | Loi fédérale sur l'encouragement des hautes écoles et la coordination dans le domaine suisse des hautes écoles |
| LERI | Loi fédérale sur l'encouragement de la recherche et de l'innovation |
| MEMS | microsystèmes électromécaniques |
| Mio | Millions |
| NEMS | Nanosystèmes électromécaniques |
| NRC | National Research Council |
| NTF | Nano-Tera.ch Focused |
| O-LERI | Ordonnance relative à la loi fédérale sur l'encouragement de la recherche et de l'innovation du 29 novembre 2013 |
| O-LERI-DEFR | Ordonnance du DEFR relative à l'ordonnance sur l'encouragement de la recherche et de l'innovation du 9 décembre 2013 |
| PI | Principal investigator |
| PME | Petites et moyennes entreprises |
| PNR | Programmes nationaux de recherche |
| PPR | Programmes prioritaires de recherche |
| precoR | Initiative for funding precompetitive research |
| PRN | Pôles de recherche nationaux |
| RS | Recueil systématique |
| RTD | Research, Technology and Development Projects |
| SCCER | Swiss competence centers for energy research |
| SER | Secrétariat d'Etat à la recherche |
| SSSTC | Sino-Swiss Science and Technology Cooperation program |
| swissuniversities | Conférence des recteurs des hautes écoles suisses |
| SWR | Schweizerischer Wissenschaftsrat |
| TRL | Technology Readiness Level |
| TST | Transfert de savoir et de technologies |
| Unibas | Université de Bâle |
| Unige | Université de Genève |
| Unil | Université de Lausanne |
| Unine | Université de Neuchâtel |

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## Annexes

***A.*** ***Mandat et concept du SEFRI, septembre 2016***

***B.*** ***Rapport d'auto-évaluation de Nano-Tera.ch, octobre 2017***

***C.*** ***Rapport du panel d'experts CSS et prises de position, 2017-2018***

- ***C1.*** ***Terms of reference of external experts (TOR)***
- ***C2.*** ***Questions du CSS au panel d'experts***
- ***C3.*** ***Rapport du panel d'experts CSS***
  - ***C31.*** ***Prise de position FNS sur le rapport du panel d'experts CSS***
  - ***C32.*** ***Prise de position Nano-Tera.ch sur le rapport du panel d'experts CSS***

***D.*** ***Le transfert de savoir et de technologie dans Nano-Tera.ch, octobre 2017***

Meyer, L., Rieder, S. (Interface) (2017). Wissens- und Technologietransfer von Nano-Tera.ch. Schlussbericht zuhanden der Geschäftsstelle des Schweizerischen Wissenschafts- und Innovationsrates (SWIR), 3. Oktober 2017, Luzern, Interface-Politikstudien.

***E.*** ***Nano-Tera.ch: related grants awarded by the SNSF, avril 2017***

***F.*** ***Entretiens CSS: liste des personnes rencontrées et guides d'entretien, 2017-2018***

***G.*** ***Programme et liste des participants à la rencontre «Site Visit», novembre 2017***

## Annexe A – Mandat et concept du SEFRI, septembre 2016

# MANDAT

## (Verwaltungsinterne Vereinbarung)

des

Eidgenössischen Departements für

Wirtschaft, Bildung und Forschung (WBF)

vertreten durch das

Staatssekretariat für Bildung, Forschung und Innovation (SBFI)

an den

Schweizerischen Wissenschafts- und Innovationsrat (SWIR)

**Wirkungsprüfung
der beiden nationalen Förderprogramme
Nano-Tera.ch sowie SystemsX.ch**

**Vertragsnummer: 2016.0009**

## I. Ausgangslage

Unter dem Titel "NanoTera.ch" und "SystemsX.ch" wurden mit den Entscheiden zur BFI-Botschaft 2008-2011 zwei nationale Förderinitiativen lanciert. Angesichts des Profils dieser beiden Initiativen als "nationale Verbundaufgaben" wurde für jede eine spezifische *Aufbauorganisation* (Konsortium - verantwortlich u.a. namentlich für die strategische Führung) geschaffen. Mit einer Laufzeit von nunmehr insgesamt 9 Jahren werden beide Förderprogramme auf Ende 2016 beendet. Dabei hat der Bund über die gesamte Laufdauer insgesamt rund 340 Mio. CHF Fördermittel zur Verfügung gestellt.

In Absprache mit den involvierten Stellen hat das zuständige SBFI entschieden, beide Förderinitiativen vor ihrem Abschluss einer umfassenden Wirkungsprüfung zu unterziehen. Gestützt auf Artikel 44 Absatz 3 und Artikel 54 Absatz 2 FIFG sowie in Abstimmung mit seinem Legislaturprogramm 2016-2019 wird der SWIR mit der Wirkungsprüfung der beiden nationalen Förderprogramme "Nano-Tera.ch" sowie "SystemsX.ch" beauftragt.

## II. Auftrag/Ziele – Gegenstand

Das SBFI beauftragt den SWIR mit der Durchführung einer Wirkungsprüfung beider Programme. Deren übergeordnetes Ziel besteht darin, unter programmspezifisch relevanten Aspekten die Wirkungen umfassend festzustellen und aus übergeordneter Sicht zu bewerten. Ziel und Gegenstand der Wirkungsprüfung sind in den beiden Konzeptdokumenten "Framework of the impact evaluation for the National Funding Program *NanoTera.ch*" sowie "Framework of the impact evaluation for the National Funding Program *SystemsX.ch*" detailliert dargestellt (fortan: *Konzeptunterlagen*).

## III. Zeitplan

Die Arbeit des SWIR richtet sich nach Zeitplan gemäss Konzeptunterlagen. Danach ergeben sich folgende Meilensteine:

| | NanoTera-ch (Abschluss) | SystemsX.ch (Abschluss) |
|---|---|---|
| Bericht der zuständigen Konsortien ("Selbstevaluation") | 10/2017 | 03/2017 |
| Bericht der externen Fachpanels ("Panelberichte") | 3/2018 | 12/2017 |
| Stellungnahmen zum "Panelbericht" (Konsortien; SNF) | tbd | tbd |
| SWIR Abschlussbericht (zuhanden SBFI) | 06/2018 | 02/2018 |

## IV. Weitere Bestimmungen

*Methodisches Vorgehen*
Der SWIR ist in der Wahl seiner Methoden frei.
Betreffend Nominierung der externen Fachpanels durch den SWIR gelten die in den Konzeptunterlagen gesetzten Rahmenbedingungen.

- Aktenzugang: Die Konsortien sind gegenüber dem SWIR auskunftspflichtig. Sie stellen ihm auf Nachfrage namentlich sämtliche offiziellen Strategie- und Entscheiddokumente in ihrem Zuständigkeitsbereich zur Verfügung.

- Weitere Vorgaben hinsichtlich Berichte der Konsortien, der externen Fachpanels sowie zu den übergeordneten Abschlussberichten des SWIR sind in den Konzeptunterlagen dargelegt.

*Publikation*
Über die Publikation seiner Abschlussberichte entscheidet der SWIR.

- Form: Die Publikation umfasst pro Abschlussbericht neben den übergeordneten Befunden / Bewertungen und allfälligen Empfehlungen des SWIR auch den Bericht des Konsortiums (Selbstevaluation), den externen Panelbericht, die formelle Stellungnahme des Konsortiums und des SNF zum Panelbericht sowie allfällige weitere Begleitmaterialien oder ergänzende Untersuchungen des SWIR.
- Fristen: Die Publikation der Abschlussberichte erfolgt frühestens nach Zustellung derselben an das SBFI.

*Bestandteile: Konzeptunterlagen*
Die beiliegenden Konzeptunterlagen "Framework of the impact evaluation for the National Funding Program *NanoTera.ch*" (datiert vom 29.08.2016) sowie "Framework of the impact evaluation for the National Funding Program *SystemsX.ch*" (datiert vom 30.08.2016) bilden einen integrierenden Bestandteil dieser Vereinbarung.

## V. Finanzierung und Auszahlung

*Finanzierung und Auszahlung*
Das Staatssekretariat für Bildung, Forschung und Innovation SBFI beteiligt sich mit höchstens CHF 30'000 (inkl. MWST) an den Kosten, die dem SWIR durch die Erfüllung dieses Mandats entstehen (Kostendach).

Darin eingeschlossen sind namentlich die Aufwendungen für die vom SWIR mandatierten externen Fachpanels sowie für logistische Kosten der Expertisierung durch die Fachpanels.

Dieser Beitrag gilt als Obergrenze und darf ohne Abänderung dieser Vereinbarung im beiderseitigen Einvernehmen nicht überschritten werden. (Allfällige, dieses Kostendach übersteigende Aufwendungen des SWIR sind im Prinzip durch sein allgemeines Funktionsbudget zu decken wie unter Punkt 5 in den Konzeptunterlagen vermerkt.)

Die Auszahlung bzw. Freigabe der Mittel erfolgt gestützt auf eine entsprechende Rechnungsstellung des SWIR zuhanden SBFI (Ressort Nationale Forschung) unter Angabe der Vertragsnummer (siehe Deckblatt) an folgende Adresse

Staatssekretariat für Bildung, Forschung und Innovation SBFI
c/o. DLZ FI EFD
Effingerstrasse 27
3003 Bern

Eine erste Rechnung (1/3 des Gesamtbetrages) kann nach Unterzeichnung des Vertrages bis spätestens Ende November 2016 eingereicht werden. Weitere Teilrechnungen (zu einem Maximalbetrag von 10'000 CHF im Rechnungsjahr 2017 bzw. im

Rechnungsjahr 2018) können entweder nach effektiv anfallendem Aufwand *oder* tranchenweise (maximal je 1/3 des Gesamtbetrages) nach Abschluss der Hauptphasen (Abschluss Konsortialberichte - Abschluss Panelberichte - Abschlussbericht SWIR) eingereicht werden. Mit der letzten Teilrechnung muss auch eine Gesamtrechnung (Projektgesamtaufwand) vorgelegt werden. Die verrechneten Positionen werden in den Rechnungen detailliert ausgewiesen (Honorare, Spesen, etc.). Es gelten die Honoraransätze des SBFI bzw. die (Reise-)Spesenregelungen des Bundes.

Fehlerhafte Rechnungen werden zur Korrektur an den Absender zurückgeschickt.

## VI. Schlussbestimmung

*Inkrafttreten, Beendigung*

Die Vereinbarung beginnt am 30.09.2016 und dauert bis 30.06.2018. Sie tritt nach beiderseitiger Unterzeichnung in Kraft. Sie ist mit der Erfüllung der vereinbarten Verpflichtung beendet, spätestens am 30.06.2018. Die vorzeitige Beendigung bleibt vorbehalten.

*Kontaktperson*

Für Fachkontakte zum Mandat und während der Durchführung der Wirkungsprüfung gemäss Mandat sowie für allfällige Anpassungen der vorliegenden Vereinbarung ist seitens des SBFI Dr. G. Haefliger, Vizedirektor und Leitung Abteilung Nationale Forschung & Innovation zuständig.

***

**Staatssekretariat für Bildung, Forschung und Innovation SBFI**

Dr. Mauro Dell'Ambrogio

Staatssekretär

Bern, der September 2016

**Schweizerischer Wissenschafts- und Innovationsrat (SWIR)**

Prof. Gerd Folkers

Präsident SWIR

Bern, der 29. September 2016

Beilagen:

- FRAMEWORK OF THE IMPACT EVALUATION for the NATIONAL FUNDING PROGRAM "SystemsX.ch" (SBFI, 30.08.2016)
- FRAMEWORK OF THE IMPACT EVALUATION for the NATIONAL FUNDING PROGRAM "Nano-Tera.ch" (SBFI, 29.08.2016)

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Eidgenössisches Departement für
Wirtschaft, Bildung und Forschung WBF

**Staatssekretariat für Bildung,
Forschung und Innovation SBFI**
Nationale Forschung und Innovation

**CH-3003 Bern**, NFI /SBFI/hae

# FRAMEWORK OF THE IMPACT EVALUATION for the NATIONAL FUNDING PROGRAM "Nano-Tera.ch"

## 1. Background

Based on the decisions announced in the SERI message of 2008-2011[1], a national funding program named "Nano-Tera.ch" has been launched in accordance with Article 41, paragraph 5 of the Federal Act on the Promotion of Research and Innovation (RIPA).[2]

The main goal was the development of key technologies involving micro- and nano-scale components in the framework of an interdisciplinary national network with the scientific challenge of developing basic technologies in electronics, information and communication sciences as well as materials science, to create blocks at the micro- and nano-scale able to generate large amounts of useful data and to be used in various engineering applications. In the foreseeable future, the program should lead to a significant strengthening in the domain of Knowledge and Technology Transfer and to an increased collaboration with the interested players from the private sector.

As the program has been created in the form of a "national joint task", it has been implemented with a specific organizational structure (the Nano-Tera.ch Consortium, responsible in particular for the strategic management). In addition, a scientific evaluation mechanism independent from the Consortium has been institutionalized by the Swiss National Science Foundation in the form of a special commission (the SNSF Evaluation Panel). A specific reporting mechanism has also been established as part of the procedures associated to "project-linked contributions" (cooperative projects).

Already at its launch in 2008, the perspective of approximately 10 years of financial support has been envisioned for the program. With a one-year extension in 2012 (SERI message of 2012) and a 4-year extension based on the decisions announced in the SERI message of 2013-2016, the Nano-Tera.ch program is terminating at the end of 2016 and will thus have been running for a total of 9 years. Altogether, the Swiss Confederation has provided a total funding of about 120 million CHF over the lifetime of the program.

In agreement with the involved parties, the SERI, as competent authority, decided that the "Nano-Tera.ch" program should undergo an impact evaluation before its formal conclusion[3].

[1] BBl 2007 1223 ; see in particular chapter 2.2.2, project-linked contributions.
[2] The current legal basis is ruled by the fully revised law of Dec. 14 2012 (AS 420.1). For the legal basis at the time concerning project-linked contributions, see SERI message of 2008-2011.
[3] The *formal* conclusion (including all final reports, audits and the dissolution of the associated legal entity) should take place by June 2018 at the latest.

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## 2. Nano-Tera.ch objectives

The activities proposed by Nano-Tera.ch to the Swiss government were articulated in a Proposal (for a cooperative project) and in a Business plan both presented in 2007. The **overall vision** can be articulated as follows.

The program aims at bringing Switzerland to the forefront of a new technological revolution driving engineering and information technology for health and security of humans and the environment in the 21$^{st}$ century. This revolution is rooted in advances in engineering nano-scale materials and their exploitation in a variety of systems, requiring extreme integration and coordinated control of diverse micro- and nano-scale components.
In this perspective, the mission of the program can be summarized as the *research, design and engineering of complex (tera-scale) systems and networks* to monitor and connect humans and/or the environment. Beyond straightforward integration, the program aims at identifying and fostering the potential synergies between micro- and nano-scale component technology and large-scale system design technologies (ranging from hardware to software and networking).

### Strategic objectives

Nano-Tera.ch's original strategic objectives (described in the 2007 Proposal and Business plan) call for the collaboration of the main scientific institutions in Switzerland to create *interdisciplinary* and *inter-institutional* teams of researchers. Namely:

The program is a collaborative engineering program that fosters the research and crossbreeding of hardware and software technologies in the areas of wearable, ambient and space systems. The program is mainly expected to:

- be instrumental in keeping Switzerland in the lead in the high-tech industrial sector, in particular by fostering innovation through collaboration between researchers and industrial partners with large research projects
- develop advanced technologies, such as micro/nano-electronics, sensors, micro/nano-electromechanical systems (MEMS/NEMS), systems and software, information and communication
- integrate these technologies to better the quality of health, security and environment systems in Switzerland, thus promoting a vision of engineering with social objectives
- embody the research outcomes into prototypes, acting both as demonstrators and technology drivers to strengthen technology transfer to the Swiss industry
- train junior scientists through interdisciplinary graduate/doctoral education programs and workshops in the domains covered by the program.

### Operational plan

In 2008, the governing bodies of Nano-Tera.ch (Steering and executive committees) in consonance with the Swiss National Foundation plan set up operational procedures, taking into account realistic constraints related to budget and priorities. Specifically, the Swiss National Foundation requested excellence in research as a primary objective, and the Nano-Tera.ch boards requested a fair distribution of the Nano-Tera.ch activities through the various institutions and over the various scientific topics. As a result, Nano-Tera.ch focused on supporting and nurturing *pinnacles of excellence* within the broad area of research proposed in the original vision.

# 3. Impact Evaluation

## 3.1 Goal / Main issues for the Impact Evaluation

In addition to providing an overall synthesis of the Nano-Tera.ch program (see below 3.3), the main objective of the evaluation is to assess the **impact** of the program in several key dimensions and based on various **objective metrics** described in the appendix.

The impact dimensions expected to be relevant are:

- The scientific impact
- The educational impact
- The economic impact
- The societal impact
- The institutional impact.

For each of the impact dimensions indicated, there **is a set of the key statements** to be assessed, along with related factual data and metrics to be used (see appendix).

For each of the key statements, the goal is to evaluate to what extent it has been fulfilled and to what extent the Nano-Tera.ch framework has been efficient. The evolution of the evaluation results from Phase 1 (2008-2012) to Phase 2 (2013-2016) may also be considered as an interesting aspect to analyze the impact of the program.

| **Dimension I** | **Scientific impact** |
|---|---|

- *Key statement 1:* "Nano-Tera.ch has promoted **excellence** in research in various domains of engineering sciences."
- *Key statement 2:* "Nano-Tera.ch has fostered strongly **collaborative** research."
- *Key statement 3:* "Nano-Tera.ch has fostered strongly **interdisciplinary** research."
- *Key statement 4:* "Nano-Tera.ch has triggered **inter-institutional** collaborations among very diverse players at the national level."
- *Key statement 5:* "Nano-Tera.ch has fostered strongly **applications-oriented research** in various domains of engineering sciences."
- *Key statement 6:* "Nano-Tera.ch has funded **ambitious projects."**
- *Key statement 7:* "Nano-Tera.ch has an **almost exhaustive coverage** of the Swiss scientific community in the program's fields**."**

| **Dimension II** | **Educational impact** |
|---|---|

- *Key statement 8:* "Nano-Tera.ch has substantially contributed to the **training of next generation researchers** (PhD students, Post Docs)."

- *Key statement 9:* "Nano-Tera.ch has encouraged stronger **collaborative spirit** in the community of PhD students involved in the program and increased their autonomy by giving them the opportunity to submit their own collabora tive research proposals."

- *Key statement 10:* "Nano-Tera.ch has encouraged stronger **entrepreneurial spirit** in the community of PhD students involved in the program."

| **Dimension III** | **Economic impact** |
|---|---|

- *Key statement 11:* "Nano-Tera.ch has fostered research with **high economic potential."**

- *Key statement 12:* "Nano-Tera.ch has deployed a novel pilot funding instrument (the "Gate way"program) **efficiently combining support for research and inno vation** and integrating an appropriate **monitoring mechanism**."

- *Key statement 13:* "Nano-Tera.ch has fostered **user-centric research** with an early in volvement of field practitioners through field tests, clinical studies, etc."

- *Key statement 14:* "Nano-Tera.ch has contributed to the **dissemination of the scientific results achieved** to the Swiss industry."

| **Dimension IV** | **Societal impact** |
|---|---|

- *Key statement 15:* "Nano-Tera.ch has contributed to steering the research funded toward **current social needs** (health, environment, energy, etc.)."

- *Key statement 16:* "Nano-Tera.ch has contributed to **disseminating the results** achieved within and beyond the Nano-Tera.ch community."

- *Key statement 17:* "Nano-Tera.ch has implemented efficient **pilot actions** to promote the activities of the programs in high school and towards younger children."

| **Dimension V** | **Institutional impact** |
|---|---|

- *Key statement 18:* "Nano-Tera.ch has substantially contributed to the setup of the **joint SNSF-CTI program "Bridge"**, a novel funding instrument aiming at bet ter exploiting the economic and societal potential of scientific research by promoting the transfer from scientific knowledge to innovation."

- *Key statement 19:* "The **operational procedures** deployed and tested during the Nano-Tera.ch program represent an interesting example of innovative mechanisms for financing and monitoring research with high economic potential."

## 3.2 Procedure and responsibilities

The impact evaluation is carried out in the two following steps:

- *An internal* impact evaluation under the responsibility of the Nano-Tera.ch Consortium.
  The result is an analysis report (hereinafter: the Consortium report; language: English) to the attention of the SSIC.
- *An external* impact evaluation under the responsibility of the SSIC.
  The result is a final report (hereafter: the SSIC final report; language: German / French) to the attention of the SERI.

## 3.3 Requirements / conditions for the internal impact analysis

Consortium report structure

| | | |
|---|---|---|
| Part I: Overview (Organization / Finances) | - Description of the organizational structure and of the main decision procedures (including SNSF)<br>- Financial Overview (whole period) | *Sources*: activity and financial reports |
| Part II: Objectives | - Original set of goals (presentation)<br>- Presentation/justification of possible goal adjustments during the course of the program | *Sources*: relevant strategy documents and implementation measures |
| Part III: Overview of the outputs of the program | Overall synthesis of the Nano-Tera.ch program, in the form of a report compiling the main facts and statistics (at a high level of aggregation and limited to the most important areas) | |
| Part IV: Impact Analysis (main part) | Data analysis and assessment/justification of the key statements (1 to 19) identified for the impact analysis | *Sources*: Data / Outputs from the Consortium's Monitoring procedure; Metrics in accordance with the Appendix |
| Part V: Conclusion | Overall Conclusion: Lessons learnd | |

Methodology
The impact analysis (Part IV) is essentially carried out on the basis of the data and information identified in the established monitoring procedure (no additional extensive surveys).

A factual selection of the adequate data/information should be made for the assessment/justification of the key statements used for the analysis (in part IV). For the different areas or domains, a multi-methodological approach may be used to show evolution over the duration of the program.

## 3.4 Requirements / conditions for the external impact evaluation

*Expert Panel*
For the external impact evaluation, the SSIC appoints an expert panel, consisting of national and international experts. For this task, the SSIC consults the Nano-Tera.ch Consortium, and, if necessary, the SNSF. While only the SSIC is accountable and responsible for the final expert nomination, *the Nano-Tera.ch Consortium is given both a proposition and a veto right*.

The nomination and formal appointment of the panel experts is the SSIC's responsibility. The only associated condition is that the SSIC ensures the evaluation panel produces an independent evaluation report (hereinafter: the Panel report) according to the mandate specifications. Based notably on the Consortium report and further on the additional findings resulting from complementary measures agreed with the SSIC such as a site visit, discussions with the Consortium, etc., this report should present the panel's position/assessment about/of the key statements used for the Impact Evaluation (see 3.1 above).

*SSIC Final Report*
The SSIC produces an independent final report to the attention of the SERI. In this report, the SSIC takes a broader view to provide an overall evaluation in addition to their own position about the assessment of the key statements used for the Impact Evaluation (see 3.1 above). For this, the SSIC should take into account the Consortium report, the panel report, the Consortium and SNSF position about the panel report, as well as the SSIC's own findings.

## 3.5 Coordination

The coordination between internal and external impact evaluations (agreements on temporal and content related issues, specification and implementation) is exclusively the SSIC's responsibility. The required interactions and contacts with the Nano-Tera.ch Consortium and governing bodies are to take place under the direct authority and responsibility of the SSIC.

# 4. Timeline

Milestones (draft schedule) as follows:

| | | |
|---|---|---|
| 09/2016 | Mandate finalization | SERI (with SSIC and Consortium) |
| 11/2016 | Coordination & Implementation scheduling | SSIC (with Consortium) |
| 12/2016 - 10/2017 | Internal Impact Analysis; Consortium Report | - January to June 2017 (Data acquisition; Metric Production)<br>- July to October 2017: Production of the report and approval by the Consortium<br>Consortium transmits their report to SSIC by the end of Octobre 2017. |
| 04/2017 | External Impact Evaluation: Expert Panel Nomination | SSIC |
| 11/2017 - 3/2018 | External Impact Evaluation: Panel Report | SSIC / Expert Panel |
| 6/2018 | Final Report | SSIC transmits their report to SERI by the end of June 2018 |

## 5. Funding

The cost of the internal impact analysis, including all costs related to the production of the Consortium report as well as the contribution to the external Impact Evaluation according to the SSIC's specifications will be covered by the Nano-Tera.ch Consortium.

The cost of the external Impact Evaluation, including all organizational costs related to the production of the panel report and final report will be covered by the SSIC's operational budget. Any additional cost incurred by SERI will be settled in the framework of the SSIC's Global Mandate (Impact Evaluation of the "SystemsX.ch" & "Nano-Tera.ch" funding programs).

SERI, 29/08/2016
Dr. G. Haefliger, Vice-director

Appendix: Nano-Tera.ch Consortium: objective metrics for the key statements.

## Appendix

### Nano-Tera.ch Consortium: objective metrics for the key statements

| **Dimension I** | **Scientific impact** |
|---|---|

- ***Key statement 1***: "Nano-Tera.ch has promoted **excellence** in research in various domains of engineering sciences."

  *Factual data:* The complete database of publications and presentations reported by the project consortia during the lifetime of the program; history of various scientific awards (lifetime achievements, best papers, fellowships, etc.) received by Nano-Tera.ch researchers; list of the events organized in the framework of the Nano-Tera.ch International exchange program.

  *Metrics to be used:* Various measures of bibliometric performance (number of citations, H-index); various absolute and normalized counts; ability of Nano-Tera.ch to attract the participation of the most renowned international experts in the field.

- ***Key statement 2***: "Nano-Tera.ch has fostered strongly **collaborative** research."

  *Factual data:* The publication database; collaborative tasks reported in the scientific reports provided by the consortia; the list of the collaboration grants awarded in the framework of the Sino-Swiss Science and Technology Cooperation.

  *Metrics to be used:* Average number of institutions per project; average number of research groups per research task; amount of joint publications between partners; level of funding granted.

- ***Key statement 3***: "Nano-Tera.ch has fostered strongly **interdisciplinary** research."

  *Factual data:* List of main fields of research for all co-investigators in the projects; list of conferences where Nano-Tera.ch researchers have made a contribution.

  *Metrics to be used:* Average number of research fields covered by the project consortia; diversity of the conference fields.

- ***Key statement 4***: "Nano-Tera.ch has triggered **inter-institutional** collaborations among very diverse players at the national level."

  *Factual data:* List of the institutions involved in each Nano-Tera.ch project.

  *Metrics to be used:* Diversity of the profiles of the institutions involved (ETH Board, universities, universities of applied sciences, industrial partners, hospitals, etc.)

- ***Key statement 5***: "Nano-Tera.ch has fostered strongly **applications-oriented research** in various domains of engineering sciences."

  *Factual data:* List of the demonstrators obtained; produced videos describing Nano-Tera.ch's concrete achievements; photos from the exhibition areas organized at the occasion of the various Annual meetings of the program.

  *Metrics to be used:* Number of the demonstrators obtained; distribution of demonstrators over the engineering sciences domains covered.

- ***Key statement 6***: "Nano-Tera.ch has funded **ambitious projects."**

  *Factual data:* Budgets allocated to the projects; list of staff members involved in each project; duration of the projects; profiles of the researchers involved.

  *Metrics to be used:* Level of funding; average number of researchers involved; amount of achievements; reputation of the researchers involved.

- ***Key statement 7***: "Nano-Tera.ch has an **almost exhaustive coverage** of the Swiss scientific community in the program's fields**."**

  *Factual data:* List of the funded projects; overall budget available; localization of the involved research teams.

*Metrics to be used:* Territorial coverage of the involved research teams and institutions; distribution of the number of involved researchers over the covered research topics; level of funding compared with other funding instruments.

**Dimension II Educational impact**

- ***Key statement 8:*** "Nano-Tera.ch has substantially contributed to the **training of next generation researchers** (PhD students, Post Docs)."

  *Factual data:* List of PhD students involved; analysis of their activities after their PhD thesis defense; list of Nano-Tera activities (coaching, training, information, MT180 contest) specifically tailored for PhD students.

  *Metrics to be used:* Number of PhD students funded/impacted/trained in the framework of the program; invested budget; activity level (number of days).

- ***Key statement 9:*** "Nano-Tera.ch has encouraged stronger **collaborative spirit** in the community of PhD students involved in the program and increased their autonomy by giving them the opportunity to submit their own collaborative research proposals."

  *Factual data:* Detail on the various actions set up by Nano-Tera.ch in this perspective (NextStep collaborative research program with specific ED calls).

  *Metrics to be used:* Attendance of the PhD students to these programs; resulting achievements and satisfaction.

- ***Key statement 10:*** "Nano-Tera.ch has encouraged stronger **entrepreneurial spirit** in the community of PhD students involved in the program."

  *Factual data:* Detail on the various actions set up by Nano-Tera.ch in this perspective (NextStep entrepreneurship program, support for participation to high impact events).

  *Metrics to be used:* Attendance of the PhD students to these programs; resulting achievements and satisfaction.

**Dimension III Economic impact**

- ***Key statement 11:*** "Nano-Tera.ch has fostered research with **high economic potential."**

  *Factual data:* List of patents filed; CTI projects originating from the program; startups and spinoffs created; industrial collaborations resulting from the program; interviews with RTD projects principal investigators; results of the Nano-Tera.ch Industrial Valorization Fund.

  *Metrics to be used:* Standard performance metrics based on absolute of normalized counts; multi-dimensional analysis (radar plots) of the industrial potential of the scientific results achieved.

- ***Key statement 12:*** "Nano-Tera.ch has deployed a novel pilot funding instrument (the “Gateway” program) **efficiently combining support for research and innovation** and integrating an appropriate **monitoring mechanism**."

  *Factual data:* Results of the quarterly Gateway progress meetings; description of the industrial prototypes achieved; feedback from the industrial partners.

  *Metrics to be used:* Success rate in producing well-accepted industrial prototypes; satisfaction level of industrial players.

- ***Key statement 13:*** "Nano-Tera.ch has fostered **user-centric research** with an early involvement of field practitioners through field tests, clinical studies, etc."

  *Factual data:* List of various non-academic partners involved in Nano-Tera.ch projects (hospitals, private institutions); list of field experiments (field tests, clinical studies) carried out and corresponding budgets.

  *Metrics to be used:* Level of involvement (matching funds) of various non-academic end-users; funding level dedicated to field experiments.

- ***Key statement 14**:* "Nano-Tera.ch has contributed to the **dissemination of the scientific results achieved** to the Swiss industry."

  *Factual data:* Details regarding the Information Days organized for Swiss industrial players.

  *Metrics to be used:* Attendance to the organized events and feedback from participants.

| Dimension IV Societal impact |
|---|

- ***Key statement 15**:* "Nano-Tera.ch has contributed to steering the research funded toward **current social needs** (health, environment, energy, etc.)."

  *Factual data:* List of the calls published by the program; description of the projects selected; strategic actions launched.

  *Metrics to be used:* Level of overlap with identified social trends (e.g. Google trends) and future priority programs.

- ***Key statement 16**:* "Nano-Tera.ch has contributed to **disseminating the results** achieved within and beyond the Nano-Tera.ch community."

  *Factual data:* List of all communication, documents and videos produced and disseminated; details and statistics regarding the Nano-Tera.ch website; list of mentions of the program in the media; information regarding the Nano-Tera.ch Annual Meetings and other public events; contacts with the Swiss Science journalists; description of the various dissemination channels set-up in social networks (Facebook, Twitter).

  *Metrics to be used:* Google Analytics of the Nano-Tera.ch website; various standard audience measures for disseminated documents; results of satisfaction evaluations for organized events; measure of the impact in the media.

- ***Key statement 17**:* "Nano-Tera.ch has implemented efficient **pilot actions** to promote the activities of the programs in high school and towards younger children."

  *Factual data:* Detail of the Nano-Tera.ch action in high school and in the framework of the EPFL Scientastic festival; List of participants; Photos produced.
  *Metrics to be used:* Level of involvement and feedback of the high school students; perceived level of motivation and satisfaction

| Dimension V Institutional impact |
|---|

- ***Key statement 18**:* "Nano-Tera.ch has substantially contributed to the setup of the **joint SNSF-CTI program "Bridge"**, a novel funding instrument aiming at better exploiting the economic and societal potential of scientific research by promoting the transfer from scientific knowledge to innovation."

  *Factual data:* Various internal documents produced by Nano-Tera.ch during the setup of the Bridge program.

  *Metrics to be used:* Overlap of the Nano-Tera.ch suggestions with the final Bridge program framework.

- ***Key statement 19**:* "The **operational procedures** deployed and tested during the Nano-Tera.ch program represent an interesting example of innovative mechanisms for financing and monitoring research with high economic potential."

  *Factual data:* Description of the Nano-Tera.ch operational mechanisms in comparison with the other existing funding instruments.

  *Metrics to be used:* Identification of important differences and similarities.

## Annexe B – Rapport d’auto-évaluation de Nano-Tera.ch, octobre 2017

Swiss Research Program

# Nano-Tera.ch

Engineering Multi-Scale Systems for Health, Security, Energy and the Environment

# Impact Analysis Report 2017

State Secretariat for Education and Research SER

ETH BOARD

FNSNF

SUK·CUS

nano-tera.ch

Nano-Tera.ch is an unprecedented nation-wide program that has contributed to positioning Switzerland at the forefront of research on multi-scale engineering of complex systems and networks. It has been operational for almost 10 years, was supported by public funds of more than CHF 120 million, and has had a strong impact on the Swiss Engineering Sciences landscape. It has led to numerous scientific and technological breakthroughs exploiting synergies between various disciplines, and explored topics at the boundary of traditional scientific domains to generate highly exploitable demonstrators with socially relevant applications in the areas of health, energy, and the environment.

**At the scientific level**, Nano-Tera.ch strongly promoted ambitious cutting-edge research. It strengthened inter-institutional collaboration at the boundary of traditional disciplines, by heavily supporting large, long-lasting, collaborative research projects. In particular, it specifically contributed to synergies between micro/nanocomponent technology and large-scale system design to achieve scientific and technological breakthroughs. These synergies have produced, amongst other examples, miniaturized X-ray sources with exceptional tomographic imaging capabilities; highly robust sensor networks deployed in the Alps to monitor rock falls; super-paramagnetic particles used for the detection and treatment of cancer; and perovskite-based tandem solar cells with world-leading performance.

Nano-Tera.ch significantly impacted Swiss research in Engineering Sciences. This was demonstrated by nearly 1,600 peer-reviewed publications and more than 2,000 presentations at conferences and workshops. Annual evaluations conducted by the Swiss National Science Foundation and the Nano-Tera.ch Scientific Advisory Board have consistently pinpointed scientific excellence during the entire course of the program.

Most of the scientific impact is due to 44 large research projects, each benefitting from CHF 2,000,000 of public funding on average over four years, matched by an equivalent contribution provided by the project partners. These projects established truly collaborative and interdisciplinary research, with an average per project of six research teams combining expertise from three different disciplines.

Furthermore, Nano-Tera.ch increased its scientific impact by spearheading an International Exchange program. The program organized symposia on emerging trends in fields it was covering, and invited world-leading scientists to interact with the Nano-Tera.ch community through discussions and talks.

**At the educational level**, Nano-Tera.ch focused on training the next generation of scientific talents by funding more than 360 PhD students. Furthermore, a specific NextStep program has been created to help these PhD students increase their autonomy, collaborative spirit, entrepreneurial mindset, and communication abilities. About 40% of the doctoral graduates decided to pursue a career in academia (of which 57% stayed in Switzerland) and 60% in industry (75% in Switzerland). This shows that Nano-Tera.ch has provided Swiss academic institutions and industry with a substantial number of highly skilled researchers and engineers with the potential to efficiently develop their research and innovation.

The NextStep program has been implemented along three complementary tracks: (1) a Collaborative Research track offering Nano-Tera.ch PhD students the opportunity to autonomously apply for collaborative research projects; (2) an Entrepreneurship track providing Nano-Tera.ch PhD students with the opportunity to interact with entrepreneurship coaches to help them examine the economic potential of their scientific skills and results; and (3) an MT180 track in which Nano-Tera.ch organized the "My Thesis in 180 Seconds" contests to train Nano-Tera.ch PhD students to present their research to a larger audience outside their field.

In addition, the program also strengthened its general educational impact by funding 61 educational actions, such as specialized courses, summer/winter schools, and workshops.

**At the economic level,** the program has contributed to the strengthening of the economic potential of research results. This was achieved by focusing on establishing the proper conditions for economic value creation. Major projects were required to deliver research prototypes, acting both as demonstrators and technology drivers. They were also required to bring on board industrial or industry-oriented partners and end users (e.g., hospitals), respectively representing 31% and 10% of the project consortia (the rest being research partners). As a result, the program has achieved a strong impact in terms of *knowledge transfer*. Indeed, the project consortia were able to satisfy the absorptive capacity of the involved industrial partners by giving them access to experts in areas they consider to be strategic for their development and competitiveness.

In addition, Nano-Tera.ch has also strongly contributed to Knowledge and Technology Transfer by funding a large number of PhD students who transferred to industry after graduation. These students made a substantial contribution to industry by bringing with them fresh ideas and the substantial knowledge of new technologies they acquired during their research. Some of the funded PhD graduates and Postdocs directly contributed to the creation of 10 start-up/spin-off companies, such as IRsweep, a spin-off bringing a novel optical frequency comb laser spectroscopy to the market, or Zaphiro Technologies, a start-up developing real-time monitoring systems for the smart grid.

Furthermore, Nano-Tera.ch used strategic funds to launch the Gateway program, which translated research results into industrial-grade prototypes. Within this program, Nano-Tera.ch launched eight projects specifically positioned at the interface between research and innovation. This enabled the involved industrial partners to quickly take on highly exploitable demonstrators, such as smart wound pads exploiting fluorescent dyes for non-invasive wound monitoring. The Gateway program also provided the opportunity to validate a novel project monitoring mechanism specially designed for projects focusing on innovation stemming from forefront research.

**At the societal level**, the primary objective of Nano-Tera.ch was to promote a vision of engineering with true social objectives. This goal has been achieved by strategically supporting research at the intersection of industrially relevant, cutting-edge, technologies and three socially relevant application areas: health, environment, and energy. The social relevance of the selected areas was confirmed by an *a posteriori* analysis of their match with the topics covered by the mainstream media, parliamentary proceedings, and Federal investments over the lifetime of the program.

Encouraging the funded research to aim to produce concrete prototypes also substantially helped the industrial partners and end-users involved in the program to envision and suggest concrete applications linked to actual needs and potentially benefitting the whole of society. These included high-performance tandem solar cells, advanced monitoring systems for neonates, and urban air quality monitoring sensor networks.

**At the institutional level**, Nano-Tera.ch triggered intense nationwide collaboration between various Swiss research institutions involved in Engineering Sciences, such as the two Federal Institutes of Technology (EPF Lausanne and ETH Zurich), several universities and universities of applied sciences, as well as industry-oriented research and technology institutions (CSEM and Empa).

With more than 91% of its budget invested in 127 research projects (including the 44 large ones mentioned above) and 61 educational actions, the Nano-Tera.ch has managed to create a community of around 1,600 members from more than 40 different research institutions, representing a very substantial proportion of the Swiss scientific community in the fields covered by the program.

Nano-Tera.ch further increased its institutional impact by implementing various dissemination tools designed to showcase the results achieved within the program (e.g. the Nano-Tera.ch website and the Nano-Tera.ch presentation videos), or to nurture the Nano-Tera.ch research community (e.g. the Nano-Tera.ch Annual Meetings). The Nano-Tera.ch website has attracted about 160,000 unique visitors accessing 7–8 pages per session. The seven annual meetings organized by the program allowed the Nano-Tera.ch community to meet and share results, and attracted a steadily increasing audience, growing from 200 to 350 participants.

Finally, the specific organizational framework put in place for the program strongly contributed to the strengthening of its overall achievements. In particular, Nano.Tera.ch.'s lean, autonomous management structure gave it the required flexibility to rapidly implement novel instruments, such as the NextStep and Gateway programs when this was deemed necessary. Similarly, splitting responsibility for evaluation between the Nano-Tera.ch Executive Committee, in charge of the strategic monitoring of the program, and the Swiss National Science Foundation, responsible for the scientific evaluation of the submitted proposals and the annual review of the large research projects, further reinforced the impact of the program by strengthening its links with the Swiss authorities in charge of science at the federal level.

Lausanne, October 31st, 2017

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## NANO-TERA.CH: FUNDING RESEARCH IN SYSTEMS ENGINEERING

Prof. Giovanni De Micheli
Nano-Tera.ch Program Leader,
Executive Committee Chair

Nano-Tera.ch is a national funding program supporting research in engineering of complex (tera-scale) systems for health and the environment using nanotechnologies. Energy and security issues are also investigated as crucial transversal themes for system design.

Nano-Tera.ch funding is open to all Swiss research institutions according to the corresponding legislation and its mission includes research, development and technology transfer, as well as education and dissemination. In particular, Nano-Tera.ch puts a special focus on PhD students by providing them with a specific training, the Nano-Tera.ch NextStep program, targeting collaborative research and the economic exploitation of scientific results.

Moreover, Nano-Tera.ch fosters collaboration among researchers and industries that are partners or supporters of the research projects. In this perspective, Nano-Tera.ch strongly contributed to the design of BRIDGE, a new concept for jointly funding research and pre-competitive technological innovation that has been deployed by the Swiss National Science Foundation (SNSF) and the Swiss Commission for Technology and Innovation (CTI) in the form a novel common funding instrument for the period 2017-2020.

The Swiss National Science Foundation (SNSF) also contributes to the Nano-Tera.ch program by evaluating and monitoring the large research projects through an international panel of experts, thus ensuring the high scientific quality of the program.

Nano-Tera.ch strives to enable mechanisms that can map the high productivity of research ideas, publications and patents of the Swiss community into a significant momentum in terms of industrial growth as well as job and enterprise creation. To further strengthen its contribution to this goal, Nano-Tera.ch has joined efforts with CSEM and Empa, and created a specific funding instrument, the Gateway program, intrinsically positioned at the frontier between research and innovation. Gateway aims at the translation of research results obtained within Nano-Tera.ch projects into industrial demonstrators directly exploitable by the industrial partners involved in the Gateway projects.

## NANO-TERA.CH: SWISS EXCELLENCE IN RESEARCH

Prof. Heinrich Meyr
Nano-Tera.ch
Scientific Advisory Board Chair

The Scientific Advisory Board has been reviewing the Nano-Tera.ch program as a whole and providing criticisms and suggestions for its growth. The Board regards the Nano-Tera.ch program as a unique blend of technology exploration and system design. The scientific and industrial challenges studied in the program were related to exploiting micro and nano components within complex systems whose added value is much larger than the sum of their parts. A notable example is networked sensors for medical and environmental applications. Networking boosts the intrinsic power of local measurements, and allows to reach new standards in health and environment management, with positive fallout on security of individuals and communities.

Smart and diversified energy generation, such as harvesting and low-power system design are of the utmost importance to society and the economy. Truly innovative approaches are needed, that can only be found by massively investing in engineering research. Thus the Board lauded the extension of the Nano-Tera.ch scope to include energy as an application area.

The upcoming scientific and engineering challenges are too heterogeneous and complex to be solved within a single scientific domain. They require a truly collaborative and cross-disciplinary approach. In this perspective, the Nano-Tera.ch program brought together excellent researchers in various fields from many Swiss institutions with outstanding reputation.

The program was not only of high scientific value but also of eminent economic importance for the industrial sector of Switzerland. The program served as the seed for truly innovative products and industries. It also fostered the education of highly-qualified engineers and researchers who are the most valuable and indispensable resource of this country.

# TABLE OF CONTENTS

# PART I

# OVERVIEW

# I.1 GENERAL OVERVIEW OF THE PROGRAM

Nano-Tera.ch is a Swiss national program supporting research in multi-scale system engineering for health, energy and the environment using nano-technologies. Launched in 2008, the program focused on excellence in collaborative research in engineering disciplines, the design of applied demonstrators, targeted educational programs, and the transfer of acquired research results to Swiss industry. It was jointly funded by the Swiss ETH-Board (ETH) and Swissuniversities (formerly CUS/SUK), under the general responsibility of the State Secretariat for Education, Research, and Innovation (SERI).

Nano-Tera.ch is one of the largest federal programs funding research in engineering sciences. It supported 188 projects with a total budget of about CHF 110 million of public funds (representing 91% of the overall budget of the program), complemented by about CHF 150 million of matching funds provided by the project partners. The funded projects range from large, 3-4 year research projects (RTD projects), carried out by consortia of 3 to 10 research groups from various Swiss institutions (Federal Institutes of Technology, Universities, Universities of Applied Sciences, etc.) to smaller research projects (NTF projects) focused on technologies, as well as various educational actions (ED projects).

The Nano-Tera.ch research community represents a network of more than 40 Swiss research institutions and involves about 1,600 members, covering a substantial fraction of the Swiss scientific community in the relevant fields.

The funded research resulted in nearly 1,600 peer-reviewed publications (44% of which were in established journals) and more than 2,000 presentations at conferences and workshops worldwide. A total of 77 awards have been received by Nano-Tera.ch researchers during the course of the program.

The scientific results were showcased each year at the Nano-Tera.ch Annual Meetings. Numerous prototypes and demonstrators were presented during those meetings, showing that the program focused on concrete collaborative research leading to potentially exploitable results. The scientific excellence of the funded projects was acknowledged by the annual evaluations carried out by a Panel of international experts under the responsibility of Swiss National Science Foundation and by the Nano-Tera.ch Scientific Advisory Board, who also continuously stressed the strong contribution the Nano-Tera.ch program made to the multidisciplinary development of Swiss engineering sciences.

The funded research was exploring various key thematic areas related to health and the environment. During the Phase 1 of the program (2008-2013), the research projects focused on topics such as enabling technologies for nano-systems (e.g. sensors, 3-dimensional integration), or various Heath-Energy-Environment applications (e.g., environmental sensing of air quality and alpine movements, metabolic and biological cell monitoring, circuit design and cryptography). In the Phase 2 of the program (2013-2017), the research projects were exploring various topics combining engineering with life sciences, medicine and energy. For example, projects on smart prosthetics and body repair covered topics ranging from image-guided micro surgery for hearing aid implantation to tactile prosthetics for amputees or spinal cord neuro-prosthesis for restoration of locomotion. Health monitoring projects addressed the use of smart textiles for monitoring long-term obesity, smart bandages, newborn care, and personalized therapeutic drug monitoring. Projects on innovative medical platforms include flexible MRI detectors, cancer diagnostic using cantilever sensors, or high-performance portable 3D ultrasound platforms. In addition to these health-related challenges, Nano-Tera.ch was also tackling important issues in environmental monitoring, with technologies such as distributed sensor networks for air quality monitoring or natural hazard detection, multi-color lasers analyzing greenhouse gases or aquatic robots tracking water pollutants. Finally, Nano-Tera.ch was focusing on the crucial theme of smart energy, with projects addressing ultra-high performance photovoltaic solar cells, economically viable renewable energy production through solar-hydrogen generators, or smart power grid monitoring and management.

To further strengthen the impact of the research carried out in the program, the Nano-Tera.ch Executive Committee launched six strategic projects on topics such as the setup of industrial test-beds for research on smart energy systems, the promotion of user involvement in the domain of pervasive health systems, and the detailed analysis of the reliability/usability of sensor generated data.

At the international level, Nano-Tera.ch has contributed to several symposia, courses and seminars in collaboration with worldwide partners, and provided visibility for its research by taking booths at large conferences. In 2011 the program launched a strategic initiative aimed at encouraging Sino-Swiss research collaborations within Nano-Tera.ch thematic areas. This initiative benefitted from the existing agreement between the Chinese Academy of Sciences and the Sino-Swiss Science and Technology Cooperation program (SSSTC) supported by the SERI, and took the form of a competitive call for collaborative Sino-Swiss projects that led to the approval of 6 joint projects. Furthermore, Nano-Tera.ch launched an International Exchange Program inviting several prominent scientists to deliver a series of talks in various institutions involved in the program.

At the educational level, Nano-Tera.ch set up a specific NextStep program, designed to help PhD students explore different ways of increasing their potential as highly skilled staff for Swiss research and the Swiss economy. In particular, Nano-Tera.ch has provided coaching to PhD students to encourage them to consider economic applications for their scientific results. It provided research grants to fund collaborative research exclusively involving PhD students, and organized “My Thesis in 180 Seconds” contests to train PhD students to present their research to a larger audience outside their field.

From an industrial perspective, most of the RTD projects received support from industrial partners and/or hospitals: in total, industrial partners/hospitals have been involved in about 60% of the Nano-Tera.ch research projects, for a total of more than CHF 19.7 million of matching funds. Furthermore, 67 patent applications have been filed since the beginning of the program.

The impact on Swiss industry has been further strengthened by the Gateway pilot program, whose purpose was to transfer research results to Swiss industry. Concretely, eight projects were launched with a total public funding of around CHF 1.66 million, involving laboratories, institutions specialized in technology transfer (Empa and CSEM), as well as industrial partners. The goal of these projects was to convert the laboratory prototypes resulting from Nano-Tera.ch research projects into industrial demonstrators with high economic potential, directly exploitable by the industrial partners involved in the projects.

The Nano-Tera.ch results have raised public awareness of the program's achievements, with reports broadcast on national TV and Radio networks (SFR and RTS), articles published in the national press (the "Neue Zürcher Zeitung" and "Le Temps" newspapers) and international news networks (e.g. CNN).

Detailed information about Nano-Tera.ch can be found on the Nano-Tera website (www.nano-tera.ch), which is one of the main dissemination channels for the program. It typically attracts around 100,000 page views per year from more than 140 countries.

## Nano-Tera.ch: Key figures

nano-tera.ch

| | | | |
|---|---|---|---|
| **Lifetime** | 2008-2017 | (~10 years) | |
| **Budget** | 273,779,298 CHF | Nano-Tera Funding | 120,198,800 CHF |
| | | Own Contributions | 153,580,498 CHF |
| **Projects** | 188 | Large collaborative research projects (RTD) | **44** |
| | | Focused research projects (NTF) | **24** |
| | | RTD extensions (add-on, Gateway, PhD) | **47** |
| | | International research collaboration (SSSTC) | **6** |
| | | Strategic projects (STRAT) | **6** |
| | | Education and Dissemination activities (ED) | **61** |
| **Institutions** | 44 | **ETH-Domain** | EPFL • ETHZ • Empa • Eawag • PSI |
| | | **Universities** | UniBas • UniBE • UniFR • UniGE • UNIL • UniNE • UniSG • USI • UZH |
| | | **Uni. Appl. Scn.** | BFH • FHNW • FHO • HESSO • SUPSI |
| | | **Translational** | CSEM • Empa |
| | | **Hospitals** | CHUV • Insel • HRC • HUG • Spitäler SH • Kinderspital ZH • KSW • USB •USZ |
| | | **Others** | 15 |
| **Industrial partners** | 69 | | |
| **Personnel** | ~1,600 | 294 | Project partners |
| | | 366 | PhD students<br>involved in research projects and actions |
| **Publications** | ~1,600 | | |
| **Awards** | 77 | | |
| **Patents** | 67 | | |

# I.2 TERMS AND FIGURES

The purpose of this section is to define the key terms used in this evaluation report, and to summarize the main figures (duration, budgets, numbers of projects funded, etc.) providing a quantitative description of the overall operation of the Nano-Tera.ch program.

## PROGRAM DURATION AND PHASES

The program has been organized in two main parts:

**Phase 1**: 2008 – 2012 (including the 2012 transition year)

**Phase 2**: 2013 – 2017

**Ramping down Phase**: January 2018 – June 2018

## FUNDING INSTRUMENTS

To meet its strategic objectives, Nano-Tera.ch has deployed three main types of projects/actions:

- **Research, Technology and Development (RTD)** projects, representing about 80% of the Nano-Tera.ch budget, are large research projects involving a collaboration between several research groups from different disciplines, preferably from different institutions. Within an RTD project, the involved research groups contribute to a coordinated research efforts and exploit the synergies between their disciplines to explore topics at the boundary of traditional scientific domains. As the focus is on research projects with size, budget, and duration that could not be otherwise achieved through usual funding channels, RTD projects are ambitious research projects, with an expected duration of 3 or 4 years, and allocated budgets in the range of CHF 550,000/year, aiming at research on multi-scale system engineering, as well as at the training of doctoral students. An RTD project typically focuses, either on the in-depth study of a particular vertical technology or on the development and implementation in a specific horizontal application area. In addition to novel scientific and technological results, the RTD projects must also produce a system demonstrator showing how the achieved results can be used to seed a prototype/product development with tangible benefits to health, energy and the environment. An RTD project consortium should include one (or more) end-user(s) for the technology being developed, and the participation of industrial partners providing in-kind or in-cash contributions was strongly encouraged.
- **Nano-Tera Focused (NTF)** projects are small-scale research projects addressing specific scientific/technical issues and needs. Examples include, but are not limited to, activities collateral to RTDs, activities that are in-between the scope of two RTDs (glue projects) and activities that promote technology transfer. A limited percentage of the grant could be used for lab materials and supplies. Typical NTF duration range from one to two years, with an allocated funding of around CHF 110'000/year.
- **Education and Dissemination (ED)** actions correspond to activities aiming at supporting short courses, workshops, mini-conferences, and developing new curricula in domains covered by Nano-Tera.ch that are not provided by Swiss Universities or Polytechnic Institutes. ED actions may address the in-depth study of a technology or interdisciplinary horizontal activities, and their typical funding level is in the range of CHF 15-30,000.

Furthermore, additional types of projects have been supported to meet specific needs during the course of the program:

- **RTD Add-on projects** aimed at further consolidating the strategic vision of the program towards synergy between "Nano" and "Tera", strengthening and expanding presently established network of expertise and increasing industrial participation. RTD Add-on applications were restricted to Principal Investigators (PIs) from already existing Nano-Tera.ch, but each proposal could involve partners from other RTDs and/or totally new partners. Typical duration ranged from 6 months and beyond, but the any RTD Add-on had to terminate at the latest at the same time as the correlated RTD project. The total budget invested over the two phases by Nano-Tera.ch in RTD Add-ons was slightly above CHF 2.5 million.
- **SSSTC projects:** Under the umbrella of the Sino Swiss Science and Technology Cooperation (SSSTC), a Swiss national program for the promotion of bilateral science and technology cooperation with China., the SSSTC projects aimed at creating synergy and encouraging Swiss-Chinese research collaboration within the Nano-Tera.ch thematic areas. Project duration is at most 1 year, with a maximum funding per project of CHF 100'000.
- **Gateway projects:** Within the framework of the Gateway program (described in detail in Key Statement 12), the Gateway projects aimed at supporting the translation of research results obtained within Nano-Tera.ch RTD or NTF projects into operational industrial demonstrators, directly exploitable by the involved industrial partners. The total budget invested by Nano-Tera.ch in such projects was slightly above CHF 1.6 million.
- **Strategic projects:** To further strengthen the impact of the research carried out in the program, the Nano-Tera.ch Executive Committee has launched six strategic projects, focusing on topics such as the setup of industrial test-beds for research on smart energy systems, the promotion of user involvement in the domain of pervasive health systems or the detailed analysis of the reliability/usability of sensor generated data; for a total budget of about CHF 1.6 million.

## CALL MECHANISMS

RTD and RTD Add-on projects were subject to specific calls and submission deadlines. Their competitive selection was operated under the supervision and evaluation of SNSF. NTFs and EDs resulted from a periodic call mechanism, with deadlines at the end of each quarter. The evaluation of the EDs was under the direct responsibility of the Executive Committee. For the NTF projects, a specific evaluation panel consisting of seven international experts external to Nano-Tera.ch has been put in place (see "The Nano-Tera.ch NTF Evaluation Panel" in section "I.3 Organizational Structure"). The responsibility of this panel was to evaluate the received NTF proposals, and to provide their recommendations in the form of a ranked list to the Executive Committee, who then took the final funding decisions. Strategic and Gateway projects were subject to specific calls launched under the responsibility of the Executive Committee. For the Gateway projects, an evaluation mechanism relying on a specific external evaluation panel, similar to the one put in place for NTF projects, has been used (see Key Statement 12 in "Part IV: Impact Analysis" for more detail).

The strategic positioning of the Nano-Tera.ch program has been translated into eligibility conditions imposed in the program calls, and which gave specific characteristics to the Nano-Tera.ch projects and consortia. In particular, for the RTD projects, Nano-Tera.ch imposed the following criteria:

- A clear positioning of the targeted research objectives in a "technology by applications" matrix, with vertical technologies intersecting horizontal application areas. This made it possible (1) to concentrate the research on three application areas (health, environment, energy), thus avoiding to scatter the available funds on too many topics, while contributing to a socially relevant scientific progress with a strong potential for the whole society; and (2) to focus on research in the engineering of integrated technological systems and platforms requiring a substantial collaboration between several scientific disciplines, and thus defining new areas of interdisciplinary research;
- The participation of industrial partners and end-users (typically hospitals);
- The required development of technology demonstrators, which encouraged integrative approaches involving industrial partners and end-users, and increased the potential for a transfer of the results to the Swiss industry.

### Matching funds

As requested be the existing legislation, the budget of any project funded by Nano-Tera.ch had to include matching funds provided by the involved partners. To guarantee a matching fund ratio of 50% for the whole budget received by Nano-Tera.ch, including the management budget, the imposed level of matching fund for the funded projects was 53% of the total project cost in Phase 1 and 55% in Phase 2.

### Eligible Applicants

Applications for Nano-Tera.ch projects were open to faculty members and senior scientists of both Polytechnic Institutes and other institutions of the ETH-Domain, of Swiss Universities and Universities of applied sciences, as well as of public and private research institutions outside of academia. In the case of private research institutions, eligibility for Nano-Tera.ch funding was regulated by the applicable legislation.

## LAUNCHED CALLS

From 2008 to 2017, Nano-Tera.ch has launched 10 calls for proposals:

| Year | Call | Launch Date |
|---|---|---|
| 2008 | 1st Call for RTD, NTF, and ED projects | 28.01.2008 |
| 2009 | 2st Call for RTD, NTF, and ED projects | 11.12.2009 |
| 2010 | Call for RTD-ADD-ON projects | 16.09.2010 |
| 2011 | Call for SSSTC, and ED projects, and for RTD PhD extensions | 11.10.2011 |
| 2012 | 3rd Call for RTD, NTF, and ED projects | 23.05.2012 |
| 2012 | Call for Phase 1 Strategic projects | 12.10.2012 |
| 2013 | 4th Call for RTD, NTF, and ED projects | 14.02.2013 |
| 2015 | Pilot call for Gateway projects | 01.07.2015 |
| 2015 | Call for Phase 2 Strategic projects | 01.07.2015 |
| 2015 | Call for Gateway projects and RTD PhD extensions | 19.07.2016 |

*Table 1. Calls for proposals.*

The distribution of accepted proposals by project type and the year of the corresponding call is provided below.

| Project Type | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| RTD | 10 | 9 | | | 18 | 7 | | | | 44 |
| RTD-ADD-ON | | | 8 | | | | | | | 8 |
| GTW | | | | | | | | 4 | 4 | 8 |
| PHD | | | | 18 | | | | | 13 | 31 |
| SSSTC | | | | 6 | | | | | | 6 |
| STRAT | | | | | 3 | | | 3 | | 6 |

*Table 2. Projects by call year.*

For the two funding instruments that were implemented in the form of periodic calls, the distribution by starting year is given in the table below.

| Project Type | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2016 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NTF | 1 | 1 | 12 | 1 | | 9 | | | | | 24 |
| ED | 1 | 2 | 4 | 12 | 5 | 8 | 9 | 12 | 5 | 3 | 61 |

*Table 3. NTF projects and ED activities by starting year.*

The competitive nature of the Nano-Tera call is illustrated by the table below, summarizing the acceptance rates achieved for RTD and NTF calls:

| RTD projects | call | submitted proposals | accepted proposals | acceptance rate |
|---|---|---|---|---|
| **Phase 1** | 2008 | 54 | 10 | 19% |
| | 2009 | 15 | 9 | 60% |
| | **Total** | **69** | **19** | **28%** |
| **Phase 2** | 2011 | 20 | 6 | 30% |
| | 2012 | 31 | 12 | 39% |
| | 2013 | 27 | 7 | 26% |
| | **Total** | **78** | **25** | **32%** |
| **TOTAL** | | **147** | **44** | **30%** |

| NTF projects | submitted proposals | accepted proposals | acceptance rate |
|---|---|---|---|
| Phase 1 | 31 | 15 | 48% |
| Phase 2 | 37 | 9 | 24% |
| **TOTAL** | **68** | **24** | **35%** |

*Table 4. Acceptance rate.*

## PROJECT PARTNERS, THIRD PARTIES AND STAFF MEMBERS

Any of the accepted Nano-Tera.ch RTD project proposals was led by one of the applicants, called the Principal Investigator, or PI. The PI managed the project and ensured that it was carried to completion in all its aspects including reporting. The other applicants were called the project Co-PIs, and, collectively with the PI, the project partners. All partners of an accepted project signed a contractual agreement with Nano-Tera.ch (the "project guidelines") defining their rights and obligations.

Each partner could use their allocated budget to fund full-time or part-time positions for staff to be involved in the project. Staff funded by other sources than Nano-Tera.ch could also be involved in accepted projects and their costs then became eligible as matching funds (also called "own contributions").

Furthermore, any partner could also be associated with one or more additional teams that provided expertise and matching funds to the project. These additional teams were called project 3rd parties, and, contractually, each partner was responsible for the 3rd parties they have brought to their project.

Each project partner and 3rd party was attached to an institution/company, and institutions/companies involved in Nano-Tera.ch projects have been further categorized into a small set of types: research institutions, translational institutions, industry and end-users., where "translational" institutions are the ones, CSEM and Empa, specifically concerned with the transfer of research results to the industry, and "end-users" the ones, University hospitals for example, bringing real end-users to the project consortia, as well as concrete applicative contexts for the resulting prototypes/demonstrators.

The 188 projects and actions funded by Nano-Tera.ch involved a total of 346 partners and 3rd parties, stemming from 111 institutions/companies. The distribution of all partners and 3rd parties involved in Nano-Tera.ch projects by institution type is displayed in the chart below.

| Type | Partners | 3rd Parties | Total |
|---|---|---|---|
| Research | 166 | 7 | 173 |
| Translational | 51 | 1 | 52 |
| Industry | 18 | 62 | 80 |
| End user | 33 | 8 | 41 |
| **Total** | 268 | 78 | 346 |

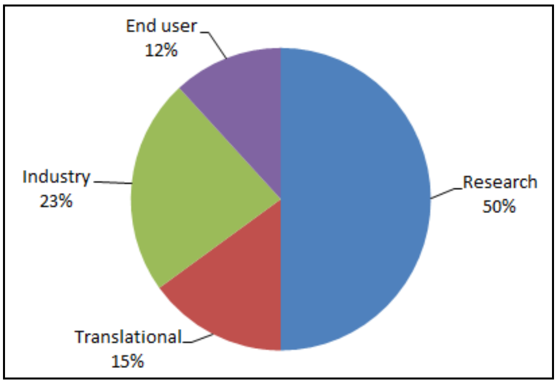



*Figure 1. Number of partners and third parties by institution type.*

## FINANCIAL DATA

The Nano-Tera.ch program benefitted from a total budget of 120'198'800 CHF, provided at two-thirds by the ETH-Board and at one-third by the Board of the Swiss Universities, under the supervision of the Swiss National Science Foundation (SNSF). The original distribution of this budget over the Phases and the budget types was defined in the SERI decrees related to the Nano-Tera.ch, and is given in the table below:

| Budget type | Phase 1 (2008-11) | Transition year (2012) | Phase 2 (2013-17) | Total | % |
|---|---|---|---|---|---|
| Management budget | 3'200'000 | 800'000 | 3'200'000 | 7'200'000 | 6% |
| Strategic budget | 2'000'000 | 600'000 | 2'000'000 | 4'600'000 | 4% |
| NTF projects | 3'000'000 | 90'000 | 2'400'000 | 5'490'000 | 5% |
| ED projects | 1'500'000 | 375'000 | 600'000 | 2'475'000 | 2% |
| RTD projects(*) | 48'942'800 | 12'935'000 | 38'556'000 | 100'433'800 | 83% |
| **Total** | **58'642'800** | **14'800'000** | **46'756'000** | **120'198'800** | |

(*) The 48 942 800 CHF budget planned for Phase 1 RTD projects includes the Federal cut imposed in 2010 by the Swiss government on all research programs. In the case of Nano-Tera.ch, this cut amounted to 557'200 CHF.

*Table 5. Original budget overview.*

The final budget distribution resulting from the balancing between the program phases and budget types required by the call results and operational constraints of the program is given in the table below:

| Budget | Phase1 | Phase2 | Total | % |
|---|---|---|---|---|
| Management | 3'483'730 | 4'339'354 | **7'823'084** | 6.5% |
| Strategic | 954'564 | 1'448'111 | **2'402'675** | 2.0% |
| STRAT projects | 890'787 | 780'000 | **1'670'787** | 1.4% |
| NTF projects | 2'823'746 | 2'466'894 | **5'290'640** | 4.4% |
| ED projects | 825'044 | 600'000 | **1'425'044** | 1.2% |
| RTD projects | 44'348'595 | 51'215'184 | **95'563'779** | 79.5% |
| PHD projects | 876'747 | 418'119 | **1'294'866** | 1.1% |
| RTD-ADD-ON projects | 2'530'425 | 0 | **2'530'425** | 2.1% |
| SSSTC projects | 530'526 | 0 | **530'526** | 0.4% |
| GTW projects | 0 | 1'666'975 | **1'666'975** | 1.4% |
| **Total** | **57'264'163** | **62'934'637** | **120'198'800** | |

*Table 6. Actual budget distribution.*

In addition, the charts below are displaying the distribution of the project allocated budgets (left), and associated matching funds (right).

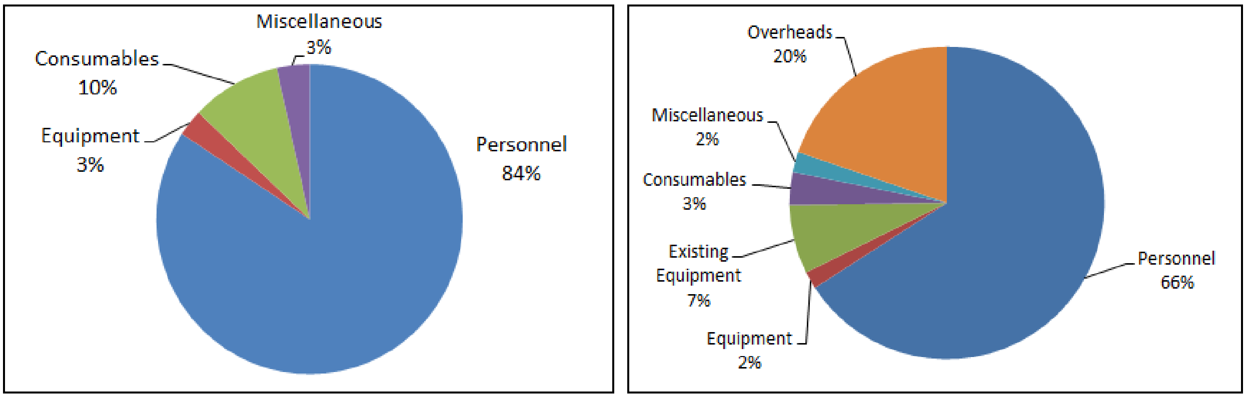



*Figure 2. Left: Distribution of Nano-Tera budget by cost categories. Right: Distribution of matching funds provided by project partners.*

A more detailed analysis of the Nano-Tera.ch budget invested in personnel in RTD projects further provided the budget distribution by personnel categories given in the figure below. In particular, this distribution indicates that more than 69% of the RTD personnel budget has been invested in junior researchers (PhD students and Postdocs).

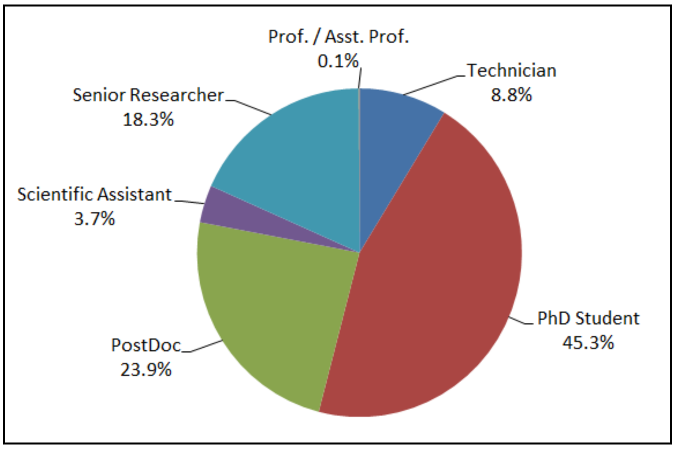



*Figure 3. Distribution of budget invested in personnel by personnel categories (RTD projects).*

Finally, the chart below provides the distribution of the allocated budgets by institution type.

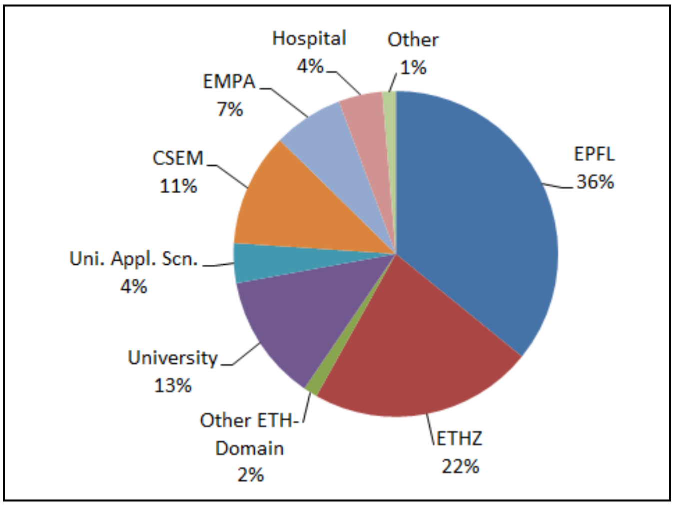



*Figure 4. Distribution of allocated budget by institution type.*

## FUNDED PROJECTS

The distribution by project type of the 188 projects funded by Nano-Tera.ch during each if its two phases is provided in the table below, along with the average duration, number of partners and third parties, and average budget.

| Project Type | Phase 1 | Phase 2 | Total | Avg. duration (months) | Avg. Nb. Partners & 3rd parties | Avg. Budget (CHF) | % from Research | % from Translational | % from Industry | % from End Users |
|---|---|---|---|---|---|---|---|---|---|---|
| RTD | 19 | 25 | **44** | 48 | 7 | 2'171'904 | 58% | 12% | 19% | 12% |
| RTD-ADD-ON | 8 | 0 | **8** | 28 | 5 | 316'303 | 63% | 11% | 21% | 5% |
| GTW | 0 | 8 | **8** | 16 | 3 | 208'372 | 7% | 37% | 56% | 0% |
| PHD | 18 | 13 | **31** | 7 | 1 | 41'770 | 97% | 3% | 0% | 0% |
| SSSTC | 6 | 0 | **6** | 13 | 2 | 88'421 | 83% | 17% | 0% | 0% |
| STRAT | 3 | 3 | **6** | 23 | 3 | 278'465 | 81% | 6% | 6% | 6% |
| NTF | 15 | 9 | **24** | 25 | 2 | 220'443 | 56% | 20% | 11% | 13% |
| ED | 29 | 32 | **61** | 6 | 2 | 23'173 | 85% | 14% | 0% | 1% |
| **Total** | **98** | **90** | **188** | | | | | | | |

*Table 7. Statistics showing the number of projects by phase, the average duration, number of partners and budget.*

# I.3 ORGANIZATIONAL STRUCTURE

The Nano-Tera.ch program built on the experience acquired in several Swiss initiatives, such as NCCRs, the National Competence Centers for Research launched by the ETH-Board, and received a strong support from the Swiss National Science Foundation (SNSF), who has been in charge of the evaluation of the proposals received for the RTD calls, and for the annual review of the accepted RTD projects. As a result, the State Secretariat for Education, Research, and Innovation (SERI) has set up Nano-Tera.ch as a consortium (the "Nano-Tera.ch Consortium") of seven member institutions: the two Federal Institutes of Technology (EPF-Lausanne and ETH-Zurich), the Centre Suisse d'Electronique et de Microtechnique (CSEM), and four universities (the University of Basel, of Neuchâtel, of Geneva, and of Svizzera Italiana). The consortium took the legal form of an Ordinary Partnership ("société simple" or "Einfache Gesellschaft"), relying on four governing bodies: the Nano-Tera.ch Steering Committee, the Nano-Tera.ch Executive Committee, the Nano-Tera.ch Scientific Advisory Board, and the SNSF Evaluation Panel. An additional evaluation panel, the Nano-Tera.ch NTF evaluation panel, has been set up by Nano-Tera.ch specifically for the evaluation of the NTF calls. The operational management of the program is carried by a specific management structure, the Nano-Tera.ch Management Office, hosted at EPFL.

## NANO-TERA.CH STEERING COMMITTEE

The Nano-Tera.ch Steering committee is responsible for the overall monitoring and responsibility of the program. It is composed of the Rectors, Presidents, and CEOs of the partner institutions, and chaired by the President of EPFL. The Steering Committee makes all high-level decisions and conducts actions requiring statutory authority.

These attributions include, notably:

- government and institutional relations;
- decisions that directly impact the structure of the partnership (e.g., new partners, legal form of the partnership);
- appointment of the members of the Executive committee and of the Scientific Advisory Board;
- approval of the global strategy of the program, and of its annual budget and annual report.

Institutions with the statute of partner in Nano-Tera.ch have up to one representative in the Steering committee. The Steering committee may also invite non-voting members, from other institutions or from companies that have close collaborations with Nano-Tera.ch.

Voting members each have one vote, the Chair having a casting vote in a case of tie. The Steering committee typically meets once a year. Generally, the Chair of the Executive committee participates to the meetings as a non-voting invited member. If needed, the committee decides on measures to be implemented, that take into account some suggestions provided by the Nano-Tera.ch Executive Committee.


Prof. Patrick Aebischer
Chairman and President
of EPFL


Prof. Philippe Gillet
Alternate to the Chair and
Vice-President for
Academic Affairs, EPFL


Dr. Mario El-Khoury
CEO
CSEM


Prof. Yves Flückiger
Rector
UniGE


Prof. Detlef Günther
Vice-President
ETHZ


Prof. Piero Martinoli
President
USI


Prof. Martine Rahier
President
UniNE


Prof. Andrea Schenker-Wicki
Rector
UniBas

As the composition of the Nano-Tera.ch Steering Committee changed over the lifetime of the program, the above mentioned list of current members is complemented below by the list of all former members:

| | | |
|---|---|---|
| Prof. Jean-Pierre Derendinger | UniNE | Until 07.2008 |
| Prof. Ralph Eichler | ETHZ | Until 01.2015 |
| Dr. Thomas Hinderling | CSEM | Until 10.2009 |
| Prof. Antonio Loprieno | UniBas | Until 07.2015 |
| Prof. Jean-Dominique Vassalli | UniGE | Until 07.2015 |

In addition, as Vice-President for Academic Affairs of the hosting institution, Prof. Giorgio Margaritondo also played a central role in the setup of the initial Steering Committee and was responsible for the overall supervision of the program as substitute of the Steering Committee president.

## NANO-TERA.CH EXECUTIVE COMMITTEE

The Nano-Tera.ch Executive committee (ExCom) is the scientific executive body of Nano-Tera.ch. It consists of a group of nine representatives from partner institutions, and is chaired by the spokesperson of the program. The ExCom coordinates and fosters collaborations between the research groups that participate to Nano-Tera.ch. As the overarching scientific body of Nano-Tera.ch, it provides the scientific guidance for the program. Members of the ExCom cover collectively all strategic orientations and thematic foci of Nano-Tera.ch. Their candidacy is put forward by their respective institutions and they are appointed (or dismissed) by the Steering committee.

By delegation of the Steering committee, the ExCom has all competences not otherwise attributed.

In particular, the ExCom:

- defines and implements the scientific and academic strategy;
- plans, announces and coordinates the calls for proposals;
- proposes cross-disciplinary projects with other major initiatives;
- plans and implements educational initiatives in the framework of Nano-Tera.ch;
- designs and coordinates outreach initiatives (e.g. continuing education and training);
- defines and ensures communication, both among the researchers of Nano-Tera.ch and in Switzerland, and with similar institutions or Centers outside Switzerland;
- finalizes the financial planning and annual budget;
- decides the funding of tactically important projects, according to predefined rules and attributions decided by the Steering committee and the competent federal agencies.
- plans and coordinates the scientific reviews and corresponding reporting;
- ensures the necessary monitoring and follow-up, both scientific and financial;
- proposes the names of international specialists to be appointed by the Steering Committee for the Scientific Advisory Board.

The ExCom meets six to twelve times a year. The Executive director of Nano-Tera.ch generally participates to the meeting as a non-voting member. The general practices and organization of the ExCom are detailed in the founding agreement for Nano-Tera.ch.


Prof. Giovanni De Micheli
Chair, EPFL


Prof. Nico de Rooij
EPFL


Dr. Michel Despont
CSEM


Dr. Alex Dommann
EMPA


Prof. Boi Faltings
EPFL


Prof. Christofer Hierold
ETHZ


Prof. Qiuting Huang
ETHZ


Prof. Miroslaw Malek
USI


Prof. Hugo Zbinden
UniGE

As the composition of the Nano-Tera.ch Executive Committee changed over the lifetime of the program, the above mentioned list of current members is complemented below by the list of all former members:

| | | |
|---|---|---|
| Prof. Mehdi Jazayeri | USI | Until 03.2013 |
| Prof. Christian Schönenberger | UniBas | Until 01.2010 |
| Prof. Lothar Thiele | ETHZ | Until 03.2014 |

Note that Prof. Lothar Thiele is now serving as President of the BRIDGE Steering Committee.

## NANO-TERA.CH SCIENTIFIC ADVISORY BOARD

The role of the Nano-Tera.ch Scientific Advisory Board is to provide the necessary input on performance and overall quality of the entire program. The board consists of industry representatives and academics from institutions other than institutions participating in Nano-Tera.ch. In 2017, the Nano-Tera.ch Scientific Advisory Board was composed of the following eight members:

| | |
|---|---|
| Prof. Heinrich Meyr, Chair | TU Dresden |
| Dr. Andreas Cuomo | STMicro |
| Prof. Satoshi Goto | Waseda University |
| Prof. Enrico Macii | Politecnico di Torino |
| Prof. Khalil Najafi | University of Michigan |
| Prof. Calton Pu | Georgia Tech |
| Prof. Lina Sarro | Technical University Delft |
| Prof. Göran Stemme | Royal Inst. of Technology Stockholm |

As the composition of the Nano-Tera.ch Scientific Advisory Board changed over the lifetime of the program, the above mentioned list of current members is complemented below by the list of all former members:

| | | |
|---|---|---|
| Prof. Nick Jennings | University of Southampton | Until 05.2011 |
| Prof. Teresa Meng | Stanford University | Until 2015 |

## SNSF EVALUATION PANEL

To fulfil their evaluation and review responsibility in Nano-Tera.ch, the SNSF appointed a specific panel to evaluate the proposals and activities developed within Nano-Tera.ch that are not of the exclusive responsibility of the Nano-Tera.ch ExCom. The panel comprises international and Swiss experts in the fields of engineering relevant to Nano-Tera.ch. The recommendations of the panel are transmitted to the SNSF National Research Council that takes the final decisions. The latest SNSF Evaluation Panel was composed of the following 17 members:

| | |
|---|---|
| Prof. Paul Leiderer, Chair | SNSF |
| Dr. Amara Amara | ISEP |
| Prof. Manfred Bayer | TU Dortmund |
| Dr. David Bishop | Boston University |
| Prof. Chris Boesch | University of Bern |
| Prof. Harald Brune | SNSF |
| Prof. Frederica Darema | NSF (USA) |
| Dr. Urs Dürig | SNSF |
| Prof. Georges Gielen | Leuven University |
| Prof. Chih-Ming Ho | UCLA |
| Dr. Patrick Hunziker | UniBas |
| Prof. Mary Jane Irwin | Penn State University |
| Dr. Karl Knop | SATW |
| Prof. Leila Parsa | Rensselaer Polytechnic Institute |
| Prof. Jan Rabaey | University Berkeley |
| Prof. Albert van den Berg | University Twente |
| Prof. Hubert van den Bergh | SNSF |

As the composition of the SNSF Evaluation Panel changed over the lifetime of the program, the above mentioned list of current members is complemented below by the list of all former members:

| | | |
|---|---|---|
| Prof. Patrick Dewilde | TU München | Until 2010 |
| Prof. Rolf Ernst | TU Braunschweig | Until 2013 |
| Prof. Jeff Maggee | Imperial College | Until 2009 |
| Prof. Jürg Osterwalder | SNSF | Until 2009 |
| Prof. Christopher Rose | Brown University | Until 2009 |
| Prof. Rodney Ruoff | University of Texas at Austin | Until 2009 |
| Dr. Marco Wieland | SNSF | Until 2013 |
| Prof. Hiroto Yasuura | Kyushu University | Until 2013 |

## NANO-TERA.CH NTF EVALUATION PANEL

The NTF Evaluation Panel consists of international experts, responsible for the evaluation of the NTF proposals.

The current members of the Nano-Tera.ch NTF Evaluation Panel are:

| | |
|---|---|
| Dr. Thomas Burg | Max Planck Inst. for Biophys. Chemistry |
| Dr. Thomas Ernst | CEA-LETI |
| Dr. Victor Erokhin | Università degli studi di Parma |
| Prof. Luca Fanucci | Università di Pisa |
| Dr. Ahmed Jerraya | CEA-LETI |
| Prof. Jan Madsen | Technical University of Denmark |
| Dr. Firat Yazicioglu | GlaxoSmithKline |

## NANO-TERA.CH MANAGEMENT OFFICE

The operational administration and management of Nano-Tera.ch are ensured by a specific structure, the Nano-Tera.ch Management Office, supervised by the Chair of the ExCom and hosted by EPFL. The Management Office is headed by the Nano-Tera.ch Executive Director, whose tasks and competences are proposed by the Chair of the ExCom and approved by the ExCom.

In particular, the Nano-Tera.ch Executive Director is responsible to:

- implement the strategy, vision and plan proposed by ExCom;
- be the point of contact between the ExCom and the research teams involved in Nano-Tera.ch;
- be the contact point between the ExCom, the Steering Committee, the CUS, the ETH Board and the SERI;
- serve as the secretary of the Steering committee and ExCom; this includes preparing the agenda and possible decision protocols, organizing the meetings and recording their corresponding minutes and decisions;
- elaborate the financial planning and annual budget;
- set-up and run the administrative structure of the program;
- ensure management, accounting and reporting of all resources transiting through or contributed to Nano-Tera.ch;
- coordinate the implementation of education and outreach initiatives, evaluation procedures and overall monitoring of the program;
- prepare and coordinate meetings and timely reporting;
- provide the necessary support and assistance for issues pertaining to intellectual property, industrial liaison, research contracts and interface with other similar initiatives, in Switzerland and abroad.
- organize scientific events (meetings, workshops, etc.) and contribute to the international visibility of nano-tera.ch through adequate communication (e.g. web site, newsletters, etc.)

# PART II

# OBJECTIVES

# II.1 ORIGINAL OBJECTIVES

## BACKGROUND

Based on the decisions announced in the SERI message of 2008-2011, the national funding program Nano-Tera.ch was launched in accordance with Article 41, paragraph 5 of the Federal Act on the Promotion of Research and Innovation (RIPA).

The main goal of this program was the development of key technologies involving micro- and nano-scale components in the framework of an interdisciplinary national network, with the scientific challenge of developing basic technologies in electronics, information and communication sciences, as well as material sciences, to create blocks at the micro- and nano-scale, able to generate large amounts of useful data and to be used in various engineering applications. In the foreseeable future, the program should lead to a significant strengthening in the domain of Knowledge and Technology Transfer and to an increased collaboration with the interested players from the private sector.

As the program has been created in the form of a *national joint task*, it has been implemented with a specific organizational structure (the Nano-Tera.ch Consortium, responsible in particular for the strategic management). In addition, a scientific evaluation mechanism independent from the Consortium has been institutionalized by the Swiss National Science Foundation in the form of a special commission (the SNSF Evaluation Panel). A specific reporting mechanism has also been established as part of the procedures associated to *project-linked contributions* (cooperative projects).

Already at its launch in 2008, the perspective of a relatively long-term financial support had been envisioned for the program. With a one-year extension in 2012 (SERI message of 2012) and a 4-year extension based on the decisions announced in the SERI message of 2013-2016, the Nano-Tera.ch program is terminating at the end of 2017 and will thus have been running for a total of 9 years. Altogether, the Swiss Confederation has provided a total funding of about CHF 120 million CHF over the whole lifetime of the program.

In agreement with the involved parties, the SERI, as competent authority, decided that the Nano- Tera.ch program should undergo an impact evaluation before its formal conclusion.

## VISION

The activities proposed by Nano-Tera.ch to the Swiss government were articulated in a Proposal (for a cooperative project) and in a Business plan, both presented in 2007. The overall vision can be articulated as follows.

The program aims at bringing Switzerland to the forefront of a new technological revolution driving engineering and information technology for health and security of humans and the environment in the 21st century. This revolution is rooted in advances in engineering nano-scale materials and their exploitation in a variety of systems, requiring extreme integration and coordinated control of diverse micro/nano-scale components.

In this perspective, the mission of the program can be summarized as the research, design and engineering of complex (tera-scale) systems and networks to monitor and connect humans and/or the environment. Beyond straightforward integration, the program aims at identifying and fostering the potential synergies between micro/nanocomponent technology and large-scale system design technologies (ranging from hardware to software and networking).

## STRATEGIC OBJECTIVES

Nano-Tera.ch's original strategic objectives (described in the 2007 proposal and business plan) call for the collaboration of the main scientific institutions in Switzerland to create interdisciplinary and inter-institutional teams of researchers.

Namely, the Nano-Tera.CH program should be a collaborative engineering program that fosters the research and crossbreeding of hardware and software technologies in the areas of wearable, ambient and networked systems. The program is mainly expected to:

- be instrumental in keeping Switzerland in the lead in the high-tech industrial sector, in particular by fostering innovation through collaboration between researchers and industrial partners within large research projects;
- develop advanced technologies, such as micro/nano-electronics, sensors, micro/nano-electromechanical systems (MEMS/NEMS), as well as systems and software for information processing and communication;
- integrate these technologies to better the quality and security of health and environment systems in Switzerland, thus promoting a vision of engineering with social objectives;
- embody the research outcomes into prototypes, acting both as demonstrators and technology drivers, to strengthen technology transfer to the Swiss industry;
- train junior scientists through interdisciplinary graduate/doctoral education programs and workshops in the domains covered by the program.

## TARGETED RESEARCH

Advanced research for health, energy and the environment requires the meaningful and efficient acquisition, processing, transmission, and integration of data coming from a very large number of heterogeneous sources. Thus, the scientific unifying theme of this program is to design and demonstrate tera-scale networks that combine information coming from different sources, such as biomedical information, physical quantities, audio-visual-sensorial information, etc. Whereas the design of large-scale networks proved to be feasible and successful in many domains (e.g., the Internet revolution), Nano-Tera.ch aims at raising current network capabilities in two directions: (1) the heterogeneity of sources and applications; and (2) adaptation to the scale and complexity human and environmental landscape.

To achieve its scientific objectives, Nano-Tera.ch covers two major dimensions:

- Research and development of advanced technologies, such as (1) micro/nano-electronics, electromechanical systems (MEMS/NEMS) and manufacturing processes; (2) (bio)-sensors, actuators and their system-level integration; (3) information and communication sciences, as well as systems and software engineering.
- Integration of these technologies into application fields, such as wearable systems (e.g., for monitoring of patients, sportsmen, and the elderly), ambient systems (e.g., for environmental intelligence, building monitoring and virtual world) and networked systems (e.g., sensor networks operating in various environments, ranging from rock movement monitoring networks deployed in the very adverse conditions of high altitude mountains to city scale air pollution monitoring networks operating with mobile sensors on buses or trams).

The program has been organized in a matrix-like structure, intersecting targeted cross-disciplinary research with three socially relevant areas: health, energy and the environment.

The underlying enabling technology is relying on micro/nano-technologies and their applications to the design of distributed, networked, embedded systems. Thus, Nano-Tera.ch is built around a technology kernel that supports embedded system applications. Beyond the mere straightforward integration, the program aims at identifying and fostering the potential synergies between micro/nanocomponent technology and large-scale system design technologies, ranging from hardware to software and networking. Indeed, the availability of sensing, computing and communication technologies enables and constrains the design of embedded systems. Conversely, the stringent requirements of embedded systems on size, weight, power dissipation and communication range demand major innovation in micro/nano-technologies. While the existence of such synergy opportunities is widely recognized, an ambitious large-scale holistic approach such as the one proposed by the Nano-Tera.ch initiative was still unheard of at the inception of the program.

# II.2 GOAL ADJUSTMENTS

## INITIAL ADJUSTMENTS: RESHAPING THE RESEARCH SPACE

In 2008, the governing bodies of Nano-Tera.ch (Steering and executive committees) and the Swiss National Science Foundation set up operational procedures for the program, taking into account realistic constraints related to budget and priorities. Specifically, the Swiss National Foundation requested excellence in research as a primary objective, and the Nano-Tera.ch boards requested a fair distribution of the Nano-Tera.ch activities through the various institutions and over the various scientific topics. As a result, Nano-Tera.ch focused on supporting and nurturing pinnacles of excellence within the broad area of research proposed in the original vision.

The original matrix-like structure of the program has been modified in order to match the program objectives with the current most adequate research topics.

In the first call for proposals (2008), the reference matrix was the following:

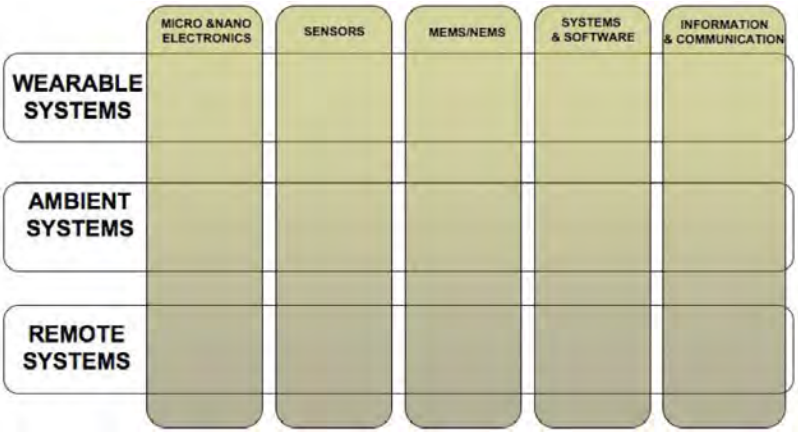



*Figure 5. Original matrix structure.*

In the 2011 call for proposals, the matrix was altered to include the theme of energy and the domains have been consolidated to take into account the distribution of the past proposal submissions and of the research activities in Switzerland. It took the shape displayed in the figure below and was no longer modified.

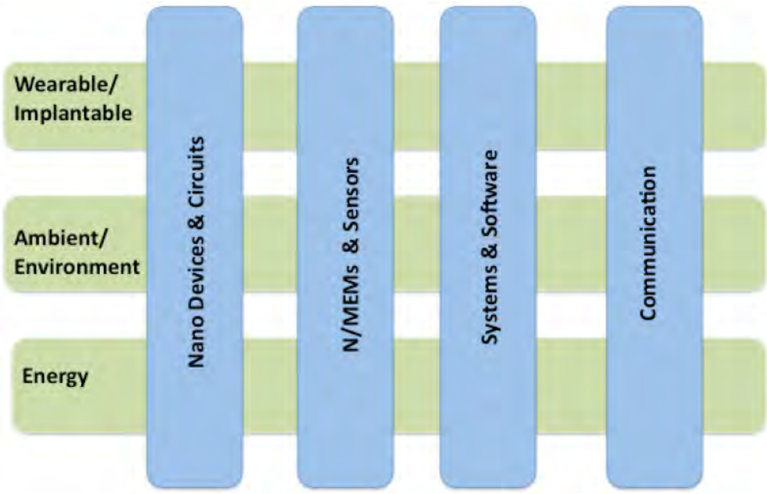



*Figure 6. New matrix structure, call 2011.*

## SPECIFIC ADJUSTMENTS: ANALYZING TECHNOLOGY TRANSFER

### Tech Transfer Maps

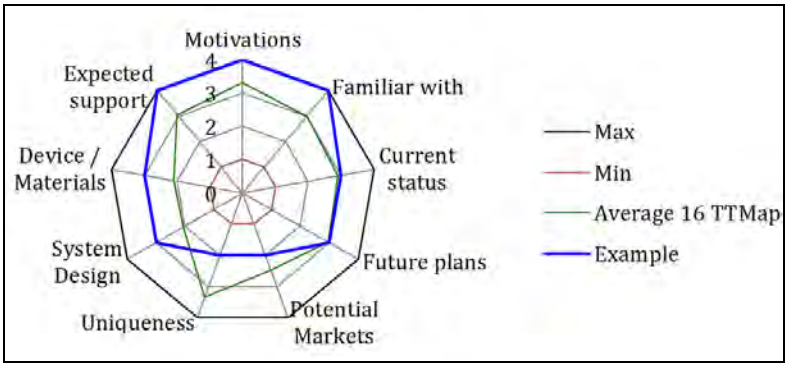
At the end of Phase1, Nano-Tera.ch hired an external consultant to conduct a survey of the Knowledge and Technology Transfer activities performed within the RTD projects. The survey took the form of a questionnaire sent to the PIs of the 19 RTD projects, and exploring the following 9 Technology Transfer related dimensions:

- Motivation — Motivations within the RTD project for Technology Transfer
- Familiar with — How familiar are the RTD partners with Technology Transfer?
- Current status — What is the current status in terms of Technology Transfer?
- Future plans — What are the future plans?
- Potential markets — What are the potential markets for the generated research results?
- Uniqueness — How unique is the expertise developed in the RTD project?
- System Design — What is the level of integration of the generated prototype(s)?
- Device/Materials — Where is the key differentiator (in devices or in materials)?
- Expected Support — Do you expect to receive support from Nano-Tera.ch for Technology Transfer issues?

In total, the questionnaire consisted of more than 100 questions, and 15 of the 19 contacted PIs accepted to participate to the survey. The provided answers were used to produce, for each of the surveyed RTD projects, a global rating for each of the 9 dimensions considered, ranging from 0 (the dimension has not really been taken into account in the RTD project) to 4 (the dimension has strongly been taken into account in the RTD project).

Finally, the ratings of each of the 15 projects analyzed have been displayed in the form of a "radar plot", hereafter called the "Tech Transfer Map" of the project (or TTMap). All the maps have been validated by the involved PIs.

The chart below displays the aggregated results of the survey in the form or the min, max and average radar plots.




The survey resulted in the following specific conclusions, corresponding to the dimensions associated with higher or lower overall scores.

Five dimensions have been associated with higher score:

- "Motivation" (scored 3.3/4): The PIs are understanding the importance of Technology Transfer, even if they do not plan to lead an specific action related to it;
- "Uniqueness" (scored 3.3/4): The PIs have a very clear understanding of the scientific positioning of their research, and a good knowledge of their scientific competitors (i.e. other laboratories worldwide carrying out similar research);
- "Expected support" (score 3.1/4): The PIs demand for Nano-Tera.ch support related to Technology Transfer is high, but not very specific due to the lack of precision of the associated future plans (see "Future plans" below);
- "Familiar with" (scored 3.0/4): The PIs are quite familiar with various approaches to Technology Transfer, in particular the creation of start-ups;
- "Future plans" (scored 3.0/4): Many PIs can imagine a future in terms of Technology Transfer, but few of them can be very specific in describing such plans.

Four dimensions have been associated with a lower scores, in particular:

- "Potential markets" (scored 2.5/4): Exploring potential markets is not a central concern for the PIs, and the RTD project thus remain quite far from market considerations;
- "System design" (scored 2.1/4): Targeting an integrated demonstrator requires a lot of effort and time, and it is therefore truly challenging to develop a "unique blend of technology exploration and system design".

Furthermore, the survey led to the following general conclusions:

- Scientific inter-disciplinarity is seen as a necessity, as it represents a true differentiator, but it also substantially adds to the complexity of possible go-to-market strategies;
- The "system engineering" approach is considered as essential and complements the scientific inter-disciplinarity; it is a key element for the production of socially relevant results, but it also strongly adds to the complexity of the possible "go-to-market" strategies.

**Tech Transfer Positioning Tables (Phase 1)**

The answers to the survey have also been used to derive a "Tech Transfer Positioning Table" (or TTPositioning Tables) in which each of the analyzed RTD projects has been positioned along two dimensions: (1) Fundamental research vs. pre-competitive research; and (2) Short vs Long Time to market.

On the "Fundamental research vs. pre-competitive research" dimension, the positioning of the projects has been derived from the analysis of the answers provided to the survey, and resulted in the clustering of the project results (i.e. demonstrators and prototypes) in 3 distinct clusters:

- Cluster 1 (prototype in an industrially relevant environment, i.e. at Technology Readiness Level 6+, or TRL6+, for a precise definition of the various TRLs, see Appendix B): There is a prototype that demonstrates the feasibility and the usefulness and the integration in the "value chain", and researchers *with* users *and* companies are able to answer the questions: What is the problem solved? How to produce it at a reasonable cost in the market?
- Cluster 2 (prototype in simulated operational environment, i.e. at Technology Readiness Level 5, or TRL5): There is a prototype, demonstrating viability and usefulness of the technology, able to convince industrial partners to consider its exploitation, and researchers *with* users are able to answer the questions: What is the problem solved? What's the point?
- Cluster 3 (prototype in laboratory environment, i.e. at Technology Readiness Level 4, or TRL4): The prototype is not yet mature enough to convince industrial partners to exploit it; researchers mainly target a proof-of-concept and were so far the only ones considering the question: What is the problem solved?

On the "Short vs Long Time to market» dimension three time horizons have been considered:

- Short term, i.e. 2013 – 2016;
- Mid-term, i.e.2016 – 2019;
- Long term, i.e. beyond 2019.

The resulting Tech Transfer Positioning Table obtained for the 15 analyzed Phase 1 RTD projects is provided in the figure below:

| Technology Readiness Level (TRL) | Long-term (>2019) | Mid-term (2016-2019) | Short-term (2013-2016) |
|---|---|---|---|
| industrially relevant environment (TRL6+) | | | X-Sense<br>OpenSense<br>CMOSAIC<br>QCrypt |
| simulated operational environment (TRL5) | ISyPeM<br>PATLiSci<br>i-IronIC<br>Nutrichip<br>SimOS | IrSens<br>NexRay | |
| laboratory environment (TRL4) | MIXSEL<br>CabTuRes<br>SelfSys<br>LiveSense | | |
| | | | Potential Time-to-Market |

*Figure 7: Tech Transfer Positioning Table (Phase 1 RTD projects).*

In this figure, the 6 projects highlighted in green have been extended with follow-ups to Phase 2.

The major conclusion to be derived from the resulting Phase 1 TTPositioning Table is that 31.5% of the RTD projects were able to produce industrially exploitable (or nearly exploitable) prototypes (i.e. prototypes at TRL5 or higher with an expected mid- or short-term Time-to-Market).

The combined analysis of Phase 1 TTMaps and TTPositioning Tables led to the following overall conclusion related to the Knowledge and Technology Transfer aspects in Nano-Tera.ch: while the Knowledge Transfer resulting from the set-up of long-lasting research consortia (the ones of the RTD projects) mixing research partners and industrial partners has been operating very efficiently, the impact in terms of Technology Transfer needed to be further strengthened to increase the fraction of RTD projects producing industrially exploitable (or nearly exploitable) prototypes. In this perspective, the following corrective measures have been implemented:

- Modifying the eligibility conditions of the Phase 2 RTD calls Phase 2 by making the presence of end-users mandatory: the goal is to increase the applicative relevance of the produced prototype, thus making them easier to consider for exploitation by the involved industrial partners;
- Launching a specific program, the NextStep program, aiming at helping the PhD students involved in Nano-Tera.ch increase their entrepreneurial mindset and consider the economic exploitation of the results of their research, e.g. by the creation of start-ups (see Key Statement 10);
- Launching a specific program, the Gateway program, aiming at strengthening the conversion of forefront research results into industrially exploitable prototypes (see Key Statement 12).

**Tech Transfer Positioning Tables (Phase 2)**

In March 2017, the oral presentations made by all the Phase 2 RTD project PIs about the intermediate results obtained in their projects, as well as the Impact Sheets produced by Nano-Tera.ch for each of these projects, have been analyzed to produce a "Tech Transfer Positioning Table" for the 25 Phase 2 RTD projects. This table, built according to the same principle as the one produced for Phase 1 RTD projects, is provided below.

| Technology Readiness Level (TRL) | | | |
|---|---|---|---|
| industrially relevant environment (TRL6+) | | IrSens II<br>SHINE<br>SmartGrid | FlusiTeX<br>HearRestore<br>ObeSEnse<br>OpenSense II<br>Synergy<br>X-Sense II<br>YINS |
| simulated operational environment (TRL5) | Envirobot | ISyPeM II<br>UltraSoundToGo<br>WearMeSoC | NewbornCare |
| laboratory environment (TRL4) | BodyPoweredSense<br>MagnetoTheranostics<br>SmartSphincter<br>SpineRepair<br>WearableMRI<br>WiseSkin | IcySoC<br>HeatReserves<br>PATLiSci II<br>MIXSEL II | |
| **Potential Time-to-Market** | Long-term<br>(>2019) | Mid-term<br>(2016-2019) | Short-term<br>(2013-2016) |

*Figure 8: Tech Transfer Positioning Table (Phase 2 RTD projects).*

In this figure, the 6 projects highlighted correspond to follow-up extensions of Phase 1 projects.

The major conclusion derived from this table is that 56% of the Phase 2 RTD projects were able to produce industrially exploitable (or nearly exploitable) prototypes, while this ratio was of 31.5% for the Phase 1 RTD projects. This substantial increase clearly illustrates the positive impact of the corrective measure taken at the end of Nano-Tera.ch Phase 1.

# PART III

# PROGRAM OUTPUTS

# III.1 MAIN SCIENTIFIC ACHIEVEMENTS, PHASE I

## HEALTH MANAGEMENT

Future health management systems require an increasingly large presence of automation, information extraction and elaboration, as well as control of the medical procedures. In this perspective, three major innovation areas have been addressed in the first phase of the Nano-Tera program: biosensing, advanced diagnosis tools, and medical care support.

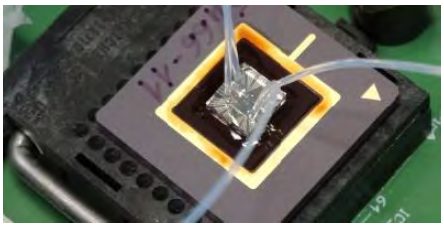
### BIOSENSING

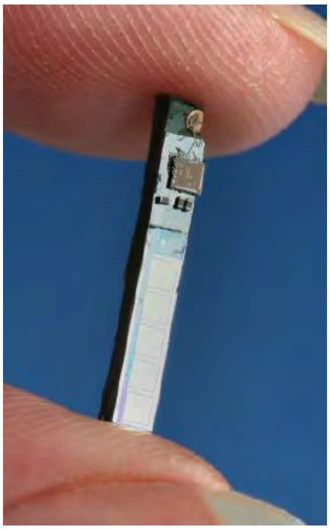
Although some biosensors are already available on the market, there is a strong potential for improvement of the techniques used to perform bio-measurements, for example by exploring novel sensing mechanisms, by using advanced electronic devices and materials, or by tightly coupling electronic sensing to data acquisition chains.

In this perspective, Nano-Tera.ch projects have been exploring different avenues:

**Building sensing platforms based on optical near and mid-infrared range spectroscopy** that exploit optical absorption properties of the analytes. In such platforms, the sensors probe the vibrational frequencies of molecules present in fluids and gases. A typical example of such an approach is the IrSens project that has led to the industrialization of a hydrogen fluoride sensor, a compact instrument measuring $CO_2$ isotopes with record precision, as well as the first detection of cocaine in saliva using mid-infrared sensing techniques.

**Developing modular sensor platforms** using silicon nanowire (SiNW) field-effect transistors, interfaced to electronics and microfluidic channels for liquid handling. As illustrated in the NanowireSensor project, one of the important advantages of such platforms is that the sensors have the potential to be mass manufactured at reasonable costs, allowing their integration as the active sensor part in electronic point-of-care diagnostic devices.



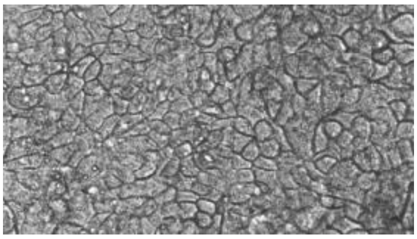


Health monitoring systems combining networked databases with on-line (i.e. real-time) wearable/implantable monitoring devices represent a true potential for better therapy and increased autonomy of the patients. However, noting that few systems involving on-line biosensing capabilities were available – and often limited to either wearable devices for human telemetry that do not measure any molecular metabolites, or glucose monitoring systems for diabetic patients – it was important to design accurate and affordable biosensing devices able to provide fast response and secure interaction with on/in body electronics, and to detect and quantify multiple compounds in parallel several times a day. This challenge has been tackled by the i-IronIC project, which designed an on-line implant for real-time monitoring of various human metabolites (such as lactate, cholesterol, ATP, glutamate, or glucose). The prototype includes a sensor array, a CMOS mixed signal chip and a tridimensional integrated coil for receiving inductive power and transmitting data via backscattering. The sensor array is realized with an innovative technology, where carbon nanotube (CNT)-nanostructured electrodes enable the measurement of metabolites with increased sensitivity and lower detection limits as compared to the state of the art. The results have generated intense international coverage in dozens of media outlets worldwide.

### ADVANCED DIAGNOSIS TOOLS

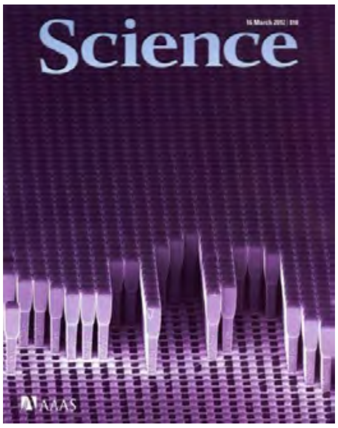
Advanced diagnosis requires the design of new methods for probing the human body, as well as the design of miniaturized (thus portable) diagnosis tools that can be made easily available at points of care. In this perspective, Nano-Tera.ch projects have been focusing on the following challenges:

**Designing novel techniques for the diagnosis of human tissues** based on micro-mechanical sensing, similar to atomic force microscopy scanning. Indeed, the measurement of nano-mechanical properties of cells and cell-cell interactions as a function of milieu parameters offers unprecedented insights into the tissue structure and is of particular interest in cancer research, where it has been recently shown that stiffness of cancer cells affects the way they spread in the body. The PATLiSci project is an example of a Nano-Tera.ch research in this direction: nanomechanical cantilever array sensors have been applied to detect a mutant gene, making it possible to apply personalized therapies for the cure of melanoma.



**Building integrated lab-on-a-chip platforms able to monitor and investigate various metabolic functions of the human body**. In particular, the NutriChip project focused on food digestion with the design of a prototype of an artificial and miniaturized gastrointestinal tract using a minimal set of biomarkers identified through in vivo and in vitro studies. Such a prototype offers novel perspectives for probing the impact on health of dairy food samples, and was tested for the screening and selection of dairy products with specific health-promoting properties.

**Developing miniaturized X-ray sources** based on multi-walled carbon nanotube (MWCNT) cold-electron emitters. When combined with novel image processing techniques exploiting X-ray time-of-flight measurements (to probe the depth inside objects), as well as the specific pixel structures of both the X-ray source and the X-ray detector, such approaches open very interesting possibilities for the design of portable X-ray systems with fully unprecedented tomographic imaging capabilities. The Nexray project is an illustration of such a research track in the Nano-Tera.ch program: the consortium produced pocket X-ray sources with a size of about 0.1 $cm^3$, producing X-rays of about 3 keV, as well as detectors involving monolithically integrated Ge absorption layers on a CMOS chip. The main scientific achievement is a breakthrough in epitaxy thick layers of Ge on Si, which made it on the cover page of Science journal and generated ample scientific press coverage.

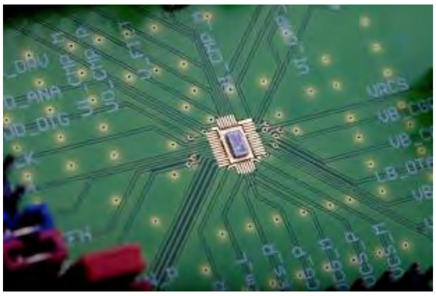



## MEDICAL CARE SUPPORT

The general area of monitoring systems for medical care support represents an extremely rich research domain with multiple research directions:

**Electronic textiles** relying on advanced (electrical/optical) fibers incorporating sensors, signal transmitters and other active nanocomponents. They provide very interesting possibilities for implementing body area networks where both sensing and communication are integrated in the same medium. In this domain, the Nano-Tera.ch TecInTex project developed such a technology demonstrator, embodied in an electronic underwear for paraplegic people able to prevent pressure ulcers (which typically occur twice a year for these patients), thus entailing an important reduction of pain and associated health care costs for such patients. Sensorized fabrics were tested on body and on wound model and the components and technology for the near-infrared spectroscopy demonstrator have been approved for the textile integration and clinical testing.

**Smart prostheses** integrating innovative micro-devices to measure in vivo crucial bio-mechanical parameters of joint prostheses, orthopedic implants, bones and ligaments. For example, the Nano-Tera.ch SImOS project designed an implant module including sensors to measure forces, interface frictions, stem micro-motion and impacts to help surgeons with prosthesis alignment and positioning during surgery, detect early migration during rehabilitation, thus potentially avoiding failure due to excessive wear or micro-motion information, and evaluate in vivo joint functions. Such capabilities represent a potentially huge progress in the domain of hip and knee prostheses, since over a million prostheses are currently implanted each year in the EU and the US, with a premature failure rate of about 20% (for people less than 50 years old) translating into a substantial amount of complex and traumatic revision surgeries.



**Smart drug delivery** based on drug response monitoring through the in vivo measurement of drug concentrations and relevant biomarkers. Indeed, while medical progress is increasingly improving the survival rate and life quality of patients affected by long-lasting diseases (HIV infection, cancers, vital organ failure, etc.), these achievements significantly rely on drug regimens and therapeutic protocols that require long-term daily administration of highly active drugs, for which the huge individual response variability raises severe problems in efficient treatment definition. In this perspective, the Nano-Tera.ch ISyPeM project sought to provide advanced technologies for seamless drug monitoring and delivery by an ultra-low power integrated system and it indeed released a set of technologies addressing drug monitoring and automated administration.

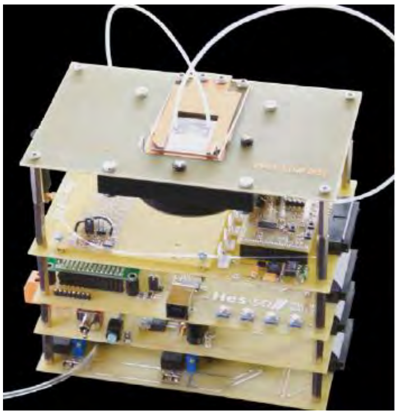
## ENVIRONMENTAL MONITORING

Within Nano-Tera's first phase (and continuing into its Phase II, see below), the objectives of the research on environmental monitoring included monitoring the quality of air and water, by measuring pollution in terms of biological and/or inorganic compounds; and instrumenting the environment to detect movements that can lead to catastrophes, such as rockslides, avalanches, floods or to the instability of constructions such as buildings and bridges.

### MONITORING WATER POLLUTION

The quality of water is crucial for both developed and developing countries, as it directly affects health and quality of living. The design of efficient, reliable and affordable technologies to measure levels of pollution in fresh waters is therefore an important problem.

In this perspective, Nano-Tera.ch research has been focusing on **environmental sensing based on living cells**. Indeed, living cells are the most natural biosensors, since they integrate the biological effects of the pollutants and respond by metabolic or phenotypic changes that are relevant to potential effects in the human body. More precisely, the general idea behind living cell-based sensors is that cellular responses are measured in real time by secondary probes or sensors integrating optical, chemical or electrical microsensors.



For example, the Nano-Tera.ch LiveSense project designed a cell-based sensing platform taking the form of an autonomous, wireless, hand-held system for fluid monitoring. The modular prototype includes a fully functional bioreactor based on genetically modified E. coli cells (HepG2/C3A hepatocytes) and cells derived from human epithelial colorectal adenocarcinoma (C2BBe1 cells), for which storage and culture protocols have been established and sensitivity to various target analytes characterized, as well as various secondary sensors for fluorescence, impedance, and mechanical/trans-epithelial resistance. The prototype (which can be remote controlled with a smart phone) has been validated by characterizing the relation between measured fluorescence intensity and the concentration of arsenic in the analyzed water sample. In addition, label-free techniques to distinguish healthy, sick and dead cells have been designed, making it possible to detect cellular changes long before cellular death, thus offering a high sensitivity in comparison with conventional viability assays.

### MONITORING AIR POLLUTION

Wireless sensor networks publishing sensor data on the Internet bear the potential to substantially increase public awareness as well as involvement in environmental sustainability. Air pollution monitoring in urban areas is a prime example of such an application, as air pollutants have a direct effect on human health.


The Nano-Tera.ch OpenSense project is an example of research on air pollution monitoring. It focused on the design of a network of mobile air pollution sensors with intermittent GPRS connectivity, deployed on top of public buses in the city of Lausanne and on top of trams in the city of Zurich (where ten sensor boxes on trams have been deployed, monitoring a wide range of pollutants on an area of 100 $km^2$). The prototype sensor network is operational and provides valuable insights on sensor capabilities and behaviors in realistic environments. The generated network and air pollution data have been used for the various modeling tasks (mobility, air pollution, etc) and the resulting models in turn serve for generating numerical input that can be used for efficient signal processing and machine learning. Different modeling methods were used to produce high quality and fine-grained pollution maps. In addition, a collaboration with the Nokia Research Center in Lausanne led to the setup of user studies that clearly demonstrated both the public interest for air pollution data and the commercial potential of the developed technology. The dimension of crowdsourcing is being addressed in a project follow-up (see below).

### MONITORING ROCK AND GLACIER MOVEMENTS

Global climate change dramatically influences the visual appearance of mountain areas like the European Alps, and may trigger or intensify destructive geological processes that impact the stability of slopes, thus posing a threat to local communities.

In this perspective, research in Nano-Tera.ch has been focusing on the development of wireless sensing technologies for environmental sensing under extreme environmental conditions (temperature, humidity, mechanical forces, snow coverage, etc). In particular, in the Nano-Tera.ch X-Sense project, various rugged electronic chips have been built to install more than 50 sensors in the Mattertal area of Switzerland. The corresponding prototype of wireless sensor network and GPS data processing framework has been deployed with improved system reliability and data quality derived from model-based design principles. The full pipeline from GPS and image sensors to the data-base servers has been established and thoroughly tested. New algorithms have been developed and applied that lead to high precision sensing, high data quality by means of network tomography and highly robust processing and communication in extreme environments. The installation has been in operation for over 4 years: this continuous operation period as well as the corresponding data quality is unique. As a result, many new scientific results in the area of geoscience have been made possible. They help us understand the complex geophysical processes in permafrost regions and the destructive processes due to global warming. Currently, hardware and software are built and transferred to the Federal Office for the Environment for early warning purposes. Further field sites are envisioned for the next year. It was therefore shown that wireless sensor network technology makes it possible to quantify mountain phenomena, and can be used for safety critical applications in a hostile environment.

## ENABLING TECHNOLOGIES

In some cases, research and development may impact several areas in the health and environment domains, and some of the Nano-Tera.ch projects have therefore been focusing on generic enabling technologies.

For example, the Nano-Tera.ch MIXSEL project has been investigating the use of laser sources to create short pulses that can support microscopy and optical tomography. Similarly, the CabTuRes project studied new materials, such as carbon nanotubes (CNTs),using them as resonators for electronics applications as well as mass balances for sensing.

Heat management in high-performance multi-processing systems, realized as 3-Dimensional Integrated Circuits is another generic track of research, and, in this domain, the Nano-Tera.ch CMOSAIC project combined competencies in thermodynamics, mechanics of materials, and dynamic power management to design liquid cooling techniques specifically tailored for 3D chips.

On the other side of the spectrum, research in Nano-Tera.ch also concentrates on low-power electronic systems, and specifically autonomous systems, that are crucial for both health and environment applications. In this perspective, the Nano-Tera.ch PlaCiTUS project focused on the design of a generic technology platform that can be used to deploy biomedical wireless sensor networks. Such a platform typically consists of many sensors and actuators connected together and to the outside world, through a short range wireless network, and interfaced with micro-power data acquisition and driver circuits supplied either by battery or by inductively coupled remote power.

Another critical issue is the manufacturing of integrated nano-systems consisting of large numbers of connected nano-devices. The Nano-Tera.ch SelfSys project studied fluid-mediated self-assembly techniques to lower manufacturing costs and enable the assembly of structures with unprecedented complexity.

In the security domain, the Nano-Tera.ch QCrypt project improved secret key distribution and message encryption based on the fundamental properties of quantum physics (Quantum Key Distribution). The team has built a complete, working prototype with unprecedented real time hardware key distillation, finite key security analyses and fully automated operation over a single fibre using wavelength division multiplexing. On the encryption side, error-free data encryption at 40 Gbit/s with 100% throughput was demonstrated. In addition, the QCrypt project is a good example of the industrial impact resulting from a Nano-Tera.ch research project. Indeed, this project not only led to a follow-up CTI project, but also made it possible for the involved ID Quantique company to market more than one hundred crypting devices using the technology developed within the project and generate about 30 new jobs.

Finally, in the energy domain, the GreenPower project developed cost-effective membranes for $H_2$-$O_2$ fuel cells suitable for mobility applications based on the conversion of solar energy into hydrogen and oxygen. A demonstrator of a self-sensing composite vessel for high pressure storage was produced. Belenos car and boat demonstrators accomplished one year test under real drive and navigation conditions.

# III.2 MAIN SCIENTIFIC ACHIEVEMENTS, PHASE II

Nano-Tera.ch Phase II supported 25 collaborative 3- and 4-year RTD projects, uniting teams right across the country. Health-related themes feature strongly among the research subjects selected, with strong participation from university hospitals and doctors. The themes related to environmental monitoring and energy are also taking pride of place. As with previous calls for proposals, the key domains of Nano-Tera.ch (Bioengineering and Electronics) are well represented in this selection. What is new compared to the earlier phase of the program is the arrival of research topics combining engineering with life sciences, medicine and energy.

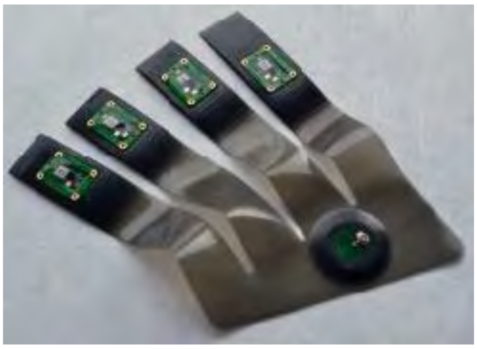
## A STRONG FOCUS ON HEALTH APPLICATIONS

The university hospitals and the specialists that thrive there, such as specialized surgeons, neurologists and cardiologists, represent about a fifth of all co-investigators involved. The CHUV, the InselSpital of Bern, the University Children's Hospital in Zurich, the University Hospitals of Basel and Zurich and the Hospitals of Schaffhausen are all bringing their knowledge and expertise to the research of the Nano-Tera program. Research with health-related applications can be loosely arranged in three distinct thematic clusters:

### SMART PROSTHETICS AND BODY REPAIR

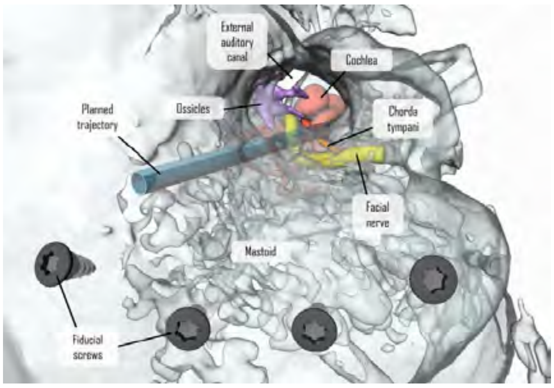
Smart prosthetics and body repair is an integral part of the program, with projects addressing tactile prosthetics and other sensorimotor functions (in particular after spinal cord injury), as well as micro surgery.

**An integrated spinal neuroprosthesis to restore leg motor control after spinal cord injury.** People who sustain a Spinal Cord Injury often do not recover the ability to stand or walk again. SpineRepair advances implantable neurotechnologies to re-establish control of the leg locomotor movements after such injuries. The multidisciplinary team first unravelled the mechanisms and neural structures through which electrical stimulation of the spinal cord facilitates motor control. They next exploited this knowledge to engineer technologies for soft implantable electrodes based on nanowire-elastomer composites and thin metal films. The project thus conceived a soft, electrochemical spinal implant, termed electronic dura mater or e-dura, capable of delivering both biochemical and electrical stimulation of the spinal cord, while demonstrating unprecedented biointegration over extended durations. Using e-dura implants, the team developed conceptually new stimulation protocols termed spatiotemporal neuromodulation therapies, whereby electrical stimulation is delivered through spatially selective spinal electrodes with an appropriate temporal structure in order to reproduce natural spinal circuit dynamics. In parallel, they designed a customized low-power CMOS chip capable of advanced stimulation pattern programming and interfaced it with miniaturized telemetry and powering hardware to fit a compact system. Using medical grade implantable technologies from Medtronic, the team also conceived a wireless brain-spine interface, decoding motor cortical activity to adjust spatiotemporal neuromodulation of the spinal cord and producing intended leg movements in a non-human primate model of spinal cord injury. Also note that the technologies developed in SpineRepair are often versatile and can be applied to a wide range of applications. For example, the nanowire based stretchable conductors or biphasic Gallium based thin films are suitable interconnect technologies for stretchable multilayered printed circuit boards.



**Wise skin for tactile prosthetics.** Amputation of a hand or limb is a catastrophic event resulting in significant disability with major consequences for daily activities and quality of life. A sense of tactility is needed for providing feedback for control of prosthetic limbs and to perceive the prosthesis as a real part of the body, inducing a sense of "body ownership" and a natural sensation of touch. The WiseSkin project has developed a non-invasive solution for the restoration of natural sense of touch to persons who have lost limbs. The solution leverages the phantom limb effect, but may also be applied where the persons lack a phantom map. Miniature wireless tactility sensors are embedded in a flexible, stretchable "skin" that provides for powering, RF waveguide and shielding against interference. Sensory feedback is provided via a tactile display (amputation stump) of miniature actuators. The sensor modules are integrated into a silicone elastomer scaffold and encapsulated on both sides with soft metallization layers. Dedicated wireless technologies were developed. The solution is scalable to many sensor devices in a high density network and offers low latency sensory feedback. Multiple tactile feedback devices were developed and tested with amputees and healthy subjects. A prosthetic hand integrated with tactility sensors and tactile feedback actuators was evaluated on an amputee with a hand phantom map. WiseSkin pushed the forefront in miniature, ultra-low power sensor and communication devices, materials and sensory feedback systems. Beyond prosthetics, the sensory skin developed in WiseSkin has potential application in the domains of rehabilitation (e.g. stroke), safety (robots working alongside people) and haptic interfaces (e.g. virtual reality, games, the haptic Internet).

**Image-guided micro surgery for hearing aid implantation.** The project HearRestore has developed novel technologies to drastically reduce the invasiveness and improve the outcome of cochlear implant surgery. HearRestore has demonstrated the potential of robotic surgery in microsurgical interventions, with its robotic surgical intervention platform for use with a robotic microsurgery treatment-model. It encompasses computer-assisted surgery planning and modelling, precision stereotactic image-guidance, in-situ assessment of tissue properties and multipolar neuromonitoring, robotic access-drilling, computer-assisted electrode selection and keyhole electrode-placement. Preclinical work included, ex-vivo and animal research trials to validate a heat-minimized robotic drilling process in which safety supervision involved a multipolarelectromyographic neuromonitoring approach. The developed models are expandable to integrate additional robotic functionalities such as cochlear access and electrode insertion. The results obtained show the applicability, feasibility and suitability of robotic technology for microsurgery on the lateral skull-base. The robotic treatment approach opens up opportunities for significant benefit in other microsurgical domains for which there is no task-oriented, robotic technology available at present. In addition to these technology outcomes, HearRestore also resulted in the successful translation of the robotic microsurgical technology into a clinical application. The project has proudly reported the first successful stereotactically-guided robotic cochlear implantation in man worldwide. To the team's knowledge, no other group in the world other than theirs has produced sufficiently safe and accurate robotic microsurgery technology to enable microsurgical interventions at this scale and in a patient clinical trial. Real-term economic impact has been created through the licensing of the technology to a consortium of industrial manufacturers of surgical robotic and navigation technology (CAScination AG, Bern) and cochlear implants (Med-El GmbH, Innsbruck). Both CE marking and commercial launch of the technology are expected in 2017.




In the associated Gateway project HearRestoreGate, the scientists have been working with the company Atracsys, whose main business is to sell medical-grade tracking systems all around the world. What limits their expansion is the price and the cumbersomeness of their systems. A development strategy is to propose innovative products in that direction, which require the use of new technologies. The HearRestore tracking system is the technological next step. It is miniaturized, lens-less and uses off-the-shelf components, thus rendering it cost effective. The team has the smallest surgical tracking device compared to the state-of-the-art. The current maturity of development (TRL4-6) of the HearRestore tracking system enables the exploration of these new opportunities and defines the starting point of a medical industrialization which might be realized through a CTI project between CSEM and Atracsys. Detailed market analysis, resulting from potential customer interaction, demonstrates that by 2020, the expected revenues will be improved from a forecast of slightly higher than 2.5 million CHF to slightly higher than 4.5 million, meaning an approximate revenue increase of 4O%. This could result in a conservative estimation to the creation of 4-5 sustainable jobs.

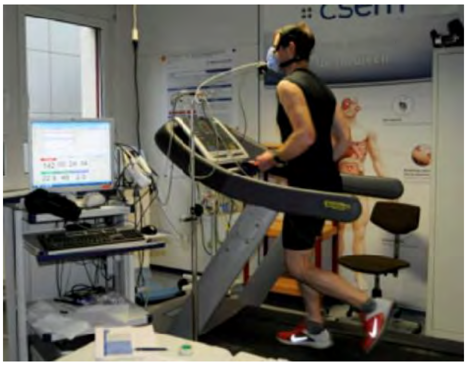
**Use of superparamagnetic nanoparticles for the detection and treatment of cancer**. Indeed, such particles are used as contrast agent for MRI, especially for the liver, and as heat sources for the treatment of tumors (magnetic hyperthermia). MagnetoTheranostics has been developing a nanomedical system utilizing nanoparticles for the detection and therapy of lymph node metastasis by applying iron oxide nanoparticles as contrast agents for metastatic lymph nodes and at the same time as a heat source for thermotherapy (Hyperthermia). Iron oxide particles were developed and the manufacturing process is so far developed, that a transfer to GMP production is possible. To achieve specific targeting, the team successfully developed a selection of coatings and targeting molecules as well as the corresponding coating technologies. In vitro tests were successful, in vivo tests are ongoing and look promising. The team was able to functionalize the particles with FDA accepted processes and materials, and a transfer to clinical tests should be feasible. Provided that the size of the particles, their performance as an magnetic resonance imaging agent, and their suitability for thermal therapy are strongly correlated, the project successfully developed novel MRI sequences and magnetic field generators as well as software which allows the medical doctors targeted planning and treatment safety/efficacy assessment. Overall, the consortium was able to develop at preclinical level a diagnostic and therapeutic tool for the detection and treatment of primary and metastatic (Lymph node) tumors.

**Cutting-edge technology for the next-generation of artificial muscles.** SmartSphincter studied smart muscles for incontinence treatment and involves hundreds of thousands of low-voltage, dielectric, electrically activated nanometer-thick polymer layers. The researchers have found two promising alternatives to conventional stiff metal electrodes for the polymer actuators and shown that they are able to power them for 10 days without recharge from available lithium ion cells. The team has also successfully applied to their local ethical committee for a full pilot study involving 10 male and 10 female participants. By summer 2015, several participants had signed up for the study from which seven male subjects have been assessed. The analysis of the data has proven the conclusion drawn based on the pre-pilot study.

## HEALTH MONITORING

Nano-Tera focuses on personalized health management through the use of implanted devices, smart textiles and intelligent drug monitoring systems. Application targets are in the fields of monitoring of obesity and neonatology, among others. Like in the initial phase of Nano-Tera, the area of health monitoring and personalized health management is well covered, with several projects addressing different research avenues, such as:

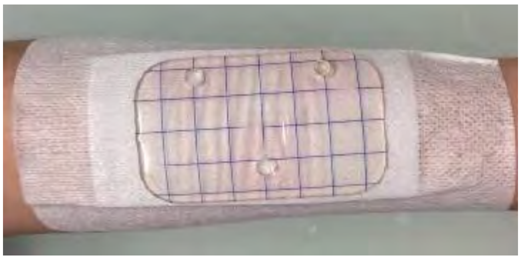
**Newborn monitoring based on multiple vision sensors.** The increasing number of parameters being monitored in preterm infants in neonatal intensive care units, and the sensitivity of these sensors to body movement (especially the limbs) are responsible for the inacceptable high rate of false alarms, which in turn generates discomfort, stress and cardiorespiratory instability. In NewbornCare, a real-time system using computer vision non-invasive techniques has been developed to estimate and monitor the heart and respiratory rates of neonates, with an accuracy and robustness that is on par with dedicated contact sensors. By tracking and monitoring the neonate constantly and remotely, the system does not suffer loss of signals due to motions and therefore limits the amount of false alarms. First prototypes of sensors that measure brain tissue oxygenation are being taken into operation at the University Hospital of Zurich. The sensor translates the intensity of travelled-through-tissue, near-infrared light to create and visualize information on the brain tissue oxygenation in real time. It is attached to the head of a newborn by a proprietary headband, which exists in different sizes. The results of preliminary measurements with the oxygen saturation on phantoms with optically well-defined properties are encouraging. Moreover a clinical trial "Exploratory study on ability of dedicated novel sensor technologies to reduce false alarms in vital sign monitoring of the neonates" has been approved by SwissMedic. Databases of signals have been collected on voluntary healthy patients for testing and calibration purposes. A full system has been developed to encapsulate the data acquisition and monitoring in order to facilitate clinical trials. The NewbornCare demonstrator consists of a system connecting the vision sensors and a dedicated head-band housing the oxygen saturation sensors into a real-time remote monitoring application, which can also communicate alarms if necessary. Signal readouts, baselines and alarms are displayed for inspection. The vision sensors are placed on the intensive care unit crib, operating contactless, while the headband housing the other sensors, and specifically designed for clinical usage, is fitted on the neonate.




**Monitoring the consequences of obesity.** Obesity is an increasing problem in high-income countries and emerging markets, because it leads to serious health issues. Obesity imposes a challenge on several modalities to assess physiology correctly, due to the thick superficial layer of fat. ObeSense provided an ideal collaboration platform to overcome limitations and develop novel algorithms and calibration methods to handle fat layers. Several demonstrators were built with some even being close to regulatory approval and being ready for translation to clinical practice. One of the most important scientific results obtained during ObeSense concerns the validation of cardiac output and pulmonary artery pressure estimates based on electrical impedance tomography principle. Moreover, a novel near-infrared spectrometry oximeter was developed, built, and validated. The oximeter showed superior precision and robustness in vitro compared to the common state-of-the-art commercial instruments. ObeSense partners have developed a touch-based ultra-low power device for real-time impedance cardiogram and ECG signal acquisition, and hemodynamic parameters estimates. A detection of obstructive sleep apnea by non-intrusive wearable system is also achieved. In many cardiovascular monitoring settings, the main physiological activities of interest are the heart rate variability, the respiration rate, and the influence of the latter on the former (respiration sinus arrhythmia). Wearable technologies present significant challenges in this context, as the electrocardiogram from which the heart rate variability is extracted is often of poor quality, and respiration may even be not recorded. In ObeSense, the team has developed real-time (which existing approaches are not) robust algorithms with a low computation cost to extract these parameters from the electrocardiogram only.

As a consequence of the development of many innovative demonstrators and their corresponding clinical validation, ObeSense partners have established serious discussion about possible technology transfers towards industrial partners, among them Edwards Lifesciences Corporation, Actelion, Iffremont, and Dräger Medical about EIT solutions and Vexatec, Bodyconnect, and Decathlon about the single-lead monitoring system. Moreover, the development of the single-lead monitoring system platform has led to a new Gateway project, the ObesenseGate project, in partnership with FieldWiz which consists in the technological transfer of the electrocardiogram front and embedded algorithms into FieldWiz actual product.

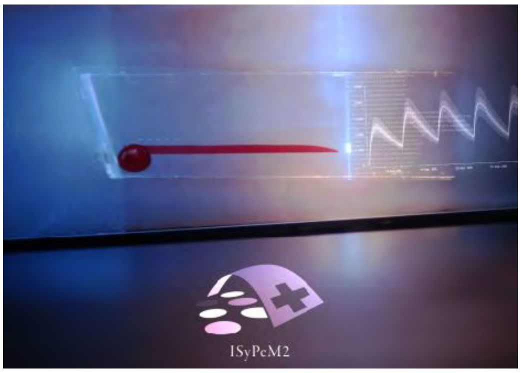
**Monitoring of the healing of chronic wounds.** The treatment of large and open wounds is a major challenge in medicine, especially after trauma or in immune-compromised patients. In particular, when wounds are associated with chronic infections, a significant threat is presented to the patient that can result in death. To date, the monitoring of the wound healing process is difficult, which is solely based on the qualitative judgment of the clinician. An accurate system that investigates the local environment at the wound site and detects the early changes before any clinical symptoms occur is highly desirable. FlusiTex has developed a textile-based sensing system to monitor the wound healing process. Within this Nano-Tera project, the team has combined fluorescence-based chemical and biochemical recognition methods with advanced optical readout methods. Sensing techniques are based on fluorescent dyes immobilized on hydrogels, and enzymatic methods.



In the associated Gateway project FlusiGate, the outcome is a functional prototype able to sense and indicate the pH of the wound via fluorescent measurements. Such a sensor is suited for a range of users/applications: at-home use for self-evaluation by the patient, or clinical use by a clinician for a precise measurement of pH evolution of chronic wounds. In particular, the team has developed a sensing patch consisting in a modified commercial wound-pad containing the fluorescent molecules: spots of either textile fibers or hydrogel containing the fluorescent molecules are incorporated into the commercial pad. The fluorescence intensity of the spots changes according to the pH of the underlying skin model. The genericity of the technologies developed in FlusiTex has been further demonstrated by another associated Gateway project, the FlusiSafe project, aiming at the exploitation of fluorescence lifetime imaging (FLIM) for anti-counterfeiting and brand protection, with lifetime-encoded security tags and associated 1D or 2D lifetime readers.

**A system on a chip to make medical devices wearable.** For both in- and outpatient applications, the electronic interface to typical sensors and electrodes still has a size and weight that prevents it from being used in the convenient and flexible way. Integration of the plethora of functionalities required in a wearable medical monitor, including the management of wireless connectivity, holds the key to the breakthrough required for clinical and user acceptance. This is why WearMeSoC has been developing a chip that will enable very small wearable medical monitors with wireless connectivity to small phones and tablets. A modular and multi-functional hardware prototype has been evaluated successfully and a miniaturization of the multi-functional device has been targeted. A first prototype of a medical monitoring SoC based on a parallel ultra-low power (PULP) multi-core processor has been developed. Finally, a first prototype of a battery-operated biomedical implant device including a wireless link with the dimensions below 1cm$^3$ has been realized.

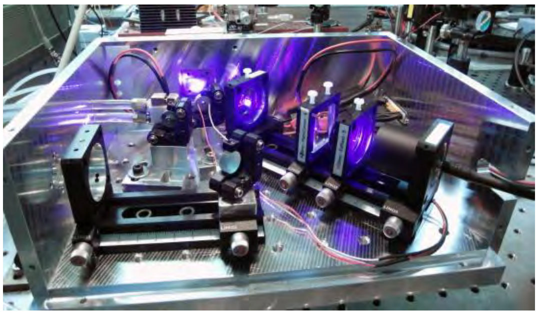
**Therapeutic drug monitoring for personalized medicine.** Modern therapeutics must benefit from the development and large-scale implementation of convenient, user-friendly, miniaturized, integrated instruments enabling drug concentration monitoring and seamless pharmacokinetically-guided dosage individualization. A portable system able to perform drug concentration measurement in patients receiving critical treatments should be offered at affordable costs to specialized clinics, and progressively to general practices or even to the patients themselves (as it is already the case, for instance, for blood glucose determination). ISyPeM II proposes a comprehensive integrated approach to Therapeutic Drug Monitoring that combines innovative point-of-care compatible assays, prescription decision support and interoperability in a complex data-sharing scenario. The consortium achieved important results in the field, all along the pipeline of this individualized therapy approach.




The design of their point-of-care system is addressed to respond to two main objectives. The first one is to perform the measurement of drug concentration in blood samples by an automated and compact analytical setup; the demonstrator performs fluorescence polarization immunoassay analytics in an ultra-compact format integrating sample preparation based on capillary separation from whole blood. The assay biochemistry is addressed to tobramycin and tacrolimus as case studies. The second main objective is to provide the medical doctor with information on the behavior of the patient within the population and accordingly suggest dosage adjustment and collect drug usage and measurement data into a remote database, enabling further refinements in dosage adjustment procedures. The consortium developed an intuitive and flexible software intended to assist clinicians in therapeutic drug monitoring interpretation that integrated innovative pharmacokinetic models. The software, which is currently in use at the CHUV Hospital in Lausanne and is connected with the internal database, is undergoing the validation process as a Class 1 medical device.

## MEDICAL PLATFORMS

In this new phase, Nano-Tera.ch is developing several medical platforms, notably a next-generation, high-quality, mobile ultrasound imaging device and elastic, lightweight MRI detectors that patients can wear like a piece of clothing. The research covers several fields of medicine, such as oncology.

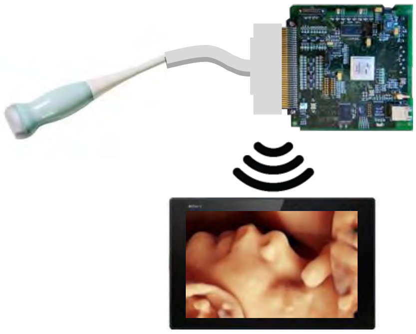


**Novel semiconductor disk lasers for biomedical and metrology applications.** In a follow-up to the original MIXSEL project, MIXSEL II is consolidating its high-power ultrafast semiconductor laser technology. Lasers generating short pulses – referred to as ultrafast lasers – enable many applications in science and technology. Numerous laboratory experiments have confirmed that ultrafast lasers can significantly increase telecommunication data rates, improve computer interconnects, and optically clock microprocessors. Some applications are better enabled with shorter femtosecond pulses, while they so far had to rely on bulky and complex ultrafast solid-state lasers. In comparison optically pumped semiconductor disk lasers such as the modelocked integrated external cavity surface emitting lasers (MIXSEL) are ideally suited for mass production and widespread applications, because they are based on a wafer-scale technology with reduced packaging requirements and a high level of integration.
The MIXSEL II project enabled world-record achievements in the development of femtosecond semiconductor disk lasers and their applications in frequency metrology and biomedical microscopy. Four laser prototypes were built for application demonstrations in different labs. A new unplanned invention and discovery was the dual-comb modelocked MIXSEL with which dual-comb spectroscopy on water vapor was demonstrated for the first time. The fast sampling rate and the single laser cavity approach supported such measurements even for a free-running laser without any additional stabilization – a paradigm shift in frequency metrology. The team has successfully demonstrated in-vivo imaging in drosophila larvae and in mouse brains using these prototype lasers in multiphoton microscopy. Compared to conventional bulky lasers, the same image quality was obtained, but suffered from less bleaching because of the higher gigahertz pulse repetition rate. Patents have been filed, efforts started for a new spin-off company with some of the graduate students.

**Wearable ICT for zero power medical applications**. Keep your friends close, but keep your medical sensors closer: such could be the motto of the BodyPoweredSenSE project, which aims to demonstrate that smart medical diagnostics can be performed using ergonomic, efficient, energy harvesting based sensors. The project has significantly contributed to the medical community understanding of the human brain and how brain rhythms and other biomarkers change as a function of ageing. Also, the ability to record or process multi-parametric medical data simultaneously from any organ (foot, heart, brain) over long periods in a comfortable manner, without power interruption or recharge, opens a new era of medical diagnostic and recovery monitoring research and application. The demonstrators of this project are extremely low-cost devices that can be manufactured as mass consumer products, thus accessible to the elderly and young for medical monitoring. These devices will offer early warning of diseases thereby improving the immediacy and efficacy of treatment, and assessment of recovery, while all focusing in the pharmacological intervention; these outcomes are important contributions to wearable medical informatics and advanced ICT in health. One spin off company has emerged and a NextStep project aims towards a second spin off. Further opportunities exist for commercial exploitation backed by strong support from the clinical partners. The interaction of so many multidisciplinary PhD students as key research personnel in this project has underpinned both the strong collaboration between the involved institutions, as well as a deepening and broadening of the knowledge base of all involved across the multiple levels of technology and medical science. Overall, this project has demonstrated, using electroencephalogram-based functional connectivity and alpha rhythm in healthy adults and mild cognitive impairment that Alzheimer's disease patients show interhemispheric functional connectivity declines with age-related diseases, and alpha rhythm loses its polyrhythmic structure forming biomarkers for monitoring age-related neurodegenerative processes in the brain.

**Rapid sensing of cancer.** Cancer is among the most frequently-occurring diseases and causes huge treatment costs. Our easy-to-use and automated quantitative diagnostic tool will lead to improved therapies to the benefit of the whole society. Swiss industry has a longstanding tradition in high precision mechanics. The techniques developed in PATLiSci II introduces nanotechnology to medical diagnostics. In particular, PATLiSci II targets fast detection of cancer in human patient's biopsy samples suffering from breast or skin cancer. A measurement module has been developed based on a commercial scanning force microscope FlexAFM head from the Swiss company NanoSurf AG, allowing rapid integration of our technology into a future commercial product. The measurement principle is based on force spectroscopy, extended here from a single cantilever to a custom-developed array of cantilevers, reducing diagnosis times drastically.

Using force spectroscopy technique, cancer cells are identified by their elastic properties that differ significantly from those of healthy cells. To complement and validate the analysis, the cantilever array is also operated in nanomechanical sensing mode, which allows chemical recognition of related biomarkers. A comprehensive study at the University hospital in Basel on discrimination of breast cancer cells from unaffected cells in tissue has been performed yielding conclusive results. For melanoma patient samples, RNA is extracted and investigated using nanomechanocal sensing with an array of cantilevers. Results allow to distinguish mutated melanoma cells from wild type tumor cells by detection of the BRAF mutations V600E and V600K, being essential to choose the appropriate treatment. Furthermore, nanomechanical cantilever sensing demonstrated reliably detection of HER2 overexpression relevant in breast cancer diagnosis.

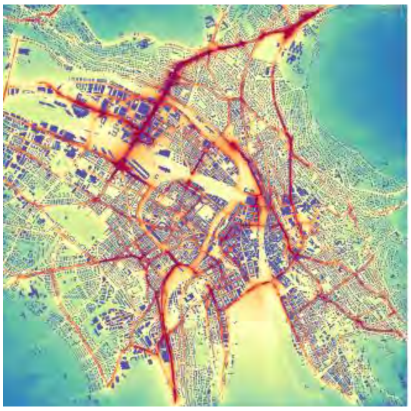


**High performance portable 3D ultrasound platform.** While ultrasound imaging is ubiquitous in medicine due to its low cost compared to other imaging techniques such as MRI – whose own challenges are addressed below – its image quality is usually poorer, and the high-quality devices that exist are expensive and aimed at hospital operation only. This is the reason why UltraSoundToGo devised hardware and software techniques to make 3D ultrasound imaging possible with off-the-shelf components in a package that can be portable and battery-operated. The objective is to decouple the acquisition of ultrasound scans and their diagnosis, both of which currently must be performed in hospitals by specialists. The team envisions that the acquisition could instead be performed locally by minimally-trained operators, like nurses or family doctors, and the scans uploaded wirelessly (telesonography) to the remote hospital. The platform to do so could be deployed in medical cabinets, in rural and developing areas, in ships, ambulances, and helicopters. The result would be drastically more ubiquitous access to diagnostic services, reduced delays, and improved healthcare costs and efficiency. Nearing its completion, UltrasoundToGo has delivered a comprehensive set of developments to unlock this vision. At one end, research on the ultrasound matrix probe itself resulted in a novel device that provides its outputs directly in digital form, enabling more compact and more robust systems. This probe can be connected to an imaging unit fully designed within the project consortium, which adopts various processing optimizations to reconstruct high-quality volumetric scans in 5W of power budget, enabling battery-powered operation. To minimize the bandwidth (and therefore cabling) in between the two, novel compressed sensing algorithms have been developed, and demonstrated to reduce the signal bandwidth. Finally, advanced software mapping toolchains have been created to efficiently deploy image processing software on the latest multi-core chips, while guaranteeing safety of operation as required by medical standards.

**Wearable MRI detector and sensor arrays.** Magnetic resonance imaging (MRI) is another widely used imaging technique in medical diagnostics and basic research. The final outcome of the WearableMRI project is the introduction of wearable detection to MRI and thus to one of the most widely used medical imaging modalities. For MRI, the advent of wearable detection marks a pivotal transition away from its current paradigm of rigid, bulky detector arrays, which limit the technology in several ways. Large numbers of RF cables next to the patient are a safety issue in MR systems, which expose the body to high-power RF transmission. One-fits-all rigid detector cages lose intrinsic sensitivity by conforming badly to individual anatomies. Moreover, they are intimidating, contribute to claustrophobia, and preclude imaging in varying states of motion or flection. The wearable paradigm alters this situation fundamentally by the transition to flexible, lightweight detectors that patients wear like pieces of clothing, improving both intrinsic sensitivity and ergonomics. On-body digitization and optical conversion remove safety and handling limits on the channel count. The advent and demonstration of this concept challenge the MRI industry and hold potential for product implementations at the systems and accessories levels. The successful introduction of integrated RF reception to the harsh electromagnetic environment inside MR systems also paves the way for expansion into a full-blown system-on-a-chip, including a local controller, optical conversion, and power management circuits. One core component of the new system is the world's very first fully integrated RF CMOS receiver for MRI. An excellent noise figure below 1dB for the entire receive chain is achieved by adaptable input noise match and noise cancellation circuitry. The receiver also features a transmit mode to track the tuning and matching of wearable MR detector coils. Integrated with optical conversion and mounted directly on a pair of receiver coils each, the receiver chip forms a first-of-its-kind wearable MRI detector module. The new system has been successfully used for actual MR imaging of test objects and humans. The demonstrator is a wearable four-channel detector array for MRI of the human knee at 3 Tesla, consisting of four flexible detector coil front-ends connected to two receiver units each comprising an integrated two-channel receiver and optical conversion for signal transmission out of the MR system. The wearable assembly will be of size suitable to be worn around a human knee for imaging, with each of the electronics units being 2 cm x 3 cm in size. The demonstrator system also includes a specifically developed out-of-field FPGA receiver that takes in and pre-processes the optical data streams before routing them to higher-level processing or storage. Demonstration amounts to actual imaging of a human knee, using regular clinical scanning procedures.

## A NEW LOOK AT ENVIRONMENTAL MONITORING WITH FURTHER CHALLENGES

Given the importance of environmental monitoring, several projects from Nano-Tera's initial phase are extended into the second phase with new directions. Projects address both air and water pollution monitoring, as well as environmental sensing in mountainous areas, as detailed below:



**Crowdsourcing high-resolution air quality sensing.** Air pollution represents the number one environmental health risk, with millions of people dying every year because of poor air quality. The urban landscape leads to highly heterogeneous pollutant concentrations, which cannot be directly captured by traditional sparse static monitoring stations. The solution proposed by OpenSense II is innovative not only because of its extended sensing coverage but also because the measurements happen in situ, essentially sampling the very same air volume citizens breathe. In OpenSense II, the researchers took a holistic approach in demonstrating the viability of mobile sensor networks to enable the high-resolution air quality monitoring needed for studying the effect of exposure to air pollution.

Leveraging mobile networks anchored to public transportation vehicles and deployed in the cities of Zurich and Lausanne, the project has produced highly original research on high-resolution urban air quality mapping. The two deployments were continuously improved over the project duration and they currently represent the longest-running testbeds of their type with the probably largest accumulated urban air quality dataset in the world. These are the first results on a number of essential topics for ensuring the data quality of this novel type of mobile monitoring systems including mitigation of mobility-induced measurement distortion, automatic sensor calibration, and measurement-driven air quality modeling, producing the first high-resolution maps (for both Zurich and Lausanne). Furthermore, in the sustained effort to ensure data quality through cross-validation, the team implemented a highly innovative dispersion multi-level modeling framework which was applied to both cities, producing a collection of modeled air quality maps over a large temporal span. Subsequently, such highly resolved air quality maps were for the first time used in a study concerned with the inflammatory effect of prolonged human exposure to PM10. Finally, to enable the inclusion of crowd-sourced measurements, OpenSense II developed two novel algorithms: a rewarding mechanism for incentivizing good-quality measurements and an algorithm for characterizing sensor accuracies, while minimizing sampling cost and maximizing data utility. The list of potential stakeholders goes beyond research institutions targeting human exposure and our work has opened the door to a wide array of novel applications for urban planning and eHealth. For instance, some of the project outputs have already been recommended or adopted by authorities in the city of Zurich, and several of the technologies developed in Opensense II have been further exploited in the associated CarboSense Gateway project aiming at the deployment of a unprecedented, dense, low power sensor network providing near-real time information based on 300 nodes equipped with battery-powered $CO_2$ sensors distributed over all of Switzerland at Swisscom radio transmitter locations.

**An aquatic robot which can "smell" polluting substances in water.** The global outcome of the Envirobot project is an integrated system that combines novel sensors to an autonomous robot in an aquatic setting, and that allows both sensor data recording/transmission to a remote observer during predefined missions, as well as a form of self-guidance based on real-time sensory input. The self-guiding aquatic robot can integrate physical, chemical and biological measurements of water quality parameters. The robot consists of a 1.0-m segmented snake/eel with anguilliform movement, which causes less turbulence to the sample measurement. The latest self-localization systems permitted the Envirobot to follow a 1 km remote-programmed track to within 2 m accuracy at cruise speed of 0.42 m/s in the lake. Adapted temperature and conductivity sensors were produced and installed in the robot segments, which can record data and transmit them remotely. These two sensors will be used to demonstrate robot self-guidance and continuous measurements in a river mouth. Prototypes of other sensor systems were fabricated (e.g., miniaturized pH and oxygen measurement), ready to be connected to the robot. Developed biological sensor modules for the robot include general toxicity measurements by Daphnia and fish cell lines, as well as light-emitting bacteria reactive to specific toxicants (e.g., mercury). Further for the biological sensors specific robot sampling segments were fabricated that include passive water samplers. The Envirobot system is the first self-guiding aquatic robot capable of performing water quality measurements during short sampling missions. The individual particular robot that was constructed is certainly impressive and will have impact by itself. However, the knowledge and experience gained from the combined engineering/robotic efforts is even more important. The combined efforts for this project have led to many novel spin-off ideas in sensor and tool development. This includes in software development, tracking algorithms, sensor miniaturizations, new sensor concepts and proof-of -principles. Many of those will continue to live on and become improved after the project's life-time, or will be starting points for spin-off activities. This includes, for example, the novel carbon nanotube printed sensors and the fish-cell line toxicity sensors.

**MEMS acoustic detectors for natural hazard warning systems.** Understanding, controlling and minimizing the risk associated with changes in our natural environment is of major societal interest, and there is an increasing need for risk-reduction methods and technology. Based on the predecessor project, X-Sense II contributes to close the growing gap by technological development and scientific advance. It investigates a complete data chain from custom designed sensor technology over networking, data storage and processing towards new discoveries in environmental sciences and new, more effective technologies for early warning from natural hazards.

The interdisciplinary team of X-Sense achieved major breakthroughs on several axes. The team investigated MEMS technology allowing for the partial relocation of signal processing and decision-making from the computing domain to the sensor itself. With this approach, for the first time, close to zero standby-power is possible, which is a prerequisite for long-term, unattended monitoring of spurious events. Integrated in a new class of even-driven wireless sensing systems and in combination with other sensing modalities unprecedented level of detail about the underlying processes leading to natural hazards is revealed.

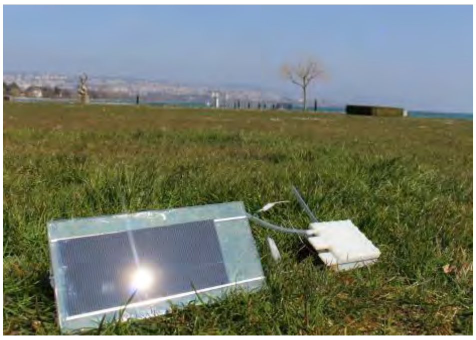
The monitoring-system produced by the project provides data on slope movements and environmental conditions in mountain permafrost that is worldwide unique with respect to temporal resolution, coverage and observation duration. The recent addition of continuous micro-seismic/acoustic emissions allows the investigation of precursor signals of failure events in (frozen) bedrock and thereby contributes towards the further development of early warning systems. X-Sense developed, operates and maintains several field-sites in the Alps, i.e., at Matterhorn, Dirruhorn/Grabengufer, Saastal and Randa. In addition, 10 long-term monitoring sites are operated in collaboration with Permafrost Monitoring Switzerland. Sensor data are locally collected and transferred to datacenter in Zurich where processing and interpretation takes place. The long-term, autonomous and dependable operation of sensor networks in harsh environment mountain areas is unparalleled in the scientific community. The numbers are impressive: 8 years operation with multi-modal monitoring (thermal sensors, crackmeters, GPS, Meteo-stations, high resolution cameras, seismic sensors and radar) and last but not least really big amounts of data that are under constant investigation, showing the applicability of the scientific results obtained, providing us with new scientific challenges, used to gather important input for novel geophysical discoveries and providing a showcase for early warning


**An all-in-one detection platform for air pollutants and greenhouse gases.** The environmental dimension can also be a new direction added to a past project. While IrSens developed a sensing platform for liquid and gases using near and mid-infrared spectroscopy to measure cocaine concentration in saliva and $CO_2$ isotope ratios in air, IrSens II is going several steps further by realizing new tools for gas monitoring, specifically analyzing nitrogen dioxide as well as major air pollutants and greenhouse gases. The final gas spectroscopy setup allows us to simultaneously measure the concentration of ten highly relevant greenhouse gases ($CO_2$, $H_2O$, $CH_4$, $N_2O$) and pollutants (NO, $NO_2$, $NH_3$, $SO_2$, $O_3$, CO) with ultrafast data acquisition. The setup reaches a precision comparable to state-of-the-art instrumentation, while reducing the footprint thanks to the use of dual-wavelength laser sources. The spectrometer produced can replace many power consuming and expensive conventional environmental gas sensors in air pollution monitoring and research stations. Moreover, the compact and portable gas detection is selective, fast, autonomous, and can be maintained via remote access. This is particularly valuable for obtaining temporally and spatially resolved data needed for future (urban) climate modelling and health studies. In general, the project has made significant contributions towards establishing laser spectroscopy as a method of choice for mid-infrared gas sensing: multi-wavelength quantum cascade lasers were developed allowing for compact and versatile instruments detecting several gases. Additionally, the researchers have developed new driving schemes and electronics for quantum cascade lasers, which allow for continuous data streaming and therefore better signal to noise ratio. Furthermore, the cylindrical multi-pass cell with the patented absorption mask is by now commercially available and will be used in many gas-sensing applications. Finally, IrSens has led to the foundation of the highly successful spin-off IRSweep AG.

A first demonstrator for nitrogen dioxide detection was installed and operated on top of a tramway in Zurich, yielding hitherto unreached precision, selectivity and time resolution. City-wide air pollution maps were simulated using 1000 hours of unique spatially and temporally resolved data.

## A CRUCIAL MATTER: THE MANAGEMENT OF ENERGY

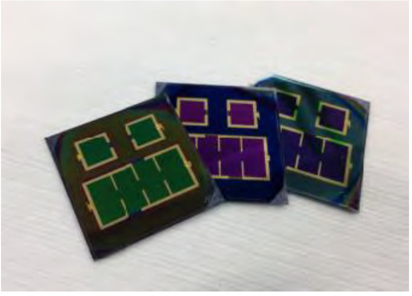
The theme of energy has taken on a whole new dimension in this phase of Nano-Tera.ch. In the past, the research being funded related mostly to ultra-low power microchip or systems. Energy is a central theme that affects system design, society and the economy, and now takes center stage: Nano-Tera.ch addresses various high relevance application areas such as low-power trustable electronics, smart grids, green data centers and environmentally friendly energy harvesting systems:



**Cost-effective and integrated solar-hydrogen generator.** The development of economically viable technologies to produce fuels such as hydrogen, solely based on sunlight and water is one of many potential solutions, on a global scale, to transition from a fossil fuel economy to a renewable energy economy. SHINE's goal is to develop the design principles and experimentally demonstrate a continuously-operating solar-hydrogen generation system with an optimal working point in terms of fuel production cost. The most important short-term outcome of the project is the demonstrated 14.2% solar to hydrogen conversion efficiency based on commercially available, abundant and affordable components. The 40% increase of hydrogen production over previous results not only decreases the cost per kg but also decreases the area necessary to collect light. Such efficient systems can be scaled with available materials by following careful system design rules. In the long term, the innovative designs for the electrolyzer, fuel cell, and self-tracking concentrators reported in this project can potentially lead a new class of electrochemical reactors and solar concentrators which are less expensive, long lasting, and more efficient. These devices have also triggered a new research line in the relevant communities as can be inferred from several recent papers reporting on similar concepts. Detailed life cycle and techno-economic analysis together with multiphysics simulations of solar water splitting with concentrated photovoltaics have also provided design guidelines for development of reactors based on efficient GaAs panels under large concentration factors.


**Green servers and datacenters.** Energy-efficient datacenters are strategic for Switzerland, as 75% of the Swiss economy is service-based and depends on the datacenter infrastructure cost. Moreover, 3-4% of the Swiss energy is devoted to datacenters, and grows by 20% annually. In YINS, energy consumption was reduced by introducing specific server nodes and new cooling technologies, as well as improving system performance by accelerating inter-server communication. Overall, YINS enabled datacenter providers, like BrainServe, to improve their energy efficiency by 30% on average, while guaranteeing reliable operation. In addition, Eaton benefitted from our virtual machines thermal-aware allocation and server power management approaches to develop intelligent power distribution units that reduce total energy consumption and carbon footprint. Finally, 29 GWh were consumed by Credit Suisse's datacenters when YINS started. Today, the newly developed energy-aware virtual machines consolidation technique in active racks enables 11 GWh of energy savings (35% on average) in daily operation. Moreover, the new thermosyphon cooling technology enables an additional 40% energy reduction. Overall, YINS enabled a total energy reduction of 75% on average in Credit Suisse data centers. Furthermore, larger energy reduction figures are expected in other businesses in Switzerland, where datacenter operations are less constrained than in the banking industry.

**Thermal storage control.** The project HeatReserves deals with the use of thermal loads as additional means for electricity grid ancillary services to account for the expected increase in renewable energy sources. The team has developed an integrated framework to enable the introduction of reserves from two types of thermal loads: Heating, Ventilation, and Air Conditioning (HVAC) systems of an aggregation of several office buildings, and a very large number of small household appliances. For the first category, a novel methodological framework was developed for estimating the amount of building reserves that can be robustly extracted; this required the development of a completely novel control algorithm involving the optimization of uncertain sets. During the last year of the project, the team plans to experimentally test this method on the NEST building on the Empa campus. For the second category, estimation and control methods were developed to allow the coordination of the energy consumption of large collections of small devices (in particular, air conditioning units, refrigerators, and water heaters) by macroscopic signals. The economic and marketing case for both types of thermal loads was also investigated; in particular, thermal deviations acceptable by users and incentive schemes for enticing users to participate in demand response schemes were determined.



**Systems for ultra-high performance photovoltaic energy harvesting.** The cost of photovoltaic (PV) modules recently dropped drastically, such that the overall PV system costs are dominated by non-module costs. Improving the efficiency of the modules at only moderate additional costs therefore is the most straightforward pathway towards lower PV electricity prices. However, many established PV technologies reached efficiencies close to their practical limits. A promising, disruptive approach is to combine an established PV technology, such as a crystalline silicon or CIGS cell, with emerging technologies, including III-V nanowire and perovskite cells, to form a tandem device with the potential for ultra-high performance. The project Synergy led to the demonstration of infrared-transparent perovskite cells with high efficiency, to the realization of mechanically-stacked and monolithically-integrated tandem cells and to several efficiency world records in that research domain. These results show that even state-of-the-art high performance single-junction solar cells can further be improved by this tandem approach. In addition, with the realization of a 5x5 $cm^2$ perovskite mini-module, it was demonstrated that the emerging perovskite PV technology can be up-scaled. Finally, together with the industrial partners, an assessment of the potential applications and markets for each of the developed tandem configurations was made.
The companion Gateway SynergyGate project has focused on bringing perovskite/silicon and perovskite/CIGS tandems closer towards commercialization by up-scaling from the typical laboratory size of <1 cm2 to 5 x 5 cm2 substrates, by using lightweight, flexible substrates, as well as by developing metallization, interconnection and encapsulation schemes that are compatible with industrial processes.

**Real time monitoring and management of smart grids.** The project SmartGrid seeks to optimize the power grid through a hierarchical vision, from the individually monitored power consumption of electrical appliances, across the mid-scale "Microgrid" that optimizes small pools of consumers and at high level with high speed electronics for power system dynamic emulation. The team has developed and validated thanks to the electrical grids of EPFL an online monitoring infrastructure for distribution systems. This infrastructure is the foundation of the modern Distribution Management Systems with reference to the smart-grid concept. The consortium demonstrated the feasibility of supporting phasor measurement unit deployments with standard TCP/IP technology while being secure and real-time. This paves the way to an online control and monitoring for intelligent and renewable energy systems. The Nano-Tera.ch infrastructures have been used for the monitoring, control and protection of new smart-grids funding from the CTI and the Canton de Vaud. In addition, the capabilities and features of the intelligent building as a service provider for the smart-grid was demonstrated. The socio-economic and technical barriers to this technology introduction were identified and solutions for several of those were provided. The study of the smart-building as a system beyond domotics and Internet of Things technologies (IoT) paves the path for sustainable smart cities and smart grid. Based on the outcome of the smart-building research, a new startup company is created and awarded by the EPFL innogrants.
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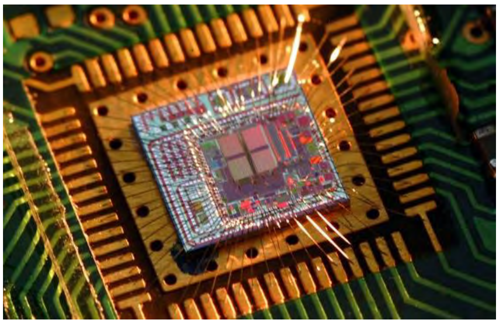


**Inexact sub-near-threshold systems for ultra-low power devices.** Ultra-low power near-sensor processing is a key requirement for many applications such as watch ICs, radio frequency identification tags, sensor interfaces and near-sensor processing in devices targeting emerging IoT applications. Unfortunately, the design of corresponding hardware becomes increasingly difficult, since low power consumption is often achieved by operating at low voltages, which leads to a loss in performance and to reliability issues, especially in modern process technologies. The main outcome of the IcySoC project is a toolset with a wide range of techniques and a platform that facilitate the design of such systems and alleviate the issue associated with low-voltage operation. As such, the technologies and building blocks developed in the project solve key problems in the design of a variety of different devices for different process nodes ranging from 180 nm down to 28 nm. It is therefore expected that many applications can benefit from the know-how and the IP generated by the project. Some of this IP (namely the PULP platform that underlies the project) is also available as Opensource hardware and therefore provides immediate benefit to industry and other research organizations that wish to develop custom circuits for their specific applications.

# PART IV

# IMPACT ANALYSIS

# IV.1 SYNTHESIS

This section provides an overall synthesis of the **impact** of the Nano-Tera.ch program, which has been assessed for several key topics, based on various **objective metrics**.

The various topics that have been considered have been categorized into the five following impact dimensions:

- The scientific impact
- The educational impact
- The economic impact
- The societal impact
- The institutional impact

The synthesis presented below covers each of the considered five dimensions, and is substantiated in the next sections by a set of **key statements**, along with associated factual data and metrics used. For each of the key statements, the goal is to evaluate to what extent and how efficiently Nano-Tera.ch has fulfilled its objectives.

Throughout the synthesis, details about the cited impacts can be found in the associated Key Statements that are indicated in brackets for reference (with the following format: [KS1], [KS2], etc.).

## SCIENTIFIC IMPACT

The nearly 1,600 publications generated with Nano-Tera.ch indicate that the research carried out in Nano-Tera.ch projects has been widely recognized by the relevant scientific communities. Moreover, 44% of the publications have been published in journals with an average Impact Factor (resp. CiteScore) of 5.3 (resp. 4.9), indicating the high scientific impact of the research carried out in the Nano-Tera.ch program. [KS1]

The attractiveness of Nano-Tera.ch has also been illustrated by the program's almost exhaustive coverage of the scientific communities related to its topical domains, as well as by the visit of several world-leading scientists who came to interact with various Nano-Tera teams as part of Nano-Tera's International Exchange Program. [KS1,7]

The broad objective of the Nano-Tera.ch program was to improve the quality of life and safety of people in three application areas: Health, Energy and Environment. Such societal issues are inherently complex. To produce significant advances, it is essential to mobilize diverse high level scientific knowledge, to leverage a broad basket of technologies that are often interrelated, and to involve industrial partners and end-users in large projects over several years, with a shared objective. The fact that the Nano-Tera.ch program funded research projects with specific characteristics was a key component, which strongly contributed to the scientific impact achieved by the program. In this respect, the crucial characteristics of the funded projects have been the following:

- **Ambitious** – The funded projects were carried out by large consortia and benefited from substantial funding (about CHF 2 million per project) over a long period of time (4 years on average). [KS6]
- **Strongly collaborative** – On average over 6 partners from 4 different institutions were involved in the RTD projects, with about 2.4 partners collaborating on any given project task during Phase 1. The strong collaboration between project partners also resulted in multiple joint publications with several Nano-Tera.ch partners as co-authors. [KS2]
- **Strongly interdisciplinary and inter-institutional** – On average, the researchers involved in RTD projects originated from about 2.7 different types of institution (ETH, universities, applied universities, hospitals, industry…) and brought expertise from about 2.7 different disciplines. [KS3,4]
- **Applications-oriented** – The RTD projects consortia involved complementary types of participants, with slightly over half (57%) being researchers as expected, but also translational partners (Empa, CSEM; 12%), end-users (typically hospitals; 12%), as well as industrial partners (19%). This type of mixed consortia represented a very favorable setup for application-oriented research, as non-academic partners tend to drive the research results towards their applicative needs. [KS5]

These projects have led to a number of breakthroughs. Examples include, but are not limited to:

- The HearRestore project resulted in the successful translation of the robotic microsurgical technology into a clinical application. The project has reported the first successful stereo-tactilely guided robotic cochlear implantation in man worldwide. To the project team's knowledge, no other group in the world has produced sufficiently safe and accurate robotic microsurgery technology to enable microsurgical interventions at this scale and on a patient in a true clinical set-up. This breakthrough would not have been possible without the collaboration in a single project of multiple partners with competencies in several disciplines (robotics, surgery, etc.) and a substantial level of funding.
- The SHINE project resulted in a proven 14.2% solar to hydrogen conversion efficiency, based on commercially available, abundant and affordable components. The 40% increase in hydrogen production over previous results not only decreased the cost per kg, but also decreased the area necessary to collect light. In the long term, the achieved innovative design for the electrolyzer fuel cell and self-tracking concentrators can potentially lead to a new class of electrochemical reactors and solar concentrators, which will be less expensive, long lasting, and more efficient.

- The IrSens II project has used near and mid-infrared spectroscopy to realize new tools for gas monitoring, specifically analyzing nitrogen dioxide as well as major air pollutants and greenhouse gases. The cylindrical multi-pass cell is now commercially available and will be used in many gas-sensing applications. IrSens has led to the foundation of the highly successful spin-off IRSweep AG. A first demonstrator for nitrogen dioxide detection was installed and operated on top of a tramway in Zurich, yielding hitherto unreached precision, selectivity and time resolution. City-wide air pollution maps were simulated using 1000 hours of unique spatially and temporally resolved data.

## EDUCATIONAL IMPACT

Nano-Tera.ch has contributed to the training of the next generation of researchers, with a total of 366 PhD students involved in the program's projects (192 in Phase 1 projects and 202 in Phase 2 projects, some of which took part to both phases of the program). These students have been about equally distributed among the thematic clusters of Nano-Tera. [KS8]

| | Phase 1 | Phase 2 | Overall |
|---|---|---|---|
| Number of PhD students | 192 | 202 | **366** |

To further strengthen the importance of the PhD students within the program, Nano-Tera set up a specific program, the **NextStep program**. This program, decomposed in three distinct tracks, was specifically designed to help PhD students explore possible ways to exploit the scientific skills that they were gaining during their PhD.

More precisely:

The Track 1 of the NextStep program has encouraged stronger collaborative spirit in the community of the PhD students involved in Nano-Tera.ch, and increased their autonomy by giving them the opportunity to submit their own collaborative research proposals. The goal was to give the PhD student the opportunity to learn the full procedure of submitting proposals to get funding: building a consortium, identifying research challenges, writing a scientific proposal, and putting together a reasonable budget. Several students expressed interest in this opportunity, and 7 projects were submitted and accepted for funding. [KS9]

Through Track 2 of the NextStep program, Nano-Tera.ch has encouraged stronger entrepreneurial spirit in the community of PhD students. To this end, it has allowed them to interact with experts and coaches in entrepreneurship and helped them learn how to describe the skills they have acquired in an effective way for potential future industrial contacts. It has also helped them develop ideas on how to economically exploit their thesis results and skills for the purposes of licensing or startup creation. For example, they were given the opportunity to do a dry run for a pitch, and to win a trip to a high impact event such as CeBit or CES. [KS10]

In the Track 3 of the NextStep program, Nano-Tera organized MT180 ("My Thesis in 180 Seconds") contests to encourage PhD students to learn how to communicate their work and results in a clear and appealing way, easily understandable outside their field of specialization. In such contests, the PhD students had 3 minutes to present the content of their research to a wide audience, with the support of only one static slide. [KS8]

Finally, the 61 Education and Dissemination activities (ED activities) funded by Nano-Tera.ch for a total budget of more than CHF 1.4 million have also strongly contributed to the educational impact of the program. More than half of the activities consisted of conferences, symposia and workshops. About a quarter have been courses and winter or summer schools. [KS8]

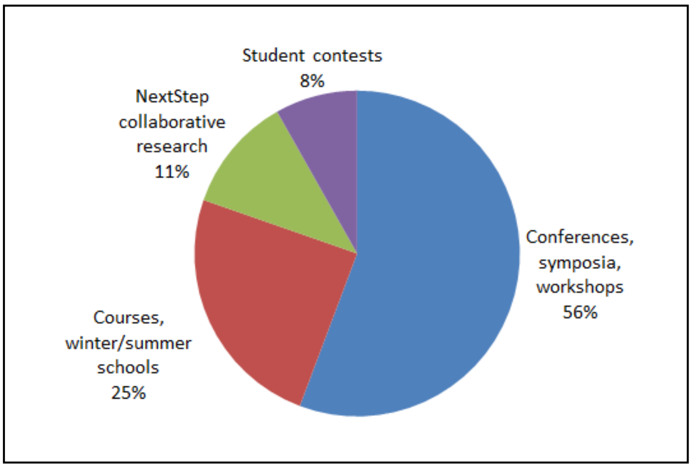



*Figure 9. ED activities by type.*

## ECONOMIC IMPACT

Within Nano-Tera.ch, by the end of 2016, 67 patents had been filed based on results stemming from Nano-Tera.ch projects, 10 start-ups had been created or were in the process of being created, and 9 CTI follow-up projects had been approved. [KS11]

However, in the specific case of a research program such as Nano-Tera.ch, such standard indicators provide a very incomplete view due to the inherent delay between the time a scientific result is produced, and the time it potentially produces economic value (e.g. a product or a service). Indeed, as there is no follow-up reporting obligation after the end of a project, the program structurally lacks effective ways to provide reliable values for many of the standard indicators. As a result, most of this sub-section focuses on the evaluation of the "Economic potential" of the program, i.e. its ability to set-up the right conditions for economic value to be created.

### INVOLVEMENT OF INDUSTRIAL PARTNERS AND END-USERS

Nano-Tera.ch exploited its pro-active role in the definition of the eligibility conditions associated with the calls for proposals launched by the program to substantially strengthen the economic potential of the funded research projects.

In particular the presence of industrial partners and end-users (e.g. hospitals) was strongly recommended in all Nano-Tera.ch RTD calls and made mandatory ("must meet" criterion) for all Nano-Tera.ch Phase 2 RTD projects. This led to the set-up of RTD project consortia consisting of an average of 57% of research partners, 31% of industrial and translational partners, and 12% end-users. Such a proportion of non-research partners in Nano-Tera.ch RTD projects, combined with their long duration, created an important economic potential for the program, as the RTD projects strongly contributed to Knowledge Transfer by playing the role of information exchange platforms, with various project consortium level meetings and events leading to numerous formal and informal contacts between partners. It is worth noting that this type of Knowledge Transfer (formal and informal information exchange) has been identified as the preferred transfer channel by more than 60% of Swiss Industry active in KTT (as shown in the KOF Knowledge and Technology Transfer Survey[1] ). [KS11]

### EDUCATION OF PHD GRADUATES FOR THE INDUSTRY

An important economic impact of the Nano-Tera.ch program resulted from the training of a substantial number of PhD students who chose to pursue their activity in industry (about 60% of the more than 360 PhD students trained in the program). This caters to strong demand from Swiss companies, who consider the lack of qualified staff as a deficiency (see KOF Knowledge and Technology Transfer Survey 2011 mentioned above). The recruitment of Nano-Tera.ch PhD graduate by Swiss companies (75% of the ones who transferred to industry) also has the advantage of increasing the ability of companies to interact with researchers and thus to utilize research results. [KS11]

Furthermore, the coaching provided in the Entrepreneurship Track of the NextStep program helped several Nano-Tera.ch PhD students develop an early-stage entrepreneurial mindset by making them explore how to generate economic value from research results, how to identify market opportunities, and how transform ideas into business propositions. As a result, four business ideas have been presented at an Impact Event and three startups were created (end of 2016). [KS10]

### THE NANO-TERA.CH INDUSTRIAL VALORIZATION FUND

In 2014, Nano-Tera.ch decided to set up a funding framework, the Nano-tera.ch Industrial Valorization Fund (IVF), specifically dedicated to technology transfer with the objectives to strengthen industrial valorization. With this fund, first jointly managed by Nano-Tera.ch and the EPFL Technology Transfer Office, and later extended to all the institutions involved in Nano-Tera.ch of EPFL, Nano-Tera.ch has supported several industrial valorization actions with promising Knowledge and Technology Transfer aspects. [KS11]

### THE NANO-TERA.CH GATEWAY PROGRAM

While all the 25 Phase 2 RTD project produced research prototypes, 56% of these projects led to demonstrators and platforms with a high potential to rapidly result in products (estimated time to market in 2017-2023).

To further strengthen the impact of these results on Swiss industry, Nano-Tera.ch used about CHF 1.66 million of its strategic funds to launch the Gateway pilot program. Within this program, Nano-Tera.ch launched eight Gateway projects specifically targeting the conversion of research prototypes with high economic potential into industrial demonstrators directly exploitable by the industrial partners involved in the projects (see also "Institutional impact" below). [KS12, 18]

[1] Knowledge and Technology Transfer between Universities and Private Enterprises in Switzerland 2011, S. Arvanitis, M. C. Ley, M. Wörter, KOF Studies, Vol. 37, KOF Zurich, 2012

## SOCIETAL IMPACT

At the societal level, the primary objective of Nano-Tera.ch was to promote a vision of engineering with true social objectives. In this perspective, the social relevance of Nano-Tera.ch's research has been confirmed by an *a posteriori* analysis of the match of the results of the program in the health, environment, and energy application areas with the topics covered by the mainstream media, parliamentary proceedings, and Federal investments. [KS15]

More precisely,

- The **media** – which often mirror the population's interests and concerns – have consistently published, throughout the 2008-2016 period, numerous articles related to specific themes addressed by the program in health, energy and environment. During this period, the presence of such themes in the media was high, with about 5% of all articles devoted to themes corresponding to some selected Nano-Tera-related keywords. In particular, the proportion of articles related to specific health-related issues considered within Nano-Tera has almost tripled. For example, the concept of wearables was virtually unheard of until 2011, picking up considerably in the past few years. Likewise the articles relating to intelligent sensors were more than 5 times more frequent in 2016 than in 2008. Most themes related to energy also attracted considerable interest during the period, with a peak in 2011, which may probably be related to the Fukushima disaster.

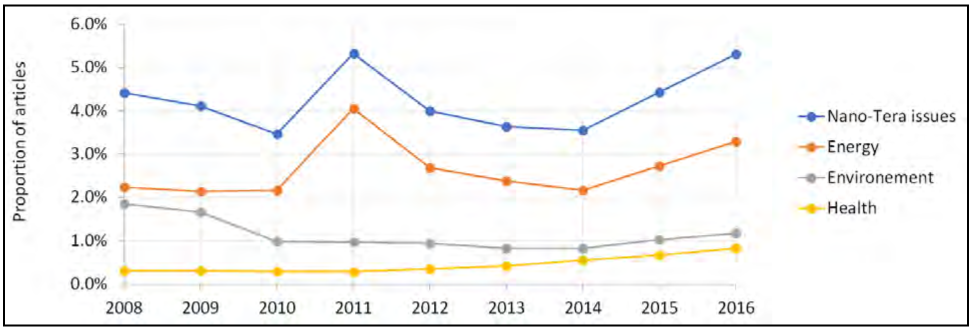



*Figure 10. Proportion of all articles in the selected media addressing certain topics.*

Furthermore, the research funded by Nano-Tera.ch also matched current social concerns and needs:

- In a annual nationwide **"Worry Barometer" survey** which has been gathering information about the concerns of the Swiss population since 1976, themes related to health or energy issues have consistently rated high – typically in the top third – among a list of themes of interest.
- The **parliamentary proceedings** offer a complementary legislative perspective on society's priorities in terms of needs. A search in the parliamentary proceedings for keywords related to Nano-Tera.ch's research (e.g. "sensors", "cancer treatment") shows a constant interest by Parliament in health, environment and energy matters. From 2008 to 2016, the total numbers of proceedings related to health, energy and environmental issues represented almost 20% of all proceedings.

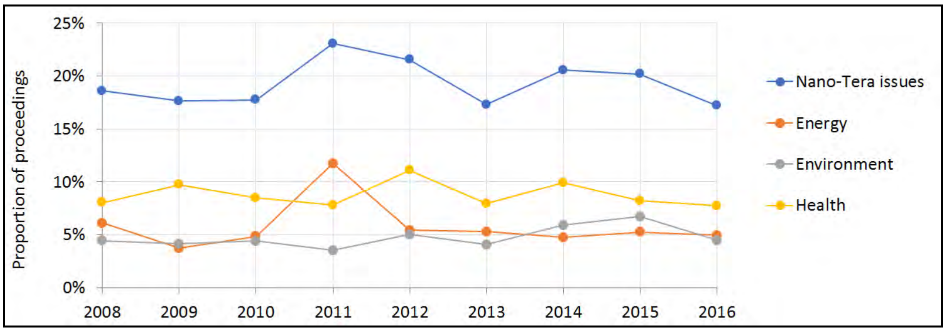



*Figure 11. Proportion of parliamentary proceedings addressing certain topics.*

- Finally, an analysis of **Federal spending** in specific departments ("Offices") related to health, energy and environment issues (the Federal Office of Public Health, the Office of Energy, and the Office for the Environment) provides crucial information about the measures taken by the authorities to tackle various problems. It shows in particular that several issues covered by Nano-Tera.ch's research benefited from substantial fundings by these three departments, and that these funding have strongly increased (by 65% overall) in the considered period.

Nano-Tera.ch has contributed to its societal impact by **disseminating** the results achieved within and beyond its community. Various communication and dissemination activities were aimed at developing the program's profile in the media, keeping governing bodies informed about the program's progress, federating the PI and PhD students, exchanging information around the results, as well as presenting the program's results to the global scientific community. This was achieved through numerous printed documents (activity reports, brochures, etc.), organization of events (including Nano-Tera Annual Meetings), participation in external events through oral presentations and conference exhibitions, creation of videos covering Nano-Tera research, as well as through the website and other media channels. [KS16]

Finally, Nano-Tera.ch implemented various pilot projects to promote the program **in high school and with younger children.** This included the set-up of a booth presenting the Nano-Tera.ch SHINE project at the Scientastic Sciences Festival 2016, an EPFL event aiming at making scientific knowledge accessible to a wide audience and generating enthusiasm for scientific and technological research. Moreover, Nano-Tera organized a dissemination event where 40 high school students had the opportunity to meet and interact with Nano-Tera PhD students and researchers, and to brainstorm about potential applications for the various technologies developed within several of the Nano-Tera.ch projects. [KS17]

## INSTITUTIONAL IMPACT

In 2015, based on the analysis of the results achieved by the program during Phase 1 and the first half of Phase 2, Nano-Tera.ch decided to embody several of the core conclusions resulting from the analysis into a specific pilot program, the **Gateway program**, intrinsically positioned at the frontier between research and innovation, and aiming to incorporate research results obtained within Nano-Tera.ch projects into industrial demonstrators directly exploitable by the industrial partners involved in the program. [KS12]

To implement this novel program, Nano-Tera.ch first joined forces with CSEM and Empa to analyze the running RTD projects and select the ones who could benefit most from a Gateway extension. As a result, four pilot Gateway projects (associated with the Synergy, HearRestore, and Flusitex RTD projects, and with the ParaTex NTF project) were launched in November 2015, with operation planned until March 2017. [KS12]

Based on the experience gained within this first pilot experiment, an official Gateway call was launched in July 2016 which led to the selection of four additional Gateway projects (associated with the IrSensII, ObeSense, and FlusiTex RTD projects, and with the Nambp NTF project). The selected projects were launched in November 2016, with operation planned until October 2017. [KS12]

Furthermore, Nano-Tera.ch has provided its expertise to contribute (through meetings, preparatory discussions and positioning documents) to the setup of the joint SNSF-CTI program **BRIDGE**, a novel funding instrument deployed at the Federal level for the budgetary period 2017-2020. The BRIDGE program aims at better exploiting the economic and societal potential of scientific research by promoting transfer from scientific knowledge to innovation. BRIDGE was designed as a new concept for jointly funding research and pre-competitive innovation in Switzerland in the field of Engineering Sciences. It aims to help turn publicly-funded research results into pre-competitive innovation. In order to achieve its goals, it plans to better connect academic and industrial players through ambitious research projects, thus creating suitable platforms for collaborative knowledge and technology transfer based on cross-exposure and inter-connection of personnel, with a special focus on junior researchers/engineers. [KS18]

# IV.2 KEY STATEMENTS RELATED TO SCIENTIFIC IMPACT

| Key statement 1 |
|---|
| Nano-Tera.ch has promoted **excellence in research** in various domains of engineering sciences. |

### EVALUATIONS PERFORMED DURING THE LIFETIME OF THE PROGRAM

The annual evaluation of the running RTD projects performed independently from Nano-Tera.ch by a panel of international experts appointed by the SNSF (the SNSF Evaluation Panel) consistently acknowledged the scientific excellence of the funded projects, while the Nano-Tera.ch Scientific Advisory Board stressed the strong contribution of the Nano-Tera.ch program to the multidisciplinary development of Swiss engineering sciences.

### NUMBER OF PUBLICATIONS

In terms of scientific dissemination, the research funded by Nano-Tera has generated almost **1,600 publications** (758 during its first phase, and 818 in the second phase).
About **44%** of these publications were articles in journal and books, the rest consisting of conference proceedings (in the conference proceedings, short abstract-style contributions have not been taken into account).
The distribution of the publications by publication type (journals or conference proceedings) is given below.

| | Phase 1 | Phase 2 | Total |
|---|---|---|---|
| Publications in journals and books | 344 | 354 | **698** |
| Publications in conference proceedings | 414 | 464 | **878** |
| Total | 758 | 818 | **1,576** |

### PUBLICATION IMPACT

The impact of the publications published in journals can be measured by several metrics: The new journal metric launched by Elsevier in December 2016, the CiteScore, now competes with the Impact Factor, produced by Clarivate Analytics (formerly part of Thomson Reuters.) The two companies also maintain competing bibliographical citation databases, with Scopus for Elsevier and the Web of Science for Clarivate. Despite being a widely used measure of journal quality for over 40 years, the Impact Factor has suffered from a lot of criticism because of some of its limitations, namely[2]

- Since the Impact Factor is derived from journals indexed in the Web of Science, no other journals can have an Impact Factor.
- Since the Impact Factor only looks at citations in the current year to articles in the previous two years, it only works well for disciplines in which rapid citation is the standard.
- The Impact Factor does not take into account disciplinary differences in expected numbers of citations.
- There is no Journal Citation Report (JCR) for arts and humanities, therefore no Impact Factor for journals in these disciplines.

Other attempts have been made to offer alternatives to the Impact Factor, such as the Eigenfactor Score, which uses the same journal source list as the JCR, the Scimago Journal Rankings, and the SNIP (Source Normalized Impact per Paper), which uses the Scopus journal source list. However, the CiteScore represents the most credible competitor to the Impact Factor because of the following aspects:

- It is free to access on the Scopus Journal Metrics website (while the JCR requires a paid subscription).
- It is derived from the Scopus journal source list, which is much larger than the Web of Science list and includes more social sciences and humanities journals.
- It provides a 3-year citation window, rather than the 2-year window used for the Impact Factor.

The Nano-Tera publications that appeared in journals with a known Impact Factor (Web of Science) or CiteScore (Scopus) lead to the following Impact Factor and CiteScore distributions.

[2] For more detail, see https://library.osu.edu/researchcommons/2017/06/12/citescore-vs-impact-factor

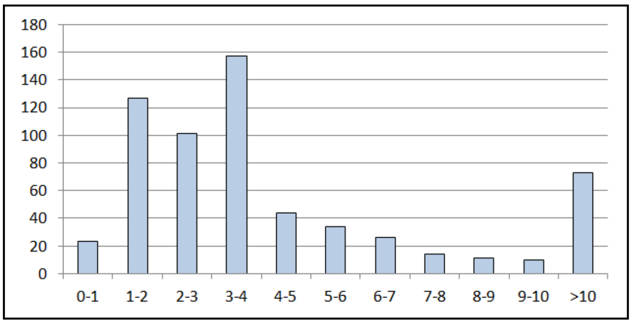



*Figure 12. Distribution of Impact Factors.*

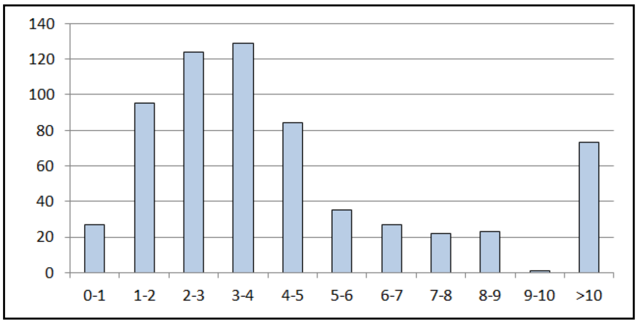



*Figure 13. Distribution of CiteScore.*

The corresponding average Impact Factor and CiteScore for Nano-Tera publications are given in the table below.

| | Phase 1 | Phase 2 | Overall |
|---|---|---|---|
| Average Impact Factor | 3.96 | 6.72 | **5.34** |
| Average CiteScore | 3.88 | 5.95 | **4.92** |

## Conferences and Workshops

In the first phase of Nano-Tera, more than **1,200 presentations** at conferences and workshops have been given, in addition to almost **900** presentations which have been reported so far for the second phase (about 40% of which were invited oral presentations, the rest being other oral presentations or posters). Furthermore, the projects have led to several presentations in the media (television, radio, press).
This brings the overall number of Nano-Tera presentations in various conferences to over **2'000** since the beginning of the program.

| | Phase 1 | Phase 2 | Total |
|---|---|---|---|
| Conferences | 1'265 | 882* | **2'147** |

* As of 2015.

## Awards

Numerous awards have been received by Nano-Tera researchers, 19 of which being awarded for personal achievements of prominent researchers for their lifetime contributions to their field, and 59 awards for best presentations, papers, presentations, demonstrator, etc.

| | Phase 1 | Phase 2 | Total |
|---|---|---|---|
| Awards for personal achievements | 12 | 7 | **19** |
| Best poster/paper/pres. awards | 25 | 33 | **58** |
| Total | 37 | 40 | **77** |

## Prominent Researchers

Below are the publication and citation statistics of some prominent Nano-Tera researchers (i.e. all Phase 2 PIs or Co-PIs with an H-index of at least 50, listed in alphabetical order). The provided statistics are taken from Google Scholar as of August 2017.

| | Publications since 2012 | Citations since 2012 | H-index |
|---|---|---|---|
| Luca Benini, ETHZ | 377 | 15'157 | **89** |
| Giovanni De Micheli, EPFL | 321 | 11'959 | **93** |
| Nico De Rooij, EPFL | 182 | 7'535 | **78** |
| Jérôme Faist, ETHZ | 171 | 11'235 | **87** |
| Hubert Girault, EPFL | 81 | 8'042 | **75** |
| Michael Grätzel, EPFL | 483 | 133'136 | **218** |
| Ursula Keller, ETHZ | 278 | 12'357 | **94** |
| Ernst Meyer, Uni Basel | 122 | 6'247 | **71** |
| Demetri Psaltis, EPFL | 131 | 7'438 | **85** |
| Philippe Renaud, EPFL | 166 | 6'636 | **64** |
| Joseph Sifakis, EPFL | 33 | 4'612 | **58** |
| Lothar Thiele, ETHZ | 167 | 20'107 | **73** |

### INTERNATIONAL EXCHANGE PROGRAM

Nano-Tera has attracted the attention of world-leading scientists through its International Exchange Program. In this framework, Nano-Tera.ch has invited three prominent internationally renowned researchers to make a series of talks in various institutions involved in Nano-Tera:

- Prof. Krishna Palem (Rice University), widely recognized for his pioneering contributions to the foundations of embedded computing, interacted with several Nano-Tera scientists at EPFL in a form of stimulating exchanges of ideas and perspectives.
  He visited Nano-Tera in July 2013.

- Prof. Rahul Sarpeshkar, currently professor at the Thayer School of Engineering at Dartmouth and former award-winning professor at MIT, presented his pioneering contributions in the area of ultra energy efficient systems in biology, engineering and medicine in a widely followed series of talks at EPFL, CSEM and ETHZ.
  He visited Nano-Tera in October 2013.

- Prof. Massimiliano Di Ventra, professor at the Department of Physics at the University of California in San Diego, presented his research on the theory of electronic and transport properties of nanoscale systems, non-equilibrium statistical mechanics, DNA sequencing/polymer dynamics in nano-pores, and memory effects in nanostructures for applications in unconventional computing and biophysics.
  He visited Nano-Tera in May 2014.

**Key statement 2**

Nano-Tera.ch has fostered strongly **collaborative** research.

## Number of Partners per Project

A central measure of the level of collaboration within a given project is the number of partners working in that project. We therefore computed how many partners (PI and Co-PIs) are officially participating in each of the Nano-Tera.ch RTD projects.
The results of this analysis show that the RTD projects have had between 3 and 10 different partners, with an overall average of 6.11 (5.8 for the first phase of the program, and an average of 6.3 for the second phase).

| | Phase 1 | Phase 2 | Overall |
|---|---|---|---|
| Average number of partners (RTD) | 5.84 | 6.32 | **6.11** |

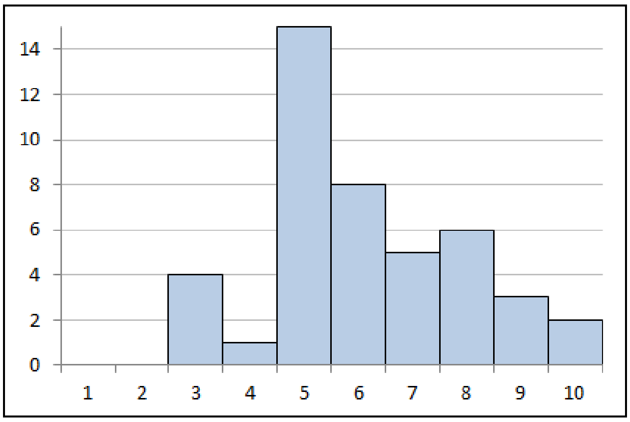



*Figure 14. Distribution of the number of partners (RTD projects).*

## Number of Institutions per Project

The above metric does not consider the potential diversity of the institutions involved in a project, as several consortium members may originate from the same institution or even the same unit within a given institution. A complementary way of evaluating the level of collaboration within a project is therefore to measure the number of different institutions represented by the project partners (PIs and Co-PIs) within each of the Nano-Tera.ch RTD projects.
The results of this analysis show that the RTD projects of both phases have had up to 7 different institutions involved, with an average of almost 4.

| | Phase 1 | Phase 2 | Overall |
|---|---|---|---|
| Average number of institutions (RTD) | 3.89 | 3.88 | **3.89** |

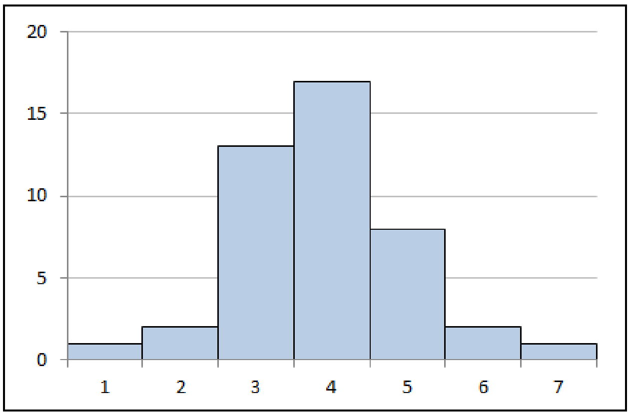



*Figure 15. Distribution of the number of institutions in RTD projects.*

## Number of Research Groups per Research Task

A more detailed way of assessing the collaborative nature of the research carried out within the Nano-Tera program is to analyze the number of research groups involved in the same research task.
Because of the very heavy workload it represents, this type of analysis has been only performed for Phase 1 RTD projects.

The results of the analysis show that, on average, 2.4 partners (PI or Co-PIs) were involved in a given task in Phase 1 RTD projects. In fact, almost two thirds of all subtasks identified in these projects are carried out by several partners, as illustrated by the distribution below.

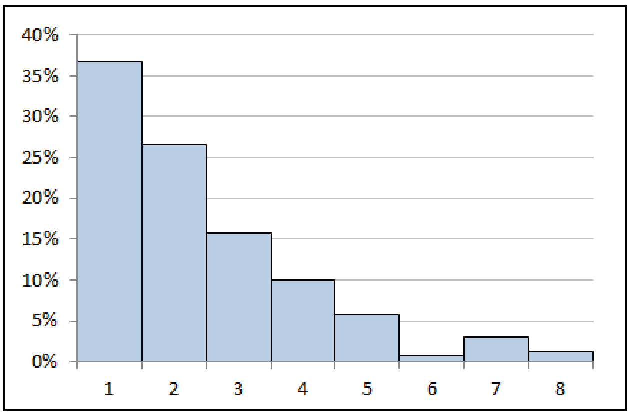



*Figure 16. Number of partners in a task (RTD projects Phase 1).*

### AMOUNT OF JOINT PUBLICATIONS

To further quantify the amount of collaboration taking place in the Nano-Tera.ch projects, we have also analyzed all the publications stemming from the RTD projects, and identified how many project partners (PIs and Co-PIs) they involve. The results show that nearly 28% of the publications are co-authored by at least two project partners, the detailed distribution being provided in the figure below.

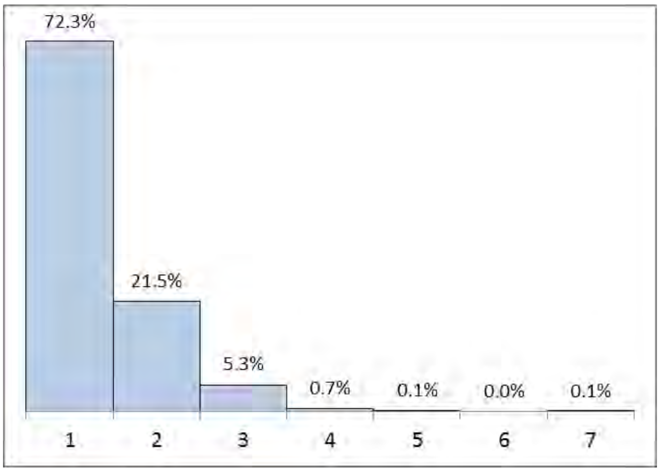



*Figure 17. Distribution of the RTD project publications by number of co-author partners.*

### NANO-TERA – SSSTC PILOT GRANTS

In 2011, Nano-Tera launched an initiative aiming at creating synergies to encourage Swiss-Chinese research collaborations within Nano-Tera.ch thematic areas.

An important first step took place in November 2010, when, recognizing the importance of bilateral relations, Nano-Tera.ch took part to an official visit to various Chinese institutions in order to initiate a dialog on possible future collaborations.

The collaboration of Nano-Tera with the Chinese Academy of Science (CAS) benefitted from the existing agreement between CAS and the Sino-Swiss Science and Technology Cooperation (SSSTC) program, hosted by the ETHZ and supported by the State Secretariat for Education, Research, and Innovation (SERI) in the framework of the promotion of bilateral science and technology cooperation with China. Following this first exploratory phase, and combining the strengths of Nano-Tera.ch and SSSTC, a joint call for Sino-Swiss Pilot Grants was launched in Spring 2011.

The same funding rules as the ones defined for standard Nano-Tera.ch Phase 1 projects have been imposed for this collaboration: total own contributions had to be at least 53% of the total budget. In addition, it was highly recommended that Chinese matching funds amounted to at least 33% of the total budget. In order to support the initiative and increase Nano-Tera.ch visibility in China, a booth presenting Nano-Tera.ch activities and promoting the SSSTC call was set up at the large Transducers conference held in Beijing in early June 2011, and benefitted from the presence of several Nano-Tera investigators, thus initiating discussions between Swiss and Chinese scientists.

The initiative coincided with the visit to China of Federal Councilor Didier Burkhalter, and his discussions with the ministers of science and technology, education and health aiming at reinforcing common programs in sectors such as health, environment, and energy, to cite those directly correlated to the strategic objectives of Nano-Tera.

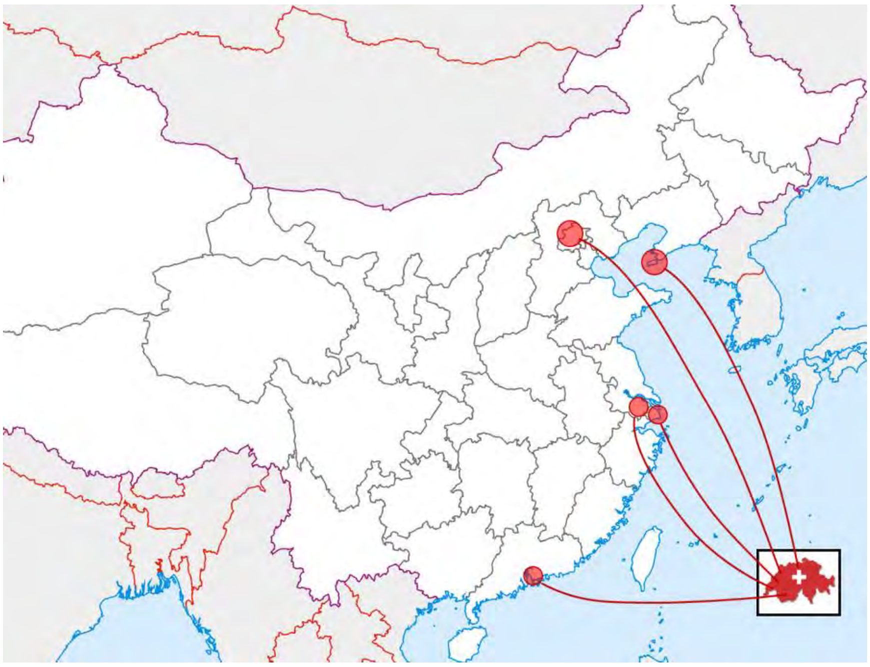


*Figure 18. Location of Chinese partners.*

The Nano-Tera.ch SSSTC call resulted in the selection of the following SSSTC projects:

| | | |
|---|---|---|
| i-Needle | Intelligent Needles with Wireless Connection to Internet for Biophysical Bases of Acupuncture | Dr. S. Carrara EPFL |
| M3WSN | Mobile Multi-Media Wireless Sensor Networks | Prof. T. Braun UniBE |
| NaNiBo | Nano-Confinement of Nitrogen and Boron based Hydrides | Prof. A. Züttel EMPA |
| NetCam | Real Time Computation & Optimization for Networked Camera Surveillance | Prof. J. Lygeros ETHZ |
| SiC-nanomembranes | SiC Nanomembranes for MEMS Biofuel Cell | Prof. J. Brugger EPFL |
| 3DOptoChemiImage | Optofluidic 3D Chemical Imaging Cytometry based on inline Digital Coherent anti-Stoke Raman Scattering Holography | Prof. D. Psaltis EPFL |

**Key statement 3**

Nano-Tera.ch has fostered strongly **interdisciplinary** research.

## Number of Disciplines per Project

To analyze the inter-disciplinarity of the research carried out within Nano-Tera.ch RTD projects, the following list of disciplines has been considered to categorize the researchers involved in the projects:

- Bioengineering & Life Sciences
- Information & Communication Systems
- Electrical Engineering
- Electronic & Optical Systems
- Medicine
- Micro-engineering
- Energy
- Environment
- Fundamental Sciences

The results of the analysis show that most projects indeed include specialists from different disciplines, with the project consortia covering on average almost 3 different disciplines:

| | Phase 1 | Phase 2 | Overall |
|---|---|---|---|
| Average number of disciplines (RTD) | 2.74 | 2.72 | **2.73** |

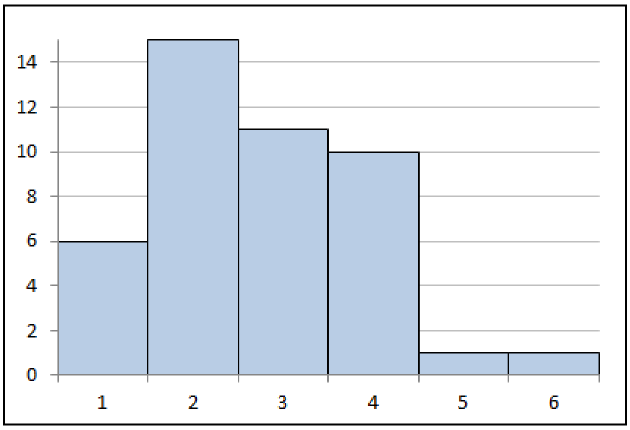



*Figure 19. Distribution of the number of disciplines brought by project partners to RTD projects.*

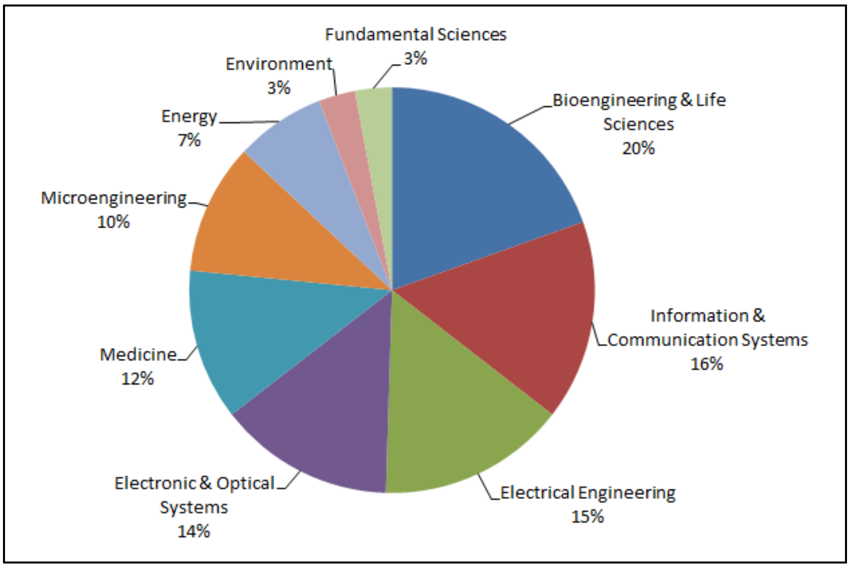



*Figure 20. Distributioons of disciplines among project partners (RTD projects).*

**Key statement 4**

Nano-Tera.ch has triggered **inter-institutional** collaborations among very diverse players at the national level.

## NUMBER OF DIFFERENT TYPES OF INSTITUTIONS PER PROJECT

For the inter-institutional nature of the consortia of the Nano-Tera.ch RTD projects, the following five institution types have been considered:

- ETH-Domain institutions (EPFL, ETHZ, Empa, Eawag, etc.)
- Universities
- Universities of applied sciences
- Hospitals
- Others (private institutions, etc.)

Overall, 9 of the 44 main RTD projects have had 4 types of institutions represented, with the following averages and distribution:

| | Phase 1 | Phase 2 | Overall |
|---|---|---|---|
| Average number of inst. types (RTD) | 2.63 | 2.80 | **2.73** |

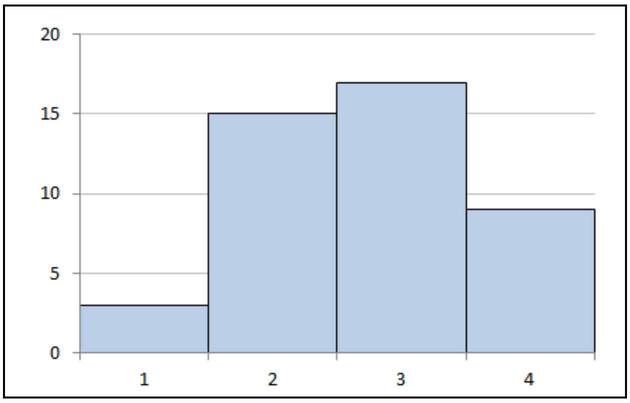



*Figure 21. Distribution of the number of institution types in RTD projects.*

In addition, an analysis of the distribution in the RTD projects of project partners (PIs & Co-PIs) by institution type has been carried out with a finer grained set of institution type distinguishing the two Federal Insitutes of Technology from the other ETH-Domain institutions. The results of this analyisis are shown below.

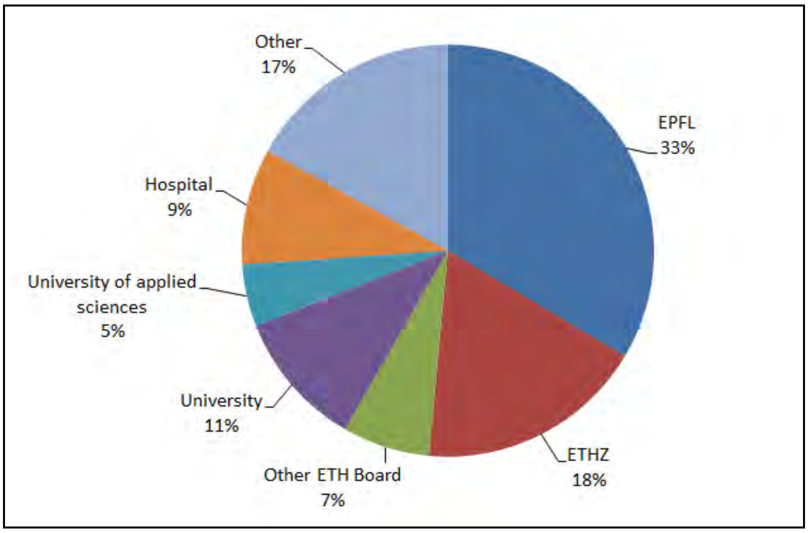



*Figure 22. Distribution of the project partners by institution type (RTD projects).*

## IMPROVEMENT OF THE RELATIONS BETWEEN FEDERAL INSTITUTIONS

As a result of the true inter-institutional nature of the Nano-Tera.ch projects, one of the important impacts of the program has been to substantially strengthen the relations between the involved institutions, and especially between the two Federal Institutes of Technology (EPFL and ETHZ).

## Key statement 5

Nano-Tera.ch has fostered strongly **applications-oriented research** in various domains of engineering sciences.

To some extent, fundamental research and application-oriented research can be considered as the two faces of the same coin, as they can be carried out by the same researchers. However, they strongly differ in the nature of the expected results. On one hand, when working on fundamental research issues, researchers are usually operating in a very exploratory mode, faced with highly evolving conditions, dealing with a high level of uncertainty, and ready to react to unexpected findings by rapidly adapting the original research objectives. On the other hand, when working on application-oriented research issues, researchers have to deal with very different concerns, typically resulting from their interaction with partners focusing on the exploitation of the research results for non-scientific purposes (typically applicative or economic). This thus requires from the researchers to take time to discover the expectations of the non-research partners, to concretize the research results into exploitable prototypes, and to stick to a more stable set of shared goals, expressed in terms of broadly understandable applicative objectives.

In consequence, to strengthen its application-oriented, Nano-Tera had to

- translate its scientific vision into more specific applicative goals associated with the broad application areas defined for the program: health, energy and the environment,
- foster the synergies between partners with scientific and non-scientific profiles,
- encourage the production of technology demonstrators potentially exploitable for the development of products in the medium term.

### STRENGTHENING THE PARTICIPATION OF INDUSTRIAL PARTNERS AND END-USERS

Nano-Tera.ch mainly achieved this objective by exploiting the eligibility conditions imposed on the consortia of the RTD projects. Concretely, the presence of industrial partners and end-users (e.g. hospitals) has been strongly recommended in all Nano-Tera.ch RTD calls, and made mandatory for Nano-Tera.ch Phase 2 RTD and Gateway projects. Indeed, building research consortia with industrial partners eager to benefit from the research results for economic exploitation, and with end-users seeking solutions to specific problems contributed to turn the RTD projects into very early stage incubators. This type of approach can therefore be considered as an effective way to foster application-oriented research.

As a result, 80 industrial partners and third parties as well as 41 end users (partners and third parties) were involved in the Nano-Tera.ch program..

Moreover, the RTD projects consortia involved complementary types of partners, with a bit more than half (57%) being researchers as expected, but also translational partners (CSEM and Empa, 12%), end-users (mainly hospitals, 12%), as well as industrial partners (19%). This type of mixed consortia represented a very favorable setup for application-oriented research, as the non-academic partners contributed to channel the research towards results that matched their applicative needs.

### ENCOURAGING THE PRODUCTION OF CONCRETE DEMONSTRATORS

The outputs of the Phase 1 and Phase 2 RTD projects have been analyzed (see Key Statement 11 and 12 for more detail on the performed analysis) to identify the number and nature of demonstrators and platforms produced. These demonstrators and platforms have been further characterized in terms of marketability (e.g., expected time to market – TTM – where lower TTM corresponds to higher marketability) and exploitability (e.g., technology readiness levels – TRL – where higher TRL identify results closer to industrialization, see Appendix B for details).

In particular, the results of the analysis showed that 31.5% of the 19 Phase 1 RTD projects and 56% of the 25 Phase 2 RTD projects led to demonstrators and technology platforms with a high potential to rapidly convert into products, which clearly indicates that Nano-Tera.ch managed to deploy the proper measures for strengthening the application-oriented nature of the research carried out in in the program.

## Key statement 6

Nano-Tera.ch has funded **ambitious projects**.

One of the important goals of the Nano-Tera.ch program was to provide a funding structure able to support large, ambitious research projects that could not be otherwise funded through the existing funding instruments.

### LEVEL OF FUNDING

The RTD projects have benefitted from an ambitious funding, as shown below.

| | Phase 1 | Phase 2 | Overall |
|---|---|---|---|
| Amount of NT funding (M CHF) | 2.33 | 2.05 | **2.17** |

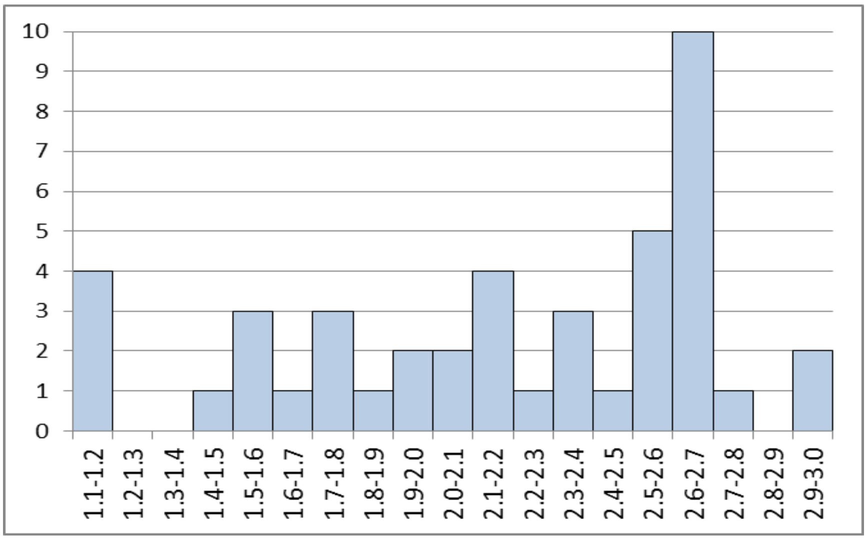



*Figure 23. Distribution of the level of Nano-Tera.ch Funding per RTD project.*

### NUMBER OF RESEARCHERS IN EACH PROJECT.

In order to address ambitious projects, a substantial team is needed. Nano-Tera.ch has provided the opportunity to build large consortia, which was much harder with other funding instruments.

On average, the RTD projects have included 36 (possibly part-time) members (Co-PIs, senior scientists, postdocs, PhD students, etc.), with the distribution of the consortium sizes provided below. Note that all types of projects members are considered in this analysis: both full-time and part-time members, either funded by the allocated budgets or by the matching funds provided by the project partners.

| | Phase 1 | Phase 2 | Overall |
|---|---|---|---|
| Size of consortium | 41.7 | 30.8 | **35.5** |

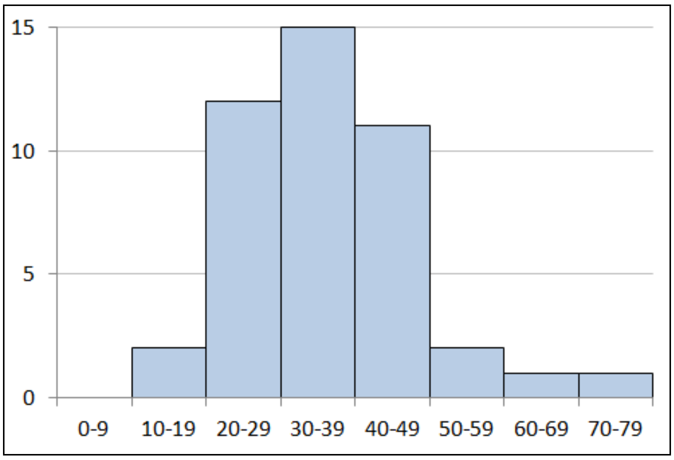



*Figure 24. Distribution of the number of researchers in RTD projects.*

### PROJECTS DURATION

The RTD projects have extended over a significant period of time, spanning at least 3 years, and sometimes more than 4.5 years. Note that we consider the effective duration of projects, potentially different from the originally planned one, because many projects have been extended with no additional funding.

On average, RTD projects of Phase 1 have spanned over 46.3 months and Phase 2 projects over 49.2 months, thus leading to an overall average of almost exactly 4 years.

| | Phase 1 | Phase 2 | Overall |
|---|---|---|---|
| Average project duration (in months) | 46.3 | 49.2 | **47.9** |

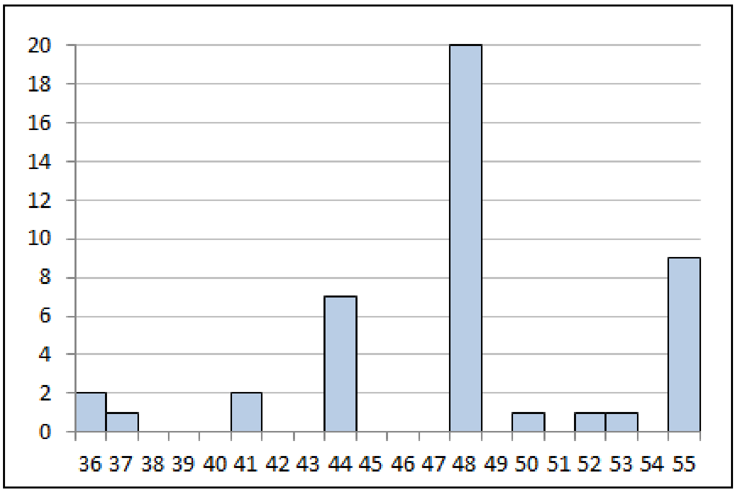



*Figure 25. Duraction of the RTD projects (in months).*

**Key statement 7**

Nano-Tera.ch has an **almost exhaustive coverage** of the Swiss scientific community in the program's fields.

### A DENSE GEOGRAPHICAL COVERAGE

The maps below show, for each phase of the program, the geographical coverage of the partners present in all the projects. The size of the displayed circles is proportional to the number of involved research partners in the corresponding site and institution. The thickness of the displayed links indicates the number of projects that a given pair of institutions is involved in. Over both phases of the program, about **1,600 different researchers** have been involved in Nano-Tera projects, and, when taking into account the fact that a researcher can be involved in several projects, the total amounts to almost 2,300 persons.project.

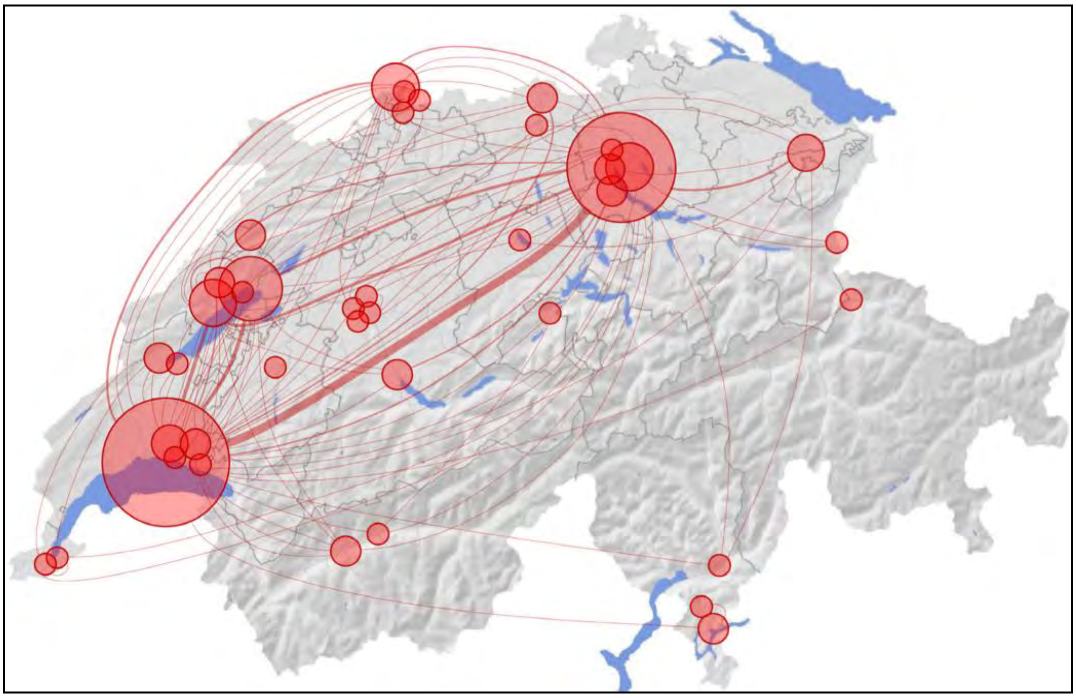


*Figure 26. Geographical coverage of the partners present in all projects (Phase 1).*

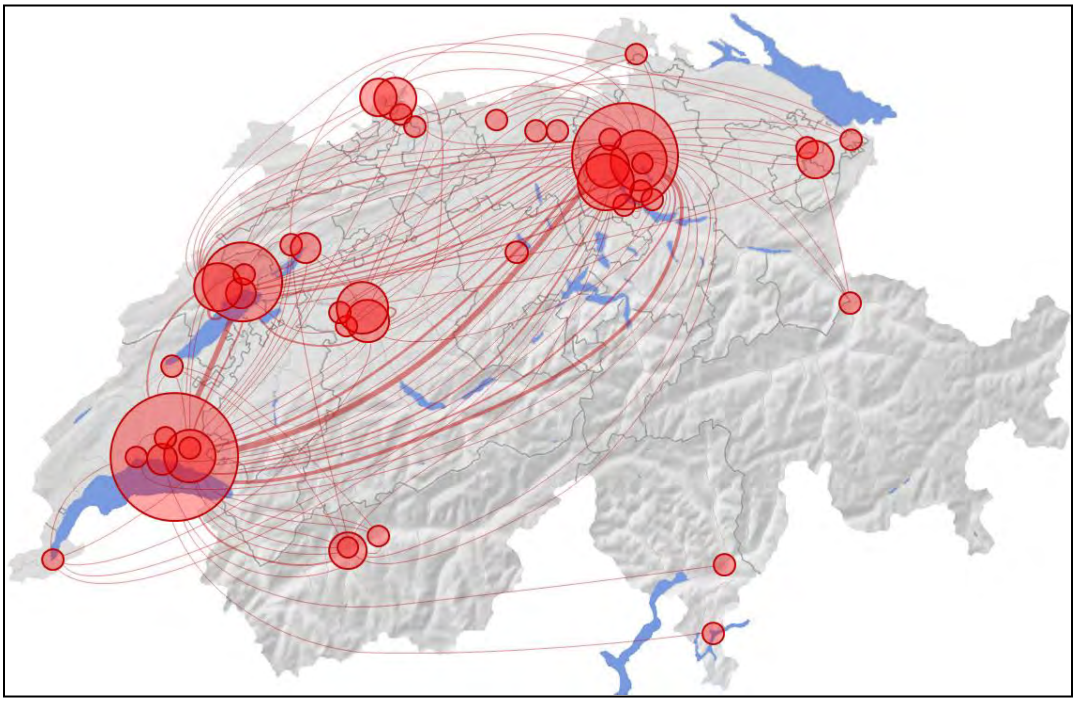


*Figure 27. Geographical coverage of the partners present in all projects (Phase 2).*

# IV.3 KEY STATEMENTS RELATED TO EDUCATIONAL IMPACT

**Key statement 8**

Nano-Tera.ch has substantially contributed to the **training of next generation researchers** (PhD students, Post Docs).

### A LARGE NUMBER OF PHD STUDENTS

Nano-Tera.ch has contributed to the training of the next generation of researchers, with a total of 366 PhD students involved in the program's projects, 192 in Phase 1 projects and 202 in Phase 2 projects (some of which took part to both phases of the program).

| | Phase 1 | Phase 2 | Overall |
|---|---|---|---|
| Number of PhD students | 192 | 202 | **366** |

### DISTRIBUTION OF PHD STUDENTS BY INSTITUTION

About 77% of all PhD students are affiliated with EPFL, ETHZ or another ETH-Domain institution, as shown in the graph below. About 15% study in a university or a university of applied sciences. The rest are affiliated with hospitals or other institutions.

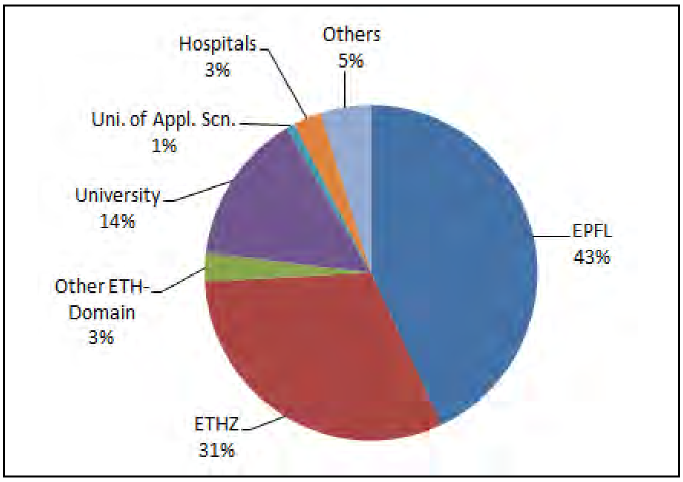



*Figure 28. Distribution of PhD students by institution.*

### DISTRIBUTION OF PHD STUDENTS BY THEMATIC CLUSTER, PHASE II

Based on the thematic clusters defined for Phase II projects, the distribution of PhD students by topic is shown below. There are 31 PhD students are involved in a project related to environmental monitoring, and 57 are involved in smart energy. The three health-related clusters (health monitoring, smart prosthetics & body repair, medical platforms) have 49, 29 and 36 PhD students respectively.

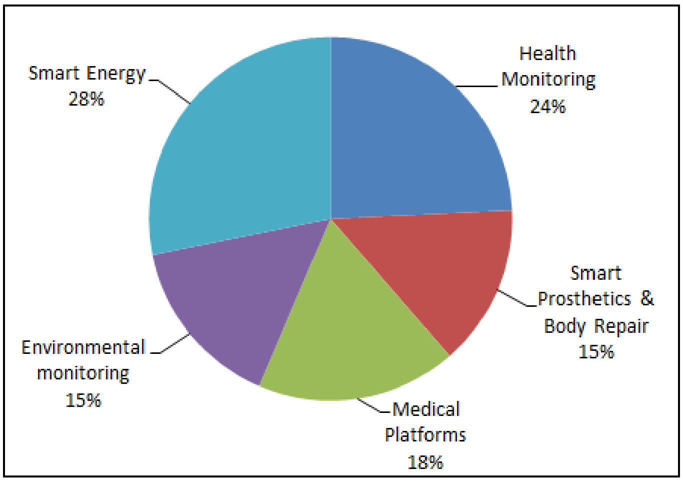


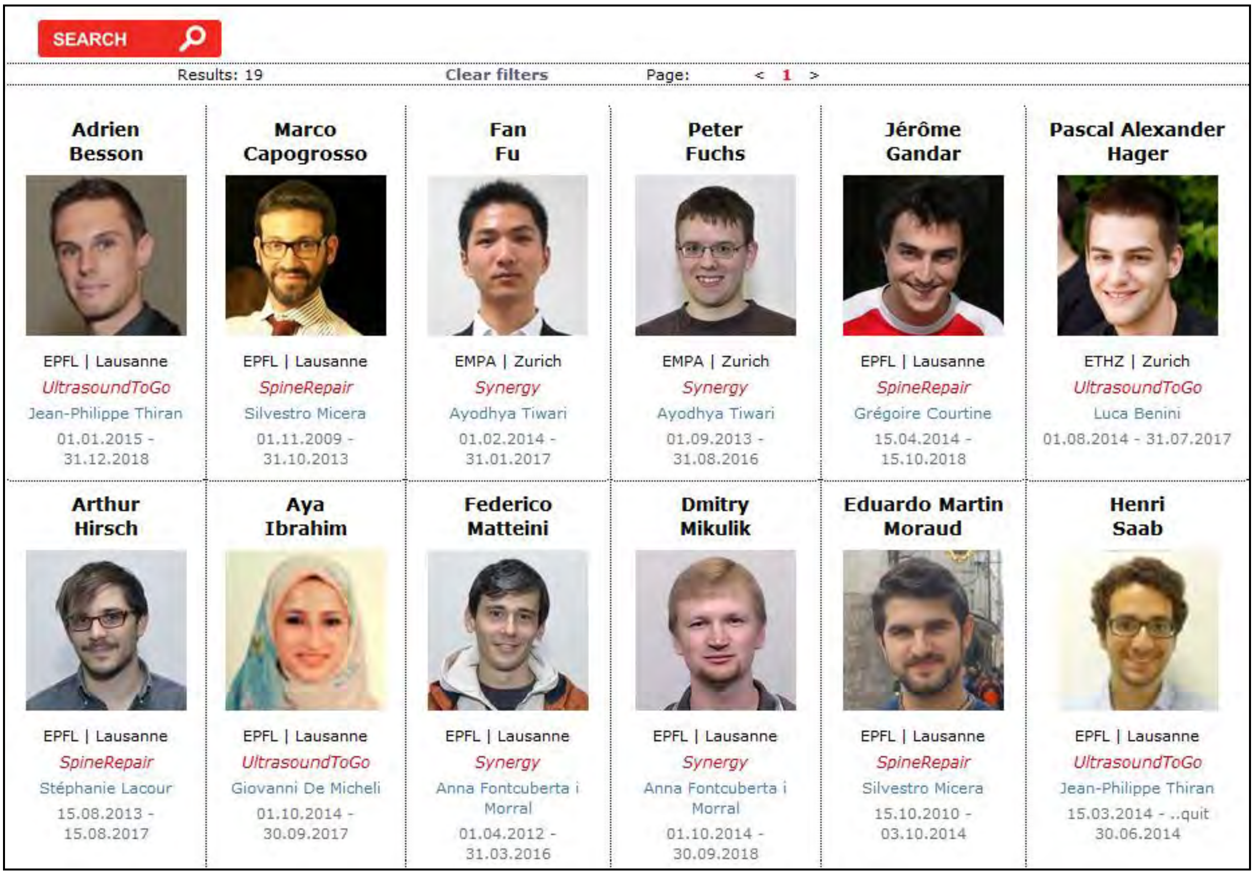

*Figure 29. Distribution of PhD students by thematic cluster (Phase 2).*

### DISTRIBUTION OF PHD STUDENTS BY GENDER

There are 77 female PhD students, representing about 21% of the total.

### PROFILE DIRECTORY OF PHD STUDENTS

A special page devoted to PhD students has been created on the Nano-Tera website. It consists of a complete directory of students, which can be sorted and filtered by project, by institution and several other criteria: www.nano-tera.ch/phd




### TIMELINE

Based on the starting dates and expected end dates of the PhD students, the graph below indicates how many PhD students have been active at any given time.

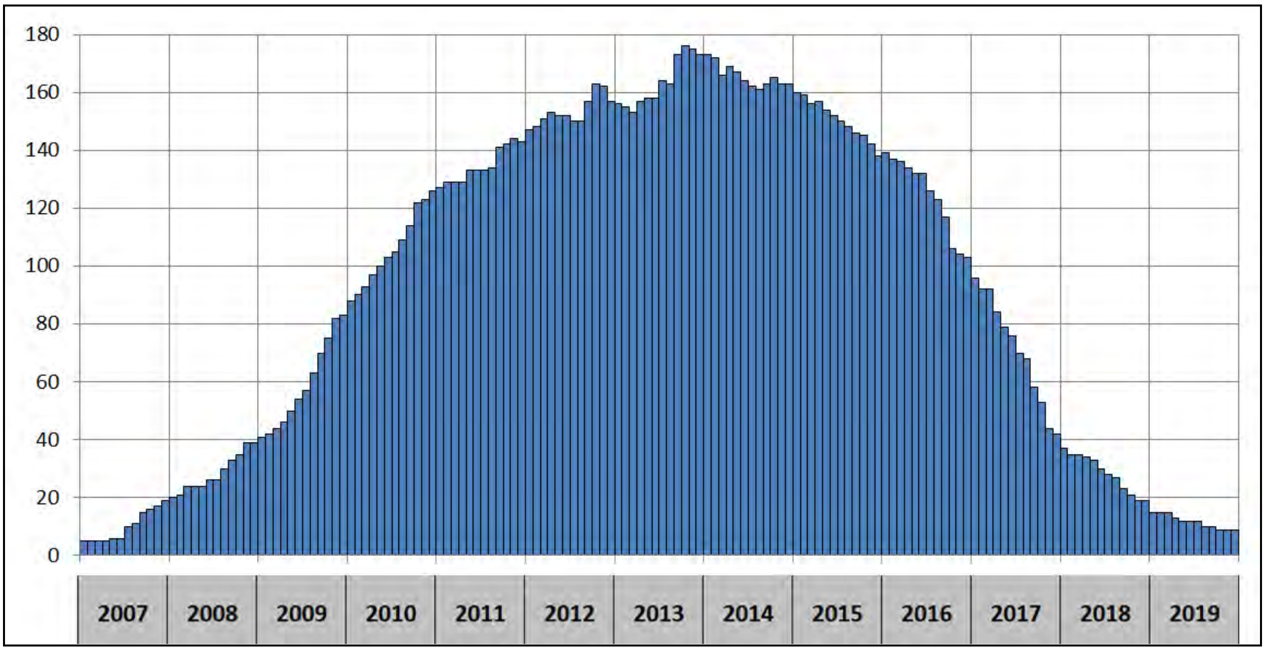



*Figure 30. Time evolution of the number of PhD students that have been active in the Nano-Tera program.*

### THE NEXTSTEP PROGRAM FOR PHD STUDENTS

To strengthen the importance of PhD students within the program, Nano-Tera has set up the NextStep program, specifically for PhD students. This program has been designed to help the PhD students explore possible ways to exploit the scientific skills they had acquired during their PhD. In particular, NextStep was promoting the possibility for them:

- to apply for specific research grants to fund collaborative research involving several PhD students. (Track 1, **described in Key statement 9**)
- to be exposed to different ways of considering economic exploitation of the scientific skills and results obtained during their PhD work. (Track 2, **described in Key statement 10**)
- to present their research to a larger audience outside their field (Track MT180, see below).

### NEXTSTEP TRACK MT180: MY THESIS IN 180 SECONDS CONTESTS

In addition to carrying out excellent science, it was important for PhD students to be able to communicate their work and results, in a clear and appealing way, easily understandable outside their field of specialization.

As it is now done in many higher education institutions to help their junior researchers acquire the required communication skills, Nano-Tera has organized MT180 ("My Thesis in 180 Seconds") contests, where PhD students had 3 minutes to present the content of their research to a wide audience, with the support of only one static slide.

A first contest, open to all Nano-Tera PhD students, ended up giving six of the participants the opportunity to benefit from personal coaching under the supervision of Swiss journalists specialized in science and technology. Furthermore, three PhD students have been selected by a jury involving journalists and researchers to make their MT180 presentation in front of the whole Nano-Tera community at the Nano-Tera Annual Meeting 2016.

Concretely, interested participants first had to submit their draft MT180 presentation in the form of a video contribution of at most 3 minutes, involving the presentation of one static slide. The contributions have been evaluated by a jury composed of six researchers and six scientific journalists. The jury selected the six most promising contributions, and each of the selected PhD students benefitted from a personalized coaching by one of the scientific journalists in the jury, to help them improve the content of their presentation.

After their coaching, the six selected PhD students participated to a "semi-final" in the form of a live presentation in front of the jury. The three best participants faced off in the final at the Nano-Tera Annual Meeting 2016, with Débora Bonvin declared the winner by the audience.

*Figure 31. Débora Bonvin (EPFL), Romain Jacob (ETHZ) and Leila Mirmohamadsadeghi (EPFL), 3 finalists.*

Following the success of this Nano-Tera contest, **an international contest** has been organized in early 2017, involving parallel competitions in Brazil and in Switzerland. The more than 20 students who participated to the event were evaluated by a local jury as well as by a jury in the other country and the students from the other country.

Two Swiss and two Brazilian students have been declared winners and received a grant to give their 3-minute presentation along with a more extensive talk to host institutions of their choice, with Swiss students traveling to Brazil and vice versa.

## THE EDUCATION AND DISSEMINATION ACTIVITIES

Nano-Tera Education and Dissemination (ED) activities. are actions aiming at supporting short courses, workshops, mini-conferences, and developing new curricula in domains covered by Nano-Tera.ch that are not provided by Swiss Universities or Polytechnics. ED activities may address the in-depth study of a technology or interdisciplinary horizontal activities.

Nano-Tera.ch funded 61 ED actions for a total budget of more than CHF 1.4 million More than half of the activities funded consisted of conferences, symposia and workshops. About a quarter have been courses and winter or summer schools.

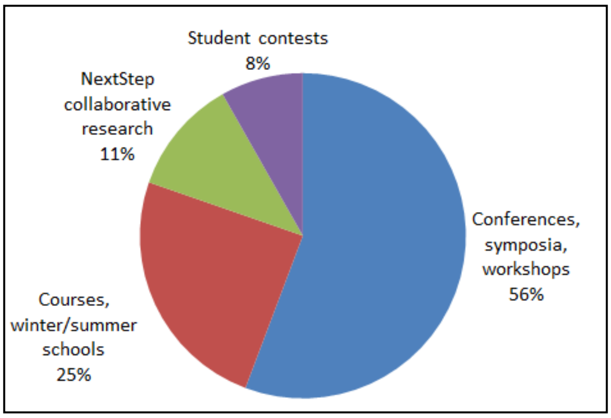



*Figure 32. ED activities by type.*

### iCAN student contests

Nano-Tera has supported several years the Swiss selection for the international student contest in micro/nanodevice applications. Swiss student teams were competing to develop new applications using commercial sensor devices, donated by the industry.

In the iCAN 2016 selection for example, after a preparation phase of 3-4 months, the Swiss selection took place with a jury composed of industry professionals. The Swiss selection was open to all Swiss higher education systems, As a result of the Swiss selection day, two Swiss winning teams were sponsored to travel to Paris to participate to the international iCAN contest. The two Swiss teams performed very well in the finals, receiving a 1st and 2nd place award. It was deemed an excellent project involving young, ambitious students to work as a team on a tightly scheduled project.

*Figure 33. Adrian Sarbach (EPFL), Pius Theiler (ETHZ), Ricarda Nebling (ETHZ) winners of the first prize (left) and Arthur Gay and Thibaut Paschal (EPFL), winners of the second prize (right)*

### Artist School 2013

In the continuation of the Artist Summer School series of events (2003, 2005, 2007–2012), the program of the Nano-Tera/Artist International Summer School 2013 was tailored to compensate for the lack of curricula in European universities introducing a rigorous approach to system design, providing the attendees with an overview of the state-of-the art research in the relevant domains.

The topics usually addressed at the school include, among others, Modelling and Validation, Compilers and Timing Analysis, Control for Embedded Systems, Execution Platforms and MPSoC, Temperature- and Energy-Aware Design of Systems and Sensor Networks. Thus, the topics of the Artist Summer School are highly relevant to the application areas and basic engineering technologies composing the Nano-Tera research space, and particularly Software and Systems, Communications, Wearable and implantable and Energy systems.

A total of 67 participants, including 56 students for 15 countries attended the summer school. The students involved with Nano-Tera projects were registered free of charge.

**Training and Education Activities**

This ED activity consisted of a package of training activities spanning two years. The activity included the following three main activities:

- Internal workshops for NanoTera scientists:
  The Nano-Tera.CH program gathers scientists from different backgrounds working on common projects in different fields. This leads to a large demand for cross-disciplinary education among the scientists, which was addressed by the internal workshops program where experienced scientists presented the most relevant enabling technologies to the NanoTera researchers. The aim of the workshops was to exchange experience and know-how and to create a real NanoTera community. This resulted in the organization of four workshops for Nano-Tera researchers (duration 1-2 days each), gathering a total of 119 participants.
- Training courses for professionals in the field of micro/nano
  In order to ensure the success of the industrialization stage, there is a need for transfer of knowledge form the research institutions to the industry. This was addressed by a large Nano-Tera.ch continuous education program for professionals. This resulted in the organization of 16 short training courses for industrial and academic participants (duration 1-2 days each)
- A Summer school for academic education
  Nano-Tera.CH pursues scientific excellence in many technologies and in their integration into systems. For students and researchers at Swiss and foreign universities and especially for young researchers from the Nano-Tera community, a condensed summer school on specific topics has been organized.

**Key statement 9**

Nano-Tera.ch has encouraged stronger **collaborative spirit** in the community of PhD students involved in the program and increased their autonomy by giving them the opportunity to submit their own collaborative research proposals.

## NEXTSTEP PROGRAM FOR PHD STUDENTS: TRACK 1 – SCIENTIFIC COLLABORATION

### Goal

The lone scientist in his laboratory is an idealized image far from reality. As the multidisciplinary nature of Nano-Tera projects illustrates, it is becoming more and more crucial to be able to conduct research in a collaborative manner. The objective of Track 1 of the NextStep action is therefore to give students the opportunity to consider the development of a collaborative work, within the framework of their thesis. This can be done via a joint validation of their results, for example by building a common prototype.

In general, the goal is to expose the PhD student to new concepts and approaches, thus strengthening the educational impact of the NextStep program within a multidisciplinary framework.

Concretely, Track 1 of the NextStep program gives them the opportunity to learn the full procedure of submitting proposals to get concrete funding: from building a consortium, picking the research challenges, writing the scientific proposal, and building a reasonable budget.

### Timeline

The program consisted of 4 modules, with a first one taking place in March 2015: the scientific collaboration track gathered all interested students for a day in order to start sharing their preliminary ideas of potential collaborations.

The second module took place during the 2015 Nano-Tera Annual Meeting, giving participants the possibility to present their collaborative research ideas to a panel of experts. Based on this first interaction, the ideas have become more mature and more precise: in a third stage of the Track 1 program, participants have submitted proposals, all of which have been accepted for funding.

Finally, the last module took place at the Nano-Tera Annual Meeting 2016, where some first results of the approved collaborative projects were presented.

*Figure 34. Nano-Tera.ch annual meeting 2016, Lausanne.*

## Projects

The funded projects are summarized below:

| Name | NT Project | Acronym | Title |
|---|---|---|---|
| T. Brusa, UniBE<br>*PI: P. Büchler* | SmartSphincter | BAFIARS | Assessment of anatomic, physiologic & bio-mechanical characteristics of the anal canal & pelvic floor: an observational study in patients |
| M. Thielen, ETHZ<br>*PI: C. Hierold* | BodyPoweredSenSE | BioFlex | Soft dry Biopotential Electrodes for Long-Term EEG recording |
| T. Wyss, UniBE<br>*PI: P. Büchler* | HearRestore | BonePro | HearRestore: Bone Impedance modelling |
| P. Hager, ETHZ<br>*PI: L. Benini* | UltraSoundToGo | LightProbe | Digital UltraSound Head |
| J. Ansó, UniBE<br>*PI: S. Weber* | HearRestore | NerveSafe | Facial nerve monitoring during robotic cochlear implantation |
| D. Mikulik, EPFL<br>*PI: A. Fontcuberta* | Synergy | SolCelMeas | Analyzing optical and electrical measurements of GaAs nanowire solar cells |
| H. Huang, BFH<br>*PI: V. Koch* | WiseSkin | MultiHaptic | Human study: info transfer analysis & early evaluation of multi-modality haptic displays for sensory feedback |

- BAFIARS, the first project, was a clinical study on the anatomy and morphology of the anal canal, anatomical and functional parameters were studied in order to prepare a guideline for artificial sphincter implant. The study already presented a surprising fact; pressure measurements showed that the anorectal sphincter pressure among men could amount to 156mmHg when squeezed versus 77mmHg for women. This recently discovered fact is of great importance for the production of future implants.
- Moritz Thielen (pictured) presented his BioFlex project, which addresses a new generation of electrodes that do not need conductive gels to work properly. New conductive nanostructures in flexible substrates compare with standard wet electrodes for electrocardiography as supported by tests in laboratory.


- BonePro focused on a mathematical model of the electrical properties of the mastoid, the bony structure behind the ear, for the creation of a new and safe surgical procedure which consists of drilling a narrow tunnel to the cochlea for placement of a cochlear implant. This rigorously precise surgical operation is going to be more extensively described later in these lines.
- LightProbe, presented by Pascal Hager (pictured), proposed a new type of portable system for ultrasonography for use in places where size, cost and flexibility matter, like in emergency cases or in rural areas for medical use or during inspections of pipes and channeling infrastructures for industrial use. This new ultrasonograph includes its piezoarray, its ultrasound pulses emitter as well as its processing module packed together in the same hand-holdable body. In addition to this, the user can have access to the raw data stream thanks to a fully open development platform.


- NerveSafe developed a neuromonitoring drill for robotic cochlear implantation. The challenge in the new surgical operation for cochlear implants is to be able to drill through the mastoid without touching or damaging the facial nerve. This highly delicate operation currently needs the insertion of a multi-electrode probe in order to test the proximity to the facial nerve. The idea here is to include stimulating electrodes inside the surgical drill in order to reduce the time consuming and complex procedure of drill-test-drill by an all-in-one procedure.

- SolCelMeas, established a series of tests to measure the efficiency of gallium arsenide vertical nanowires solar cells for the production of ultrathin and highly flexible equipment. These tests gave some indications for low efficiency reasons that could be compensated by introducing an AlGaAs (aluminium gallium arsenide) capping layer.
- With her MultiHaptic project, Huaiqi Huang exposed a way for amputees to get tactile feedback by embedding miniaturized pressure sensors in a glove and wirelessly transmit the information to the patient so that he or she can feel what the prosthesis is holding in its artificial hand. The main idea is to combine two kinds of haptic receptors, pressure and vibration, and generate a third kind of sensory receptor for more precise feedback.

## Key statement 10

Nano-Tera.ch has encouraged stronger **entrepreneurial spirit** in the community of PhD students involved in the program.

## NEXTSTEP PROGRAM FOR PHD STUDENTS: TRACK 2 – ENTREPRENEURSHIP TRACK

### GOAL

A survey of the Nano-Tera PhD students who were involved in the program during its earlier phase (2009-2013) has shown that only about 40% of PhD students stayed in academic research, while the other 60% have moved on to the industry or other activities. It is therefore important for them to think as early as possible about their next steps, in particular to consider how to exploit the experiences gained in their PhD work for future professional activities outside of academia.

This is the purpose of Track 2 of the NextStep program. It allows them to interact with experts and coaches in entrepreneurship, in order to learn how to

- describe the skills they have acquired in an efficient way for potential future industrial contacts ("elevator pitches").
- develop ideas on how to economically exploit their thesis results and skills for goals such as licensing or startup creation.

Concretely, NextStep gives them the possibility to follow a coaching program to elaborate their own business idea and present it to a real investor panel to seek funds. For example, they were given the opportunity to dry run a pitch, with the possibility to win a trip to a high impact event such as CeBit or CES.

The **NextStep** program, **Entrepreneurship Track** was set up as a "Coaching Program & Support for participation to High Impact Events" to develop an early-stage entrepreneurial mindset, to help PhDs explore how to generate economic value from research results, how to identify market opportunities and how to transform an idea into business. Out of about 150 PhD students who were active at the time, 31 were interested, 15 benefited from support, 4 business ideas went to an Impact Event and 3 startups were created (end of 2016) out of 4 created in total! This corresponds to one of the shortcomings ("lack of entrepreneurial spirit", see KOF survey 2011) mentioned by the Swiss companies.

### TIMELINE

The entrepreneurship track also consisted of 4 modules, with a first one taking place in March 2015: this track introduced the students to the ideas of business development and helped them think of their own ideas that they can safely test run.

The second module took place during the 2015 Nano-Tera Annual Meeting, giving participants the possibility to present their initial business ideas (Track 2) to a panel of experts composed of Nano-Tera Executive Committee members and scientists. Following their pitch, the PhD students involved in Track 2 have been awarded a grant to attend an impact event or their choice.

These pitches cover interesting ideas on a variety of topics: in a third stage of the program, the students involved have received mentoring support (two workshops and monthly personalized coaching) in order to help develop and refine their business project.

In addition, Nano-Tera has offered other actions open to all PhD students interested, consisting of:

- 6 coaching sessions (30 min each), from October 2015 to February 2016, to work on the business case
- 2 half day workshops (Sept. 2015 and January 2016) to support the project development, prepare the presentation, etc.
- selection of existing entrepreneurial contests in the Swiss ecosystem, to participate
- among all groups having submitted a project to the Swiss ecosystem, 3 have been selected tol present at the 2016 Annual Meeting

Finally, the last module took place at the Nano-Tera Annual Meeting 2016, where Track 2 participants got the opportunity to make a business pitch in front of the whole Nano-Tera.ch audience.

### THE BUSINESS IDEAS

The ideas developed by the students are summarized below:

| Name | NT Project | Idea title | Key concepts |
|---|---|---|---|
| Alevtina Dubovitskaya, EPFL | ISyPeM II | EzeCHiel | Attaining personalized medicine. Prediction engin (Bayesian approach). Ergonomic software. |
| Arthur Hirsch, Hadrien Michaud, EPFL | SpineRepair WiseSkin | Wearable sensing devices | B2B technological solution. Wearable electronics: conformal, light-weight and unnoticeable to maximize users comfort and acceptance. |
| Federico Matteini, EPFL | Synergy | Solstice | Solar wearable devices: better performance, flexible batteries. |
| Saurabh Tembhurne, Meng Lin, EPFL | SHINE | SoHHytex | Solar Fuel. On site H2 production system – cost effective, cleaner and greener. |

As mentioned, the final step of the program took place at the 2016 Nano-Tera annual meeting. At that final event, three finalists were invited to defend their entrepreneurship project in front of the Nano-Tera community and of a panel of experts. Instead of a show of hands, the audience was encouraged to vote by SMS and see the progression of the result live on screen.

- Arthur Hirsch and Hadrien Michaud started the NextStep entrepreneurship session by presenting their project Feeltronix of soft bioelectronic interfaces that could equip a wide variety of wearables and body devices such as watch bracelets or a headband for sleep monitoring.



- Federico Matteini then presented his Solstice project of solar energy collection through vertical nanowires instead of the classical planar solar panels. Nanowires offer the great advantage of reducing the amount of materials used for the construction of solar panels by a factor of one thousand. Which means that for the same energy production a solar panel could weigh a few grams instead of several kilograms and could be as flexible and soft as plastic foil.


- Saurabh Tembhurne closed the chapter by presenting his SoHHytec business project for the production of cleaner and greener hydrogen for fertiliser industries and in the residential sector. Today 95% of H2 production comes from off-site and non-renewable facilities. SoHHytec proposes to use a mix of solar energy and grid electricity to produce H2 , using an integrated photoelectrochemical device. This system is not only cleaner, but cheaper, since one kilogram of H2 would cost US$1.69 only instead of today's US$2 or more.


The audience vote went for the SolStice project and the SoHHytec project was awarded by the experts.

# IV.4 KEY STATEMENTS RELATED TO ECONOMIC IMPACT

| Key statement 11 |
|---|
| Nano-Tera.ch has fostered research with **high economic potential**. |

### NUMBER OF PATENTS

In total, at end of 2016, 67 patents were filed on results stemming from Nano-Tera.ch projects. The distribution of these patents over the various project types is provided in the table below.

| Phase | Type | Nb. Projects | Nb. Patents |
|---|---|---|---|
| 1 | RTD | 19 | **28** |
| 1 | RTD-ADD-ON | 8 | **1** |
| 1 | NTF | 15 | **3** |
| 2 | RTD | 25 | **34** |
| 2 | GTW | 8 | **0** |
| 2 | NTF | 9 | **1** |
| | **Total** | **84** | **67** |

*Table 8. Statistics of Patents.*

### NUMBER OF STARTUPS/CTI PROJECTS

In total at the end of 2016:

- 10 startups resulted from Nano-Tera.ch (out of which 4 were under creation at the time of this report)
- 9 CTI follow-up projects have been approved.

The distribution of these start-ups/CTI projects over the Nano-Tera.ch projects is provided in the table below.

| | Startups created | Startups being created | Approved CTI projects |
|---|---|---|---|
| BodyPoweredSenSE | 1 | 1 | |
| Envirobot | | | |
| FlusiTex | | | 2 |
| HearRestore + HearRestoreGate | | | 5 |
| HeatReserves | | | |
| IcySoC | | | |
| IrSens II | 2 | | |
| ISyPeM II | 1 | | 1 |
| MagnetoTheranostics | | | |
| MIXSEL II | | 1 | |
| NewbornCare | | | |
| ObeSense | | | |
| OpenSense II | | | |
| PATLiSci II | | 1 | |
| SHINE | | 1 | |
| SmartGrid | 1 | | 1 |
| SmartSphincter | | | |
| SpineRepair | | | |
| Synergy + SynergyGate | | | |
| UltraSoundToGo | | | |
| WearableMRI | | | |
| WearMeSoC | | | |
| WiseSkin | | | |
| X-Sense II | 1 | | |
| YINS | | | |
| Total | **6** | **4** | **9** |

*Table 9. Statistics of startups and CTI projects.*

## Economic potential resulting from the involvement of Industrial Partners and End Users

The presence of industrial partners and end-users (e.g. hospitals) has been strongly recommended in all Nano-Tera.ch RTD calls and made mandatory ("must meet" criterion) for Nano-Tera.ch Phase 2 RTD and Gateway projects.

As a consequence, all RTD and Gateway projects receive support in the form of matching fund from various industrial partners and/or end-users. In total, 103 such partners have been involved, and provided a total of 18.2 million CHF of matching funds (see the two tables below).

| Type | Role | RTD | GTW | Total |
|---|---|---|---|---|
| Industry | Partner | 13 | 0 | 13 |
| | 3rd Party | 44 | 14 | 58 |
| End user | Partner | 25 | 0 | 25 |
| | 3rd Party | 7 | 0 | 7 |
| **Total** | | **89** | **14** | **103** |

| Type | Role | RTD | GTW | Total |
|---|---|---|---|---|
| Industry | Partner | 2 930 340 | 0 | 2 930 340 |
| | 3rd Party | 5 969 122 | 1 456 840 | 7 425 962 |
| End user | Partner | 6 963 303 | 0 | 6 963 303 |
| | 3rd Party | 845 500 | 0 | 845 500 |
| **Total** | | **16 708 266** | **1 456 840** | **18 165 106** |

*Table 10. Involvement of industrial partners and end-users.*

Furthermore, the RTD project consortia consisted on average of 57% of research partners, 31% of industrial and translational partners, and 12% of end-users.

Such a presence of industrial partners and end-users, combined with the long duration of the RTD projects, represents a strong economic potential for the program. Indeed, with adequate partner profiles, the projects can valuably contribute to Knowledge and Technology Transfer by playing the role of an information exchange platform, with various project consortium level meetings and events leading to numerous formal and informal contacts between partners. In particular, it allows the industrial partners to be well informed about new technologies, to evaluate the associated business potential, to estimate the consequences that these technologies may have on the existing production lines, to identify possible normative and regulatory issues, etc. In short, by participating in RTD projects, industrial partners increase their capacity to absorb research results and thus get ready to initiate "market pull" actions, such as participating in the production of system demonstrators.

Notice that this type of KTT (formal and informal information exchange) has been identified as the preferred transfer channel by more than 60% of the Swiss Industry active in KTT (see KOF Knowledge and Technology Transfer Survey 2011).

In addition, the KTT potential resulting from the presence of industrial partners in RTD project is further strengthened by the fact that the technologies and applicative areas in which Nano-Tera.ch has been focusing ("Environmental technologies", "New materials", "Energy technologies", "Medical technologies") strongly overlap the ones considered as most critical by the Swiss industry (see the KOF Knowledge and Technology Transfer Survey 2011 in which the afore mentioned technologies are ranked n°2, n°3, n°4 and n°7 respectively in the list of most critical technologies resulting from the survey of the Swiss industry).

## Economic potential resulting from the training of PhD students

One of the important economic impacts of the Nano-Tera.ch program is the training of the substantial number of PhD students who pursue their activity in the industry. This responds to strong demand from Swiss companies who consider the lack of qualified staff as a deficiency (see KOF Knowledge and Technology Transfer Survey 2011). This integration of Nano-Tera.ch PhD students into Swiss companies also has the advantage of increasing the ability of companies to interact with researchers and thus absorb the research results.

In order to evaluate this aspect, Nano-Tera.ch has surveyed all the PhD students involved in the program to know what they were doing after completing their PhD. Among the 308 students who replied the survey, 7 were unemployed and 93 were still working on their PhD at the time. Among the 208 others, 126 were working in the industry (61%), while 82 were pursuing a career in academia (49%). In addition, about 75% of the students working in the industry did so in Switzerland, while 57% of students working in academia stayed in Switzerland.

The detail of the various PhD distributions is given below.

| Occupation | Number | Switzerland | Abroad |
|---|---|---|---|
| Academia | 82 | 47 | 35 |
| Industry | 126 | 95 | 31 |
| Still PhD student | 93 | | |
| Unemployed | 7 | | |
| **Total who replied** | **308** | | |

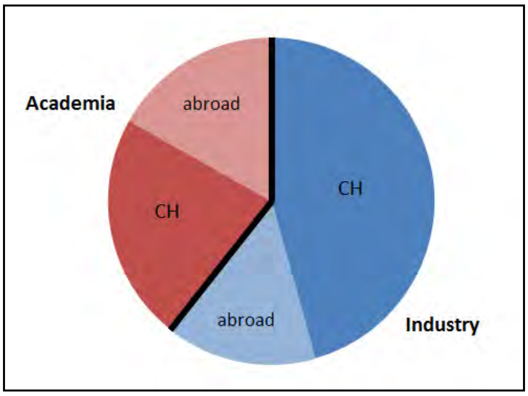



*Figure 35. Distribution of PhD students working in academia or in the industry.*

Among students working in the industry, the breakdown by size of company (below) shows that about 60% of them work in large companies (with 200 employees or more).

| Type of company | Number |
|---|---|
| Micro(1-10) | 22 |
| Small(11-50) | 16 |
| Medium(51-200) | 13 |
| Large(200+) | 75 |
| **Total Industry** | **126** |

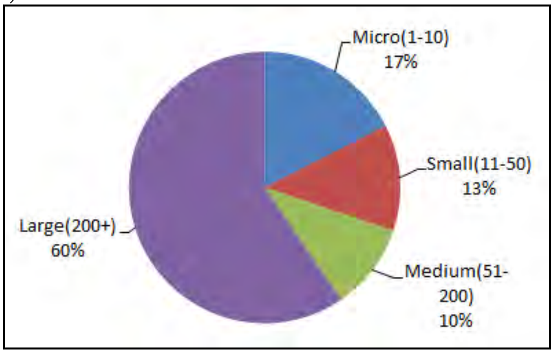



*Figure 36. Distribution of the PhD students working in the industry by size of company.*

In addition, the coaching provided in the Entrepreneurship Track of the NextStep program helps several Nano-Tera.ch PhD students develop an early-stage entrepreneurial mindset by making them explore how to generate economic value from research results, identify market opportunities and transform an idea into business. four business ideas have been presented at an Impact Event and three startups were created (end of 2016).

### Economic potential resulting from the Production of exploitable Demonstrators/platforms

To evaluate the economic potential of the achievements generated in the program, Nano-Tera.ch hired an external consultant to analyze the main outputs of Phase 2 RTD and Gateway projects. In this analysis, the outputs have been first categorized as:

- **Demonstrators** focused on specific use cases and integrating the required technologies.
- **Platforms** consisting of larger sets of integrated technologies and functionalities. Such platforms encourage the involvement of a diversity of partners and promote interaction, facilitate the sharing of scientific knowledge and application expertise.

Second, the identified demonstrators and platforms have been further characterized in terms of marketability (expressed in terms of expected time to market – TTM – where lower TTM corresponds to higher marketability) and technology readiness (expressed in terms of technology readiness levels – TRL – where higher TRL identify results closer to industrialization, see Appendix B for details).

The results of the categorization are provided in the table below for the 25 Phase 2 RTD projects and the 4 Gateway projects running at the time of the analysis:

| | Demonstrators / Platforms | | |
|---|---|---|---|
| | **TRL4** | **TRL5** | **TRL6** |
| BodyPoweredSenSE | >2023 | | |
| Envirobot | | >2023 | |
| FlusiTex + FlusiGate | 2020-23 | | 2017-20 |
| HearRestore + HearRestoreGate | | | 2017-20 |
| HeatReserves | 2020-23 | | |
| IcySoC | 2020-23 | | |
| IrSens II | 2017-20 | | 2020-23 |
| ISyPeM II | | 2020-23 | |
| MagnetoTheranostics | >2023 | | |
| MIXSEL II | **2x** 2020-23 | | |
| NewbornCare | | 2017-20 | |
| ObeSense | 2020-23 | | 2017-20 |
| OpenSense II | | | 2017-20 |
| PATLiSci II | 2020-23 | | |
| SHINE | | | 2020-23 |
| SmartGrid | | | 2020-23 |
| SmartSphincter | >2023 | | |
| SpineRepair | >2023 | | |
| Synergy + SynergyGate | | | **2x** 2017-20 |
| UltraSoundToGo | | 2020-23 | |
| WearableMRI | >2023 | | |
| WearMeSoC | | 2020-23 | |
| WiseSkin | >2023 | | |
| X-Sense II | | | **2x** 2017-20 |
| YINS | | | 2017-20 |
| **Total: 31 demonstrators & platforms** | **10 + 4** | **3 + 2** | **12** |

*Table 11. Statistics of demonstrators and platforms.*

The analysis shows that important fraction (56%) of the Phase 2 RTD projects have led to highly exploitable results (15 demonstrators and 2 platforms in technology readiness level of 5 or above) and clearly substantiates the fact that, by encouraging the creation of research results with a high potential to be rapidly transformed into products (estimated time to market in 2017-2023), Nano-Tera.ch was able to create favourable conditions for Knowledge and Technology Transfer, thus increasing its economic potential.

## ECONOMIC POTENTIAL RESULTING FROM NOVEL FUNDING MECHANISMS

### The Gateway program

Gateway, the Nano-Tera.ch program focusing on innovation stemming from "on the edge research" (see the Key Statement 12 for a detailed description), demonstrated a strong potential for Knowledge and Technology Transfer.

First, the Gateway program led to project consortia with a substantially stronger presence of industrial partners, which, as mentioned above, further increases the potential for Knowledge Transfer.

Second, the Gateway program strongly channeled the activities performed in the projects on increasing the industrial exploitability of research results, thus accelerating the production of demonstrators directly exploitable by the industry, and thus also contributed to Technology Transfer. Altogether, at the end of the first wave of Gateway projects, 5 demonstrators were produced: one with Technology Readiness Level 4 (TRL4), 2 with TRL5 and 2 with TRL6 (the definition of the various TRLs is given in Appendix B).

Notice that the above mentioned activity channelling has been achieved by excluding the research activities from the ones eligible for funding, which was a necessary measure, as illustrated by the following comparison between the Gateway projects and the Phase 1 RTD Add-On extensions:

- In the Phase 1 RTD Add-On extension (for which no specific constraints had been imposed in the call on the eligible activities), 78% of the allocated budgets went to research partners, 7% to the translational partners, and 1% to end users; while
- In the Phase 2 Gateway projects, 94% of the allocated budgets went to translational partners (CSEM and Empa) and only 6% to research partners.

### The Industrial Valorization Fund (IVF)

In 2014, Nano-Tera.ch decided to set up a funding framework, specifically dedicated to technology transfer with the objectives to strengthen industrial valorization. This is the Industrial Valorization Fund, jointly managed with Nano-Tera.ch and the Tech Transfer Office of EPFL. The eligibility conditions imposed to proposals for this program have been defined as follows:

- The requested funds should be exclusively used to cover the specific actions required to acquire a suitable industrial partner (market study, conversion of a lab prototype into an industrial demonstrator, etc.); in particular, these funds could not be used to finance the patenting procedure itself
- The application is indicated as generated in the framework of a Nano-Tera.ch RTD project
- The application must be linked to an Invention Disclosure; an initial patent application ("priority application") is filed
- The decision for funding shall be taken by a committee composed through Nano-Tera.ch and EPF Tech Transfer Office representatives
- The funds requested should be allocated on an overall 1-to-1 matching basis, i.e. the global funding provided by the EPF TTO should be (at least) equivalent to the funding provided by the Nano-Tera.ch Industrial Valorization Fund
- The cumulated funds should not exceed 60 KCHF.

Within this framework, Nano-Tera.ch supported 4 industrial valorization actions with promising the Knowledge and Technology Transfer perspectives:

- Fastree3D (laser based 3D cameras, low cost and low power consumption): Fastree3D is very promising: in the top 25 Swiss Startup 2015, awarded Venturekick III, named among top 15 startups at SPIE Photonics West, Top 10 transportation startup at Verizon Powerful Answers 2014, etc.
- IVF_Mixsel (production of high power optically pumped lasers at 1300/650 nm): RTI-Research S.A. at Y-park in Yverdon has invested more than one million CHF in modern wafer bonding equipment and related infrastructure to produce wafer-fused vertical cavity laser structures on 2-inch and 3-inch wafers.
- IVF_SoHHytec (onsite cost effective hydrogen and power generation systems): IVF_SoHHytec was able to attract its first customers for two products including industries like GNFC, MRF and government entities like HOPCOMs and Goa State pollution control board in India. A startup was found in April 2015.
- FixPosition (real-time dynamic GNSS algorithm). The Industrialization Valorization action started May 2017.

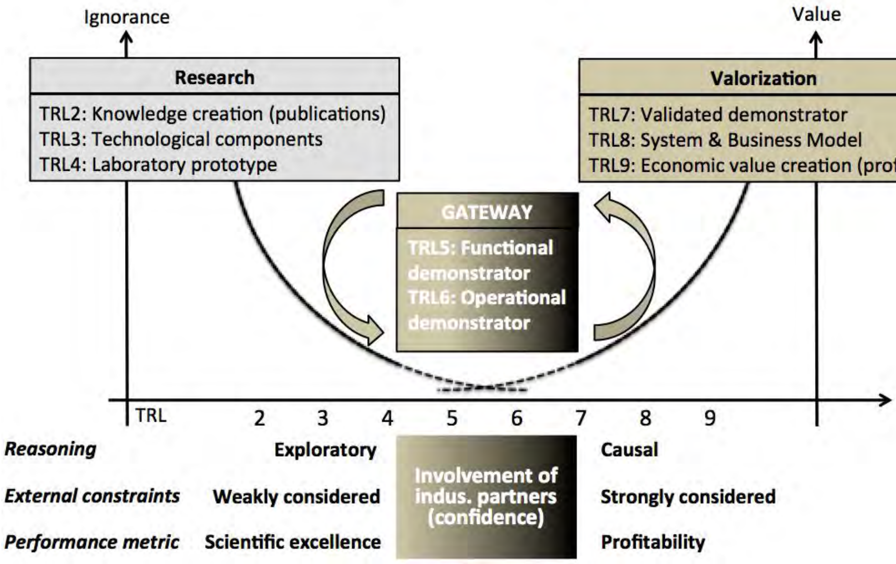
## Key statement 12

Nano-Tera.ch has deployed a novel pilot funding instrument (the "Gateway" program) **efficiently combining support for research and innovation** and integrating an appropriate **monitoring mechanism**

### THE GATEWAY PROGRAM

In 2015, at the mid-term of Phase 2, the Nano-Tera.ch ExCom decided to use a fraction of the Strategic funds to launch a new funding instrument, the Gateway program, intrinsically positioned at the frontier between research and innovation, to explore new approaches to transform results from forefront research into economic value, with the objective to further increase the Knowledge and Technology Transfer potential of the Nano-Tera.ch program.

The main ambition of the Gateway program was to support the translation of research results obtained within Nano-Tera.ch RTD or NTF projects (typically research prototypes at Technology Readiness Level, or TRL, 4 or 5; a more precise description of the TRLs is provided in Appendix B) into operational industrial demonstrators, tested in relevant environments (i.e. at TRL 6), and directly exploitable by the involved industrial partners. This ambition has been implemented by providing funding for a new type of projects, the "Gateway projects" (often referred to in this report as GTW projects), the positioning of which is illustrated in the following diagram, which summarizes the main aspects to be considered when transiting from research prototypes to operational industrial demonstrators.




One of the evident characteristics of this type of transfer is the change it requires in the definitions of the overall objectives of the funded activities. While a research project intrinsically aims at creating new knowledge (thus the "Ignorance reducing" trajectory in the above diagram), economic exploitation naturally focuses on generating economic value (thus the "Value increasing" trajectory in the diagram).

However, the targeted transfer further entails additional changes on several important dimensions. One concerns the quality metrics to be used to quantify progress, with novelty and research excellence indicators being progressively replaced by exploitability and profitability measures. Another dimension is the way of reasoning about expected results, with very exploratory approaches focused on feasibility proofs being progressively replaced by a more causal logic, driven by the targeted applications and the associated external constraints.

In short, a Gateway project is a transition between two very different worlds. It thus requires the involvement of a specific partner, explicitly responsible for the transfer, in addition to the researchers providing the research results/prototypes and the industrial partners potentially interested in their exploitation. These specific partners (also called translational partners in this report) are typically industry-oriented research institutions specialized in technology transfer, such as the Centre Suisse d'Electronique et de Microtechnique (CSEM), or the Swiss Federal Laboratories for Materials Science and Technology (Empa).

Finally, it is also important to notice that the deployment of Gateway projects also required the creation of a new monitoring mechanism, better adapted to the specificities of these projects. This monitoring mechanism is described in the Key Statement 19.

## Implementation

To implement the Gateway program, Nano-Tera.ch proceeded in two steps.

First, Nano-Tera.ch joint forces with CSEM and Empa to analyze the running RTD projects and identify the most suitable ones for benefitting from a Gateway extension. Criteria such as the availability of a promising research prototype, the presence of interested industrial partners, or the perspective of a convincing market potential have been considered and discussed with the partners of the RTD projects. The resulting proposals have been evaluated by a jury consisting of representatives of Nano-Tera.ch, CSEM and Empa, and, as a result, 4 pilot Gateway projects have been selected and launched in November 2015, for a planned duration of 18 months.

The launched projects respectively focused on the following technology transfer objective:

- The Flusigate project aimed at transferring to the involved industrial partners specialized in smart textiles and biosensors of a prototype of novel wound pad integrating the non-invasive monitoring of the wound healing process based on indicator dyes and fluorescence lifetime imaging (FLIM), developed in the FlusiTex RTD project.
- The Syngate project, associated to the Synergy RTD project, targeted two main demonstrator transfers: (1) the transfer to the involved industrial partners (Meyer Burger and Solaronix) of prototype high performance encapsulated perovskite/Si heterojunction tandem cell, with an active area of 4x4cm2, full metallization and external contacts; and (2) the transfer to the involved industrial partner (Flisom) of a demonstrator implementing a perovskite solar module on a 5x5cm2 flexible and transparent substrate with external contacts.
- The Heargate project, associated with the HearRestore RTD project, aimed at providing a highly precise and accurate tracking system for minimally invasive microsurgery (in particular cochlear implants); the transfer to the involved industrial partners (Atracsys) led to the currently smallest surgical tracking device when compared to the state-of-the-art, with a highly improved accuracy of the 6D position and a reduced distance of the tracking device to the operating site.
- The Paragate project, associated with the ParaTex NTF project, : The "ParaTex" project aimed at developing textile sensors for long-term pressure monitoring (typically for patients lying in hospitals), and targeted the transfer of a lab-scale prototype based on textiles integrating polymer optical fibers (POFs) will be a very good alternative for long-term monitoring of such patients.

Based on the experience gained within this first pilot action, an official Gateway call has been launched in July 2016, with the following eligibility conditions:

- The main applicant for a Gateway extension must be a PI or Co-PI with a strong record in technology transfer, involved in a running RTD or NTF project.
- The Gateway extension must involve an industrial partner able to efficiently support the transfer of the research results achieved within the associated RTD project into activities with high economic potential.
- The Gateway extension is restricted to the funding of activities aimed at increasing the industrial exploitability of research results and therefore should not fund any additional research.
- The Gateway extension must be relatively short, with typical durations from 12 to (max) 18 months.

The 11 received submission have been evaluated by a selection committee specifically set up for the Gateway call, and consisting of 4 external members:

- Sophie Pellat, associate partner of the investment fund IT translation;
- Olivier Picard, Senior Manager in Altran Prisme, a consulting company specialized in support for the creation and development of startups;
- Thomas Ernst, senior researcher at CEA Tech, France;
- Jan Madsen, professor at the Technical University of Denmark.

The evaluation consisted of 3 phases:

1. Each panel member was assigned 6 proposals to review, with an evaluation form including 9 specific quality metrics;
2. The full selection committee met at EPFL for a one day « consolidation meeting » resulting in a recommendation to the Nano-Tera.ch Executive Committee in the form of a consolidated ranked list of the submitted proposals;
3. Based on the received recommendation, the Nano-Tera Executive Committee decided to accept and fund the top 4 submissions, respectively associated with the RTD projects IrSensII, ObeSense, and FlusiTex, and with the NTF project Nambp.

The 4 Gateway projects have then been launched in November 2016, with a planned duration of 12 months.

## Key statement 13

Nano-Tera.ch has fostered **user-centric research**
with an early involvement of field practitioners through field tests, clinical studies, etc.

### Nano-Tera.ch Positioning

Two of the Nano-Tera.ch strategic objectives, namely:

- The decision to focus on technologies aiming at improving the quality and security of health and environment systems in Switzerland; and
- The decision to embody the research outcomes into prototypes, acting both as demonstrators and technology drivers;

clearly had a strong impact on the ability of the program to foster user-centric approaches.

The combination of concrete technological goals (the demonstrators) with socially relevant application areas made it indeed possible for potential end users to envision and propose concrete applications for the targeted research, and thus strongly encouraged them to participate in Nano-Tera.ch projects.

### Exploiting the eligibility conditions

While the participation of end-users was strongly recommended in Nano-Tera.ch Phase 1 RTD calls, it has been made for all Nano-Tera.ch Phase 2 RTD projects. This decision led to the set-up of RTD project consortia including on the average 12% end-users, which further strengthened the targeted user-centric approach.

### Benefiting from the convergence of engineering and medicine/Life sciences

In the second phase of the program, many of the funded research projects were exploring topics combining engineering with life sciences or medicine (e.g., projects on smart prosthetics and body repair, or projects focusing on various health monitoring systems, or innovative medical platforms).

In consequence, the project consortia truly needed expertise of partners from the health domain to be able to achieve their research objectives. This translated into the participation in the RTD projects of a large number of hospitals (CHUV, HUG, UZH, Inselspital, Kinderspital, etc.), who played an important role in the specification of precise applicative goals for the research, and for the validation of the achieved results (e.g. by conducting clinical tests or through the deployment of concrete prototypes in clinical environments).

### Examples

IST (Institut de Santé au Travail) is the only institute in Switzerland devoted entirely to Occupational Health: the OpenSense II project has benefitted from IST's Particles and Health Group, whose team provided considerable experience in the assessment of personal and population exposure to ambient and industrial fine and ultrafine particles, noise, gaseous co-pollutants.

IST
Institut universitaire romand de Santé au Travail

INSELSPITAL
UNIVERSITÄTSSPITAL BERN
HÔPITAL UNIVERSITAIRE DE BERNE

The InselSpital in Bern is involved in the Phase II RTD projects HearRestore, MagnetoTheranostics and SmartSphincter. In particular, the Department of Ear, Nose and Throat Surgery, actively involved in HearRestore, is one of the early adopters of computer assisted and image-guided procedures around the head. Early work in the field dates back to 1995, when some of the first of such interventions were carried out. Today, the department's research focuses on the advancement of technologies towards a combination with the latest developments in hearing aid technology and physiological measurements.

The University Hospital of Zurich (USZ) is involved in the Phase II RTD projects NewbornCare, ObeSense and WearMeSoC. In particular, at the Division of Neonatology, the head of the Biomedical Optics Research Laboratory and the head of Clinical Research provide their combined expertise in neonatal intensive care medicine, lung physiology, intelligent data analysis, quantitative measurements of tissue composition, oxygenation and perfusion to the NewbornCare project.

UniversityHospital
Zurich

**Key statement 14**

Nano-Tera.ch has contributed to the **dissemination of the scientific results achieved** to the Swiss industry

## INFO DAYS

Nano-Tera.ch organized information days for industrial players in March 2014. In the perspective of technology transfer toward the industry, the objective of the information sessions was to present the industrial potential of some of the projects financed in the period 2008-2012. The presentations have been followed by an interaction with the participants in order to discuss the various possibilities for industrial involvement in the program. Nano-Tera.ch decided to focus on "Sensors of tomorrow" because Switzerland (both in German-speaking and French-speaking parts) has a strong industry of sensors and measuring instruments, made up of many SMEs.

The first Info Day session was held on March 12th in Yverdon with presentations in French from 6 Co-PIs. There were **86 participants** from various companies, ranging from Logitech to Piaget.


The second Info Day was held on March 25th in Zurich with presentations in German from the same 6 projects and mostly different Co-PIs. There were **48 participants** from various companies, including ABB, Alstom or Phonak.


*Figure 37. General introductory video on Nano-Tera.ch (left); Dr. Harry Heinzelmann presenting the PATLiSci project (right).*


*Figure 38. Prof. Karl Aberer pretenting OpenSense (left), Prof. Gerhard Tröster presenting TecInTex (right).*

Based on the observation that several Nano-Tera.ch projects address medical problems, Nano-Tera.ch decided to provide research teams with information on regulatory constraints (at what time in the project and how to address them), also to facilitate the transfer of technology. This "Medical Technology Regulations" Info Day took place on February 5th 2015; it presented an overview of the medical regulations, notifying bodies and competent authorities (Swissmedic, etc.) to the researchers. It also helped in classifying the research activity according to applicable regulations (well-being, diagnostics, treatment, implants, etc.), and explaining at what time in the project the regulations apply, and how to address them. The 89 participants represented all the partner institutions of Nano-Ter.ch (ETHZ, EPFL, CSEM, Empa, Universities, HES-SO, etc).

Thus, as explained above, Nano-Tera.ch has combined "Techno push" (such as PhD training and their transition in the industry or the production of enabling technologies or the "Sensors of tomorrow" Info Days) and "Market pull" (such as the production of demonstrators or the "Medical technology regulations" Info Day) approaches in order to increase the Knowledge and Technology Transfer.

# IV.5 KEY STATEMENTS RELATED TO SOCIETAL IMPACT

**Key statement 15**

Nano-Tera.ch has contributed to steering the research funded toward **current social needs** (health, environment, energy, etc.)

## APPROACH

Four nationwide sources of data and information have been identified, which address current social needs, trends or concerns over the period 2008-2016:

- The media are the vehicle of the populations' centres of interest and worries. Swissdox is a Swiss media database listing any article published in 243 different magazines, newspaper, web portals, news agencies, etc.
- The Credit Suisse Worry Barometer/gfs Institute is a nationwide survey which has been gathering information about the mood and the worries of the Swiss population since 1976.
- Curia Vista is the mirror image of Swissdox but from the parliamentary proceedings point of view, where any Federal Council dispatches, procedural requests, elections, petitions, etc. are listed. The members of the parliament pay close attention to what the voters are concerned about or foresee the major changes the society will face in the future
- Public spending: as an echo of parliamentary proceedings, did the concerned federal offices invest funds in the fields of health, energy and environment?

## CURRENT SOCIAL NEEDS INFERRED FROM THE MEDIA

We selected the most popular Swiss daily and week-end newspapers (18 in total), covering the French and German-speaking part (see "Sources" below for more details). The service provided by Swissdox allows users to search by channel (newspaper, website), by year and by keywords. The 3 criteria were combined. Key words – related to the various projects – were chosen in English, French and German, with the caveat that some keywords are not easily translated into French or German (such as "wearables" or "e-health"). The table below shows the number of articles published in a given year including certain keywords that are representative of Nano-Tera research interests.

| | Keyword | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| HEALTH | cancer treatment | 596 | 583 | 693 | 593 | 734 | 859 | 709 | 820 | 1'052 | 6'639 |
| | intelligent sensors | 194 | 217 | 247 | 287 | 344 | 521 | 875 | 869 | 1'102 | 4'656 |
| | advanced diagnosis | 412 | 446 | 216 | 209 | 271 | 274 | 264 | 332 | 349 | 2'773 |
| | life sciences applications | 220 | 221 | 201 | 210 | 233 | 197 | 250 | 298 | 346 | 2'176 |
| | sensors health | 177 | 164 | 115 | 108 | 205 | 236 | 363 | 364 | 418 | 2'150 |
| | personalized medicine | 73 | 91 | 136 | 183 | 193 | 220 | 198 | 276 | 273 | 1'643 |
| | wearables | 0 | 1 | 0 | 3 | 5 | 19 | 269 | 340 | 349 | 986 |
| | connected health | 69 | 56 | 64 | 81 | 99 | 117 | 139 | 104 | 174 | 903 |
| | e-health | 51 | 78 | 94 | 73 | 71 | 44 | 60 | 135 | 118 | 724 |
| | Total Health | 1'792 | 1'857 | 1'766 | 1'747 | 2'155 | 2'487 | 3'127 | 3'538 | 4'181 | 22'650 |
| ENERGY | renewable energy policy | 5'203 | 5'534 | 5'174 | 9'600 | 6'544 | 6'332 | 5'433 | 5'720 | 6'374 | 55'914 |
| | nuclear energy | 2'258 | 1'907 | 1'805 | 7'865 | 3'535 | 2'199 | 2'007 | 2'278 | 3'567 | 27'421 |
| | solar hydrogen energy | 2'342 | 2'561 | 2'641 | 3'279 | 2'993 | 2'730 | 2'347 | 3'052 | 3'160 | 25'105 |
| | fossil fuels | 2'302 | 2'154 | 1'832 | 2'488 | 2'031 | 2'013 | 1'931 | 2'768 | 2'762 | 20'281 |
| | photovoltaic solar energy | 426 | 556 | 1'500 | 782 | 746 | 545 | 466 | 527 | 605 | 6'153 |
| | smart grid | 12 | 88 | 189 | 278 | 245 | 233 | 140 | 142 | 140 | 1'467 |
| | Total Energy | 12'543 | 12'800 | 13'141 | 24'292 | 16'094 | 14'052 | 12'324 | 14'487 | 16'608 | 136'341 |
| ENVIRONMENT | environment energy | 5'945 | 5'531 | 2'515 | 2'690 | 2'436 | 1'972 | 1'731 | 1'899 | 1'684 | 26'403 |
| | environment protection | 2'700 | 2'494 | 1'842 | 1'750 | 1'748 | 1'593 | 1'616 | 1'606 | 1'580 | 16'929 |
| | global warming | 852 | 1'156 | 777 | 640 | 616 | 603 | 524 | 1'019 | 1'821 | 8'008 |
| | water pollution | 353 | 277 | 350 | 338 | 362 | 295 | 369 | 422 | 404 | 3'170 |
| | water quality control | 319 | 290 | 306 | 217 | 262 | 266 | 255 | 291 | 239 | 2'445 |
| | quality water air | 235 | 219 | 221 | 233 | 225 | 210 | 224 | 242 | 247 | 2'056 |
| | Total Environment | 10'404 | 9'967 | 6'011 | 5'868 | 5'649 | 4'939 | 4'719 | 5'479 | 5'975 | 59'011 |
| | **Total Nano-Tera issues** | **24'739** | **24'624** | **20'918** | **31'907** | **23'898** | **21'478** | **20'170** | **23'504** | **26'764** | **218'002** |
| | **Total articles published** | **560'253** | **597'634** | **603'512** | **598'550** | **596'908** | **589'613** | **566'978** | **530'685** | **504'528** | **5'148'661** |

*Table 12. Number of articles published in a given year including certain keywords that are representative of Nano-Tera research interests.*

The proportion of all articles published per year in each category is shown below, along with the corresponding graphs showing the prevalence of each keyword for the three Nano-Tera domains.

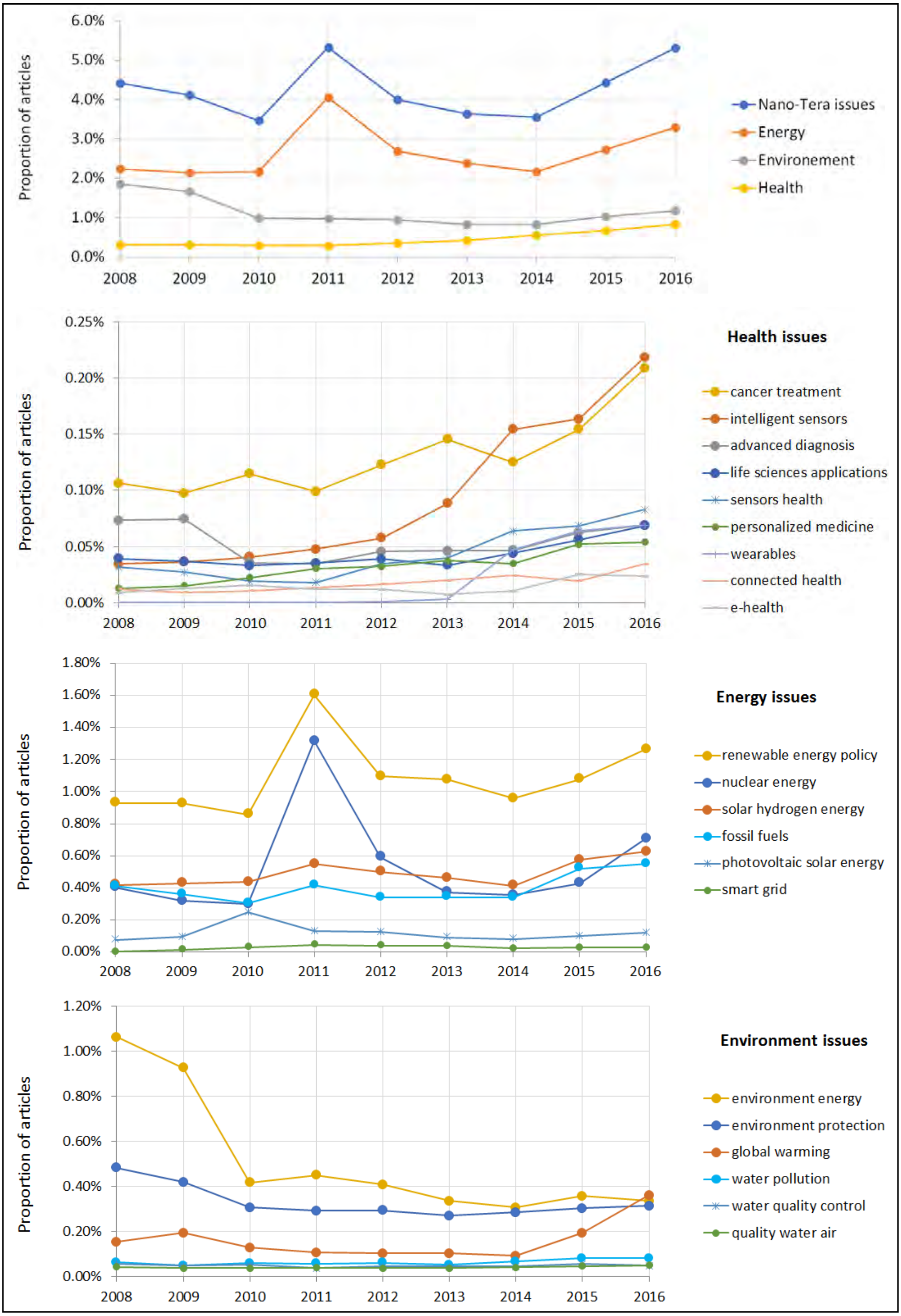



*Figure 39. Proportion of all articles published per year in each Nano-Tera domain (top), and graphs related to specific issues in Health, Energy and Environment issues (respectively, below).*

The first chart shows that, despite the overall number of articles in the period decreasing by almost 20% from 2010 to 2016, the number of articles related to Nano-Tera issues has remained steady and even slightly increased. The interest is general very high, with about 5% of all articles devoted to these few specific Nano-Tera-related keywords.

The increase is particularly strong when it comes to **health**-related articles, whose proportion has almost tripled during that period. More precisely, the concept of wearables was virtually unheard of until 2011, picking up considerably in the past few years, and the concept of intelligent sensors appearing more than 5 times more frequently in 2016 than in 2008. Most themes related to **energy** have also attracted considerable interest during the period, with a peak in 2011 which is probably related to the Fukushima disaster. Regarding the **environmental** issues, the high points of 2008 and 2009 are likely related to the fact that new energy programs were implemented, leading to debate in the media and more articles on those issues. However, from 2010 on, the interest in environment/energy remained important throughout the period. The interest in the media is stronger for the protection of the environment and the impact of energy consumption than for the quality of air and the water.

### SOURCES

We have selected the most popular Swiss daily and week-end newspapers (18 in total), covering the French and German-speaking part. [Data : REMP (Recherches et études des médias publicitaires)]. No Italian newspaper were considered in this survey as there's no Swiss-Italian newspaper collaborating with Swissdox database. The selected publications are:

*20 Minutes – Blick am Abend – SonntagsBlick – 20 Minutes – Schweiz am Sonntag – SonntagsZeitung – Blick – Tages Anzeiger – Berner Zeitung BZ – Le Matin Dimanche – NZZ am Sonntag – Neue Luzerner Zeitung – Sankt Galler Tagblatt – Neue Zürcher Zeitung – Le Temps – 24 Heures – Le Nouvelliste – La Liberté*

Note that the Neue Zürcher Zeitung was added even though it didn't belong to the most popular newspapers; it is however one of the leading newspapers in Switzerland. The 4 last ones were also added as they are newspaper of reference in the French-speaking part of Switzerland.

## CURRENT CONCERNS OF THE SWISS POPULATION

Every year, the Swiss research institute GFS Bern, mandated by Credit Suisse, interviews a representative panel of the population about their concerns and the main characteristics of the country's identity. Since 1976, if the structure of the survey hasn't changed, new items have been regularly added to the list of questions such as terrorism, migration issue or EU integration.
The study includes a total of 49 questions. We have selected the questions related Nano-Tera and also took into account the most cited items (unemployment, immigrants, etc.) as a benchmark. The graph below plots the ranking of these top concerns, showing for example unemployment as being the top worry of the population between 2008 and 2014.

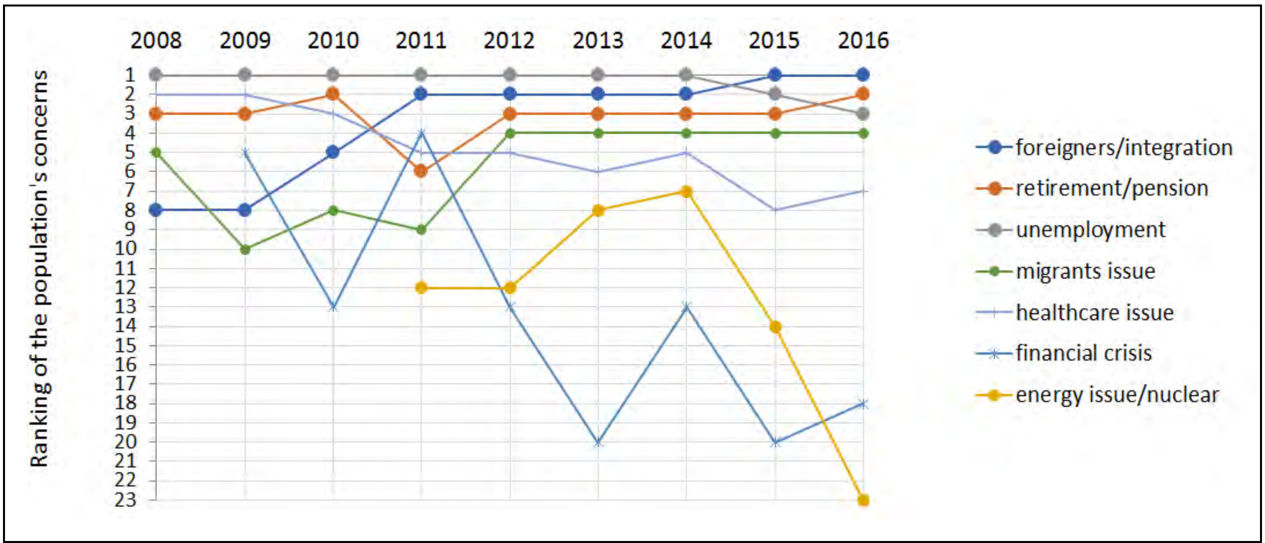



*Figure 40. Ranking of the Swiss population's top concerns according to the GFS Bern survey.*

In 2011 (Fukushima), as the energy/nuclear problem was raised, it only appeared at the 12th position. The Swiss were constantly more worried about their pension, the unemployment, the integration of increasing flow of foreigners and the problem with the refugees. Two new items were added to the survey: nuclear energy and the financial crisis but they did not become a major and constant worry.
Among all the 49 questions, the energy, the healthcare and the environment are a concern for the Swiss people, as the subjects are part of the annual survey. They rank in the first third among all the topics.

## PUBLIC POLICIES (CURIA VISTA AND PUBLIC SPENDING)

### PARLIAMENTARY PROCEEDINGS - CURIA VISTA

The observation of the parliamentary proceedings offers a complementary viewpoint on the society's priorities: the legal perspective. The service provided by the secretary of the Swiss parliament allows to search parliamentary proceedings by supervisory department, by year, by theme (energy, health, defence, etc.), and by keywords (sensors, cancer treatment). The four criteria were combined. The number of parliamentary proceedings by topic and by year is given below.

| Categories | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Health | 157 | 241 | 192 | 166 | 251 | 185 | 232 | 188 | 164 | 1'776 |
| Energy | 119 | 93 | 110 | 250 | 123 | 123 | 111 | 120 | 105 | 1'154 |
| Environment | 87 | 103 | 100 | 75 | 114 | 95 | 138 | 153 | 95 | 960 |
| Total Nano-Tera issues | 363 | 437 | 402 | 491 | 488 | 403 | 481 | 461 | 364 | 3'890 |
| **Total annual proceedings** | **1'952** | **2'477** | **2'266** | **2'127** | **2'264** | **2'327** | **2'339** | **2'284** | **2'115** | **20'151** |

*Table 13. Number of parliamentary proceedings by topic and year.*

The following graph shows the corresponding proportion of proceedings per topic and year.

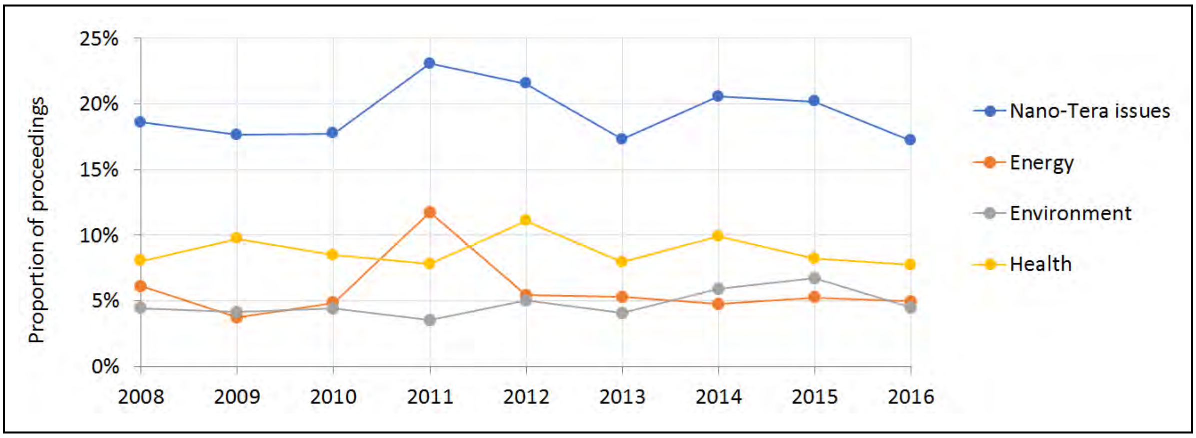



*Figure 41. Proportion of parliamentary proceedings by topic and year.*

The data collected show a constant interest of the Parliament in health, environment and energy matters. From 2008 to 2016, the total numbers of proceedings related to health, energy and environmental issues represented almost 20% of all the proceedings handled by the parliament. In other words, 1/5 of the attention was spent on these 3 issues; it witnesses the importance attached by the legislature, with health-related proceedings being the most prominent of the three issues.

### PUBLIC SPENDING

A look at the federal spending provides crucial information about the actions taken by the authorities to tackle the various problems. The Swiss government's data center enables to select expenditure according to the function (e.g. social welfare, national defence, transportation, health program, etc.)

For the public spending, we have identified the three offices in charge of the energy, health and environmental policies; we then looked for the spending – related to specific tasks and/or programs – which were carried out.

- The Federal Office of Public Health (FOPH) is responsible for public health in Switzerland; it develops Switzerland's health policy and works to ensure that the country has an efficient and affordable healthcare system in the long term
- The Swiss Federal Office of Energy (SFOE) is the country's competence center for issues relating creating a crisis-proof, broad-based, economic and sustainable energy supply, ensuring the maintenance of high safety standards in the production, transport and utilisation of energy, as well as promoting efficient energy use, an increase in the share of renewable energy and a reduction in CO2 emissions.
- The Federal Office for the Environment's (FOEN) responsibility is to ensure the sustainable use of natural resources including soil, water, air, quietness and forests, protection against natural hazards, protection of the environment and human health against excessive impacts, and conserving biodiversity and landscape quality.

The following table and graph show the amount of spending per year for various programs and measures in these three offices, in million CHF. [Note that in 2015, a new management model of the federal administration was implemented. Even though, the financial accounts are available, it isn't possible to compare the figures, therefore timeframe is here limited to the period 2008-2014]

| | Tasks | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | Total | var. 2008-14 |
|---|---|---|---|---|---|---|---|---|---|---|
| Federal Office of Public Health | Health implementing measures | 10.7 | 17.5 | 17.6 | 19.6 | 19.7 | 20.6 | 21.0 | 126.8 | +97% |
| Swiss Federal Office of Energy | SwissEnergy Program | 19.0 | 19.8 | 18.9 | 17.1 | 21.6 | 22.5 | 30.6 | 149.6 | +61% |
| | Management of radioactive waste | 1.5 | 3.3 | 4.0 | 6.2 | 6.4 | 6.3 | 5.0 | 32.8 | +247% |
| | Buildings Program | 14.0 | 98.6 | 62.0 | 67.0 | 43.2 | 46.0 | 39.5 | 370.3 | +182% |
| Federal Office for the Environment | Environment implementing measures | 13.8 | 14.9 | 14.9 | 14.1 | 16.6 | 15.9 | 16.1 | 106.4 | +16% |
| | Observing the environment | 16.1 | 20.4 | 19.9 | 18.2 | 18.5 | 18.1 | 18.2 | 129.3 | +13% |
| | Remediation of contaminated sites | 29.4 | 23.3 | 14.3 | 9.9 | 19.1 | 62.1 | 41.4 | 199.6 | +41% |
| | Environmental Technologies | 2.1 | 3.5 | 4.3 | 3.5 | 2.9 | 4.1 | 4.3 | 24.6 | +103% |
| | Total | 106.7 | 201.2 | 155.9 | 155.6 | 148.1 | 195.6 | 176.2 | 1'139.4 | +65% |

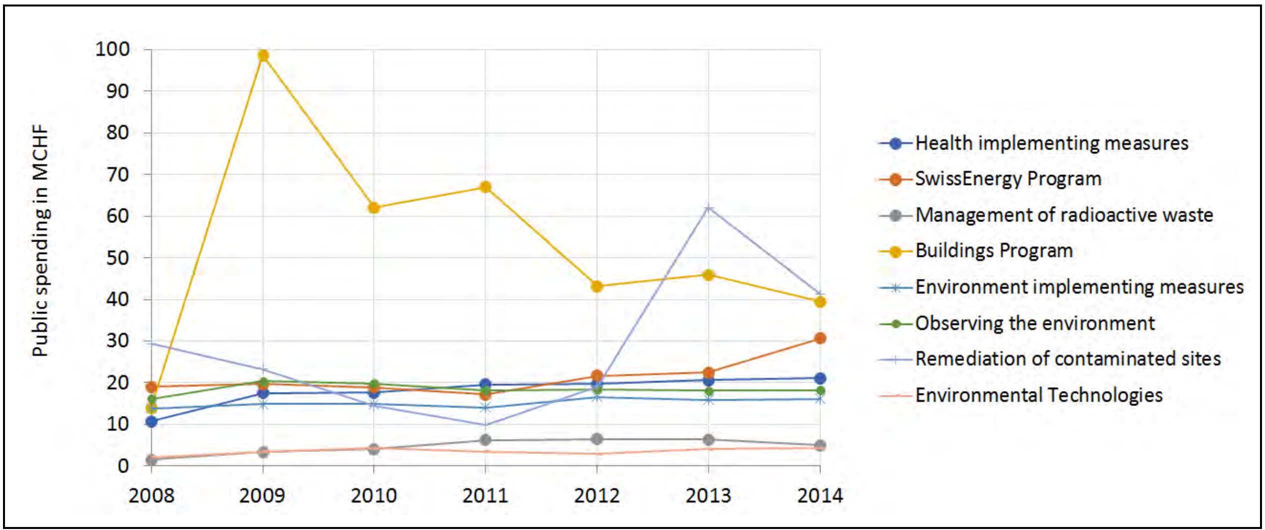



*Figure 42. Spending per year for certain programs and measures in three federal offices (see text for details).*

In the Federal office of public health, the spending has almost doubled between 2008 and 2014 for health implementing measures. Overall, several issues in these three offices benefit from substantial funding, all of which have increased (by 65% overall) in this period.

## Key statement 16

Nano-Tera.ch has contributed to **disseminating the results** achieved within and beyond the Nano-Tera.ch community

# OVERVIEW

Dissemination of information is an important factor leading to societal impact by reaching various audiences. The communication actions were aimed at: developing the program's notoriety in the media, keeping its governing bodies informed about the program's progress, federating the PI and the PhD students, by exchanging information around the results, as well as presenting the program results to the global scientific community. Nano-Tera has undertaken several dissemination measures, though printed documents, events, and various media channels (website, newsletters, wiki and social media) in order to achieve these goals.

## PRINTED DOCUMENTS

The Management Office published an annual scientific report and public activity report to inform its different stakeholders on the advancement of the program and the achieved results. In addition to the activity report, project reference sheets have been created, providing a self-contained summary of each project's research challenges and results highlights.


*Figure 43. Example of a Nano-Tera.ch activity report (top) and project reference sheets (bottom).*

## EVENTS

Nano-Tera.ch has organized its annual meeting – with ca. 250 participants – every year starting in 2010, always with overwhelmingly positive feedback from the community (more details below). In addition to Nano-Tera scientists presenting their results in numerous conferences worldwide, members of the Nano-Tera Management Office have participated to several international events as speakers or exhibitor in order to present the program and its main achievements. While the annual meetings were held in Switzerland, the other events took place in Italy, China, USA, Germany, Korea, Greece, France, Japan, etc. In total, Nano-Tera organized 48 events and participated to 62.

## Media channels

173 interviews were given to leading newspapers or national Swiss TV such as Neue Zürcher Zeitung, CNN, Euronews, Radio Télévision Suisse Romande, Berner Zeitung, etc. On average, it corresponds to 1-2 interviews/month from 2008 to 2016. Given the complexity of subjects – complex engineering systems, this shows the interest of the society for the problems Nano-Tera has been addressing.

The Nano Tera website (www.nano-tera.ch) is the main dissemination tool used throughout the lifetime of the program. From 2008 to 2016, it has been visited by about 160'000 unique users who visited almost 800'000 pages. The sessions originate from virtually every country in the world, with the top 3 being Switzerland (52% of all sessions), the United States (7%) and Germany (5%). On average, 1'500 unique users have been visiting the website every month from 2008 to 2016, each of them visiting about 7-8 pages among the website's 386 pages. The yearly breakdown shows the following evolution:

| Item | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | Total | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|
| visitors | 9'854 | 12'777 | 15'069 | 13'867 | 16'028 | 19'063 | 20'145 | 17'658 | 13'791 | 1'132'182 | 15'361 |
| sessions | 15'594 | 19'875 | 24'159 | 23'619 | 26'940 | 30'402 | 29'970 | 26'920 | 21'051 | 993'930 | 24'281 |
| pages viewed | 59'786 | 82'426 | 90'580 | 87'246 | 90'060 | 102'132 | 101'604 | 94'593 | 66'973 | 775'400 | 86'156 |

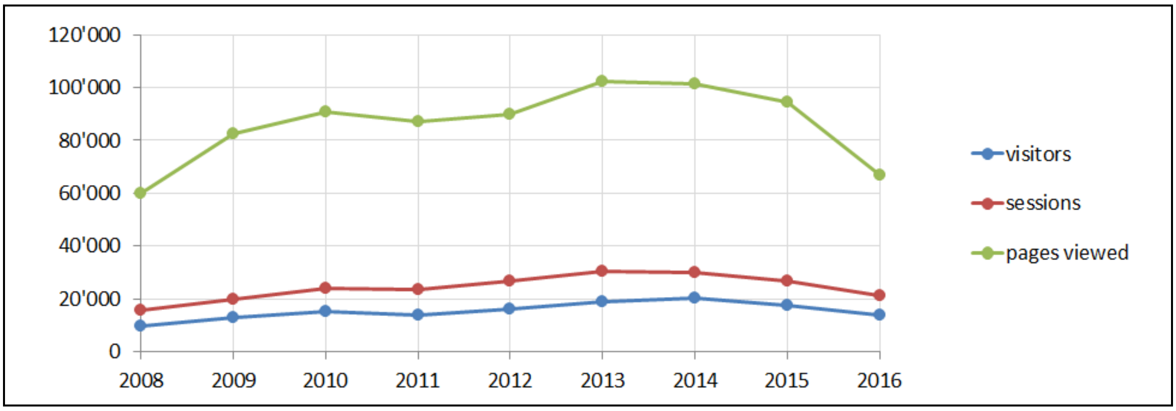



*Figure 44. Nano-Tera.ch website statistics.*

In terms of dissemination, the website has been a key element giving the opportunity to people inside and outside the Nano-Tera community to have access to the projects and their results. To this end, Nano-Tera.ch encouraged and helped researchers produce videos about their results (so about 250 videos can be found on the website). Furthermore, the Nano-Tera website also represented an efficient way to make information available for the industry, which have ranked the need for information as a key element of technology transfer (see KOF Survey 2011, Information being the category used to Knowledge and Technology Transfer with 62.9%).

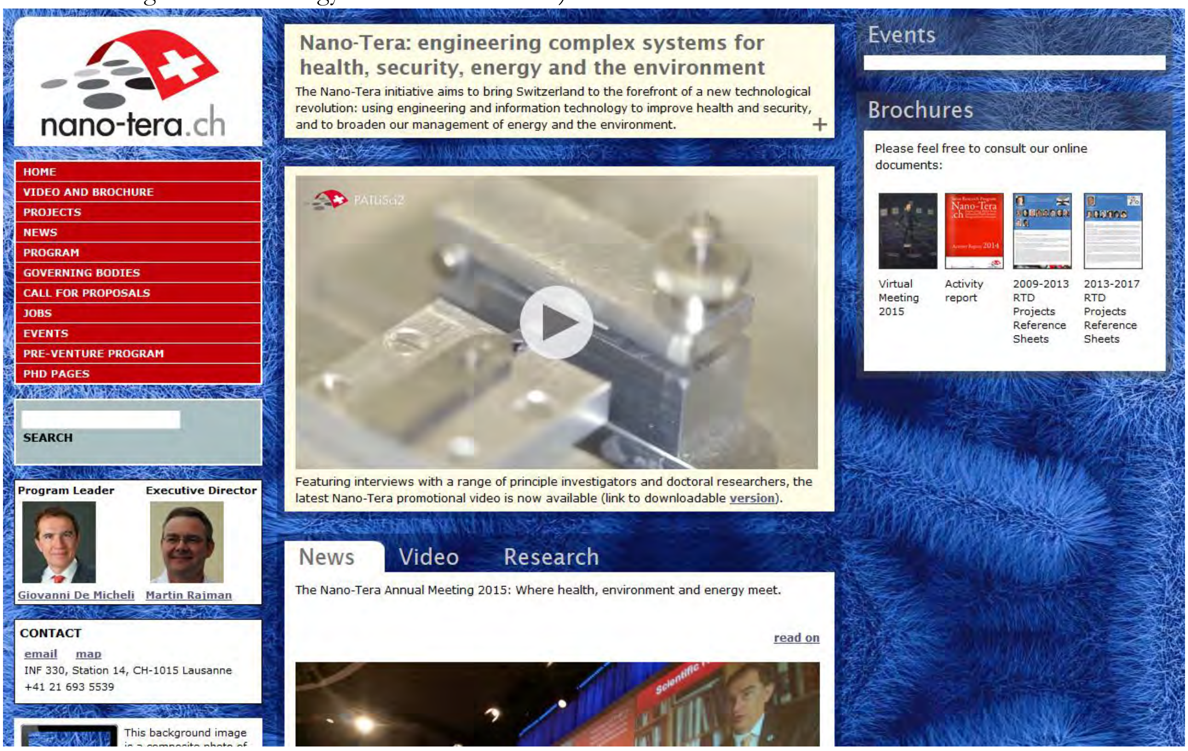



*Figure 45. Main page of the Nano-Tera.ch website.*

Finally, Nano-Tera circulated an electronic newsletter to its community, announcing various events and presenting the latest scientific breakthroughs and success stories.

The following table summarizes the various actions:

| Item | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|---|---|---|---|
| Printed documents | | | | | | | | | | |
| Activity report | | | X | X | X | X | X | X | X | |
| Scientific report | | X | X | X | X | X | X | X | X | |
| Project reference sheets | | | X | X | X | X | X | X | X | |
| Other brochures | | X | | X | | | | | | |
| Events | | | | | | | | | | |
| Annual meeting | | | X | X | X | X | X | X | X | X |
| Virtual meeting | X | X | X | X | X | X | X | X | X | X |
| International Exchange Program | | | | | | X | X | | | |
| Participation to external events | | | 1 | 15 | 6 | 11 | 10 | 8 | 6 | 5 |
| Organization of internal events | | | 3 | 13 | 4 | 7 | 11 | 4 | 5 | 1 |
| Media channels | | | | | | | | | | |
| Videos | | | X | X | X | X | X | X | X | X |
| Newsletter | X | X | X | X | X | | | | | |
| Website | X | X | X | X | X | X | X | X | X | X |

## THE NANO-TERA ANNUAL MEETING

Nano-Tera.ch has organized 7 annual plenary meetings, from 2010 to 2016. Typically organized over 1 or 2 days, the Nano-Tera annual meeting took place 4 times in Bern, twice in Lausanne and once in Zurich. The event attracted about 200 participants in its first year, later on growing to about 250-300 participants and even reaching 350 participants in its final 2016 edition.


*Figure 46. Keynote speech by Prof. Jan Rabaey (UC Berkeley) at the 2015 Nano-Tera.ch annual meeting.*

The Nano-Tera annual meetings have adopted different formats over the years, but have usually included presentations of the progress made in the various projects by the PIs. There has typically been one of two keynote presentations delivered by prominent scientists. One of the most important aspects of the meeting is the possibility for PhD students and younger researchers to present their research in the form of posters (or, on one occasion, to deliver the oral project presentation), with about 140-150 posters being presented each year in the exhibition hall.

| Year | Day(s) | Date | Location | Participants | Posters |
|---|---|---|---|---|---|
| 2010 | 1 | 29.04.2010 | Bern | ~200 | 64 |
| 2011 | 2 | 12-13.05.2011 | Bern | ~250 | 109 |
| 2012 | 2 | 26-27.04.2012 | Zurich | ~250 | 130 |
| 2013 | 2 | 30-31.05.2013 | Bern | ~310 | 140 |
| 2014 | 1 | 20.05.2014 | Lausanne | ~330 | 141 |
| 2015 | 2 | 04-05.05.2015 | Bern | ~320 | 147 |
| 2016 | 2 | 25-26.04.2016 | Lausanne | ~350 | 152 |

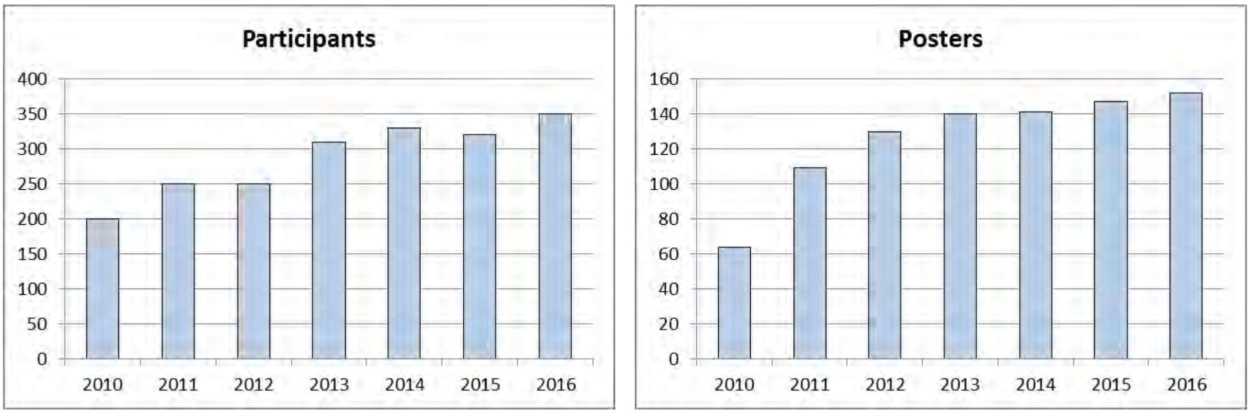
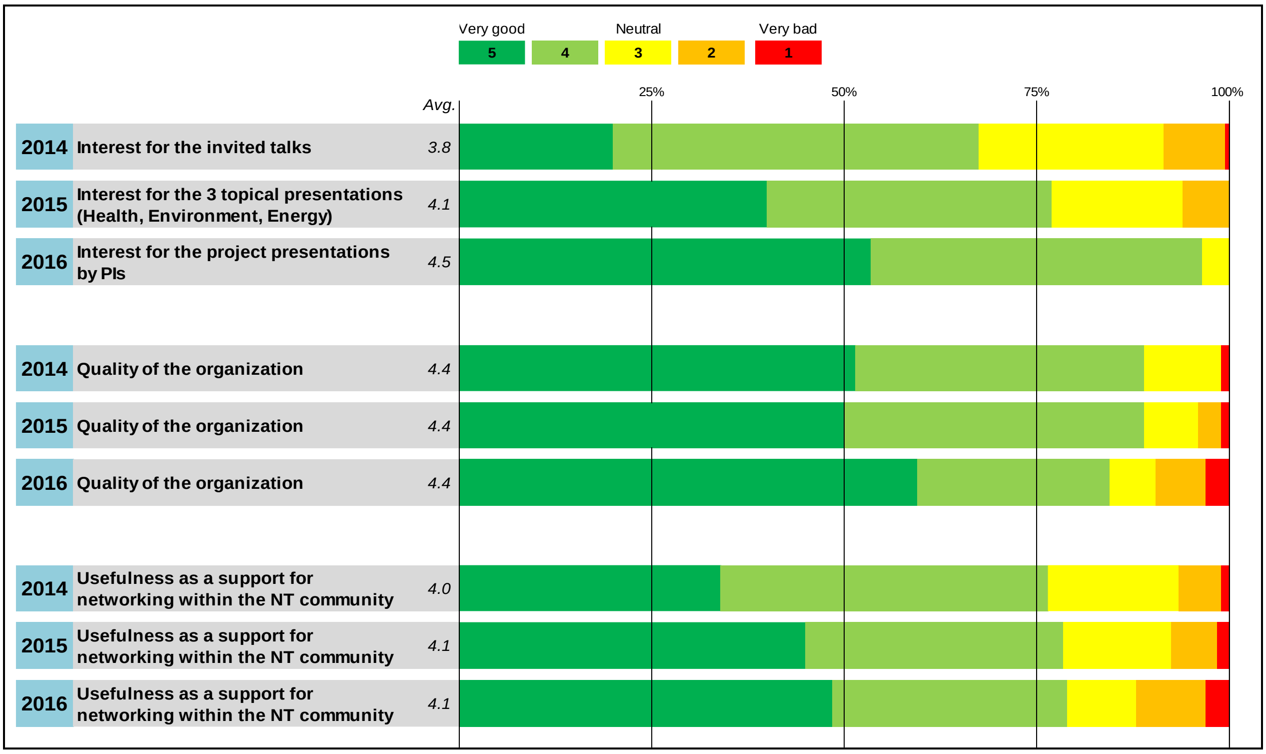



*Figure 47. Statistics of the number of participants (left) and posters (right) at the Nano-Tera.ch annual meetings.*

The projects have also had the opportunity to present concrete early demonstrators and prototypes of their research. This aspect logically took more and more importance with the advancement of the program, with a wide range of projects presenting devices and elaborate demonstrations of their systems.

The Nano-Tera annual meetings have received very positive feedback from the participants. In systematic surveys, particularly in the last 3 years where comparable questions have been used, the results have been overwhelmingly positive, the audience showing great interest in the presentations, recognizing the importance of the meeting as a support for networking within the Nano-Tera community, and lauding the quality of the organization in general.



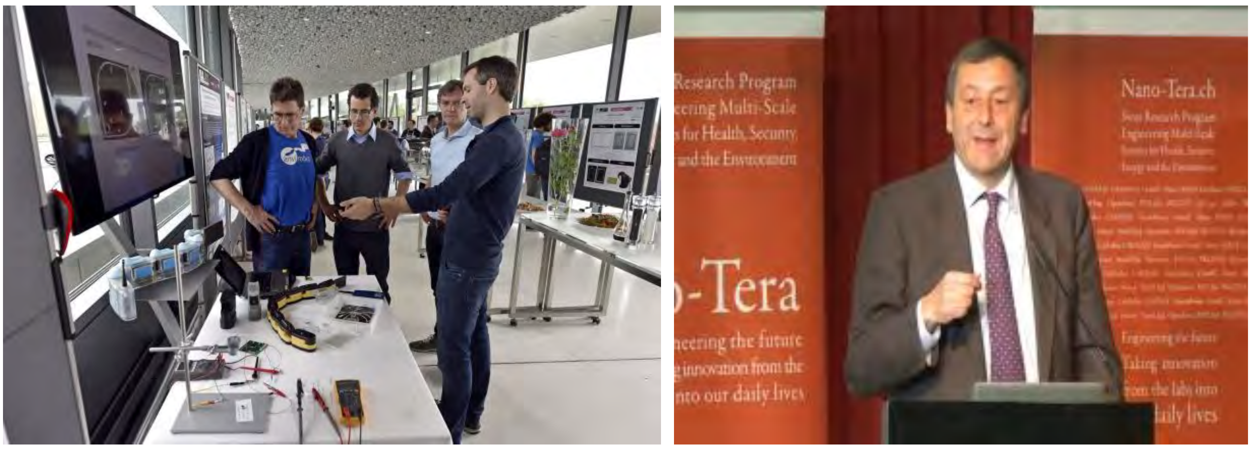




*Figure 48. Left: Presentation of demonstrators in the 2015 annual meeting exhibition area.*
*Right: Address by former Italian Minister of Education Francesco Profumo at the 2013 annual meeting.*

**Virtual annual meeting**

Every year, the content of the Nano-Tera.ch meetings has been made available online on a virtual annual meeting platform.
All the posters, as well as the available videos of presentations can be browsed directly from the page, and provide a way for anyone to consult the content of the meeting.

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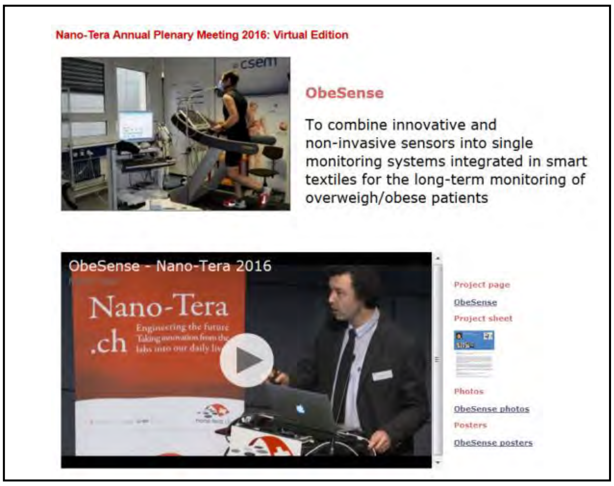



## SYMPOSIA WITHIN THE NANO-TERA.CH INTERNATIONAL EXCHANGE PROGRAM

Organized in the framework of the Nano-Tera.ch International Exchange Program and chaired by Prof. Giovanni De Micheli, the **Symposium on Emerging Trends in Electronics** has brought to Montreux in December 2014 almost 100 renowned scientists and business leaders and addressed the means to grow the European economy by creating new jobs and products enabled by advances in electronics.

Representatives from the European Industry presented the latest semiconductor processes for high-performance, low-power applications and the Internet of Things. Academic and industry leaders discussed the advantages and limitations of the American and European models for design and product creation.

The symposium featured presentations in technology applications, ranging from A. Chandrakasan (MIT) who addressed miniaturized circuit design, to T. Sakurai (U. Tokyo) who described flexible electronic circuits to achieve electronic skin, and K. Shepard (Columbia University) who demonstrated electrical circuits applicable to sensors and DNA sequencers. S. Furber (U. Manchester) explained progress in neuromorphic energy sustainable high-performance computing with the Spinnaker chip, while G. Fettweis (U. Dresden) showed how 5G communication technology will improve our living standards, from automatic driving to the connected smart city. Giorgio Cesana (STMicroelectronics) presented a brief history of FD-SOI.

The symposium featured several round tables, including one panel of University Presidents, Rectors, Vice-Presidents and Vice-Rectors addressing how electronic means influence education (e.g., through MOOCs) and how education should address more emerging technologies. Emphasis was placed on students and the universities' task to forge thinking skills, while educating the best scientists, engineers and managers for a rapidly evolving world. This event included excellent presentations and discussions that are available on the Nano-Tera.ch web portal in the form of a virtual meeting.


Similarly, in the **Symposium on Emerging Trends in Computing** in October 2016, more than 80 prominent researchers and business leaders gathered in Montreux and addressed new computing paradigms and systems design, ranging from Yankin Tanurhan (Vice President Engineering, Synopsys) who addressed IoT optimized IT, to Prof. Jason Cong (UCLA) who discussed options and opportunities of customizable computing, and Dave Liu (President Emeritus Tsing Hua university) who presented an overview of the IT revolution since the 1950s. Prof. Luca Benini (ETHZ) addressed parallel computing in CMOS and Prof. Subhasish Mitra (Stanford) discussed carbon nanotube computing.

The symposium featured several round tables, including one panel of University Presidents, Rectors and VPs/VRs which addressed key questions such as the impact of data-driven science on research, education and human interaction.


In addition, an EPFL **Workshop on Logic Synthesis and Verification,** as well as an EPFL **Workshop on Logic Synthesis and Emerging Technologies** were organized in Lausanne in 2015 and 2017, respectively.

| Year | Title | Date | Location | Speakers | Panelists |
|---|---|---|---|---|---|
| 2014 | Symposium on Emerging Trends in Electronics | 01-02.12.2014 | Montreux | 9 | 31 |
| 2015 | EPFL Workshop on Logic Synthesis & Verification | 10-11.12.2015 | Lausanne | 22 | - |
| 2016 | Symposium on Emerging Trends in Computing | 10-11.10.2016 | Montreux | 9 | 29 |
| 2017 | EPFL Workshop on Logic Synthesis & Emerging Technologies | 28-29.09.2017 | Lausanne | 21 | - |

## PRESENTATION OF THE PROGRAM AT CONFERENCES AND EXHIBITIONS

Nano-Tera.ch was present at numerous conferences, selected for being major events in the fields covered by the program. The program was visible either in the form of oral presentations delivered by members of the Management Office, or with booths in the exhibition areas of these events.


*Figure 49. Examples of presentations delivered by Prof. Giovanni De Micheli (left) and Dr. Martin Rajman (right).*

*Figure 50. Examples of Nano-Tera.ch booths at conferences, presented by Dr. Patrick Mayor.*

## SWITZERLAND-KOREA JOINT WORKSHOPS

The 4th Korean Swiss Science Days were held at EPFL in May 2013: the Science Days have been held yearly alternating in Korea and Switzerland since 2010 and are an integral part of the bilateral Korean-Swiss Science and Technology Program. That year's edition was jointly organized by EPFL's International Relations, Nano-Tera.ch (responsible for the scientific content) and ETH Zurich as the Swiss Leading House. The Science Days were financed with a conference grant from Nano-Tera.ch and from the bilateral program through ETH Zurich and the Korean National Research Foundation (NRF). 75 participants from Korea and Switzerland registered and 17 posters were displayed.

The Science Days opened directly with a highlight, the welcome dinner at the Korean Ambassador's Mr. YoungHan Bae Residence in Bern on May 6. The two following days saw a series of lectures within four key topics: 1) bio-sensing and health management, 2) energy-aware electronics, 3) architectures and networks for the Internet of things, and 4) emerging devices. Talks included outstanding speakers from EPFL, ETH Zurich and CSEM on the Swiss side and from KAIST, Seoul National University (SNU) and Yonsei University on the Korean side. Speakers from LG Electronics Ltd and Samsung Advanced Institute of Technology (SAIT) complemented the program from the private industry perspective.

The purpose of the Science Days to increase scientific collaboration between the two countries was clearly met, in particular because of the match of interests between the Nano-Tera.ch and the Korean scientists. The lively discussions after the talks demonstrated the large interest in each other's research. Several Korean participants also visited EPFL laboratories after the symposium to discuss cooperation opportunities.

The Science Days were a high level event that also attracted many Swiss researchers from various institutions including the Universities of Applied Sciences to participate. They also provided a platform for students to present their research to the Korean partners. Unfortunately, the participation of Korean students was only marginal despite the offered travel grants, it is hoped that it will be easier to include them in a next edition of the Science Days in Korea.

Following this successful event, Nano-Tera participated in a joint workshop hosted by the Center for Integrated Smart Sensors (CISS) at the Korea Advanced Institute of Science and Technology (KAIST), which took place on October 17-18, 2013. The invited Nano-Tera delegation consisted of Prof. Giovanni De Micheli, Dr. Martin Rajman, Prof. Karl Aberer, Prof. David Atienza, Prof. Yusuf Leblebici and Prof. Peter Ryser of EPFL, as well as Prof. Luca Benini and Prof. Qiuting Huang of ETHZ. The Swiss researchers and their Korean counterparts (including Prof. Byeong Guk Park of SNU, Prof. Hoi-Jun Yoo of KAIST) delivered presentations on topics such as smart healthcare, biosensing or sensing architectures.

The workshop was a good opportunity to strengthen partnership between Nano-Tera.ch and CISS and hold comprehensive discussions on the future of next generation smart sensors, including advanced implantable biosensors, mobile sensor networks and low-power sensors for applications such as ECG monitoring.

## Key statement 17

Nano-Tera.ch has implemented efficient **pilot actions** to promote the activities of the programs in high school and towards younger children

### SCIENTASTIC – SCIENCES FESTIVAL

In 2015, the EPFL organized its first festival of science. With the creation of the Department for the Promotion of Science in 2015, EPFL expressed its willingness to consolidate mediation efforts with the young and the general public for all the MINT branches (mathematics, computer science, natural sciences and technical).

The goal was to promote dialogue between science and society, make scientific knowledge accessible to a wide audience by presenting them in a comprehensible manner, encourage succession and generate enthusiasm for scientific and technological research. Nano-Tera.ch provided Scientastic with a film on hydrogen storage, describing the research carried out in the project SHINE, which was used and shown in an interactive workshop "How does it work?". It provided a module for visitors to understand how hydrogen storage works, for example for hydrogen cars. The festival was a success: more than 6'000 people participated and a large number of visitors showed a marked interest and would have enjoyed an extension of the event over two days, according to testimonies collected on the day of the festival.

### HIGH-SCHOOL STUDENTS MEET PHD STUDENTS

Two classes of students from the high school of St-Maurice were invited to the EPFL campus to meet PhD students on March 23 and April 26, 2016. In total, 40 high school students studying biology, chemistry and physics were present. Prior to the visit, a delegation of the Nano-Tera Management Office and 4 PhD students went to St-Maurice to present the research program, its clusters and provide the students with the necessary background information.

The main visit took place during Nano-Tera's final event. Four groups of 10 students visited the demonstrators of 4 projects: SmartGrid, SHINE, NewbornCare and Envirobot. Each group was under the responsibility of a Nano-Tera PhD students while visiting each booth. The exhibitors had been briefed to tune their explanations in order to make them understandable for high school students. The potential applications for the various technologies developed within each of the projects was a key message.

After the visit, a workshop was organized, where the high-school students were asked to imagine a different application (co-design sessions) to what they had seen. At the end, each group presented their option.

The day generated a real interest not only from the high school students but also from the Nano-Tera researchers presenting their demonstrators, who were delighted to share their results with potential future scientific/engineering students. The latter got a glimpse of what a student's life would look like and what their current studies could lead them to.

# IV.6 KEY STATEMENTS RELATED TO INSTITUTIONAL IMPACT

**Key statement 18**

Nano-Tera.ch has substantially contributed to the setup of the **joint SNSF-CTI program "BRIDGE"**, a novel funding instrument aiming at better exploiting the economic and societal potential of scientific research by promoting the transfer from scientific knowledge to innovation

### Motivation

Nano-Tera.ch has provided its expertise to contribute (through meetings, preparatory discussions and positioning documents) to the setup of the joint SNSF-CTI program **BRIDGE**, a novel funding instrument deployed at the federal level for the budgetary period 2017-2020. The BRIDGE program aims at better exploiting the economic and societal potential of scientific research by promoting the transfer from scientific knowledge to innovation. BRIDGE has been designed as a new concept for jointly funding research and pre-competitive innovation in Switzerland in the domain of Engineering Sciences. It proposes to strengthen the translation of publicly-funded research results into pre-competitive innovation. To do so, it plans to better connect academic and industrial players through ambitious research projects, thus creating suitable platforms for collaborative knowledge and technology transfer based on cross-exposure and inter-connection of personnel, with a special focus on junior researchers/engineers.

### The BRIDGE Program

The first motivation of BRIDGE was to correct the fact that current research and innovation funding models in Switzerland address the transition from research to innovation in a sequential way: research first, with objectives related to the advancement of science and technology, and only later considers (usually competitive) innovation (products or services) in collaboration with industry. BRIDGE seeks to introduce continuous interactions between researchers and industrial players to leverage the influence of both research achievements on new product ideas and of market needs on research directions.

The second motivation of BRIDGE is linked to the way graduate education is currently carried out in the Swiss Polytechnics and Cantonal Universities. In these institutions, most research is performed by doctoral and post-doctoral researchers under professorial supervision, funding is specifically targeted to research and success/reward indicators mainly related to publications. As a consequence, there is little interaction with industry, and doctoral students have limited exposure to Swiss industrial players and needs. BRIDGE proposes that graduates are in constant interaction with industry, through regular meetings and mutual visits, to strengthen the economic and social impact of scientific result.

To answer these motivations, BRIDGE has been designed as a new concept for jointly funding research and pre-competitive innovation in Switzerland in the domain of Engineering Sciences. It proposes to strengthen the translation of publicly-funded research results into pre-competitive innovation. To do so, it plans to better connect academic and industrial players through ambitious research projects, thus creating suitable platforms for collaborative knowledge and technology transfer based on cross-exposure and inter-connection of personnel, with a special focus on junior researchers/engineers.

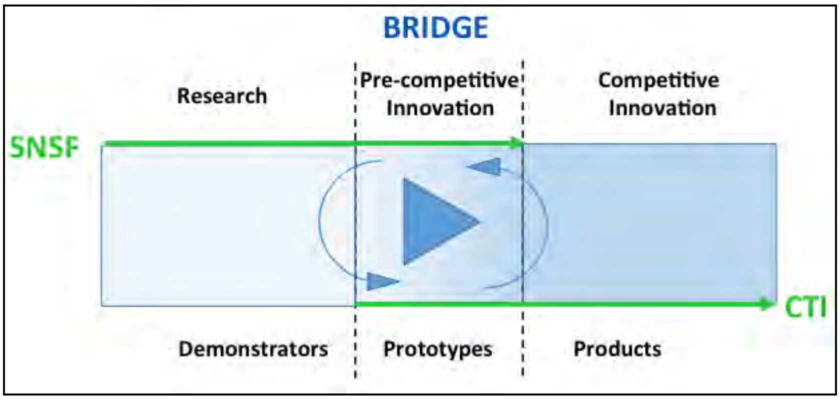



*Figure 51. The BRIDGE concept.*

The goals of BRIDGE will be achieved by creating a new funding instrument that: i) Integrates a granting mechanism addressing both research and innovation deliverables; ii) Introduces a continuous interaction between researchers and industrial players to leverage the influence of both research achievements on new product ideas and of market needs on research directions; iii) Relies on a new dual evaluation mechanism involving both scientific and economic dimensions.

BRIDGE is intrinsically positioned at the frontier between research and innovation, and its launch and operation require a concerted effort of institutional players (SERI, SNSF and CTI), as well as a consortium involving the Polytechnics, the

Cantonal Universities, the Universities of Applied Sciences and Swiss Research/Innovation Centers (e.g., CSEM, Empa, etc.). Representatives of the Swiss economy will also be integrated through an Industrial Advisory Board.

BRIDGE consists of two funding opportunities:

- Proof of Concept is aimed at young researchers who wish to develop an application or service based on their research results. These projects may target innovations of all kinds from all research areas.
- Discovery is aimed at experienced researchers who aim to explore and implement the innovation potential of research results. Only technological innovations that have a societal and economic impact will be funded.

These two funding schemes Proof of Concept and Discovery are being rolled out in the 2017-2020 test phase, for which a budget of CHF 70 million has been made available.

Experts from research, industry and administration are responsible for the successful execution of BRIDGE. Together they form the Steering Committee, which is elected by the presiding boards of the two funding organizations. The BRIDGE office set up by the SNSF and CTI is responsible for the operational management of the program. Each funding scheme will have its own evaluation panel, which will be appointed by the Steering Committee. The panels are composed of experts from science, business and industry.

From the perspective of Nano-Tera.ch, Gateway can be seen as a form of pilot program for BRIDGE. Note that Lothar Thiele, former founding member of the Nano-Tera.ch Executive Committee, is now serving as President of the BRIDGE Steering Committee.

## Key statement 19

The **operational procedures** deployed and tested during the Nano-Tera.ch program represent an interesting example of innovative mechanisms for financing and monitoring research with high economic potential

### THE GATEWAY MONITORING MECHANISM

The success of a technology transfer project requires three key factors: a shared vision of the goal to be achieved, the quality and density of interactions between the participants and the contribution of the project to the strategic objectives of the company. In this perspective, a specific monitoring mechanism has been created for the Gateway projects within the Gateway program.

This mechanism is characterized by three main innovations:

- The appointment of an "innovation manager" specifically responsible for the monitoring of the Gateway projects. The innovation manager must be a specialist with a general technical culture (typically in engineering), and an excellent knowledge of the state-of-the-art tools for innovative project management (iterative cycles, Lean Management, Minimum Viable Product, etc.). His/her role is to remain focused on the expectations of the industrial partners, the progress of the targeted demonstrators, and the evaluation of their exploitability for the industrial partner strategy. The innovation manager is directly reporting to the Executive Director and the Executive Committee of the program, and provides recommendations on potential corrective measures to be considered in relation with the Gateway projects.
- The replacement of the standard annual reporting describing the obtained results by quarterly progress meetings, corresponding to short face-to-face meetings (typically 1-1.5 hour) between the Innovation Manager and the project PI. The goal of these meetings is to dynamically assess the progress of the project, and to evaluate potential corrective measures if necessary.
- The creation of a new monitoring tool, the Balanced Score Card, specifically designed to serve the purposes of the quarterly progress meetings (see below for a more detailed description of the tool).

The general goal is to target an efficient, but very light monitoring mechanism (compatible with a quarterly occurrence), well adapted to the specificity of innovation projects. In particular, the main objectives were:

- To provide a framework specially adapted to monitor innovation, and, more specifically, to provide a grid of analysis for the iterations/exchanges taking place between researchers and industrial partners;
- To feed the quarterly interaction between the PI and the Gateway program manager with an overview able to foster efficient discussions;
- To provide the PI with a useful synthetic information that (1) allows them to self-assess the project progress, (2) represents a snapshot of project status, and (3) tracks the project dynamics and expected development;
- To contribute to prepare a successful CTI application at the end of the project.

During its design, the monitoring based on the Balanced Score Card has been presented to and discussed with Prof. Yves Pigneur (Lausanne University), one of the world-leading specialists in the domain of innovation management. It has been further discussed with him after its first 12 months of operation. The approach has also been presented to more than 200 representatives of major French companies during a “Mardi de l’Innovation” conference, organized by the “Club de Paris des Directeurs de l’Innovation” on March 14, 2017, in Paris-La Sorbonne.

The general adequacy of the Gateway monitoring mechanism has been confirmed, both by the positive feedback received from the PIs of the Gateway project, and by its ability to rapidly highlight potential difficulties faced by the running Gateway projects, which made it possible to propose timely and appropriate corrective measures.

### THE BALANCED SCORE CARD

The Balanced Score Card consists of three main components: the demonstrator status table, the stakeholder network display, and the industrial credibility assessment plot.

**The demonstrator status table** is a way to represent the status and the dynamics of the development of the targeted demonstrators. At each progress meeting, each of the targeted demonstrators is positioned within an iterative cycle relying on a 3 stage model:

1. Built: this stage concerns the development of the demonstrator; it is is associated with the following possible statuses: “on going” (the development is in progress), “finalizing” (the technical solution is almost finalized) or “done” (the demonstrator is built with the expected features);
2. Exposed: this stage concerns the delivery of the produced prototypes/demonstrators to the involved industrial partner(s); it is associated with the following possible statuses: “started” (the person responsible for the development of the prototype/demonstrator has been identified), “providing prototype” (a prototype has been provided to the industrial partner), “providing demonstrator” (a demonstrator resulting from the prototype has been presented to the industrial partner and they used it), and “delivered” (the research team considers the development of the demonstrator is completed);

3. Revised: this stage concerns the integration in the development of the demonstrator of the feedback provided by the industrial partner; it is associated with the following possible statuses: "started" (the person in charge of the testing of the demonstrator by the industrial partner has been identified), "testing prototype" (the prototype is tested in a simulated environment), "evaluating demonstrator" (the demonstrator is evaluated in quasi-real environment), and "satisfied" (the industrial partner has clearly stated their satisfaction with the delivered demonstrator).

A concrete example of a demonstrator status table is given in the figure below:

| October 23, 2017 | Changes vs previous monitoring | | | Operational $CO_2$ sensor Low-Power network for Switzerland and Zurich | | |
|---|---|---|---|---|---|---|
| | 03/02/17 | 25/06/17 | 12/09/17 | Planned Delivery Month | Reviewed Delivery Month | |
| | | | | December-17 | December-17 | |
| **Built** | on-going | on-going | finalizing | Finalizing | | x *the technical solution is almost finalized* |
| **Exposed** | providing demonstrator | providing demonstrator | providing demonstrator | Delivered | | x *the research team considers the development of the demonstrator is completed* |
| **Revised** | evaluating demonstrator | evaluating demonstrator | evaluating demonstrator | Delivered | | x *the industrial partner has clearly stated its satisfaction with the delivered demonstrator* |

*Figure 52: Example of Demonstrator status table.*

**The stakeholder network** is a way to visually represent the various partners ("stakeholders") involved in a Gateway project (with their type identified by a color coding), and their interactions (automatically derived from their co-presence in the various meetings reported in the project). The stakeholder network allows to question the organization of the project and the involvement of various players, in order to detect potential anomalies.

A concrete example of a stakeholder network is given in the figure below. Typical possible questions emerging from this network are: Why is "People10" (in a real network "People 10" would of course correspond to the name of a specific person) not connected to anyone? Why are "People1" and "People7" directly interacting without the intervention of a translational partner? Does this represent a sign that the objectives of the demonstrator are questioned?

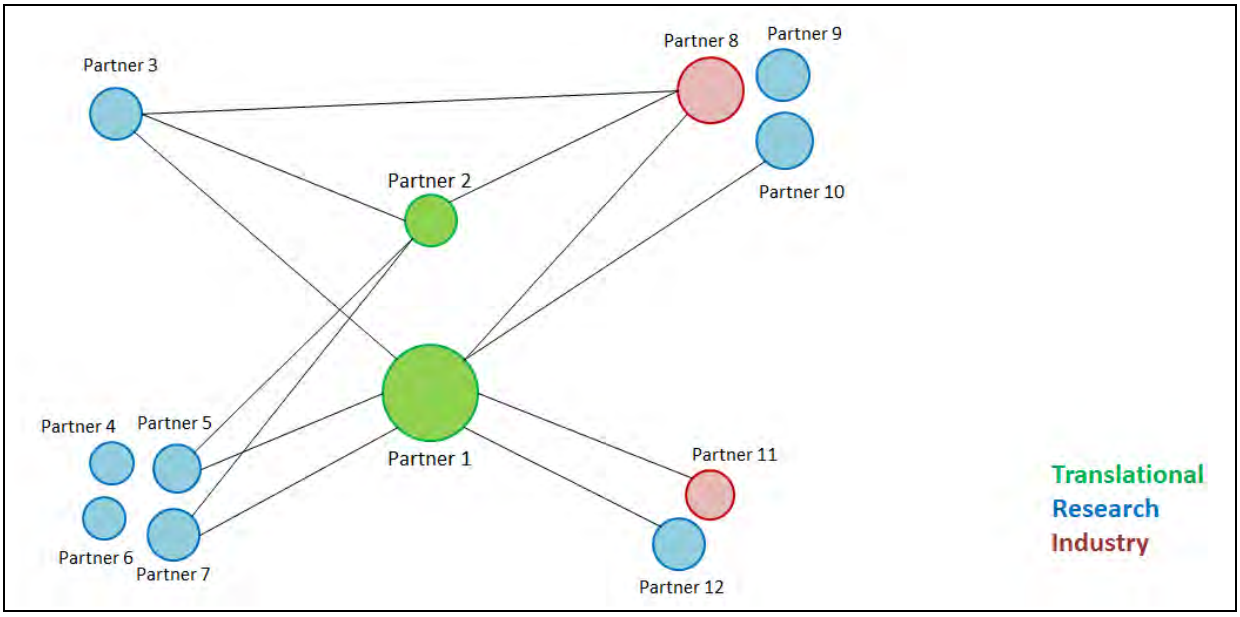



*Figure 53: Example of Stakeholder Network.*

**The credibility assessment plot** is a way to represent the confidence of the industrial partner(s) in the results of the Gateway project, and, more precisely, to their confidence in the contribution of the Gateway project to their strategic objectives. The level of confidence of monitored through three complementary aspects:

1. The current level of matching funds provided by the industrial partner(s);
2. A set of questions related to the perception of how the Gateway project allows the industrial partner(s) to position with respect to their competitors. The associated 5 questions concern planned market segments, product positioning, regulation or certification obligations, income generation and challenges as perceived by the industrial partners; the answers corresponds to quantitative importance assessments ranging from 0 to 5, which allows to display the answers in the form of a 5-dimensional radar plot.
3. A set of questions related to the evaluation of the amount of market considerations brought by the industrial partner(s) in the Gateway project. This associated 4 questions concern growth strategy (optimization, diversification,

etc.), potential internal impact the developed technology on the industrial partner, costs required to put it in production, and possible changes in the associated revenue model(s); the answers corresponds to quantitative importance assessments ranging from 0 to 5, which allows to display the answers in the form of a 4-dimensional radar plot.

A concrete example of a credibility assessment plot is given in the figure below:

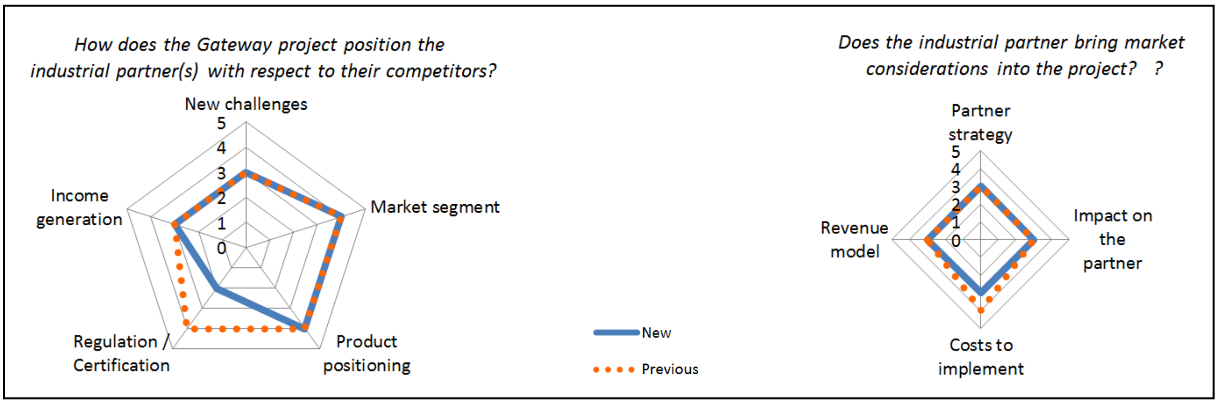



*Figure 54. Example of Credibility Assessment Plot.*

# PART V

# CONCLUSION

# CONCLUSION

Nano-Tera.ch is a very successful research program that has strongly impacted the Swiss research landscape in the domain of Engineering Sciences. It has led to numerous scientific and technological breakthroughs exploiting synergies between micro/nanocomponent technology and large-scale system design, and generated highly exploitable demonstrators with socially relevant applications in the areas of health, energy, and the environment.

**At the scientific level**, Nano-Tera.ch has significantly impacted Swiss research in Engineering Sciences by strongly promoting ambitious cutting-edge research, and strengthening inter-institutional collaboration at the boundary of traditional disciplines. The program operated through competitive calls for proposals, with an average acceptance rate of about 30%, to support 44 large, long-lasting, collaborative research projects. These projects have resulted in a large number of scientific results, with a level of scientific excellence consistently acknowledged over the lifetime of the program by annual evaluations conducted by the Swiss National Science Foundation and the Nano-Tera.ch Scientific Advisory Board.

This success confirms the crucial importance of two of the salient characteristics of the strategic vision of the Nano-Tera.ch program: (1) the clear decision to focus on a targeted research space at the intersection of industrially relevant technologies and socially relevant application areas. This has avoided spreading the available budget across too many research directions, thus making it possible to support truly large, ambitious collaborative research projects; and (2) careful use of the eligibility conditions associated with the planned calls for proposals to shape the targeted research consortia in accordance with the strategic aims of the program.

**At the educational level**, Nano-Tera.ch has achieved a major impact by focusing on training the next generation of scientific talents and funding more than 360 PhD students. The program further amplified this impact by establishing a specific NextStep program, designed to help the PhD students involved increase their autonomy, collaborative spirit, entrepreneurial mindset, and communication abilities.

With more than 68% of its PhD graduates pursuing their career in Switzerland, Nano-Tera.ch has been instrumental in providing the Swiss academic community and Swiss industry with the highly skilled staff they need to efficiently develop their research and innovation.

This success stresses the importance of a research program that contributes to scientific and technological progress. One that not only generates actual breakthrough results, but also secures the conditions for future achievements by injecting young graduates with fresh ideas and substantial, new knowledge of up-to-date technologies into the Swiss academic community and industry.

**At the economic level**, a major impact of the program stemmed from its contribution to strengthening the economic potential of the research results by focusing on creating the proper conditions for economic value creation. By requiring major projects to include industrial partners and end users, Nano-Tera.ch achieved a strong impact in terms of knowledge transfer. The resulting project consortia were able to satisfy the needs of the industrial partners involved by giving them access to experts in fields they consider to be strategic for their development and competitiveness. This impact has been furthered by Nano-Tera.ch funding a large number of PhD students who transferred to industry after graduation. This is an invaluable mechanism to transfer knowledge and skills which Swiss industry needs to innovate.

In addition to once again emphasizing the importance of the highly skilled young graduates trained in a research program such as Nano-Tera.ch, this success also highlights the importance of the regular interaction between industrial and research partners in long-lasting collaborative projects. This aspect has been repeatedly mentioned by the industrial partners involved in Nano-Tera.ch projects as one of the major reasons for their involvement.

Finally, in terms of Technology Transfer, Nano-Tera.ch required major projects to deliver exploitable research prototypes, and accelerated their absorption by the industrial partners involved by launching the Gateway program, specifically focused on translating research results into industrial-grade demonstrators.

The impact of the Gateway Program illustrates how crucial it is for a program such as Nano-Tera.ch to benefit from an autonomous management structure providing the required flexibility to quickly implement novel instruments such as Gateway (or NextStep).

**At the societal level**, the primary intention of Nano-Tera.ch was to promote a vision of engineering with true social objectives. This was a result of the strategic decision to strongly encourage the funded research partners to target concrete prototypes helping the industrial partners and end-users to take advantage of their involvement in the research projects. The aim was to envision and propose concrete applications for the scientific results achieved, associated with actual needs and potentially benefitting society as a whole.

It is important to note that the societal impact has been greatly amplified by the strategic positioning of the research targeted within Nano-Tera.ch at the intersection of industrially relevant technologies and socially relevant application areas (health, environment, and energy).

**At the institutional level**, Nano-Tera.ch spearheaded an intense nationwide collaboration between various Swiss research institutions involved in Engineering Sciences, such as the two Federal Institutes of Technology (EPFL and ETHZ), several universities and universities of applied sciences, and industry-oriented research and technology institutions (CSEM and Empa). In particular, the creation of a Nano-Tera.ch community involving about 1,600 members from more than 40 different institutions, and interacting through structured communication platforms (such as the Nano-Tera.ch annual meetings) and tools (such as the Nano-Tera.ch web site) have resulted in very substantial institutional impact, which is of crucial importance to the Swiss academic community.

In addition, the specific organizational structure of Nano-Tera.ch presents an interesting opportunity to define and validate innovative interaction mechanisms with Federal research management institutions. This is true in particular for aspects such as the distribution of the evaluation responsibility between the Nano-Tera.ch Committees, which was in charge of the strategic monitoring of the program, and the Swiss National Science Foundation, which was responsible for the scientific evaluation of the submitted proposals and the running of RTD projects.

Finally, one of the undeniable signs of the overall success and impact of Nano-Tera.ch has been that many of the new ideas developed and tested within the program have been included in BRIDGE, a new funding instrument deployed by the Swiss government for the funding period 2017–2020 to jointly support research and precompetitive innovation in the field of Engineering Sciences.

The Nano-Tera.ch scientific community would like to thank the Swiss authorities for their trust and foresight. We strongly believe that the Swiss government made a bold move by financing Nano-Tera.ch, and, ten years after the inception of the program, facts show that the country has significantly benefitted from it.

# APPENDICES

# A. TIMELINE OF MAIN PROJECTS

## PHASE 1

| RTD | | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|
| CabTuRes | C. Hierold | | | | | |
| CMOSAIC | J Thome | | | | | |
| GreenPower | J-A. Månson | | | | | |
| i-IronIC | G. De Micheli | | | | | |
| IrSens / IR-N-ox | J Faist | | | | | |
| ISyPeM / TWPeM | C. Guiducci | | | | | |
| LiveSense | P. Renaud | | | | | |
| MIXSEL | U. Keller | | | | | |
| NanowireSensor | C. Schönenberger | | | | | |
| Nexray / COSMICMOS | A. Dommann | | | | | |
| NutriChip / Ca-NutriChip | M. Gijs | | | | | |
| OpenSense / OpenSense+ | K. Aberer | | | | | |
| PATLiSci / MINACEL | H. Heinzelmann | | | | | |
| PlaCiTUS | Q. Huang | | | | | |
| QCrypt | N. Gisin | | | | | |
| SelfSys / SelfSys+ | J Brugger | | | | | |
| SImOS / SImOS+ | P. Ryser | | | | | |
| TecInTex | G. Tröster | | | | | |
| X-Sense | L. Thiele | | | | | |

| SSSTC | | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|
| i-Needle | S Carrara | | | | | |
| M3WSN | T. Braun | | | | | |
| NaNiBo | A. Züttel | | | | | |
| NetCam | J Lygeros | | | | | |
| SiC-nanomembranes | J Brugger | | | | | |
| 3DOptoChemiImage | D. Psaltis | | | | | |

| NTF | | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|
| BioAnt | A. Skrivervik | | | | | |
| BioCS-Node | P. Vandergheynst | | | | | |
| EMoA | F. Tièche | | | | | |
| Enabler | A. Ionescu | | | | | |
| G-DEMANDE | M. Schumacher | | | | | |
| MicroComb | T. Kippenberg | | | | | |
| NanoUp | A. Sienkiewicz | | | | | |
| NaWiBo | T. Zambelli | | | | | |
| NeoSense | M. Wolf | | | | | |
| PMD-Program | S Maerkl | | | | | |
| SecWear | M. Sami | | | | | |
| SMTS | C. Dürager | | | | | |
| TWIGS | D. Briand | | | | | |
| ULP-Logic | Y. Leblebici | | | | | |
| ULP-Systems | Y. Leblebici | | | | | |

## PHASE 2

### RTD

2013 | 2014 | 2015 | 2016 | 2017

| | |
|---|---|
| BodyPoweredSenSE | P.-A. Farine |
| Envirobot | J van der Meer |
| FlusiTex | B. Nelson |
| HearRestore | S Weber |
| HeatReserves | J Lygeros |
| IcySoC | A. Burg |
| IrSens II | J Faist |
| ISyPeM II | C. Guiducci |
| MagnetoTheranostics | H. Hofmann |
| MIXSEL II | U. Keller |
| NewbornCare | P. Vandergheynst |
| ObeSense | J-P. Thiran |
| OpenSense II | A. Martinoli |
| PATLiSci II | E Meyer |
| SHINE | C. Moser |
| SmartGrid | M. Kayal |
| SmartSphincter | B. Müller |
| SpineRepair | S Lacour |
| Synergy | C. Ballif |
| UltraSoundToGo | G. De Micheli |
| WearableMRI | K. Prüssmann |
| WearMeSoC | Q. Huang |
| WiseSkin | J Farserotu |
| X-Sense II | L. Thiele |
| YINS | D. Atienza |

### NTF

2013 | 2014 | 2015 | 2016 | 2017

| | |
|---|---|
| Breathe | M. Liley |
| D1NAMO | K. Aberer |
| IronIC++ | S Carrara |
| MiniHolter | J-M. Vesin |
| NAMBP | J Solà |
| ParaTex | M. Wolf |
| TANDEM | A. Weidenkaff |
| 3D-SensTex | D. Briand |
| 3D-Systems | Y. Leblebici |

### GATEWAY

2013 | 2014 | 2015 | 2016 | 2017

| | |
|---|---|
| CarboSense | L. Emmenegger |
| FlusiGate | L. Boesel |
| FlusiSafe | B. Nelson |
| HearRestoreGate | E Franzi |
| NambpGate | J Solà |
| ObeSenseGate | M. Bertschi |
| ParaTexGate | R. Rossi |
| SynergyGate | C. Ballif |

### STRAT. ACTIONS

2013 | 2014 | 2015 | 2016 | 2017

| | |
|---|---|
| InUse | C. Hüglin |
| Transcend | D. Atienza |
| Tera-Health | P. Pu |
| BioDev | G. De Micheli |
| MSSdevices | E Meyer |
| OpenSWISS | A. Martinoli |

# B. TECHNOLOGY READINESS LEVELS

| TRL | Technology readiness level | Description | Supporting information |
|---|---|---|---|
| **1** | Basic principles observed and reported | Scientific research begins to be translated into applied research and development (R&D). Examples might include paper studies of a technology's basic properties. | Published research that identifies the principles that underlie this technology. |
| **2** | Technology concept and application formulated | Applications are speculative, and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies. | Publications or other references that outline the application being considered and that provide analysis to support the concept. |
| **3** | Analytical and experimental proof of concept | Analytical and laboratory studies to physically validate the analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative. | Results of laboratory tests performed to measure parameters of interest and comparison to analytical predictions for critical subsystems. |
| **4** | Component and breadboard system validation in laboratory environment | Basic technological components are integrated to establish that they will work together. Examples include integration of "ad hoc" hardware in the laboratory. | System concepts that have been considered and results from testing laboratory-scale system(s). |
| **5** | Component and breadboard system validation in relevant environment | The basic technological components are integrated with reasonably realistic supporting elements so they can be tested in a simulated environment. Examples include "high-fidelity" laboratory integration of components. | Results from testing laboratory breadboard system are integrated with other supporting elements in a simulated operational environment. |
| **6** | Prototype system demonstration in a relevant environment | Prototype system is tested in a relevant environment. Examples include testing a prototype in a high-fidelity laboratory environment or in a simulated operational environment. | Results from laboratory testing of a prototype system that is near the desired configuration in terms of performance, weight, and volume. |
| **7** | Prototype system demonstration in an operational environment | Prototype near or at planned operational system. Requires demonstration of an actual system prototype in an operational environment. | Results from testing a prototype system in an operational environment. |
| **8** | Actual system completed and qualified through test and demonstration | Technology has been proven to work in its final form and under expected conditions. Examples include developmental test and evaluation (DT&E) of the system to determine if it meets design specifications. | Results of testing the system in its final configuration under the expected range of environmental conditions in which it will be expected to operate. Assessment of whether it will meet its operational requirements. |
| **9** | Actual system proven through successful deployment | Actual application of the technology in its final form and under conditions, such as those encountered in operational test and evaluation (OT&E). Examples include using the system under operational conditions. | |

## Annexe C – Rapport du panel d’experts CSS et prises de position, 2017-2018

### Annexe C1 – Terms of reference of external experts (TOR)

**Impact evaluation "Nano-Tera.ch"**

**Terms of reference for external experts (TOR)**

April, 2017

# 1 Purpose of TOR

The following TOR are to clarify the rights and obligations of the panel of experts on the one hand and the Swiss Science and Innovation Council (SSIC) and its staff on the other. These TOR also determine procedures and deadlines.

# 2 Purpose and context of the impact evaluation by the SSIC

In accordance with the official mandate of the State Secretariat for Education, Research and Innovation (SERI) delivered in September 2016, the SSIC conducts an impact evaluation of the national funding program "Nano-Tera.ch".

The impact evaluation focusses on the following dimensions:
- Scientific impact (excellence in science)
- Educational impact (promoting young talents)
- Economic impact (knowledge and technology transfer)
- Societal impact (social needs are taken into account)
- Institutional impact (structural changes in the Swiss research landscape)

# 3 Procedure of the impact evaluation

The complete evaluation procedure consists in three phases:

A. Self-evaluation report
Internal impact evaluation carried out under the responsibility of the Nano-Tera.ch Consortium. The requirements and conditions are stated in the SERI mandate

B. Panel report
Independent external assessment by a panel of international experts, based on the self-evaluation report by Nano-Tera.ch, additional documents provided by the SSIC and the information gathered during a site visit incl. interviews

C. SSIC report
Synthesis and overall assessment of the information gathered from national sources, from the self-evaluation report and from the panel report by the SSIC

See Annex for a timetable of the complete procedure.

# 4 Objectives of the assessment by the panel of experts

The assessment by the panel of experts focusses on a list of questions of the SSIC (based on the "dimensions" mentioned above, especially on scientific impact and economic impact).

Based on the documentation delivered by the SSIC as well as other sources (i.e. interviews at the site visit, see 7 below), the panel of experts shall critically assess the findings from an international perspective. The panel can draw comparisons with funding schemes or programs from other countries.

The SSIC will use the results of the expert panel assessment for its own analysis. Furthermore, the panel report will be addressed to the Swiss Federal Government as an annex to the SSIC report.

# 5 Procedure of the assessment by the panel of experts

| | | |
|---|---|---|
| **A** | **2017, Oct. 4** | The SSIC provides general documentation and the SSIC's main questions to the expert panel |
| **B** | **2017, Oct. 31** | The SSIC provides the self-evaluation of Nano-Tera.ch to the expert panel |
| **C** | **2017, Nov. 13-14** | The site visit will take place in Lausanne: coordinated by the SSIC, the expert panel will meet the Nano-Tera.ch Consortium and other actors |
| **D** | **2018, Jan. 8** (at the latest) | A first draft of the expert report will be delivered to the SSIC |
| **E** | **2018, Feb. 14** | The SSIC will send the positions of the Nano-Tera.ch Consortium and of the Swiss National Science Foundation on the draft report to the expert panel |
| **F** | **2018, Feb. 28** (at the latest) | The expert panel will decide about making a comment to the positions and, if appropriate, send the comment to the SSIC on February 28, 2018, at the latest |

# 6 Constitution of the panel of experts

The assessment will be carried out by an international panel of 3 independent experts. The SSIC is responsible for selecting the panel.

The panel organizes itself and will nominate a contact person for the SSIC. Every member of the panel can address the SSIC's office for any questions.

# 7 Documentation

The SSIC will provide the panel of experts with all the necessary documentation and information. This includes:
- General information on Swiss higher education system
- A summary of the SERI mandate
- The self-evaluation of the Nano-Tera.ch Consortium
- Additional documents and questions by the SSIC
- Administrative information (i.e. on participants and agenda of the site visit)

# 8 Tasks and responsibilities of the experts

At their discretion, experts can gather additional information they regard as relevant. In its report, the panel must disclose all sources of additional information.

The SSIC will receive the draft report from the contact person of the experts' panel on January 8, 2018, at the latest. This report will contain the panel's findings and recommendations, in accordance with the SSIC's questions, as well as a statement on the methods and documentation used by the panel.

The report will be in English. It will be no longer than 20 pages. The report must be delivered in electronic form, both as a PDF and as a Word file.

The report is meant to have group authorship. If the panel cannot reach a consensus, each member of the panel will sign his own text.

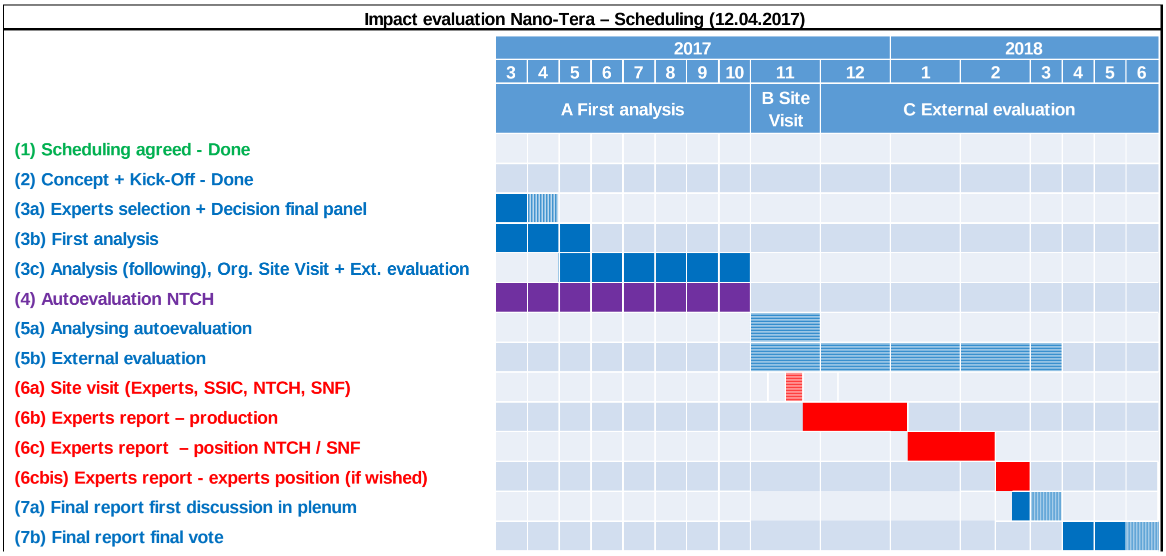
# 9 Independence, confidentiality and conflicts of interest

The members of the panel work independently and do not represent any organization. Panel members are required to declare any personal or other conflicts of interest.

Discussions between the panel of experts and the SSIC occurring during the site visit are not public and their content is confidential. No official minutes will be kept, but all participants are free to take notes for their own use.

Panel members may not make any use of, and may not divulge to third parties, any non-public information they learned or accessed during the procedure, including but not limited to information, knowledge, documents or other matters that are communicated to them or brought to their attention.

## Annex



## Annexe C – Rapport du panel d’experts CSS et prises de position, 2017-2018

### Annexe C2 – Questions du CSS au panel d’experts

# 1 Questions for the international expert panel

**Introduction**

In September 2016, the Swiss Science and Innovation Council (SSIC) received a mandate from the Swiss State Secretariat for Education, Research and Innovation (SERI) to conduct an impact evaluation of the National Funding Program Nano-Tera.ch.

The complete evaluation procedure consists of three phases:

a) Internal impact evaluation (*self-evaluation report, delivered to the SSIC on November 1, 2017*) carried out by the Nano-Tera.ch Consortium. The requirements and conditions are stated in the SERI mandate.

b) Independent external assessment by a panel of international experts (*panel report,* ***to be delivered to the SSIC on January 8, 2018***)

c) Synthesis and overall assessment of the information gathered from national sources, from the self-evaluation report and from the panel report by the SSIC (*SSIC report, to be delivered to the SERI end of June 2018*)

Following, the SSIC formulates questions to the international experts, in order to benefit as much as possible from their view, which will underpin SSIC's overall assessment.

**Questions (explanations and eventual complementary questions will occur during the briefing with SSIC on November 13, 2017, 12.15)**

**Dimension I: Scientific impact**

I/1. To what extent has the Nano-Tera.ch initiative contributed to foster excellence in research in Swiss engineering sciences? And in other scientific fields?

I/2. How well did the research activities comply with the a) collaborative, b) interdisciplinary and c) interinstitutional orientation of the program?

I/3. To what extent did the initiative contribute to bridge the gap between fundamental and applications-oriented research resp. between science and engineering?

I/4. How do you assess the originality of the projects funded (mainstream or cutting-edge)?

I/5. The selection and evaluation procedure for the main funding scheme (Research, Technology and Development Projects, RTD) was organized by an external panel from the Swiss national science foundation (SNSF). Was this procedure an advantage or a disadvantage to a) interdisciplinary research and b) the coverage of the whole spectrum of disciplines involved in the program?

**Dimension II: Educational impact**

II/1. How do you assess the measures taken to promote PhDs, especially the funding scheme NextSteps, introduced in 2015?

**Dimension III: Economic impact**

III/1. How do you assess a) the strategy to promote KTT on program level and b) the realization within the projects?

III/2. How do you assess the funding scheme Gateway?

III/3. How do you assess the measures taken by Nano-Tera.ch to promote KTT in comparison with similar initiatives at the international level?

**Dimension IV: Societal impact**

IV/1. How do you appreciate the societal impact of Nano-Tera?

**Dimension V: Institutional impact**

V/1. Which elements will remain in place after the end of the program, what was just part of a passing phase?

V/2. How do you assess the sustainability of the KTT after the end of the program, and especially the funding scheme Gateway?

**Overall appreciation**

VI/1. To what extent was the program Nano-Tera.ch able to implement the underlying vision?

VI/2. What are strengths and weaknesses? What might be the general lessons learned from the program?

VI/3. Do you see an added value of such a comprehensive program or would some smaller but focused programs be more efficient?

**Overall schedule**

| When | What |
|---|---|
| Now, present paper | The expert panel gets the SSIC's questions and additional documents |
| **2017, November 1** | The SSIC provides the self-evaluation of Nano-Tera.ch to the expert panel |
| **2017, November 13-14** | The site visit and other meetings take place in Bern (see below) |
| **2018, January 8** (at the latest) | The draft of the expert report is submitted to the SSIC |
| **2018, February 14** | The SSIC sends the comments of the Nano-Tera.ch Consortium and of the Swiss National Science Foundation on the draft report to the expert panel |
| **2018, February 28** (at the latest) | The expert panel decides about making an addition or a change to their report and, if appropriate, sends a final version of the report to the SSIC |
| **2018, June 30** | The SSIC submits the complete impact evaluation to the SERI. The expert report is included in the SSIC evaluation report. |

## Annexe C – Rapport du panel d’experts CSS et prises de position, 2017-2018

### Annexe C3 – Rapport du panel d’experts CSS

Swiss Science Council

Impact Evaluation of the National Funding Programme Nano-Tera.ch

# Report on Nano-Tera.ch by the expert panel

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January, 2018

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**Nano-Tera.ch Impact Evaluation: Report of the Expert Panel**

Prof. Jeremy Baumberg (Cambridge)
Prof. Rudy Lauwereins (Leuven)
Prof. Mark Lundstrom (Purdue)

Final Report December 18, 2017

**Preface:**

The Swiss Science and Innovation Council (SSIC) has a mandate from the Swiss State Secretariat for Education, Research and Innovation (SERI) to conduct an impact evaluation of the National Funding Program Nano-Tera.ch. One part of the evaluation procedure consists of an independent evaluation by a panel of international experts. The SSIC posed a set of questions to the Expert Panel and organized a "site visit" on Nov. 13, 2017 followed by a meeting with the Swiss National Science Foundation (SNSF) on Nov. 14, 2017. The site visit was chaired by Jean-Marc Triscone, SSIC and attended by the Nano-Tera.ch PI, Giovanni De Micheli, and several Nano-Tera.ch faculty participants. Prior to the site visit, the Expert Panel was provided with a self-study Impact Analysis Report 2017. The site visit consisted of short presentations that summarized the self-study report, followed by questions, answers, and discussion. On November 14, the Expert Panel met with scientists from the SNSF, who provided their perspectives on the program and participated in a discussion with the Expert Panel. Following the meeting with the SNSF, the Expert Panel was provided with additional information:

-RTD Calls 2008-2016
-Recommendations of SNSF Panel to the PIs and on phase 2 (2013-2016)
-External report on KTT by Interface
-Analysis of Nano-Tera.ch grants related to SNSF grants

The specific objectives and expected outcomes of the program were summarized for the Expert Panel in Annex 1 (The SERI Mandate) of the document: "Questions for the international expert panel and documentation". Fifteen specific questions were posed to the Expert Panel. Before responding to the specific questions, we briefly summarize our main conclusions and recommendations.

**Summary Conclusions and Recommendations**

By way of preface, the panel would like to say that we understand both the considerable challenges and opportunities of running large, comprehensive programs like Nano-Tera.ch. The Nano-Tera.ch leadership team should be complimented on their hard work, dedication and achievements. It is the Panel's conclusions that Nano-Tera.ch was a highly successful and innovative program. Some of the specific successes are identified below along with some suggestions that can be considered for future programs.

- Nano-Tera.ch was very successful in establishing a collaborative, multi-disciplinary, inter-institutional program, but the project selection mechanism made it difficult for Nano-Tera.ch leadership to establish a coherent, overall vision.

- The creation of 40 startup companies is convincing evidence that Nano-Tera.ch succeeded in its mission to bridge fundamental and application-oriented research, but stronger connections to advisors from industry would have benefitted the program.

- The decision to allocate 80% of the budget to large, multi-disciplinary projects was wise. It allowed Nano-Tera.ch to address science to applications research in a way that differentiated Nano-Tera.ch from smaller scale programs.

- Nano-Tera.ch provided Ph.D. students with a unique research experience. The connection of research to applications provided them with a strong foundation for success in industry and in academic research, which is increasingly driven by applications. The NextSteps program can be a good model for the future.

- The KTT program was largely a traditional academic one that would have benefitted from an examination of KTT models from programs in other countries. Gateway stands out as an example of a new approach to KTT. Gateway and the overall KTT program would have benefitted from stronger connections to industry.

- Nano-Tera.ch addressed broad, societal challenges in health, the environment, and energy that are strategic research goals in most countries. The focus of Nano-Tera.ch on broadening academic research to include applications significantly increases the potential for societal impact. This was a major success of Nano-Tera.ch, but more emphasis on outreach to industry, pre-college students, and government could have increased the visibility and impact of Nano-Tera.ch.

- Significant successes have been achieved but the panel is concerned about the legacy of Nano-Tera.ch. Enduring outcomes of Nano-Tera.ch do not appear to have received strong consideration in the definition, review, or operation of the program. The panel did not see evidence that successful programs and practices have been institutionalized at the participating universities. The SNSF should consider a set of small follow-on grants specifically directed institutionalizing some of the key programmatic successes.

**Dimension I Questions: Scientific impact**

***I/1. To what extent has the Nano-Tera.ch initiative contributed to foster excellence in research in Swiss engineering sciences? And in other scientific fields?***

The large number of publications and awards attest to the excellent research that has been done. Research quality benefitted substantially from the real-world application focus embedded in the projects thanks to the multi-disciplinarity that brought together application domain experts with enabling technologies experts, as well as scientists with engineers. Unfortunately, the project selection mechanism, being focused solely on the quality of an individual project proposal, hampered strategic steering based on one central high-level vision per domain (health, environment, energy). This led to a collection of very high quality but disjoint projects rather than to a coherent visionary program of complementary projects. One challenge in Nano-Tera.ch was maintaining balance between high impact science and translations to applications. It was not clear how different teams made this trade-off. Finally, while it was clear to the Expert Panel that Nano-Tera.ch fostered excellence in engineering science, the connection to "other scientific fields" was less clear.

**I*/2. How well did the research activities comply with the a) collaborative, b) interdisciplinary and c) inter-institutional orientation of the program?***

The specific structure and ambition of Nano-Tera.ch effectively led to cross-disciplinary and cross-institutional cooperation between teams that did not cooperate with each other or even did not know each other before the start of this program. Since the most important innovations happen at the boundaries of scientific disciplines and at the boundary between science and engineering, the nano-tera.ch management should be complimented for having been able to realize this cooperation in a Swiss university organizational structure that was not favorable to such cooperation and that was mainly built on a mutual competition model. This cooperative spirit fostered by Nano-Tera.ch was an important outcome of the program, but the Expert Panel is concerned about whether it can be maintained after the Nano-Tera.ch program has ended.

The Expert Panel noted that fewer than a one-third of the resulting journal papers were jointly authored by two or more partners within the same project. The Nano-Tera.ch team's response was that individuals tend to publish research papers on their own discipline-specific contributions to the larger project. Putting these disciplinary components together creates larger impact at the project scale, but this did not seem to be documented in jointly authored papers on the larger project. The Nano-Tera.ch team emphasized that the added motivation for the researchers in being supported in projects that brought different specialists together was extremely effective. While this seems reasonable to the Expert Panel, it raises the question of what metric can be used to assess successful collaboration and interdisciplinary, if not joint publications or patents?

***I/3. To what extent did the initiative contribute to bridge the gap between fundamental and applications-oriented research resp. between science and engineering?***

The fact that the program created 40 startup companies is strong evidence that the goal to bridge the gap between application-oriented science and engineering was realized. Startup companies create disruption at the engineering level by creatively solving important scientific problems and, at the same time, end user pain by creating disruption at the application level. It was unclear specifically how much Nano-Tera.ch funding had contributed to each startup (since only 10 were specified in the reporting). We were surprised that this reporting back from the teams was not specifically built into their contracts, nor was there a larger understanding of the spin-out space from Nano-Tera at this end stage of the program.

While it was clear to the Expert Panel that the gap between "engineering science" and applications was bridged, it was not at all clear that the gap between "fundamental science" and applications was addressed. Most of the participants were applied scientists already on the engineering science/applications edge. Nevertheless, Nano-Tera.ch provided crucial funds to bridge the applied science to applications gap, and this was an important outcome.

***I/4. How do you assess the originality of the projects funded (mainstream or cutting - edge ) ?***

The choice to allocate 80% of the budget to larger multi-disciplinary projects with enough critical mass was wise. Because funding of this kind is rare, it differentiated Nano-Tera.ch from more traditional, smaller scale programs. Allocating a smaller amount of money to projects that glued existing large projects was an excellent decision too. The Expert Panel did not, however, see a scientific justification for the small cooperation projects with China.

The quality of the projects was high and helped achieve the goal of bringing Switzerland to the forefront of a new technological revolution. There were few highly original, "signature projects" that set Switzerland apart. The program looks to have taken most of the strong engineering science teams in Switzerland and extended their reach further into application spaces, rather than insisting on completely original research.

***I/5. The selection and evaluation procedure for the main funding scheme (Research, Technology and Development Projects, RTD) was organized by an external panel from the Swiss national science foundation (SNSF). Was this procedure an advantage or a disadvantage to a) interdisciplinary research and b) the coverage of the whole spectrum of disciplines involved in the program?***

Selection of projects through a panel that was independent from the groups submitting the proposals, i.e. independent from the ExCom of Nano-Tera.ch was essential to ensure fairness in selecting the scientifically highest quality multi-disciplinary projects. However, when scientific excellence is not the only criterion, but when also potential future economic impact and the fit to an overall strategic vision has to be taken into account, the SNSF-only selection procedure led to a collection of disjoint projects rather than to a coherent visionary program of complementary projects. It emphasized scientific quality and fairness for the applicants above originality, thought leadership and economic impact for Switzerland and, in fact, underutilized the scientific leadership of the ExCom.

## Dimension II Questions: Educational impact

### *II/1. How do you assess the measures taken to promote PhDs, especially the funding scheme Next Steps, introduced in 2015?*

The focus of Nano-Tera.ch was on research, so the strong focus of the educational activities on Ph.D. students made sense. A large number of Ph.D.'s was produced (366), and the program gave them a kind of training in applications that should make them especially attractive to industry (61% entered industry). It was clear to the Expert Panel that the PhD experience through Nano-Tera was very different than the typical Ph.D. experience in Switzerland as a result of exposing research students to a much wider range of disciplines, motivations, and interactions than is common.

The Next Steps scheme is excellent, though participation (15%) was not as large as might have been expected - possibly because individual PIs were less supportive of this use of Ph.D. students' time. The possibility of offering Next Steps to all PhD students in Switzerland should be considered; it would make Ph.D. students much more capable of taking the next steps in their careers with confidence. Questions raised by the Nano-Tera.ch team about who would mandate Ph.D. students to participate and who would monitor the program would need to be considered, but if done, Next Steps could be a Nano-Tera.ch contribution with lasting impact.

On top of the Next Steps program for PhD students, a program to increase the business awareness of the PIs would have been beneficial since the projects aim at developing demonstrators and proof-of-concepts with high economic valorization potential. Specially to prepare Gateway project proposals, concepts like unique selling proposition, red/blue, ocean, go-to-market strategy, IP protection strategy, business models, … are of high importance and typically less familiar to academic PIs.

The total amount of funding devoted to education per se (i.e. exclusive supporting Ph.D. students) was small (<1%).  Much was accomplished with little funding, but this raises the question of what could have been accomplished with more funding. For example, there was no mention of MOOCS and other kinds of online education that are widely discussed today. Such an initiative could have provided students across the spectrum of Switzerland's educational institutions with access to some of the rich educational resources available at EPFL and ETHZ as well as serving as a resource for working engineers in a period of rapid technological change.

**Dimension III Questions: Economic impact**
***III/1. How do you assess a) the strategy to promote KTT on program level and b) the realization within the projects?***

One of the goals of the SERI mandate was "a significant strengthening in the domain of Knowledge and Technology Transfer and an increased collaboration with the interested players from the private sector." The Expert Panel hoped to find some innovative and successful new idea, but the KTT program appears to have been a traditional academic one. There were a large number of publications (1600, 700 of which were journal publications). The nano-tera.ch team pointed out that people are the most effective means of KTT. The large number of Ph.D.'s produced (366) and the high percentage that took non-academic positions (61%) reflects a high degree of success in people-based KTT.

Despite a very traditional approach to promote knowledge transfer, the nano-tera.ch program obtained substantial, though local, economic impact through e.g. the creation of 40+ startup companies. Although the program aimed clearly for future valorization and addressed challenges that are matching industrial needs, the program did not install an Industry Advisory Board, not at the program level nor consequently within each project. Other programs have found value in associating "industrial mentors" with university-based research projects. Such people are often friends with experience in industry who visit the team regularly to discuss progress. Good mentors ask hard questions about where the team is really going, how best to get to a strong demonstrator, and in what timeframe and with what resources. In addition to the benefits to students, industry mentors can help educate PIs in the issues involved in application development.

Despite the strategic basic research nature of the projects, the Expert Panel feels that having an industrial sounding board is necessary to ensure that the boundary conditions assumed in those projects are not conflicting with industrial needs. There was no detailed mechanism to get feedback from industrial partners and outside industry as to what they wanted to see in this engineering science programme. With only one industrialist on the scientific advisory board, this was not sufficient feedback for an industry-connecting programme like this. How did the team know if industry would find other approaches more effective than theirs, and how did they try to find this out? Were industry partners in the projects suggesting of some improvements, and how were these acted on in a concerted way?

***III/2. How do you assess the funding scheme Gateway?***

Funding for Gateway was modest, but it was a good idea and would naturally look like the new Bridge scheme. Selection of the projects seems reasonable, but little is available to describe how the projects were really pushed forward, and how the outcomes to commercialisation will really be improved. In our view, this scheme should have been instigated from the very beginning and given greater funding, however it would also have to have robust evaluation of which projects are suited to this acceleration of TRL level.

For the Gateway projects, the Expert Panel also feels that having a critical industrial sounding board should have been mandatory for every project, thereby ensuring a smoother knowledge transfer to industry after the end of the project. One measure of success would be the number of projects commercialized, but an equally important measure (especially given the level of funding) would be the educational value to Ph.D. students learning how to translate science into real applications. This educational value of the program could have been greatly enhanced by a strong set of industry advisors.

**III/3. How do you assess the measures taken by Nano - Tera.ch to promote KTT in comparison with similar initiatives at the international level?**

In contrast to the Next Step program, which introduced some innovations to prepare Ph.D.'s for careers in industry, the Expert Panel did not see innovations in KTT.

Because the Nano-Tera.ch program was led by science not industry, there was a strong element of technology push. Because of the project selection process, Nano-Tera.ch was also not very focused and ended up being rather diffuse, with no apparent cohorts of projects to help support each other or attract panels of potential investors. Other countries use a range of initiatives. In the UK there have been Eu2-4M 5 year Basic Technology projects which occupied a similar space, however these were successfully run by the research councils, rather than making another body. There are also Impact Acceleration Accounts (IAAs) in the UK which the research councils provide as funding to universities, who are then able to freely fund Gateway-type programs from, involving industrial mentors (or anything else to help this stage).

In Flanders, fundamental research projects and single-disciplinary strategic basic research is carried out by the universities and universities of applied sciences via the FWO funding agency. Multidisciplinary research is strategically driven by the Strategic Research Centers (SRCs) (imec, VIB, VITO and FlandersMake) that either have close relationships with universities (imec-process technology and hardware; VITO) or are a virtual organization of research teams of multiple universities (imec-software; VIB; FlandersMake), and that have at the same time very close ties with industry and have an industrial knowledge transfer end goal. The central leadership of these Strategic Research Centers ensures strategic domain thinking, fast adaptation to economic changes and fosters an application pull mindset. The PhD students working at the SRC and graduating at one of the affiliated universities all get a Next Steps-like training on entrepreneurship and public speaking. The SRCs thereby fulfill the roles that were taken up or aimed at by Nano-Tera.ch. Gateway-like projects are run by the SRCs in close cooperation with universities and with friendly but critical industrial guidance. Closer to market projects are the so-called ICON projects where the Vlaio funding agency (cf CTI) ranks projects according to quality and the SRC finally decides among the projects surpassing the quality threshold based on strategic and valorization criteria. ICONs must be executed for more than 50% by industry and should involve multiple university groups to ensure multi-disciplinarity.

These experiences from just a few countries make us question how much Nano-Tera looked at outside models for ways to structure their program most beneficially. It appeared that the programme management did not explore collaborative industry-science models already tested in different countries (not necessarily the USA), as there are many established ideas for linking the science and technology base. It is not clear if this arises from the feeling of Swiss participants that there are particular difficulties special to them related to the federalised structure. On the other hand, many specific delivery schemes (wording of call documents, formulation of graduate training, use of mentors,..) have been tried in many other EU countries, and the team was slower to develop many of theirs because they did not reach out to see best practice elsewhere. The team emphasized their ability to try new ideas due to their separate structure, but then did not evidence so much.

The international visitors program could have played a stronger role in Nano-Tera.ch. The Expert Panel was unable to discern a strategy for inviting specific speakers. Which parts of the agenda were they invited to impact? The number of visitors also seems low for a 10-year program. The international visitors program could have played a strong role in helping Nano-Tera.ch strongly reach out to involve other countries.

Nevertheless, Nano-Tera.ch successfully filled two gaps in the existing Swiss landscape: (1) it did an excellent job to encourage multidisciplinary strategic basic research in the diverse university landscape of Switzerland and (2) it experimented with making technology push results ready for industry uptake by matching it with some application pull. As such, it positioned itself between the traditional SNSF projects and CTI projects. With the end of Nano-Tera.ch, the Expert Panel fears that this gap will again become more prominent, despite the synergy between SNSF projects and the Bridge program since these by nature can only focus on per project evaluation and miss the strategic leadership domain thinking that is essential at the boundary between technology push and market pull.

**Dimension IV Questions: Societal impact**
***IV/1. How do you appreciate the societal impact of Nano - Tera ?***

Potential for societal impact is the relevant measure for projects of this kind, and the range of projects with a strong potential impact on society is extremely good. This is partly the result of the very broad goals of Healthcare, Environment, and Energy, which are the strategic paths of all countries, but there must also have been a sensible selection of projects in Phase II. We note that many of the individual projects were able to generate strong publicity and reach through press reports to the public. Another measure of potential for impact is the increased number of faculty and students interested in using nano- and tera-technologies to address societal challenges.  Nano-Tera.ch has been a success from this perspective.

Efforts to increase societal impact in ways beyond the ongoing projects and increased number of people appear rather less strong. Opportunities to combine different themes together and engage with schools and the parliament were missed. For instance, using the school kids brainstorming on the societal impact of projects if they come to fruition, could then have been connected to their feeding back to politicians to both raise the standards of political debate as regards science futures, while bringing young generations with an attitude to embrace technologies into this debate with a key stake in the outcomes.

**Dimension V Questions: Institutional impact**
***V/1. Which elements will remain in place after the end of the program, what was just part of a passing phase?***

One hopes that a program with the size, scope, and duration of Nano-Tera.ch would make lasting contributions. The emphasis on multi-disciplinary research, on application-driven research, and the connections between Swiss institutions and between academia and industry were important contributions, but the concern is that these contributions do not appear to have been institionalized. In fact, it appears that very little will be left in place after a quite significant investment of time and funding. The individual projects having birthed spin-outs, and some new research focus will continue (many of these seem to be applying for the Bridge program). The earlier stage work of Nano-Tera.ch, despite being seen as a success, does not seem to have settled in the institutions as a permanent feature. Rather the pervasive nature of interdisciplinary research seems to have caught hold better, with institutional provision now for cross-faculty and theme-based appointments and support. For specific appetite in pushing engineering science to engage with end-users much more, it seems this is left to individuals rather than institutions.
Even the significant increase in PhD students emerging with these key skills demanded by industry (broad focus, strong training, applications oriented) will just disappear with no legacy. This is a problem for the Swiss economy, which seems to be demanding ever larger numbers of these skilled researchers.

Perhaps even more worrying is the breakdown in support for long-lived projects between ETH/EPFL/universities and industrial partners. This has been highlighted as a key gain, opening up continuous dialogue that is not only valuable for the specific projects being worked on, but generally allowing industry to gain expert feedback and insights into changes in the technologies that are emerging, and thus to better plan their developments. This dialogue will not happen without programs like NanoTera.

Many of the projects involved collaborations with hospital partners. These apparently went well, but this is a notoriously difficult interface, and it would be valuable to understand if there was anything in the current structure that helped this (not obvious), or the teams had already good interactions with hospitals (dealt with issues already or outside the knowledge of NanoTera), or there were in fact problems. It is noted that SNSF was able to bring in division III reviewers to help on these grants, but it is not clear if there were additional interactions with strategic focus of this division, linking to division II. Some strategic overview of the engineering science to bio-healthcare interface would have been helpful.

***V/2. How do you assess the sustainability of the KTT after the end of the program, and especially the funding scheme Gateway?***

Overall the early stage nature of the investments in Nano-Tera.ch make it very unlikely to be self sustaining, as if it were some Venture Fund. In the latter case, it would avoid too much risk and demand a later stage than the Nano-Tera.ch projects were at (more like Bridge). Instead, it is more appropriate to ask how these projects will feed back to the Swiss economy after 10 years, and this is much more likely to be a positive success with new companies, new relationships, new agendas, and new partnerships all developed.

The Gateway scheme is unlikely to generate revenue that will make it self-sustaining. It should help cross the “valley of death” between R & D, not act as a resource to give funds for future project support. It is possible that individual institutions will support some of this, but considering of providing governmental funding to this should be given.

The Bridge program, as it is currently implemented, does not address the gap created by the end of Nano-Tera.ch for several reasons. It does not support the upstream multidisciplinary research, and it also does not provide the strategic leadership and vision necessary to go beyond the level of selecting interesting disjoint projects. The Bridge projects themselves and their selection process are heavily dominated by scientific quality with economic valorization potential only considered a second criterion (more SNSF than CTI); there is, for example, no mandatory industrial advisory board per project; the selection panel consists almost entirely of people with a university appointment and less than 20% of the external experts have an industrial affiliation.

**Questions about Overall appreciation**

***VI/1. To what extent was the program Nano - Tera.ch able to implement the underlying vision?***

The vision was a program on large-scale, multidisciplinary research on complex systems for health, the environment, and energy. Nano-Tera certainly provided a strong platform to bring engineering science towards applications. It had a strong management team, and eventually strong buy-in from a range of PIs. The vision evolved over the duration of the project, which makes implementation measures harder to evaluate. Was the over-arching vision to change practice in academics, or was it to found new companies, or was it to generate patents, or to educate young researchers about innovation, or to bring together different teams to focus on applications? Nano-Tera found implementations for all of these; some were stronger than others. Nano-Tera did manage to correct issues as they were identified, and this has been a major strength of the management structure that it had.

In summary, the program strengthened connections between engineering science and applications. It connected scientists throughout Switzerland. Nano-Tera also strengthened connections between academia and industry. The Expert Panel is concerned about where these accomplishments have been institutionalized to a degree that will ensure their continuation.

***VI/2. What are strengths and weaknesses? What might be the general lessons learned from the program ?***

The strength of Nano-Tera.ch was to enable cross-disciplinary research across teams from (competing) federal and cantonal universities and universities of applied sciences, resulting in high quality and highly visible research projects with tangible demonstrators and in some cases also proof-of-concepts. At the same time, it educated a large group of PhD students in skills that are essential for the Swiss economy and only sparsely available.

It was not clear why the program did not at the earliest time after funding, scout around a number of other countries to look at what worked well in similar programs, and what worked less well. This could also have been done at the end of Phase I. Instead they seemed to develop everything themselves, which led to patchy incorporation of different schemes (like Next Step which seems anyway to have emerged from EPFL) and reduced impact among their own researchers as well as in wider society.

The lack of serious, sustained efforts to ensure a legacy of the Nano-Tera program can be viewed as a weakness. While it appears the Bridge program is now a downstream version of Nano-Tera.ch, there appears to be nothing like it on the horizon, doing the crucial job of connecting early-stage promising research with technological development and innovation into applications. Perhaps the legacy among the specific researchers is an appetite for engaging in this, but they may become now frustrated that there is no instrument to help them on this journey. We understand that some of the PI's are now looking for private resources to bridge this "funding gap", but this will not be suitable for the full Swiss engineering science community.

***VI/3. Do you see an added value of such a comprehensive program or would some smaller but focused programs be more efficient ?***

This comprehensive program is very strong in changing the practice and vision of engineering research and in injecting trained people into the industrial base. Now that Nano-Tera has demonstrated what is possible, similar results could probably be delivered from within a funding council rather than outside it, as long as a specific manager is given the responsibility for delivery and there are suitable evaluations, and no turf warfare in between science and application-based research funders. Both NanoTera and SNSF recommended in our site visit that decisions of excellence and strategic direction are integrated into the same committee, to avoid tensions between them (Excom and SNSF panels). This would also require clear guidelines on how to balance these tensions to the committee, but would lead to better transparency of decision making.

We asked if NanoTera could have been achieved as a dedicated ring-fenced fund inside SNSF delivering multiple calls for different themes, twinned with funding for a network and PhD training programme. One reason not to do this would be added value from Excom (though this also could be integrated into the SNSF delivery) and other management. It is not clear where the added value was, since many of the components like NextStep were produced separately from the NanoTera management. The team gave not so obvious help to the different projects in market/business/mentoring directions, nor much engagement with industry (for instance no workshops for industries along themes as originally promised). The main dangers for a nanotera model embedded within SNSF are several fold: thought-leadership aside from internal review can be lacking, and extra funding promised by government to such programmes would not arise if they were vested in the existing research councils, and instead would take away money from existing funding for science. However the ranking system from SNSF, combined with another ranking by CTI or separate industrial board, and final decision by the ExCom, might combine the different aims well as long as a neutral but strong body oversaw it.

## Annexe C – Rapport du panel d’experts CSS et prises de position, 2017-2018

### Annexe C31 – Prise de position FNS sur le rapport du panel d’experts CSS

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Berne, 2 February 2018/AK

**SNSF comments on the « Report on Nano-Tera.ch by the expert panel »**

Dear Dr. Joye-Cagnard,

We would like to thank you for the *«Report on Nano-Tera.ch by the expert panel»* and the opportunity to offer our comments with respect to the role of the SNSF evaluation panel.

**A)** ***SNSF Panel criteria/composition***. The SNSF Panel applied a set of criteria that can be split into two groups. First, the SNSF project evaluation criteria: Scientific quality, originality, adequacy of the methodology, feasibility, scientific track record. Second, a NT specific set of criteria, see for instance the Call Document 2013

- Integration into the overall Nano-Tera.ch vision
- Potential of the proposal in extending the state of the art in the Nano-Tera.ch domains
- Significant and genuine collaborative effort and synergy of the participants
- Ability to deliver realizations of the proposed results within the NT program lifespan
- Proven industrial interest in the research via financial and/or technical contributions
- Differentiation of the proposed activities when compared to other funded programs

The SNSF Panel had members from various industries: ICT (*IBM*, U. Dürig), medical technology (*Straumann*, M. Wieland), ICT (*Bell Labs*, D. Bishop), industrial consulting (Crossbow Consulting, A. Dunlop) and several from applied research.

Thus, we would like to emphasize that the "SNSF-only selection" included also NT specific criteria beyond scientific excellence and non-academic experts, which is in contrast to the statement by the Expert Panel:

**I/5** *"However, when scientific excellence is not the only criterion, but when also potential future economic impact and the fit to an overall strategic vision has to be taken into account, the SNSF-only selection procedure led to a collection of disjoint projects rather than to a coherent visionary program of complementary projects."*

**B)** ***Conflicts of interest***. It is an inherent challenge to embed a coherent program in a small country, as a participation of the leading people is desirable in both the governance of the program as well as in the execution of the program. In the case of NT, members of ExCom were at the same time in the role of applicants. For the SNSF, it is in such a situation of utmost importance to perform an independent evaluation. This is the reason for the "underutilization" of ExCom by the SNSF Panel that the Expert Panel stated:

**I/5** *"the SNSF selection procedure underutilized the scientific leadership of the ExCom"*

**C)** ***Overall strategic vision.*** The Expert Panel states that the success of NT in implementing a coherent "overall strategic vision" of the program was limited and connects this observation to the selection mechanism:

**I/1** *"the project selection mechanism, being focused solely on the quality of an individual project proposal, hampered strategic steering based on one central high-level vision per domain (health, environment, energy). This led to a collection of very high quality but disjoint projects rather than to a coherent visionary program of complementary projects…"*

**V/1** *"Some strategic overview of the engineering science to bio-healthcare interface would have been helpful"*

The design of the selection mechanism (call documents and evaluation criteria) was in the responsibility of ExCom based on the mandate by SEFRI. The SNSF panel was responsible of implementing the selection procedure (see point A) above).

**D)** ***Sustainable impact/legacy.*** There is no strategic follow program of NT as correctly stated by the Expert Panel:

**V/2** *"….The Bridge program, as it is currently implemented, does not address the gap created by the end of Nano-Tera.ch for several reasons. It does not support the upstream multidisciplinary research, and it also does not provide the strategic leadership and vision necessary to go beyond the level of selecting interesting disjoint projects."*

However, the Bridge program targets the same critical step in a bottom-up instrument open for a broader range of disciplines. From the terms of reference: "The goal of BRIDGE is to foster knowledge transfer in the critical precompetitive phase when a vision of potential applications of a scientific result exists, but further efforts are needed to bring the corresponding product, technology or service to a marketable form".

The observed demand (see point E) below) confirms that the following statement by the Expert Panel is not to the point:

**VI/2** *"…there appears to be nothing like it on the horizon, doing the crucial job of connecting early-stage promising research with technological development and innovation into applications"*

**E)** ***Bridge.*** Innosuisse and SNSF launched the Bridge Program in December 2016 with two instruments: Proof of Concept (young researchers, small grants, short duration) and Discovery (established researchers, substantial grants). In the meantime, Bridge has evaluated one

Discovery Call and five Proof of Concept Calls. The demand in both types of calls was strong, potentially also due to the preparation of the community by NT.
The evaluation in Proof of Concept focuses on the potential of innovation and economic impact and uses the implementation strategy based on a scientific idea by the applicants as the main evaluation criteria. The evaluation in Discovery attributes in the evaluation an equal weight to the potential of innovation/economic impact and to scientific quality. Thus, the following statement by the Expert Panel is in our opinion not justified:

**V/2** *"The Bridge projects themselves and their selection process are heavily dominated by scientific quality with economic valorisation potential only considered a second criterion (more SNSF than CTI)"*

The Bridge evaluation panels must have a balanced mix of people. Currently, in Proof of Concept, we have a distribution between panel members with an industrial (43%), an applied research (28.5%) and a basic research (28.5%) affiliation. In Discovery, where the scientific impact is more important, the distribution is different with industrial (18%), applied research (32%) and basic research (50%). These numbers are in contrast with the statement:

**V/2** *"... the selection panel consists almost entirely of people with a university appointment ..."*

The Discovery Evaluation Panel uses reviews from external experts as a part of the funding decision. In 90% of the proposals, there is at least one review from experts from industry or universities of applied science. These numbers are in contrast with the statement:

**V/2** *"...less than 20% of the external experts have an industrial affiliation"*

The large demand for Bridge indicates that the offered funding schemes fill an important gap. The potential frustration mentioned by the Expert Panel is rather a result of the limited available funding (success rates of 11% after first call Proof of Concept, stabilizing at ca. 20% now; 4.2% in first call for Discovery) than of the lack of an appropriate instrument:

**VI/2** *"Perhaps the legacy among the specific researchers is an appetite for engaging in this, but they may become now frustrated that there is no instrument to help them on this journey"*

**Comment:** One of the authors of the report of the Expert Panel, Prof. Rudy Lauwereins, is co-authoring three publications[1] with Prof. Giovanni De Micheli.

We hope that these clarifications will be useful in finalizing the SSC report on Nano-Tera and remain at your disposal for any other questions.

Yours sincerely,

Dr. Angelika Kalt

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[1] The titles and links to the publications are:
Wave pipelining for majority-based beyond-CMOS technologies,
Inversion optimization in Majority-Inverter Graphs,
Design and benchmarking of hybrid CMOS-Spin Wave Device Circuits compared to 10nm CMOS.

## Annexe C – Rapport du panel d’experts CSS et prises de position, 2017-2018

### Annexe C32 – Prise de position Nano-Tera.ch sur le rapport du panel d’experts CSS

Département fédéral de l'économie, de la formation et de la recherche DEFR
Conseil Suisse de la Science
Einsteinstrasse 2, CH-3003 Berne

Lausanne, February 16th, 2018

**Ref: Nano-Tera.ch Impact Evaluation: Answer to the report from Expert Panel**

We would like to thank the Expert Panel for the effort and time spent for the evaluation. We agree with most findings of the Panelists: here we rebut some of the issues that were raised. First of all, it has to be understood that the Nano-Tera.ch program operated under the Rules and Regulations that were imposed on us at the start of the program. In some cases, these rules were limiting. Nevertheless a strong effort was put into making the best program within the given constraints. Second, we focus here on rebutting only the main criticisms.

***Lack of a coherent, overall vision in the selection of the funded projects***: the project selection (and yearly evaluation) was based on intrinsic excellence and performed by the Swiss National Science Foundation Panel. The Nano-Tera.ch EXCOM objected to some of the project choices during Phase 1, because the EXCOM required more continuity among projects and a better fit with the strategic vision. This concern was echoed by both the Scientific Advisory Board and the Steering Committee. The issue was formally brought to the highest level of SNF in a meeting in Bern in February 2009, but unfortunately the SNF rejected any dialog on the project selection issue. The situation improved in Phase 2, when the SNF Panel agreed on some cooperation, such as adding women to the evaluation panel, as the female gender was unrepresented. In Phase 2, the SNF panel was also more open to receive some indications from the EXCOM on the strategic fit of the projects, but it still executed selection decisions singlehandedly. There were two other unfortunate outcomes of the project selection policy: 1) only six projects (out of 19) were continued from Phase 1 to Phase 2 (thus hurting continuity) and 2) the SNF Panel had a bias against selecting projects involving industry, as considered not in the direction of pure research. However, it has to be noted that the panel executed its duties according to their marching order. There was no adverse feeling between SNF Panelists and NT EXCOM members. Rigidity, which is deprecable, was a result of the imposed Rules and Regulations.

***The KTT dimension***: The nature and extent of Nano-Tera's KTT-related measures have been strongly constrained by the imposition to work under SNF's umbrella, while typically projects involving industry are run by CTI/KTI which was not involved in Nano-Tera.ch. Within this rather unfavorable context, the program nevertheless fostered people-based KTT by requiring the presence of industrial, translational, and use-oriented partners in the project consortia. This approach turned out to be very successful (with 50% of non-academic partners active in the project consortia) and has been considered as a very efficient KTT channel by the KOF expert mandated by NT to evaluate the economic impact of the program. In addition, Nano-Tera.ch also invested much of the residual funds of Phase 1 and a fraction of the strategic funds of Phase 2 into additional specific KTT measures, selected because of their synergistic value with research. Namely, the *Gateway* program for the transfer of research results into industry-level prototypes, and the *NextStep* entrepreneurial track helping PhD students explore the economic value of their research. Both efforts have been considered as successful and original, and it is very questionable whether additional actions (such as the setup of an Industrial Advisory Board or Industrial Mentoring program) would have been realistically possible with the financial and human resources available.

***The institutional legacy***: the specific legal status of Nano-Tera.ch ("National Joint Action") did not provision for any potential legacy of the program. In particular, it did not require from the involved institutions any commitment in terms of long-term structural investment (such as the creation of permanent chairs, or institutionalized entities), while this is the case for other funding instruments such as the SNF's NCCRs. As a consequence, the 9-year funding provided to Nano-Tera.ch has to be considered as transitory, and not targeted to the setup of a permanent structure. Within this framework, Nano-Tera.ch proposed BRIDGE as a continuation and implementation plan, and produced BRIDGE's first concept. However, for various reasons, it was decided (above the Nano-Tera.ch level) to exclude Nano-Tera.ch from the BRIDGE constituency, thus impeding an explicit institutional legacy for the program. Nevertheless, Nano-Tera's impact on BRIDGE has been clearly substantiated by the fact that about 60% of the selected projects in the first BRIDGE Discovery call were building on results achieved within Nano-Tera, thus providing a scientific legacy of Nano-Tera.ch.

Overall, we want to stress that Nano-Tera.ch research has achieved a worldwide strong impact while staying within the rules and framework that were imposed. We believe that the relative autonomy of Nano-Tera.ch from funding agencies was a key to the overall success, and that eventual drawbacks just came from limitations in project selection and evaluation. We would hope that future program have more autonomy from funding agencies and be based on real trust of scientists in pursuing and managing independently research objectives, because they can decide better and return more value of taxpayer money in terms of research and innovation.

I am available after February 19 for any further clarification.

Best regards

G De Micheli

Giovanni De Micheli
Program leader, Nano-Tera.ch

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## Annexe D – Le transfert de savoir et de technologie dans Nano-Tera.ch, octobre 2017

Meyer, Lea, Rieder, Stefan (Interface) (2017), Wissens- und Technologietransfer von Nano-Tera.ch. Schlussbericht zuhanden der Geschäftsstelle des Schweizerischen Wissenschafts- und Innovationsrates (SWIR), 3. Oktober 2017, Luzern, Interface-Politikstudien.

INTERFACE

# Wissens- und Technologietransfer von Nano-Tera.ch

Schlussbericht zuhanden der Geschäftsstelle des Schweizerischen Wissenschafts- und Innovationsrates (SWIR)

Luzern, den 3. Oktober 2017

# IMPRESSUM

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# INHALTSVERZEICHNIS

## ABKÜRZUNGSVERZEICHNIS

| | |
|---|---|
| CCMT: | Competence Center for Medical Technology |
| ED: | Education and Dissemination Activities |
| EPFL: | École Polytechnique Fédéral de Lausanne |
| ETH: | Eidgenössische Technische Hochschule |
| KMU: | Kleine und mittlere Unternehmen |
| KTI: | Kommission für Technologie und Innovation |
| NCCR: | National Center of Competence in Research (Nationaler Forschungsschwerpunkt) |
| NFS: | Nationaler Forschungsschwerpunkt |
| NFT: | Nano-tera focused Project |
| RTD | Research, Technology and Development Project |
| SBFI: | Staatssekretariats für Bildung, Forschung und Innovation |
| SFI: | Swiss Finance Institute |
| SNF: | Schweizerischer Nationalfonds zur Förderung der wissenschaftlichen Forschung |
| SNI: | Swiss Nanoscale Institute |
| SWIR: | Schweizerischer Wissenschafts- und Innovationsrat |
| WTT: | Wissens- und Technologietransfer |

# EXECUTIVE SUMMARY

Nano-Tera.ch is a Swiss national program supporting research in multi-scale system engineering for health, security, energy, and environment. The main objectives are: excellence in collaborative research in engineering disciplines, educational programs, design of applied demonstrators, and transfer of acquired research results to the Swiss industry.

The program is partly financed through public contributions and partly through matching funds from project partners. Running between 2008 and 2016, the overall costs of the program have been approximately CHF 259 million. As the program came to an end, the Swiss Science and Innovation Council mandated *Interface Policy Studies, Research, Consulting* to carry out an analysis on the knowledge and technology transfer (KTT) of Nano-Tera.ch. The goal was to collect and analyse relevant information concerning the KTT.

Interface has analysed relevant documents and interviewed 15 persons involved with the program. It has further conducted three case study analyses of projects that received Nano-Tera.ch funding. As a result, the following conclusions on the KTT concept and its implementation in the Nano-Tera.ch program have been reached:

*Nano-Tera.ch has no explicit and integrated KTT concept.* This is somehow surprising as the main objective of the program was to promote the step from fundamental research to its application. The lack of an explicit KTT concept may render its practical implementation and monitoring difficult. Based on the documents and the interviews, an implicit reflective concept can be identified. Its aim is to promote the exchange between science, industry, and users, and to bridge the gap between fundamental and applied research. The concept of Nano-Tera.ch has evolved over time, and resulted in a shift towards the implication of end-users in the research, rather than of industrial partners. Further, in a second phase of the program a specific instrument (Gateway) was introduced in order to turn demonstrators into potential industrial prototypes.

*Nano-Tera.ch was mainly promoted indirectly.* In literature it is argued that the best effect of KTT is to use a mix of instruments promoting a direct transfer across people, rights, and technologies, and an indirect transfer through communication, and implementation structures. Nano-Tera.ch mainly makes use of instruments promoting an indirect transfer, namely the standard academic knowledge-transfer instruments such as publications, presentations, and conferences. Furthermore, Nano-Tera.ch implemented structures and special programs for PhD students. A unified, consistent, and systematic monitoring of the numbers and the extent to which the instruments are applied in order to promote KTT appears to be lacking. Nano-Tera.ch is currently undertaking much-needed efforts to collect data in this area.

*The understanding of KTT differs across projects.* To illustrate the implementation of KTT in the funded projects, Interface conducted three case studies. These showed that the understanding of KTT differs from project to project: some of the interviewed persons saw KTT as the sharing of knowledge, whereas others linked it to the development of an application that has a potential for the industry. Such differences could also be related to the maturity level of the projects. Those with a more fundamental research orientation seem to see KTT more on the knowledge-sharing side. More advanced and applied projects focus more strongly on the technological aspects of KTT.

*Different concept, but similar application as in former programs*. Compared to the previous NCCR (National Centres of Competence in Research) research program (so-called NFS Nationale Forschungsschwerpunkte), Interface observes a very similar approach to KTT. Like Nano-Tera.ch, the NFS projects have no explicit concept. However, the implicit concept found for the NFS shows a more linear approach towards KTT, with industrial users and end-users not being included in the research from the beginning. Furthermore, like Nano-Tera.ch, the NFS projects also used very similar and mainly indirect instruments to promote KTT.

# 1 ZUSAMMENFASSUNG DER ERGEBNISSE UND SCHLUSSFOLGERUNGEN

Der SWIR beauftragte Interface Politikstudien, eine Beurteilung des Wissens- und Technologietransfers (WTT) von Nano-Tera.ch vorzunehmen. Ziel des Auftrags war es, das Konzept und die Umsetzung des WTT von Nano-Tera.ch zu analysieren und zu beurteilen. Zu diesem Zweck wurden eine Reihe von Dokumenten ausgewertet und mit 15 Personen Interviews geführt. Ferner wurden drei Fallstudien erstellt und ein Vergleich mit den NFS der ersten Serie durchgeführt. Wir fassen an dieser Stelle die wichtigsten Ergebnisse zusammen und ziehen einige Schlussfolgerungen.

## 1.1 ERGEBNISSE

Die Ergebnisse lassen sich in vier Gruppen einteilen, die gleichzeitig auch den Gegenstand der Analyse bildeten.

### Ergebnisse zur Konzeption: Welches Konzept des WTT liegt vor?

Nano-Tera.ch verfügt über kein explizites und geschlossenes Konzept zum Wissens- und Technologietransfer. Dies ist erstaunlich für ein Programm, das sich explizit zum Ziel gesetzt hat, den Sprung von der Grundlagenforschung in die Anwendung zu überbrücken. Das Fehlen eines expliziten, dokumentierten Konzeptes erschwert vermutlich die Umsetzung des WTT in der Praxis und den Aufbau eines entsprechenden Monitorings.

Betrachten wir die analysierten Dokumente und die Ergebnisse der Interviews, so lässt sich bei Nano-Tera.ch ein *implizites reflexives WTT-Konzept* erkennen. Es soll ein Austausch zwischen der Wissenschaft, der Industrie und den Endnutzern gefördert werden. Gemessen an seinen Zielen ist dieses reflexive WTT Konzept angemessen: Nano-Tera.ch will einen Bogen zwischen Grundlagen- und angewandter Forschung schlagen, um so das Potenzial zur Nutzung von Forschung durch Industriepartner zu erhöhen. In einer ersten Phase wurden Industriepartner in den Projekten vorgeschrieben. In einer zweiten Phase, wurde der Einbezug von Endnutzern in den Projekten obligatorisch. Die Industriepartner und Endnutzer mussten zudem einen finanziellen Beitrag (in bar oder Sacheinlagen) leisten. Was dem WTT von Nano-Tera.ch in der Praxis im Vergleich zum theoretischen Anspruch eines reflexiven Modells abgeht, ist ein substanzieller Input der Industriepartner zu den Forschungsfragen vor allem zu Beginn des Forschungsprozesses. Wir haben keine Indizien dafür gefunden, dass dieser Einbezug stark ausgeprägt war, wie es für ein reflexives Modell an sich postuliert würde.

Nano-Tera.ch hat im Verlauf der Programmdauer sein WTT-Konzept etwas verändert und sich stärker den Endnutzern seiner Forschung zugewendet, um den Transfer von Wissen zu stärken. Dies erscheint angesichts der Ziele konsequent. Für die zweite Phase des Programmes konnten *Interfaces* identifiziert werden, die den WTT befördern: Mit der Einführung von Gateway-Projekten wurde ein Instrument gestaltet, das die Brücke zwischen Forschung und Industrie schlägt. Zudem hatte Nano-Tera.ch in der zweiten Phase einen Innovation Manager angestellt, der den Fortschritt der Gateway-Projekte überwachte. Dieser traf die Programmverantwortlichen alle drei Monate zu einem Gespräch und evaluierte den Projektfortschritt anhand von Balanced Scorecards. Betrachten wir den Mitteleinsatz, so muss dennoch festgestellt werden, dass die Verschiebung hin zur Anwendungsorientierung gemessen an den Mitteln für die Gateway-Projekte eher klein ist.

### Ergebnisse zur Umsetzung

Nano-Tera.ch hat eine breite Palette von Instrumenten eingesetzt, um den WTT zu fördern. Dies ist positiv, ist aus der Literatur doch bekannt, dass der WTT idealerweise über *direkten* (über Personen, Rechte und Technologien) wie auch über *indirekten Transfer* (Kommunikationsmittel, Aufbau von Strukturen) erfolgen muss, um besonders erfolgreich zu sein. Positiv fällt auf, dass dem Transfer von implizitem Kontextwissen über Personen ein grosses Augenmerk geschenkt worden ist. Allerdings wird dieser Eindruck dadurch getrübt, dass wenig systematisch erhobene Zahlen vorhanden sind, die den Umfang dieser Aktivitäten beschreiben würden. Zudem fällt auf, dass die Beurteilung des WTT ausschliesslich quantitativ erfolgte (Anzahl Start-ups, Publikationen etc.) und keine qualitative Beurteilung, z.B. in Form von Interviews mit Industrie-Partnern, erfolgte.

Die grösste Zahl von Instrumenten werden im Bereich des indirekten Transfers eingesetzt: Es handelt sich dabei um die im akademischen Umfeld üblichen Publikationen, Präsentationen und Konferenzen. Auch wurden Strukturen geschaffen und spezielle Programme für Doktorierende geschaffen.

### Ergebnisse aus den Fallstudien: Wie wird der WTT im konkreten Fall umgesetzt?

Für drei Projekte von Nano-Tera.ch wurde der WTT mittels Dokumentenanalyse und Interviews genauer untersucht. Die drei Projekte sind erstens *HearRestore* (Image-guided microsurgery for hearing aid implantation), zweitens *OpenSense* (Crowdsourcing High-Resolution Air Quality Sensing) und drittens *FlusiTex* (Fluorescence sensing integrated into medical textiles). Die Erhebungen führten zu folgendem Befund: In keinem der drei untersuchten Projekte existierte ein explizites, in Dokumenten festgehaltenes WTT-Konzept. Auf Grund der Recherchen konnte in zwei der drei Projekte ein implizites reflexives WTT-Konzept ermittelt werden. OpenSense entspricht eher einem linearen WTT-Verständnis.

Die Projekte zeigen auch einen unterschiedlichen Forschungsverlauf: Zwar haben alle drei im Rahmen der Fallstudien untersuchte Projekte eine Entwicklung in Richtung Markt hinter sich. Allerdings verfügten die zwei Projekte (HearRestore und FlusiTex) mit einem eher reflexiven WTT-Verständnis schon bei Projektstart über eine engere Vernetzung mit den Marktpartnern. Logischerweise ist die Marktnähe dieser beiden Projekte am Schluss ihrer Laufzeit vergleichsweise höher.

In der Umsetzung der Fallstudien zeigt es sich, dass verschiedene Instrumente für den WTT benutzt werden. Es überwiegen aber die indirekten Instrumente, zum Beispiel Publikationen und Konferenzen. Der Einbezug von Partnern scheint für den WTT zentral zu sein, er ist aber aufwändig und benötigt Zeit und Ausdauer. Die Gateway-Projekte haben sich dafür bewährt und wurden geschätzt.

Die Interviews wiesen auf verschiedene Stärken und Schwächen in der Umsetzung des WTT hin. Demnach funktioniert der WTT dann besonders gut, wenn die Konsortien (Hochschulen, Industrie, Anwender) einen klaren Willen zur Zusammenarbeit bekunden, früh im Forschungsprozess mit dem Austausch beginnen und sich bereits aus früherer Zusammenarbeit gut kennen. Ebenso dürften Folgeprojekte wie die Gateway-Projekte und der gezielte Einsatz von Instrumenten den WTT voranbringen.

Es haben sich im Rahmen der Fallstudien aber auch Schwächen im WTT gezeigt. Bedeutend sind dabei strukturelle Aspekte. Nachfragen bei den Programmverantwortlichen, wieso die Gateway-Projekte als erfolgreiches Instrument erst am Schluss im Verlaufe der zweiten Phase von Nano-Tera.ch eingeführt worden seien, führten zu folgendem Befund: Offenbar war die Verteilung der Mittel bereits zu Beginn des Programmes festgelegt worden. Die Gateway-Projekte konnten daher nicht mehr aus dem ordentlichen Programmbudget sondern mussten aus dem (wesentlich kleineren) strategischen Budget der Programmleitung finanziert werden. In diesem Kontext wurde von einigen Interviewten weiter kritisiert, dass der SNF bei seiner Beurteilung der Projektanträge primär die wissenschaftliche Exzellenz im Auge gehabt, das Potenzial eines Projektes für den WTT hingegen eher gering gewichtet habe. Diese beiden Aspekte können als zwei wichtige strukturelle Schwächen von Nano-Tera.ch in Bezug auf den WTT gewertet werden.

Eine dritte Schwäche betrifft das Monitoring des WTT. Es überrascht, dass die Projekte nur einmal jährlich anlässlich des Jahrestreffens beurteilt wurden. Nachfragen bei den Verantwortlichen zeigten, dass bei den RTD-Projekten (Forschung, Technologie und Entwicklung), kein vertraglicher Mechanismus vorhanden war, der ein Monitoring des WTT erlaubt hätte. Das Reporting beschränkte sich daher auf die Jahrestreffen und die Präsentationen der Projektteams vor dem Evaluations-Panel.

### Vergleich mit der ersten Serie der nationalen Forschungsschwerpunkte (NFS)

Ein Vergleich mit der ersten Serie der NFS zeigt, dass bei beiden Programmen kein explizites Konzept für den WTT vorlag. Der Ansatz ist aber unterschiedlich, da die Mehrheit der Programme der ersten Serie des NFS im Gegensatz zu Nano-Tera.ch einen linearen WTT-Ansatz verfolgt hat. Bei den WTT-Instrumenten sind viele Ähnlichkeiten zu beobachten und in beiden Programmen werden am häufigsten Instrumente für den indirekten Transfer benutzt. Was auffällt ist der Umstand, dass die Ausgaben für den WTT bei Nano-Tera nicht wesentlich höher liegen als beim Schnitt der Programme der ersten Serie des NFS. Dies ist für ein besonders auf WTT ausgerichtetes Programm doch eher erstaunlich. In Bezug auf die Outputs des WTT (im Sinne von Patenten, Transfer von Doktorierenden, Produkten etc.) lässt sich festhalten, dass viele Daten bei Nano-Tera.ch (noch) fehlen, um einen aussagekräftigen Vergleich anstellen zu können.

## 1.2 FOLGERUNGEN

Es ist nicht das Ziel dieses Berichtes, Empfehlungen an Nano-Tera.ch oder an den SWIR zu formulieren. Wir beschränken uns daher an dieser Stelle auf einige Schlussfolgerungen allgemeiner Natur.

### Explizite WTT-Konzepte formulieren

Der Wissens- und Technologietransfer lässt sich nicht einfach beschreiben. Er hängt in hohem Masse von den Eigenschaften von Disziplinen ab, von der Bereitschaft der beteiligten Forschenden und dem bestehenden Beziehungsnetz zwischen Forschung, Industrie und Endanwendern, um nur einige Faktoren zu nennen. Dennoch oder gerade wegen der situativen Unterschiede von Fall zu Fall scheint es uns sinnvoll, Konzepte für WTT in Forschungsprogrammen *explizit zu formulieren*. Diese WTT-Konzepte sollten im Minimum spezifische Ziele für den WTT, die Benennung von Instrumenten, die erwarteten Outputs, ein Budget und eine Verantwortlichkeit für WTT umfassen. Ein solches Konzept hat drei Vorteile: Erstens zwingt die Formulierung eines WTT Konzeptes die Verantwortlichen von Forschungsprogrammen, sich mit den Zielen und Wirkungsweisen des WTT auseinanderzusetzen. Zweitens ist der WTT gegenüber den Forschenden, der Industrie und den Anwendenden einfacher zu kommunizieren, wenn er schwarz auf weiss beschrieben ist. Auch wenn sich nicht alle Parteien über den Sinn des WTT einig sein dürften, wird ein explizites Konzept die Diskussion über den WTT erleichtern. Drittens lässt sich mit einem expliziten Konzept auch der Erfolg des WTT besser überprüfen. Bei impliziten Konzepten ist umgekehrt die Versuchung gross, expost beobachtete Entwicklungen in ein bewusstes Konzept umzumünzen.

### Verstärktes Monitoring der WTT-Aktivitäten

Die Analyse hat gezeigt, dass ein begleitendes Monitoring der WTT-Aktivitäten sinnvoll ist. Ein nachträgliches Erfassen von Monitoring-Grössen ist zwar sicherlich interessant und eröffnet Einsichten. Es erlaubt aber keine aktive Steuerung des WTT-Prozesses, ist aufwändig und führt wegen fehlender Daten oft nicht zum Ziel. Voraussetzung für ein solches Monitoring ist allerdings seine Verankerung in den Projektentscheiden. Dabei ist nicht entscheidend, dass besonders viele Daten erhoben werden, sondern dass jene Daten erhoben werden, welche bei der Überprüfung der Ziele des WTT-Konzeptes notwendig sind. Die Auswahl der möglichen Indikatoren ist gross und kann leicht erstellt werden.

### WTT als Selektionskriterium bei der Auswahl von Projekten festlegen

Im Rahmen der Interviews wurde immer wieder auf das Dilemma bei der Auswahl von Projekten hingewiesen: Bei der Selektion von Forschungsgesuchen werde den akademischen Kriterien mehr Gewicht eingeräumt als den Fragen des WTT. Wir glauben, dass erstens eine ex-ante Festlegung der Art der auszuwählenden Projekte im Diagramm von Ruttan sinnvoll wäre, um die Bedeutung des WTT im Auswahlprozess zu stärken. Wenn der WTT eine wichtige Rolle spielen sollte (also Projekte im Bereich der angewandten Grundlagenforschung, der Ressortforschung oder der industrienahen Forschung gefördert werden sollten), wäre dem WTT bei der Auswahl der Forschungsgesuche angemessen Rechnung zu tragen.

WTT-Erwartungen an Projekte anpassen und Flexibilität erlauben

Die von Nano-Tera.ch finanzierten Projekte haben einen unterschiedlichen TRL (also Reifegrad in Bezug auf den Transfer zur Wirtschaft). In den Projekten zeigt es sich, dass die WTT-Aktivitäten auch darum nicht gleich gut gestaltet worden sind, weil gewisse Projekte ausschliesslich als Grundlagenforschung gestaltet worden sind. Für solche Projekte kann von vornherein die Erwartung an den WTT gesenkt werden, was Forschende und WTT-Verantwortliche gleichermassen entlastet.

# 2 EINLEITUNG

Im September 2016 beauftragte das Staatssekretariat für Bildung, Forschung und Innovation (SBFI) den Schweizerischen Wissenschafts- und Innovationsrat (SWIR), eine Wirkungsprüfung des Förderprogramms Nano-Tera.ch 2008–2016 durchzuführen. Ein spezielles Augenmerk sollte auf den Wissens- und Technologietransfer (WTT) gerichtet werden.

Der SWIR beauftragte Interface Politikstudien, ihn hinsichtlich des zuletzt genannten Punkts zu unterstützen. Ziel des Auftrags ist die Zusammenstellung und Analyse von relevanten Unterlagen und Informationen bezüglich des WTT von Nano-Tera.ch. Parallel dazu wird das Programm Nano-Tera.ch eine Selbstevaluation durchführen, die dem SWIR zugeleitet wird. Die Untersuchung des WTT durch Interface soll es dem SWIR erlauben, die in der Selbstevaluation von Nano-Tera.ch dokumentierten Ergebnisse besser beurteilen und Schlüsse im Rahmen der Gesamtevaluation ziehen zu können.

## 2.1 AUSGANGSLAGE

Bei Nano-Tera.ch handelt es sich um ein Forschungsprogramm, das mit ca. 249 Millionen Franken insgesamt ungefähr 150 Projekte finanzierte.[1] Die Finanzierung wurde mit ungefähr 110 Millionen Franken aus öffentlichen Geldern unterstützt[2], der Rest wurde durch Projektpartner finanziert.[3] Das Programm unterschied zwischen zwei Phasen: 2008 bis 2012 und 2013 bis 2016. In der zweiten Phase wurden total 134 Millionen Franken für Projekte ausgegeben. Nano-Tera.ch fördert gemäss Jahresbericht 2016 vier Arten von Projekten:[4]

- Der überwiegende Teil der Projekte von Nano-Tera.ch zählt zur Gruppe der RTD-Projekte, die eine Laufzeit von zwei bis drei Jahren aufweisen und mit 1 bis 2 Millionen Franken pro Projekt gefördert wurden. In der zweiten Phase wurden 25 solche Projekte gefördert. Diese entsprechen 95 Prozent der gesamten Nano-Tera.ch Finanzierung und sind deshalb der Kern der Analyse zum WTT.
- Ein Teil der Projekte fokussiert auf bestimmte ausgewählte Fragestellungen; sie werden als Nano-Tera.ch Focused (NTF) Projekte bezeichnet. Deren Laufzeit beträgt ein bis zwei Jahre und die Unterstützungssumme betrug zwischen 100’000 und 200’000 Franken. In der zweiten Phase wurden neun solche Projekte unterstützt.
- Nano-Tera.ch finanzierte auch Ausbildungs- und Verbreitungsaktivitäten. Dazu zählen Konferenzen, Minikonferenzen, Workshops und neue Curricula, welche die

1 Zahlen aus Nano-Tera.ch, Scientific Reports 2013 und 2016, S. 7.

2 Die öffentlichen Gelder werden durch jährliche Beiträge der Schweizer Universitätskonferenz und des ETH-Rats zur Verfügung gestellt (Nano-Tera.ch, Ordinary Partnership Contract, January 2008, art. 35 abs. 1).

3 Nano-Tera.ch, Scientific Report 2016, S. 3.

4 Nano-Tera.ch, Scientific Report 2016, S. 7.

Schweizer Hochschulen nicht anbieten. Diese Projekte sind vergleichsweise klein und wurden mit Beträgen zwischen 15'000 und 30'000 Franken unterstützt. In der zweiten Phase wurden 21 solche Aktivitäten gefördert.

- Die kleinste Gruppe bilden die sogenannten Gateway-Projekte, die eng mit der Industrie kollaborieren. In der zweiten Phase wurden acht solche Projekte durchgeführt. Diese werden in der Analyse ebenfalls berücksichtigt, da sie gezielt den WTT fördern.

Im Kontext der Wirkungsprüfung durch den SWIR soll auch der Wissens- und Technologietransfer zwischen dem Programm und den Forschenden an den beteiligten Universitäten einerseits und den potenziellen Nutzenden der Forschungsergebnisse andererseits untersucht werden. Zu den Nutzenden gehören insbesondere die Wirtschaft (Unternehmen) wie auch die Verwaltung und weitere Organisationen.

## 2.2 ZIELSETZUNG UND FRAGESTELLUNGEN DES AUFTRAGS

Das Ziel des Auftrags an Interface lässt sich wie folgt umschreiben:

- Das Konzept des Wissenschafts- und Technologietransfers (WTT) von Nano-Tera.ch ist zu beschreiben und aus einer theoretisch Perspektive heraus zu würdigen.
- Anhand von ausgewählten Fallbeispielen soll die Umsetzung des WTT exemplarisch beschrieben werden.
- Soweit möglich soll der WTT von Nano-Tera.ch mit jenem der ersten Serie der Nationalen Forschungsschwerpunkte (NFS) verglichen werden.

Der SWIR wird die gemäss diesen Zielen gewonnen Erkenntnisse in seine eigene Evaluation einfliessen lassen. Ausgehend von den drei Zielen lassen sich drei Gruppen von Fragestellungen identifizieren.

### Fragestellung zum Konzept des WTT: Wie sieht das WTT-Konzept von Nano-Tera.ch aus?

- Ist ein Konzept zum WTT erkennbar und dokumentiert?
- Welcher Ansatz wird gewählt?

### Fragestellung zur Umsetzung des WTT: Welche Elemente des WTT sind in der Umsetzung erkennbar?

- Sind Informationen zur Umsetzung der Konzeption verfügbar (Statistiken, Output-Daten usw.)?
- Lassen sich die in der Konzeption vorgefundenen Prozesse in ausgewählten RTD-Projekten exemplarisch erkennen und nachvollziehen?

Fragestellung zum Vergleich mit den NFS der ersten Serie: Wie sieht das WTT-Konzept von Nano-Tera.ch im Vergleich aus?

- Wie ist das Konzept von Nano-Tera.ch im Vergleich mit den Konzepten der NFS der ersten Serie zu beurteilen?
- Wo ergeben sich Unterschiede in der Umsetzung?

## 2.3 METHODISCHES VORGEHEN

Um den Wissens- und Technologietransfer in Nano-Tera.ch zu untersuchen, wurden vier Arbeitsschritte durchgeführt.

Schritt 1: Analyseraster und Dokumentenanalyse

Um erste Informationen über die WTT-Aktivitäten von Nano-Tera.ch zu erhalten, erstellte Interface ein Analyseraster (vgl. Anhang A1). Dieser wurde auf die vorhandenen Dokumente von Nano-Tera.ch angewendet. Die wichtigsten ausgewerteten Dokumente seien hier aufgeführt.

- Dokumente von Nano-Tera.ch wie die Jahresberichte („Scientific Reports"), die Ausschreibungen („Calls") für die Unterstützung von Projekten und die Jahresreportings („Scientific Project Reports") der einzelnen Projekte
- Informationen auf den Internetseiten von Nano-Tera.ch
- Vom SWIR zur Verfügung gestellte Dokumente wie zum Beispiel die Programmvereinbarungen zwischen dem Schweizerischen Nationalfonds (SNF) und Nano-Tera.ch, der Business Plan von Nano-Tera.ch, Angaben zu den finanziellen Kennzahlen, die Beurteilung des SNF von Projekten und Sitzungsprotokollen
- Vereinzelte, von den Gesprächspartnern zur Verfügung gestellte Dokumente und Daten zu Projekten und WTT-Aktivitäten

Daneben standen eine Fülle von Informationen aus rund 200 Dokumenten des Programmes und der Fallstudien zur Verfügung. Diese Unterlagen wurden in Hinblick auf die Fragestellung zum WTT nur grob gesichtet und mit verschiedenen Schlagworten in drei Sprachen (Technologie, Zusammenarbeit, Austausch, Wissenstransfer, Transfer, WTT) durchsucht. Eine Synthese findet sich in Anhang A3. Eine vollständige Analyse aller Inhalte war im Rahmen dieser Untersuchung aber nicht möglich.

Schritt 2: Interviews mit Nano-Tera.ch-Verantwortlichen und Programm-Partnern

Basierend auf den Ergebnissen der Dokumentenanalyse wurden mit vier Verantwortlichen von Nano-Tera.ch Gespräche geführt (vgl. Liste der Gesprächspartner im Anhang A2). Daneben wurde mit einer Partnerorganisationen auf Programmebene ein Interview geführt. Hier stehen generelle Fragen zum WTT auf Stufe des Gesamtprogramms im Zentrum.

Schritt 3: Durchführung der Fallstudien
Es wurden drei Fallstudien durchgeführt. Die möglichen Kriterien für die Auswahl der Fallstudien waren zahlreich: Fälle konnten entweder nach den thematischen Schwerpunkten (Bioengineering und Electronics), nach den vier Bereichen (Gesundheit, Sicherheit, Energie, Umwelt) oder aber nach Art des Projektes (RTD, NTF, Gateway and Strategic Action) ausgewählt werden. Schliesslich war auch eine Auswahl von Projekten aus den zwei Projektphasen 2009 bis 2013 oder 2013 bis 2016 denkbar.

Angesichts der Zahl von drei Fallstudien waren die Auswahlkriterien zu hoch. Die Auswahl erfolgte deshalb sehr pragmatisch: Die Fallstudien konzentrieren sich auf die finanziell betrachtet wichtigste Gruppe der RTD-Projekte. Die SWIR-Geschäftsstelle, Nano-Tera.ch und Interface wählten je zwei Projekte aus. Die Projekte sollten möglichst typisch sein für die jeweilige Serie und zwar im Hinblick auf die Grösse des Projekts, den Einbezug von Unternehmen und Verwaltung in den Forschungsprozess und dem WTT-Konzept, das in den Projekten zur Anwendung kommt. Aus dieser Auswahl wählte der SWIR gemeinsam mit Interface zwei Projekte. Ein drittes Projekt wurde vom SWIR und von Interface unabhängig vom Vorschlag von Nano-Tera.ch ausgewählt. Als Fallstudien wurden schliesslich folgende Projekte ausgewählt:

- HearRestore: Image-guided microsurgery for hearing aid implantation
- OpenSense: Crowdsourcing High-Resolution Air Quality Sensing
- FlusiTex: Fluorescence sensing integrated into medical textiles

Die Fallstudien wurden alle nach dem gleichen Verfahren erstellt:

- Die wichtigen Dokumente und Ergebnisse des WTT wurden analysiert.
- Anschliessend wurden jeweils der Projektverantwortliche oder ein Stellvertreter sowie ein bis zwei Projektpartner interviewt. Die Interviews gaben Aufschluss darüber, ob ein WTT bei den Zielgruppen bekannt ist, welche WTT-Förderungsaktivitäten stattfanden und wie das Ergebnis des WTT durch die Partner und Nutzer beurteilt wird.
- Die Ergebnisse wurden entlang der theoretischen Kriterien gemäss Kapitel 3.2 aufbereitet. Alle Fallstudien haben den gleichen Aufbau und sollen zeigen, ob und in welchem Masse sich Indizien und Beispiele finden lassen, die einen WTT zu illustrieren und zu verdeutlichen vermögen.

Schritt 4: Erstellen der Synthese
Die ersten Ergebnisse der Analyse wurden mit dem Auftraggeber anhand eines Berichtsentwurfes besprochen. Anschliessend wurde die vorliegende Synthese fertig gestellt.

## 2.4 GRENZEN DER UNTERSUCHUNG

Die vorliegende Untersuchung weist einige Grenzen auf: Der zeitliche Rahmen war sehr knapp gesetzt und der Untersuchungshorizont fiel in die Sommerpause, was gerade im universitären Umfeld aufgrund von Ferienabwesenheiten schwierig ist. So musste auch eine der Fallstudien im Verlaufe der Untersuchung ausgewechselt werden, da der Programmverantwortliche im Ausland weilte und keine Zeit für ein Gespräch fand. Weiter erlaubte das begrenzte Budget nicht, eine repräsentative Anzahl Fallstudien zu untersuchen. Auch waren die Gespräche mit den Partnern unterschiedlich ergiebig. Partner, die nicht eigentliche Nutzer oder Vermarkter der Technologie sind, konnten nur begrenzt über den WTT Auskunft erteilen. Schliesslich waren einzelne Gesprächspartner irritiert darüber, dass Nano-Tera.ch gleichzeitig eine Selbstevaluation durchführte, wodurch sie teilweise zweimal Auskunft geben mussten. Mit einer Ausnahme haben sich aber alle angeschriebenen Personen zum Interview bereit erklärt. Es fiel auf, dass sich die Verantwortlichen in der Geschäftsstelle von Nano-Tera.ch von der vorliegenden Analyse inspirieren liessen und Denkanstösse aufgenommen haben.

## 2.5 AUFBAU DES BERICHTS

Der Bericht enthält in Kapitel drei das WTT-Konzept von Nano-Tera.ch. Im vierten Kapitel wird die Umsetzung besprochen. Im fünften Kapitel werden Schlussfolgerungen zum WTT von Nano-Tera.ch gezogen. Der Anhang enthält die Liste der interviewten Personen, weitere Analysen sowie die ausgefüllten Raster der Dokumentenanalyse, Interviews und Fallstudien.

# 3 DAS WTT-KONZEPT VON NANO-TERA.CH

In diesem Kapitel steht das WTT-Konzept von Nano-Tera.ch im Zentrum. Zunächst wurde analysiert, wie sich das Konzept darstellt. Anschliessend wird es mit Ansätzen verglichen, die in der Literatur für den Wissens- und Technologietransfer entwickelt worden sind. Im Einzelnen sind wir wie folgt vorgegangen:

- *Kurzbeschreibung der Phasen von Nano-Tera.ch:* Für die Analyse ist es zentral, die beiden Phasen von Nano-Tera.ch zu unterscheiden, weil sich der WTT in den Phasen jeweils anders darstellt und sich mit dem Programmfortschritt gewandelt hat. Die Beschreibung findet sich im ersten Abschnitt dieses Kapitels.
- Theoretische Konzepte zum WTT*:* Aus der Theorie werden drei gängige Modelle des WTT vorgestellt. Wir haben dabei auf eine frühere Studie zurückgegriffen, welche wir für den SWIR erstellt haben.[5]
- *Beurteilung der Konzeption:* Basierend auf der Beschreibung und der Theorie wurde geprüft, welches der theoretischen Konzepte wir bei Nano-Tera.ch in Gänze oder wenigstens in Teilen explizit oder implizit wiederfinden.
- *Instrumenteneinsatz zur Förderung des WTT:* In der Theorie finden sich verschiedene Gruppen von Instrumenten für den WTT. Es wird überprüft, welche der Instrumente wir bei Nano-Tera.ch wiederfinden und welche Messgrössen für das Monitoring des WTT bei Nano-Tera.ch vorgesehen sind.

## 3.1 DIE ZWEI PHASEN VON NANO-TERA.CH

Nano-Tera.ch ist ein Förderprogramm, das sich als eine einfache Gesellschaft konstituiert hat.[6] Die Gründungsmitglieder sind die EPF Lausanne, die ETH Zürich, die Universitäten Basel, Neuchâtel, der italienischen Schweiz und das „Swiss Center for Electronics and Microtechnology (CSEM)“.[7]

### Ziele

Das Ziel von Nano-Tera.ch ist die Förderung der Entwicklung von komplexen Systemen im Bereich der grundlagenorientierten Ingenieurswissenschaften und Informationstechnologien. Damit sollen zukünftige Anwendungen in den Gebieten der Gesundheit, Sicherheit, Energie und Umwelt angestossen werden.[8] Das Kooperationsprogramm hat sich explizit das Ziel gesetzt, die Lücke in der Finanzierung zwischen Grundlagenforschung und der anwendungsorientierten Forschung zu schliessen. Im Rahmen von Nano-Tera.ch sollen innovative Systeme mit sehr kleinen Komponenten

[5] Rieder et al. 2014.

[6] Nano-Tera.ch, Business Plan, 19. November 2007, S. 24.

[7] Nano-Tera.ch, Ordinary Partnership Contract, January 2008, S. 23.

[8] Nano-Tera.ch, Business Plan, 19. November 2007, S. 3.

(„Mikro“- und „Nano“-Bereich) und Systeme, die mit sehr grossen Datenmengen arbeiten („Tera“) erforscht und entwickelt werden.[9]

Das Programm zielt auf die Exzellenz in der Forschungszusammenarbeit in den Ingenieurwissenschaften und will Demonstratoren entwickeln, Bildungsangebote auf- und ausbauen und die Forschungsergebnisse in die Schweizer Industrie transferieren.[10]

### Budget und Finanzierung

Nano-Tera.ch verfügte insgesamt über ein Budget von ca. 259 Millionen Franken und wurde mit ca. 110 Millionen Franken an öffentlichen Mitteln unterstützt. Diese finanzierten der ETH-Rat und die Schweizer Universitätskonferenz. Die Gesamtverantwortung von Nano-Tera.ch oblag dem SBFI. Die öffentlichen Mittel wurden jeweils vom Parlament bewilligt. Die Projektpartner brachten insgesamt ca. 149 Millionen Franken an Matching Funds in Nano-Tera.ch ein.

Anhand von Ausschreibungen (sogenannten „Calls“) wurden die finanziellen Mittel zur Unterstützung von Projekten vergeben. Die unterstützten Projekte können in drei Kategorien eingeteilt werden:

- *Grosse Forschungs-, Technologie-, Entwicklungsprojekte (RTD)*, die in der Regel 3 bis 4 Jahre dauern und durch ein Konsortium von 3 bis 10 Forschungsgruppen unterschiedlicher Schweizer Institute umgesetzt werden.
- *Kleinere Forschungsprojekte* (nano-tera-focused NTF), die sich auf Technologien konzentrieren.
- *Bildungs- und Verbreitungsmassnahmen* (Educational and Dissemination ED). Die Projekte widmen sich unterschiedlichen Themen wie beispielsweise Technologien für Nano-Systeme, Gesundheits-, Sicherheits-, Umwelt-Anwendungen oder die Kombination von Ingenieurwissenschaften mit Life Sciences, Medizin und Energie.[11]

### Projektphasen

Das Programm verlief in zwei Phasen:

- *Die erste Phase dauerte von 2008 bis 2012.* Es wurden primär RTD Projekte lanciert. Das Jahr 2012 war zudem ein Übergangsjahr, da der SNF vorschlug, gewisse gut laufende RTD-Projekte als RTD-add-on Projekte zu verlängern und sie zusätzlich mit rund 2,5 Millionen Franken zu unterstützten.[12]
- *Die zweite Phase dauerte von 2013 bis 2016.* Neben den RTD-Projekten wurden neu Gateway-Projekte lanciert. Gateway-Projekte haben explizit den Technologie-

[9] Schweizerischer Nationalfonds, <http://www.snf.ch/de/foerderung/ehemalige-foerderungsinstrumente/nano-tera/Seiten/default.aspx>, zuletzt besucht am: 25. August 2017.

[10] Nano-Tera.ch, Scientific Report 2016, S. 3.

[11] Nano-Tera.ch, Scientific Report 2016, S. 3.

[12] Schweizerischer Nationalfonds, Nano-Tera.ch: Genehmigung Add-on Projekte, Schreiben vom 23. November 2011.

transfer zum Ziel. Es handelt sich um Projekte, welche aus RTD-Projekten entstanden sind und ein grosses Potenzial für den Transfer in die Wirtschaft aufweisen. Ziel von Gateway war es, industrielle Prototypen zu entwickeln, um so das Potenzial für den Technologietransfer zu erhöhen. Bei den Gateway-Projekten wurde das Monitoring des WTT verstärkt und in einem Bericht festgehalten. Für die Gateway-Projekte wurde zudem ein Innovation-Manager eingestellt, der den WTT in den Gateway-Projekten verfolge und diese regelmässig evaluierte.[13]

Ausgaben

Die nächste Tabelle stellt für die zwei Phasen die unterstützten Projekte und deren finanzielle Unterstützung nach Beitragsgeber dar.

**D 3.1: Ausgaben von Nano-Tera.ch**

| | Anzahl Projekte | Gesamtmittel | Öffentliche Mittel | Eigenmittel Partner | Drittmittel |
|---|---|---|---|---|---|
| RTD insgesamt | 44 | 210'762'613 | 86'339'165 | 118'809'831 | 5'613'617 |
| davon Phase 1 | 19 | 105'757'200 | 44'768'101 | 57'684'410 | 3'304'689 |
| davon Phase 2 | 25 | 105'005'414 | 41'571'065 | 61'125'421 | 2'308'928 |
| RTD-add-on (Phase 1) | 8 | 5'723'982 | 2'550'006 | 2'323'640 | 850'336 |
| Gateway (Phase 2) | 8 | 4'170'032 | 1'666'975 | 986'217 | 1'516'840 |
| NTF insgesamt | 24 | 13'922'149 | 5'598'835 | 7'841'879 | 481'435 |
| davon Phase 1 | 15 | 7'459'765 | 3'147'850 | 4'311'915 | 0 |
| davon Phase 2 | 9 | 6'462'384 | 2'450'984 | 3'529'964 | 481'435 |
| ED insgesamt | 59 | 4'347'553 | 1'520'571 | 1'805'573 | 1'021'409 |
| davon Phase 1 | 29 | 3'082'927 | 1'122'452 | 1'267'067 | 693'408 |
| davon Phase 2 | 30 | 1'264'626 | 398'120 | 538'506 | 328'001 |
| Total | 143 | 238'926'329 | 97'675'553 | 131'767'140 | 9'483'637 |

Quelle: Darstellung Interface basierend auf Daten aus Dokument Project Evaluation Impact vom SWIR (März 2017).[14]

Legende: NTF = Nano-Tera focused projects, ED = Education and Dissemination Activities, RTD = Research, Technology and Development Projects.

Auf der Tabelle lassen sich folgende Beobachtungen machen:

- Die grösste finanzielle Unterstützung kam den RTD-Projekten zugute. Diese wurden mit rund 86,3 Millionen Franken an öffentlichen Mitteln unterstützt. Dazu

[13] So fand alle drei Monate ein Treffen mit den Projektteams statt. Der Projektverantwortliche erstellte vor dem Treffen jeweils eine Balanced Scorecard (BSC), in der über den Status des Demonstrators bzw. Prototypen anhand einer Skala mit den Stufen built; exposed; revised berichtet wurde. Das Stakeholder-Netzwerk wurde erfasst und dem Industriepartner wurden folgende Fragen gestellt: 1. Höhe seines Beitrages; 2. inwiefern das Projekt dem Partner hilft, sich von Wettbewerbern abzugrenzen, und 3. ob der Industriepartner seine Markt-Perspektive in das Projekt einbringt. Die BSC wurde von Innovations-Manager und Programmverantwortlichem besprochen; nach dem Treffen wurde eine Synthese erstellt.

[14] Die Tabelle wurde auf den Werten zu den "actual budget" erstellt. Es fähllt auf, dass sich die Zahlen von den Angaben in den Scientific Reports von Nano-Tera.ch unterscheiden.

kamen rund 118,8 Millionen aus den Eigenmitteln der Projektpartner und weitere 5,6 Millionen von Drittmitteln durch Industriepartner und Endnutzer.

- Die RTD-add-on-Projekte wurden mit 3,2 Millionen Franken durch eigene bzw. Drittmittel und mit 2,5 Millionen Franken aus öffentlichen Beiträgen finanziert.
- Die Verteilung ist sehr ähnlich bei den Gateway-Projekten. Diese wurden mit rund 2,5 Millionen Franken durch eigene und Drittmitel finanziert. Dazu kamen ungefähr 1,7 Millionen Franken aus der Nano-Tera.ch Finanzierung.
- Die Finanzierung der NTF-Projekte beläuft sich insgesamt auf 13,9 Millionen Franken. Der grösste Beitrag stammt dabei aus den eigenen Beiträgen der Projektpartner (ca. 7,8 Millionen Franken). Die Finanzierung aus den Drittmitteln beträgt rund 0,5 Millionen Franken.
- Die ED-Projekte (Ausbildung) sind finanziell kleinere Projekte und wurden relativ gleichmässig durch die öffentlichen Mittel (1,5 Millionen Franken), die Mittel der Projektpartner (1,8 Millionen Franken) und die Drittmittel (1 Million Franken) finanziert.

Die rund 20 Millionen Franken, dies sich aus der Differenz zwischen der Gesamtfinanzierung (rund 259 Millionen Franken) und der Projektfinanzierung (ca. 239 Millionen Franken) ergeben, wurden (gemäss unseren Annahmen) für den Betrieb von Nano-Tera.ch (wie dem Management Office), für strategische Tätigkeiten und Doktoranden-Programme verwendet.

Die Budgetaufteilung lässt vermuten, dass der spezifisch für den Bereich WTT reservierte Betrag im Programm relativ klein ist: Fassen wir die Gateway-Projekte und die ED-Projekte (Ausbildung) zusammen, so beläuft sich der Mitteleinsatz auf 8,5 Millionen Franken (4,1 Millionen Franken Gateway und 4,4 Millionen Franken für Ausbildung), was etwa 3,5 Prozent der Gesamtmittel des Programmes ausmacht. Wie viele Mittel darüber hinaus aus allgemeinen Programmmitteln für den WTT eingesetzt worden ist, konnten wir nicht ermitteln.

## 3.2 THEORETISCHE ÜBERLEGUNGEN ZUM THEMA WISSENS- UND TECHNOLOGIETRANSFER

In diesem Abschnitt stellen wir kurz einige ausgewählte theoretische wie praktische Ansätze zur Konzeptualisierung von WTT vor. Die nachfolgende Darstellung beruht auf dem Schlussbericht von Interface zum Wissens- und Technologietransfer im Rahmen der ersten Serie der NFS. Dieser Bericht wurde im Auftrag der Geschäftsstelle des Schweizerischen Wissenschafts- und Innovationsrates (SWIR) im Jahr 2014 verfasst.[15] Generell lassen sich aus der Literatur folgende Modelle ableiten:

### Klassisches lineares Konzept des WTT

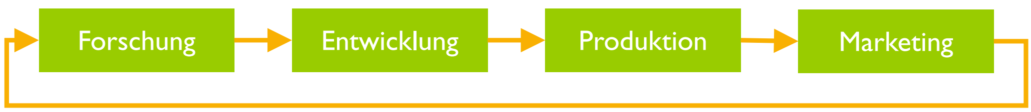
Basis bildet eine Unterscheidung verschiedener Stufen der Wissensgenerierung: Grob lässt sich zwischen der Grundlagenforschung, der angewandten Forschung, der Ent-

[15] Rieder et al. 2014.

wicklung von Produkten und Dienstleistungen, deren Verbreitung auf dem Markt und der Anwendung durch bestimmte Nutzergruppen unterschieden. Das Konzept postuliert für den WTT ein Nacheinander der Wissensgenerierung, wobei das Wissen in jeder Stufe transformiert wird. In der Theorie werden die Stufen unterschiedlich differenziert. Ein WTT ist dann erfolgreich, wenn die verschiedenen Stufen der Wissensgenerierung vollständig durchlaufen werden und er in einer Diffusion des Wissens im Markt in Form von Produkten oder Verfahren, Wissen oder Dienstleistung resultiert.[16]

Folgende einfache Darstellung soll diesen Prozess illustrieren:

D 3.2: Lineares Konzept des WTT

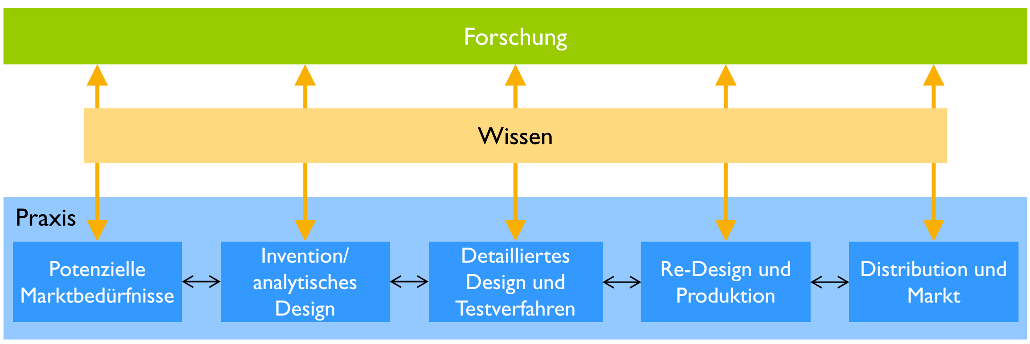



Quelle: Darstellung Interface nach <http://innovate.ucsb.edu/89-benoit-godin-making-science-technology-and-innovation-policy-conceptual-frameworks-as-narratives>, Zugriff am 10. März 2014.

### Reflexives Konzept

Beim reflexiven Konzept wird im Unterschied zum linearen Konzept eine starke, parallel stattfindende Interaktion zwischen den verschiedenen Akteuren der Wissensproduktion postuliert. Diese Interaktion findet nicht erst beim Transfer in die Praxis statt, sondern ist prägend für den gesamten Prozess der Wissensgenerierung. Der Einbezug kann dabei graduell unterschiedlich sein: Die einfachste Form liegt bei der Beteiligung von Zielgruppen in den Leitungsgremien von Forschungsprojekten vor und kann bis hin zu gemischten Forschungsgruppen reichen, die gemeinsam am Prozess der Wissensgenerierung beteiligt sind. Das folgende Modell des Innovationsprozesses soll die Reflexivität des Konzepts illustrieren.

D 3.3: Reflexives Modell des WTT (Kline/Rosenberg)




Quelle: Darstellung Interface nach Koschatzky 2001, S. 47.[17]

### Interfaces

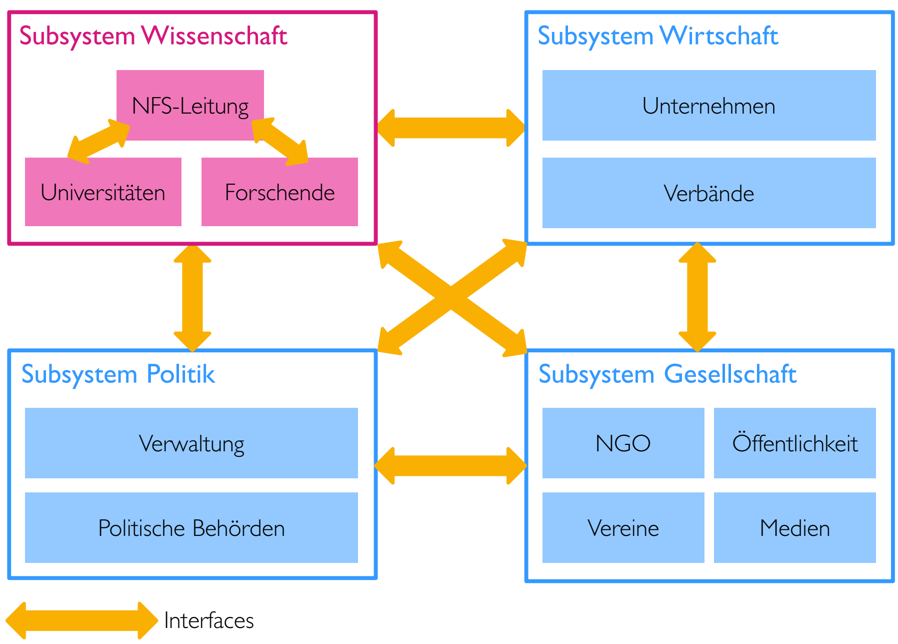
Aus der Systemtheorie stammt der Begriff der Interfaces. Im Kontext des WTT hat Dieter Freiburghaus in Rückgriff auf die Systemtheorie den Begriff verwendet und da-

16 Campbell/Carayannis 2012.

17 Koschatzky 2001.

rauf hingewiesen, dass die verschiedenen Systeme der Wissensgenerierung und Wissensverwendung (sowohl im linearen wie auch reflexiven Modell) unterschiedlichen Rationalitäten gehorchen und unterschiedliche „Sprachen“ sprechen. Ein Transfer von einem System in das andere ist daher wahrscheinlicher, wenn Interfaces auftreten (wobei dies sowohl für lineare wie reflexive Modelle gilt). Diese haben die Eigenschaft, in beiden Systemen „daheim zu sein“ und beim Austausch vermittelnd tätig werden zu können. Einfache Formen sind der Einbezug von ausgewählten Personen in die Führungsgremien von Forschungsprogrammen oder Forschungseinrichtungen, die die Interaktion fördern sollen. Aufwändigere Formen von Interfaces können eigene WTT-Organisationen darstellen.[18] Schliesslich können auch einzelne Projekte oder Vorhaben den Charakter von Interfaces wahrnehmen. Voraussetzung ist es, dass die Projekte Personen und Institutionen zusammenführen, welche sich jeweils aus anderen Subsystemen rekrutieren. In der Theorie wird hier von sogenannten Boundary-Projekten gesprochen.[19] Die folgende Darstellung soll die Funktion von Interfaces illustrieren.

D 3.4: Interfaces als Förderer




Quelle: Rieder et al. 2014.

In der praktischen Umsetzung wird vielfach nicht explizit auf ein theoretisches Konzept von WTT Bezug genommen. Vielmehr werden Listen von Instrumenten erstellt, die zur Anwendung gelangen, um den WTT zu fördern. Obwohl rein deskriptiv geben die Listen doch Einblick in die Art und Weise, wie WTT interpretiert wird (vgl. dazu Abschnitt 3.3.2).

18 Freiburghaus 1989.

19 Guston 2001.

## 3.3 WTT-KONZEPT VON NANO-TERA.CH

Wir prüfen in diesem Abschnitt, welche der geschilderten Konzepte oder Teile davon wir in den Dokumenten und den Gesprächen mit den Programmverantwortlichen eruieren konnten. Aufgrund der Dokumentenanalyse und der Interviews haben wir nachfolgende zwei Befunde zum WTT innerhalb des Nano-Tera.ch Programms gemacht.

## 3.4 BEFUND I: DER WTT VON NANO-TERA.CH ENTSPRICHT AM EHESTEN EINEM REFLEXIVEN KONZEPT MIT VEREINZELTEN INTERFACES

Wir haben zunächst nach Dokumenten gesucht, welche das Konzept des WTT von Nano-Tera.ch explizit beschreiben würden. Wir konnten aber kein Dokument finden, welches sich explizit und ausschliesslich dem WTT von Nano-Tera.ch widmet, diesen theoretisch reflektiert und eine Strategie für dessen Umsetzung im Rahmen von Nano-Tera.ch beschreibt.

Was wir vorgefunden haben, sind einerseits Teilelemente der Beschreibung des WTT, die auf verschiedene Dokumente verteilt sind. Darüber hinaus haben sich in den Interviews implizite Vorstellungen des WTT ergeben. Wir würden daher von einem impliziten Konzept des WTT sprechen. Dieses lässt sich wie folgt beschreiben. Wenn wir die Auswertung von *Dokumenten* betrachten, so lassen sich namentlich aus dem Business-Plan von Nano-Tera.ch nicht weniger als sieben Ziele zum WTT ableiten:

- Es ist eine nationale Koordination zwischen Forschungsinstituten in den Projekten vorzunehmen und die Zusammenarbeit von unterschiedlichen Disziplinen in den Konsortien zu fördern.[20]
- Die Ergebnisse von Nano-Tera.ch sollen den Schweizer Industriezweigen wie dem Banken- oder dem Versicherungssektor dienlich sein.[21]
- Es ist die Bildung einer Plattform für die Zusammenarbeit mit der Industrie und gut etablierten Schweizer Kompetenzzentren anzustreben.[22]
- Die führende Rolle von universitären Einrichtungen, die im Projekt vertreten sind, soll den Transfer von Ergebnissen in Bildungsprogramme sicherstellen, es sollen zudem Bildungsprogramme erweitert und geschaffen werden.[23]
- Die Zusammenarbeit zwischen Schweizer Forschungszentren in Konsortien und die Zusammenarbeit mit Industriepartnern in den Projekten soll gestärkt werden.[24]

[20] Nano-Tera.ch, Business Plan, 19. November 2007, S. 3.

[21] Nano-Tera.ch, Business Plan, 19. November 2007, S. 3.

[22] Nano-Tera.ch, Business Plan, 19. November 2007, S. 4.

[23] Nano-Tera.ch, Business Plan, 19. November 2007, S. 15.

[24] Nano-Tera.ch, Business Plan, 19. November 2007, S. 16.

- Es soll der Technologie-Transfer durch Nano-Tera.ch gesteigert werden, dies vor allem durch die Gründung von Start-ups und Partnerschaften mit der Industrie.[25] Es sollen neue High-Tech Unternehmen nach Schweizer Qualität entstehen.[26]
- Die Konstruktion von Demonstratoren und Prototypen bis zur Stufe der vorindustriellen Anwendung soll gefördert werden, um die Ergebnisse in die Schweizer Industrie transferieren zu können.[27]

Die oben genannten Ziele lassen auf ein eher reflexives Modell des WTT schliessen, der in ausgewählten Bereichen mit Interfaces (Gateway-Projekten) ergänzt wird. Die Ergebnisse aus den *Interviews* mit den Programmverantwortlichen haben diesen Befund bestätigt und ergänzt. Unter WTT, so wird es in den Gesprächen dargestellt, wird vor allem die Zusammenarbeit verschiedener Disziplinen in den Konsortien, die Einbindung von Industrie-Partnern und die Ausbildung von neuen Forschungskräften durch die PhD-Programme verstanden. Interessant war die Positionierung von Nano-Tera.ch in der Schweizer Finanzierungslandschaft von Forschungen durch die Programmverantwortlichen: Bis anhin gebe es auf der einen Seite die Finanzierung durch den SNF, die auf Grundlagenforschung ausgerichtet sei. Auf der anderen Seite des Spektrums seien die KTI-Projekte anzusiedeln, die explizit die Vermarktung von Forschung zum Ziel haben. Nano-Tera.ch sei in der Mitte dieser zwei Pole anzusiedeln und habe zum Ziel, die Lücke zwischen der Grundlagen- und der angewandten Forschung zu schliessen, indem Forschungsprojekte unterstützt werden, die ein Potenzial für die Vermarktung haben, aber noch nicht für den Markt bereit sind. So ziele Nano-Tera.ch darauf ab, beide Welten, die Forschung und die Praxis, zu vereinen.

Die Auswertung von Dokumenten und Interviews zeigt, dass sich das WTT-Konzept von Nano-Tera.ch über die Zeit verändert hat. Um dies zu illustrieren, verwenden wir das Modell zur Beschreibung verschiedener Arten von Forschung von Ruttan an.[28] Dieses Modell erlaubt es, verschiedene Arten von Forschungsprojekten und ihre Institutionen zu kategorisieren und zwar in vier Gruppen von Forschungsvorhaben. Je nachdem, wo sich die Forschungsprojekte einordnen, ist der Grad der internen Kontrolle durch die Forschenden selber respektive jene der externen Partner wie etwa der Unternehmen oder Verwaltungen unterschiedlich gross. In der folgenden Abbildung haben wir die zwei Phasen des WTT-Konzepts von Nano-Tera.ch abgebildet.

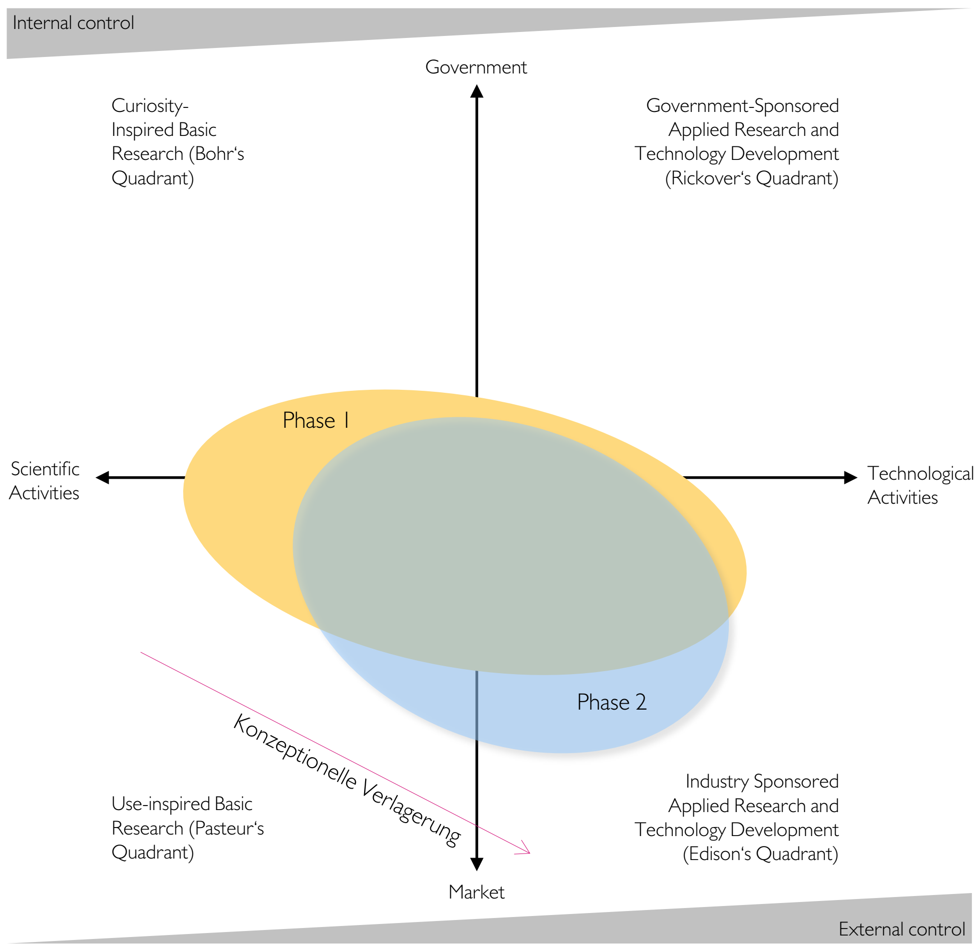
[25] Nano-Tera.ch, Business Plan, 19. November 2007, S. 17.

[26] Nano-Tera.ch, Business Plan, 19. November 2007, S. 3.

[27] Nano-Tera.ch, Business Plan, 19. November 2007, S. 21.

[28] Ruttan 2001.

D 3.5: Mögliche Positionierung der Institute nach Forschungstypen




Quelle: Darstellung Interface nach Ruttan 2001.

Die Veränderung der Ausrichtung von Nano-Tera.ch in seinen zwei Phasen kann wie folgt beschrieben werden:

- In einer *ersten Phase* positioniert sich Nano-Tera.ch auf der wissenschaftlich-technologischen Achse eher auf der wissenschaftlichen Seite. Ein Indiz dafür ist das in diesem Zusammenhang von den Verantwortlichen von Nano-Tera.ch verwendete Technology Readiness Level (TRL) für die Positionierung von Nano-Tera.ch Projekten.[29] Mittels TRL werden Forschungsprojekte auf einer Skala von Grundlagenforschung (TRL 1) bis zur vollständig kommerziellen Umsetzung (TRL 9) eingeteilt.[30] Nach Angaben der Nano-Tera.ch Verantwortlichen haben viele der unterstützten Projekte in Phase eins ein TRL von 3 bis 5 (wobei auch Projekte mit kleinerem TRL dabei waren). Dies sei genau die Lücke, die Nano-Tera.ch mit dem Slogan „bridge the gap" zu füllen versuche.

29 Vgl. Anhang 4 zum Technology Readiness Level für eine Übersicht.

30 Armstrong 2014.

Auf der „Government-Market“ Achse positionierte sich Nano-Tera.ch in seiner ersten Phase näher beim Markt-Pol: Man war sehr darauf bedacht, Projekte mit den Nano-Tera.ch-Mitteln zu finanzieren, die Partner aus der Industrie von Beginn an in die Projekte integrieren. So war der Einbezug von industriellen Partnern obligatorisch.

- In seiner *zweiten Phase* beobachten wir eine konzeptionelle Verlagerung in Richtung Anwendungsorientierung und Marktorientierung. Es wurde vermehrt Wert auf technologische Aktivitäten gelegt und die anwenderinspirierte Forschung verstärkt. Dies manifestierte sich erstens in einem Wechsel von industriellen Partnern zu den Endnutzern der Technologien. Die industriellen Partner waren keine Voraussetzung mehr für die Projektunterstützung, wurden aber immer noch empfohlen. Die Endnutzer waren in dieser Phase aber für die Projektunterstützung obligatorisch. In den Interviews wurde dieser Wechsel damit begründet, dass die Industriepartner zu wenig daran interessiert seien, von Beginn an in einem Projekt tätig zu werden. Sie seien schwer für die konzeptionelle Phase zu motivieren und eher später im Projektverlauf an einer Zusammenarbeit interessiert. So wurde dann in der zweiten Phase der Fokus auf Endnutzer (d.h. Spitäler) gelegt, da diese direkt von den Entwicklungen profitieren würden und die wirtschaftliche Vermarktung für sie zweitrangig sei.
- Über die Phasen hinweg zeige sich auch, dass die finanziellen Beiträge der Endnutzer (in Bar- oder Sacheinlagen) in der zweiten Phase bedeutender wurden, als die Beiträge der Industriepartner in der ersten Phase. Die konzeptionelle Verschiebung zeigt sich zudem durch die gezielte Schaffung eines WTT-Instrumentes bei den Gateway-Projekten: Damit sollten Technologien aus RTD-Projekten unterstützt werden, welche ein TRL von 5 oder 6 aufweisen. Ziel der Projekte war, die Labor-Demonstratoren in industrielle Prototypen umzuwandeln (und einen TRL 7 zu erreichen), um so das Potenzial für den Technologietransfer zu erhöhen.

Insgesamt können wir mit Hilfe der Darstellung von Ruttan eine Verschiebung von anwendungsorientierter Grundlagenforschung hin zu einer stärker industrieorientierten Forschung feststellen. Die Projekte haben im Vergleich zur reinen wissensgetriebenen Grundlagenforschung einen stärkeren Fokus auf die Problemlösung und die Kooperation mit der Industrie und den Endnutzern.

## 3.5 BEFUND 2: ES WURDE EINE BREITE PALLETE VON INSTRUMENTEN ZUR UMSETZUNG DES WTT EINGESETZT

In der praktischen Umsetzung ist eine Vielzahl Instrumenten denkbar, mit deren Hilfe sich der WTT in der Praxis umsetzen und befördern lässt. Die nachfolgende Darstellung beruht auf dem Schlussbericht von Interface zum Wissens- und Technologietransfer im Rahmen der ersten Serie der NFS.[31] Dabei werden die Instrumente zur Förderung des WTT in zwei Gruppen eingeteilt, je nachdem welche Art von Wissen sie helfen sollen zu transportieren: Eine erste Gruppe von Instrumenten soll explizites Wissen

[31] Rieder et al. 2014.

transportieren. Dies ist jenes Wissen, das von einem Empfänger durch die Konsultation von Literatur, Kursen, Ausbildung und ohne Unterstützung von Dritten erworben werden kann. Unter implizitem Wissen wird das Verständnis von Prozessen und Verfahren verstanden, die notwendig sind, um Wissen jeweils situationsspezifisch anwenden zu können.[32] Dieses implizite Wissen ist offenbar stark an Personen gebunden und kann nur schwer mittels Publikationen oder anderer Instrumente vermittelt werden. Vielmehr ist dazu eine Interaktion zwischen Personen oder aber ein Transfer von Personen, die Wissen besitzen, notwendig (zweite Gruppe von Instrumenten).

Inwiefern ist diese Einteilung in Instrumente zum expliziten oder impliziten Wissenstransfer hilfreich? Es wird in der Literatur oft davon ausgegangen, dass WTT besonders erfolgreich ist, wenn sowohl implizites *und* explizites Wissen übertragen wird und somit eine breite Palette von Instrumenten zum WTT eingesetzt wird.

Mittels der zur Verfügung stehenden Unterlagen und den Ergebnissen der Interviews haben wir nun geprüft, welche Instrumente von Nano-Tera.ch effektiv eingesetzt worden sind, um den WTT zu fördern. Als *erstes* haben wir dabei festgestellt, dass es keine Gesamtplanung über den Einsatz der Instrumente gibt und ihr Einsatz auch nicht systematisch und explizit mit einer Gesamtübersicht dokumentiert ist. Aus den Dokumenten[33] und aus den Gesprächen lässt sich aber eine Gesamtübersicht rekonstruieren. Unsere Hauptquelle waren dabei die jährlichen Scientific Reports auf Programmebene.[34] Basierend auf diesen Informationen haben wir folgendes Inventar an Instrumenten erstellt, das im Rahmen von Nano-Tera.ch eingesetzt worden ist. Wo immer möglich, haben wir quantitative Daten zum Umfang des Instrumenteneinsatzes angefügt (im Anhang haben wir einzelne Messgrössen im Detail aufgeführt).

32 Meissner/Sultanian 2007.

33 Nachfolgende Zahlen basieren aus den Scientific Reports 2009 - 2016 von Nano-Tera.ch.

34 Nano-Tera.ch erstellt aufgrund ihrer Selbstevaluation gegenwärtig eine Zusammenstellung von Messgrössen, welche aber nicht auf jährlicher Basis gemessen und berichtet wurden und uns noch nicht vorliegen.

## D 3.6: WTT-Instrumente

| Direkter Transfer | | |
|---|---|---|
| Instrumententypen | Bei Nano-Tera.ch eingesetzte Instrumente | Quantitative Angaben |
| 1 Transfer über Personal | Start-up-Firmen gegründet von Forschenden | 4 gegründet; 6 im Gründungsprozess |
| | Transfer von Personen von der Akademie in die Praxis (Doktorierende und Post-docs) | *Keine Angaben verfügbar* |
| | Gezielte Rekrutierung von Personen, welche WTT durchführen können (Interfaces) | *Keine Angaben verfügbar* (in den drei untersuchten Fallstudien kein Fall dokumentiert) |
| | Austausch von Personen (Personen wechseln von Industrie und Praxis in die Akademie und umgekehrt) | *Keine Angaben verfügbar* |
| 2 Transfer über Technologien | Demonstratoren und Prototypen | *Keine Angaben verfügbar* |
| 3 Transfer über Rechte | Patente | 67 Patentanmeldungen ausgefüllt |
| Indirekter Transfer | | |
| Instrumententypen | Instrumente | Quantitative Angaben |
| 4 Kommunikationsmittel | Publikationen | 1309 |
| | Konferenzen und Workshops | 2165 |
| | Internetseiten | 80'000 Besuche in 2016 |
| | Umfragen | 1 (nach Jahrestreffen 2016) |
| | Weiterbildung und Ausbildung | *Keine Angaben verfügbar* |
| 5 Finanzielle Förderung | Programme für Doktoranden | 2 auf Nano-Tera.ch-Programmebene |
| 6 Aufbau von Strukturen | Gateway | 8 (1 Innovation Manager angestellt) |
| | Jahrestreffen | 7<br>2016: 350 Teilnehmer; 152 Poster und 15 Videos. Grosse Anzahl von RTDs zeigten Demonstratoren und frühe Prototypen. |
| | Strategic Actions | 3 in 2015 |
| | Einrichtung von Kooperationen mit Universitäten und Partnern | u.a. 1 Sino-Swiss collaboration |

Quelle: Darstellung Interface basierend auf Interviews und Dokumenten der vorliegenden Analyse.

Betrachten wir die Tabelle, so lässt sich folgendes daraus ableiten: Es wird eine breite Palette von Instrumenten zum direkten wie auch indirekten Transfer eingesetzt. Dies ist aus theoretischer Sicht sinnvoll und wünschenswert. Betrachten wir den *direkten Transfer* fällt folgendes auf:

- Für ausgewählte besonders interessante Instrumente zum Transfer von implizitem Wissen über *Personen* sind leider keine quantitativen Daten verfügbar: So existieren für den Transfer von Personal in die Praxis keine Messgrössen. Das gleiche gilt für die Rekrutierung von Personen, die WTT durchführen. In den Gesprächen wurde das Fehlen von Daten zwar eingeräumt, der Transfer von Doktorierenden und Postdocs in die Praxis aber als wichtiges Instrument für den WTT bezeichnet. Weiter wurde in diesem Zusammenhang auf die Start-up-Firmen als wichtige Messgrösse für den WTT hingewiesen. So wurden bis jetzt 4 Start-ups gegründet und weitere 6 finden sich im Gründungsprozess.
- Die *Demonstratoren und Prototypen* wurden in den Gesprächen mit den Nano-Tera.ch-Verantwortlichen und einigen Projektverantwortlichen als wichtige Messgrösse für den Transfer von *Technologien* erwähnt. Auch ist es ein erklärtes Ziel in den Dokumenten von Nano-Tera.ch. Dazu gibt es aber in den Unterlagen bisher keine statistischen Angaben. Weiter wird die Weiterführung der Projekte mittels neuer Finanzierungen als wichtiger WTT-Effekt erwähnt. So hätten 9 Projekte eine KTI-Finanzierung erhalten.
- Zum Transfer *von Rechten* über Patente wird die Anzahl der Patentanmeldungen erhoben. Im Nano-Tera.ch Programm wurden insgesamt 67 Patentanmeldungen eingereicht. Deren Aussagekraft ist allerdings relativ gering. Entscheidend sind die Art der Patente (in welchem Land wurden sie eingereicht und haben sie Geltung) und die daraus resultierenden Lizenzen. Dazu liegen uns keine Informationen vor (es wäre dazu eine Aufbereitung der Daten von Seiten der Projekte notwendig gewesen).

Im Bereich des *indirekten Transfers* lassen sich viele Instrumente erkennen:

- Am häufigsten werden die *klassischen Kommunikationsmittel* eingesetzt. Im Verlauf der Nano-Tera.ch Projekte gab es ca. 1300 Publikationen und über 2165 Konferenzen und Workshops. Die Internetseite wird gerade auch bei den Nano-Tera.ch-Verantwortlichen in den Gesprächen als wichtiges Instrument für den WTT eingestuft. 2016 wurden 80'000 Seitenbesuche aus 140 Ländern verzeichnet. Im Rahmen von Nano-Tera.ch fanden verschiedene Umfragen statt. Eine Umfrage erfolgte nach dem Jahrestreffen von 2016 und fragte die Zufriedenheit der Teilnehmenden mit dem Event ab. Weiter müssen die Programmverantwortlichen vor den Quartalstreffen gegenüber Daten zur Balanced Scorecard melden. Im Rahmen der Jahresreportings machen alle Programmverantwortlichen der RTD-Projekte schriftliche Angaben zum Projektverlauf anhand eines strukturierten Formulars. Das Nano-Tera.ch-Office organisierte im Verlauf des Programms verschiedene Weiterbildungen und Ausbildungen. Dazu sind allerdings keine statistischen Angaben verfügbar.

- *Finanzielle Förderprogramme* für Doktorierende im klassischen Sinne (Stipendien) wurden keine entrichtet. Es wurden aber zwei spezielle Förderprogramme gestaltet: Erstens das NextSteps-Programm, welches erst im Jahr 2015 entwickelt wurde, in welchem Doktorierende sich mit dem Unternehmertum vertraut machen konnten. Zweitens das Projekt „My thesis in 180 seconds", in welchem Doktoranden lernen, ihre Forschung einem breiten Publikum zu vermitteln. Bei beiden Gefässen handelt es sich allerdings nicht um klassische Förderprogramme mittels Stipendien.
- Beim Aufbau der *Strukturen* gibt es ebenfalls verschiedene Instrumente: Erstens das bereits erwähnte Pilot-Programm Gateway, das gezielt die Weiterentwicklung von Demonstratoren in Prototypen finanziert. Zweitens die Jahrestreffen, bei denen jeweils die Projektverantwortlichen dem SNF-Panel in einer 30-minütigen Evaluation das Projekt vorstellen mussten. Drittens sogenannte strategic actions von Nano-Tera.ch selber. Diese können die Finanzierung von Projekten oder Konferenzen sein. Dazu gibt es keine systematische Statistiken. Im Jahr 2015 wurden drei solche Tätigkeiten lanciert. Viertens organisierte Nano-Tera.ch auch Kooperationen mit Universitäten und anderen Partnern. Auch hierzu gibt es keine statistischen Angaben. Ein Beispiel ist die die Sino-Swiss Collaboration, die 2011 gestartet wurde.

# 4 WTT IN DREI AUSGEWÄHLTEN PROJEKTEN

In diesem Kapitel werden Ergebnisse aus den Fallstudien zur Umsetzung des WTT in den Projekten dargestellt. In einem ersten Abschnitt beschreiben wird das Verständnis und die Umsetzung des WTT von Nano-Tera.ch auf Stufe der drei untersuchten Projekte. In einem zweiten Abschnitt gehen wir auf die eingesetzten Instrumente zur Förderung von WTT ein. Im letzten Abschnitt beschreiben wir Stärken und Schwächen im Zusammenhang mit dem WTT in den Projekten.

## 4.1 VERSTÄNDNIS UND UMSETZUNG DES WTT IN DEN UNTERSUCHTEN PROJEKTEN

In einem ersten Schritt haben wir erfragt, ob bei den untersuchten drei Projekten ein explizites WTT-Konzept dokumentiert ist. In den Unterlagen zu den Projekten gab es dazu keine Hinweise. Auf Nachfrage bei den Programmverantwortlichen wurde bestätigt, dass es kein explizites Konzept zum WTT in den Projekten gebe. Daher wurde die Frage des WTT in den Gesprächen mit den Programmverantwortlichen und den Partnern besprochen. Aufgrund der Interviews können wir folgende Beobachtungen zum WTT-Verständnis in den drei untersuchten Projekten machen.

### OpenSense

OpenSense durchlief zwei Phasen (OpenSense I und II), die mit den zwei Phasen von Nano-Tera.ch korrespondieren. Es handelt sich gemäss unserer Auffassung um ein klassisches Grundlagenprojekt, was in den Gesprächen auch bestätigt worden ist.

Wie wurde WTT interpretiert? In den Interviews mit den Programmverantwortlichen von OpenSense I und II zeigte sich, dass in diesem Projekt vor allem die Zusammenarbeit der verschiedenen Disziplinen und das Teilen von Wissen als WTT verstanden wird. Das Projekt ist denn auch mit einem sehr tiefen TLR innerhalb von Nano-Tera.ch gestartet (je tiefer der TLR auf der Skala von eins bis neun, desto näher ist ein Projekt an der reinen Grundlagenforschung). OpenSense hat auch keine eigentlichen industriellen Partner. Dies, so Aussagen aus den Gesprächen, sei aber von Seiten von Nano-Tera.ch auch nicht gefordert worden. Es sei allen klar gewesen, dass es sich eher um ein Grundlagenforschungsprojekt handle. Es hätte auch nicht viel Sinn gemacht, bereits zu Beginn industrielle Partner für eine potenzielle Kommerzialisierung einzubeziehen. OpenSense habe zum Ziel gehabt, Disziplinen zusammenzuführen (in diesem Falle Forschungsbereiche wie künstliche Intelligenz, Medizin, Computerwissenschaften, Material Science und Computer Engineering). Es sei ein grosser Schritt gewesen, die Zusammenarbeit zu fördern. Im Verlaufe der Zeit stieg der TLR etwa auf Stufe fünf. Gemäss den Gesprächen hat dies auch damit zu tun, dass man mit OpenSense II „das Labor verlassen habe“, um die Technologie in der realen Umwelt anzuwenden. OpenSense II verfügt über verschiedene Partner (wie die Transports Public Lausanne [TL], das Universitätsspital des Kantons Waadt [CHUV], die Verkehrsbetriebe der Stadt Zürich [VBZ] etc.) welche helfen, Daten anhand der entwickelten Technologie zu sammeln (z.B. Sensoren auf den Bussen des TL). Diese Partner sind aber nicht Industriepartner, die die Technologie kommerzialisieren wollen. Sie waren konzeptionell

nicht in die Forschung eingebunden, indem sie z.B Inputs zu Forschungsfragen gaben. Gemäss den Gesprächspartnern müsse die Kommerzialisierung in einem nächsten Schritt erfolgen. So sei vorgesehen, das Projekt für eine Bridge-Finanzierung anzumelden. Der TL habe dafür beispielsweise schon einen letter of intent verfasst.
Insgesamt lässt sich in diesem Projekt ein klassisch lineares WTT-Konzept erkennen. Anzumerken wäre aber, dass ein Gateway-Projekt (CarboSense) entstand, dessen Ursprung in OpenSense II liegt. Somit wurde ein Instrument eingesetzt, um den WTT für eine aus dem Projekt entstandene Technologie zu fördern.

### FlusiTex

FlusiTex ist ein Nano-Tera.ch Projekt der zweiten Phase, in das von Beginn an industrielle Partner eingebunden waren. Die Verantwortlichen geben an, dass der WTT schwierig zu realisieren gewesen sei: Industrielle Partner zu finden, brauche viel Überzeugungsarbeit und es sei viel Zeit dafür investiert worden. Mittlerweile gebe es einen regelmässigen Austausch zwischen den Partnern, die Industrie-Partner seien an der Entwicklung interessiert. Der Input der Industriepartner bestehe heute beispielsweise darin, Marktanalysen zu verschiedenen Technologien im Projekt zu verfassen. Das Zusammenspiel im Konsortium sei sehr wichtig für den WTT.

Das Projekt mündete in zwei verschiedene Gateway-Projekte (FlusiGate und FlusiSafe). Ein Industriepartner von FlusiSafe gab im Gespräch an, dass heute ein regelmässiger Austausch stattfinde, Laborbesuche stattfinden würden und man das Know-how für die Vermarktung in das Konsortium einbringe. Dies werde sehr gut aufgenommen. Bedauert wird, dass die Finanzierung bald zu Ende gehe und das weitere Vorgehen noch offen sei.

FlusiTex und die daraus resultierenden Gateway-Projekten können aus unserer Sicht als ein Beispiel für ein reflexives WTT-Modell gelten. Was dem Modell entspricht, sind die Forschungsinputs in Form von Analysen zu Machbarkeit, Marktchancen und Produkteentwicklung. Was eher schwach ausgeprägt ist, ist der Beitrag der Industriepartner zur Formulierung der Forschungsfragen und des Forschungskonzeptes.

### HearRestore

HearRestore ist ein Projekt der zweiten Phase von Nano-Tera.ch. Es vereint ein Konsortium an Partnern, welche hauptsächlich an der Universität Bern angesiedelt sind. Die Gespräche mit den Projektverantwortlichen und Partnern zeigen, dass die Forschungen schon vor Nano-Tera.ch begonnen hatten und es von Beginn an industrielle Partner im Projekt hatte. Industriepartner zu finden, sei aber aufwändig und zeitintensiv gewesen und es brauche viel Glück. Ein Industriepartner müsse ein Potenzial für ein Produkt sehen.

HearRestore ist offenbar schon weit fortgeschritten in Bezug auf den Transfer in die Praxis: Gemäss den Interviewten sei das Projekt klinisch ausgerichtet und man operiere mit der entwickelten Robotertechnik schon erfolgreich am Patienten. In den Gesprächen kam zum Ausdruck, dass die Universität Bern auf solche Finanzierungen wie sie Nano-Tera.ch anbiete, angewiesen sei und man bereits in einem Netzwerk von Partnern eingebettet sei. Dies sei ein grosser Vorteil der Institution.

HearRestore vereine industrielle Partner sowie Endnutzer und sei geprägt von einem engen Austausch zwischen diesen Partnern und der Forschung. Die Nähe zu den Partnern aus der Praxis erlaubt es, effizient zu forschen und zu testen. Man habe rasch in die klinische Phase einsteigen können, was als Vorteil für den WTT sei. WTT wird in diesem Projekt somit als Entwicklung von einer in der Praxis anwendbaren Technologie verstanden. In einem nächsten Schritt werde man sich für eine Bridge-Finanzierung bewerben. HearRestore habe alle TRL-Stufen vorbildlich durchlaufen; man könne es aus Forschungssicht nicht besser machen.

Aus den Gesprächen ergibt sich aus unserer Sicht, dass HearRestore am ehesten dem reflexiven Modell zugeordnet werden kann. Die Endnutzer und Industriepartner geben Forschungsinputs und man tauscht sich zum Projekt aus. Zudem mündete das RTD HearRestore in ein Gateway-Projekt (HearRestore Gate), um den WTT weiter zu stärken.

### Vergleich der drei Fallbeispiele

Die drei ausgewählten Fallstudien zeigen die Vielfalt der Verständnisse von WTT in Nano-Tera.ch auf. Wenn wir die Ergebnisse zusammenfassen und mit den theoretischen Ansätzen in Kapitel 2 vergleichen, ergibt sich in etwa folgendes Bild: In keinem der Projekte gibt es eine explizite Reflexion über die Gestaltung des WTT. Implizit lässt sich aufgrund der Interviews und Dokumente OpenSense eher dem linearen, die anderen beiden Fallstudien eher dem reflexiven Modell eines WTT zuordnen. Alle drei Projekte weisen einen Follow-up in Form eines Gateway-Projektes auf, das als Interfaces interpretiert werden kann. Dass alle Fallbeispiele ein solches Element aufweisen, ist eher untypisch, da die Zahl und der Umfang der Gateway-Projekte insgesamt doch beschränkt ist.

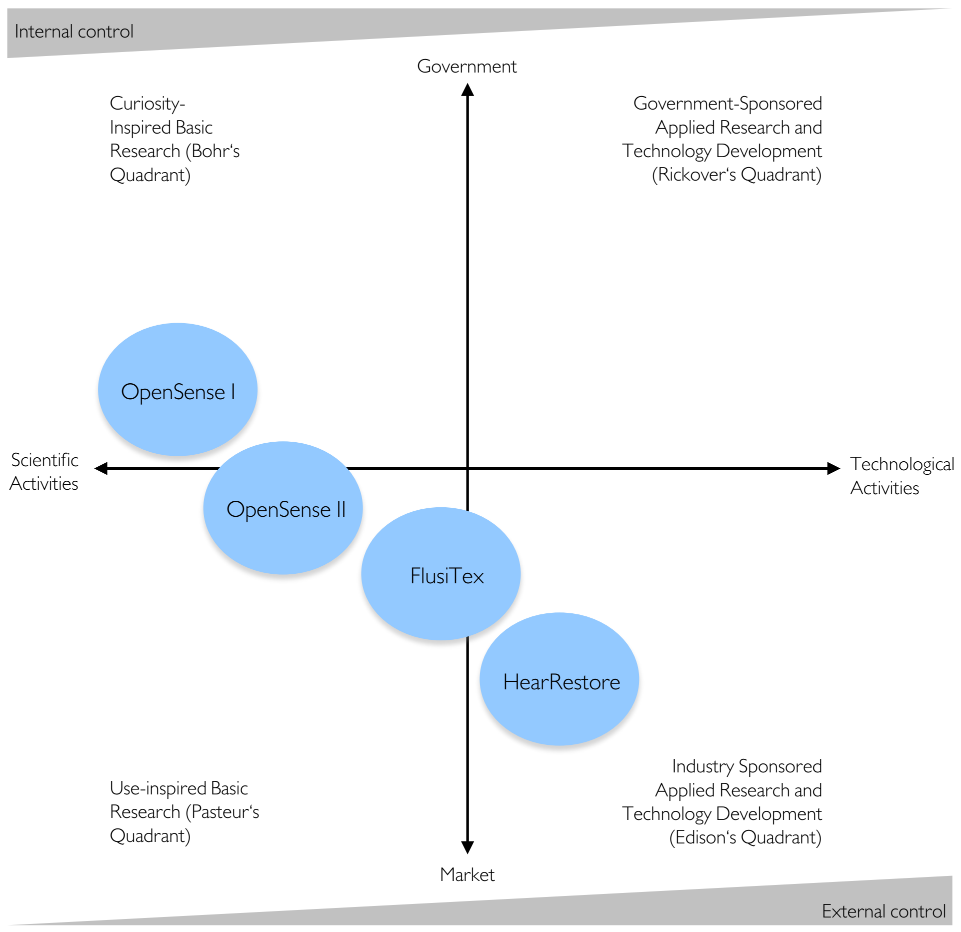
**D 4.1: Theoretische WTT-Konzepte**

| Nano-Tera.ch Projekt | Konzept explizit vorhanden? | Klassisches lineares Konzept | Reflektives Konzept | Interfaces |
|---|---|---|---|---|
| OpenSense I und II | Nein | X | | 1 Gateway Projekt: CarboSense |
| FlusiTex | Nein | | X | Zwei Gateway-Projekte: FlusiSafe und FlusiGate |
| HearRestore | Nein | | X | Ein Gateway-Projekt: HearRestore Gate |

Quelle: Darstellung Interface.

Wenn wir die drei Fallstudien in unser weiter vorne in Kapitel 3 eingeführtes Diagramm gemäss Ruttan einordnen, so lässt sich folgende Beobachtungen machen: OpenSense I und II sind Projekte, die sich von der Grundlagenforschung in Richtung der angewandten Forschung entwickelt haben. Sie sind im Vergleich zu FlusiTex und HearRestore noch weiter vom Markt entfernt.

D 4.2: Mögliche Positionierung Fallstudien




Quelle: Darstellung Interface nach Ruttan 2001.

Aus den Gesprächen ergibt sich, dass vier Faktoren das unterschiedliche Verständnis des WTT in den drei Fallstudien beeinflussen.

- *Forschungsfortschritt im Projekt*: OpenSense I hat sich von einer sehr grundlagenorientierten Forschung zu einer vermehrt anwendungsorientierten Forschung in OpenSense II entwickelt. Im Gegensatz dazu ist FlusiTex durch eine höhere Praxisorientierung geprägt. HearRestore schliesslich ist beides: Nahe bei der Nutzung mit der klinischen Anwendung, aber auch schon weit fortgeschritten mit der Robotertechnik und deren Potenzial für die Industrie.

- *Vernetzung der Partner*: Es zeigte sich, dass sich die Partner in den Konsortien unterschiedlich gut kennen und dies womöglich den WTT beeinflusst: Die Partner bei HearRestore, so wird in den Gesprächen gesagt, kennen sich gut und arbeiten auch in anderen Projekten zusammen. Bei FlusiTex sei die Zusammenarbeit ebenfalls eingespielt. In den Gesprächen mit OpenSense wird demgegenüber unterstrichen, dass man sich in einer ersten Zeit zuerst kennenlernen und die Zusammenarbeit der unterschiedlichen Disziplinen aufbauen musste.

- *Unterschiede zwischen den Disziplinen*: Der WTT bei den Computerwissenschaften, den klinischen Projekten und den Nano-Technologien in den Labors gestalte sich jeweils anders. Es habe Zeit gebraucht, die verschiedenen Disziplinen (künstliche Intelligenz, Medizin, Computerwissenschaften, Material Science und Computer Engineering) in OpenSense miteinander vertraut zu machen. In den Gesprächen wird unterstrichen, es sei ein essentieller Erfolg von OpenSense gewesen, dass die Forschung aus dem Labor herauskam und eine praktische Anwendung entwickelt wurde. Dies ist an sich erstaunlich, denn die Computerwissenschaften sind gemäss den Erfahrungen der Autoren eine Disziplin, die vergleichsweise nahe am Markt operiert und bei der es viele positive Beispiele von WTT gibt.
- *Unterschiedliches Interesse am Markt*: Es zeigt sich im Vergleich der Fallstudien, dass das Interesse des Marktes unterschiedlich hoch ausgeprägt ist: OpenSense hat noch keine Industriepartner (im Sinne von Partnern, die die Technologie kommerzialisieren wollen) im Projekt integriert. FlusiTex und HearRestore sind näher am Markt und bekommen von Industriepartnern Feedback; diese produzieren schon Teile der Technologie (z.B. die Roboter bei HearRestore).

## 4.2 INSTRUMENTENEINSATZ

Wir haben auch in den Fallstudien untersucht, welche Instrumente in den Projekten zum Einsatz kamen. Folgende Tabelle fasst die Informationen aus den Dokumenten und Gesprächen zu den WTT-Instrumenten pro Fallstudie zusammen.

D 4.3: Instrumententypen zur Förderung des WTT in den Fallstudien

| | | OpenSense II | FlusiTex | HearRestore |
|---|---|---|---|---|
| Direkt | Transfer über Personal | Hoch (ein Forschender arbeitet in einer neuen Einheit in der Stadt Paris) | Keine Angabe | Hoch: Zwei Lizenzierungen der Technologie mit CAScination, Bern Med-el GmbH Innsbruck |
| | Transfer über Rechte | | | 3 Patente |
| | Transfer über Technologien | Hoch: Sensoren auf Bussen, Autos und Bauten in Lausanne und Zürich Health Optimal Route Planner App wird von der Stadt Zürich empfohlen | Hoch: Flusi Tex Prototyp und verschiedene Sensoren entwickelt | Hoch: 2 neue Produktlinien geschaffen Roboter in Produktion |
| Indirekt | Kommunikationsmittel | Hoch: 45 Forschungsartikel Verschiedene Presseartikel | Mittel: 7 Publikationen | Hoch: 40 Forschungsartikel, Presseartikel |
| | Finanzielle Förderung | Mittel-Hoch: 8 PhD Studierende, mehrere PostDocs | Tief: Keine PhD Studierenden gefördert | Mittel-Hoch: 6 PhD Studierende |
| | Aufbau von Strukturen | Mittel: Gesundheits-APP; Zusammenarbeiten mit Unternehmen für die Sensoren Gateway | Mittel: Gateway, Zusammenarbeiten mit verschiedenen Industrie-Partnern | Hoch: Gateway, 3 KTI-Projekte 1 weiteres geplant, in Gespräch mit privaten Investoren |

Quelle: Darstellung Interface auf Basis der Interviews.

Wir gehen nacheinander auf die sechs Instrumententypen ein und illustrieren diese mit Beispielen aus den Gesprächen.

- *Transfer über Personal:* Hierzu haben wir nur für das Projekt OpenSense eine Angabe: Im Gespräch mit dem Projektverantwortlichen wurde erwähnt, dass ein Forschender aus dem OpenSense-II-Projekt, bei der Stadt Paris in einer neuen Abteilung zur Luftverschmutzung angestellt wurde. HearRestore hat zwei Lizenzierungen mit Firmen. Bei FlusiTex wurden keine Aussagen über Transfer zu Personal gemacht.

- *Transfer über Rechte*: Das HearRestore Projekt hat drei Patentanmeldungen hervorgebracht. Nach Angaben aus den Dokumenten und Gesprächen gibt es für OpenSense und FlusiTex bis jetzt keine Patentanmeldungen. Die Gesprächspartner bei OpenSense gaben an, dass Patente in ihrer Disziplin nicht wirklich eine Rolle spielen.

- *Transfer über Technologien (Demonstratoren oder Prototypen):* Dieser Typ von Instrumenten ist in allen drei Fallstudien stark präsent. OpenSense hat Sensoren auf Bussen, Autos und Bauten in Lausanne und Zürich installiert. Es gibt eine Applikation für das Handy, über die gesundheitsoptimierende Routen in der Stadt Zürich abgefragt werden können. FlusiTex hat ebenfalls einen hohen Transfer über Technologien: Es existieren ein Prototyp und verschiedene Sensoren. Zudem werden die ersten Pflaster an Tieren getestet. Auch bei HearRestore ist der Transfer über Technologien hoch: Es wurden Roboter produziert und zwei neue Produktelinien geschaffen. Zudem wird mit der Technologie schon erfolgreich an Patienten operiert.

- *Kommunikationsmittel*: Bei den Kommunikationsmitteln sind OpenSense und HearRestore sehr gut positioniert: Es gibt je über 40 Forschungsartikel und zudem Pressemeldungen. FlusiTex nutzt dieses Instrument mit nur sieben Publikationen weniger.

- *Finanzielle Förderung*: Bei der finanziellen Förderung von Doktoranden ist nur FlusiTex nicht aktiv. Die anderen zwei Fälle finanzieren mehrere Doktoranden.

- *Strukturen:* Beim Aufbau von Strukturen haben alle drei Projekte ein Gateway Projekt vorzuweisen. FlusiTex und HearRestore sind durch ihren nahen Einbezug von Industriepartnern und den guten Austausch mit diesen noch etwas stärker im Strukturaufbau. HearRestore hat zudem schon drei KTI-Finanzierungen erhalten und die Folgefinanzierung steht somit fest.

## 4.3 STÄRKEN UND SCHWÄCHEN IN DER WTT-UMSETZUNG

In den Gesprächen haben sich neben den weiter vorne dargestellten Konzepten und Instrumenten des WTT die Stärken und Schwächen in der Umsetzung abgefragt. Wir stellen das Ergebnis aus den Interviews dar.

### Stärken

- *Zusammensetzung der Konsortia und Wille zum WTT:* Eine wichtige Rolle bei der Umsetzung des Ziels der WTT-Förderung spielt die Zusammensetzung des Konsortiums im Projekt. Der Wille zur Zusammenarbeit müsse gegeben sein, ansonsten könne kein WTT erreicht werden. Dies wurde in den Gesprächen mit HearRestore- und OpenSense-Verantwortlichen losgelöst von ihren Projekten zum Ausdruck gebracht. In manchen Gesprächen mit Projektverantwortlichen wurde generell unterstrichen, dass gerade Universitäten und Technische Hochschulen vor allem an der Grundlagenforschung und der Anzahl Publikationen interessiert seien. Dies sei aber nur ein Teil des WTT. So brauche es den Willen im Konsortium, den WTT auch mit anderen Instrumenten zu fördern.

- *Kooperationen mit Industriepartnern und Endnutzern*: Als wichtiges Element wird die Kooperation mit den Industriepartnern und Endnutzern beschrieben. In den Gesprächen mit den Programmverantwortlichen von Nano-Tera.ch wird festgehalten, dass ein zu früher Einbezug weniger effizient sei, da die Industriepartner bei einem tiefen TRL wenig Interesse hätten, sich einzubringen. Andere Gesprächspartner widersprechen dem. Ein früher Einbezug erlaube es, dass schon in der Konzeptphase die Anwendbarkeit und der wirtschaftliche Nutzen diskutiert werden könne. In Gesprächen mit Industriepartnern wurde deutlich, dass ein solcher Einbezug für KMU elementar sei, da diese die Forschung nicht selber bezahlen können. Solche Kooperationen seien darum äusserst wichtig.

- *Weiterführung der Aktivitäten nach dem Ende der Nano-Tera.ch-Laufzeit:* Alle Gesprächspartner aus den Fallstudien geben an, dass sie die Forschungen weiterführen wollen – auch nach der Nano-Tera.ch Finanzierung. In den Gesprächen wird fast immer auf das Bridge-Programm und die Möglichkeit, sich zu bewerben, verwiesen. Das Bridge-Programm sei das Nachfolgeprogramm von Nano-Tera.ch, wobei es für alle Disziplinen und Bereiche offensteht. Zudem wurde für HearRestore ausgesagt, es stünden KTI-Finanzierungen bereit.

- *Veränderung der Forschungskultur:* Nano-Tera.ch, so die Aussagen von vielen Gesprächspartnern, füllt eine Finanzierungslücke in der Schweizer Forschungslandschaft, nämlich jene, die zwischen Grundlagen- und praktischer Forschung entsteht. So wurde in mehreren Gesprächen darauf hingewiesen, dass der SNF primär grundlagenorientierte Forschung, die Kommission für Technologie und Innovation (KTI) unterstütze praxisorientierte Forschung (sogenannte KTI-Projekte). Die dazwischenliegenden Forschungsvorhaben kämen damit eher zu kurz. Nano-Terra.ch decke genau diese Finanzierungslücke ab. Dies wird von allen Personen als sehr positiv bewertet. Die drei Fallstudien sind sich darin einig.

- *Gezielte Instrumente:* In fast allen Gesprächen mit den Projektverantwortlichen wurden die WTT-Aktivitäten des Nano-Tera.ch-Office unterstrichen: die Videos, die Jahresanlässe, die Massnahmen für die Doktorierenden usw. Eine Mehrheit der Personen meint, es sei viel unternommen worden, um den Austausch zu stärken. In allen Fallstudien wird das Gateway-Instrument durchgehend als positiv beurteilt. Es wurde zudem auch bedauert, dass in der Nachfolge-Finanzierung Bridge bis jetzt kein solches Instrument vorgesehen sei. Für den WTT wäre es daher sinnvoll, auf den Erfahrungen mit den Gateway-Projekten aufzubauen und vergleichbare Instrumente einzusetzen.

- *Gute WTT-Outputs*: Die Programmverantwortlichen in allen Fallstudien nennen Messgrössen für den WTT in ihren Projekten. Genannte Beispiele sind der Personentransfer von der Hochschule in die Wirtschaft (OpenSense); die Publikationen und Konferenzen (alle Fallstudien); die Anwendung der Technik an den Patienten (HearRestore); die Tests der Technologie an Tieren (FlusiTex), die Prototypen (alle Fallstudien) oder die Start-ups (HearRestore).

### Schwächen

Die Verantwortlichen der Projekte sahen bei der Realisierung der WTT-Aktivitäten Schwächen, die in den folgenden Abschnitten erläutert werden.

- *Strukturelle Faktoren bei der Projektvergabe:* In einigen Gesprächen mit Programm- und Projektverantwortlichen kam zum Ausdruck, dass die strukturellen Faktoren von Nano-Tera.ch ein Hindernis für den WTT darstellen würden. Die Struktur von Nano-Tera.ch inklusive die Finanzierungsanteile für die verschiedenen Tätigkeiten wurden im Voraus festgelegt. Für die RTD-Projekte war der SNF für die Vergabe verantwortlich; Nano-Tera.ch konnte zwar seine Meinung abgeben, aber der Entscheid lag beim SNF. Einige Gesprächspartner gaben an, der SNF habe bei seiner Beurteilung der Projektanträge primär die wissenschaftliche Exzellenz im Auge gehabt, das Potenzial eines Projektes für den WTT hingegen eher gering gewichtet.

- *WTT ist personenabhängig*: In verschiedenen Gesprächen zum WTT von Nano-Tera.ch wurde generell darauf hingewiesen, dass der WTT stark von den Personen in den Projekten abhängig sei. In jedem Fall – egal bei welchen Partnern – müsse der Wille zur Zusammenarbeit bestehen. Bei den Industriepartnern müsse eine gewisse Neugierde da sein und sie müssten gewillt sein, ein Risiko einzugehen. Dies sei nicht immer der Fall gewesen. Eine weitere Schwierigkeit des WTT seien die Kosten für die Suche nach Industriepartnern. Dies sei zudem auch mit Glück verbunden und nicht immer planbar. Erschwerend bei der Suche nach Industriepartnern komme manchmal hinzu, dass Universitäten ihr Eigeninteresse (Publikationen und Kongressteilnahmen) manchmal zu stark betonten und damit zu wenig auf die Interessen der Partner eingehen würden.
- *Unterschiedliche Dauer für die Entwicklung des WTT-Potenzials*: Im OpenSense-Projekt wurde darauf hingewiesen, dass zu Beginn viel Zeit notwendig war, damit die verschiedenen Disziplinen zusammenfanden und ein gemeinsames Verständnis für den WTT entwickelt hätten. Auch im medizinischen Bereich braucht der WTT gemäss Aussagen der Interviewten Zeit, bis eine Technologie wirklich am Patienten getestet werden kann.
- *Angemessenes Monitoring*: Manche Gesprächspartner hinterfragen die Monitoringgrössen zur Erfassung des WTT-Potenzials (zum Beispiel die Anzahl PhD-Studierende, Start-ups, Patente, Publikationen oder der Werdegang von Doktoranten). Bei den Patenten beispielsweise komme es darauf an, ob es um eine Patentanmeldung oder den Erhalt eines Patentes gehe. Zudem seien für gewisse Disziplinen, zum Beispiel in den Computerwissenschaften, Patente weniger aussagekräftig; die Lizenzierung sei entscheidend. Es gehöre zum Werdegang von Doktoranden, dass sie einmal eine Stelle finden, ob dies wirklich WTT sei, wurde in manchen Gesprächen hinterfragt. Ferner ist festzuhalten, dass das WTT-Monitoring durch Nano-Tera.ch zu wenig regelmässig vorgenommen worden ist. Nachfragen bei Nano-Tera.ch ergaben, dass bei den RTD-Projekten (im Gegensatz zu den Gateway-Projekten) keine vertragliche Vereinbarung bestand, die WTT-Umsetzung systematisch zu überwachen. Das einzige Instrument des Monitorings waren die Jahresmeetings und die Vorträge der Programmverantwortlichen über den Stand der Arbeiten an das SNF-Panel. Weiter fällt auf, dass das Monitoring (ausser bei den Gateway-Projekten) fast ausschliesslich aus quantitativen Daten bestand, wohingegen qualitative Beurteilungen, beispielsweise über Interviews mit Industrie-Partnern, fehlen.

# 5 KURZVERGLEICH MIT DER ERSTEN SERIE DER NATIONALEN FORSCHUNGSSCHWERPUNKTE (NFS)

Dieses Kapitel zieht einen kurzen Vergleich des WTT von Nano-Tera.ch mit den 16 Programmen der ersten Serie der Nationalen Forschungsschwerpunkte (NFS). Wir vergleichen zunächst die Befunde zu den WTT-Konzepten und widmen uns anschliessend dem Vergleich der eingesetzten Umsetzungsinstrumente. Als empirische Basis für den Vergleich dienen uns die Ergebnisse aus dem Bericht von Interface aus dem Jahre 2014.[35]

## 5.1 KONZEPTVERGLEICH

Ein Vergleich der Konzepte führt uns zu folgendem Befund:

- Sowohl bei Nano-Tera.ch wie bei der ersten Serie der NFS existiert kein Konzeptpapier, das den WTT für die Programme beschreibt und Ziele definiert, Umsetzungsmassnahmen festsetzt und das Vorgehen für das Monitoring beschreibt. Die WTT-Konzepte ergeben sich implizit aus den Zielsetzungen der Programme oder lassen sich über Interviews mit den Programmverantwortlichen erschliessen.
- Im Vergleich zur ersten Serie zeigt sich bei Nano-Tera.ch ein viel stärker reflexives Modell kombiniert mit Interfaces. Bei den NFS der ersten Serie hatten 12 der 14 Programme ein klassisch lineares WTT-Konzept, sieben hatten zusätzlich Interfaces. Lediglich zwei Programme der NFS wiesen reflexive WTT-Konzepte auf. Insofern ist Nano-Tera.ch ein Programm, das konzeptionell die Industrie und die Anwendungspartner früher und intensiver in den Forschungsprozess einbindet.
- Der WTT ist für Nano-Tera.ch ein wichtiger Aspekt und bedeutender als über alle Programme der ersten Serie der NFS betrachtet. Hier haben nur fünf von 16 Programmen angegeben, dass der WTT eine grosse Rolle spielen würde. Allerdings darf bei dieser Betrachtung nicht ausser Acht gelassen werden, dass es auch bei den NFS Programme gab, die eine sehr stark ausgeprägte WTT Strategie verfolgten.
- Bei Nano-Tera.ch und den NFS waren die WTT-Verantwortlichen innerhalb der Leitungsgremien von nano-tera.ch angesiedelt. Bei Nano-Tera.ch ist dies der Executive Director. Die Ausnahme sind die Gateway-Projekte, die durch einen Innovation Manager des Nano-Tera.ch-Office betreut wurden. Auch bei den NFS war meistens ein Mitglied der Programmleitung für den WTT zuständig, wobei auch externe WTT-Verantwortliche eingesetzt worden sind. Dies ist bei Nano-Tera.ch nicht der Fall.

35 Rieder et al. 2014.

## 5.2 INSTRUMENTENVERGLEICH

Auf der Ebene der Umsetzung zeigt es sich *erstens*, dass die Instrumente zur Förderung des WTT in der ersten Serie der NFS und bei Nano-Tera.ch sehr ähnlich sind. So waren Patente, Kooperationen mit Industriepartnern, Prototypen, eingeworbene Drittmittel, Start-up-Firmen, die Weiterführung der Aktivitäten nach dem Ende der Programm-Laufzeit sowie die Anzahl Doktoranden und deren Werdegang bei beiden Programmen wichtige Messgrössen.

*Zweitens* sind alle Typen von Instrumenten (direkter/indirekter Transfer) in beiden Programmen anzutreffen.

*Drittens* sind das Reporting und das Monitorings der beiden Programme zu den WTT-Aktivitäten etwa vergleichbar. Für Nano-Tera.ch lässt sich ergänzen, dass die Messgrössen nicht alle regelmässig und auch nicht systematisch überwacht wurden. Einige der Daten (Start-ups, Patente, KTI usw.) werden erst bei Programmende aufbereitet. Bei der ersten Serie der NFS sind die Daten eher regelmässig erhoben worden.

Interessant ist *viertens* ein Vergleich der Ausgaben für den WTT: Bei den Programmen der ersten Serie der NFS betrug der durchschnittliche Anteil der Ausgaben für WTT 1,29 Prozent der gesamten Ausgaben von 1,528 Milliarden Franken (Rieder et.al, 2014:29). Bei Nano-Tera.ch können die Ausgaben für die Gateway-Projekte als Ausgaben für den WTT gelten: Sie machen rund 1,7 Prozent der Ausgaben von Total 249 Millionen Franken aus und liegen damit nur wenig höher als bei der ersten Serie der NFS. Einzelne der Teilprogramme des NFS weisen durchaus höhere Ausgaben für WTT aus. Der grösste Anteil liegt bei 3,3 Prozent, der kleinste Anteil bei 0,1 Prozent.

Ein Vergleich der Outputs muss vorsichtig vorgenommen werden, da die einzelnen NFS-Projekte viel grösser sind als die RTD-Projekte von Nano-Tera.ch. Die nächste Tabelle gibt eine Übersicht über die Outputs der zwei Programme. Um die Relationen zu vergleichen, muss jeweils berücksichtigt werden, dass den Programmen der ersten Serie des NFS etwa 6 mal mehr Mittel zur Verfügung standen als Nano-Tera.ch.

D 5.1: Vergleich der WTT-Outputs der NFS mit Nano-Tera.ch

| Output | Total aller NFS der ersten Serie | Total Nano-Tera.ch |
|---|---|---|
| Gegründete Start-up-Firmen | 81 | 4 (6 noch in Gründung) |
| Eingereichte Patente | 330 | 67 Patentanmeldungen ausgefüllt |
| Zugesprochene Patente | 163 | Keine Angaben |
| Lizenzen | 70 | Keine Angaben |
| Prototypen/Demonstratoren | 271 | Keine Angaben |
| Produkte/Prozesse | 213 | Nicht zutreffend |
| Kooperationen mit Industriepartnern | 737 | 74 (in 53 Projekten) |
| KTI-Projekte | 127 | 9 |
| Drittmittel Industriepartner (in Mio. CHF) | 164,28 | 9,5 |
| Durchschnittlicher Anteil der Doktorierenden und Postdocs, die eine Stelle im privaten oder öffentlichen Sektor (d.h. ausserhalb der Akademie) fanden | 22,4% | Keine Angaben |

Quelle: Darstellung Interface. Daten: Scientific Reports von Nano-Tera.ch und der Bericht von Interface zu den NFS der ersten Serie, welcher auf die Daten der 14 Schlussberichte des Schweizerischen Nationalfonds (SNF) zuhanden des Staatssekretariats für Bildung, Forschung und Innovation (SBFI) zurückgreift.

Wir beobachten folgendes:

- *Es werden die gleichen Daten zur Beschreibung der Outputs verwendet:* In Nano-Tera.ch und den NFS werden die Outputs der gegründeten Start-up-Firmen, die eingereichten Patente, Kooperationen mit Industriepartnern, die KTI-Projekte (obwohl erst am Schluss des Programms) und die Höhe der Drittmittel gemessen.
- *Für einige Outputs von Nano-Tera.ch liegen keine Zahlen vor:* Diese Outputs werden zwar in Dokumenten oder Interviews genannt, ohne aber Angaben zu deren Grössenordnung. Dies gilt für die Lizenzen, Prototypen/Demonstratoren und den durchschnittlichen Anteil der Doktorierenden und Postdocs, die eine Stelle im privaten oder öffentlichen Sektor (d.h. ausserhalb der Akademie) fanden. Diese letzte Messgrösse wird von Nano-Tera.ch für die Selbstevaluation aufbereitet.
- *Einige Outputs des NSF sind für Nano-Tera.ch nicht verfügbar:* So liegen bei Nano-Tera.ch beispielsweise noch keine Angaben über die zugesprochenen Patente vor; es wird bisher nur die Anzahl der Patentanmeldungen erfasst.
- *In einigen Bereichen liegen die Werte eher tief*: Die Zahl der Startups und die Zahl der KTI-Folgeprojekte ist auch unter Berücksichtigung des sechs Mal kleineren Budgets von Nano-Tera.ch eher tief.

Insgesamt stellen wir fest, dass Nano-Tera.ch die Outputs bis jetzt weniger systematisch erfasst als die NFS. Dies liegt eventuell daran, dass die Daten für die NFS aus den Schlussberichten stammen, während für Nano-Tera.ch noch kein Schlussbericht vorliegt.

# ANHANG I: ANALYSERASTER

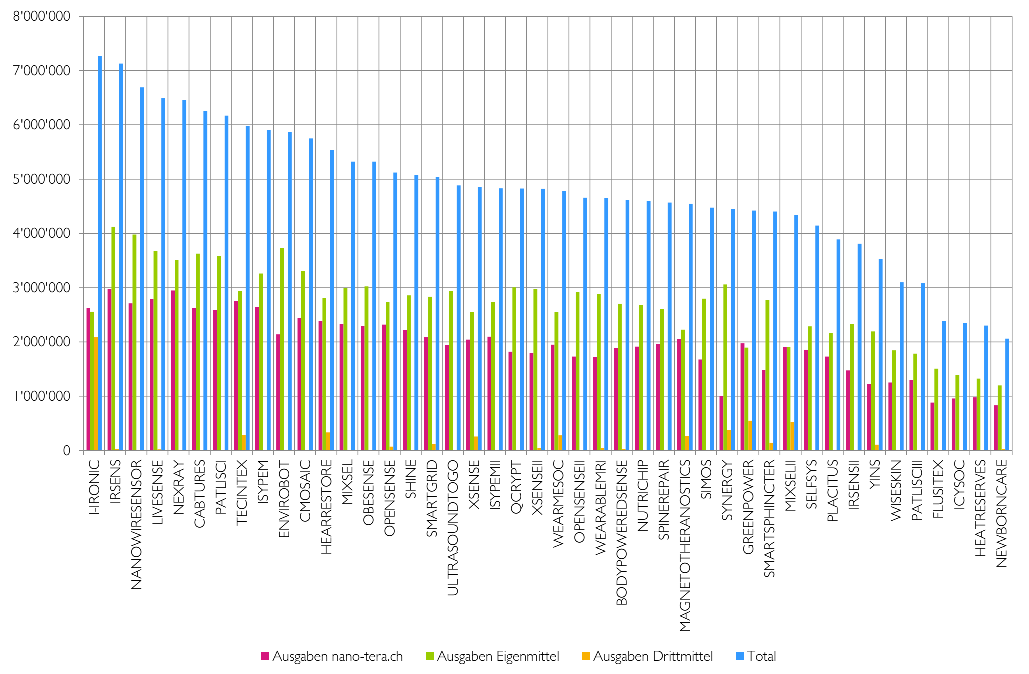
| Fragen |
|---|
| Begriffsverständnis von WTT: Welche Arten des WTT finden sich in auftrags-relevanten Dokumenten? |
| Was sind die Ziele anhand welcher der WTT in Nano-Tera.ch erreicht werden soll? |
| Wie sollen die Ziele erreicht werden? |
| Was sind die Umsetzungsinstrumente für den WTT von Nano-Tera.ch? |
| Wie hat sich das WTT-Konzept von Nano-Tera.ch auf der Programmebene und in den Projekten entwickelt? |
| Messgrössen von WTT: Wie werden die Konzepte in den Dokumenten präzisiert? |
| Wie wurde das Niveau des WTT auf Programmebene und in den Projekten beurteilt? Welche Indikatoren werden verwendet? |
| Was wurde bei ungenügender Leistung im WTT-Bereich unternommen? |
| Was sind Stärken und Schwächen des WTT von Nano-Tera.ch? |
| Was ist ihre Gesamteinschätzung des WTT von Nano-Tera.ch? |

# ANHANG 2: LISTE DER INTERVIEWTEN

| Interviewpartner | Funktion |
|---|---|
| Martin Rajman | Executive Officer Nano-Tera.ch (3 Gespräche) |
| Giovanny De Micheli | Director Nano-Tera.ch (zusammen mit Martin Rajman) |
| Roland Pesty | Pre-Venture Program Coordinator (Gateway) |
| Bengt Alexandre Elmér | NextStep Community Manager (zusammen mit Martin Rajman) |
| Stefan Weber | Programmverantwortlicher HearRestore |
| Marco Cavesaccio | User/Partner HearRestore |
| Daniel Ahmed | Programmkoordinator FlusiTex/FlusiSafe |
| Karl Aberer | Programmverantwortlicher OpenSense Phase 1 (zusammen mit Martinoli Alcherio) |
| Martinoli Alcherio | Programmverantwortlicher OpenSense Phase 2 (zusammen mit Karl Aberer) |
| Jonas Reinhardt | Industrial Partner FlusiSafe |
| Paul Burkhard | Ehemals SNF |
| Harry Heinzelmann | CSEM, Partner Nano-Tera |
| Marco Matulic | CTO CAScination (Partner HearRestore) |
| Muriel Bochud | CHUV (Partner Open Sense) |
| Laurent Mudry | TL Lausanne (Industrial Partner Open Sense) |

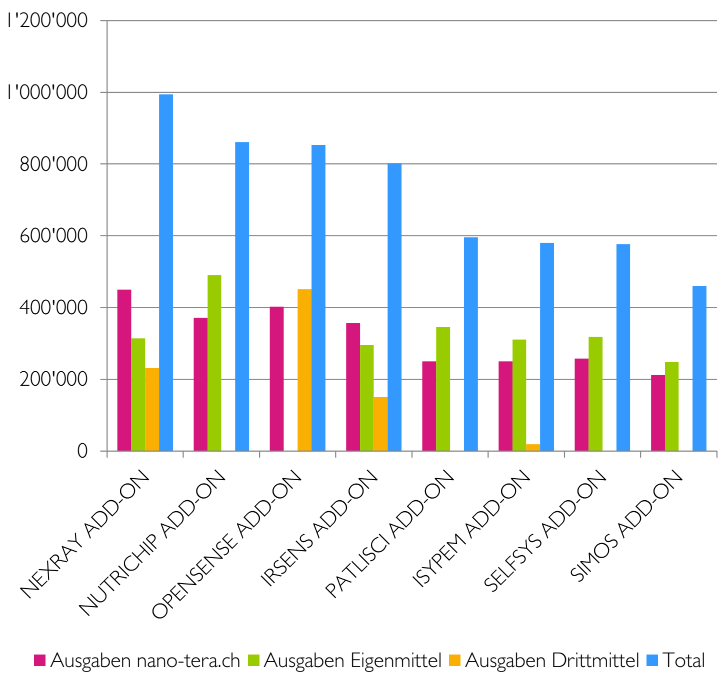
# ANHANG 3: AUSGEWÄLTE DATEN ZU NANO-TERA.CH

## DA 1: RTD-Projekte 2008–2016




Quelle: Darstellung Interface basierend auf Daten aus Project Evaluation Impact vom SWIR.

## DA 2: RTD add-on Projekte 2012




Quelle: Darstellung Interface basierend auf Daten aus Project Evaluation Impact vom SWIR.

# ANHANG 4: TECHNOLOGY READINESS LEVELS (TRL)

Forschungsprojekte können folgende Niveaus durchlaufen:

TRL 1 – basic principles observed

TRL 2 – technology concept formulated

TRL 3 – experimental proof of concept

TRL 4 – technology validated in lab

TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)

TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)

TRL 7 – system prototype demonstration in operational environment

TRL 8 – system complete and qualified

TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

Quelle: <https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf>.

# ANHANG 5: VERWENDETE LITERATUR ZUM THEMA WTT

Armstrong, Katy (2014): Emerging Industrial Applications, in: Styring, Peter; Quadrelli, Elsje A.; Armstrong, Katy (Hrsg.): Carbon Dioxide Utilisation: Closing the Carbon Cycle, Elsevier, Amsterdam.

Campbell, David F. J.; Carayannis Elias G. (2012): Lineare und nicht-lineare Knowledge Production: innovative Herausforderungen für das Hochschulsystem, in: Zeitschrift für Hochschulentwicklung, 7(2), S. 64-72.

Freiburghaus, Dieter (1989): Interfaces zwischen Wirtschaft und Politik, in: Schweizerisches Jahrbuch für Politikwissenschaft 29, S. 267-277.

Guston, David H. (2001): Boundary Organizations in Environmental Policy and Science. An Introduction, in: Science, Technology, & Human Values, 26(4), S. 399-408.

Koschatzky, Knut (2001): Räumliche Aspekte im Innovationsprozess. Ein Beitrag zur neuen Wirtschaftsgeographie aus Sicht der regionalen Innovationsforschung, Lit Verlag, Berlin-Münster-Wien-Zürich-London.

Meissner, Dirk; Sultanian, Elena (2007): Wissens- und Technologietransfer – Grundlagen und Diskussion von Studien und Beispielen, Center für Science and Technology Studies (CEST), Bern.

Rieder, Stefan; Knubel, Stefanie; Gärtner, Stefan (2014): Der Wissens- und Technologietransfer im Rahmen der ersten Serie der Nationalen Forschungsschwerpunkte (NFS). Schlussbericht zuhanden der Geschäftsstelle des Schweizerischen Wissenschafts- und Innovationsrates (SWIR), Interface Politikstudien Forschung Beratung, Luzern.

Ruttan, Vernon W. (2001): Technology, Growth, and Development: An Induced Innovation Perspective, Oxford University Press, New York.

# ANHANG 6: WEITERFÜHRENDE LITERATUR ZUM WTT

European Commission (2009): Metrics for Knowledge Transfer from Public Research Organisations in Europe. Report from the European Commission's Expert Group on Knowledge Transfer Metrics, <http://ec.europa.eu/invest-in-research/pdf/download_en/knowledge_transfer_web.pdf>, Zugriff 28.09.2017.

Reinhard, Michael; Schmalholz, Heinz; Schneider, Leander (1996): Technologietransfer in Deutschland. Stand und Reformbedarf, Duncker & Humblot, Berlin/München.

Rösner, Helmut; Strassburger, Gunter (2003): Erfahrungen und Probleme des Technologietransfers externer Industrieforschungseinrichtungen, in: Pleschak, Franz (Hrsg.): Technologietransfer – Anforderungen und Entwicklungstendenzen, Fraunhofer IRB, Karlsruhe, S. 53–64.

Sabisch, Helmut; Esswein, Werner; Meissner, Dirk; Wylegalla, Jörg (1998): Quantifizierung und Messung des Erfolgs von Technologieförderprogrammen. Studie im Auftrag des Sächsischen Rechnungshofs, Rechnungshof des Freistaates Sachsen, Leipzig.

## Annexe E – Nano-Tera.ch: related grants awarded by the SNSF, avril 2017

SWISS NATIONAL SCIENCE FOUNDATION

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19 April, 2017

## Nano-Tera.ch: related grants awarded by the SNSF

The impact of the Nano-Tera.ch program is currently being evaluated by the SWIR. To support this evaluation, the SNSF in this document provides data on its funding in the research areas of the Nano-Tera.ch program. To identify the relevant research areas we choose a simple approach: we assume that all applicants for Nano-Tera.ch applications are active in the relevant field. We therefore identify all involved responsible applicants and co-applicants in the program and list all other SNSF grants that these researchers have been awarded (after the earliest submission date to Nano-Tera.ch until the present date). We include both researchers whose Nano-Tera.ch applications were approved as well as those whose were rejected, as both groups can safely be assumed to consist of active researchers in the relevant research area. The following tables provide information about their non-Nano-Tera.ch SNSF grants[1].

The first application to Nano-Tera.ch was submitted on 2008-04-24, and has since involved:

| Total Applications | Total People (primary and co-applicants) |
|---|---|
| 147 | 472 |

These researchers were also funded by the following SNSF grants, not related to Nano-Tera.ch:

| Awarded projects with same people | Funding to same people (MCHF) | Publications from same people |
|---|---|---|
| 1077 | 401.7 | 3172 |

These funded SNSF projects can be broken down into funding categories, which were awarded the following funding, representing the following percentages of total SNSF funding in each category (since the first submission to Nano-Tera.ch until the present date).

| SNSF Funding Category | # grants | MCHF | % total funding |
|---|---|---|---|
| Project funding | 728 | 225.5 | 7.4 |
| Programmes | 179 | 133.3 | 13.7 |
| Infrastructure | 122 | 31.5 | 10.7 |
| Science communication | 33 | 1.2 | 2.7 |
| Careers | 15 | 10.3 | 0.9 |

[1]We include projects in all funding schemes of the SNSF except for NCCRs, where - for technical reasons - we do not have fine-grained information on involved researchers on a project or sub-project level. The numbers we report are therefore probably lower than the effective total SNSF funding.

## Annexe F – Entretiens CSS: liste des personnes rencontrées et guides d'entretien, 2017-2018

Deux séries d'entretiens ont été réalisées. La première (mars 2018) concernait des entretiens de recherche portant sur Nano-Tera.ch et SystemsX.ch. La seconde série (novembre 2017 à février 2018) consiste en des entretiens d'analyse consacrés à Nano-Tera.ch uniquement. Toutes les personnes contactées pour des entretiens n'ont pas pu être rencontrées.

*Entretiens de recherche*

| Prénom Nom | Principale fonction |
|---|---|
| Dr Paul Burkhard | Responsable pour Nano-Tera.ch à la Division II du secrétariat du FNS |
| Dr Daniel Höchli | Directeur du secrétariat du FNS |
| Dr Charles Kleiber | Secrétaire d'Etat à la recherche |
| Dr Martin Rajman | Executive Director, Nano-Tera.ch |
| Dr Raymond Werlen | Secrétaire général adjoint de la CRUS |

*Entretiens d'analyse*

| Prénom Nom | Principale fonction |
|---|---|
| Prof. Dr Gabriel Aeppli | Prof. de physique EPFL et EPFZ, membre du CSS |
| Prof. Dr Murielle Bochud | Prof. à l'Institut Universitaire de Médecine Sociale et Préventive (UNIL). Co-PI du projet Nano-Tera.ch «OpenSense II» |
| Dr Christian Brunner | Coordinateur du programme Bridge FNS-Innosuisse |
| Prof. Dr Nico De Rooij | Prof. Microengineering EPFL, Membre de l'ExCom de Nano-Tera.ch (2008-2017) |
| Prof. Dr Ralph Eichler | Président de l'EPFZ 2007-2014 ; membre du Steering Committee de Nano-Tera.ch (2007-2014) |
| Dr Philippe Fischer | Directeur de la Fondation suisse pour la recherche en microtechnique |
| Prof. Dr Lutz-Peter Nolte | Prof. Institute for Surgical Technology & Biomechanics, Université de Berne, Co-PI du projet Nano-Tera.ch «SmartSphincters» |
| Prof. Dr Laurent Sciboz | Prof. Haute école du Valais, directeur Institut Icare, Co-PI du projet Nano-Tera.ch «Selfsys» |
| Prof. Dr Gabor Szekely | Prof. Computer Vision Laboratory EPFZ, Head MedTech CTI ; directeur du PRN CO-ME Computer Aided and Image Guided Medical Interventions (série 1) |
| Prof. Dr Stefan Weber | Prof. Center for Biomedical Engineering (ARTORG), Université de Berne, PI du projet Nano-Tera.ch «HearRestore» |

*Guide utilisé pour les entretiens de recherche*

**1. Positionnement de l'institution resp. de la personne**

- Comment avez-vous pris connaissance du lancement de l'Initiative NTCH / SXCH?

**2. Origine de NTCH / SXCH + Contexte général**

- Quelle était l'analyse de fond qui a motivé son lancement? Quelles étaient les principales motivations de cette initiative?
- Comment caractériser le contexte d'alors sur le plan de l'encouragement de la recherche? Quels enjeux? quel positionnement des acteurs?

**3. Appréciation de l'initiative (au niveau interne à NTCH / SXCH)**

- Quels sont les principaux résultats de NTCH / SXCH?
- Les succès? Les échecs? «More of the same»? Les problèmes?
- Quelle est la valeur ajoutée de NTCH / SXCH en général et par rapport à un PRN?

**4. Appréciation de l’initiative (niveau système FRI)**

- Est-ce que NTCH / SXCH peut être considéré comme un instrument resp. un programme d’encouragement de la recherche, au même sens que les PRN ou que les SCCER, ou bien est-ce qu’il s’agit d’une initiative ad hoc, unique «One shot program»? Y avait-il une volonté d’influer sur le paysage de l’encouragement de la recherche?
- Comment faut-il comprendre les demandes faites par différents acteurs lors de la révision de la LERI en 2011 de placer SXCH et NTCH dans la LERI et non plus dans la LAU (Contributions liées à des projets / Projektgebundene Beiträge)?
- Y a-t-il eu des conséquences particulières de NTCH / SXCH sur les formes d’encouragement de la recherche en Suisse? p. ex. est-ce que BRIDGE est une conséquence? et les SCCER? Autres ( i.e. SPHNI) ?
- Le contexte d’encouragement a passablement changé depuis 2008. Serait-il aujourd’hui encore possible / justifié / nécessaire de lancer une initiative de ce type? avec ce mode d’organisation?

*Guide utilisé pour les entretiens d’analyse*

**Scientific impact**

1 Which was the main goal of Nano-Tera on the scientific level ?
2 To what extent has Nano-Tera.ch contributed to foster excellence in research in Swiss engineering sciences? And in other scientific fields?
3 Did the initiative contribute to bridge the gap between fundamental and applications-oriented research resp. between science and engineering?

**Educational impact**

4 Which was the main goal of Nano-Tera on the educational level ?
5 How do you assess the measures taken to promote PhDs? Original ?
6 The main educational impact of Nano-Tera.ch are 366 PhD students. Is that “enough” considering the funding scope (ca. 200 MCHF) and the duration (9 years) of the program?

**Economical impact**

7 Which was the main goal of Nano-Tera on the economical level ?
8 Did Nano-Tera.ch formulate an explicit strategy to promote KTT on program level? How was it organized in the projects funded (for example at your institution)?
9 What would you consider as best practices for KTT in a similar research program (interface science – engineering)?

**Societal impact**

10 Which was the main goal of Nano-Tera on the societal level ?
11 How would you measure the societal impact of such a program?

**Institutional impact**

12 Which was the main goal of Nano-Tera on the institutional level ?
13 To what extent did your institution benefit from Nano-Tera from an institutional resp. structural perspective ? What was the institutional interest in Nano-Tera ? (scientific profiling, attract scientists, funding source, …?)
14 How do you consider the SNSF-KTI Bridge funding scheme ? Is it related to Nano-Tera ?

**Broader impact**

15 How do you consider the Nano-Tera program under the governance of the initiative?
16 To what extent was Nano-Tera an open network resp. community ? (to: other scientists, other institutions like UAS, etc.)
17 Which are the strengths and weaknesses of Nano-Tera?
18 What is the overall added-value of this program within your scientific domain and for Switzerland (sustainability)?

## Annexe G – Programme et liste des participants à la rencontre «Site Visit», novembre 2017

**Impact evaluation "Nano-Tera.ch" – Meetings in Bern, November 13 and 14, 2017**

**Schedule and Participants**

**Place & Contact**
The meetings take place at Hotel Kreuz, Zeughausgasse 41, Meeting room "Bovet", 1st floor
Contact Hotel: +41 (0)31 329 95 95 / Contact SSIC: +41 (0)58 463 28 89

**Participants**

| | |
|---|---|
| **SSIC** | Jean-Marc Triscone (chair), Fariba Moghaddam (Staff: Frédéric Joye-Cagnard, Eva Herrmann, Claudia Acklin) |
| **Expert panel** | Jeremy Baumberg, Rudy Lauwereins, Mark Lundstrom |
| **Nano-Tera.ch** | Giovanni De Micheli, Giorgio Margaritondo, Mario El-Khoury (Nov. 14), Harry Heinzelmann (Nov. 13), Heinrich Meyr, Christofer Hierold, Martin Rajman |
| **SNSF** | Dieter Imboden, Paul Leiderer, Urs Dürig, Albert van den Berg, Liz Kohl |

**November 13, 2017 – Meeting "Site visit"**
**Chair**: Jean-Marc Triscone, SSIC
**Participants**: SSIC, Expert panel, Nano-Tera.ch
Aim of the meeting is a discussion, especially between the international experts and the Nano-Tera.ch Consortium, in order to help them to answer the SSIC's questions. The structure of the discussion complies with the SERI Mandate. Each part will be introduced by a short presentation of Nano-Tera.ch.

| | |
|---|---|
| 14.00 – 14.15 | **Welcome address** |
| 14.15 – 14.40 | **Nano-Tera.ch main achievements**<br>(20' presentation by program leader G. De Micheli + 5' discussion) |
| 14.40 – 15.40 | **Dimension I – Scientific impact**<br>20' Introduction by Nano-Tera.ch (including a short video)<br>40' Discussion |
| 15.40 – 16.00 | *Coffee break* |
| 16.00 – 16.45 | **Dimension II – Educational impact**<br>15' Introduction by Nano-Tera.ch (including a short video)<br>30' Discussion |
| 16.45 – 17.30 | **Dimension III – Economic impact**<br>15' Introduction by Nano-Tera.ch (including a short video)<br>30' Discussion |
| 17.30 – 18.15 | **Dimension IV + V – Societal & Institutional impacts**<br>15' Introduction by Nano-Tera.ch (including a short video)<br>30' Discussion |
| 18.15 – 18.20 | **Closing remarks** |

**November 14, 2017 / 09.15-10.15 – Meeting with SNSF**
**Chair**: Jean-Marc Triscone, SSIC
**Participants**: SSIC, Expert panel, SNSF

Aim of the meeting is a discussion between the expert panel and scientists who accompanied the Nano-Tera.ch funding processes for the Swiss National Science Foundation SNSF. The SNSF was responsible for the evaluation of the RTD projects and has a well-founded external view on the program.

10.15 – 10.30 *Coffee break: arrival of Nano-Tera.ch*

**November 14, 2017 / 10.30-11.30 – Meeting "final round"**
**Chair**: Jean-Marc Triscone, SSIC
**Participants**: SSIC, Expert panel, SNSF, Nano-Tera.ch
Aim of the meeting: Discussion on unresolved issues / Information on procedure and scheduling

**Annex – Full participants list**

| Name | Group, function | Attends to… |
|---|---|---|
| Moghaddam, Fariba | SSIC Member | All meetings |
| Triscone, Jean-Marc | SSIC Member | All meetings |
| | | |
| Baumberg, Jeremy | Expert Panel | All meetings |
| Lundstrom, Mark S. | Expert Panel | All meetings |
| Lauwereins, Rudy | Expert Panel | All meetings |
| | | |
| De Micheli, Giovanni | Nano-Tera, Executive Committee, Chair | Site visit + Final round |
| El-Khoury, Mario | Nano-Tera, Steering Committee Member | Final round |
| Heinzelmann, Harry | Nano-Tera, Steering Committee Member | Site visit |
| Hierold, Christofer | Nano-Tera, Executive Committee | Site visit + Final round |
| Margaritondo, Giorgio | Nano-Tera, Vice-President EPFL (2004-2010) | Site visit + Final round |
| Meyr, Heinrich | Nano-Tera, Scientific Advisory Board, Chair | Site visit + Final round |
| Rajman, Martin | Nano-Tera, Executive Director | Site visit + Final round |
| Faist, Jérôme | Nano-Tera, PI IrSens2 | Site visit (Scientific) |
| Lacour, Stéphanie | Nano-Tera, PI SpineRepair | Site visit (Scientific) |
| Hager, Pascal | Nano-Tera, PhD student | Site visit (Educational) |
| Murali, Srinivasan | Nano-Tera, Post-Doc | Site visit (Educational) |
| Dommann, Alex | Nano-Tera, Executive Committee | Site visit (Economic) |
| Pesty, Roland | Nano-Tera, Pre-Venture Program (Gateway) | Site visit (Economic) |
| Duval, Etienne | Nano-Tera, Producer, reporter and trainer | Site visit (Societal) |
| Weber, Stefan | Nano-Tera, PI HearRestore | Site visit (Societal) |
| | | |
| Leiderer, Paul | SNSF, Expert Panel for Nano-Tera, Chair | SNSF + Final round |
| Dürig, Urs | SNSF, Expert Panel for Nano-Tera | SNSF + Final round |
| Van den Berg, Albert | SNSF, Expert Panel for Nano-Tera | SNSF + Final round |
| Imboden, Dieter | SNSF, President (2005-2012) | SNSF + Final round |
| Kohl, Liz | SNSF, Office Division II: Mathematics, Natural and Engineering Sciences | SNSF + Final round |
| | | |
| Acklin, Claudia | SSIC, Head of secretariat | All meetings |
| Herrmann, Eva | SSIC Staff | All meetings |
| Joye-Cagnard, Frédéric | SSIC Staff | All meetings |

Prof. Dr Stefan Weber was not able to attend the meeting.