ETH Board

and

Commission for Technology and Innovation (CTI)

Of the Swiss Federal Office for Professional Education and Technology

Peer Review of TOP NANO 21

February 27 – March 2, 2005

Report of the Peers

May 18, 2005

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Executive summary

The Board of the Swiss Federal Institute of Technology (ETH Board) and the Federal Office for Professional Education and Technology (OPET) commissioned an international peer review of the Technology Oriented Program TOP NANO 21. For this purpose, nine international and Swiss peers from various disciplines were invited to evaluate TOP NANO 21. The peers were documented with reports on the program, mainly a self-evaluation by the program management, an industrial impact analysis and an interview report. At the peer review itself, which took place in Zurich and Lausanne from 27 February to 2 March 2005, twelve TOP NANO 21 projects were presented by the respective research and industry partners and discussed with the peers.

The peers assessed the achievement of the four objectives of the TOP NANO 21 Program as well as the mission and objectives, the design and management of the program:

Expanding the scientific horizon

The projects funded successfully reinforced Switzerland's very good position in important areas of nanotechnology. Most participants had strong international competence and visibility. Moreover, TOP NANO 21 increased academic–industrial and interdisciplinary interactions and the exchange of knowledge and skills and the program provided basic scientific research to a large number of complementary industry partners. However, the communication of program activities and results is not easily accessible to industry, the scientific community and other interested parties.

Strengthening the Swiss economy

The overall economic impact is expected to be considerable given the short duration of the program. Expectations for commercial effects were too high given that nanotechnology-driven projects need more than 3 to 4 years for commercial and employment effects to materialise. In many cases, additional funding is thus indispensable to realize the full market potential. However, the program has triggered the application of nanotechnology to several highly relevant present and future commercial areas and created a number of new jobs. Effects are more immediate and obvious in the transfer and build-up of knowledge and skills to companies. The program was instrumental in creating new collaborations between industry and universities.

Teaching and promotion of young scientists

The inclusion and support of post-graduate students as well as the exposure of students to collaborative and application-oriented projects were highly beneficial. The expansion to vocational training needs to be redesigned and expanded to high school. Gender broadening

has to be approached more systematically and aggressively. Finally, the high potential to better educate the general public regarding nanotechnologies and their applications is not yet fully realized and needs to be pursued if these areas are to be fully allowed to benefit society.

Encouraging new companies

TOP NANO 21 has succeeded in seeding an impressive number of start-up and spin-off companies. The support of young and small companies by cooperation with academia led to particularly positive effects. Here it proved to be particularly useful to relax the general funding scheme of CTI, as small companies are often unable to finance 50 percent of a project.

Overall assessment of the program

Overall, the peers rate the program as highly successful. They strongly recommend that it should be continued in the spirit of TOP NANO 21 to bridge the gap between basic science funding and general CTI funding.

Finally, the peers forward the following **four recommendations**:

(1) The program must be continued if the investment in TOP NANO 21 is to be secured for the benefit of the Swiss economy.

(2) The funding should favor spin-offs and start-ups, allowing their financial contribution to be substantially smaller than 50 percent to better reflect the economic situation of these young companies.

(3) The future use of nanotechnology for the benefit of society crucially depends on its general appreciation and understanding, which in turn will require enhanced educational efforts.

(4) In order to maximize the potential for Switzerland, the future program management must retain its flexibility and enhance marketing and competitive aspects.

1 Introduction

The Board of the Swiss Federal Institute of Technology (ETH Board) and the Federal Office for Professional Education and Technology (OPET) commissioned an international peer review of the Technology Oriented Program TOP NANO 21. The peer review took place from 27 February to 2 March 2005. This report is the result of that peer review.

The structure of the report is as follows. This chapter briefly describes the TOP NANO 21 program. Chapter 2 presents the assessment of the impact of TOP NANO 21 structured in separate sections following the objectives of the program: knowledge effects, economic effects (commercial and employment effects), the creation of spin-offs and start-ups, and finally education and training effects. Then follows the peers' overall assessment of TOP NANO 21 including comments on the program's design and mission, program management, the output and the impact of the program. Chapter 3 presents the peers' recommendations.

The following sources of information were available to the peers for their assessment (the current report also refers to these documents):

(1) the Self-Evaluation TOP NANO 21 by the program management,[1]

(2) the Industrial Impact Analysis and Report of Face-to-face-interviews with Industrial Partners by Interface and Fraunhofer-ISI,[2]

(3) Presentations by and discussions with the project leaders (both research and industrial partners) of twelve TOP NANO 21 projects in the course of the peer review sessions in Zurich and Lausanne,[3]

(4) TOP NANO 21 program documents such as the Final Report 2000–2003.[4]

The process was administered and supported by Interface Institute for Policy Studies, Lucerne, and the Fraunhofer Institute for Systems and Innovation Research, Karlsruhe.

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1 Hans-Joachim Güntherodt, Annemarie Gemperli, Karl Höhener (2004): Self-Evaluation TOP NANO 21, November 2004. From now on referred to as Self-Evaluation.

2 Balthasar, Andreas, Lehmann, Luzia, Bierhals, Rainer, Ebersberger, Bernd and Edler, Jakob (2005): Industrial Impact Analysis and Report of Face-to-face-interviews with Industrial Partners, May 18, 2005, Lucerne/Karlsruhe.

3 The 12 projects presented to the peers were chosen in a combination of random selection and the consideration of several criteria. Since the projects had to include different types and criteria of projects, they were first grouped by the following criteria: Projects with the participation of industry, important research institutions including universities of applied science, distribution of industry partners by size, thematic areas and project types, German and French-speaking Switzerland. The projects were then selected at random from the various groups.

4 TOP NANO 21 Final Report 2000-2003, Bern, 2003.

1.1 Background of the TOP NANO 21 Program

Nanoscience and nanotechnology in Switzerland were launched well before the international wave in research and development in this field picked up momentum. It materialized with the invention of the STM in 1981 by Binnig, Rohrer, and Gerber at the IBM Research Laboratory in Rueschlikon. As the Self-Evaluation notes, the STM was exactly the instrument to realize the vision of Feynman outlined in his famous talk in 1959, when he suggested that future applied research will be based on the control of individual atoms and molecules. The first exciting results of the STM were followed by the setting up of STMs - and later in 1986 of AFMs - in most Swiss universities including the ETH. Additionally, individual financial support from the Swiss National Science Foundation (SNF) and the Commission for Technology and Innovation (CTI) was granted. The first joint effort within the National Research Programs (NRP) was the supplement to NRP24 (Chemistry and Physics of Surface), followed by NRP 36 (Nanoscience). The subsequent Swiss Priority Program in Micro & Nano System Technology (MINAST), managed by the ETH Board, was more application-oriented. Yet MINAST required established companies as industrial partners, thus not including funding for start-ups. Overall, MINAST was fairly narrowly focused and primarily science and technology-oriented. CTI was not involved in MINAST.

Focus and Objectives of TOP NANO 21

From the financer's point of view, the TOP NANO 21 program was a successor to MINAST, yet with an exclusive emphasis on nanotechnology. The program evolved around the role of the nanometer in the world of science, technology and industry at the beginning of the 21st century. The program aimed at increasing the levels of knowledge about the NANOMETER in order to encourage new technologies, to support existing technologies through synergies as well as to encourage the development of the industrial application of such technologies. Therefore, in contrast to MINAST, the emphasis of TOP NANO 21 was to be on technology transfer and application. TOP NANO 21 was initially geared towards science (ETH domain, universities, research institutes) and industry. Later, universities of applied science (Fachhochschulen) were involved.

The TOP NANO 21 program was set up to pursue the following goals:

Goal 1: Extend the scientific horizon to include the relevant sectors at the research centers and consolidate the awareness of technology.

Goal 2: Strengthen the Swiss economy through the development and application of new technologies based on the nanometer.

Goal 3: Integrate (nanoscience and) nanotechnology in teaching.

Goal 4: Encourage the creation of new companies.

In the course of the peer review another goal became evident that was not formally among the objectives made explicit at the outset but was added in the conclusion of the TOP NANO 21 Final Report (p. 6), namely to promote the concept of competition in ETH funding.

1.2 Characteristics of the TOP NANO 21 Program

Financing model

TOP NANO 21 was a joint effort of the ETH Board - the proponent of the concept and the dominant financier - and of the CTI as the agency in charge of successfully implementing and running the program. TOP NANO 21 accounted for some 20 percent of the CTI's annual budget. The usual 50-50 rule guiding CTI funding that requires industrial partners to provide 50 percent of the funding was in part lifted and gave way to more flexible financing in the case of TOP NANO 21.

Project types

TOP NANO 21 allowed the following project types, to which about 90 percent of the overall budget was allocated: (1) technological fundamental projects to provide fundamental technological knowledge, (2) feasibility studies for areas of high risk and high potential, (3) alliance projects involving several industry partners and (4) individual projects to support the development of prototypes, products and processes. These major project types were supplemented by a range of supporting measures (e.g. coaching) and special schemes for PhD students (3 year funding scheme and PhD awards).

The following indicators provide a brief picture of the activities and the structure of participation of TOP NANO 21. These indicators are based on the self-evaluation of the program management. There is some conflicting information on the definitive figures regarding the total number of TOP NANO 21 projects and industrial partners. Contrary to the official documents, the peers noted an impressive output of patents and publications. These numbers will continue to increase as the projects reach fruition.

Table 1: Some structural data on TOP NANO 21

Duration	2000 – 2003
Financial support by the ETH Board	CHF 62 million
Financial support by the CTI Board	CHF 10 million
Financial support from industry	CHF 37 million
Number of projects	260
Number of participating research groups	200
Number of industrial partners	170
PhD students	168
Post-docs	258
Publications	> 210
Patents (applied for or granted)	> 40
Spin-offs / Start-ups	22[5]
Seminars with economic development agencies	16
Seminars with partners from science	23

Source: Self-Evaluation

5 The Self-Evaluation includes the *support* of spin-offs, i.e., not only *the creation of spin-offs as a result of* Top NANO 21, whereas the Industrial Impact Analysis includes figures for the latter only. Self-Evaluation, p. 48, 54; Industrial Impact Analysis, p. 17. The TOP NANO 21 Final Report speaks of “spin-off and start-up companies resulting from/or being influenced by TOP NANO 21”, Final Report, p. 455.

2 Assessment of TOP NANO 21

2.1 Expanding the scientific horizon

As Switzerland has a long tradition of scientific success in the micro- and nano-sciences and TOP NANO 21 was not the first program to target nanoscience and its application, TOP NANO 21 drew on an excellent and established background in Swiss academia.

By bringing together industry and academia, TOP NANO 21 increased sensitivity to apply nanoscience to solutions of industrial problems and to develop new nanotechnologies. There was a clear response from the scientific community to the needs of industry. In doing so, TOP NANO 21 increased academic – industrial and interdisciplinary interactions.

The projects funded through the program thus reinforced the good position of Switzerland in the area of nanotechnology and supported scientific partners in maintaining their position at the scientific frontier in nano-sciences.

By and large the initiative for the projects was with the scientific partners, suggesting that many projects were driven by scientific challenges coupled with the desire to apply scientific results to solve technological problems. Given the scientific excellence of the Swiss universities and ETH research in the field of nano-science, the market application dimension appeared to be a real challenge for scientific partners within the projects. This challenge of the program, however, contributed significantly to the extension of the horizon of science partners towards the industry and market perspective. This was also true for young scientists (see below).

Furthermore, the program enabled universities of applied sciences to participate in applied and scientific research. Through their participation, universities of applied sciences improved their scientific ambitions as they competed with other TOP NANO 21 projects run by universities. This had potentially positive effects on their research activities and, as we will discuss below, on education. It might also influence their cooperation with industry in other contexts.

Scientific and technological aims, output and impacts of the projects and the program

The program provided basic scientific research to a large number of complementary industry partners. It led to the successful development of new technologies and new applications of proven technologies. Given the relatively short duration of TOP NANO 21, the technical impact was impressive. The ex-post evaluation of the projects revealed that the majority of the projects performed according to the expectations or better.

Most of the participants had strong international competence and visibility. Together with the number of publications presented, this suggests scientific excellence of a majority of the projects. Overall, there were a relatively large number of high-quality projects and feasibility studies, thus extending the Swiss nano-science and technology foundation.

Moreover, the scientific horizon of both industrial and scientific partners was expanded by the cooperation requirement. The resulting complementary capabilities enabled the exchange of knowledge and skills between industry and academia. This is indicated by the joint publication of papers by scientific and industrial partners and by the project presentations during the peer review.

Public dissemination of program activities and achievements

Beyond program participation and collaboration therein, various activities such as workshops and conferences of TOP NANO 21 enhanced the networking opportunities for project partners. The conferences and workshops were open to international participation and, thus, they increased the visibility of the Swiss nano-science and technology community internationally. The conferences and workshops attracted public attention, although public attention towards nano-science and technology is still quite low in Switzerland, as it is elsewhere. TOP NANO 21 workshops and conferences also created a forum for presenting the state of the ongoing research and helped to disseminate the results of ongoing research within the nano-community. The conferences and workshops started communication and collaboration with previously unknown partners on previously untouched issues.

Nevertheless, the communication of the program activities and results was not easily accessible to industry, the scientific community and other interested parties. For example, the project description in the final report of the program did in most cases not do justice to the technological and application potential of the projects. The user-friendliness of the documentation is limited as the contribution of individual partners was not made explicit and the scientific publications are difficult to associate with specific projects. For potential industrial partners the documentation was not sufficiently transparent. This limited the broader use of the project results. On the basis of the documentation alone, it was not possible to appreciate the high overall scientific quality of the projects.

2.2 Strengthening the Swiss economy

2.2.1 Economic impacts

The program has triggered the application of nanotechnology to highly relevant commercial areas for future economic exploitation such as lubrication, food processing, life science, quality control, manufacturing methods, personal care products, medical implants, information technology and data storage. This potential is significantly enhanced by the creation of start-up companies and the new jobs inherent to them.

Commercial and employment effects

The initial impulse to create TOP NANO 21 was to better utilise nano-science and technology competencies in the Swiss economy. The major challenge therefore was to break up the perceived compartmentalization in nano-sciences between the academic and the industrial world. The idea of the program was thus to increase the awareness of the scientific community to industrial demands and ideas and to open industry's awareness to opportunities that the academic nano-community offers.

However, the expectations raised for the immediate commercial and market impact were too high. In most areas, the nanotechnology-driven projects cannot provide commercial products within 3-4 years.[6]

This does *not* imply that the overall economic impact was low, as it must not only be defined in immediate commercial or employment effects. The topicality of the projects exhibits a high market relevance with significant potential for future business opportunities. The industrial impact analysis, the interview report and the projects presented at the peer review provide evidence that out of many projects future market applications can be expected. As a consequence, most of the companies that got seriously involved increased their future international competitiveness. These companies are poised to profit from the TOP NANO 21 projects.

In several cases the technology has advanced to a stage where it might enable market entry without further public funding. In many cases, however, additional funding is indispensable to realize the full market potential.

In addition, many projects have prepared the ground for appropriation of the economic yields of their research by applying for patents. However, in some cases new results were not suitable for patents owing to prior art or inadvisability of disclosure.

The program has already helped to create a number of new jobs. The most positive overall employment effects are discerned in small companies (20 percent good and excellent). However, these figures only provide a very short term picture; ultimately the potential of the start-up companies created is most likely to realise much higher economic effects in the future (see below).

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6 This is confirmed by the industrial impact analysis showing that only 13 percent of respondents consider overall commercial effects as good or excellent, whereas over half consider them weak or non-existent.

In addition to those projects that have not advanced enough, there are projects that, in the perception of industry, have failed to meet commercial expectations. However, it is the nature of research programs that not all projects live up to their scientific or commercial expectations. Thus, the share of reported failures or disappointments of some companies involved appears to be well within the range of what is to be expected in complex research programs.

Moreover, there are indications of a correlation between the level of involvement and commitment of the companies on the one hand and the economic effect they perceive on the other hand. Strong commitment of both partners is a prerequisite for the economic value they might realize. In general, SMEs seem to have been more committed than large companies.

Last but not least, failures also have their economic merit. For example, some interviews revealed cases where a failure in a feasibility study prevented the partners from entering a field in which considerable resources would have been lost.

Knowledge and skill effects on companies

Build-up and transfer of knowledge and skills to companies, as well as the development of advanced tools to be used by companies, are another pillar of economic impact. Here the effects are more immediate and more obvious. First, the self-evaluation indicates that the program actively pushed for fundamental technological projects in the second phase, as there was a need to overcome knowledge bottlenecks in companies. Thus, the program has filled a competence gap in industry. Second, and more importantly, the program enabled more companies to tap into the knowledge sources of universities and to take advantage of methods and tools developed in the projects.

The industrial impact analysis reveals that the overall knowledge effects associated with TOP NANO 21 are assessed as good or excellent by more than two thirds of the respondents. In addition, the interview report as well as the presentations at the peer review indicate that the industrial partners in general were highly satisfied with their scientific partners. This is especially true for young and small companies, which gained access to otherwise unaffordable research carried out by scientific partners. In this regard, TOP NANO 21 succeeded in supporting small companies with access to infrastructure and knowledge deemed essential for their success.

Future oriented collaborations

A third long-term economic impact arises from structural and behavioural effects. The program helped to create a range of new collaborations between industry and universities. Not all of these collaborations have been equally fruitful to all their participants; some companies have not lived up to their collaboration commitment. But overall, the structural effect is considerable. More than 250 companies have participated in collaborations. In many of those cases the companies intend to prolong cooperative relations with scientific partners; 42 percent of the responding companies in the industrial impact analysis plan collaborations in the future on the basis of the participation in TOP NANO 21.

2.3 Teaching and promotion of young scientists

2.3.1 Teaching and education

PhD involvement

The PhD participation in the program is internationally competitive and the work done by PhD students is highly economically and scientifically relevant. The program thus contributed to the training of a new generation of PhDs in nano-science with the awareness of the possible use in nanotechnology. The program has been successful in getting students exposed to industrial problems and collaboration. This develops a high degree of self-confidence.

TOP NANO 21 provided a special funding scheme for PhD students, as it offered three years of funding independent of project duration. This is welcome and appropriate as it takes account of the fact that PhD research requires a time frame that may not be compatible with the project duration.

Evidently, TOP NANO 21 has also been attractive to foreign PhDs as 40 percent of the PhD participants came from abroad. This can be rated as a good ratio, albeit Switzerland as such is a highly attractive academic location and the ratio of foreign students and post-docs is rather high by international comparison.

Training in universities and universities of applied sciences

The academic program participants incorporated their results and experiences into their lectures and the usage of equipment and tools developed within the project in their classes. This is true for universities of applied sciences and universities alike. This development is to be welcomed and should indeed be strengthened in the future, as this confronts students with research work directly relevant for future industrial application and, linked to that, to interdisciplinarity. Moreover, as collaboration with industry is inserted into the curricula, the long-term propensity of future scientists to cooperate with industry partners is – likely – enhanced.

The industrial impact analysis indicates that within the participating companies the training effects on young researchers are mixed. Most importantly, the rate of participation of company staff in continuing education programs or workshops associated with TOP NANO 21 is encouraging.

In addition to the traditional curricula the University of Basel has introduced a bachelor and master program in nanoscience with over 50 students enrolled, and the TOP NANO 21 objectives are likely to benefit from this new curriculum.

Vocational training

Including nanoscience and nanotechnologies in vocational training is an important endeavor for the future prospects of nanotechnology in industry. However, the presented approach was not convincing and should be redesigned with a more creative approach and extended to high school and younger students and pupils. The process seems to be too isolated from the TOP NANO 21 activities; the program should be more accessible to vocational training. The scientific community as such should be much more involved in this exercise and take more responsibility in training teachers and students alike.

A more aggressive stance must be taken to bring women into the areas of nano-science and -technology.

General awareness

Nanoscience and nanotechnology are complex issues that raise high expectations and concerns alike. To this end the program has contributed to the general awareness of nanoscience in Switzerland and internationally. As a thematic, top down program it indicated a public commitment to the field and mobilized industry selectively. Furthermore, the TOP NANO 21 conference and the various public events have contributed to inform a broader audience.

Nevertheless, the program has not fully exploited the potential to raise awareness and understanding in the scientific community and the public as such. As stated above, the documentation of the projects is comprehensive, but not easily accessible to those interested in certain topics. Furthermore, the success stories of the program are not broadly and generally enough communicated to the scientific and industrial community or to the interested general public.

In the future, the program management and individual participants should be encouraged to report in easily accessible formats to the general public about the activities and impacts of the program. This would increase the leverage of the activities and strengthen the case for future activities and collaborations in the field.

2.4 Encouraging new companies

2.4.1 The influence of the program on founding and supporting start-ups

As acknowledged by the peer review panel TOP NANO 21 has succeeded in seeding an impressive number of start-up and spin-off companies.

The support of young and small companies by cooperation with academia leads to particularly positive effects: First, companies and academia engaged each other in solving problems in the applications and developments of nanotechnolgy. This was particularly true for small companies and spin-offs. For young people this was an especially creative atmosphere. Second, these researchers then served as an energetic work force that subsequently moved into these companies. Hence, the strongest leverage to generate positive impacts on the application of nanotechnology can be found among the small and young companies, largely because of their more intense participation in TOP NANO 21.

Large and established companies are normally highly focused on their core business and typically less open to additional opportunities outside of their existing business. This explains that their commitment to TOP NANO 21 projects was not always at the same level as that of the small companies.

A problem for small companies is the general CTI funding scheme, since most of them cannot finance 50 percent of the project, be it in kind, in cash or labor. Matching the funding and keeping their business running is a high burden on exactly those companies that have the highest potential. The relaxation of the general CTI funding rules in TOP NANO 21 has been very helpful. In addition, the ETH scheme of partially supporting students engaged in start-up activities has been rated positively.

2.5 What is the Peers' overall assessment of the program?

Overall, the peers rate the program as highly successful. They strongly recommend that it should be continued in the spirit of TOP NANO 21 to bridge the gap between basic science funding and general CTI funding.

2.5.1 Mission and objectives of the program

Improving the system

(1) Filling the knowledge gap - the need for Switzerland to continue in the spirit of TOP NANO 21

The program set out to fill the gap between SNF funding of basic science and traditional CTI funding of co-operations between universities and established industries. The TOP NANO 21

Program aimed at knowledge generation directed towards applications of nanotechnology in industry, supporting the utilisation of nanoscience inspired by basic and frontier research and oriented towards communities of joint technological practice in various fields of potential applications of nanosciences. It has begun to do so very successfully, but a follow-on program of national scope needs to be created and nurtured in order to more fully realise the potential for positive economic impact from the strong Swiss scientific and technological base in nanoscience and nanotechnology. The flexibility of funding in TOP NANO 21 needs to be retained. Because of the high-risk nature of many potential projects, industry is usually not prepared to fund at the high rate of 50 percent and therefore relies on a higher share of public funding, as was the case in TOP NANO 21. Furthermore, a broader net needs to be cast to involve the largest number of highly competitive programs in institutions of higher learning coupled with industries that can most positively impact the Swiss economy. A new program of this type will be a sound investment of public funds.

(2) Enhancing competition

A second effect on the research system was the introduction of more competition, especially within the ETH domain. However, this effect was limited as the number of project applications was too low for the given budget to stimulate intensive competition. In a future starting phase it would be sensible to even more broadly advertise the program and to further increase the efforts for soliciting proposals for feasibility studies and projects in order to mobilize the community. In a second future stage, however, the competition should be enhanced such that the project selection becomes more rigorous. This is likely to lead to more focussed projects of even higher quality and leverage.

(3) Bringing worlds together

Thirdly, the program changed the quantity and quality of cooperations between industry and universities, as it increased awareness of scientists for industrial demands and ideas and raised industry's awareness for opportunities in the academic nano-community through cooperation. While in CTI projects the cooperation is mainly geared towards market applications and thus exerts a certain selection bias against those scientists working in new technologies or in research areas further away from immediate application, TOP NANO 21 was much broader in the inclusion of academia and thus brought together formally separated worlds. Addressing complex issues that require strong interdisciplinary action, it also increased interdisciplinarity in academic research.

Goal attainment

(1) The program had a strong impact. It seeded new technologies that are most likely to strengthen the Swiss economy in the future. The initially stated economic expectations in

terms of market application and commercial success of the program were unrealistically high. Within the given time frame an economic impact could not have possibly been achieved at the level suggested in the program goals. Nevertheless, the potential or expected economic effects are very promising in many cases. A follow-up funding possibility will be needed for a selected set of projects in order to realize this potential. Furthermore, the knowledge and skill effects on the companies are of high value. Moreover, in the longer term the structural effects in terms of increased future collaboration are very positive.

(2) The program has supported a significant number of start-up and spin-off companies that are likely to have the highest technological and economic impacts. Flexible conditions in terms of financing and support were used in the program and are considered of high value. However, the funding conditions are problematic for many SMEs, especially the start-ups. In order to realize their potential, the incentive structures for SMEs should be improved and the funding conditions adjusted to be more beneficial for the SMEs.

(3) The TOP NANO 21 program triggered a number of new basic scientific research projects answering to the needs of industry. It achieved the goal of knowledge transfer between science and industry and vice versa. By putting new problems on the table scientists stretched their capabilities into new directions. The overall quality of the projects was very good but could be further strengthened through increased competition.

(4) The inclusion and support of post-graduate students as well as the exposure of students to collaborative and application-oriented projects were highly beneficial. The expansion to vocational training needs to be redesigned and expanded to high school. Gender broadening has to be approached more systematically and aggressively. Finally, the high potential to better educate the general public regarding nanotechnologies and their applications has not yet been fully realized. This potential needs to be pursued in order for nanotechnologies and their applications to fully benefit society.

2.5.2 Design

Types of projects

In light of the complex array of objectives and the structural missions of TOP NANO 21, the set of project types seems basically appropriate. Individual projects, technological fundamental and feasibility studies were particularly strong, whereas the alliance projects were of varied quality.

Feasibility studies are essential, as they enable the testing of risky research approaches as well as new forms of cooperation. They provide for an effective and cost-efficient inclusion of a broad community and are especially important to lower the threshold for companies and universities to get involved. All evidence available suggests that feasibility studies are highly appreciated by industry.

Alliance projects bring together a set of different capabilities. They can be very fruitful, however, only under certain conditions. The consortia have in some instances been too big or too heterogenous. Big consortia are sensible only if there are clear complementarities – for example if the industrial value chain is represented – and if full commitment of all partners is guaranteed.

Budget

The financial program volume was appropriate, and so was the number of funded projects. Compared with other European countries, the budget spent on nanotechnology is appropriate and has put Switzerland at the leading edge of governmental commitment towards nanotechnology.

Internationality

The international dimension of the program was essential for TOP NANO 21 in that it has linked the Swiss situation to international developments, thus benchmarking the efforts undertaken.

The program was also open to international firms. It is highly appreciated that for the first time in Switzerland foreign companies had the same program conditions as domestic companies. The project participation of foreign scientists from universities abroad was possible in cases where the expertise was not available in Switzerland.

Proposal application procedure

The application procedure incorporating the possibility to deliver a pre-proposal, to run a feasibility study and then start the full application process is basically appreciated. The proactive role of the innovation committee in defining and launching project ideas is to be welcomed as a measure to get a follow-up program to TOP NANO 21 started. However, a reduction of the top-down approach seems more appropriate in the course of a potential successor program to TOP NANO 21. The scientific and technological evaluation of applications by an international peer review team is an excellent measure to secure the scientific quality of the projects. Additionally, it enhances international visibility.

2.5.3 Program management

The highly flexible program management was very successful. The type of division of labor chosen for TOP NANO 21 was appropriate, namely a separation between the ETH Board as the funding institution, which delegated the program to CTI as the overall implementing institution, which in turn hired the subcontractor Temas for the day-to-day management of TOP NANO 21.

The agency CTI and especially the consultancy agency Temas implemented the program very well. The overall administration of the program and the assistance given by the management team was rated very positive by the participants.

The program management team has been very active in personally mobilizing engagement. At the same time, the promotion and general marketing of the program via public events, easily accessible publications and the like would have benefited from broader visibility. Thus, especially in the beginning, the response from the science community was rather low. For the future, a successor program should rely even more on general marketing and awareness measures and on bottom-up initiatives from the community.

3 Recommendations

(1) **The program must be continued if the investment in TOP NANO 21 is to be secured for the benefit of the Swiss economy.** The program should continue to concentrate its funding on the gap between CTI funding and SNF funding and thus contribute to the improvement of the Swiss research system. In that respect, it could function as a model for further technological areas. The program should continue and expand its attractiveness for international companies and scientists.

(2) The funding should favor spin-offs and start-ups, allowing their financial contribution to be substantially smaller than 50 percent to better reflect the economic situation of these young companies.

(3) The future use of nanotechnology for the benefit of society crucially depends on its general appreciation and understanding, which in turn will require enhanced educational efforts. While the present program has successfully developed education at the post-graduate level, a future program should strive to also effectively address high school, vocational training and the general public. An understanding and awareness of the importance of nanotechnology is crucial for a knowledge-based economy. Special efforts should be made towards mobilizing and expanding female participation in the program.

(4) In order to maximize the potential for Switzerland, the future program management must retain its flexibility and enhance marketing and competitive aspects. The marketing of the program should be broader and more systematic in order to target the relevant community up front. In mobilizing the community, economic goals and potentials should be stated in realistic terms reflective of the conditions of a young technology. Preference should be given to feasibility studies and individual as well as fundamental technological projects. Alliance projects should only be funded with strong active commitments from *all* partners. The future program should be more selective. It should strive to attract more project proposals and thus be more selective and competitive. The high acceptance rate of TOP NANO 21 should not be the benchmark of a successor program. The implementation and the management should in any case maintain flexibility and make possible longer term projects with a periodic review and assessment.

4 Appendix

4.1 Annex 1: Members of the external evaluation group (peers)

Professor Jörg P. Kotthaus (Chair of Peer Review Group),

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Professor James R. Heath,

Director, California Institute of Technology, Pasadena, CA, and Professor of Chemistry, California Institute of Technology

Professor Winfried J. Huppmann,

Leiter Corporate Innovation Management, Hilti AG, Schaan (retired)

Professor Richard W. Siegel,

Director, Rensselaer Nanotechnology Center, Rensselaer Polytechnic Institute, Troy, NY

Dr. Dieter Weller,

Seagate Recording Media Operations, Fremont, CA

4.2 Annex 2: Peer review program and projects presented

Peer review program

Sunday, 27 February 2005: Hotel Zurichberg, Zurich

Time	Issue
15.00	Meeting ISI/Interface
16.00	Meeting ISI/Interface with Prof. Kotthaus, Chair
18.30	**Formal beginning of the peer review:** Welcome and introduction to TOP NANO 21 by Dr. S. Bieri, TOP NANO 21 Executive Committee. Also present: U. Koenig, Federal Office for Professional Education and Training (OPET)
19.30	Dinner
20.45	Closed session of Peers: introductions, main questions, initial appreciation of TOP NANO 21; discussion of structure of final report

Monday, 28 February 2005: ETH-Zentrum, Zurich

Time	Issue
8.30	Welcome by U. Koenig, OPET, and Dr. H. Neukomm, Director of Research, ETH Board
8.40	Presentation of TN21 Program by Prof. H.J. Guentherodt and K. Hoehener, program management
9.30	Coffee break
9.50	Closed session by Peers
10.15 bis 12.15	Project presentations (see below): per project 10 min. presentation and 20 min. discussion
12.15	Lunch
13.15 bis 15.55	Project presentations (see below)
15.55	TN21 and vocational education: Martin Wild, SIBP
16.30	Break
16.45	Closed session by Peers, preliminary conclusions
18.15	Return to hotel
20.00	Dinner: Peers, E. Fumeaux, H.J. Guentherodt, K. Hoehener, U. Koenig

Tuesday, 1 March 2005: EPFL Lausanne

Time	Issue
6.45	Departure from hotel
9.30	Arrival at ETH Lausanne and w elcome by Prof. Horst Vogel
	Coffee break
9.45 - 13.00	Project presentations see below
13.00	Lunch
14.00 - 16.30	Closed session of Peers: conclusions
16.30 - 17.00	possible telephone inquiries with Program Management (Prof. Guentherodt)
Approx. 17.00	return to Zurich
20.00	Dinner

Wednesday, 2 March 2005: Hotel Zurichberg, Zurich

Time	Issue
7.45	Closed session of Peers
8.00	Presentation of the peers' assessment, questions for Program Management: H.J. Guentherodt, K. Hoehener
8.30	Continuation of closed session of Peers
10.15	Coffee break
10.45	Presentation of results and recommendations of Peers to Executive Committee and Program Management: S. Bieri, S. Braendli, H.J. Guentherodt, K. Hoehener, U. Koenig
	Discussion with Executive Committee
11.45	Closed session of Peers to finalise the final report
12.45	**Formal end of the peer review**
12.45	lunch at the hotel

Projects presented during the peer review

Proj. nr.	*Project title*	*Institute*	*Professor*	*Industry partner*	*Discipline*	*Project type*
5706.2	Nanobiotribology: Biological + bioinspired approaches to lubrication by means of biolubricants + controlled surface nano-architecture (Innovation committee project)	ETHZ Laboratory for surface science and technology, EPFL, Imperial College London	Prof. N. D. Spencer, with Prof. H. Vogel	none	Life science	Funda-mental
4597.1	Conformation and Molecular Interaction of Proteins at Nanoscale Patterned Interfaces of Biomaterials and Biosensors	ETHZ Laboratory for surface science and technology	Dr. M. Textor, Prof. Spencer, 2 ETHZ Institutes, Universität Freiburg	Zeptosens AG, Strau-mann, Robert Mathys Stiftung	Life science	Alliance
4786.2	Nanometer-scale analysis of magnetic materials, hard disc components + current distributions in semi-conductor devices using quantitative magnetic force microscopy	University of Basel Dept. of Physics	Prof. H.J. Hug	Swiss-probe	Tools and sensors	Individual project
5697.3	Surface inspection system for industrial applications	FH Tessin/ FH Wallis / EPFL	Dr. S. Balemi	Nanosurf mit Mecarte, AGIE	Tools and sensors	Alliance
4750.2	Magnetic resonance imaging with local probes (MRI-SPM)	Univ. BS Dept. of Physics, EPFL (R. Popovic), ETHZ (B. Meier)	Prof. E. Meyer	Omicron Micro-scopy, IBM, Bruker	Tools and sensors	Alliance
5929.1	Silica-Tantalum + Silica-Ytterbium oxide nanoparticles by flame spray pyrolysis for dental nanocomposites	ETHZ Dept. of Mechanical + Process Engineering	Prof. S. E. Pratsinis	Ivoclar Vivadent AG	Material	Individual
5773.2	Rational Design of Sol-Gel Synthesis of Nanostructured Particles in Sheared Suspensions	ETHZ Dpt Mechanical + Process Engineering	Prof. S.E. Pratsinis	Nestlé PTC	Life science	Individual
5968.1	Characterization of photo-plastics in view of full-wafer microfabrication of low cost scanning probe microscopy sensors	University of Neuchâtel, Dept. of Microtechnology	U. Staufer	Nano Worlds AG	Tools and sensors	Feasibility
5479.2	Nanoreplication	PSI, CSEM, KATZ	Dr. H. Schift	AWM Werkzeug-bau, Leister, OVD King-ram, Weid-mann, SPT	Material	Alliance
5904.1	Removal of trace contaminants with TiO2-photocatalyst immobilized on different substrates	EPFL, Institut de chimie moléculaire et biologique	Dr. K. R. Thampi with Prof. Graetzel	Christ	Material	Individual
5200.1	Development of bioassays for odorant molecule analysis	EPFL Laboratoire du chemie physique des polèmeres + membranes	Prof. H. Vogel	Firmenich SA	Life science	Funda-mental
6101.3	Digital holographic micro-scopy, a new technology for high resolution 3D imaging: application to biology + metrology at nanoscale	EPFL, Laboratoire d'optique appliquée and Université Lausanne	Dr. C. Depeursinge	Lyncée Tec SA	Optics	Funda-mental