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Report by Working Group 4 on

Knowledge and Technology Transfer

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Introduction

Knowledge transfer (KT) from fundamental research to society is of paramount importance to demonstrate the impact of basic science on everyday life. Particle physics addresses basic science issues but the cutting-edge technologies developed in the fields of accelerators, detectors and IT to permit ground-breaking scientific results have the potential to generate important spin-offs, as has been demonstrated in the past in several domains, from the Worldwide Web to the development of innovative medical diagnostic and therapeutic facilities. The need to provide active support for the transfer of knowledge generated by public research organisations (PROs) and the socio-economic benefits are well described in the "European Commission recommendation on the management of Intellectual Property (IP) in KT activities in public research organisations" (ISSN 1018-5593) which refers to general principles widely applicable to particle physics:

- the knowledge transfer offices of each organisation should be given the necessary means to identify the most promising innovations and the most suitable partners for their exploitation, and be supported by the adoption of a clear and unambiguous policy for IP protection and knowledge transfer.
- The identification of technologies and know-how with a significant exploitation potential is a critical step in which the involvement of researchers is essential. Public research organisations should adopt an IP management strategy that includes an attractive incentive scheme for personnel and proactive internal communication aimed at raising awareness about the importance of knowledge transfer. Knowledge transfer offices should also rely on a capillary internal network within their organisations, comprising scientific staff who have a broad knowledge and understanding of the research activities in their field of expertise, who can support the KT process by spotting new developments of potential interest.
- IP protection must be considered within the framework of an impact-driven model and pursued with a view to securing investments. External partners willing to contribute to the commercial exploitation of a given technology must be identified and incentivised. The importance of patents as valuable knowledge dissemination tools (apart from their legal commercial purpose) should be also highlighted, and researchers should be made aware of the usefulness of patent databases for their own research activities. Open Science approaches should be adopted (both for software and hardware), favouring unrestricted direct knowledge dissemination and the proper recognition of the origin of innovations.

These principles should be taken into account in the development of an effective *impact-driven KT model*, focused on indirect and long-term return strategies to foster industry-academia collaborations and to disseminate the applications of basic science. Exploitation will then proceed through various strategies (e.g. technology push, market pull and spin-off creation) based on an original model considering PROs as “knowledge producers” and industry as “knowledge consumers”. Recently, the model has evolved towards a more complex one based on collaborative research with industry, seeded by background IP. In this spirit, the mobility of human capital between industry and academia, via joint projects and mechanisms to implement KT in the execution of technology-intensive procurement contracts, also plays a significant role in enhancing the effectiveness of KT.

The above text was sent as input to the update of the European Strategy for Particle Physics in 2013, and all the statements remain valid for the 2020 update.

Working Group 4 is expected to address the following main topics as input for the Strategy: knowledge and technology transfer from particle physics to industry and other fields of science and vice versa; the interdisciplinary nature of particle physics research; relations with industry; existing organisations involved in knowledge transfer.

Eight questions were distributed among the members of the working group, and the answers they provided form the basis of this report.

1. Importance of knowledge and technology transfer to society

High-energy physics (HEP) creates new technologies and products for society that improve the quality of life of many people. It is our duty to give the European taxpayers who fund our research endeavours the greatest possible return on their investment.

Technology transfer from HEP to society also helps improve existing technologies, thus creating a virtuous circle as these improvements are fed back into HEP.

HEP research has a high financial cost but the science and the technologies developed can also bring huge rewards for society. This is an economic cycle than citizens and politicians understand.

Several developments with the greatest societal impact over the past century would never have appeared without the contribution of fundamental research (radio/TV, semiconductors, internet, GPS etc.). Synergy between research and society is imperative. Well-known technology transfer success stories such as the Worldwide Web and PET or IRM technologies are obviously fantastic showcases for our field of research. They demonstrate that spin-offs from the high-end technologies developed for our instruments can have a significant impact on everyday lives. This in turn helps to justify to the general public and national funding agencies the high level of funding required for our field. We often develop very specific technologies usable only for very few projects and for a very short period of time before switching to more modern ones, and it is only right that such technologies, which were developed using public money, should be used for other purposes to boost the economy and employment.

Also, transferring our technologies to industry:

- decreases their cost (because more volume is produced);
- makes them more sustainable (as long as the corresponding industrial market exists);
- creates new providers who can become contributors to our projects;
- improves the technology readiness level (TRL) thanks to the feedback of the companies;
- potentially mutualises the cost of R&D for the next generations of technologies we and industry need;
- develops a network of possible partners to answer national or international funding calls, requiring more and more industrial partnership.

Career opportunities for the HEP community:

- KT and TT also generate entrepreneurship or industrial career opportunities for early-career researchers in HEP: we know that many will only stay a few years in the HEP. Part of the societal impact is the inspiration that influences people to choose education paths in STEM subjects.

2. Technologies developed or emerging in the field of HEP with good potential for transfer to industry and other fields of science

The list of technologies (developed and under development) can be summarised as follows:

- Accelerator technologies (including, magnets, cost-efficient superconducting magnets/systems)
- Cryogenics and high vacuum;
- Radiation detectors and particle tracking systems;
- Radiation-resistant detectors, electronics and other components;
- Laser technology, mirrors, and coatings;
- Monitoring systems, remote control software, automation;
- Digital sciences in general, data management, data analytics, embedded online distributed computing; (handling and transfer of large data sets, e.g. GRID);
- Online cloud computing ;
- Fast networks, synchronising systems;
- Low noise electronics;
- High-level expertise on underground and harsh-environment infrastructure.

The above-mentioned technologies have been transferred (or have the potential to be transferred) to fields such as medical applications, safety, homeland security, ICT, industrial electronics and controls, environment and life sciences, lithography, etc.

It is difficult to define a current status, as developments in these technological fields are in a dynamic process.

It is also important to point out that in many cases HEP is not the main driver of the developments of the underlying technologies. For example, it is the telecommunications and metallurgical industries, rather than HEP, which are driving semiconductor or cryogenic technologies.

Another important contribution of our field is that we integrate technologies, pushing the limits of existing technologies and therefore contributing to worldwide development.

Last but not least, our leadership model "cooperation in competition" has also been transferred to other fields.

3. Technologies with the potential to be transferred to HEP from other fields of science and industry

Most of the technologies mentioned above are not unique to HEP, and we benefit a lot from work done outside our community, by both industry and academia. Notable examples are microelectronics and artificial intelligence. In some cases, a virtuous circle is created, where technologies developed outside HEP are "adopted" by HEP and developed further for HEP needs. This results in enhanced/improved technologies, which find new applications outside HEP through technology transfer.

Technologies with the potential to be transferred from other fields of science to HEP include the following:

- Quantum engineering (quantum computing + quantum sensors);
- High-field magnets (MRI);
- Material science, new materials, ultra-pure materials, nano-detectors/materials, high-quality thin films;
- Low-energy radioactivity simulations for medical and industrial applications;
- Microelectronics;
- Radiation testing and development of radiation-hard technologies also connected to fusion reactor technologies;
- Cooling and cryogenics;
- Artificial intelligence and machine/deep learning also developed for industry and informatics;
- Safety, seismic sensors, muon tomography with applications to volcanoes and glaciers;
- High-performance computing (supercomputers to tackle CPU extensive calculations, GPU to tackle fast calculations and for triggering and tracking in the experiments) and data storage;
- Additive printing technologies, especially metal printing;
- Developments in the field of high-power lasers, which would benefit particle acceleration based on laser-plasma, lidar and climate monitoring.

It is essential to strengthen links with industry by providing support to scientists in dedicated technology transfer offices in institutes and by establishing networks of such offices. Particle physics experiments and accelerators are becoming larger and larger and more synergies need to be found between the technologies needed for our field (a small market) and what is done by outside industry for other applications. By adopting technologies available in industry we will be able to build large infrastructures faster and at a lower cost.

4. HEP contribution to other science fields

In terms of interdisciplinary research, fundamental science in HEP has an overlap with scientific domains close to its core interests:

- Astrophysics and astroparticle physics (e.g., relating to the neutrino mass hierarchy); cosmology (e.g., through studies relating to dark matter, the cosmic microwave background anisotropies and the matter power spectrum); gravitational waves (e.g., their use in studying Beyond the Standard Model theories) and cosmic rays. Cosmic rays are explicitly mentioned in the 1953 CERN Convention (Art 2.2). Today the study of cosmic rays is an integral part of the broader discipline commonly referred to as "Multi-messenger Astrophysics" (MMAP), including also direct observation of electromagnetic radiation in general, gravitational waves and neutrinos. Many independent contributions to the ESPP process have highlighted the scientific community's interest in strengthening the links between HEP and the various disciplines studying MMAP. This natural convergence path could/should be driven and supported in two ways: (a) through a scientific analysis aimed at identifying complementarities in the experimental objectives of MMAP and HEP experiments; (b) via an in-depth technical assessment looking for development synergies in technologies and infrastructure. The knowledge/technology transfer community could strongly contribute to the latter assessment, based on its transverse access and multidisciplinary understanding of HEP areas of expertise and value proposition. The synergies obviously work both ways: the HEP community can derive benefit from MMAP-driven developments and joint developments would allow resources to be optimised when requirements overlap.
  To understand how activities in this area could be expanded and better coordinated, we recommend establishing a dedicated knowledge-transfer task-force with representatives of both the HEP and MMAP communities, with the specific mandate of reviewing approved and planned MMAP projects in order to identify and prioritise mutually beneficial technologies for HEP and MMAP.
- For gravitational waves, the following areas have already been identified: cryogenics, sensors, big data management and analysis, civil engineering, vacuum technology, operation and monitoring of large underground infrastructures.
- HEP also requires state-of-the-art methodology that can also be applied to or inspired by research in the following fields: signal processing and statistics (e.g., de-noising, signal extraction, anomaly detection) applied to or inspired from research in astroparticle physics, astrophysics, cosmology, medical research, environmental monitoring, remote sensing, applied mathematics.

Other examples of knowledge and technology transfer from one field of research to another are:

- Know-how in anomaly detection in totally different data sets (finance to help regulators and to detect fraud, predictive maintenance, predicting failure, monitoring safety in underground and harsh-environment infrastructures);
- Medicine as more and more medical tools and solutions are digitally driven, connected and intelligent pushing patients towards self-care: this generates lots of data that need to be managed;
- Accelerators: used in fields ranging from material sciences to radiotherapy and radioisotope production;
- Magnets (normal and superconducting): MRI, NMR, hadrontherapy gantries, shielding (aerospace and astroparticle physics);
- Novel radioisotope production and separation methods: the mass separation method used at ISOLDE/MEDICIS can produce innovative isotopes for fields such as medical research or can enhance the activity/purity of isotopes whose use is restricted to a few applications, for instance by the low activity achievable today;
- Electronics capable of working in high magnetic fields, which are becoming increasingly relevant for simultaneous PET-MR or CT-MR imaging;
- Detectors: PET, CT, SPECT, radiology, astroparticle, single-photon detectors for atomic and molecular physics, biology, medicine, pharmacy, imaging, magnets, superconducting components; X-ray technologies for material tests, Alpha gaseous detectors for applications in pharmacology, miniaturised gamma detectors for applications in proton/ion therapy, neutron detectors for neutron tomography (materials); silicon pixel detectors to read out monkey retinas; development of new a EEG machine that stimulates the brain and records its reactions.
- High-performance parallel computing: speeding up biological and other simulations;
- Test facilities: HEP labs possess very special beams/facilities that can be useful for example for aerospace testing (material, electronics) or radiobiology;
- AI: predictive maintenance of accelerators or complex systems (industry, medicine, possibly pharmaceuticals and energy), image analysis, better image reconstruction (medical imaging), intelligent systems (self-driving cars);
- Expertise in system integration: relevant e.g. for multimodality imaging;
- Robotics: health and safety monitoring;
- Digital sciences: data preservation, resources for small research communities (Zenodo);
- Radiation-hard (or not) microelectronics, associated electronics, hybridisation for space-science applications;
- Ultra-cryogenics instrumentation (electronics) for developments in quantum technologies;
- Detectors and accelerators are used for scanning and dating of archaeological objects and remnants and in investigation of artworks;
- Timing encoding and analysis methods (use time as analog information, which allows for usage of lower power electronics);
- Geology, map out volcanos with cosmic muons and muon chambers;
- Banks, PhD physicists are hired by banks to apply their simulations and mathematical skills.

5. Relations with industry

There are several ways HEP laboratories collaborate with industry (and transfer knowledge in both directions).

- Procurement: In the framework of procurement contracts HEP laboratories very often transfer their knowledge to industry, to help the execution of contracts. This know-how can in turn be used in other fields.
- Human Capital: HEP labs hire and train professionals with expertise covering many different fields, ranging from science and engineering to legal and administrative services. A large proportion of these professionals leave the field for industry.
- Formal Knowledge and Technology Transfer activities: HEP engages in formal knowledge and technology transfer activities with industry, whether large multinationals, SMEs (Small and Medium Enterprises) and start-ups.

What is done today is not enough and a more strategic collaboration between industry and HEP is needed. Due to short-term pressure for results, industry is increasingly looking to universities and start-ups to try and test new ideas and invest in them further if they prove successful. By combining resources with complementary expertise, the HEP community can be used to pursue further mid/long term innovations in collaboration with industry. ***In practice this means that a shift is needed from providing "pure" technology to industry towards new, strategic, skills-based collaborations between industry and HEP.***

6. Existing organisations for knowledge and technology transfer

TT Offices

TT offices are designed according to the needs of each institute. Learning from each other and best-practice exchange are great opportunities for all. A list of some of the well-known structures existing in the HEP field in Europe and the USA follows:

- Nikhef in the Netherlands has an Industrial Liaison officer. P2IP (a joint venture between a venture capital firm and Nikhef) was established 5-10 years ago, which launched about four start-ups. Some were successful. There is a CERN BIC (Business Incubator centre) in The Netherlands with now also a branch at a large chemical campus in The Netherlands (Chemelot) and within The Netherlands there is the Big Science consortium (see: https://www.bigscience4business.nl/nl/), which organizes regular events where industry meets science. It is focused on CERN, Astroparticle Physics, ITER and astronomy.

- Italy's INFN has a TT National Committee (CNTT) and a TT Office that support the interaction with industries and promote the Intellectual Properties (IP) management. Specifically to promote the TT from the INFN labs to the industries and society INFN have defined some specific programs: R4I (Research for Innovation) is specifically dedicated to support research activities developed inside INFN to increase the TRL of technology developed in the research community; R2I (Research to Innovation), in collaboration with CERN, is dedicated to guaranty the access from start-up and small companies to well established INFN technologies supporting the TT; PoC (Proof of Concepts), in collaboration with some external founding investors, dedicated to support the birth of new and innovative spinoff connected with INFN activities. Considering also some peculiar characteristics of INFN, under the TT infrastructure some dedicated network on specific technology fields were created, such as CHNet (Cultural Heritage Network) that applies all the developed technologies to cultural heritage field.

- Germany's Helmholtz centres (DESY, GSI and KIT, e.g.) have specialized departments for TT and Helmholtz has a special program for IT-Incubator projects (particularly for EOSC).

- At France's IN2P3, TT is part of a global and strong initiative of CNRS, under the leadership of a dedicated directorate for innovation. IN2P3 effort is monitored by the technical directorate who has commissioned a network of persons throughout its 20 laboratories. They are in charge of detecting and promoting new technologies that can be transferred to industry. The scheme of TT varies depending on the maturity of the concept: brand new technologies issued from experiences are bridged and financed through "DELIC" actions then to pre-maturation actions that permits to develop proof of concept demonstrators. This process permits then industry to take the relay in a joint venture with the research team that invented the technology. This work is accompanied by regional dedicated enterprises (SATT) under the umbrella of CNRS. The SATT, in particular, accompany very closely the teams in the work to obtain the licenses to protect their know-how, and create start-up or also to address partnerships with well-established industrial teams.

- A wide spectrum of TT exists in France's CEA. An office of the Fundamental Research Directorate exists Inside CEA, a dedicated directorate (DRT: Technological Research Direction) is in charge of developing and transferring technologies to industry. They are specifically organized for this purpose (including manpower focused in industrialization and business development) with a special structure named "CEA Tech" with offices in the main French towns supposed to make the link between industries and all the directions of CEA.

- DESY (Germany) installed a strong division and the position of the CTO as member of the directorate board. Therefore, a very systematic and strategic approach for TT is possible and led to a lot of successes in the past three years. DESY does a lot to create a real ecosystem for new inventions, services for industry and start-ups.

- TT at GSI (Germany) is organizationally located directly under the administrative management as a staff unit. This structure helps to maximize the transfer possibilities of the innovative impact of the large-scale science project FAIR in the current construction and research phases.

- Big Science Sweden is the official ILO-organisation in Sweden for connecting industry to Big Science facilities. The organization is jointly funded by Swedish Innovation

Agency, Swedish Research Council and Swedish Agency for Economical and Regional Growth.

- CERN's TT activities are under the responsibility of the Knowledge Transfer Group, assisted by the various networks mentioned below.
- US - Fermilab - Office of Partnerships and Technology Transfer (https://partnerships.fnal.gov/), Federal Laboratory Consortium for Technology Transfer (FLC).
- US - LBNL Innovation and Partnership Office (https://atap.lbl.gov/about-us/tech-transfer/, https://atap.lbl.gov/about-us/tech-transfer/).

Incubators

For the establishment of start-ups , CEA/IRFU has "Incuballiance" (the mutualised incubator for the Paris-Saclay cluster). In some specific cases, they have access to the SATT of Paris-Saclay that can help for TT.

CERN has established a network of Business Incubation Centres (BICs), present today in nine countries.

HEPTech and other networks

A list of the existing networks assisting HEP in TT activities follows, with a special focus on HEPTech.

CERN KT Forum: The CERN KT Forum brings together CERN's Knowledge Transfer group and knowledge transfer representatives from CERN Member and Associate Member States.

EIROforum: EIROforum is a collaboration between eight European intergovernmental scientific research organisations: CERN, EMBL, ESA, ESO, ESRF, European XFEL, EUROfusion and ILL. EIROforum has a dedicated working group on innovation management and knowledge and technology transfer.

TTO Circle: The TTO Circle is an initiative of the Joint Research Centre of the European Commission aiming at connecting the technology transfer offices of large European public research organisations.

EEN (Enterprise Europe Network): an EC network that helps small businesses make the most of the European market place.

ENLIGHT (The European Network for LiGht Ion Hadron Therapy): established in 2002 to coordinate European efforts in hadron therapy, today has more than 700 participants from 25 European countries. It is an example of multidisciplinary network connecting clinicians, physicists, biologists and engineers.

HEPTech is a network whose objective is to enhance technology and knowledge transfer from fundamental research in high-energy physics to society. It is run by TT and KT professionals from large-scale HEP science projects and research facilities in Europe active in particle, astroparticle and nuclear physics.

HEPTech helps identify and exploit synergies among its members and promotes the sharing of best practice and experience on the challenges of TT and KT in the specific HEP niche so to maximise the socio-economic impact of IP generated.

To facilitate commercial exploitation of both the skills and technologies developed across large-scale HEP projects, HEPTech organises Academia-Industry-Matching Events (AIMEs) for specific HEP-related topics. Thereby HEPTech focuses on attracting more start-ups and SMEs in order to foster their involvement in applied research and development that will bridge the gap between fundamental research and its applications, especially in the validation phase.

7. Problems and obstacles for the successful transfer of technology to society

Several challenges and obstacles for successful knowledge and technology transfer, related to the various themes listed below have been identified.

Strategic focus on the HEP side:

- Many HEP institutes (including CERN) are not applied research centres: the core activity is basic research, and the development of technologies for it;
- Lack of career-relevant rewards to “recruit” internal experts (see “Difficulty in finding human capital below”);
- Little funding available internally to support projects and their selection process;
- No sense of urgency among the HEP community that technology transfer is critical to maintaining the long-term funding commitment for science initiatives;
- The political aspect: selection of collaborating institutes or companies is politically relevant. Often institutes have limitation and strategies have to be defined accounting for them.

Strategic focus on the science and technology policy side:

- Tenuous links to (local) governmental funding tools: if a company wants to adopt a technology, there is no pre-allocated funding mechanism.
- No built-in strategic connection between the technology developed for HEP and global needs expressed by governments/industry or found in the UN sustainable development goals.
- Lack of global strategy at many levels (CERN + Member States; HEP community + political stakeholders, funding bodies; HEP + industry)
- Lack of appropriate funding schemes (e.g. EC) to cover the intermediate technology readiness level (TRL) phases – when technology is not yet of interest to companies.

Strategic focus on industry side:

- The business model of the companies in some cases makes it difficult to collaborate. HEP technologies often have great potential, but only in a future that is too distant for a company to get engaged.
- In some fields (medical technologies), HEP technologies are not regarded as technologies for health, as they are typically too far away from the patient.
- It is not always clear who owns the IP when technology originates from collaborations.

Difficulty in understanding industry needs and markets

- More outside-in thinking is needed: scientists' awareness of what is needed by industry prior to engaging into technology transfer efforts. The HEP community should improve the connection of their developments to the actual needs of the market and industrial landscape.
- Lack of input from relevant end-user communities (industries, other research communities), or input only from a subset is at the origin of this difficulty.

Technological challenges:

- HEP technologies are highly specialized and typically need adapting before transfer is possible.
- The TRL expected by industry is often higher than what the HEP field can offer. Companies (especially SME) very often need already existing equipment and not only proof of concept. This requires a large manpower effort for which it is difficult to find funding.
- Very special and sophisticated nature of many HEP technologies and solutions, which makes customisation of prototype devices for use in industry very difficult for engineers without proper assistance from developers.
- Scientists usually develop technologies or solutions for their experiments/needs, which may translate into only one product. Nonetheless, a spin-off company is hardly sustainable with just one product. Additionally, institutes usually do not allow their scientists to work part time in research and part-time in the spinoff so they have to make a choice. In the vast majority of cases the spin-off is abandoned.

Finding the human capital on the HEP side and "Image" of technology transfer:

- Lack of career-relevant rewards and recognition (e.g., career, visibility): there are few objectives or incentives for scientists to contribute / allocate time to TT initiatives, in combination with fewer resources for scientific work, in a context where scientists are already overcommitted to the core activities of their organisations.
- Lack of hierarchical support: can be a personal position of a supervisor/group leader (either against TT activities in general or motivated by the overall lack of time), or a more general attitude in the laboratory/institute.
- "Moral" aspect: scientists' belief that they should not be working for industry or that everything they do should simply be made publicly available and free. Lack of understanding (from the scientists) of the TT process (patents, licenses) or of the meaning of "societal impact" and how to achieve it (e.g. medical applications can only be made and certified by companies; or understanding the real impact of developments for users and/or industry).
- Lack of professional teams also covering representation towards industry, networking, commercial aspects and communication.

Intellectual Property Rights (IPR):

- The different policies concerning IP and IP valorisation from one institution to the next can make it difficult to transfer joint developments.
- Patents vs publications might be (wrongly) perceived as an issue.
- Large collaborations are difficult to handle in terms of IP and structured transfer.

8. Possible measures to significantly increase the efficiency and visibility of KT and TT to society

Based on a careful analysis of knowledge transfer and technology transfer to other fields of science and industry, and given the difficulties with this process that have been identified in this report, the following possible measures to increase significantly the efficiency and visibility of KT and TT to society can be made.

Strategic focus on the HEP side:

Clear messages about the importance of KT and TT from HEP to society are needed both in the European Strategy and from HEP laboratories and institutes.

- Mindset change: the era where 100+millions are allocated for pure science is coming to an end, and governments are seeking a greater economic and societal return when choosing what to fund. A change in mindset, similar to what other sciences (biology, computing, medicine) have done, is needed. The importance of KT/TT for the long-term survival of HEP – without giving up on the importance of basic research *per se*, is needed. ***Industry should be considered as a privileged partner so that research can have stronger impact on society.***
- Top-down push in the HEP community for KT-relevant objectives. ***The request to outline how scientists' projects can be useful to society should be present in project funding proposals and annual performance reviews with experts.***
- Additionally, dedicated funding lines for KT projects should be pre-set internally in laboratories and institutes as well as externally (e.g. the ATTRACT project).

Strategic focus on the science and technology policy side:

- Clarify at the strategic level what "impact" means, and how it should be achieved, beyond "romantic" definitions (statements such as "we want to do something good for society, but not work with industry" do not work).
- National governments should create/reinforce funding mechanisms that make it easier for companies to link HEP technology and available funding. A good example is the Israeli Innovation Authority approach.
- ***Key research programmes in HEP should fit what society is looking for. From the outset, HEP projects should adopt the goal of introducing a societal change and providing what industry needs, instead of looking for this only once the technology has been developed.***
- ***More funding programmes dedicated to joint R&D for HEP, other scientific fields and industry should be created.***

Understanding industry needs and markets:

- It is important to establish networks of communication between stakeholders, industries and end-user communities on their needs and expectations.
- Given the scarce resources available, it is crucial that KT projects in the various laboratories and universities are selected judiciously; among the criteria for selection, there should be a positive assessment from the local TT office, possibly with input from external reviewers.

Finding the human capital on the HEP side:

- Career-relevant rewards for scientists contributing to KT activities, for example by incentivising contributions from HEP experts through awards, prizes, high-visibility fellowships and chairs and increased visibility.
- Dedicated training programmes for researchers to explain the TT implicitly connected with their research activities and the management of the associated IP.
- Internal motivation for researchers to be developed in each laboratory – both financial and non-financial as well as support measures to accelerate technology development.

Communication and marketing:

- An outreach effort to collect, verify, and propagate information about how HEP has already impacted society, including the variety of contributions through technological, business, economic, societal and human capital. Obtain successes, then communicate on those successes (cf. CEA LETI).
- Part of the career-relevant rewards is increased visibility, for example by providing testimonials of leading HEP experts and their role in KT activities.
- Standards for communication plans should be developed and made mandatory for every project approved for TT/KT; required supporting measures provided.
- Communicate the benefit that HEP has on society and of the benefit of TT for society. The Science Gateway can become a useful portal for CERN to show the benefit of the HEP community to society.

Funding:

- Special grants for R&D and the development of prototypes for different applications produced in joint R&D projects with industrial partners; cross-border, flexible innovation funds.
- Costs for TT/KT should be included in the research project application package when submitted to the funding agency;
- Allow scientists to work part-time in research and in the development of commercial products in the private sector.
- TT and KT need to be part of all projects and be supported by adequate funding. The integrated transfer strategy of a project should be indicated from the very beginning when a project is proposed.
- Identify the reasonable TRL/MRL achievable with the scientific strategy and then establish the relevant agreements with other institutes or companies. For instance, the

ComptonCam TT collaboration identified parts of the design to be carried out by private companies (user interface, mechanical interface), so to reduce the time to high TRL.

- The assessment of Big Science infrastructure projects should include an estimation of their potential for TT and connections with industrial partners. The realisation of this potential should receive funding reserved for this purpose.

Conclusions

1. A huge number of technologies exist that have been developed or are under development by the HEP community, with excellent potential for transfer to other fields of science and industry.
2. The HEP community is not only the developer but is also a major user of new technologies coming from other fields of science and from industry.
3. The HEP community should establish close connections with other branches of science and industry in the framework of common projects in order to foster the efficiency of both R&D and KT transfer for society's benefit. In this common effort, the HEP community will probably be the first user of the new product, but not the only one.
4. Special funding instruments for the execution of common R&D projects should be developed. Such funding can be established in the framework of the Horizon Europe programme.
5. The human resources required by these common projects should be partially supported by newly established funding schemes and partially by the HEP community.
6. In this way the main obstacle in current TT practice i.e. the adaptation of the new technologies to the needs of the industry and society, will be resolved.
7. The transfer of existing technologies to industry should be a common effort on the part of the science community (developers and integrators) and industry, funded by existing national and European innovation programmes.
8. A large network of TT offices, incubators and technology parks should be established in order to create and develop connections between different fields of science (i.e. physics, chemistry, life sciences, new materials and IT) and industry.

Proposal for contributions to the Strategy statements and recommendations

1. **In the part concerning the R&D (item i) in the 2013 Strategy) should be added:**

The HEP community should establish close connections with other branches of science and industry in the framework of common projects in order to foster efficiency of both R&D and KT transfer for society's benefit. In this common effort, the HEP community will be the first user of the new product.

2. **In the part Organizational issues**:

   CERN and the HEP community should strengthen their relations with the European Commission in order to participate further in the development of the European Research Area. Special funding instruments for the execution of common R&D projects should be developed in the framework of the Horizon Europe programme. The human resources required for these common projects should be partially supported by newly established funding schemes and partially by the HEP community.

3. **In the part Wider impact of particle physics**

   High-energy physics has contributed to advances in many fields which have benefitted humankind. A huge number of technologies exist that have been developed or are under development by the HEP community with excellent potential for transfer to other fields of science and industry. The HEP community is not only the developer, but is also a major user of new technologies coming from other fields of science and from industry. Industry-HEP partnerships are very important to both sides, and in the future, the HEP community will need to work more closely with industry and other fields of science. Launching new strategic partnerships will help create and capture value from state-of-the-art technology for both the HEP community and industry. These partnerships will help to address and tackle global societal challenges, for example in the field of medicine, aerospace, environment, IT etc. Fostering synergies with diverse research fields will help pool resources and expertise, and help prevent the duplication of efforts and facilities. A large network of TT offices, incubators and technology parks should be established in order to create and develop connections between different fields of science (i.e. physics, chemistry, life sciences, new materials and IT) and industry. Clear messages of support are needed both in the European Particle Physics Strategy update and from individual HEP laboratories and institutes, in order to highlight the importance of KT/TT activities to both the HEP and industry/entrepreneurship communities.