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The role of big laboratories

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Abstract
This paper presents the role of big laboratories in their function as research infrastructures. Starting from the general definition and features of big laboratories, the paper goes on to present the key ingredients and issues, based on scientific excellence, for the successful realization of large-scale science projects at such facilities. The paper concludes by taking the example of scientific research in the field of particle physics and describing the structures and methods required to be implemented for the way forward.

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1. Introduction

In the challenging period of today, all regions need to enhance support for research and innovation in order to ensure, in a global competitive environment, the sustainable development of science and technology necessary for the upturn and growth of national economies. Research infrastructures, of which big laboratories are key constituents, are important 'tools' for accomplishing this and are vital for the development of large-scale science projects.

The mission of research infrastructures is driven by four elements: research, innovation, education and outreach. Research pushes forward the frontiers of knowledge. This is realized with the development of new, cutting-edge technologies and provides the platform for the training of the scientists and engineers of tomorrow. The scientific and technological results coming out of research infrastructures are then promoted in and transferred to society at large.

2. Large-scale science projects

Large-scale science projects address fundamental science questions at the forefront of research and technology. These projects require large and sustained infrastructures and a global collaboration on long time scales. In turn, such projects provide unique equipment, challenging requests for high technology and innovation, stimulating ideas that attract good people, and offer the occasion to bring people closer together.

Large-scale science projects are realized by large international collaborations, which have a very vibrant and stimulating sociological make-up and influence the way of thinking and planning at a general level. The collaborations provide the opportunity for people to learn to work together, they provide a forum for co-operation and competition, they promote diversity through the recognition of differences, and they encourage the sharing of information. The experience one obtains by working in such collaborations can be used in many fields beyond science. An important sociological aspect of scientific collaborations, in particular, is that the management of such entities is enabled through the existence of common goals by its constituent people and by convincing the stakeholders and partners of these common goals.

Large-scale science projects stimulate innovation. This has been the case, in particular, in the space programmes (e.g. the Apollo Missions, the International Space Station and the Pioneer/Voyager Missions) and in particle physics (e.g. accelerators, detectors and computing in general and at the Large Electron–Positron Collider and the Large Hadron Collider (LHC) at CERN in particular). Innovative technologies that have been driven by large-scale science projects at CERN include superconductivity, magnets, cryogenics, vacuum, survey, transport/installation of heavy equipment, solid-state detectors resistant to high-intensity radiation, large-scale industrial control systems, electronic and information systems, and project management and co-ordination. For this innovation environment to flourish, it is well known that certain essential ingredients need to be in place. Amongst the most critical factors are the existence of a concrete project with ambitious goals and a deadline; highly competent and motivated teams in all domains and at all levels; an open collaboration with competent partners; the willingness of people to learn from others and to share results freely; and an investment in education and training.

3. Key issues in scientific excellence

Scientific excellence is a central element of research infrastructures and world-class and exceptional facilities require excellent people. This in turn requires mobility for staff and users, resulting in staff transfers, dual career partnerships and transfer of social security between research infrastructures. Excellence also requires the continuous training for staff and users, including the management.

Moreover, both international and national scientific co-operation is vital to ensure the long-term viability of world-class and exceptional research infrastructures. An example of international co-operation is CERN, which is global but keeps its European component, while national co-operation includes the establishment of close linkages of research infrastructures with national facilities and universities.

Another key issue is outreach. Since all countries need more scientists and engineers, society needs to realize and appreciate science as a driving force behind the development of their countries. This should be done through targeted outreach activities and by encouraging interest in careers in science. Outreach activities should bring the innovative science and technology and the exciting results achieved through, for example, research infrastructures, and their application to societal challenges, to the attention of society. This requires more imaginative and ambitious outreach activities than those currently available. An important ingredient in this effort is science education through inquiry-based novel teaching methods in primary and secondary schools.

Cutting-edge science relies on cutting-edge instrumentation. Research infrastructures develop new technologies and techniques. There is a need to strengthen the relations between academia and industry in the field of scientific instrumentation. This could be accomplished through the promotion of knowledge and technology transfer between the two entities. Knowledge transfer is channelled through people and CERN is a prime practitioner of this since every year hundreds of students come to CERN to contribute to research programmes—not only physicists, but also engineers, computer scientists and students studying administration.

In addition, circulation of scientific knowledge needs to be improved. There is a vast and greatly increasing amount of data and information being produced at research infrastructures for which access should be facilitated—both open access to scientific publications and open access to data.

4. Particle physics and scientific discoveries

Today, the particle physics community, in general, and CERN, in particular, are in an exciting era involving every step of the development process from planning, design, and construction and running of large-scale science projects. In order to proceed, there is a need for intensified efforts on R&D and technical design work to enable new projects, coupled to a global collaboration and stability on long time scales (cf the first workshop on the LHC was held in 1984).

These new projects should be presented and discussed in an international context before making choices. Decisions should be taken after including input from the physics, taking into account the latest results at existing facilities. Moreover, the scientific community needs to present the benefits to society from the outset of the project and this must be accompanied by excellent communication and outreach.

The particle physics community ought to define the most appropriate organizational form and needs to be open and inventive in doing so; this dialogue should include the scientists, funding agencies and politicians. It is mandatory to have accelerator laboratories in all regions working as partners in accelerator development, construction, commissioning and exploitation. Furthermore, the planning and execution of contemporary high-energy physics projects require world-wide partnerships for global, regional and national projects, i.e. for the whole particle physics programme. The exciting times ahead should be used to establish such partnerships.

Particle physics will need to adapt to the evolving situation. Facilities for high-energy physics (but also for other branches of science) are becoming larger and more expensive. Funding for the field is not increasing and the timescale for projects is becoming longer; both factors resulting in fewer facilities being realized. Moreover, several high-energy physics laboratories are changing their missions.

All this leads to the need for more co-ordination and more collaboration on a global scale. Expertise in particle physics needs to be maintained in all regions, ensuring the long-term stability and support throughout the entire lifetime of a project. It will be necessary to engage all countries with particle physics communities and to integrate the communities in the developing countries. The funding agencies should, in their turn, provide a global view and synergies between various domains of research, such as particle physics and astroparticle physics, should be encouraged. Moreover, a closer linkage of partners for the development of technologies will be required.

To promote greater international integration, CERN Council opened the door to greater integration in particle physics when, in 2010, it unanimously adopted the recommendations to examine the role of CERN in the light of increasing globalization in particle physics. The key points agreed by Council include (a) all states shall be eligible for CERN Membership, irrespective of their geographical location; (b) a new Associate Membership status is introduced to allow non-Member States to establish or intensify their institutional links with CERN; and (c) the participation of CERN in global projects is enabled wherever they are sited. As a result, several countries are now in the process of greater integration with CERN.

5. Conclusions

In this paper, we have provided an account of big laboratories and their role as key research infrastructures for hosting large-scale science projects. The paper presented arguments for the successful implementation of such facilities, using the field of research in particle physics as a prime example. Specifically, the paper sets forth claims that the role of such big laboratories is to innovate, discover, publish and share, while bringing the world together.

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