OECD Global Science Forum

Large Research Infrastructures

Report on
Roadmapping of Large Research Infrastructures
(2008)

Report on
Establishing Large International Research Infrastructures: Issues and Options
(2010)

BETTER POLICIES FOR BETTER LIVES

Forward

Ever since the creation of the OECD Megascience Forum in 1992, large research infrastructures have been a major topic for analysis and discussion at the Organisation for Economic Co-operation and Development. This did not change when the Megascience Forum received a new name and a new, enlarged mandate in 1999, becoming the Global Science Forum (GSF). Like its predecessor, the GSF is a committee whose members are senior science policy officials of the governments of the OECD countries. Two types of activities have been undertaken over the years: strategic foresight in specific scientific disciplines, and generic policy studies that provide useful advice about research infrastructures, based on past experiences and current requirements. In all cases, the GSF's activities have involved not just government officials, but also administrators of research institutes, representatives of various scientific unions and advisory committees, as well as prominent individual researchers. The work has been organised, managed and assisted by a small secretariat of international civil servants, based at OECD headquarters in Paris.

Among the scientific domains that have been the subject of the first type of GSF activity are nuclear physics, high-energy physics, astronomy and astrophysics, radio astronomy, the study of condensed matter, neutron science, high-intensity lasers, proton accelerator-based facilities, structural genomics, grid computing and, most recently, astroparticle physics. In each case, the scientific imperatives were listed, and desired generic measurement capabilities were enumerated along with the main technical challenges. Finally, opportunities for international collaboration and coordination were identified, especially for those anticipated experimental efforts where the size, complexity and cost of future infrastructures are likely to make international cooperation a necessity.

The two reports that are contained in this publication are instances of the second type of GSF activity. They pertain, respectively, to two important phases in the realisation of large research infrastructures: systematic strategic planning (also known as roadmapping) and the process of establishing a new international infrastructure. In both cases, the GSF's objective was not to carry out an exhaustive, academic, theoretical study based on a universal intellectual framework that would be valid in all cases and at all times. Instead, the goal was to provide useful information and advice to scientists and policymakers who are faced with very specific, practical challenges related to future research programmes: planning ahead for a series of significant investments in infrastructures, or bringing several countries together to jointly implement a large research facility. To reach its objective, the GSF adopted a down-to-earth, empirical methodology: a systematic critical review of existing roadmap documents, and a series of confidential interviews with persons who have gone through the difficult task of establishing a big international collaboration.

In putting these reports into the hands of scientists and administrators, we are aware of the fact that not all of their concerns will be addressed, and not all of their questions will be answered. Each major planning or implementation effort is, to some extent, *sui generis*. Accordingly, the OECD reports are essentially a compendium of issues that should be considered, and of solutions that have been found to be applicable in certain cases. We sincerely hope that the reports will be informative and useful: making collaborative projects run more smoothly, helping to avoid misunderstandings, disputes and delays. Naturally, we would be interested in receiving comments and corrections from readers. The GSF staff can be reached at gsforum@oecd.org.

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Report on Roadmapping of Large Research Infrastructures

December 2008

Based on the *Workshop on Enhancing the Utility and Policy Relevance of Roadmaps of Large Research Infrastructures* held in Bologna, Italy, on June 10/11, 2008

Contents

1 Introduction and background

In various fields of science, policy-makers – among them delegates to the OECD Global Science Forum – face decisions about the planning, funding and implementation of large research infrastructures. They must take into consideration the priorities and requirements of many scientific communities, the international context, and the priorities of society in general. As an aid to the decision-making process, they are increasingly making use of strategic, long-range planning exercises, and of the resulting documents which are often called "roadmaps".

The generic issues associated with infrastructure roadmapping were discussed by the delegates to the Global Science Forum during several bi-annual GSF meetings but, to address the topic more systematically and to produce a more concrete outcome, the GSF agreed to convene a two-day workshop that would bring together science funding agency officials, roadmap practitioners and members of the scientific community.

The goal of the workshop was to explore ways of maximising the utility of roadmaps, i.e., of ensuring that the process, and the findings and recommendations contained in the roadmaps, respond to the actual needs of the policymakers. Specifically, the objectives were to:

- better understand the needs of the policymakers, to identify common issues, questions, and "good practices" in the preparation of roadmaps;
- assist those who are currently undertaking the preparation of new roadmaps, or the updating of existing ones;
- share experiences and information, and strengthen contacts between the stakeholders.

It was not the goal of the workshop to assess past efforts, or to design a one-size-fits-all model for a universal roadmap. Indeed the discussions confirmed that such a model is neither desirable nor feasible. Furthermore, the focus was on the roadmapping process, and not the contents of particular roadmaps.

The workshop was held in Bologna, Italy, on June 10/11, 2008, hosted by the *Università degli Studi di Bologna*. It was chaired by Dr. Hermann-Friedrich Wagner, Chairman of the Global Science Forum since 2004. Preparations were supervised by an International Experts Group whose members were appointed by the GSF delegations[1]. Two documents were provided as input to the workshop: (1) a compendium and analysis of sixteen roadmaps, written by Dr. Stefano Fontana, and (2) a detailed annotated agenda prepared by the GSF secretariat. Both documents can be found on the GSF website, www.oecd.org/sti/gsf. The workshop was attended by thirty-three participants[2], appointed by the delegations of seventeen OECD member and observer countries[3], the European Commission, and two invited international scientific organisations[4].

A first draft of this report was written by the GSF secretariat, based on the discussions that took place during the workshop, as well as the two input documents. At the end of July 2008, it was submitted for comment and revision by all of the workshop participants. Their input was integrated into a revised version that was submitted for discussion by the Global Science Forum at its meeting in Rome in October, 2008. This final version was then prepared, incorporating the views expressed by GSF delegates. It was cleared for general release by the GSF Bureau in December 2008.

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The Global Science Forum (GSF) is a venue for consultations among senior science policy officials of the OECD member and observer countries on matters relating to fundamental scientific research. The Forum's activities produce findings and recommendations for actions by governments, international organisations, and the scientific community. The GSF's mandate was adopted by OECD science ministers in 1999, and extended by them in 2004. The current mandate will expire in 2014. The Forum serves its member delegations by exploring opportunities for new or enhanced international co-operation in selected scientific areas; by defining international frameworks for national or regional science policy decisions; and by addressing the scientific dimensions of issues of social concern.

The Global Science Forum meets twice each year. At these meetings, selected subsidiary activities are reviewed and approved, based on proposals from national governments. The activities may take the form of studies, working groups, task forces, and workshops. The normal duration of an activity is one or two years, and a public policy-level report is always issued. The Forum's reports are available at www.oecd.org/sti/gsf. The GSF staff are based at OECD headquarters in Paris, and can be contacted at gsforum@oecd.org.

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[1] The list of members of the Experts Group can be found in Appendix 3.
[2] The list of participants can be found in Appendix 2.
[3] Australia, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Japan, Netherlands, Norway, Poland, Slovak Republic, South Africa, Switzerland, United Kingdom, United States.
[4] The International Astronomical Union, and the International Committee for Future Accelerators.

2. The diversity of infrastructure roadmaps

There are no consensus definitions of the terms "research infrastructure" or "roadmap". There is general recognition, however, that the former extends beyond large centralised facilities (such as telescopes or research vessels) to include physically distributed resources for research, such as computing networks, and large collections of data or physical objects.

While the term "roadmap" was adopted by the GSF for the purposes of the workshop, the word is not universally applied to the results of strategic long-term planning exercises. Thus, when twenty such exercises were examined in detail by the GSF secretariat during the preparations for the Bologna workshop, the term appeared in only four of the titles[5]. Thus, "roadmap" cannot yet be considered as a standard term of art, although it is commonly used in the science policy community, and is used exclusively in this report.

In analysing the contents and impact of a roadmap (or when undertaking a new roadmapping project) it is important to clarify the roles played by two principal actors/stakeholders: the scientific community and the governmental authorities (notably, funding agency officials). The former normally restrict themselves to scientific arguments, aimed at defining the most pressing research questions, and identifying a corresponding optimal set of high-priority research infrastructures. But even in cases where the entire roadmapping exercise takes place among scientists, a significant measure of policy-relevance, political sensitivity and budgetary discipline are needed. Any scientific community would be ill-advised to generate a lengthy "wish list" of expensive projects that had little prospect of being funded.

In recent years, a specific roadmap category has gained increasing popularity: strategic plans elaborated jointly by scientists and policymakers, under the aegis of the latter, with well-defined explicitly-stated contexts, goals, procedures and outcomes. Within this category, the role of the scientists is conceptually straightforward, although, in practice, it may prove to be difficult and time-consuming. Typically, it involves the organisation of extensive "bottom-up" consultations, leading to tough choices among competing projects. The role of the policymakers is quite different, since they are public servants whose work is embedded in a broad, multi-agency governmental agenda. They must often introduce non-scientific issues and priorities into the roadmapping process, among them: (1) political and societal goals such as sustainable development, capacity building in developing countries, environmental protection, energy security; (2) national and/or regional development goals, including the evolution and potential re-direction of existing infrastructures (such as large laboratories or research centres); (3) imperatives linked to innovation, economic competitiveness, technology development and job creation. These national social, political and economic considerations have high priority; therefore, it is to be expected that some of the research infrastructures that are relevant for these priorities will be implemented even if they are not the ones that would have been chosen by scientists alone, i.e., they may end up being implemented outside of any roadmapping process.

The purposes of roadmaps can vary a great deal. In a broad sense, roadmapping reflects a wish to advance the policy-making process, beyond past practices in which proposals for large infrastructures where considered separately based on lobbying by strongly motivated individuals or communities of scientists. Some roadmaps are broad "vision statements" that are meant to contribute to the general debate about future large projects, while others delve deeply into the details of specific proposals, concluding with carefully worded evaluations that can determine the fate of major infrastructure initiatives. In rare cases, a finished roadmap can become a "blueprint", i.e., it is treated as a list of projects that are to actually receive funding, and are to be implemented as described. More often, the roadmap reflects the consensus intentions of both the policy (funding agency) and scientific communities.

[5] The designation "strategy" also appears four times, "vision" thrice, with "plan", "survey", "perspective", "outlook" and "guide" also used.

The following parameters may be useful when classifying and comparing roadmaps:

Scientific scope. In some cases, a roadmapping process may target infrastructures from many non-overlapping scientific domains, their only shared quality being their importance to science. The roadmap of the European Strategy Forum on Research Infrastructures (ESFRI) is probably the most prominent example[6]. Or, the scientific scope of a roadmap may simply reflect the historical mandate of the agency that commissioned it. In many cases, a single scientific domain is under consideration, or a single important research question. The ever-increasing interdisciplinarity of the research enterprise (and, hence, of science policy-making) will probably lead to more instances of roadmaps with methodologies for assessing infrastructures across a wide range of disciplines.

Geographic and/or administrative scope. Probably the smallest scale at which a roadmap can be meaningfully implemented is that of a national funding agency. More commonly, roadmaps are created at the national level. It is interesting to note that the purpose of any particular national roadmap is not always readily apparent from a superficial reading of the introductory material, unless there is a very explicit reference to a planned expenditure for research infrastructures. The stated goals usually make general references to a desire to maintain excellence in research, enhance strategic thinking, accountability and interdisciplinarity, make better use of scarce resources, etc. In some cases, there is an implied message of frustration with the difficulties of coordinating large investments across ministries/agencies, or among the administrative regions of a single country. A desire may be expressed to better position national decision-making relative to upcoming international efforts, or to strike a good balance when promoting the economic development of a country's administrative regions. Recently, regional roadmapping has become very prominent in Europe, under the auspices of the European Commission, the European Science Foundation, and other entities, notably ESFRI.

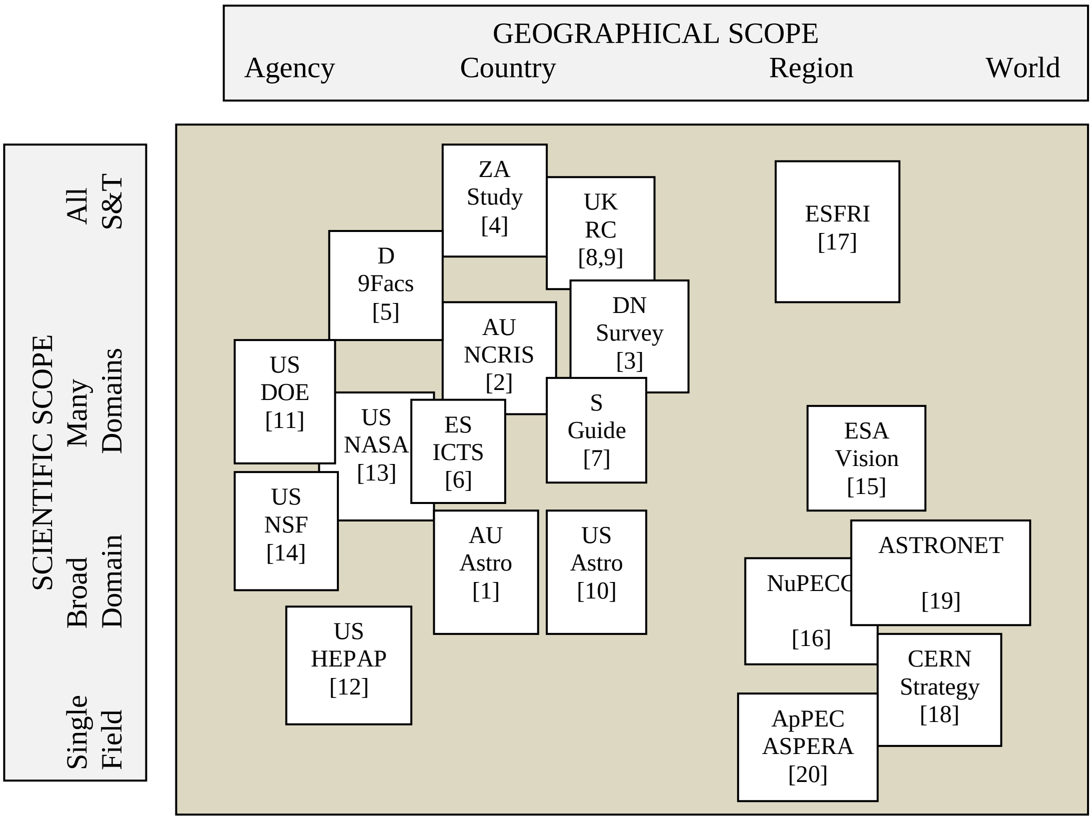
Temporal scope. Some roadmaps are very explicit about the look-ahead time for which infrastructure planning is being done. Thus, for example, the USDOE "20-Year Outlook", the U.S. and Australian astronomy "decadal surveys", or the "ESA Cosmic Vision 2015-2025". In most cases, however, the time horizon is only vaguely specified, or not at all. In a small number of cases (for instance, the NASA and ESA roadmaps) the outcome document includes a time sequence of facilities, to be implemented in a certain scientifically valid order.

For a small, but growing, number of roadmaps, provision is made for updating or repeating the exercise periodically.

Size of considered infrastructures. The roadmapping process seems to go most smoothly when the infrastructures considered do not differ excessively in size as well as type. There are obvious methodological difficulties is assessing projects of different sizes and costs, especially when it comes to assigning priorities. Consequently, an implicit size or cost threshold is usually incorporated.

[6] Another instructive instance of this is the 2002 "Statement" of the German Wissenschaftsrat, which compared and evaluated nine very diverse proposed facilities, including a high-altitude aircraft, an icebreaker research vessel, and a linear electron-positron collider.

The figure below attempts to convey the considerable diversity, and the interesting correlations, between the geographic and scientific ranges covered in a selection of examined roadmaps (identified in Appendix 4).



The extreme right-hand side of the above chart is necessarily empty, since there is no global-scale funding agency that could commission a roadmap (or act on one). To a limited extent, the reports of the OECD Megascience Forum and Global Science Forum (on neutron sources, neutrino observatories, structural genomics, nuclear physics, proton accelerators, high-intensity lasers, high-energy physics, and astronomy) play such a role.

Roadmaps typically focus on new research infrastructures – ones that generate great enthusiasm in the scientific community and that promise to enable entirely new kinds of measurements or calculations. Few roadmaps deal extensively with the difficult matter of existing infrastructures – whether to continue to operate them, to upgrade them, or to close them down to free up financial and human resources[7]. But any projection of future needs and requirements necessarily sheds light on the issues associated with existing projects and, in that sense, policymakers find such projections useful. Another major concern of policymakers that tends to be bypassed in roadmaps is that of defining the legal, administrative and managerial aspects of proposed new projects. By and

[7] There exist strategic planning documents that are commissioned from scientific advisory bodies, whose stated purpose is to advise the agencies about shutting down facilities, and making choices between existing and/or future projects. Typically, these are initiated in response to a possible cut in funding. However, these narrowly-focussed documents probably should not be labelled as "roadmaps" in the sense of this report.

large, OECD workshop participants took the view that it would be undesirable and unrealistic to expect to deal properly with these two issues in the course of a standard roadmapping exercise.

3. The significance and impacts of roadmaps

To a first approximation, the significance of a roadmap is embodied in the final outcome document, and the ensemble of infrastructures that it enumerates, plus the associated analyses and information (science cases, cost estimates, R&D needs, etc.). However, discussions at the OECD workshop revealed some interesting wider impacts of the roadmaps and the processes that lead to their creation. Accordingly, these deserve to be taken into account when deciding whether and how to prepare a roadmap. The impacts affect both the scientific and policymaking communities, as follows:

The undertaking of a roadmap obviously galvanises the proponents of specific infrastructures, and motivates them to develop the strongest possible submission. This in itself can lead to more precise and innovative thinking, plus the formation of useful collaborations at national and international levels. The prospect of a critical review encourages the seeking out of all possibly interested partners, some of whom may be researchers from widely disparate fields (this is especially likely to be the case for large user facilities which can serve multiple scientific domains). If the prospective roadmap is of a competitive type[8], the proponents' chief goal (and the source of their greatest fear) is not to be eliminated during the process of assessment and prioritisation. Indeed, it would be hard to overestimate the consequences of not being included on a roadmap, which is yet one more reason why the scope and rules of each exercise need to be stated clearly and explicitly.

In addition to spurring the development of individual projects, the undertaking of a roadmap has been known to mobilise an entire scientific community (at least at a national level) and motivate it to think strategically about its status, priorities, prospects and requirements. It cannot be assumed that communities are naturally inclined towards this type of introspection without an external stimulus that a roadmapping exercise provides. The experience of the Global Science Forum has shown that a certain such reluctance can be observed (for example, within the international community of astronomers) due possibly to the egalitarian nature of the scientific enterprise, which makes researchers unwilling to openly criticise the work or ideas of colleagues to an audience of funding agencies.

Forward-looking strategic thinking about infrastructures is valuable for new and/or interdisciplinary fields, whose future needs may not be well known to policymakers, especially if the funding and administrative structures for these fields are not yet fully developed at the governmental and institutional levels. For major new user facilities, the roadmapping process may represent the sole mechanism for assembling a critical mass of users from disparate fields, thus making the case for the facility that might not otherwise emerge in the conventional planning process.

For science policymakers, too, roadmapping is an occasion for taking a fresh look at options for the future, and for working with officials from other agencies, both within and across national borders. In some cases inter-agency collaborations are historically under-developed, to the detriment of science policy-making in general[9]. It appears that, at the national level – and especially in smaller countries – the completion of a regional or global roadmap can lead to a corresponding national effort, aimed at deciding which projects should be considered for partnership, based on projected local requirements. Such an effort may not, however, be entirely unconstrained: if a given proposed infrastructure has already been identified on a regional or global roadmap as

[8] That is, if the roadmapping process is essentially a competition, where only some of the proposed projects are retained in the final outcome document.

[9] It was noted in previous GSF reports that ground- and space-based astronomy suffered, in some countries, from historical divergences between the corresponding responsible agencies. The recently-concluded ASTRONET European Infrastructure Roadmap and the well-established "decadal surveys" of astronomy (carried out by the U.S. National Academy of Sciences) are significant efforts aimed at breaking down barriers to inter-agency cooperation.

being preferably an international one, it can be very difficult to reverse that categorisation at the national level by proposing to implement the project on a purely local basis. In general, long-range regional or global planning presents both opportunities and challenges to officials and scientists in small countries: it gives them a chance to participate in decision-making about projects that they could not afford to implement on their own, but it can also tie their hands by constraining them to align their policies and decisions to those made collectively with other countries.

The elaboration of a new roadmap for a particular scientific field provides an opportunity to systematically examine some of the key enabling conditions that may not be inherently scientific, but are nonetheless very relevant to maintaining strong research programmes over the long term. It may be the case that these conditions tend to be unexamined during the course of normal year-to-year science policymaking. Among these conditions are:

Supply and demand of research resources. It is important that the provision of resources match (in both qualitative and quantitative terms) the size of the corresponding scientific community. Maintaining such a balance is not always a recognised priority, yet its lack can be a serious problem if the number of highest-quality instruments (e.g., large telescopes or elementary particle detectors) shrinks around a small set of very expensive ones which can only be used by a relatively limited number of scientists at any time.

The size of the research effort, in absolute numbers and relative to other fields. The work of the Global Science Forum has revealed a curious feature of the global science policy landscape: with all of the statistical data-gathering and analysis that is done by OECD and other organisations, it is often impossible to answer simple questions regarding the total public investment, and the size of the scientific community, in specific areas of basic or applied research (for example, astronomy, physics, molecular biology, aeronautical engineering). And yet the information would be of great value to policymakers as they seek to develop balanced and coherent research portfolios. It could be compiled as part of the roadmapping process.

The conditions of access to research infrastructures. There is a large diversity in policies that determine researchers' abilities to gain access to large infrastructures. Even when it is claimed that access is entirely merit-based (i.e., does not depend on whether the proposing scientist is affiliated with the facility or comes from a country that funds it) there are various unspoken conditions and requirements. The preparation of a roadmap can shed light on the policies, thus facilitating the work of national policymakers who seek to ensure that their researchers will be able to use the best tools. Roadmapping can in itself promote open access and sharing, if these are made a condition of being included in the final outcome document.

Workforce issues. All branches of science must continually renew themselves by attracting and retaining talented young people. The provision of state-of-the-art infrastructures, their role in training new generations of scientists, and other matters relating to scientific careers, can be among the topics considered during the preparation of a roadmap.

Links to industry and competitiveness. The implementation of a new research infrastructure may involve significant technological challenges that could, in turn, produce industrial spinoffs with commercial potential. Involvement of potential industrial partners in the roadmapping process can help to identify such opportunities, and can also be useful for making more reliable cost projections for proposed projects.

4. Caveats

Roadmapping is widely praised as a way of conducting science policy-making in a strategic, systematic and objective way. It is, however, a resource-intensive task, subject to a variety of methodological challenges, as described in other sections of this report. But there are also fundamental, existential questions about the general utility of roadmapping, and about potentially detrimental unintended consequences. Five categories of caveats were mentioned at the Bologna workshop. Each can be dealt with constructively, if proper care is taken when designing and carrying out a roadmapping exercise, and when properly situating roadmapping within the broader contexts of national and international policy-making for science.

- The large infrastructures that are the object of roadmaps are very costly. As more and more of them are proposed, planned and implemented, the funding available for non-infrastructure oriented research necessarily shrinks. This can be harmful if, instead of being justified by scientific requirements, it is merely an artefact of roadmapping's natural focus on large projects. The effect could hypothetically be aggravated by the known methodological problems of roadmapping: imprecise (and, typically, underestimated) cost projections, plus the neglect of operating and decommissioning costs.
- By promoting long-term commitments based on fixed scientific rationales, roadmaps have been criticised as being too inflexible. The concern is that they rob the science policy-making process of the ability to respond quickly and creatively to new discoveries (this matter is discussed further in Section 5b).
- Because they focus, by definition, on large infrastructures, roadmaps may lead to distortions in decision-making for small- and medium-sized projects (whose value is widely acknowledged by experts, and has been emphasised repeatedly in the reports of the Global Science Forum). Besides their intrinsic merits, they often play a valuable supportive role in conjunction with the large infrastructures, for instance, as venues for developing and testing instrumentation, and as training grounds for students and young researchers. Still, there is a tendency to not consider them in the roadmapping process, potentially resulting in a distorted image of a scientific domain and its needs for the future. This may be particularly damaging for research domains that only have a limited (but vital) need for large infrastructures (for example, the biological and environmental sciences).

  Smaller projects are typically implemented at a national level. By making commitments to the large international infrastructures that are featured in prominent roadmaps, national authorities risk losing autonomy and flexibility.
- Roadmapping can be a victim of its own success, when increasing numbers of scientific domains are included in large interdisciplinary roadmaps, extending to the social and behavioural sciences, and even the humanities. Methodological problems can arise when dealing with very diverse multiple disciplines, especially if an attempt is made to set priorities across disparate fields. With a broad scientific case that goes beyond the mandates of individual funding agencies, and with a loss of specificity and focus, there is a danger that the outcomes of the exercise could become less actionable, even as the scientific arguments continue to be appealing and correct.
- The sheer proliferation of roadmaps can create confusion, especially if there is a lack of clarity as to the scope, authority and methodology of the individual outcome documents. It can be difficult to interpret the presence (or absence) of a proposed infrastructure on one or more roadmaps, which may reflect the true merits of the project, or simply be an artefact of the roadmapping processes.

5. The roadmapping process

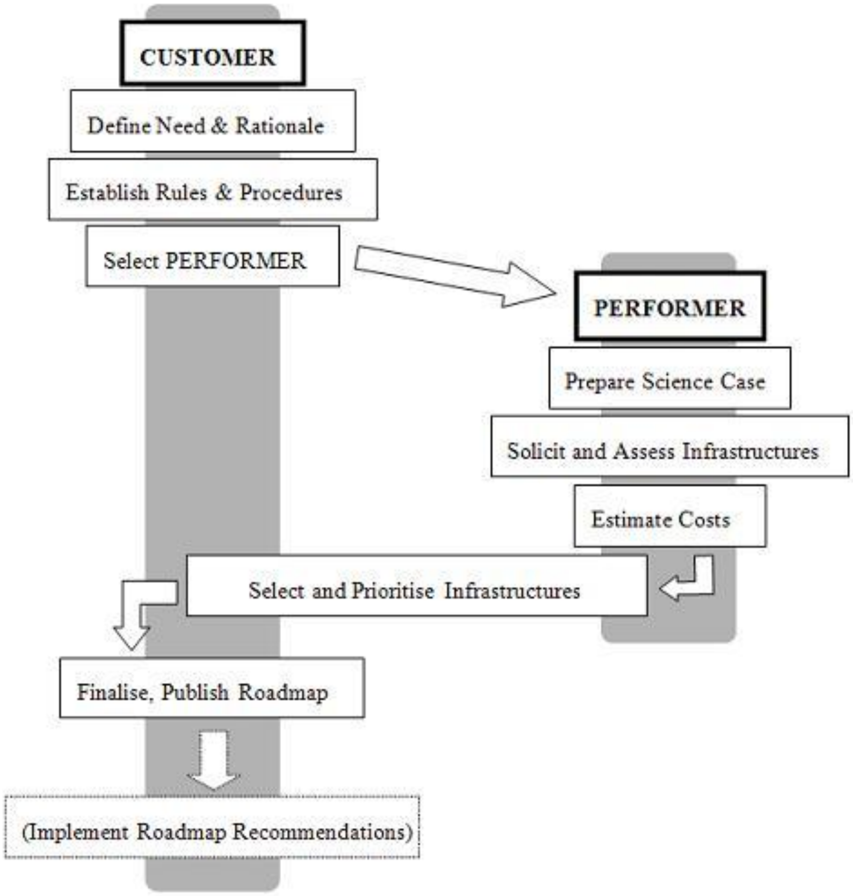
When examining any particular roadmap, the generic questions that can be asked regarding process are:[10]:

1. What is the status/authority of the entity that commissions the roadmap, and that carries it out?
2. What rules govern the ways that infrastructures are submitted, evaluated and selected?
3. Are the costs of the infrastructures estimated and, if so, how?
4. How is the international context incorporated into the roadmap?
5. Is there any follow-on activity, in terms of implementation, or repeating the process periodically?

[10] These questions apply mainly to mature policy-planning roadmaps, not those that are primarily scientific vision statements.

5a. Customers, Performers and procedures

The following graphic is meant to illustrate a generic process through which a policy-relevant roadmap is generated:



Usually, the Customer is a governmental funding agency. It initiates the entire process and provides the rationale, such as the necessity for making a major series of infrastructure commitments, or the availability of special funding. The Customer sets out the procedures and timescales that will be followed and, in many cases, it selects an independent Performer to carry out the work[11]. The primary requirement for the latter is a high degree of prestige and authority in the scientific community, plus strong political skills and connections. Thus, a Performer might be a national scientific academy or other established high-level scientific entity (Science Council, etc.), an established scientific advisory body that is already linked to the Performer, or an *ad hoc* group of prestigious scientists[12].

It is important that the Performer be perceived as objective, and not merely a lobbying group for large new investments in a given field. When only one scientific domain is being roadmapped, such a perception can be difficult to achieve. Accordingly, those who commission a roadmap may choose to define a broad scientific scope that encompasses more than one scientific community, and to explicitly require that priority-setting and multiple choices be a part of the process.

[11] Typically, the Customer also pays for the exercise.
[12] In at least one instance (in South Africa) a commercial consulting firm prepared the roadmap for a Ministry.

The above scheme is not universally applied. Sometimes, the Customer and Performer may be the same entity. A funding agency entity may choose to conduct the roadmapping internally, especially if it is a research organisation as well. Or, a non-governmental scientific organisation may choose to create a roadmap without having a governmental mandate. In both cases, the organisers will want to take special care to ensure that the results have scientific credibility (in the first instance) and adequate policy relevance (in the second).

Given the high scientific reputation of the Performer, it is a relatively straightforward matter to identify the main scientific goals (i.e., to elaborate the "science case") and to then assess proposed infrastructures in terms of their relevance to achieving those goals. The final step, however – making a final selection of facilities that are to be included in the roadmap – is the most sensitive one, and a variety of solutions have been adopted historically. In at least one instance, the final choice was made in solitary deliberation by a senior official of a funding agency. In other cases, the Performer is authorised to convene an open, transparent dialogue involving a large number of prominent scientists[13]. Decisions regarding the actual implementation of an infrastructure, which involve complex issues of funding, siting, staffing, possibly negotiating international agreements, are necessarily beyond the scope of a roadmapping exercise, and involve a separate set of stakeholders (for example, parliamentary and regulatory authorities).

The process that is used by the Performer may incorporate some of the following[14]:

- Adopting a contest/competition format, where only a sub-set of submitted infrastructures are included in the final roadmap (versus simply identifying the final set of facilities, or evaluating a given fixed set of projects). The rules that govern the submission of infrastructures for consideration constitute a particularly sensitive issue for scientists. Their natural inclination is for a "bottom up" process, i.e., an open call for submissions.
- Allowing proponents to make the case for the infrastructures that they advocate, possibly including a questionnaire that must be submitted by all project proponents.
- Defining specific criteria for assessing the infrastructures. These may be quite complex (for example, they can be a function of the size of the proposed project).
- Sponsoring "town meetings" at which any recognised scientist can provide spontaneous, unsolicited input.
- Making intermediate results (e.g., interim reports) openly available to the community for comment.

Some roadmaps are one-off exercises, while others are part of a continuing series. The former may, however, contain a recommendation (or even commitment) to repeat or update the study in the future. The latter group prominently includes the "decadal astronomy survey" of the U.S. National Research Council, which is currently beginning its sixth iteration, following the reports of 1964, 1972, 1982, 1991 and 2001. The U.K. and USDOE roadmaps (including the USDOE "Four Years Later" report) deserve special attention because of the interesting changes in perspective over time. Obviously, continuing roadmapping process allows for the development and subsequent refinement of a methodology, and for the accumulation of experience and expertise.

[13] It is probably worth reiterating the point made in the opening paragraphs of this report: no attempt is being made to prescribe any particular standard methodology for infrastructure roadmapping. Above all, roadmaps are intended to be useful, policy-relevant documents that respond to the real-life needs of those who solicit them. In any case, a complete review of process and prioritisation is beyond the scope of this report.

[14] There is a special category of roadmaps where little or no information is provided on the process through which the document was prepared and conclusions reached.

The assignment (or not) of priorities to individual infrastructures is clearly a major issue. Some roadmaps explicitly disallow prioritisation; in other cases, making tough choices is the principal *raison d'être* of the whole exercise. Two sample strategies are as follows:

- Selecting a limited set of projects via internal intra-agency consultation; solicitation of advice from formally chartered advisory groups; preparation of a 2-dimensional (scientific importance, readiness for implementation) classification; selection of the final 28 projects by a senior agency official, grouped into 3 categories: near-term priorities, mid-term priorities, far-term priorities. Within each category, further prioritisation, including many ties. (U.S. Department of Energy, Office of Science, 2003)
- Thirty-five large European infrastructures across many scientific fields (including social sciences and humanities) selected by a government-appointed committee, based on "200+" submissions (from governmental sources). Three Working Groups were established (with sub-groups as needed). There is no prioritisation among final selected infrastructures. (ESFRI, 2006)

Other prioritisation schemes were noted in the roadmaps that were reviewed during the workshop preparations. As already mentioned, even when no priorities are assigned, the mere fact of being included on a roadmap (or, perhaps more importantly, of not being included) can be very significant.

5b. Science cases

Most roadmaps include a section that describes the scientific background and imperatives. Since roadmaps are policy-level documents, not scientific papers, the language used is typically aimed at the "intelligent layman" – roughly the level of a *Scientific American* or *New Scientist* article. A technique that is commonly used is the enumeration of a finite number of "Big Questions" which can then be mapped on to the set of infrastructures that can be used to find the answers.

Some roadmaps encompass facilities from scientific and technological domains that are not overlapping, i.e., they are compiling and comparing "apples with oranges". When this occurs, the science case typically becomes fragmented as well, i.e., each proposed facility is assessed within its own sub-domain. When roadmaps independently address the same well-defined scientific domain, the wisdom of developing multiple versions of science cases can well be questioned[15], since the processes are time consuming and the results tend to be nearly identical. The consensus opinion of the OECD workshop attendees is that these exercises are valuable, and should continue, even if duplication is bound to occur. It was pointed out that the act of constructing a science case (holding meetings, commissioning reports, thinking strategically about a scientific field and its links to other domains) helps to build cohesion in the scientific community, and makes it more likely that, at the end of the process, the outcome will win the community's approval. When new (e.g., interdisciplinary) domains are under consideration, the process can bring together groups of researchers who do not normally interact. In addition, science cases involve the detailed exploration of connections between proposed facilities and scientific priorities. One delegate to the Bologna workshop revealed that his ministry decided to not join a large international project, based on its assessment that the scientific case for it was too weak.

A recurring criticism of science cases is that they do not accurately account for the nature and pace of scientific discovery, especially in the case of very large, multi-year projects that only begin to produce data a decade (or more) after they first appear on a roadmap. By the time observations begin, the primary scientific goal (for example, the detection of an elementary particle, or the accurate measurement of a cosmological parameter) may no longer be of interest. Retrospectively, it has been found that the most important discoveries that are made using major scientific instruments are often ones that were not mentioned (or foreseen) in the original science case. Accordingly, it has been suggested that, in assessing major research infrastructures, special

[15] This becomes quite evident to anyone who reads roadmaps for fundamental physics, astronomy, energy-related sciences, or materials sciences.

consideration should be given to those that are likely to open up new “discovery spaces”, i.e., are unique in terms of sensitivity and resolution (spatial, temporal, spectral, etc.). These can be expected to generate exciting serendipitous discoveries. There was only limited support for this argument at the Bologna workshop. It was pointed out that governmental authorities are very unlikely to accept a science case that is based on serendipity alone, but the “serendipity potential” of a proposed infrastructure could be included in the science case that is made.

It is important that the potential users of future infrastructures participate in the elaboration of science cases, especially when the user community does not overlap that of the designers, builders and operators the infrastructure. This is to ensure that the justification for the project extends beyond the reflexive desire of the latter community to implement a next generation in a historical series of facilities, each bigger and better than the previous one. In a similar vein, it is important, when preparing a science case, to avoid conflicts of interest, such as can occur when known proponents of specific projects are asked to make an impartial assessment of future needs. Ideally, roadmapping should result in the generation of new ideas, and not merely the reiteration of familiar arguments.

5c. Costs of infrastructures

There is significant diversity in the way that costs are incorporated into roadmaps. In some cases, the issue is deliberately and explicitly omitted. Sometimes, an overall spending envelope is specified, usually reflecting a moderate increase that can motivate scientists to generate innovative proposals. In other documents there is an elaborate computation of construction, commissioning, operation and de-commissioning expenses. There is a special class of roadmaps linked to a large dedicated funding allocation. Interestingly, it has been found that roadmapping exercises that do not offer any specific prospect for funding still manage to attract strong interest in the scientific community.

There appears to be a systemic difficulty with estimating infrastructure costs for roadmapping purposes, i.e., in the early stages of project development when significant R&D remains to be done, and in a competitive environment where less expensive projects might have an advantage. Although acknowledging that efforts should always be made to project costs as accurately as possible, participants at the Bologna workshop agreed that, at a minimum, cost estimates should be performed uniformly across all considered projects, but the results should not be treated as definitive[16]. More rigorous costing should be done later, after a project passes the initial authorisation hurdles.

Another source of concern for agency officials is the difficulty of properly accounting for contingencies, and for operating costs[17]. The latter can be very high for large facilities (typically, 10% of total construction costs, annually). The well-known (and highly-prized) principle of “free, open, merit-based access” for external users, which is applied in many countries, requires that operating costs be carefully considered when planning a new facility. A related issue, already mentioned in Section 2, relates to the recuperation of funds through the shutting down of existing infrastructures (many of which continue to be scientifically productive). The roadmapping process is probably not an ideal one for dealing with the difficult questions involved.

[16] One workshop participant jokingly asserted that initial estimates and final infrastructure costs normally differ “by a factor of π”.

[17] In the work of the GSF, the problems associated with adequately budgeting for instrumentation have been highlighted on several occasions.

5d. International considerations

More and more, the international dimension of infrastructures is explicitly incorporated into roadmaps. Even for purely national roadmaps, the plans and priorities of other countries and regions have to be accounted for[18]. Smaller countries, in particular, use roadmapping to assist in making crucial decisions regarding the implementation of home-grown infrastructures, versus joining an international effort. Conversely, the prospects for international contributions to a national project may be advanced as an important feature (or even a requirement) for the success of a proposed large infrastructure.

Successful roadmapping exercises are being emulated, although this is not usually explicitly stated. It could well be, for example, that the Australian "New Horizons" effort was inspired by the U.S. decadal survey of astronomy. The CERN "Strategy" complements the ESFRI roadmap which deliberately excluded particle physics infrastructures. Increasingly, there are cross-references to existing roadmaps. Thus, the U.K. 2007 roadmap explicitly refers to the one of ESFRI. That roadmap, in turn, was inspired, it is sometimes said, by the USDOE project.

6. Summary of main points and conclusions

1. Roadmaps of large research infrastructures are the results of strategic, long-term, policy-relevant planning exercises. Government officials and scientists are making increasing use of this policymaking tool. Many successful roadmaps are now available for analysis and review, and it has been found that they display a wide diversity in terms of rationale, scope, and process. Accordingly, it is neither desirable nor feasible to define a preferred universal model or template for a scientific infrastructure roadmap. Furthermore, great care must be taken when comparing and combining roadmaps, especially when evaluating the merits of any particular proposed project; its presence (or absence) on multiple roadmaps may have real significance, but it could merely be an artifact of how the individual roadmaps were conceived and prepared.

2. While recognising the legitimate diversity of roadmaps, it is possible to specify general desiderata for consideration by those who are undertaking a roadmapping exercise:

    a. In many instances, roadmaps incorporate scientific and non-scientific considerations. The later usually reflect national priorities, and deserve special attention because they may be more complex, and less familiar to researchers, than those of pure science. They may concern such matters as economic development, industrial innovation, education and workforce issues, regional or international political integration, or national security. To avoid potential disputes and controversies, it is vital that the various categories of issues that characterise a particular roadmap be described clearly and explicitly from the outset.

    b. Clarity, completeness and transparency are essential desirable features of the roadmapping process. To the greatest extent possible, those who commission a roadmap, and those who produce it, should publicise and provide information about the policy context and motivation for the exercise, the rationale and details of the chosen process, the criteria for assessment and priority setting, the rules for cost estimates (if appropriate), the roles of key individuals, and the way that the results will be used.

[18] Curiously, roadmaps do not always reflect the degree and significance of existing international co-operation. Thus, for instance, given the historically extensive and fruitful collaboration between ESA and NASA (e.g., the ongoing Cassini-Huygens mission, and many others) the reader may be surprised by the fact that two recent agency roadmaps are essentially unconnected. The NASA document (22 pages) does not mention ESA or Europe at all (although there are two references to Europa, a moon of Jupiter). The ESA "Cosmic Vision" (97 pages) contains 39 references to NASA (primarily in picture captions, but once in a general promise to cooperate with international partners when it's appropriate).

c. Special efforts should be made to promote credibility within, and cooperation with, the scientific community. Experience shows that properly designed roadmapping exercises can stimulate the communities to think strategically about their future goals and requirements, can generate consensus within individual fields, can promote international cooperation, and can enhance interdisciplinary approaches to complex scientific challenges. To achieve this, the community should be engaged early in the process, and should be given the time and resources that it needs to participate in the preparation of the roadmap. As stated above, the non-scientific aspects of the exercise need to be clearly defined.

d. If the roadmap is to include cost estimates for infrastructures, the challenges should not be underestimated. At a minimum, there should be a detailed description of how the estimates are to be made, and the potential uncertainties should be taken into account in a realistic way. If feasible, consideration should be given to the likely costs of R&D, instrumentation, contingencies, operating and decommissioning expenses.

e. If appropriate within the given science policy context, a clear distinction and separation should be made between preparation of a scientific roadmap, and the final steps of decision-making, funding, and implementation by the responsible governmental bodies. The scientific community, working with senior programme managers, can produce a consensus roadmap, but they should recognise that final decisions (including decisions about funding, management, international agreements, siting) are of a different nature, involving, in many cases, complex, sensitive and lengthy interactions with an expanded set of stakeholders (for example, non-science ministries, parliaments, as well as local, national or international authorities).

3. Without detracting from the demonstrated utility of roadmapping, practitioners should be mindful of potential pitfalls and unintended negative consequences. These are described in Section 4 of this report, and relate to the following potential concerns: (1) over-commitment to costly, large projects that can stress available science resources; (2) lack of flexibility for responding to new scientific challenges; (3) neglect of small and medium projects; (4) loss of focus through overly broad scoping of roadmapped scientific domains; (5) inappropriate combining of information from dissimilar roadmaps.

4. Given the growing popularity of roadmapping, it may be worth considering the desirability of enhanced information exchange (notification) about upcoming regional and national roadmapping exercises. On a voluntary basis, roadmap Customers (in the sense of Section 5a of this report) could decide to adjust the parameters of the exercises[19], or to synchronise their strategic planning in related fields. Even roadmap mergers could be envisaged.

[19] An instance of an adjustable parameter is the scientific scope. The current discussion in the Global Science Forum regarding nuclear physics and astroparticle physics provides examples of fields whose boundaries can be defined differently in different countries and regions.

Appendix 1: Workshop Agenda

Workshop on Enhancing the Utility and Policy Relevance of Roadmaps of Large Research Infrastructures

10-11 June 2008
Bologna, Italy

Agenda

Tuesday, June 10

1	9:00–10:00	Brief Chair's introduction. Background and objectives of the Workshop One or more keynote presentations by senior policy-makers who commission or use roadmaps for planning, prioritisation and funding decisions.
2	10:00–11:00	General introduction to the roadmapping process. Presentation of selected findings from the pre-workshop survey by the OECD secretariat. Rationales for roadmaps, non-scientific considerations, etc.
	11:00–11:30	*Break*
3	11:30–13:00	Science cases in roadmaps. Involvement of the scientific community. Issues of inclusiveness, openness and transparency.
	13:00–14:30	*Break*
4	14:30–15:30	Estimating costs of infrastructures. Links to implementation mechanisms and funding.
	15:30–16:00	*Break*
5	16:00–18:00	Assessment of infrastructures: submission, evaluation criteria, prioritisation, achieving consensus.

Wednesday, June 11

6	09:00–10:00	The international dimension of roadmaps and infrastructures. Potential for coordination, harmonisation, linkages between roadmaps.
7	10:00–11:00	Ongoing and upcoming roadmapping exercises.
	11:00–11:30	*Break*
8	11:30–13:00	General discussion. Extraction of "good practices". Conclusions. Next steps.

Appendix 2: Workshop Participants

Workshop on Enhancing the Utility and Policy Relevance of Roadmaps of Large Research Infrastructures

10-11 June 2008
Bologna, Italy

<u>Workshop Participants</u>

Chairman	Hermann-Friedrich Wagner
Australia	Anne-Marie Lansdown
Belgium	André Luxen, Jean Moulin
Denmark	Anders Odegaard
European Commission	Anna Maria Johansson
Finland	Eeva Ikonen
France	Denis Raoux, Martine Soyer
Germany	Hans-Juergen Donath, Rainer Koepke
Greece	Christos Vasilakos
IAU	Giancarlo Setti
ICFA	Albrecht Wagner
Italy	Sergio Bertolucci, Mafalda Valentini, Gianpaolo Vettolani
Japan	Taku Ujihara
The Netherlands	Jeannette Ridder-Numan
Norway	Jon Børre Orbæk, Kjersti Wølneberg
Poland	Jacek Kuznicki
Slovak Republic	Andrej Slancik
South Africa	Daan du Toit, Charles Mokonoto
Switzerland	Joel Mesot, Leonid Rivkin, Paul-Erich Zinsli
United Kingdom	Ron Egginton
United States	Wayne Van Citters
OECD	Katsuyuki Kudo, Stefan Michalowski, Frédéric Sgard

Appendix 3: International Experts Group

The Bologna workshop preparations were overseen by an International Experts Group whose members were nominated by the Global Science Forum delegations:

Chairman	Hermann-Friedrich Wagner
Australia	Anne-Marie Lansdown
Belgium	Jean Moulin
European Commission	Robert Jan Smits, Elena Righi-Steele
Finland	Eeva Ikonen
France	Dominique Goutte, Martine Soyer
Germany	Rainer Koepke, Hans-Juergen Donath
Italy	Umberto Dosseli, Paolo Vettolani
Japan	Shinichi Akaike
The Netherlands	Hans Chang
Norway	Bjørn Jacobsen, Britt Ann Hoiskaar
Poland	Jacek Kuźnicki
South Africa	Daan du Toit
United Kingdom	Ron Egginton
United States	Joan Rolf, Mark Coles
OECD	Stefan Michalowski, Frédéric Sgard

Appendix 4: Roadmaps examined in preparation for the workshop and report

(In the figure on page 5, the roadmaps are referred to by the corresponding number in square brackets)

Australia	1	2005	New Horizons: A Decadal Plan for Australian Astronomy
	2	2006	National Collaborative Research Infrastructures Strategy
Denmark	3	2005	Future Research Infrastructures: Needs Survey and Strategy Proposal
South Africa	4	2006	A Study of the Required Infrastructures for Attaining the Vision of the National System for Innovation
Germany	5	2002	Science Council Statement on Nine Large-Scale Facilities for Basic Scientific Research and on the Development of Investment Planning for Large-Scale Facilities
Spain	6	2007	Singular Scientific and Technological Infrastructures
Sweden	7	2006	The Swedish Research Council's Guide to Infrastructure
United Kingdom	8	2005	Research Councils UK Large Facilities Roadmap
	9	2007	Research Councils UK Large Facilities Roadmap
United States	10	2001	Astronomy Decadal Survey: Astronomy and Astrophysics in the New Millennium
	11	2003	USDOE Facilities for the Future of Science, a 20-Year Outlook
		2007	Four Years Later: An Interim Report
	12	2004	HEPAP Quantum Universe
	13	2004	NASA Vision for Space Exploration
	14	2005	NSF Facility Plan
Europe	15	2005	ESA Cosmic Vision 2015 - 2025
	16	2005	NuPECC Roadmap for Construction of Nuclear Physics Research Infrastructures in Europe (linked to Long Range Plan 2004)
	17	2006	ESFRI European Roadmap for Research Infrastructures
		2008	ESFRI Roadmap Update 2008
	18	2006	CERN European Strategy for Particle Physics
	19	2007	ASTRONET Science Vision for European Astronomy
		2008	ASTRONET Infrastructure Roadmap
	20	2007	ApPEC/ASPERA Status and Perspective of Astroparticle Physics in Europe
		2008	ASPERA Astroparticle Physics – the European Strategy

Glossary:

USDOE	United States Department of Energy
HEPAP	High-Energy Physics Advisory Panel (U.S.)
ESA	European Space Agency
CERN	European Organisation for Nuclear Research
ApPEC	Astroparticle Physics European Coordination
ESFR:	European Strategy Forum on Research Infrastructures
NuPECC	Nuclear Physics European Cooperation Committee
NSF	National Science Foundation (U.S.)
NASA	National Aeronautics and Space Administration
ASPERA	Astroparticle European Research Area

Organisation for Economic Co-operation and Development (OECD)
Global Science Forum

Establishing Large International Research Infrastructures: Issues and Options

December, 2010

Contents

1. Introduction and Rationale

Introduction This report of the OECD Global Science Forum (GSF) describes issues and options to be considered when establishing large international research infrastructures. The report is concerned with infrastructures that are truly international; that is, that are based on formal agreements between governments, agencies, or research institutions from more than one global region. Explicitly excluded are national projects and programmes that are planned, implemented and funded by one nation, even if generous international access is provided by the host country. Also excluded are purely regional infrastructures, notably European ones. National and regional infrastructures that are globally accessible have a rich and productive history, but they are not characterised by the large set of challenges and opportunities that emerge when multiple international partners from around the globe come together as equal (or nearly equal) partners. These special challenges and opportunities are the subject of this report. The report is intended for scientists and research administrators who are contemplating a major new international project. They need to be alerted to the diversity and complexity of the issues, the options that are available and their implications, plus the timescales and the expenses involved. The report addresses a wide spectrum of practical matters, from the formal aspects of legal agreements to less easily codified "lessons learned and good practices".

The report is advisory rather than prescriptive and, although it is grounded in past instances of international collaboration, it is not a review/assessment of any individual project. It is fully recognised that every large research project is *sui generis*, so this report is no more than a guide, a checklist, a non-exhaustive compendium of useful information, not all of which will be relevant to any particular undertaking. However, the Forum encourages those planning large infrastructures to give consideration to the issues raised in the report since, from experience, they will need to be addressed at some time in the life of the project. While the report is intended to benefit all proponents of international infrastructures throughout their deliberations, it should be of greatest value during the critical period when serious negotiations involving potential funders are about to begin. In earlier stages, the focus is primarily on the scientific desirability and feasibility of the contemplated infrastructure, and informal arrangements among the potential partners (for example, a Memorandum of Understanding signed by laboratory directors) are usually sufficient to carry the work forward. Such arrangements can even support coordinated R&D and advanced prototyping. However, they are unlikely to suffice for implementing a large infrastructure that is characterised by the complex, long-term legal and financial requirements that are the subject of this report.

This report is based on the analysis of existing and planned large research facilities. Examples[1] of these facilities (those still being planned are in italics) are:

- Single experiments [for instance, ITER, JET, CERN (with accelerators like LHC), CERN detectors, Pierre Auger Observatory, *ILC, SuperB*]
- User facilities for a small number of simultaneous users [ALMA, big optical telescopes, *SKA, ELTs*]
- User facilities for many simultaneous users [ESRF, ILL, XFEL, FAIR, *ESS]*

[1] Some of these facilities are regional or national in character, but it is the aspects of their structure and functioning relevant to international infrastructures that have been mined for information in the preparation of this report.

Other types of infrastructures and cooperative programmes exist, and many of the matters described in this report are relevant to these other programmes. Non-facility projects and programmes, such as collaboration networks and research programmes, linked sensor arrays, computing grids, coordinated databases, and scientific research collections, can benefit from consideration of the issues raised in this report, and may become the object of follow-on work by the OECD.

Rationale The factors that motivate scientists and science policy makers to pursue large international projects are well known. Among the potential benefits are:

- Implementing projects that exceed the funding capacity of individual countries;
- Optimising the global inventory of state-of-the-art scientific facilities while avoiding unnecessary duplication;
- Accessing a unique geographical location, or other unique local resource;
- Bringing together the best scientists, engineers, technicians, and administrators;
- Accessing data and other resources that are distributed world-wide;
- Providing international experience for young scientists and engineers.

The long and productive history of international collaboration by scientists (which has transcended not just national borders, but ideological and cultural boundaries as well) is a strong incentive and precedent for establishing new, large global-scale projects.

As the twenty-first century begins, the process of *globalisation* is the hallmark of many spheres of activity, including scientific research. Since 1961, the Organisation for Economic Co-operation and Development, home of the Global Science Forum, has been a venue where policymakers, representatives of industry and of NGOs, academic experts, and others come together to explore the practical side of globalisation, with the overall goal of achieving a "stronger, cleaner, fairer world economy". However, the automatic, uncritical promotion of internationalisation has never characterised the work of the Global Science Forum since its beginnings in 1992. Indeed, participants in GSF activities have always favoured a cautious, deliberate approach, being mindful, based on real-life experiences, of the difficulties that can arise when familiar national procedures have to be adapted to the complex, diverse, and sometimes unfamiliar environment of international affairs. While the benefits of international planning and implementation can be significant, due attention must be given to the potential complications, among them:

- Delays and expenses associated with protracted international negotiations, and the necessity of involving non-scientific experts (e.g., lawyers, diplomats);
- Adoption of sub-optimal technical solutions due to *juste retour* sourcing/contracting requirements, or multiple sources for components of the infrastructure;
- Creation of sub-optimal financial or organisational arrangements due to the diverse reporting, oversight and authorisation requirements of international partners;
- Exclusion/isolation of certain national scientific communities whose countries are not part of the collaboration;

- Inhibition of competition in scientific fields where it has traditionally been vigorous and productive;
- Creation of new administrative structures that may take time to come up to desired standards of efficiency;
- Potential transformation of large international infrastructures into conservative, self-perpetuating entities that may not respond optimally to new scientific needs.

Given these complexities and potential pitfalls, great care must be taken when undertaking any international project. This report is not intended to discourage these undertakings, but to allow the stakeholders and participants to anticipate and prepare for likely developments.

2. Methodology

The Global Science Forum authorised an activity on the establishment of large infrastructures at its 20th meeting in April, 2009. To supervise the project, ten delegations appointed members of an International Experts Group[2]. The Group was led by Dr. Hermann-Friedrich Wagner, Chairman of the Global Science Forum. The implementation of the project was assigned to the secretariat of the GSF, principally to its Executive Secretary, Stefan Michalowski, who is the author of this report. It was stipulated that the activity should be completed before the end of 2010, and that a workshop be held, with participants nominated by GSF member countries.

The Terms of Reference of the activity were agreed to during a teleconference of the International Experts Group on July 2, 2009. In accordance with the approved work programme, the OECD secretariat conducted confidential interviews with knowledgeable individuals during the summer, fall, and winter of 2009. Each discussion lasted one to two hours. Thirty-three persons were interviewed – they are listed in Appendix B. All of the essential information in the interviews is incorporated into the text[3]. Given that the interviewed experts had a wide range of experiences and represented diverse points of view, the report as a whole does not constitute a self-consistent description for how to go about bringing international partners together to implement a joint research project.

An advanced draft of this report was discussed at a workshop that was held in Bologna, Italy, on October 7/8, 2010. The participants, listed in Appendix C, were nominated by GSF delegations, and six independent experts were invited by the OECD secretariat. The present final draft incorporates the results of the workshop. It was reviewed and approved for public distribution by the Bureau (the Chair and Vice-Chairs) of the Global Science Forum in December, 2010.

As already mentioned, this report is, by design, non-prescriptive. However, there are places in the text where strict neutrality is not feasible, principally because the point being made is almost indisputably true, and was asserted strongly by more than one of the persons interviewed during the course of the project.

[2] The members of the International Experts Group are listed in Appendix A.

[3] The interviewed experts were given a chance to review an early draft of the report, and their comments were incorporated into a revised version, prior to the Bologna workshop.

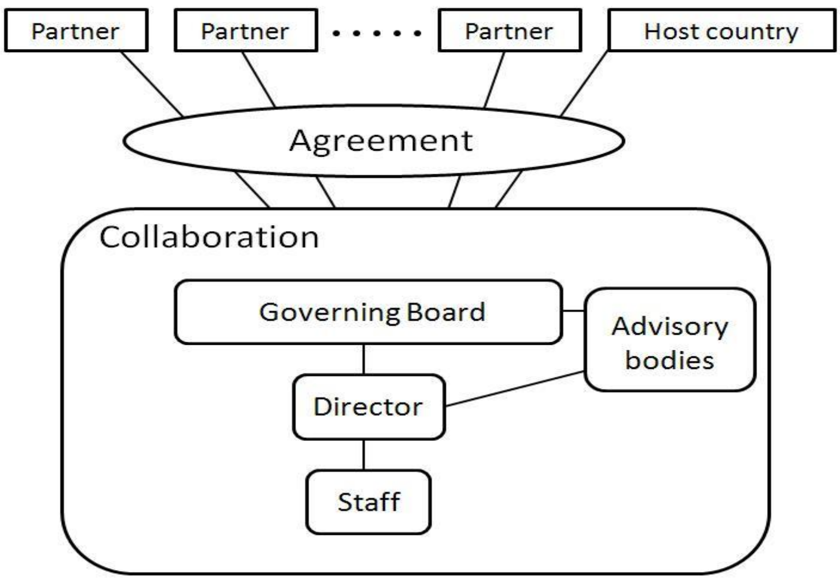
3. Legal and Administrative Issues

3.1 Legal/administrative structures, and governance

The term "governance" encompasses the set of structures, principles, rules and procedures through which a collaboration operates, and through which decisions are made by the parties to the collaboration. One of the most important decisions regarding a large infrastructure is its fundamental legal/administrative structure. Among the possible arrangements are:

- International Organisation [archetype models: CERN, EMBL, JINR (Dubna), ITER]
- Limited Liability Company or a *société civile* under national law [archetype models: ESRF, XFEL, FAIR]
- Association of independent national or regional infrastructures [archetype model: ALMA]
- Large collaboration between research institutions [archetype model: CERN detectors]
- Ex-post-facto collaborating infrastructures [archetype model: LIGO/VIRGO/GEO collaboration]
- Foundation under national law [archetype model: Pierre Auger Observatory, JIVE]
- European Research Infrastructure Consortium (ERIC) [a new mechanism, as yet untried (2010)]

For the purposes of this report – and as a way of introducing its basic terminology – the elements of governance are depicted in the figure and described in the paragraphs that follow[4]. It is recognised, of course, that not all collaborations have this structure (indeed, some are explicitly designed to avoid creating anything with this level of complexity and formality). The terminology ("Partner", "Governing Board", etc.) is purely notional – many other terms are can, and have been, used.



[4] As already stated, the fact that this particular structure is described in some detail should not be taken to signify that it (or any other arrangement) is being promoted or endorsed by the OECD. In this report, the depicted structure merely serves as a vehicle for enumerating a maximum number of issues that came up in the course of the interviews that were conducted with the experts listed in Appendix B.

Depending on the nature of the new infrastructure, different legal/administrative structures may be appropriate for the successive phases of the project (R&D/design, construction, commissioning, utilisation, decommissioning). This is because the requirements could be quite different in such matters as financing, management, and oversight. Thus, for example, the construction of a telescope could be a very large, complex operation involving the expenditure of hundreds of millions of dollars/euros, a changing cast of dozens of contractors in as many countries, hundreds of technical staff, numerous contingencies and complications, etc.; whereas the research exploitation of the instrument could be accomplished by a handful of technical personnel working at a single remote location.

3.1.1 The Agreement

The Agreement document needs to be carefully prepared by a group representing the potential Partners. The effort involved should not be underestimated: for large infrastructures, several years, and numerous physical meetings, may be needed to reach consensus on the Agreement. Strong leadership is essential: the effort is unlikely to succeed without the personal dedication of at least one individual who has the necessary ability, experience, authority, interpersonal skills and professional reputation.

Proponents of any potential infrastructure must make two key initial choices: deciding on the administrative level at which the negotiations will take place, and the political level at which the Agreement will be signed. The advantage of a high-level Agreement is that it both embodies and symbolises the strong commitment of the Partners, which may be useful at a future time, when difficulties are encountered and the strength of the partnership is put to the test[5]. On the other hand, high-level Agreements tend to be difficult to change - a future potential liability when practical experience may necessitate adjustments or even major modifications.

Formal collaboration documents sometimes state explicitly whether the terms of the agreement are "legally binding" (or "not legally binding") on the signatories. Negotiations on this sensitive point may become difficult and protracted. Even if the clause is adopted, the practical implications may be unclear, especially if the signing parties are governments, and in the absence of an international constraint or enforcement mechanism. In negotiating the Agreement, a potentially useful alternative strategy is to agree on concrete actions that would be taken in the event of explicitly specified departures from the terms (for example, if one of the Partners does not provide the agreed financial contribution, or wishes to leave the collaboration).

The Agreement will normally be valid for a fixed time period. It should include a description of the processes through which it can be modified, terminated or extended. When planning extensions, consideration must be given to the amounts of time that will likely be needed by the Partners to complete their consultation and authorisation processes.

[5] Thus, an Agreement signed by the heads of university departments is unlikely to be as robust as one that is signed by the heads of national research agencies.

3.1.2 The Partners

The Partners are the parties to the Agreement and the participants in the scientific collaboration. They fund the project, and collectively make all major decisions concerning it. It is desirable for all of them to be of the same or similar type, e.g., national governments (countries) or intergovernmental organisations, government laboratories, academic institutions. This simplifies the issue of representation on the Governing Board, but in practice it is not always possible. In OECD countries alone, there is considerable diversity in the types of organisations that make up national research systems[6]. Within individual institutions, various combinations of the essential functions (priority-setting, planning, funding, conducting research, oversight, evaluation) are possible. Diversity of mandates and levels of authority (and, especially, of relationships to governments) may complicate the establishment and operations of a partnership.

Intergovernmental organisations as Partners present a special challenge, due to a possible perception that a country can acquire an inappropriate advantage (for example, when voting takes place) by being a Partner in its own right and also a member of an intergovernmental organisation.

There may arise a situation in which an international collaboration is negotiated by representatives of a national funding agency, but the agency itself cannot be a Partner because it itself does not perform research. The agency will award a grant (possibly based on a competition) to some research institution (e.g., a university department or a laboratory) which will be the Partner. The agency may, at some future date, want to have the option of changing the identity of the operational grantee (for example, based on a new competition following the expiration of the grant period). In a case such as this, the Agreement will have to provide a simple mechanism for such a change of Partner.

Having the smallest possible number of Partners participating in negotiations and signing the Agreement can be an advantage. Accordingly, various forms of collective partnerships can be envisaged. For example, two or more countries can form a consortium that, collectively, exceeds a threshold for a required financial contribution[7]. Existing collective structures offer a potential advantage of efficiency and simplicity, especially at the European level, where there is already an ensemble of well-established partnerships, beginning with the European Union itself. Other European entities, such as the research organisations of the EIROForum (CERN, EFDA JET, EMBL, ESA, ESO, ESRF, ILL) could, under the right circumstances and if the members so desire, play the role of a Partner in a new undertaking. The European Research Infrastructure Consortium (ERIC) mechanism could, in principle, be used to create a nucleus around which a global-scale (i.e., not uniquely European) collaboration could be constructed, or as a (European) Partner in a global project. As of the date of this report, however, no ERICs have been established, although a number are under consideration.

The possibility of collective memberships located in other world regions could be considered. A related option involves constructing "trans-regional" collective memberships (e.g., a South American country

[6] For example, scientific academies can be either independent member-based organisations or, in some countries, they can be governmental funding agencies.

[7] Presumably, the consortium would be treated as a single Partner in such areas as access rights or voting on the Governing Board.

joins a European body in order to participate in an infrastructure agreement of which the European body is a collective Partner). The prospects for collective participation by Asian and South American countries are of interest, given that these new centres of scientific excellence are growing and evolving rapidly.

It may be useful to define two or more categories of participation, depending on the degree of partners' involvement (especially in terms of financial contributions). Thus, there can be Observers, Associate Partners, etc. In each case, the categories should be clearly described in the Agreement, along with any associated rights and obligations.

3.1.3 The Collaboration

The Collaboration[8] is the entity established by the Partners, through the Agreement, in order to carry out the planned scientific project. The Collaboration has a legal identity in the host country, allowing such functions as the hiring of staff and consultants, purchasing equipment, owning land, and entering into contracts of various kinds. (As will be seen below, a Collaboration may be created within a larger, pre-existing Collaboration, and be incorporated into the legal and organisational structures of that Collaboration.)

3.1.4 The Governing Board

The Governing Board is the principal decision-making body for the Collaboration. Its mandate, and its fundamental structure and procedures, must be laid out clearly in the Agreement. Typically, it will meet once or twice a year to review progress and to make major decisions. Normally, each Partner names one representative to the Governing Board. If there is more than one category of Partner, the roles of their representatives on the Board must be precisely defined.

If the Governing Board is very large, it may be useful to establish an Executive Committee to which the Governing Board will delegate some decision-making authority, especially in between Board meetings.

It is usually desirable for the Governing Board to make decisions by consensus, without the necessity of voting. But major decisions (for example, approval of budgets and work programmes) may require a vote, in which case the procedures must be spelled out in detail. It may be desirable to adopt different voting schemes (absolute majority, qualified majority, etc.) for different classes of decisions. A possible complication arises if there is more than one Partner (for example, a research institution, university, or laboratory) per country. In such a case, it must be decided whether each one will be represented (and will have a vote) on the Governing Board.

When devising a governance structure, and in the early stages of their consultations, the Partners should decide about the balance of power and authority that they want to attribute to themselves individually (i.e., their home institutions: ministries, agencies, etc.), to the Governing Board (which will represent them collectively), and to the Director with his/her Staff. There is an understandable desire among the Partners to maintain control of the project, since they are accountable at the national level for the efficient spending of public funds. On international projects, they may face extra scrutiny (for example, from parliaments), especially in countries that have a tradition of strong, predominantly national programmes.

[8] In this report, "Collaboration", when capitalised, designates an international infrastructure that is defined by an Agreement, as illustrated on page 6. Thus, CERN, ALMA, ITER, etc. are all Collaborations.

But the Collaboration's staff will need the authority and resources to make timely decisions as well, without the necessity of always seeking the explicit approval of the Partners. Failing this, demoralisation may occur, and it can become increasingly difficult to recruit high-quality, dynamic individuals to join the project.

With time, as a Collaboration matures and acquires an identity, it may (via its Director and senior staff) also acquire a tendency to protect its interests, to enlarge its scope and ambitions, and to perpetuate itself indefinitely. This natural tendency could manifest itself as tension between the Governing Board (which collectively represents the Partners) and the Director and his/her Staff (who represent the Collaboration). Properly anticipated, it can be channelled constructively. The question of how much power and authority to vest in the Director and Staff is not an abstract, philosophical one. It influences, and is influenced by, other fundamental features of the Collaboration: its legal standing, the ratio of cash to in-kind contributions, the types of contracts offered to employees, etc. These are described in more detail in other sections of this report.

3.1.5 The Host country

The Host country provides the physical and legal venues for the Collaboration. The Collaboration, Director and Staff will be subject to the laws of that country, but their precise status, rights, and obligations have to be clearly defined.

All of the Partners must be satisfied that the Host country will not exert an excessive influence within the Collaboration simply by virtue of being its physical host. Naturally, national and local laws, regulations and administrative requirements will impose certain constraints on the partnership, for example, in the matters of safety or labour laws (e.g., working hours, retirement age, evaluation, promotion, dismissal). Given the diversity of such laws in different countries, the Partners can, if so desired, configure the Collaboration as an international organisation, which may be granted a kind of quasi-diplomatic status with a variety of immunities and exemptions from some (but certainly not all) national laws. Given the benefits to the Host, there will be an expectation that it will pay an additional contribution ("premium") towards the overall budget (unless, of course, the Partners decide otherwise, for example, by committing themselves to strictly equal shares).

The benefits that accrue to the Host country should not be confused with any natural, legitimate advantage that the country may have due to its excellence in the relevant scientific fields. It is not at all unusual for a scientifically prominent country to offer to host a state-of-the-art infrastructure. Furthermore, it is understood that the host country will derive legitimate rewards, both tangible (e.g., employment of local support staff) and intangible (international prestige, attractiveness to students and researchers, etc.).

As depicted in the figure on page 6, the Host country is normally one of the parties that establishes the Collaboration via the Agreement. The other Partners may be countries (governments) as well, or they could be entities of another kind (agencies, institutions, laboratories, universities). There may be a need for a separate document (not depicted in the figure), negotiated and signed by the Collaboration and the Host country. It would specify the legal and financial arrangements that apply to the Collaboration in the Host country.

The Partners will want to derive maximum benefits from their financial contributions, so they will be very reluctant to augment the national treasury of the Host, for example, in the form of customs duties or income/sales taxes. Thus, the Host will be well advised to offer the appropriate special status or exemptions that are compatible with its national laws, and to specify the details of these concessions in the Agreement.

It may not be possible to reach final agreement on some aspects of governance until the Host country (and therefore, in many cases, the physical location) of the infrastructure is chosen. This is due to possible divergences in national laws and regulations concerning such matters as employment (e.g., non-discrimination, pensions and retirement, job security) or safety and environmental issues. It is, therefore, pointless to spend any time in detailed consideration of these matters prior to the selection of the site/host.

In most cases, large international research infrastructures will be independent entities with a well-defined legal status (e.g., limited liability company, foundation, international organisation) in a Host country. But, as discussed in Section 3.2, a new infrastructure can be established within an already existing organisational and legal entity (for example, a university, laboratory or international organisation). In all cases, the laws and regulations of the Host country will be applicable (unless explicit exemptions are granted).

3.1.6 The Director and the Staff

The Staff (whether full- or part-time) are paid by funds provided by the Partners. They may be employees of the Collaboration, or, as detailees/secondees, they may retain an affiliation with a national institution. They are supervised by the Director, and, through him/her, answer to the Governing Board.

The Director is a key individual, and the success of the Collaboration will, to a significant extent, depend on his/her abilities as a scientist, manager, spokesperson and diplomat. The Director needs to be someone of experience and stature, chosen on the basis of reputation and excellence. It may be best to not link this selection to other considerations that are part of the negotiations among the Partners (e.g., contribution levels, site). A possible strategy is to agree on the Director's qualifications, and on the selection process, in early stages of the negotiations, before contentious issues arise. In particular, it may be desirable to agree, at an early stage, that the Director's nationality will not be considered as a selection criterion.

The qualities that make a good Director are not necessarily those possessed by the scientific leaders of the field(s) which the infrastructure is to serve. This could be the case if the field is in the process of "ramping up" in scale, and where there are no individuals who have hands-on experience in the management of very large undertakings. Even a history of success in leading small- and medium-scale international collaborations does not necessarily qualify an individual to lead a much larger effort. In that case, it may be wise to bring in an experienced individual from another domain.

The Governing Board will be strongly motivated to recruit a person of high standing. This necessitates early agreement among the Partners about the salary range and other conditions of employment. To attract a person of sufficient calibre, it may be necessary to offer an employment contract of significant duration (say, five years), especially if the Director and his/her family will have to move from another country.

3.2 Creating a new structure/organisation versus using an existing one

The importance of judiciously selecting the Host and site of a research infrastructure is universally recognised. The selection involves two key linked issues: whether to choose an existing physical laboratory location versus a new "green field" site, and whether to take advantage of an existing legal/administrative entity or create a new one that is tailored to the international collaboration. This section of the report addresses the pros and cons of the second question.

The following are perceived positive aspects of using an existing legal/administrative/managerial structure:

1. The new project can benefit from the reputation, stability, established/tested mechanisms and procedures of the existing structure. This can include valuable national political support, if the existing structure is associated with a recognised priority, for example, promoting regional integration, reducing international tensions, or protecting the environment. The existing structure most likely possesses a strong, long-standing legal status (for example, if it was established via an international treaty) and, to a significant extent, the new project can instantly "inherit" some part of the attributes of the existing one. There could be very tangible benefits in associating all of the members of the existing organisation with the new project at once, via a single instrument (Memorandum of Understanding, Agreement, etc.). Historical evidence shows that starting up a new international undertaking is fraught with difficulties, many of which are hard to anticipate. These can be avoided by taking advantage of an existing body that has already gone through the "learning curve" phase. As in any organisation, an expansion may involve some temporary difficulties of adjustment; however, it seems that a stable, established entity can readily accommodate enlargement by a factor of two, or perhaps even more.

2. The host country may have a well-established history of financial and political support for the existing organisation, and may be willing to extend its generosity to the new project. The established organisation, seeing the new project as an enhancement of its own prospects and prestige (and as an opportunity to bring in new contributing members) may be motivated to provide valuable support in various forms: equipment, manpower, facilities, even cash.

3. In the most straightforward case, a new project can become the next major phase in the ongoing (and, possibly, quite long) history of an existing organisation. In that situation, familiar mechanisms of review, authorisation, monitoring and funding can be used to smooth the way for the new project, using experienced personnel and established procedures. If the new project is a logical continuation of the historical research activity at the existing organisation, this should guarantee that the local staff will be knowledgeable and motivated. The existing facility may already possess some of the permits and authorisations needed for the installation of new equipment, for handling certain kinds of materials, or other essential functions that require interaction with external authorities. Enlarging an existing organisation is sometimes unexpectedly simple, requiring only minimal modifications to existing documents and arrangements. For example, if the organisation is already a national limited liability company, it may not be difficult to allow foreign entities (even governments) to hold shares. But only a detailed analysis by qualified persons (e.g., lawyers) can ascertain the difficulty of such an enlargement.

4. There may be very practical consequences of using an existing structure, for example, the ability to borrow money should this be necessary, based on the established history, stability, credit rating and reputation of the existing organisation.

5. Bringing a new international collaboration into an established international venue can provide benefits to the Partners in the collaboration. For example, their national enterprises can be awarded contracts, and their citizens can obtain jobs in the existing organisation, including opportunities linked to established activities and projects. Furthermore, entering countries or institutions can gain a voice in the decision-making bodies of the organisation (which, almost certainly, will be one that already has high importance and prestige on a global level).

6. When the project begins, it is desirable to demonstrate success and dynamism during the first year or two, in order to reassure the Partners that the right decisions were made, and to attract additional Partners who may have been reluctant to join but who are still observing the new initiative with interest. But it is difficult to "hit the ground running" without individuals of the highest quality occupying the key staff positions, and if those who have been recruited have not yet had time to form an efficient team. Indeed, it can take more than a year to achieve stable operations during the critical initial period. This difficulty can, to some extent, be avoided if experienced individuals from the existing institution begin work immediately on the new project. With time, they can be replaced with new hires or detailees.

7. The experienced scientists and administrators who were interviewed for this report stressed the importance of intangible, qualitative factors such as reputation, experience and trust in the successful establishment and implementation of research infrastructures. These cannot be created (or even acquired) on a short-term basis. Similarly, many of the tangible assets of an established facility are only acquired with time: large and small high-tech companies nearby, a pool of skilled potential employees, a supportive local government, plus educational, cultural and recreational facilities. For some types of research infrastructures, support of the local population is vital, since civil society-based groups can sometimes delay or even prevent the establishment of a new facility. This is less likely to occur if a familiar prestigious institution is already implanted in the area. All of these advantages are unlikely to emerge *de novo* on a short time scale on an entirely new site.

The following are potential challenges or drawbacks of using an existing structure:

1. Complications can arise when the new project is only one of the multiple activities of the larger organisation within which it becomes embedded. There can be frictions due to competing interests, loyalties, preferences and priorities. A new group of Partners who integrate their project into an established institution will find that senior administrative and technical positions are occupied by strong individuals whose views and preferences need to be taken into account (this can be seen as an advantage, depending on the circumstances). All organisations seek to ensure their own survival, but this natural tendency can become a problem if the long-term interests of an organisation are somehow incompatible with the priorities of the scientific communities (or the administrations) of the Partner countries on such matters as technology choices, or the phasing-in time of various scientific measurements.

2. Difficulties may be encountered when new international Partners (governments, agencies or institutions) join the existing organisation solely because they wish to be members of the new collaboration. There may be inflexible requirements for membership that are difficult or impossible for the potential new Partner to fulfil. Additionally, a potential new Partner may not wish to participate in all of the financial and governance mechanisms that are required of all members of the organisation. A particularly sensitive subject may have to be confronted: the potential recovery from the new Partner of some fraction of the costs already incurred by the organisation that is being joined. This latter concern may not apply if the new potential Partner qualifies for membership (or is a member) of a regional grouping that is already a member of the organisation. It may, in theory, be possible to create an administrative/financial “enclave” for the new project which would isolate the new Partners from the obligations and responsibilities of subprojects that they do not participate in, but implementation could be difficult and the results imperfect. There is, additionally, a potential complication if a member of the existing body does not wish to participate in (and contribute to) the new project.

3. A number of interviewed experts expressed reservations about the potential global-scale concentration of scientific activity in a single institution and/or a single geographical location. Traditionally, science has advanced well in a spirit of constructive competition between countries and regions. Furthermore, the duplication of measurements at more than one venue (ideally, using somewhat different techniques) is a valuable, proven tool for ensuring the validity of experimental results. Indeed, experimental reproducibility is a hallmark of the scientific method. Furthermore, there is a concern that, once a single site becomes the “world laboratory” for a domain of research, this arrangement will tend to perpetuate itself for an indefinite time, thus creating an artificial barrier to the emergence of new dynamic centres of research.

3.3 Access (to the site, to the scientific resources, to the data)

Access to the scientific resources of the infrastructure is treated in the Funding and Contributions section of this report. But two related issues must be considered when the infrastructure is being established: physical access, and access to the results of measurements (the data).

When considering a potential physical site, Partners will want to scrutinise the host country’s visa requirements, especially for potential users from non-Partner countries. A proposed site may impose additional restrictions, especially if it is already being used for sensitive national activities. In some cases, special arrangements may be possible (for example, dividing the site into zones with different levels of security) but the implications and complexities should not be underestimated. In this regard, a useful mental exercise consists of imagining a hypothetical future deterioration of the international political or security environment, and the impact that it could have on physical access by users of various nationalities.

Partners need to decide on rules and procedures for making experimental data available to external researchers who were not involved in the experiments. One widely used method is to allow experimental teams to not disclose data for a finite time (e.g., twelve months) in order to extract scientific findings and to prepare publications. In theory, following that period, requests for data from external researchers should be honoured, but Partners may wish to consider whether any special conditions (for example, limiting the level of detail) should be attached to the disclosure, and who should be responsible for the effort and cost of making the data available. It may be necessary to reconcile differing national practices (or even laws: for example, "freedom of information" requirements) that apply in the Partner countries, especially those pertaining to data obtained using public funds. The advice of lawyers could be sought.

In general, raw experimental data are not very useful without a set of annotations that describe the conditions under which the data were acquired. These can be extensive, and can include the parameters of the infrastructure itself (e.g., various power readings, temperatures, pressures, positions of various assemblies), anomalies (e.g., dead pixels, channels), calibrations of many kinds (e.g., detector gains), and information about the data itself (so called "metadata" such as formats, compression protocols, commercial software standards). The scientifically unrewarding task of recording and managing these annotations must be assigned to qualified individuals. The Partners will need to allocate the required resources over the entire duration of the collaboration.

Curation and storage of data can be expensive and time-consuming. Periodically, major changes in data storage technology may require wholesale transfer to new media, which may involve significant purchases of equipment and/or services. Responsibility for these tasks must be assigned to some party.

3.4 International negotiations

3.4.1 The negotiators

There is a paradox that pervades the issue of how to organise negotiations of an Agreement to establish a Collaboration: the participants should be of an elevated rank/authority in their respective governments or institutions, so that they can make necessary decisions and proceed expeditiously; on the other hand, the participants must have the time and perseverance to deal with the many detailed issues and questions (such as the ones described in this report) on which agreement must be reached. Thus, it is important to allocate topics to the right negotiators. Too often, negotiators do not have the authority that is required, necessitating the postponement of decisions, frequent time-consuming referrals to higher-level decision-makers, and the convening of multiple meetings. In international negotiations, it is sometimes necessary for the participants to accept compromises and solutions that are sub-optimal from the national perspective, but are necessary for achieving consensus and for maintaining momentum. Typically, only senior officials have the authority, skills and experience that are needed for such negotiations to succeed. The consequences of delaying negotiations can be damaging: momentum can be lost, high-level officials can turn their attention to other projects, potential funds can vanish, national administrations and policies can change.

If the participation of senior officials is not possible during all negotiating sessions, a steering/oversight group of such persons can be established to provide overall continuity and guidance. The mere existence of such a high-level group can motivate subordinates to expedite matters.

As the text of the Agreement is refined in successive stages, the cast of participants usually needs to change. In the initial stages, scientific expertise is vital, whereas legal, political and administrative skills may be more in demand as the process nears its end. This natural progression needs to be anticipated and planned for. Diplomats and lawyers sometimes do not have the right background for fully understanding the infrastructure's research goals or physical requirements, and they will need time to acquire an adequate level of knowledge. This can be frustrating and time-consuming, especially if the compositions of Partner delegations evolve at different speeds or in different directions. In the worst case, new team members insist on a re-examination of issues that were already decided.

Strong personal leadership is a great asset in conducting negotiations and in bringing them to a timely conclusion. Ideally, a group of like-minded individuals, with good geographical distribution among participating potential Partners, will emerge to provide collective leadership. One of their more difficult tasks will be to judge the level of commitment of the potential Partners. They will certainly want to avoid a situation where one party consistently imposes significant conditions during the negotiations, but does not ultimately sign the negotiated Agreement.

3.4.2 The scope and organisation of negotiations

If, as often happens, one country or region takes the lead in initiating negotiations, the question arises: is it better to begin with a multi-lateral process, or a series of bi-lateral discussions (conducted in parallel or concurrently) between the lead entity and potential Partners? While there is no obvious unique answer to this question, it is probably desirable to explore the multilateral process first. It is inherently complex, but may lead to a speedier conclusion, with less likelihood of encountering major obstacles. As noted earlier, it is also desirable to minimise the number of Partners in a collaboration, taking advantage of various forms of collective membership.

A possible strategy for preventing delays can involve postponing sensitive questions regarding the utilisation of an infrastructure (e.g., access rules, operating costs, IPR), thus speeding up the initiation of the construction phase. However, the transition *process* from one phase to another would have to be agreed on.

The Agreement should be devoted to the most fundamental legal, financial and organisational matters, and should not over-prescribe the details of how the collaboration will operate, which are best left to the Governing Board. Once the Collaboration gets started, the Governing Board will establish its own formal rules of procedure, based on proven need. On a practical level, disagreements over small details and formulations can slow down the negotiations, causing loss of momentum, and risking a loss of support from senior officials.

Potential Partners should pay particular attention to the level of specificity used in the description of the Collaboration's work programme (which is *not* the same as the description of the rationale, legal status, mandate, and goals of the project). The work programme should be sufficiently specific to satisfy the reviewing and authorisation processes of the appropriate funding bodies, thus enabling interested parties to join. Adequate specificity also obviates the need to revisit the issues each time a new potential Partner steps forward. On the other hand, negotiators should be wary of over-determining the Collaboration via too much specificity in the Agreement, hindering the Collaboration from establishing its own subsidiary goals and activities (and from dropping others), once it begins operations.

Because negotiations may extend over several years, it is vital to ensure the proper management and storage of documents, decisions, procedures, personal information, plus other relevant materials. Accordingly, a small but adequate secretariat structure could be envisioned and modest resources allocated. For example, one of the potential Partners could take on this function, or the negotiations could be conducted under the aegis of an established international intergovernmental organisation. Naturally, care must be taken that the secretariat be strictly neutral regarding key issues such as site selection, and that the rules and procedures of the chosen venue not restrict the negotiators in a significant way.

3.4.3 The science case

In almost all instances, the early stages of international discussions include building a strong "science case" for the proposed collaborative research effort. Normally, funding agencies require this as a formal exercise, and will base decisions on a comparison of the strengths of the science cases of competing projects. The preparation of a science case is usually carried out with the participation of senior scientists, and may involve scientific associations, plus open and extensive consultation with the larger scientific community. Given the complexity and expense of large international infrastructures, robust scientific arguments are essential, based on extrapolating existing scientific knowledge and the plausibility that key unanswered questions can be addressed via the proposed new project. On the other hand, given the length of time required to negotiate, authorize, build and commission a large infrastructure (a decade or more), it can be difficult to properly account for the nature and pace of scientific discovery. By the time the proposed observations and experiments begin, the primary scientific goal (for example, the detection of an elementary particle, or the accurate measurement of a cosmological parameter) may no longer be of interest. Retrospectively, it has been found that the most important discoveries that are made using major scientific instruments are often ones that were not mentioned (or foreseen) in the original science case, but were enabled by the vastly enhanced scientific capabilities of the infrastructure. Accordingly, it has been suggested that, in making the case for major research infrastructures, special consideration should be given to the potential for serendipitous discoveries. Specifically, it is worth exploring the assignment of supplemental resources for instruments and facilities that open up new "discovery spaces" – that is, ones that allow measurements to be made in heretofore unexplored ranges of key parameters such as spectral range, sensitivity and resolution. Governmental authorities are very unlikely to accept a science case that is based on serendipity *alone*, but the "serendipity potential" of a proposed infrastructure could be included in the science case.

3.4.4 Language issues

The language in which the negotiations are conducted – and, most importantly, in which the final documents are to be written – is an issue that, if not addressed explicitly and early, can lead to delays, disputes and expenses. The issue may not be apparent when discussions about establishing an infrastructure begin among interested scientists, but it can emerge forcefully once other actors become involved. There are advantages to early selection of a single language, but this may not be possible for political, as well as practical reasons. If the potential unique language is not that of the host country, it is very likely that at least some of the collaboration documents will have to be drafted in that language. Multiple potential Partners may require that final documents be prepared in all relevant languages, and that all the versions have equal legal standing. It is possible to fulfil these requirements, albeit with considerable effort. Thus, it is important to address and resolve the language issue early, with a good understanding of the legal or administrative basis of each demand for a separate version of the Agreement. It may happen that, during the course of the collaboration, disputes emerge regarding the interpretation of certain formulations contained in the Agreement. In anticipation of this, the Agreement should contain a dispute resolution mechanism.

The final version of the Agreement must be signed by appropriate representatives of the Partners, i.e., by persons who actually have the authority to commit the Partners to observing the specified terms (notably, financial commitments). At the time when signatures are being collected, the actual entry into force of the Agreement can be contingent on the accumulation of a specified critical mass of support (for example, a certain number of signatories, or a certain total financial commitment).

3.5 Site and host selection

By many accounts, site selection for an infrastructure can be an extremely difficult and time-consuming phase of the international negotiations. If a “neutral” location of the site is imposed by science itself (for example, an orbiting observatory) then considerable simplifications can occur, even though the selection of sites for manufacturing, operations, or headquarters facilities may still present challenges to the negotiators. If, however, there is no intrinsic reason why the infrastructure should be physically located in a particular place, there is a need to anticipate the strong involvement of non-scientists in the final decision-making.

During the negotiations, an auction-like competition will likely be organised to select the Host country, with proposals (including an inventory of amenities to be contributed, e.g. buildings, furnishings, staff positions, tax and customs exemptions, etc.) submitted by the competing countries. The results will determine, among other things, the amount of the premium to be paid by the Host, thus lowering costs for the non-Host Partners. If correctly configured and conducted, such a competition can be a win-win proposition, but there is always a possibility that some competitors will emerge from the process with a variety of grievances, which is clearly undesirable since, among other reasons, it undermines the overall rationale for international collaboration on research infrastructures.

There is a strong likelihood that the final decision will be the result of complex negotiations, including non-scientific considerations, as well as economic and political tradeoffs that may never be fully explained or divulged publicly. The scientific proponents of an infrastructure will want to keep this in mind as they compile the data and analyses that they will submit to the negotiators. A helpful strategy consists of preparing a “site-independent design” that describes the infrastructure in as much detail as possible (including its all-important costs) without pre-judging its future location.

It is unlikely that a complete universal set of rules and procedures could ever be compiled for conducting site selection exercises. However, it is in the interests of all negotiating Partners to go as far as they can in defining the rules that they intend to follow, and to do so before contention between potential hosts emerges. If these rules are subsequently followed, it is less likely that the losers of the competition will resent the outcome.

An illustrative example: the particle physics detector model

In some cases, potential collaborating international Partners will seek to create the simplest administrative structure for a project, explicitly avoiding the creation of the kind of elaborate formal arrangement that is depicted in the figure on page 6. They will be naturally intrigued by the model that has, over the years, been perfected by particle physicists and which, most recently, finds its realisation in the big detectors at the LHC facility at CERN. These detector collaborations can involve very large groups (2000 or more) of scientists, working together under the terms of a memorandum of understanding, signed by 100 or more institutions in over two dozen countries. Moreover, these efforts tend to be based on in-kind contributions from the collaborators, with only a few percent of the overall budget provided in cash (primarily for system integration activities). Such arrangements are not unknown in other scientific domains, for example, they apply to some of the major instruments that have been installed on the European Southern Observatory's Very Large Telescope (VLT).

In the domain of particle physics, very large detector collaborations have an excellent reputation; however, when contemplating the possible application of this international collaboration mode to other scientific fields/domains, the following considerations are worth keeping in mind:

- The detector collaborations are initiated by self-organising groups of like-minded senior researchers, who have a long history of personal contacts and, often, collaborations on previous large projects. The individuals play key, direct roles in the projects, and have a strong personal (as well as professional) interest in their success.

- Particle physics detectors are inherently modular. While there are critical system integration issues and tasks (for example, for particle detectors, the distribution of power and signals, mechanical support, safety, etc.) the sub-units can, in general, be implemented and operated independently, which allows for a significant amount of flexibility and, hence, for distributed decentralised management.

- The management and leadership style is traditionally that of collegiality and consensus. The researchers tend to self-select based on shared technology preferences, proven expertise, and a history of success in the relevant scientific areas. The "light" management style is consistent with the fact that, in a large detector collaboration and at any given time, certain subsystems can be functioning sub-optimally (or, indeed, not at all) without undermining the entire experiment. This is usually not possible for a large complex infrastructure (for example, the accelerator) which must, accordingly, be implemented to a higher standard of performance and reliability (and must possess an organisation/management structure to match that standard).

- Most importantly (in the case of detector collaborations), the project is firmly embedded in a robust legal, administrative and technological environment: the accelerator organisation and laboratory. Typically, the laboratory itself is one of the collaborating Partners. This symbiotic configuration provides numerous advantages, with the result that the collaboration does not need to concern itself with certain matters for which it does not have to provide resources or organisational structures. Thus, the surrounding organisation provides essential services, such as purchasing and contracting, staff administration, safety management, utilities and other physical support (buildings, roads, parking, grounds-keeping, security). To the extent that the collaboration collects cash from its members into a Common Fund, the accelerator laboratory can maintain it, and disburse from it as needed. To the outside world (e.g., vendors) the collaboration appears as an integral part of the laboratory, and thus partakes of its established stability and reputation.

For the above reasons, the detector model may not be appropriate for many contemplated infrastructure collaborations, even if the overall budget and the number of collaborators are on the same scale as those of the big detectors. In any case, proponents of this particular model would do well to very closely scrutinise the degree to which their research project resembles and differs from the giant archetypes at the major high-energy physics laboratories.

4. Funding and Contributions

The initial stages of international discussions about a large international infrastructure will focus on the scientific nature of the project, the general characteristics of the project site, and a preliminary cost estimate. As the discussions advance and a seriously committed set of potential Partners emerges, an accurate cost will have to be agreed on, as well as the details of the financial rules and procedures. The goals of these advanced discussions concerning funding and contributions will be:

1. To agree on the total cost of the infrastructure. It is likely that the definition of what constitutes the "total cost" will differ significantly from country to country, so it will be important to arrive at a common understanding, and to recognize the practices, requirements and constraints that apply among the partners. The issues that will need to be discussed could include: whether to include the effects of inflation over the anticipated time span of the project (which can increase the total amount to a very significant extent); whether a contingency factor should be included to cover unanticipated expenditures (a difficult matter to reach agreement on, given that it is treated quite differently in various countries); whether to consider separately "new expenditures", as opposed to items like in-kind contributions of already-existing equipment, or the salaries of persons who will work on the project, but who are employed by national laboratories or universities, and are already budgeted for.

2. To agree on how contributions will be provided: in cash or in-kind (or a mixture), and how cash will be spent (e.g., contracting rules).

3. To arrive at an agreed scale (formula) of contributions from the Partners (which, if contributions are made in-kind, is only indirectly related to the amounts of money that will actually be spent). Historically, large international research projects have been funded using a wide variety of schemes, among them:

   - Equal shares.
   - Shares that are computed according to some algebraic formula, using one or more input variables. A common variable is Gross Domestic Product (GDP) or its equivalent, but other ones can be used, e.g., Gross Domestic Expenditure for Research and Development (GERD). In all cases, the source of data must be specified (e.g., World Bank, OECD), taking into account the delays or other complications that may apply. The formula can be tailored to suit the needs of the Partners: it can be linear or not, can include a minimum threshold, a maximum cap, etc.
   - Shares that are identical within any of several fixed "bins" that are defined according to some variable such as GDP. The advantages are that Partners that are nearly equivalent pay the same amount, that disagreements over the exact value of the variable for any Partner become irrelevant, as do annual variations (unless they are explicitly allowed to change). Naturally, problems can arise if one of the Partners crosses the boundary of a bin, with a sudden large increase or decrease of its corresponding share.

   In all cases, the Partners will need to agree on the currency that is used for defining shares, and on the method for assessing the cash-equivalent value of any non-cash contributions. In some cases, the size of the share may be linked to access to the resources of the infrastructure. As already mentioned, different categories of partnership can also be defined (for example, in order to provide access for scientists from developing countries). In addition, when assigning shares of costs to the Partners, it may be necessary to make an adjustment for amounts already spent prior to the beginning of the detailed financial negotiations.

4. To define the successive phases of the undertaking (typically, these consist of design and R&D, construction, commissioning, operations, and decommissioning) including any variations in the financial arrangements during these phases.

5. To conduct a financial risk analysis that will inform them about the probabilities and consequences of potential perturbations to the nominal work plan and financial arrangements.

6. To decide on how the operations of the completed infrastructure will be financed, including the handling of external income, if any (e.g., in the case of a user facility, payments received for services provided to private enterprises).

7. To define any special contributions or conditions that will apply to the host country or region ("host premium").

In the discussions, the collaboration Partners have the following motivations:

1. To achieve a high level of cost efficiency, recognising that, in many cases, international projects are costlier than national ones[9]. In general, collaborating Partners will wish to spend as little as possible while achieving the agreed-upon scientific objectives[10].

2. To receive benefits that are commensurate with the contributions (*juste retour*, fair return) in the form of scientific advances, contracts and employment opportunities. To profit from the potential for new technology development, contracts awarded to domestic industries, improved national economic competitiveness, plus training of students, engineers and technicians.

3. To put in place robust, transparent procedures that protect against delays and cost overruns.

4. To the extent that the scale of contributions is linked to governance mechanisms (e.g., voting in the governing bodies, access to the facilities and data), to maximise their own ability to influence decisions that will be taken during the course of the project.

[9] When asked, all of the interviewed experts agreed that a given infrastructure will cost more if it is implemented on an international basis. One expert estimated the "internationalisation penalty" for a large construction project to be on the order of 20%, but pointed out that the alternative to a costly international project may be … no project at all!

[10] There may be exceptions to this; for example, if a country seeks to stimulate an industrial sector, or the economy of a geographical region, via an infusion of R&D funds and procurements.

4.1 Cash versus in-kind contributions

In the interviews conducted by the OECD secretariat with the experts listed in Appendix B, achieving the right balance between cash and in-kind contributions emerged as a major topic, with a significant impact on the success of a large infrastructure project. Specific projects (past, existing and proposed) are often characterised by their cash/in-kind ratio[11]. Clearly, there is no universal formula that can be applied in all cases, but what follows is a compendium of factors that the potential collaborators should consider.

4.1.1 In-kind considerations

Collaborating countries are usually strongly motivated to provide their contributions in kind, i.e., directly in the form of equipment and services of national origin. Often, the responsible research ministries/agencies are mindful of the need to maintain the support of parliaments which, in turn, are particularly attached to spending taxpayer money domestically, to preserving jobs in the home country, and to maintaining oversight using familiar national tools and mechanisms. Another "political" issue concerns maintaining support of key national laboratories and other research institutions. Participation in a big project on foreign soil is bound to create some anxiety in these institutions. To some extent, it can be put to rest by giving them important, challenging tasks associated with in-kind contributions (this is especially true if any of them failed in a bid to be the site of the project).

When Partners commit to providing in-kind contributions based on agreed valuations, a time schedule, and technical specifications, they normally accept all of the associated risks. In the case of technical components, individual Partners will have to assume liability if the actual cost is higher than the valuation, due, for example, to unanticipated increases in the price of a key material, or unexpected technological difficulties and the necessity of additional R&D, prototyping, testing, etc. In this way, the adoption of an in-kind contribution scheme offloads risk from the collaboration. It also simplifies the risk analysis and risk management aspects of the project – two areas where agreement can be difficult to reach because of the diversity and even incompatibility of national approaches.

A situation may arise when one of the Partners wishes to make an in-kind contribution of an item that is of relatively little interest to the others (for example, a scientific instrument for measurements that are the special province of researchers in the potential donor country). This could be a source of contention, given that, ideally, each currency-unit contribution should be of equal weight and benefit to the project. The problem could be resolved by applying a negotiated discount (for example, 50%) to the value of the in-kind contribution.

An in-kind contribution scheme entails a degree of risk to the collaboration. The promised equipment may not be delivered on schedule (or at all) because of insurmountable technical or financial obstacles, or because the Partner leaves the collaboration. If there is sufficient transparency, communication, and foresight, these problems can be dealt with constructively. For example, financial help can be provided from a common cash fund (assuming, of course, that such a fund exists and the rules allow its use in situations of this kind). In-kind contributions are riskier when the design of the infrastructure is not sufficiently mature, and when significant R&D and testing remain to be done.

[11] Thus, for example, CERN is essentially an all-cash collaboration of its European members, whereas contributions to ITER are 90% in-kind.

Once the in-kind contributions are assessed and assigned among the Partners, there is a good prospect of minimising (or avoiding altogether) any unproductive disputes about *juste retour*. This is unlikely to be the case if large amounts of cash are to be spent.

Assigning value to in-kind contributions is a challenging process, and cannot be an exact science, especially if designs are not frozen and the technology is of an advanced kind. It must be done with care, however, especially if the relative contributions of the Partners are linked to governance or to access to the infrastructure. Normally, a formal cost assessment is carried out by a representative group of experts, who put together a consensus "Cost Book" using an agreed-upon currency. The costed values are nominal; that is, they are not expected to be exactly equal to the actual amounts that will be spent on each item. But they should accurately reflect the relative value of the items, taking into account the maturity of the technology and the designs. The following additional considerations apply:

- For unique high-tech items (e.g., exotic sensors, special-purpose computers or software) the task of assigning values is normally given to a special committee of experts, and is usually carried out <u>before</u> the assignments among the Partners are made. The experts must determine the extent to which they will enter into details of manufacturing, the costs of raw materials, etc. But a high-level policy decision may need to be made beforehand about whether VAT paid at the national level should be included in the accounting (keeping in mind that VAT rates differ among countries, and that some government-linked institutions may be exempt from VAT altogether).
- In the case of off-the-shelf commodity items (for example, cables, power supplies, computers) the distinction between cash and in-kind is less important (i.e., a Partner could just as easily send cash for purchasing the same items). However, there could be some lingering issues. If used items are provided (for example, components of a decommissioned facility) their value may need to be depreciated according to some negotiated formula. Similarly, a decision will be needed regarding payments of value-added tax.
- The Partners may agree that personnel can be classified as in-kind contributions. That is, secondees (detailees) can be provided in-kind, based on an agreed valuation of their services. There are some distinct advantages to this, notably exempting the infrastructure from various administrative obligations and burdens (recruitment, performance management, pensions, permanent accommodation of families, etc.). Furthermore, it allows optimising of operations by having, at any given time, only those people on site whose services are actually needed, without having to make long-term commitments to individuals. This is particularly welcome during the start-up phase of the project. There is a potential downside, however, especially in the case of personnel in senior decision-making positions. They should not be subject to conflict-of-interest pressures: their primary loyalty should be to the project, not to their home institution.
- Some large research infrastructures consist primarily of one kind of item (for example, linear particle accelerators which are – essentially – a linear sequence of radio frequency cavities with their associated power systems). The cost of this item dominates the overall budget and, thus, it may be necessary to divide up the in-kind contribution of this item among several Partners whose shares need to be set according to agreed proportions (for example, equal shares among the major Partners). It is unlikely that strictly identical items will then be supplied by the multiple Partners, because of variations in manufacturing processes and materials. Considerable attention must be paid to the specifications to ensure that all the units are "plug compatible", i.e., that, with regard to

an agreed set of essential performance parameters, they behave in exactly the same way when they are assembled in their final configuration. A major effort by technical experts may be needed before agreement can be reached on the detailed specifications and the measurement methodologies that will be used to ensure this "plug compatibility".

- Information technology (hardware and software, off-the-shelf and custom-made) is likely to be a costly component of a large research infrastructure[12]. The difficulties of implementing large distributed software structures that span national and institutional boundaries are well known. Among them are the measures that local system managers may need to undertake to allow secure, controlled access to their local computing systems. These managers are understandably protective of the computing assets for which they are responsible, so consultations with them must be initiated very early. To some extent, the trend towards de-centralised data storage and analysis simplifies the establishment of an infrastructure, since the overall burden (and the cost) is offloaded from the Collaboration to the Partners. However, as with the hardware components of a facility, the task of system integration has to be undertaken jointly, with an appropriate allocation of staff and resources. Ensuring overall system integrity/security is an especially important aspect of system integration. Luckily, the current expansion and popularity of Grid Computing is delivering standards and software (so-called "middleware") which automatically handle verification, authorisation and scheduling tasks based on internationally agreed standards, and across a wide range of operating systems and computing platforms. The provision of IT services during the operation of the infrastructure is normally included in operating costs, which are considered in Section 4.3.

4.1.2 Cash considerations

Some international research infrastructures are essentially "all cash", with annual contributions from the Partners that are computed using some agreed-upon formula. But other infrastructures are based on cash contributions of only a few percent of the overall budget (or even zero percent cash). During early discussions about collaborating on an international infrastructure, potential Partners, even if they have a preference for contributing in kind, will be well advised to devote considerable attention to the many goods and services for which cash may be needed.

For a variety of reasons, some Partners may prefer to provide their contributions exclusively in cash. It could be that they do not have the high-tech industries that are needed for manufacturing in-kind equipment. Or, they may simply have large amounts of cash to spend, based on a highly export-oriented economy or for other reasons. These Partners may have an expectation that a significant fraction of their cash contribution will return to their country in the form of contracts issued by the Collaboration, and they may want their expectation to be reflected in a formal agreement. This could create problems in the Collaboration, since the other Partners may wish to compete for these contracts. Furthermore, such national "earmarking" may result in less-than-optimal cost-effectiveness and, depending on the legal

[12] The volume of data flow in modern facilities can be enormous. For example, the raw data flow during one second from a CERN/LHC detector is about a terabyte, that is, the quantity of information contained in ten thousand complete sets of a twenty-volume encyclopaedia. Local pre-processing and compression can be helpful in reducing the IT burden; but there are also reasons for permanently storing as much raw data as possible, based on the hope of recovering rare/unexpected phenomena by creatively sifting through data that might seem useless at first.

standing of the infrastructure (and the privileges and immunities that it has been granted by the host country), it could violate laws that govern purchasing practices. In Europe, for example, EU legislation is quite strict about "sole sourcing" of purchases using public funds.

There is a link between the cash/in-kind ratio and the "host premium". Inevitably, a significant amount of cash will be spent in the host country, where local services and administrative/support staff can be obtained at the lowest cost and with the least effort. Accordingly, the non-host Partners will insist that a significant portion of this cash be provided by the host country. But that country will presumably want to provide in-kind contributions as well, being mindful of the advantages enumerated above (industrial development, etc.). The net result could be to increase the Host's total contribution, i.e., to inflate the "host premium". This phenomenon applies in somewhat different ways during the construction and operational phases.

A dependence on annual cash contributions will make a project more sensitive to currency exchange rate fluctuations. As in other areas, there is no recognised universal method for dealing with this difficult matter, but it should be examined during the discussions between potential collaborating Partners. Normally, cash contributions are re-computed annually (and accounts are kept) in the currency of the host country (unless the infrastructure is located in a given country simply because of scientific/physical requirements such as physical altitude, air quality, etc.). If desired, a limit can be placed on the maximum annual change in any contribution due to a change (positive and/or negative) in exchange rates.

In infrastructures where cash contributions are significant (for instance, on the order of 25% - 50%), they are normally placed in a so-called Common Fund, which can be disbursed by the Collaboration according to agreed-upon rules, under the supervision of a Finance Committee, or a similar body.

A good use of the Common Fund is purchasing a large, costly item that is not of sufficient technological interest to be an in-kind contribution from one of the Partners, but which is critical to the operation of the infrastructure and, therefore, whose design and fabrication have to be closely monitored by the Collaboration staff.

Typical expenditures from the Common Fund will involve hiring personnel, and contracting for goods and services. Contracts for items that are to be paid for out of the Common Fund could be awarded via a process of "internal bidding", in which all Partners are eligible to compete, and the lowest bidder is selected. However, the rules may allow awarding of contracts to entities in non-Partner countries. In both cases (but especially in the latter case) *juste retour* issues arise that deserve careful consideration as the collaboration is being established.

There is a linkage between the cash/in-kind ratio and governance. A cash-intensive organisation will need considerable personnel resources, and authority vested by the Partners, if it is to efficiently manage large expenditures.

The advantage of a cash-intensive project is that its administrators can exercise rigour, accountability and transparency in contracting and other financial operations, using consensus standards and procedures that are acceptable to all of the Partners. They can select the best bidders, subject to implicit or explicit *juste retour* constraints, as described below. Partner countries will appreciate the existence of a single venue where complete, accessible, up-to-date information is available regarding the financial status of the project.

The staff of the Collaboration will use a single integrated set of accounting procedures for managing incomes and expenditures, but this will probably not exempt them from fulfilling numerous requests for reporting and accounting using the diverse procedures of the Partners who will, in turn, need to report regularly to their national supervisory bodies. A knowledgeable, stable, and motivated group of local administrators will be needed to cope with all of these requests.

Regardless of the cash/in-kind ratio, system integration of in-kind components is an important responsibility of the on-site team, and it is important that the magnitude of this task not be underestimated. System integration requires an intimate knowledge of the design of the infrastructure, but also extensive experience and, if possible, first-hand knowledge about how the components of the overall system were built and tested. These are capabilities that cannot be put in place quickly. Accordingly, it is important to allocate sufficient resources, recognising that cash may be needed to hire the system integration team and to make sure that it has the resources that it needs.

Contractor oversight is an important responsibility of the Director and Staff. When a contractor (who might be a business, an academic department, or a research organisation) is located in a Partner country, subtle questions of authority and procedure could arise, especially if difficulties are encountered. The Partners need to agree on the conditions under which the Collaboration needs to consult the responsible national authorities when dealing with contractors, and the limits of the authority of the Director and Staff when dealing with national contractors (for example, access to technical and financial records, to intellectual property, or even to a sensitive physical site). As with most of the matters described in this report, it is best if agreement on issues can be reached before difficulties or complications arise.

A cash-intensive project is, sooner or later, likely to encounter problems, chiefly in the form of cost overruns and delays. In that event, it could become a target of criticism at national levels, especially in Partner countries that, in their own projects, practice financial rigour and have a very low tolerance for not meeting budgetary and schedule targets (although such countries will be more likely to allocate contingency funds to the overall budget). Countries differ in how they deal with overruns and the ease with which additional funds may be forthcoming, so it may be difficult to achieve a consensus on this sensitive matter.

When a Partner encounters difficulties in fulfilling in-kind commitments, it may turn to the Collaboration (i.e., to the other Partners) with a request for additional funds. This would typically occur when technical problems made it unlikely that performance or schedule obligations could be met for an item that the requesting Partner had agreed to deliver in-kind or via the process of “internal bidding” described above. It may be prudent for the Partners to agree beforehand on the rules and procedures (if any) that would govern the granting of such assistance. Conversely, it is possible to envisage that a Partner would return any savings or unused monies to the Common Fund.

4.2 *Juste retour*

Juste retour is the quantitative linkage between the contributions that a Partner makes to the Collaboration, and the benefits that the Partner obtains in terms of contracts awarded and nationals hired[13]. Indirect benefits, such as journal publications, personnel trained or enhanced scientific prestige, are not considered here. *Juste retour* can be a formal requirement, with strict accounting to ensure that money contributed returns to each Partner as the infrastructure is built and operated. More often, it is a "soft" requirement, where benefits, averaged over several years, are in some kind of approximate proportion to investments made. In any case, the negotiating Partners should agree on the degree to which they wish to apply *juste retour*. The responsibility for implementing the agreed-upon measures can be assigned to the individual members of the Governing Board. Their responsibilities would then include monitoring the benefits that their country receives, and intervening with the Director if an imbalance becomes a cause for concern. Or the responsibility can be assigned to the Director and the Staff.

When implementing *juste retour* provisions, all Collaborations will, at any time, have complete records of incomes (that is, funds received as contributions from Partners, payments from commercial users, etc.), but attributing a national character to contracts or other disbursements (whether for goods, services or personnel) can be problematic. It is simply not always obvious how to assign a nationality to a commercial entity or even an individual. Various attributes can be used: the location of the headquarters, the historical country of origin, the nationality of the most senior executive or the owners (who can, of course, be a vast ensemble of international shareholders), the principal manufacturing site. Furthermore, in the globalised economy, individual manufactured items (not to mention their raw materials and sub-assemblies) originate in many countries, only some of which are Partners in the Collaboration. Commercial entities that do all or most of their business online pose an even thornier problem. Similar complexities and ambiguities may apply to individuals hired by the Collaboration, and who may hold multiple passports or residency documents of various types in more than one country.

There is an intrinsic incongruity between *juste retour* and the requirement for least-cost (low bid) contracting. Countries with high manufacturing costs may consistently fail to win low-bid contracts, and may therefore wish to have exceptions made to low-bidder decisions, based on a *juste retour* argument. Sometimes, the Collaboration may need to award contracts (or hire individuals) because of uniqueness, exceptional quality or exceptionally low price, rather than national origin. Also (and least problematically) an expenditure may concern an item (typically, a large, low-tech assembly or structure) that is of no commercial interest to any of the Partners, and can be acquired in a non-Partner country for a relatively low price.

[13] Scientific *juste retour* is a separate matter, and is treated in the sections on Access and on Operating Costs. Similarly, the obvious tangible benefits to the host country are not considered here, although they can be quite substantial and can, indeed, motivate countries to step forward as potential hosts.

4.3 Operating costs, and scientific access to the infrastructure

Infrastructure operating costs can be very significant: for large research facilities, a "rule of thumb" is that the annual cost of operations is about 10% of the total construction cost. It includes: (1) the Staff of the Collaboration, including their benefits (most notably, pensions, which must be provided for in some way, if only by explicitly making employees responsible for their own arrangements); (2) the "non-scientific" infrastructure: buildings/offices and their maintenance, vehicles, roads, grounds-keeping, insurance; (3) Utilities, notably electricity (for some facilities, this can be a very high cost indeed), expendables, and replacement components; (4) maintenance and replacement of defective equipment; (5) R&D for new instruments, prototyping and upgrades; (6) educational and outreach activities.

Information technology costs (including computing services, data distribution and archiving) have to be considered in some detail, especially for data-oriented infrastructures (e.g., computing grids, supercomputer centres). Agreement must be reached on who provides the services (the Partners? the Collaboration?) and who pays the associated hardware, software and operational costs.

Any given Partner's fractional contribution to operating costs could be different from the fractional contribution to construction costs. For instance, a Partner might want to participate in the R&D and construction phases in order to acquire technological expertise and to be eligible for contracts, but may not wish to pay the same proportional amount for operations, anticipating that its scientists will not have a sufficient need for the types of measurements/experiments that the infrastructure will provide. Such a country should make its motives and intentions clear at the outset to all of the Partners, who may wish to make the matter a subject of negotiation. All Partners will want to examine their ability to fund operations over the anticipated lifetime of the infrastructure. This can be a challenging exercise, since construction and operations funds might not originate in the same national funding mechanisms. The former typically are of finite duration, while the latter will persist longer, possibly necessitating difficult decisions to reduce or terminate other projects.

The Partners need to consider the possibility that the utilisation of the infrastructure by scientists could be seen by national fiscal authorities as "purchasing a service", subject to value-added (sales) tax. Certain types of modern user facilities have the characteristic that the primary investigators do not need to spend any time at the location where measurements are made. For example, in the domain of condensed matter research, samples can be sent to a facility by post, inserted by local staff into standardised instruments, and the resulting data sent electronically to the researchers. Or, astronomers can email the coordinates of celestial objects to the operators of a telescope, together with details of how the measurements are to be made (instrument settings, etc.) and, again, obtain their data over the internet.

Potential Partners may wish to consider the possibility that, at some future time, one of them may not be able to fulfil their operating cost obligations (for example, due to unanticipated severe national budgetary restrictions, a collapse of domestic political support for the project, extreme currency fluctuations, etc.). It could be that the defaulting Partner already made a significant contribution to construction and operations, so various provisions can be designed (such as a grace period, or a graduated series of penalties: removal from decision-making, suspension from publications, etc.) to deal with the undesirable contingency, especially if the difficulties are seen as temporary.

A central issue, and a potentially contentious one, is that of a link (if any) between access to an infrastructure and the contribution to operating costs. In other words: what access conditions apply to scientists from countries that have not paid for the construction and/or operation of an infrastructure? This is a complex matter, to which justice cannot be done in this short report. In a sense, access issues mirror those associated with *juste retour* in construction and contracting. Historically, many facilities in the physical sciences followed the "ICFA guidelines for access" that were developed decades ago for particle accelerators. According to these, international access to a national facility was to be based solely on the merits of the proposed research[14], and operating costs were to be covered by the facility. Among the advantages of this scheme were the following:

- Maximising the scientific output of the facility, and advancing the frontiers of universally accessible knowledge.
- Reinforcing solidarity within the research community, and rewarding excellence regardless of factors seen as extrinsic to pure science (e.g., economic imbalances, geopolitical strife).
- Promoting balance and reciprocity in a global system where all scientists could compete, on an equal footing, for use of the best facilities anywhere in the world. Presumably, the guidelines would be most effective when, roughly averaged over many facilities and many years, and perhaps even more than one scientific domain, all countries would make comparable financial contributions to the global scientific enterprise.
- Simplifying facility operations by not having to keep track of, and manage, utilisation quotas.

It is an open question whether the ICFA guidelines (or similar "open, merit-based" principles) can continue to be applied to future infrastructures, especially in fields where cutting-edge research is increasingly concentrating around a small number (perhaps just one) of international infrastructures that are very costly to build and operate, where the scientific resources provided by the facility are heavily oversubscribed by potential users, and where the Partners are motivated to maximise their use of the infrastructure and have to provide an accounting to national authorities based on cost-effectiveness or competitive advantage. Potential collaborating Partners may wish to introduce access restrictions in order to discourage "free riding": a notional strategy in which a national entity decides not to become a paying Partner, trusting that its scientists will obtain access based on the excellence of their future research proposals. If widely practiced, such a strategy could clearly be counterproductive: in an extreme hypothetical case, a highly desirable infrastructure would not be built at all, because every country had expected to use it for free!

The ICFA guidelines lie at one end of the spectrum of possible access policies. At the other end, access is rigorously apportioned to researchers based on the fractional financial contribution of their country/institution to the Collaboration. In the latter case (and for schemes that lie in between the extremes) a procedure must be put in place for assigning a national designation to research proposals and projects. A variety of attributes could be used: the nationality of the principal investigator, of the main home institution, of the various co-investigators, etc. Each option will have advantages and drawbacks, but a choice will need to be made, and applied consistently.

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[14] In assessing merit, the capabilities of the researchers could be taken into account, along with the intrinsic importance of the proposed measurements and the chances of a successful outcome.

Even when access to the scientific resources is strictly apportioned among the Partners using an agreed formula and procedures, it may still be useful to devise a mechanism through which other researchers can apply for use of the infrastructure. For example:

- The Director may dispose of a small percentage of the resources for assignment based on his/her personal discretion, with a minimum of formalities, and without having to account for the selection.
- An institutional arrangement (e.g., a special office) can be established for the purpose of promoting research partnerships between external researchers, and those whose national or institutional affiliation entitles them to access the infrastructure.

In cases where each Partner is assigned an access quota, the Agreement may still allow for different rules for the subdivision of access within each quota, including for non-Partner researchers.

Given the complexities of the issues relating to operations, the uncertainty that pertains to estimating the actual costs of operations before they begin, and the desire to move ahead with the Collaboration in a speedy manner, the Partners may choose to postpone some or all of the decisions until construction of the infrastructure is well under way. Such a risky strategy would, presumably, only be adopted in unusual circumstances.

5. Project Management

This section of the report deals primarily with managing a research infrastructure during the planning and construction phases. Large, complex and costly research facilities such as accelerators, nuclear reactors and telescopes have, historically, been difficult to manage successfully, even though they are, in principle, no more intractable than other civilian projects of comparable (or even bigger) size, such as dams, bridges, power plants or oil refineries. A part of the difficulty lies in the traditions of empirical science on small or intermediate scales (less than, say, 100 million dollars/euros for the total budget), where charismatic scientific leaders have led highly motivated teams in a spirit of boldness, self-sufficiency and improvisation which does not always serve well at the scale of hundreds of millions dollars/euros. Accordingly, even though the ultimate goal of an infrastructure project may be to push back the frontiers of human knowledge, there is much that can be learned (and many practical techniques and tools that can be adopted) from the prosaic domains of industrial and civil engineering. Furthermore, the attributes that are possessed by strong scientific leaders may not be ideally suited to the early phases of a large project. If a distinguished scientist is chosen as Director, it could be wise to hire a highly experienced project manager as well, and to give this person the appropriate authority, staff and resources.

Standardised, proven, commercial software, and contractor services are available for supporting the management of large infrastructures. They are designed to facilitate the monitoring and coordination of multiple tasks that must go on in parallel and come together smoothly at critical stages of the project. Using these resources, all the diverse functional components of the project can be modelled and projected forward in time: delivery of raw materials, fabrication of sub-assemblies, system integration, testing, certification. Personnel and budget matters can be incorporated into the models. Project management is intimately linked to risk analysis, which is the systematic investigation of problems that could occur, combined with planning of strategies for dealing with these problems. Real or potential problems (such as delays) can be modelled as well, and their consequences studied as they propagate through the tightly coupled network of project tasks. In advanced applications, software simulations can be performed (using a Monte-Carlo-type algorithm) of multiple breakdowns in the construction/manufacturing/assembly process. Suitably interpreted, results of such a computation can provide early warning of systemic weakness in the overall plan.

Contracting for these commercial services is costly (typically, more than one million dollars/euros annually for large projects). Three considerations should be kept in mind: (1) some Partner countries may already have standard management tools and procedures that they use for large projects (indeed, their use may be mandatory at the national level); accordingly, negotiations will be needed to choose a set of consensus tools; (2) any analyses and projections will only be as good as the real-time data that they are based on – therefore, the Partners and sub-contractors must be willing to provide reliable information about the status of the sub-tasks that they are responsible for; (3) the Organisation staff cannot simply offload the entire management task to a contractor, because they are responsible for the overall project and have the specialised knowledge that is needed for making key decisions. Commercial services should be considered as merely a valuable management support tool. In particular, the Partners may wish to establish a standing committee that will monitor the status of critical components that are to be provided in kind by the Partners.

During negotiations between the Partners, project management modalities should be discussed, because they are linked to the type of legal administrative structure that is chosen (Section 3 of this report), and to the arrangements for funding and contributions (Section 4). If the Organisation staff (led by the Director) are to assume primary responsibility for overall project management, they must be endowed with the necessary resources (primarily in cash) and authority, and they must have access to real-time data about the status of all sub-tasks, even if this involves intrusive inspection of the work of national laboratories and/or industrial contractors. A complex project is unlikely to be delivered on time and on budget without a central locus of all essential information about the progress of the project.

6. Equipment

This section of the report deals with the scientific and technical components of an infrastructure facility, that is, the equipment that is needed to carry out the research mission (for example, scientific instruments/detectors, magnets, power supplies, telescope mirrors and mounts, etc.) Most of these are high-technology, one-of-a-kind items that are either provided in kind, purchased, or manufactured at the facility itself. Not considered here are items that are not unique to research infrastructures, such as buildings, utility structures, computers, or office furnishings.

In establishing the infrastructure, the Partners must decide about the ownership of the equipment. Typically, the Organisation will be the legal owner, so there must be a process associated with a transfer of title of in-kind equipment. The Organisation will presumably be provided with the results of tests and measurements as proof that technical specifications and requirements have been met, but it may want to require that a final set of tests be performed on-site, with the new components integrated into the bigger physical infrastructure. Personnel of the Organisation will be in charge of these measurements, and will authorise the change of title, but care must be taken to avoid conflict-of-interest situations if the staff members concerned have a personal link to the institution that manufactured the equipment.

If the equipment malfunctions during operations, rules and procedures should be in place to address responsibility and liability. Commercial commodity items (e.g., cables, power supplies) will be covered by a warranty. In the case of one-of-a-kind items provided by industry, the appropriate provisions will have to be written into the contract. Issues of liability for damage to persons and other equipment should also be considered. To the extent possible, it is imperative to avoid a situation in which a company's lawyers dispute liability, resulting in delays that are intolerable for a research facility. For this reason (and others) attention will need to be given to purchasing a sufficient quantity of spares for key components of the facility. This requires some discipline during the time when the total cost of the infrastructure is being defined, since it, naturally, raises that cost.

Even in cases where the Organisation assumes ownership of in-kind equipment, provided by one of the Partners, it may be desirable to stipulate that the Partner will repair the item if it malfunctions or if its performance deteriorates below a certain level.

During negotiations, the Partners will wish to look ahead to the time when the infrastructure is decommissioned. The disposition of equipment will have to be anticipated, including transfer of title if the legal partnership is dissolved. Typically, the host country will become the owner of the equipment, but the matter needs to be looked into in detail, since special considerations might apply (for example, if the equipment becomes radioactive or otherwise contaminated).

The design and construction of high-performance research equipment may result in the creation of intellectual property, and the Partners will want to consider IPR issues as they negotiate the Agreement. Historically, large research infrastructures have generated many innovative technologies, but little intellectual property, since openness and the sharing of ideas are traditional hallmarks of science. Laws concerning attribution of IPR during the course of publicly funded research vary considerably from country to country, so reaching a consensus of all the Partners could be difficult, and one simple option is to agree to systematically decline IPR during the course of the collaboration. However, when the development of certain items is contracted to industry, it could be possible to assert IPR, either by the companies concerned, or by the Organisation.

7. Personnel

In this section of the report, "Staff" are persons employed by the Collaboration, not by the home institutions of the Partners. Thus, this category does not include secondees/detailees who may, indeed, outnumber the Staff in some cases (their special concerns are addressed briefly below).

In recruiting members of the Staff, scientific/technological excellence will be a necessary, but not sufficient, requirement for employment. Thus, there may be considerations of geographical/national balance, international contacts and experience, linguistic skills, familiarity with the laws and procedures of the host country, etc. The makeup of the Staff, and certain terms of employment, could be subject to special conditions agreed to during the negotiations among the Partners, particularly during the site-selection phase. Negotiations will be required whenever there are divergences in employment practices (and even labour law) among the collaborating countries. Even when a consensus is reached among the Partners, there could still be incompatibilities with the laws or regulations of the host country. This is yet another reason why the Partners may choose to define a special legal status for the Collaboration (for example, an international organisation). The final decisions in these matters can only be taken after the host country has been selected.

The Partners must decide whether recruitment of Staff is to be entrusted to the Collaboration, or whether it is their own responsibility to select nationals that will become employees of the Collaboration. If the former option is chosen, sufficient resources have to be allocated. Recruitment and personnel management at the international level require special skills, sensitivity, and experience, for example, knowledge of different cultures, work styles, and expectations. Thus, staffing the recruitment office will itself require time and effort.

Potential candidates for staff positions will be concerned with the terms of employment and the conditions under which they and their families will live in the host country. Among their concerns will be: visa and tax status, potential employment for a spouse[15], schooling for children, health insurance, provision for loss of employment, pension rights. Although it is clearly desirable, it may prove difficult to assign identical benefits (for example, immunities and privileges such as special tax status) to all members of the Staff, especially nationals of the host country. In any case, the Governing Board will be well-advised to consider these factors from the point of view of the potential employee.

There is a linkage between the legal status of the Collaboration and the type of employees that it is likely to attract. Thus, an international organisation will most likely provide income tax exemption (and other privileges) to some or all of the Staff, which may help to draw in higher-quality candidates. Even given that large international research infrastructures tend to be prestigious undertakings at the cutting edge of science, it can be surprisingly difficult to recruit the best professionals because of practical and professional reasons (family relocation, language and cultural differences, uncertainty about future career prospects).

Salaries are a sensitive issue. Some international organisations have a globally coordinated salary scale. Although these scales are not binding, they do have an indicative value. Salaries of international civil servants tend to be high and generous benefits are usually provided (e.g., private health insurance), but

[15] Potential employees may be concerned about the rights and benefits that are accorded by the host country to same-sex or unmarried couples, and especially the extent to which they might differ from those of the country of origin.

there is considerable flexibility in assigning individuals to different grades on the salary scale. On the other hand, job security and worker rights in these organisations are weak (compared to the public sector in the developed countries). In some cases, pension schemes or unemployment insurance may be non-existent, which will discourage early- and mid-career candidates from applying. If job security is not a feature of the contracts that are offered, a larger proportion of the candidates will be older persons nearing the end of their careers.

If a Collaboration is set up as a Limited Liability Company under national law, there may be strong pressure to align the employment rules, and the salaries, with those of the public service of the host country, since that country's public funds will presumably be used for a large share of the budget. Public service rules tend to be rather inflexible, and oriented towards ensuring full rights and life-long employment, which may not be optimal for the special needs of an international research project, and the modest salary levels may make it difficult to attract the best candidates on a global scale, especially for the most senior positions.

The matter of pensions and post-retirement medical benefits for hired staff is often a difficult one, since it can entail long-term commitments to individuals, longer perhaps than the expected life-time of the Collaboration. Demographic trends and rising medical costs can lead to problems unless they are adequately addressed during the establishment phase (preferably, with assistance from qualified experts). Potential staff members are likely to scrutinise the proposed arrangements carefully when considering an offer of employment. Organisations established under national law may not have much flexibility, given the regulations and legislation of the host country. International organisations have more options (for example, withholding a fraction of the employee's monthly salary, adding an employer's contribution, and returning the entire amount – hopefully, free of taxation – when the staff member leaves). In any event, it is imperative to subject any proposed arrangement to the scrutiny of a lawyer with relevant international experience.

There is a natural desire to have the smallest possible number of Staff, with the bulk of the scientific work being carried out by persons who are employed by institutions in their home countries. Accordingly, the Collaboration will welcome detailees from various institutions. Their salaries will not be paid out of the Partners' contributions, but provision will need to be made for office space and other needs which represents an expense for the Collaboration. While this offers obvious advantages, it has the potential of weakening the Collaboration if it leads to lack of coherence and an inability to work on long-term goals in a concerted way.

- Partners who plan to staff the Collaboration with detailees from national institutions should carefully compute the true costs. Their salaries and benefits may already be budgeted for at the national level, but the additional outlays should not be underestimated: travel (including, possibly, that of family members), local cost-of-living adjustments, special kinds of leave, etc. Experience shows that it may, in the long run, be cheaper to let the Collaboration hire Staff as needed.

- When there is a significant proportion of detailees in the Collaboration, a potential source of difficulty may emerge: the disparities in salaries from the home institutions, and the resulting divergences in living standards. Over the longer term, these can generate a decline in morale. A possible remedy is the attribution of a variable salary increment, paid from the cash resources of the Collaboration.

- Concerning detailees/secondees, there needs to be consensus (albeit informal) among the Partners about responsibility, accountability, and the chain of command. The Director and the Collaboration's senior staff must be able to exercise appropriate authority, even over individuals who do not work for them in a purely administrative sense.

It is in the interest of the Partners that the Director and Staff should be advocates for the Collaboration who, to some extent, will need to distance themselves, in their attitudes and loyalties, from their home countries. They need to become a team with a truly international perspective, seeking to maximise the benefits for all of the Partners. Loyalty/dedication/commitment are intangibles, but their importance should not be underestimated. At critical moments, especially when difficulties arise, individuals must be willing to make a special effort, based on a feeling that they are doing so on behalf of "their" project. Thus, in staffing, there needs to be a correct balance of detailees and direct Collaboration hires. If Collaboration employees have to constantly worry about their situation when they return to their home institution, they risk collectively becoming an inhomogeneous group, with a mixture of incompatible interests, priorities, loyalties, and work styles. Serious consideration should be given to having a core of Collaboration employees with permanent (indefinite) contract whose loyalty, presumably, is to the project alone. For the same reasons, it may be wise to make fixed-term contracts renewable.

As with other matters enumerated in this report, different considerations can apply during different phases of the overall project. Thus, in the construction phase, many of the individuals present will be contractors or detailees, whose specialised knowledge may be needed for a short period only. During steady-state operations, however, there will be a greater need for employees with inside knowledge and experience that is more compatible with long-term or indefinite contracts.

Appendix A: International Experts Group*

Chairman	Hermann-Friedrich Wagner	Chairman, Global Science Forum
Australia	Ron Cameron	Australian Nuclear Science and Technology Organisation
	Katharine Campbell	Australian Embassy and Mission to the European Union
	Rob Robinson	Australian Nuclear Science and Technology Organisation
Belgium	Jean Moulin	Belgian Federal Science Policy Office
European Commission	Leonidas Karapiperis	Directorate B, DG Research
	Robert Jan Smits	Directorate B, DG Research
	Daniel Pasini	Directorate B, DG Research
Finland	Eeva Ikonen	Academy of Finland
France	Dany Vandromme	National Telecommunication Network for Technology Education and Research (RENATER)
Germany	Lisette Andreae	Federal Ministry of Education and Research (BMBF)
	Bettina Klingbeil	Federal Ministry of Education and Research (BMBF)
	Hans-Jürgen Donath	Deutsches Elektronen-Synchrotron (DESY)
Italy	Giampaolo Vettolani	Istituto Nazionale di Astrofisica (INAF)
Japan	Tarou Hokugou	Ministry of Education, Culture, Sports, Science and Technology (MEXT)
	Hisayoshi Muto	Ministry of Education, Culture, Sports, Science and Technology (MEXT)
	Yasushi Taguchi	Ministry of Education, Culture, Sports, Science and Technology (MEXT)
Poland	Jacek Kuznicki	International Institute of Molecular and Cell Biology
	Marek Stankiewicz	Institute of Physics, Jagiellonian University
Switzerland	Philipp Langer	State Secretariat for Education and Research
United Kingdom	Ron Egginton	Department for Innovation, Universities and Skills
	Martin Ridge	Department for Business, Innovation and Skills
United States	Mark Coles	National Science Foundation (NSF)

*During the project, the membership changed. This table lists everyone who was involved at any time.

Appendix B: Persons interviewed for this report

- Roger Blandford* [Kavli Institute for Astrophysics and Cosmology, United States]
- Catherine Cesarsky* [CEA, France]
- Ian Corbett [International Astronomical Union]
- Ben Cross [Savannah River National Laboratory]
- Jonathan Dorfan* [Stanford National Accelerator Laboratory]
- Alberto Etchegoyen [Comisión Nacional de Energía Atómica, Argentina]
- Brian Foster* [University of Oxford]
- Eva-Maria Gröniger-Voss* [CERN]
- Vera Herkommer*, Silke Schumacher* [EMBL]
- Norbert Holtkamp, Paul-Henry Tuinder* [ITER]
- Peter Jenni* [ATLAS/CERN]
- Sachio Komamiya [University of Tokyo]
- Hugo von Linstow* [GBIF]
- Christopher Llewellyn-Smith [Culham Laboratory, United Kingdom]
- Vernon Pankonin*, Philip Puxley* [U.S. National Science Foundation]
- Felicitas Pauss* [ETH Zurich/CERN], Sergio Bertolucci* [CERN]
- Hervé Pero* [EC / DG Research]
- Burton Richter* [Stanford National Accelerator Laboratory]
- Miriam Roelofs*, Patricia Vogel* [PrepSKA Organisation]
- Michel Spiro* [IN2P3/CNRS, France]
- Carl Strawbridge* [Oak Ridge National Laboratory]
- Hirotaka Sugawara [KEK, Japan]
- Albrecht Wagner [DESY, Germany]
- Karl Witte* [DESY, Germany], Thomas Beier* [FAIR, Germany], Stefanie Suhr* [XFEL, Germany], Kristina Boehlke* [DESY, Germany]
- Guy Wormser* [LAL/IN2P3/CNRS, France]

(* denotes face-to-face interviews)
(In some cases, the indicated affiliations are partial)

Appendix C: Workshop on Issues and Options for Establishing Large International Research Infrastructures

October 7/8, 2010

Bologna, Italy

List of Participants

Chairman	Hermann-Friedrich Wagner (Germany)	
Belgium	Jean Moulin	Belgian Federal Science Policy Office
European Union	Leonidas Karapiperis	Directorate B, DG Research
Finland	Eeva Ikonen	Academy of Finland
France	Annaïg Le Guen	Centre national de la recherche scientifique (CNRS)
Germany	Hans-Jürgen Donath	Deutsches Elektronen-Synchrotron (DESY)
Italy	Carla Andreani	Università degli Studi di Roma "Tor Vergata"
	Andrea Vacchi	Istituto Nazionale di Fisica Nucleare (INFN)
	Giampaolo Vettolani	Istituto Nazionale di Astrofisica (INAF)
Korea	Su-Dong Park	Korea Institute of S&T Evaluation and Planning
	Kyung-Man You	National Research Facilities and Equipment Center
Netherlands	Jeannette Ridder-Numan	Ministry of Education, Culture and Science
Norway	Hanne Monclair	Norwegian Ministry of Education and Research
	Jon Børre Ørbæk	The Research Council of Norway
OECD	Stefan Michalowski	Global Science Forum
	Frédéric Sgard	Global Science Forum
South Africa	Daan du Toit	Department of Science and Technology
Spain	José Ramón Sánchez Quintana	Ministry of Science and Innovation
Switzerland	Philipp Langer	State Secretariat for Education and Research
United Kingdom	Peter Fletcher	Science and Technology Facilities Council
United States	Mark Coles	National Science Foundation (NSF)
Invited Experts	Brian Foster	University of Oxford
	Claus Madsen	European Southern Observatory (ESO)
	Miriam Roelofs	PrepSKA NWO
	Patricia Vogel	PrepSKA NWO
	Karl Witte	European XFEL
	Naomi Wynter-Vincent	Realising and Managing International Research Infrastructures (RAMIRI)

OECD Global Science Forum

Large Research Infrastructures

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