PROCEEDING TO AN INTERNATIONAL LINEAR COLLIDER PROJECT

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I. Some Issues of Cost and Funding

The HEPAP Subpanel on Long-Range Planning for US High Energy Physics has recommended as the next major capital project the construction of an electron-positron linear collider (LC) with 500 GeV initial CM energy, upgradable to 800-1000 GeV. The estimated cost of the Collider is given as $5B- $7B for the first 500 GeV stage. The Subpanel notes that this project should be international from the start, and further recommends that the US bid to host it, at a likely cost to the US of about 2/3 of the total construction cost. For purposes of the discussion below, I shall assume a $6B total collider construction cost, and a $4B cost to the US if it hosts the machine, following the 2/3 figure proposed. From responses to questions asked at the public presentations, my impression is that the cost to increase the energy from 500 to 800-1000 GeV is about 1/3 the initial cost, or roughly another $2B total.

I have mentioned all these figures because they play a key role in the consideration of the LC as necessarily an international effort, and in understanding the challenges facing this project. There is a natural funding scale for the support of a scientific construction project by any one country or region, and the problem is that the $4B suggested US funding for a US hosted facility is, as discussed below, much higher than that natural funding scale. This is the challenge that must be faced by the US or by any country aspiring to be the host country for this project.

My estimate of the above natural funding scale for a US capital project is about twice the yearly US budget for the program to which the project would contribute, in this case HEP. For US HEP, the yearly budget of $750M would, using this formula, lead to a natural capital construction level of $1.5B. This is far lower than the LC total of $6B or even the proposed US piece, $4B, for the on-shore option. My estimate of a natural scale is based on an average yearly funding allocation for the construction of ~25% of the total program budget. Thus, over an ~8 year construction period, the total construction cost would be twice the yearly program budget. The 25% seems to me the kind of funding increase that can be achieved for a well-justified project, or that can be partially absorbed in the current budget. A request on that scale would probably not set off large levels of concern and opposition in non-HEP scientific communities.

This is not to claim that larger requests have no chance of success, but to emphasize that the scientific case then has to look extremely compelling even to scientists in other areas, and/or that the overall context has to be one of substantial funding increases for all of science. The SSC did violate my natural cost scale, but of course it never got built.

This challenge does not just apply to the US: I suspect that it is relevant for any country or region that aspires to be the host site for the proposed LC. In response to the challenge, the move to an internationally funded project provides two major benefits:
1) The cost can be shared among several countries, making each individual contribution more affordable, and
2) an international agreement that provides funding from many countries for a single agreed-upon facility makes a powerful argument to the rest of science and to government agencies for the importance of the facility being pursued.

II. Some History

It may be of some interest to recall briefly the history of how the US involvement in the LHC Collaboration, especially its accelerator component, came about.

The SSC was canceled in October 1993, and, a few weeks later, CERN Research Director Walter Hoogland invited me to help set up at CERN a meeting of scientists who had been involved in the SSC detectors and might be interested in LHC participation. This meeting took place in December 1993 with participation from leaders of the SSC detector collaborations, and representatives from Japan and Canada who had led groups active in the SSC detectors. There were no representatives of funding agencies or US national lab directorates at that first meeting. The LHC had not yet been formally approved by the CERN Council. CERN Director-Designate LLewellyn Smith pointed out the need for Non-Member-State (NMS) contributions to both collider and detectors to get them built and completed on not too long a time scale. He suggested that countries that expected their scientists to participate significantly in the LHC scientific program ought to contribute to the machine to enable the science to start as early as possible.

In the next year, 1994, the Drell HEPAP Subpanel, formed in the wake of the SSC cancellation, recommended US involvement in the LHC program, both machine and detectors. A workshop was held in February 1994 at Fermilab to help develop interest in LHC collaboration, and a US LHC Collaborators Group was formed with a dozen physicists on its executive committee (four representing US ATLAS, four US CMS, and four the LHC machine collaboration). This small group met numerous times with DOE and NSF over the next few years.

The LHC was formally approved by the CERN Council in December 1994 as a staged CERN project with the understanding that, if sufficient non-CERN contributions could be secured, the project could proceed without staging to its full energy and luminosity goals. Meetings between CERN management and DOE/NSF to discuss US participation in both machine and experiments began in April 1995 with a meeting in Washington. Many subsequent meetings both at CERN and in Washington followed, working groups were set up to define details of both machine and detector collaboration, and the US LHC Collaborators Executive Committee met several times with DOE/NSF to present its proposals and funding requests for US involvement. Near the end of the negotiations, Chairman Sensenbrenner of the House of Representatives Science Committee got involved, traveled to CERN, and made some changes in the protocols of agreement.

The whole negotiating process concluded in December 1997 (four years after the first meeting at CERN) with the signing of appropriate protocols. This was for a US commitment of $200M for the machine (all DOE), and $331M for ATLAS and CMS ($250M DOE and $81M NSF). Although there is sometimes concern that the US Congress may disregard its international scientific commitments, I believe that this has not been the case for the LHC.

It is important to recognize that the LHC international collaboration was really a rather modest extension of the usual circumstance in which the home region fully funds and builds the accelerator on its site. The LHC machine cost was a little high for that, and therefore a relatively modest contribution was solicited from the rest of the international community. However, the home institution (CERN) did pay for a very large fraction, took almost total responsibility for the overall design, is suffering through possible overruns, and will be financing the machine (not the detector) operating costs. As will be noted below, I would guess that, for the LC, we shall have to move to a level with more responsibility for the non-host partners.

Finally let me point out some lessons from the LHC negotiations:
1) It took three years (from the LHC approval) to conclude an agreement that made only modest requirements on the US, and could be funded within the existing US HEP budget.
2) From the DOE side, Martha Krebs, the Director of the Office of Science, was highly involved in the negotiations. Needless to say, the next Director of DOE/OS, whenever appointed, will need to play an important role.
3) The negotiation on the accelerator participation did not only involve money. Such issues as the ratio of in-kind technical contributions to cash input, and the amount of LHC procurements from US industry were also important.

These experiences point to the challenging road ahead.

III. The Road Ahead

In considering the LC, there are two extreme models for international collaboration: the LHC model that I just discussed and the CERN model. In the LHC model, we move just a little ways in our departure from the usual single country (or region) funding model. The host country no longer funds the whole accelerator project, but funds much more than 50% of it, and probably all of the civil construction. It carries almost the whole responsibility for the management of the project, and will probably be expected to support almost all of its operating costs (not including the detectors). This is simply an extension of what was done with the LHC with somewhat larger non-host country participation. I would say that the 2/3 figure for the host country financial participation recommended in the subpanel report is consistent with the LHC model, although CERN's contribution to the LHC was probably larger.

In the CERN model, all collaborating countries contribute in proportion to the sizes of their economies, without great differentiation for the host country. Realistically, for the LC, the host country would probably fund a substantially greater share, perhaps like 40-50%. All the collaborating countries would share in the machine operating costs, and would contribute at some level to the civil construction as well as the technical components. Like the real CERN, this collaborative organization would have to be relevant for more than just one capital project, but, unlike CERN, the various projects would have to be sited in different host regions.

Where should we try to head with the LC? Below I make some comparisons of advantages and disadvantages of the two extremes described above:
1) The LHC model has the advantage of being much simpler. The necessary agreements and organization apply to just a single project, and there is no implied or moral commitment on the siting and support of future projects. The host country benefits, but has to pay a large fraction of the cost, so that it has no obligation for the support of future large projects in other sites. If there is a country (the US or another country) willing to shoulder the host country financial burden (~$4B plus fraction of the detector costs plus machine operating costs) under conditions such that other countries are willing to participate at a sufficient level, this is the fastest way to get to a construction start.
2) The CERN model, while far more complicated, has two advantages: no one country has to provide so much funding, and, most important in my view, the necessary longer term organization that must be set up will also encompass future projects. In fact the consequence of not having the host country pay so much has to be a commitment that it will help support a future project sited elsewhere. In this model, the world would be pioneering a new way of supporting very large projects, effectively a global version of CERN.

IV. The Next Steps

My guess is that the actual model to be pursued will probably be somewhere between the two extremes that I have discussed above, looking to a host country contribution between 50% and 67%. We may have to come out with an understanding for the future that assures some reciprocity with respect to siting future projects.

I believe that a good early step would be to organize under the auspices of ICFA a meeting that would include ICFA members, Directors of large HEP Labs that are not ICFA members, a number of scientists from various countries who are playing leadership roles in detector and physics studies relevant to the LC Project, and a number of accelerator scientists from various countries who are experts in various aspects of LC machine issues. Although funding agencies will have a crucial role in the negotiations to come, I believe that it will simplify getting started if the first meeting is one just among scientists involved and interested in the LC project.

The goals of the meeting would be the following:
1) Discuss and define as well as possible the model of international collaboration to be pursued (somewhere between the CERN and LHC models?).

2) Ascertain which countries might be candidate host countries.

3) Ascertain the level of interest among each of the countries in putting substantial resources into such an international project sited outside that country.

4) Discuss how to prepare collaboratively the material that will be needed to help convince government authorities and the rest of the science community that the LC project provides an appropriate match between required resources and the anticipated new knowledge.

5) Start organizing an international collaboration for the LC physics/detector project. One of its first tasks might be the preparation of a detailed scientific report that helps justify initiating the LC construction before having substantial results from the LHC. I believe that this is a serious issue that non-HEP scientists may raise.

6) Discuss the process for making decisions on collider technology choices.

7) Discuss preparations for subsequent meetings that will additionally involve funding agency representatives. Decide who, aside from funding agency people, should attend such future meetings.

8) Form some sort of organization and set up an International Steering Committee that can oversee the above activities and their follow-ons. One of the activities that will need organizing early will be the necessary outreach effort directed at all the communities whose support will be essential in both the host and the other participating countries.

9) Do all the other important activities that I have overlooked here.

Since both Mike Witherell and Jonathan Dorfan are ICFA members, it should be straightforward to get this meeting organized.

If such a meeting can be successfully conducted with tangible results, it will give the international HEP community, including its US representation, credibility in going to its funding agencies and in talking to its scientific colleagues outside HEP about supporting the LC project. Obviously this would be just a first step, but it would begin to give the LC project some reality.