Review Panel Report.

Report to the US Department of State

Relative to:

The CANDLE Project Proposed for Armenia

August 20, 2002

Review Panel Meeting, NSF, Washington, August 14, 2002.

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Agenda for CANDLE Review, Aug. 14, 15, 2002

Aug. 14

8:30 – 9:30	Executive session (Panel)
9:30 – 9:45	Coffee Break
9:45 – 10:00	State's objectives for this Review by State*
10:00 – 10:15	Intro to Armenia by World Bank*
10:15 – 10:30	Introduction by proponents*
10:30 – 11:00	Overview*
11:00 – 11:15	Break*
11:15 – 12:00	Technical design*
12:00 – 1:00	Lunch (Executive session for panel)
1:00 – 1:45	Component, Construction and Operating costs and Schedules*
1:45 – 2:00	Project Organization and management plan*
2:00 – 2:20	Infrastructure in Armenia*
2:20 – 2:50	User Scientific program and Support*
2:50 – 3:00	Break*
3:00 – 3:20	International Participation*
3:20 – 3:50	Economic Benefits*
3:50 – 4:20	Summary and public discussion*
4:20 – 5:40	Executive session
5:40 – 6:00	Assignment of Questions to proponents as needed

* Open to the public

Aug. 15

8:30 – 9:30	Executive session w. Q&A with proponents as needed
9:30 – 10:30	Executive session
10:30 – 11:00	Coffee
11:00 – 12:30	Writing
12:30 – 1:30	Lunch
1:30 – 2:30	Prelim Review of report components
2:30 – 3:30	Writing
3:30 – 4:00	Discussion of Executive Summary
4:00 – 5:00	Closeout and delivery of executive summary and prelim report

Executive Summary

The Panel (see Appendix 3) met with the proponents and representatives of the State Department, World Bank and National Science Foundation per the Agenda found in Appendix 2 to answer the charge found in Appendix 1.

The Scientific Case

The Panel believes that the scientific case for a machine meeting CANDLE specifications is very robust and that the project has made a good start on developing it. The facility described in the proposal is a world class facility capable of enabling frontier work across the full range of physical, life and engineering sciences. Being among a few of the most modern synchrotron facilities, its users will be able to compete at the frontier. Thus the potential for enhancing scientific and technical education is great as many of the users will be faculty and their graduate students at Armenian universities and universities in the region to be served. It appears highly likely that a sufficient user community can be developed. In light of this potential for putting Armenian and regional scientists and their students at the frontiers across broad areas of science and technology, the facility is an excellent investment from a scientific/technical point of view.

Technical Design

The design of the accelerator and beam lines is sound enough to form the basis of the proposed facility. There is no doubt that a scientific instrument of this description can be built. The panel is deeply impressed with the technical quality of the proposed accelerator systems, the efficiency with which the proposal was produced and the positive attitude and commitment of the performers. The panel notes that other comparable facilities are under construction or in operation in other regions of the world so that mutual support in overcoming technical challenges that arise is readily available.

Management Plan

Considerable thought has gone into management planning but there is currently only modest written material. This is consistent with the current state of the project. Further work on this important topic remains to be done in the coming months. An overriding issue is one of project governance – establishing the chain of executive authority, accountability, responsibility and oversight. The roles of the implementing agency, VA Tech and CANDLE organizations need to be defined and explored to assure that the necessary functions are all being served.

A construction project management plan is needed to assure proper and efficient control along with the data bases and analytical tools needed to exercise that control. Such systems are also essential for good communication among the various stakeholders. Several major elements in the project management system need further development, preparation of a work breakdown structure, elaboration of the cost estimate and schedule among several others.

The cost estimate presented is based on thorough estimates made for other similar facilities to be built in the west where salaries are much higher. However, while it is true that those components to be built in Armenia can in principle be built at relatively low cost there are offsetting risk factors making a considerably larger contingency appropriate at this stage of the design process. In addition a bottoms up cost estimate particular to CANDLE, based on a detailed procurement plan, will be needed for proper contingency estimating. The Panel notes that at this stage of a project a contingency (cost uncertainty) of from 30 to 50% is appropriate, i.e. possible additional construction cost of $14M to $24M. In this regard it is to be noted that the cost of similar technical facilities in the industrialized countries can vary widely depending on local conditions. After another year or so of detailed study and experience in conducting a technical project in the local environment it will be appropriate to reevaluate the construction cost contingency (uncertainty) in anticipation of a substantial reduction in the uncertainty.

The operating cost presented seems reasonable based on experience at facilities in the US. At this stage, however, it would seem prudent to assign a similar contingency here as well. The manpower level estimated is quite reasonable based on other operating facilities of similar scope.

Needed also is a detailed and credible plan for sustaining operation after the initial operation is well established. Development of an international organization modeled, for example, on ESRF for operation of the facility could be the answer.

Experience has shown that such facilities can be operated in an environmentally neutral manner and that protection of the general public from radiation can be readily handled. The technology for doing so is widely known.

Economic Impact and Revenue Potential

The panel identified seven positive economic impacts: direct creation of jobs; potential demonstration of political stability for prospective investors; workforce enhancement; attraction of new high quality industry; multiplier on annual budget coming from outside the country by up to three times (World Bank estimate); usage of currently under-subscribed electrical generating capacity. Thus, if the planned operating budget, some 7M$ (4 operating + 3 capital improvement) can be secured outside the country, a positive impact of about 20M$ per annum to the Armenian economy might be anticipated at this stage of Armenia's economic recovery. As the economy and infrastructure improve the multiplier could improve considerably. The figure of 25 mentioned by the proponents seems unrealistic to the Panel.

While the Panel encourages the proponents to continue pursuing the possibility of deriving operating revenue from commercial users, it points out that this has never been successful elsewhere. The proponents have identified three additional potential sources of operating funds: formation of a sponsoring regional international consortium in the manner of ESRF; assistance programs; and private (Diaspora) foundations and individuals. It seems likely that a commitment for the capital construction of the facility will be necessary before commitment of operational support will be forthcoming.

CANDLE in the Worldwide Context

Candle is similar to other intermediate energy (2.4 – 3.5 GeV) third generation light source projects now in progress around the world. Under construction now are the Canadian Light Source (2.9 GeV), Diamond (UK, 3 GeV), the Australian Light Source (3 GeV) and SPEAR 3 (US 3 GeV) and Soleil (France, 2.75 GeV). The Shanghai Light Source (3.5 GeV is proposed. The Swiss Light Source (2.4 GeV) has recently been completed. CANDLE is therefore in the mainstream of current trends in the synchrotron radiation research field. For this reason it can tap into the large pool of designs for accelerator and beamline components that have been well developed at other facilities. The CANDLE team has made good use of this resource in their efforts to date, particularly in the July 2002 Design Report. Given the advanced state of technology relevant to these projects and the expertise and experience of labs around the world, there is a high level of confidence that CANDLE will be a technical success.

Scientific Case

The committee was impressed by the effort in developing the scientific case. From a review of the 69 experimental proposals produced in a very short period by nearly 200 scientists from Armenia, it is clear that strong Armenian user community will emerge as the facility is readied. The community will cover all traditional areas of application for the proposed third-generation synchrotron radiation facility including materials science, chemical science, biology, medicine, geoscience, environmental science, engineering, and instrumentation. The strong desires of the proponents to develop a sizable industrial user community is applauded by the committee and their continued effort has the potential to lead to successful participation of industries. It is fair to say that there exists a great opportunity for Candle to be the principal third-generation synchrotron facility, not only in Armenia but also in the entire region.

The robustness of the scientific case is also evident from the well-defined beamline concepts developed at this stage of planning of the facility. As the construction of Candle advances into its next stage of planning, the potential user community will get more involved and a more complete set of beamlines will be defined.

The broad experience of developing other synchrotron radiation facilities in the world leads us to believe that the Candle facility will take about 10 years for the user community to be fully mature. The return on this scientific investment in Armenia and the region will be significant, if one uses as a model the impacts of similar facilities in Asia, Europe and the USA. As an example, Candle will train graduate students and guide a pipeline of skilled scientists ready to contribute to the local industries, as well as providing sensitive tool to attack applied science problems. It is our general experience that the third-generation facilities like Candle will have a broad user base that will effectively compete on the world scientific scene. This is particularly true since there are no equivalent facility in the Russian Federation, the former Soviet Union countries, former east European countries, and the Middle East. The potential synchrotron users of Candle from these Armenian neighboring countries now have to travel to Europe or US and compete for synchrotron beam time. This is not very cost effective and has limited their active participation. Additionally, our experience in both Western Europe and US shows that the construction and operation of synchrotron facilities results in a large number of highly skilled scientists and engineers who can contribute in a major way in developing high technology industries contributing to local economies. This is an effective way in which Candle will also contribute to the technology transfer in Armenia with its very high percentage of literacy.

In the following we provide some broad recommendations that will assist the next stage of planning of Candle towards a successful project:

1. Training of Armenian scientists to perform synchrotron experiments by sending them to European and US facilities over a period of 2-5 years
2. Encourage Candle staff to attend international conferences both in the area of accelerators and synchrotron radiation instrumentation.
3. Organizing workshops on various subjects in which users from Armenia and the neighboring countries participate along with experienced users from operating synchrotron facilities in Western Europe and the US.
4. Form highest governmental-level alliance early in planning with neighboring countries so that they have both scientific and financial commitments during operation of Candle.
5. Plan strong bonds with regional universities and research institutes in the field of physical, chemical, and biological sciences, as well as engineering disciplines, through joint appointments with Candle.
6. The chosen beamlines represent a typical set. However, they do not fully project the community desires as expressed through 60 or so experiment-proposals. Future deliberation with the community will change the complexion and set priorities for early beamlines.
7. Develop concepts for the insertion devices that can meet the early beamline needs of the user community. The facility infrastructure should include capabilities to perform magnetic measurements of the insertion devices. This will be of great value in qualifying the devices prior to their installation in the storage ring and re-qualification during operations.
8. In the preliminary beam line designs, experience dictates that it is more effective to place the front-end components (masks, slits, BPMs, bremsstrahlung stops, etc) behind the storage ring shield wall. This will eliminate stray background problems and would enhance personnel safety.
9. Many components included in the first optics enclosure (FOE) are better placed behind the shield wall as part of the front end. This will have many advantages, particularly in reducing scattered radiation from the experiment. The white radiation BPMs placed in the front end can provide beam stability information even when the beamline is not taking radiation.

Technical Design

Accelerator Design

The Conceptual Design Report is a very comprehensive document. It addresses all accelerator physics issues related to the design of the accelerator systems, and demonstrates that due consideration has been given to the design and performance of similar rings such as the Swiss Light Source, SPEAR-III and the Canadian Light Source. The level of completeness is comparable to that of the NSLS and ALS Conceptual Design Reports. The committee was very impressed with the quantity and quality of work evident in this document, which was produced in only six months on a budget of only $300k out of the available $500k

The Armenian Light Source Designers are to be commended for this impressive work. When the detailed design is finished it will be appropriate to hold an extensive review for final validation and incorporation of insights from the worldwide community of synchrotron facility designers and users. At that time such matters as tolerances, beam lifetime, top-up details, correction schemes, dynamic aperture with wigglers, impedance in narrow gap sections etc. should be examined in detail.

Beam Line Design

There is not doubt that the beam lines planned can be constructed. The concepts presented are a good start. As the process matures it will be useful to have close contact with existing 3rd generation facilities and the new ones under construction.

Management Planning

Considerable thought has gone into management planning, but there is currently only a modest amount of written material. Although this status is consistent with these early stages of the project, much work is necessary in the next year to give this project a solid management foundation. We first discuss the overriding issue of project governance, followed by a discuss construction project management and then facility operations management.

Governance. The committee strongly endorses the concept of a private corporation such as CANDLE having responsibility for the construction of the project, since it is essential that the Armenian government not interfere. However, the roles and responsibilities of the State Department, Virginia Tech, the CANDLE organization need to be better defined very soon so that the legal structure for the project is sound and appropriate oversight can be provided. It is not possible to have a self-consistent approach to managing such a project without a clear plan for overall project governance. Such a governance plan will need to address questions such as legal liability, procurement policies and authorities, audit responsibilities etc. The State Department is not currently capable of providing the oversight necessary to insure successful project completion and this issue needs to be addressed as the governance system is formalized. It should also be recognized that there will be costs associated with governance activities, possibly on the order of $1-2M, not currently included in the project estimate.

Construction Project Management. Of immediate interest is the establishment of management systems and appropriate databases necessary to plan and control the construction project. These systems are also essential to be able to communicate the status of the project to various stakeholders such as potential users, funding agencies, and oversight organizations. The systems need to be entirely transparent with all relevant outputs readily available to any interested party in a useful format. Below we comment on various elements of construction project management, assessing what has thus far been done by the project team, and simply listing other elements that should receive attention within the next year to facilitate successful project execution.

- **Work Breakdown Structure.** The starting point for project management systems is the creation of an appropriate work breakdown structure (WBS) enabling the systematic tracking of all project elements. The project apparently understands the need for a WBS and has a rudimentary system. However, a more mature system is necessary probably with at least a five or six level structure. Many examples exist from recently executed projects as a guide.
- **Cost Estimate.** The current cost estimate appears to contain reasonable estimates for various technical components, but it is based on detailed estimates by other similar facilities being planned or under construction world-wide. A good deal of work is necessary to provide a much more solid basis for these costs, which would be based on the project's own design and procurement planning. In addition we saw no evidence of explicit consideration of cost escalation due to inflation over the life of the project. But most importantly, the committee disagreed with the contingency estimate the project provided and disagreed with the project's position that the contingency account is an appropriate source of funds for prototypes, spares, and test facilities. All these items should be separately budgeted with their own WBS numbers and budgets. Furthermore, the contingency at this stage of the project needs to be 30% *at minimum.* Arguments can be made that there are risks in executing a project under the circumstances of an underdeveloped country with a very difficult recent economic and political history that could necessitate an even higher contingency, say 50%.
- **Schedule.** The project presented a schedule for completion of the project in 2007, essentially five years from now. At this stage of planning, the project is at least 18 months from beginning serious construction, so a more appropriate schedule for delivery of first beam would be beginning 2009. The more important issue is not the date for completion, however, it is to establish approaches and systems for doing detailed schedule studies, starting with activities at the lowest level of the WBS and working up until the entire project is integrated in a complete schedule. It is essential that everyone in the project become "schedule-conscious" and that the system implemented be capable of quickly incorporating changes and answering "what if" questions. Commercial software systems are available to support this work.

AS WELL AS

- **Cost/Schedule Control Systems.**
- **Financial Management System.**
- **Procurement Plan.**
- **Organizational Development Plan.**
- **Internal Review/Oversight.**
- **Safety and Environment Plan.**
- **Quality Assurance Plan.**

Operations Planning.

The committee appreciates that at this early stage of the project it is not expected to have a detailed operations plan. We were pleased to see that rough estimates have been made for out-year operations costs. These levels seem approximately correct in the experience of the committee members, but an on-going effort is necessary to develop a more detailed plan to avoid future surprises and to make the transition from construction to commissioning/operations a smooth one. In addition to the costs of operation, a good operations plan assesses the effort levels necessary for the various functions necessary in operations, plans for their implementation, and deals with the human resources issues associated with the transition.

Operations Funds.

The most important issue identified by the committee, however, is the question of where the operating funds will come from. This is critical because the proposal to the State Department does not include a request for such funds, which are essential to the success of the facility. As discussed under Economic Impact, the impact of the State capital funds is much higher if they are the basis for attracting operating funds than if State were to also be the source of those funds as well. The committee urges the State Department to consider an approach in which a construction funds commitment is contingent on the project delivering a plan for operations funding with hard commitments.

ECONOMIC IMPACT AND REVENUE POTENTIAL

Is the analysis of the economic impact to the Armenian economy of the facility, and the estimate of the employment opportunities created in Armenia as result of the project reasonable ?

No. The report relies on the analysis of the Australian facility and attributes similar linkages and investment multipliers (as high as 25) to Candle related expenditures. Armenian institutional structures, industries and economic linkages do not allow such international level gains to be captured. The panel estimates a more reasonable level of 2.5-3 (see details below). The Australian analysis needs to be recast by the proponents and is being done.

Apart from estimates of employment at the facility, no other employment estimates are mentioned. Using an average wage of $500 (IMF source) per month, and an output multiplier of 2.5 for investments, a rough estimate of employment related to construction in the Armenian economy would be 60% (local expenditure) of (48,000,000*2.5)/500/12= or 60% of 20,000 man years = 12,000 man years or 2400 jobs for 5 years. To the extent this expenditure is directed to non-labor inputs, say 50%, a possible estimate would be 1200 jobs created and sustained over a 5 year period. In addition, if an operating expenditure of $7 million per year is realized, a higher multiplier, then, of 3 would induce outputs of $20m per year to be realized across Armenia.

What is the cost-benefit ratio of building the facility as compared to the economic development and employment the facility will create?

This is difficult because: 1) indirect benefits are difficult to quantify and will likely be spread out over many years; 2) the opportunity cost of displacing possible alternative uses of funds is not clear, and 3) there are multiple viewpoints from which costs and benefits should be assessed, and from the U.S. viewpoint these external benefits are largely intangible.

If the "with" and "without" Candle cases are compared, at a minimum, the above calculated output benefits of $30 million local expenditures for construction and $ 7m per year over 5 years can be nominally estimated at 30*2.5+7*5*3= $180m in multiplier effect benefits. A core cost-benefit ratio would be = 48/180 or, conversely, benefits of 3.75 times the cost which can be directly assessed.

<u>Apart form the direct job creation and multiplier effects, economic impact to be considered include:</u>

1. *General perception of private sector high technology investment climate in Armenia.* The synchrotron investment will support the overall investment climate and reputation of Armenia as a place for doing high tech business, a key World Bank strategy. It will indicate a sense of political stability that will bootstrap serious thinking on other

investments. Exclusive of direct synergy/spin-off with industry, a highly public U.S. investment in the synchrotron would imply confidence in political stability in the Armenia. This could in turn attract other high quality industries. It will require the Armenian government to provide policy support for a private initiative. The private sector operation of the facility is a key operational prerequisite

2. *Long term science benefits.* These are substantial but difficult or impossible to translate into near-term monetary terms. About 20,000 scientists and engineers now use synchrotron radiation at about 50 operational facilities around the world. The intense, bright, polarized, tunable radiation over a broad spectral range is used for applications in basic research in biology, chemistry, medicine, material science, and physics. Applications in applied research and technology include drug design, materials analysis, medical diagnostics and therapy, and environmental remediation. Many of these are directly relevant to societal concerns – e.g., developing ways to separate, remediate and store toxic and radioactive containments.
3. *"Brain growth" benefits*. A synchrotron radiation facility is arguably the most effective instrument for training graduate students in basic and applied research and technology. When fully operational, CANDLE should produce several tens to one hundred PhD's per year. Many of these will take jobs in high tech industries or initiate start-up companies of their own.
4. *Direct job creation.* Direct job creation occurs for both the construction and operating phases. Staffing for the facility is expected to grow from 120 in Year 1 to 140 in Year 4.
5. *Multiplier effect from visits by international visitors*. Perhaps ~1000 users and other visitors per year could be anticipated, for terms ranging from week-long conferences to year-long sabbaticals.
6. *Multiplier effect from outside funds contributed to operating money*. For a project annual budget of $4-8 million (operating and capital improvement), it is anticipated that at close to 90% of funds would be from external sources. A ballpark multiplier factor might be 3 times the direct value.
7. *Building in-country capability in high tech manufacturing*. The synchrotron would generate in-country purchases of highly specialized equipment (e.g., the dipole magnets and vacuum chambers), both for the accelerator complex itself as well as the initial 5-beam line configuration, and for beam lines added as the facility approaches full capacity. Approximately 60% of the equipment in the initial capital budget is expected to be produced in-country. For the participating Armenian manufacturers, these costs would likely enable an upgrade in general manufacturing capabilities such as purchase of new or used numerical control equipment for die cutting, roll bending, etc. It is also possible that an export market might be developed for other synchrotron facilities in other countries, but this is speculative, and subject to competition from other low-cost producers (e.g., Chinese-manufactured components).
8. *Helping Armenian universities attract and retain students in a broad range of sciences, including foreign students.* In addition to the immediate attraction of research opportunities for the synchrotron, there would likely be an intellectual multiplier effect in the larger academic community.
9. *Usage of current electrical generating capacity*. Power requirements for the facility would likely provide approximately $1 million/yr in revenues for the local electric utility. This could aid financial stability for power generation, which currently has underutilized capacity.
10. *Synergy with developing Armenian industry and commercial spin-offs*. Many of the panel members expressed skepticism that direct industry participation in the facility will result in significant facility operating revenues.

Can the synchrotron be commercially viable and generate enough funds to cover its operating expenses?

No. Lessons of experience from world class facilities confirm that a commercial operation is not feasible.
However, the proponents indicate three additional key areas to be exploited further – international cooperation (along the lines of CERN), assistance programs, private (Diaspora) foundations and sources.
To the extent that these funds, estimated at $7 million (including some to add beamline capacity) can be canvassed, the operation can be considered viable. They will be a major source of the positive economic impact sustained over time, till such time that world wide R&D expenditures could emerge as a potentially viable source.

Is the plan for achieving financial sustainability by attracting scientists from other countries feasible ?

As written, there is no viable plan. However, the proponents have a preliminary vision of how the facility can be operated like CERN in Switzerland or the European Synchrotron Radiation Facility (ESRF). However, the need to direct limited resources to high productivity activities (particularly the design report) has delayed detailed study of this potentially important source of funds.

How much of those expenses will be generated by the synchrotron, and how much will be left to the U.S. Government and other donors?

The panel expects that a community of international users will associate to fund the operating costs. The proponents have been asked to develop an operating cost plan that frees the US government of the obligation to fund operating costs. The success of this approach may depend on a commitment of capital construction funds by the U.S.