Report of the NSAC RIA costing Sub-committee
January 2001

Executive Summary

An NSAC Sub-committee in Chicago reviewed the RIA preliminary cost estimate on January 10/11, 2001. The charge to the Sub-committee was as follows: '*Understanding that a detailed conceptual design has not yet been completed, the Sub-committee is asked to provide NSAC with its best current estimate of the cost of the project including R&D, construction, pre-operating and operating costs. NSAC is aware that there are uncertainties regarding siting and other issues that limit the precision of such an estimate at this time. Nevertheless, the advice of the Sub-committee will be of great value to NSAC as it evaluates the relative merit of this and other initiatives*'. The estimate was prepared by a Collaboration of MSU and ANL. The Sub-committee members were Jim Beene ORNL, Mike Harrison (chair) BNL, Christoph Leemann JLAB, Jay Marx LBNL, Thom Mason SNS, and James Symons (ex-officio). Denis Kovar DOE, was present as an observer. The estimate presented was a TEC of $695M, including 32% contingency, which together with other project costs resulted in a TPC of $885M. The Collaboration expects that contributions to the costs from existing facilities or non-federal funds will reduce the TPC by ~$50M. An estimate for the annual operating costs of $65M was presented. All costs were in FY01 dollars. The proposed RIA facility consists of a driver Linac together with both ISOL and fast fragmentation beams and associated experimental facilities. A 6-year construction schedule was assumed.

The Sub-committee believes that the TEC presented is reasonable. The 32% contingency is judged to be appropriate at this point in the development of the estimate. The other Project costs (R&D, Pre-operations, conceptual design and environmental studies) were not estimated as carefully. The pre-operations costs of $150M appear to be somewhat high, whereas the R&D costs of $25M appear to be underestimated. The projected operating budget of $65M per year is found to be minimal for a national user facility of approximately the scale of CEBAF.

Background

As part of its long range planning process, NSAC will be considering the scientific priority of the proposed new Rare Isotope Accelerator (RIA). The design of the facility that emerged from a task force led by Herman Grunder, was endorsed by NSAC in November 1999. Since that time refinement of the design and the cost estimate has taken place within the RIA community. In the RIA overview provided to the Sub-committee on January 10/11 it was noted that the original design remained basically the same, however in addition, it now also includes fast fragmentation beam capabilities and associated experimental facilities. The new cost estimate incorporates these enhanced capabilities as well as the pre-operations and R&D costs that were not included in the previous estimate.

Driver Linac

The committee heard technical and cost presentations on the driver accelerator addressing the total cost estimate of $214M. The most salient performance parameters determining the accelerator design were worked out in the context of the ISOL task force driver subcommittee, and include the capability to deliver beams of all ions from protons to Uranium at energies of at least 400 MeV/u with a beam intensity corresponding to 100 kW. Ideally, the Driver should also be upgradeable without significant changes to 400 kW.

The key building blocks are two ECR ion sources, a room temperature RFQ, and several sections using srf cavities arranged in three major blocks:

- A “prestripper” consisting of 79 low-β cavities in 8 cryomodules
- A medium-β section containing 168 cavities in 11 cryomodules, followed by another stripper.
- A high-β section containing 188 cavities in 47 cryomodules.

The low and medium β cavities are of the type prototyped by the ANL team, numerous examples of which serve in the ATLAS accelerator and elsewhere. The β=0.61 and 0.81 cavities and cryomodules of the last section are identical to SNS prototypes currently being tested at Jefferson Lab, while the β=0.49 cavities are derived from them in a straightforward way.

The accelerator achieves its demanding beam current specifications easily and within current source technology due to its capability to accelerate multiple charge states, made possible through large longitudinal and transverse acceptance, and the fact that beam quality requirements are modest.

Cost of the machine has not significantly changed since the Fall of 1999, when the ISOL Task Force reported its conclusions, and appears to be credible on the basis of technical design and costing methodology. The extensive use of what is essentially existing technology creates a firm basis for the unit costs.

Experimental Facilities

The items covered under Experimental Facilities include experimental apparatus, as well as ISOL beam production and delivery systems (including gas stopping), and fast beam production and delivery systems. While the RIA driver has previously undergone both technical analysis and cost review, this is the first detailed evaluation of the cost of these aspects of the project.

The concepts presented for beam production systems and experimental apparatus cover the full range of capabilities that have been articulated by the RIA research community. The basis for costing is generally comparison to recently built facilities. Since the project has not yet reached the conceptual design stage, the contingency of 35% of technical component cost appears reasonable and prudent. In general the costing appears to be sound given the current state of the project.

The ISOL target systems have been based largely on ISAC at TRIUMF. This is certainly a relevant, recent, and reasonable comparison for developing a design and estimating a cost. Caution is warranted, however, in making any assumption concerning regulatory requirements based on experience in Canada. There is some cost risk associated with this, but it is within contingency. The ISOL beam delivery systems, including isobar separation, were well thought out, with significant performance improvement over exiting devices. Costing is based on closely related recent experience. The design and costing of hardware associated with the gas-stopping system represent a substantial extrapolation from the smaller system developed at ANL, but any uncertainty should be well within contingency. Hot cells will be required to service the radioactive beam production hardware. Two layouts for the hot cells were presented. The larger of the two, presented by MSU, appears to be preferable given the remote handling requirements of what is likely to be a hazard category III nuclear facility.

The design and costing of fragmentation targets and beam preparation and delivery systems were also based on relevant recent experience. The experience with liquid lithium targets, upon which the concept of the fragmentation target is based, comes from the fusion energy program. Concern was expressed that the structure of such a target at RIA and the conditions to which it will be exposed are sufficiently different from those in the fusion program to warrant careful consideration. The costing of the fragment separator, based on a device now being constructed at MSU, is likely to be very reliable: the most significant new challenge at RIA will be dealing with high radiation levels at the front end of the device.

The “trust fund” approach to experimental equipment is now common for a facility of this scale and type, and is appropriate given the expected evolution in both scientific priorities and technical capabilities over the life of this project. The overall allocation of funds to experimental equipment is in line with what will be required to address the scientific scope desired by the potential RIA user community. Any significant cost reductions in experimental equipment are likely to require a reduced scope of the scientific program. Indeed it is likely that as the radioactive beam nuclear physics evolves worldwide, while RIA is under development, that increased demand for instrumentation funding will develop. The resulting pressure, if it cannot generate increased funding for experimental equipment, may result in a smaller number of endstations and consequently will require careful identification of scientific priorities.

The operations cost estimates associated with the experimental facilities appear tight. The operation of the production target areas, which are likely to be a hazard category III nuclear facility, is a particular concern. A dedicated operations staff for this part of the facility was recognized as prudent to avoid exposing accelerator operations staff to burdensome and unneeded training regimes. The extent to which the in-house research effort was supported was not completely clear (or not consistent between the two groups).

Civil Construction

The civil construction costs with the associated utilities are estimated to be $126M and as such represent ~20% of the total TEC. The cost estimates were prepared from a footprint derived from building specifications defining square footage, special requirements (e.g. crane coverage, radiation issues), and utilities. Estimates involved the use of several A/E firms with prior experience in construction activities of this type. The cost per square foot of the various facilities ranged from ~$200 to ~$600 depending on the complexity of the building. Independent estimates of similar facilities from different A/E firms typically agreed on costs per square foot to within 10% at both potential sites. Independent estimates using similar specifications were performed for both MSU and ANL footprints. While the details varied somewhat between the two estimates the bottom line was consistent to within ~5%. A contingency of 20% was used for this cost element.

The Sub-committee considers the agreement between the independent estimates to verify that the cost estimate is on a firm basis for the proposed footprint. At this point the largest uncertainty is probably that arising from changes to the detailed specifications rather than improved estimates of the present buildings. The technical building specifications were judged to be suitably detailed for a conceptual design phase. The Sub-committee did not identify any major deficiencies in the proposed footprint and thus would not expect major revisions from this point. Historically both ANL and MSU have constructed similar facilities within 20% of the estimated cost and the Sub-committee accepts the use of this figure for the contingency allocated to this cost element. The overall civil construction costs are deemed realistic.

Central Facilities

This cost category refers to those items that span several sub-systems. The main components are project management, controls and cryogenic systems.

The estimate associated with the cryogenic systems is based on unit costs from the similar systems presently under procurement for the SNS Project. Cryogenic loads from the various system components (cavities, transfer lines, magnets, power leads) are well understood. Summing these components results in the overall specifications of the refrigerator capacity. A 50% safety margin is used in determining total capacity. Transfer line routings are derived from the proposed footprint. SNS cryogenic unit costs are mature and have been reviewed many times at this point. Within the next few months these costs will become actuals as bids are received. The Sub-committee views this methodology as basically sound and suggests that the combination of 50% excess capacity and a 35% contingency is somewhat conservative. When SNS actuals are known then a reduction in contingency should be considered.

The costs associated with project management were derived from a postulated management organization plan which was then adopted for a 5-year period. This resulted in a 28 FTE manpower estimate. This level of effort is less than that estimated for the SNS Project and slightly more than that required for RHIC i.e. not an unreasonable estimate given the TEC. The Sub-committee notes that project management tends to be a 'standing army' and will vary depending the length of the project. Because of this uncertainty the Sub-committee feels the 35% contingency allocation to be prudent at this time.

The controls system estimate is based on that presently in use at NSCL. A 12 FTE per year manpower estimate is somewhat less than RHIC but RIA is a less complicated machine. The Sub-committee finds the controls estimate reasonable.

Other Project Costs

The collaboration presented their analysis of the "other project costs," which together with the TEC, add up to the TPC. These costs, in FY01 dollars, include R&D, pre-operations, conceptual design and environmental permitting. These latter two items are accrued prior to the start of construction, as is a portion of the R&D.

The R&D cost estimate as presented, and without detailed justification, totaled $25M, including $15M needed before the construction period and $10M during the construction period. The Sub-committee regards this level as significantly less than would be needed for a project of this scale and complexity.

The pre-operations costs were defined as covering element, subsystem and system commissioning, replacement of components that fail during commissioning ("infant mortality"), together with utility costs and supplies to support these activities. The pre-operations cost estimate of $150M was based on an estimate of the out-year operations costs for the facility (see next section), and an assumed six year project schedule that calls for pre-operations activities to begin in the third year of construction and rising to over 95% of the estimated operating costs in the last year of the project. The total pre-operations cost estimate was calculated from an assumed ramp up of these costs from $20M in the third year of construction to $60M in the final year.

The Sub-committee was not provided with any information to indicate that this estimate was developed from a model taking into account specific pre-operational activities, their scope and duration. The proponents stated that it was assumed that for the final year of construction the major systems of RIA with the exception of the experiments would be in a commissioning mode for the entire year, thus the large pre-operations estimate in the final year compared to the operations cost.

The Sub-committee had no basis to verify the estimate and, based on other projects of comparable scale and complexity, believes that a more thorough analysis of the pre-operation costs for RIA would yield a significantly lower value. A reviewable estimate of the RIA pre-operations costs based on a detailed activity model is yet to be developed.

The remaining "other project costs" of $15M estimated to be $10.5M for pre-conceptual and conceptual design and $4.5M for analysis related to environmental permits.

Operations costs

The Sub-committee was provided with two estimates of the annual operating costs of RIA, in FY01 dollars. One was provided by Argonne and the other by Michigan State representing an MSU/ANL consensus view. Both estimate the operating costs of RIA as $65M per year.

The Michigan State estimate was based on an estimate of the staff size needed to operate experimental areas and the accelerator facility including beam delivery to the experimental areas as well as general support functions, mechanical engineering and machine shops, and safety. The staff size of 320 was determined from functional requirements and based primarily on the experience of Jefferson Laboratory. Personnel costs were estimated as $150k/FTE and are assumed to include indirect costs. Procurement costs include utilities (electricity costs of 5 cents/kWh), cryogens, stores and supplies, and equipment replacement costs. Total personnel costs are estimated to be $48M, and procurements (including $5M of equipment, $7M for electricity, and $1.5M for cryogens) are estimated to be $17M.

The Sub-committee was comfortable with much of the basis of the Michigan State estimate, especially numbers of personnel for the accelerator systems and experimental facilities. However, there are essential functional areas that seemed not to be covered by the estimate including the facility Director and associated administrative staff, staffing for "development activities" needed to keep the facility of the cutting edge, and data processing and computing staff. In addition, the estimated staff associated with the radioactive production targets seems to be underestimated.

The Argonne estimate was based on scaling from the staff size and experience of ATLAS as well as other facilities. This estimate was characterized as lean and driven by a recognition that funding for operations of facilities is extremely stressed. The Argonne estimate was presented to the sub-committee during discussions at the request of the sub-committee. The Argonne estimate also totals to $65M. It is based on a staff for accelerator and facility operations that is somewhat smaller than the Michigan State estimate (a total of 253). Higher FTE costs in the Argonne estimate (e.g. $214k/FTE for Ph'ds and engineers included full overheads) results in a total personnel cost of $48M, identical to that of the Michigan State estimate. Stores, capital equipment, electricity, cryogens, etc. are estimated to cost an additional $17M, also the same as in the Michigan State estimate.

The subcommittee considers the estimated operations costs of $65M for RIA to be minimal. The Michigan State estimate which was based on JLAB experience and has the right scale of personnel for the functions estimated, but doesn't consider some necessary functions and may be based on too low an FTE cost. The Argonne estimate is lean on staff size. The subcommittee has not done its own detailed estimate, but in discussions it became evident that the sub-committee members believed that the actual operating costs for RIA will likely be close to the CEBAF facility (~$75M FY01 dollars).

General Comments

The Sub-committee notes that the full facility overhead rates were used in evaluating the labour costs associated with the construction activities, and none were used on the materials estimates. Historically construction projects have used significantly lower overhead rates than this on direct labour and a handling burden on materials of several percent. The Sub-committee believes that if historical overhead rates could be negotiated for this Project then significant cost savings would be realized.

The Sub-committee finds the $94M 'trust fund' allocated for experimental equipment to be reasonable for the intended goal. In the sub-committee's opinion these costs should be considered fixed with the scope adjusted to maintain costs.

A pertinent issue for assessing a cost estimate is the stability of the technical design. The sub-committee finds that the technical design is essentially stable and that most recent changes have involved scope modifications.

With one or two exceptions, such as the liquid lithium targets, the sub-committee considers the technical risk for the major components to be low with appropriate R&D funding.

There does not appear to be any significant omissions from the TEC costs although the details can be expected to improve with time. We do find some issues in the TPC.

Some 30% of the TEC estimate is supported by vendor quotes, the remainder based on engineering estimates. Of these, an additional 20% is scaled from existing facilities at other laboratories. The costing methodology followed a detailed WBS structure which in some cases went down as far as a level 5 estimate. A cost book containing a comprehensive roll-up was provided to the Sub-committee. The sub-committee considers the accuracy of the cost estimates to be good for this point in any project and should provide a firm basis for subsequent refinements.

The Sub-committee considers the postulated 6-year construction schedule to be aggressive and would imply a peak funding level of ~$200M per year.

The use of existing facilities on the ANL site are estimated to result in savings of ~$50M. An alternative site at MSU is assessed as cost neutral (by definition) by dint of non-DOE support. The sub-committee finds no reason to disbelieve these statements. Both potential sites provide significant off-project office buildings.