THE US INDUSTRIAL RF UNIT COST STUDY

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Abstract

A major goal of the ILC Global Design Effort (GDE) is to produce an ILC Reference Design Report and an ILC Technical Design Report. Physicists and policy-makers will use these reports to decide the future of the project. As part of these reports detailed concept, performance assessments, reliable international costing, an industrialization plan, siting analysis, as well as detector concepts and scope must be developed. As part of this effort, a contract for an industrial cost study for fabrication of the Cryomodules and RF Power Systems that make up the RF Units of the ILC was commissioned by Fermilab to Advanced Energy Systems and their team partners, CPI and Meyer Tool. This paper presents the methodology of the industrial cost study and summarizes important assumptions. The public results and key cost drivers will be presented.

RF UNIT CONFIGURATION

At the inception of the cost study a RF Unit was defined as three cryomodules in series powered by a single RF power system. Each cryomodule contained eight RF cavities per cryomodule. The center cryomodule also contained a magnet assembly and BPM package. Production quantities of one, 250 and 750 RF Units were specified. This study addressed the manufacture of these components and did not address the integration of the three cryomodules and the RF power system into a RF Unit.

COST MODEL

Main Assumptions

Even prior to the beginning of this cost study, the study team had concluded that the U.S. Government would need to provide a facility ("The Factory") equipped with the necessary tools to accomplish the unique production steps required to achieve superconducting cavity fabrication, processing and their integration and test in the cryomodules. In general there is little interest within U.S. private industry in tooling up for a highly technical, massive, short-term program that is not related to current business.

The Factory would be responsible for producing the cryomodules. Final assembly and integration of the cryomodules would be performed within the Factory. The completed cryomodules would be delivered to the U.S. contingent of the ILC project team for final cold testing and eventual installation.

This situation does not exist for the RF power system components as there are existing companies doing production quantities of RF components and subsystems and the project will generate ongoing replacement business. RF equipment would be procured directly by the ILC program for integration into the RF Units.

Assumptions regarding the Factory include.

- Located at or near Fermilab.
- The cost of the Factory setup is not included in the study.
- Industry will operate and perform all work at the factory.
- Cryomodule components will be procured through the Factory.
- RF equipment will be procured through the local ILC program infrastructure; not through the Factory.

Cost Estimate

Figure 1 illustrates the structure of the cost model used in this study. The Factory and RF subcontractor(s) produce the components that comprise the RF Units. For Factory labor activities, labor overhead, G&A and fee were added to direct labor costs. For material and services delivered by outside suppliers and subcontractors to the Factory only G&A and profit are applied.

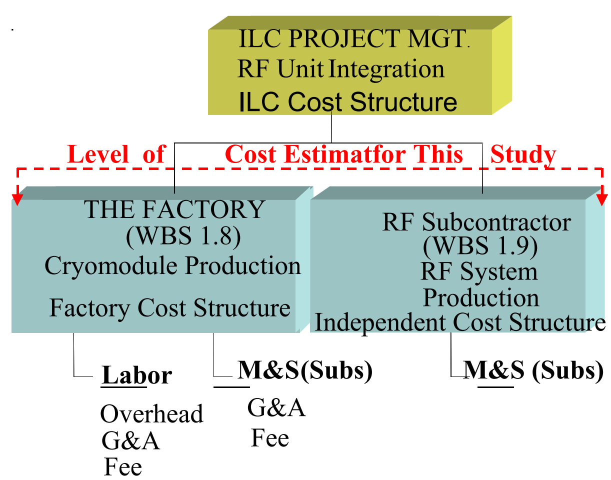

Figure 1: Cost structure for study.

Normalized Top Level Costs

A top level summary of costs resulting from this study is presented in Figure 2. These costs have been normalized with the 250 RF Unit case as baseline. This case was chosen as it represents both an optimized "high" production effort and the most likely level of U.S. participation in RF Unit manufacture.

Quantity of RF Unit	1	**250**	750
Total Quantity Cost	2.35	**250**	694
Per RF Unit Cost	2.35	**1.00**	0.92
CM w/ Magnet (1 per RF Unit)	0.51	**0.23**	0.21
CM w/o Magnet (2 per RF Unit)	0.33	**0.20**	0.20

Figure 2: Top level costs (normalized).

The top level costs were developed from detailed cost spreadsheets representing a level 6 Work Breakdown Structure. The study costs take into account quantity discounts and learning curve for multiple quantities.

The fidelity goal of the cost study was +/- 20 %. The actual estimated fidelity was +/-24%. The above costs were based on high production manufacturing methodology and are not representative of what a single prototype RF Unit would cost.

Funding Profile

A yearly funding profile is shown in Figure 3. This profile was developed to approximate the annual expense associated with manufacturing and assembling 250 RF Units, the nominal production program. The costs were tabulated in two parts; the cryomodule costs (lower section of each bar) and the RF system costs (upper section of each bar).

The funding profile was based on cost input for producing 250 RF Units in the Factory and a cost profile for a representative, large order in the RF industry.

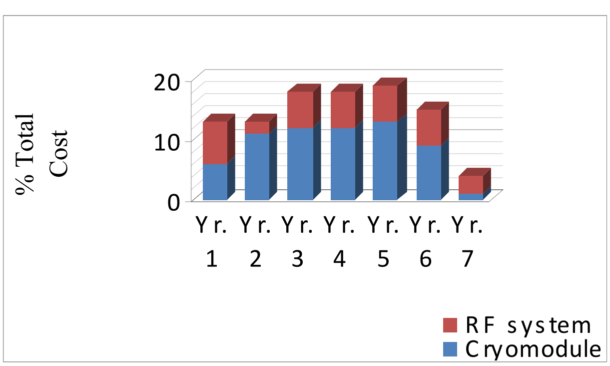

Figure 3: Funding profile for 250 RF units.

Cost Drivers

The following Figures 4 through 6 represent the relative costs of components of the nominal 250 RF Unit production case. Conclusions regarding cost drivers should not be surprising to readers familiar with superconducting cryostat fabrication.

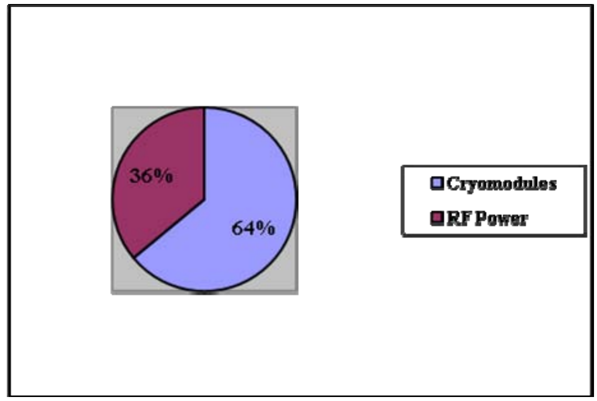

Figure 4: RF unit cost –cost drivers.

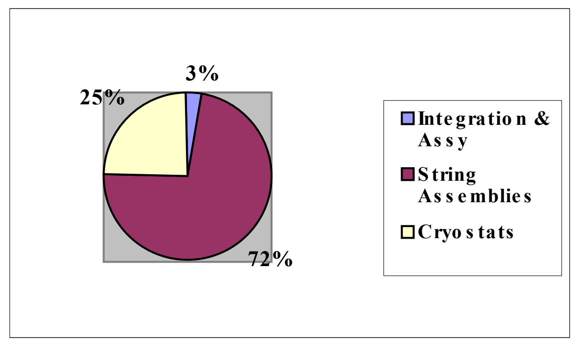

Figure 5: Cryomodule cost -cost drivers.

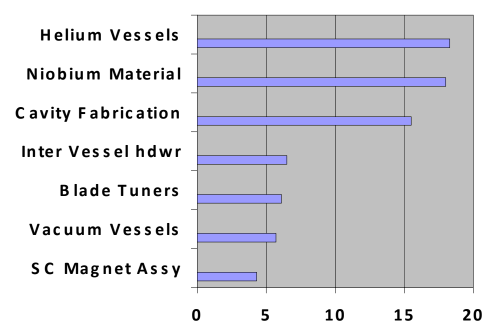

Figure 6: Percentage of cryomodule cost-cost drivers.

Production Rate

The cost study was constrained by the ILC Reference Design Report in regards to the RF Unit production schedule. A total time period of 6.5 years was permitted from the point of first funding until completion of the production run. Production work would begin in the Factory 20 months after funding to allow for setup and startup. Procurement of materials and subcontracting can begin during the first fiscal year.

Table 1: Planned Production Rate (Nominal Case)

Year	RF Units Annual Production Rate
1	--
2	Start of production at 20 months
3	6
4	36
5	82
6	86
7	40 (only 0.5 year)

Factory Equipment Requirements

The level of detail developed during the cost study allowed the estimation and optimization of overall manpower and workstations/equipment required to meet the required production rate. Key equipment requirements for the Factory are summarized in Table 2.

Table 2: Factory Equipment Requirements

Equipment Description	Quantity
Niobium Material Scanners	6
NC Machines	11
BCP Systems	2
E-Beam Welders	18
RF Tuning Benches	8
Electropolishing Systems	7
High Temperature Vacuum Ovens	7
High Pressure Water Rinse Systems	12
VTA Systems (may be able to share RF Power)	18
String Assembly Lines	5
Vacuum Vessel Final Assembly Fixtures	5
Cryomodule Integration & Assembly Lines	21

Summary and Conclusions

This is the first time that U.S. industry has participated in ILC costing. The study team worked with a set of conditions and input data that were the latest available at the start of the study. The costs developed by the study were realistic based upon inputs current at that time. At the time of the study portions of the RF Unit design were still undergoing definition and the fidelity of the cost estimate reflects this fact.

An important contribution of the cost study was the identification of component and assembly costs that are amenable to cost reductions. These cost reductions could be achieved through a combination of design configuration refinements, cavity processing optimization and manufacturing optimization and workflow improvement.

A key issue for the future will be to promote involvement from a broader base of U.S. industry. A few key U.S. companies with experience in fabrication of superconducting cryomodule components and assemblies were responsive to cost inquiries. At the time of the study U.S. companies without existing experience in these areas demonstrated little interest in participating in the cost study. Reasons expressed for this lack of interest included: They do not believe the project to be real. It would interfere with present long term business.

Recommendations for a follow up to this study include:

- Evaluate potential revisions to the present cost study, incorporating the latest guidance of the GDE on configuration and processing.
- Develop a qualified set of contract machining companies for niobium cavity parts. This has the potential to significantly reduce (~25%) cavity fabrication costs.
- Develop process improvements in fabrication and processing of components. This study was based mostly on present methods.
- Develop a plan and cost estimate for Factory setup.

REFERENCES

[1] J. Sredniaswski, et al. “Cost Study for Production of ICL Type RF Units Final Report,” Fermi National Accelerator Laboratory Purchase Order #569640, March 2007

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