Director's Review of the Project X Cost Range Estimate: Beam Instrumentation Systems

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Project X Director's Review

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Outline

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Project X Scope of Estimated Work

Beam Instrumentation and Diagnostics Systems

- Measure and characterize beam parameters (beam intensity, orbit, profiles/emittance, phase/timing, halo, etc.) for
  - Machine commissioning
  - Performance evaluation and improvements under various machine conditions, operating modes and a range(?) of beam parameters.
  - Detection and analysis of faults and error sources.
- Provide detection systems (BLMs, current monitors) for a fast Machine Protection System (MPS).
- Instrumentation hard-, firm- and software includes
  - EM and optical detection systems and control elements
  - Read-out, analysis and calibration systems
  - Infrastructure, cabling, timing and clock systems, DAQ interface
- Many beam instruments are distributed systems

Boundary Conditions & Assumptions

- Beam instrumentation systems primary interfaces with
  - The vacuum system on the detector (pickup) side.
  - The controls system on the read-out system end for DAQ, controls, and trigger events.
  - The LLRF system to supply low-jitter clock signals (for ADCs).
  - …and is linked to beam dynamics and operational requirements!
- Practical beam tests of mission critical diagnostic systems is mandatory. This instrumentation RD&D will be tested at
  - HINS: Proton and H^- diagnostics, e.g. BPMs, beam intensity monitors, beam profile monitors (wire-scanners, slit-multiwire), laser-based diagnostics, long. bunch profile, BLMs, etc.
  - NML: Diagnostics at ß≈1, BPMs for the cryomodule.
  - MI: Electron cloud diagnostics, e-beam scanner (profile monitor).
  - Other beam facilities, e.g. Fermilab Linac, SNS Linac.

Boundary Conditions & Assumptions, cont.

- Assumptions of this costing exercise for beam instrumentation:
  - Based on ICD beam parameters, with lower bunch intensities (1/4), and shorter pulse length (~100 μsec) during commissioning.
  - Based on known technologies, either in operation (Fermilab, SNS, CERN, RAL, GSI, etc.), or in a practical R&D phase with test beams.
  - Apply standardization wherever possible, e.g.
    - Apply VME/VXS crate technology everywhere.
    - Standardization of read-out, timing, processor, and other electronics.
    - Similar or same detector elements for systems with high quantities, i.e. BPMs, BLMs.
  - No active electronics components in the accelerator tunnel.
  - NOvA BPM upgrade of the Recycler, and other NOvA related beam diagnostics modifications in the MI tunnel
  - Reuse of most MI / RR beam instrumentation systems.

Basis of Estimate

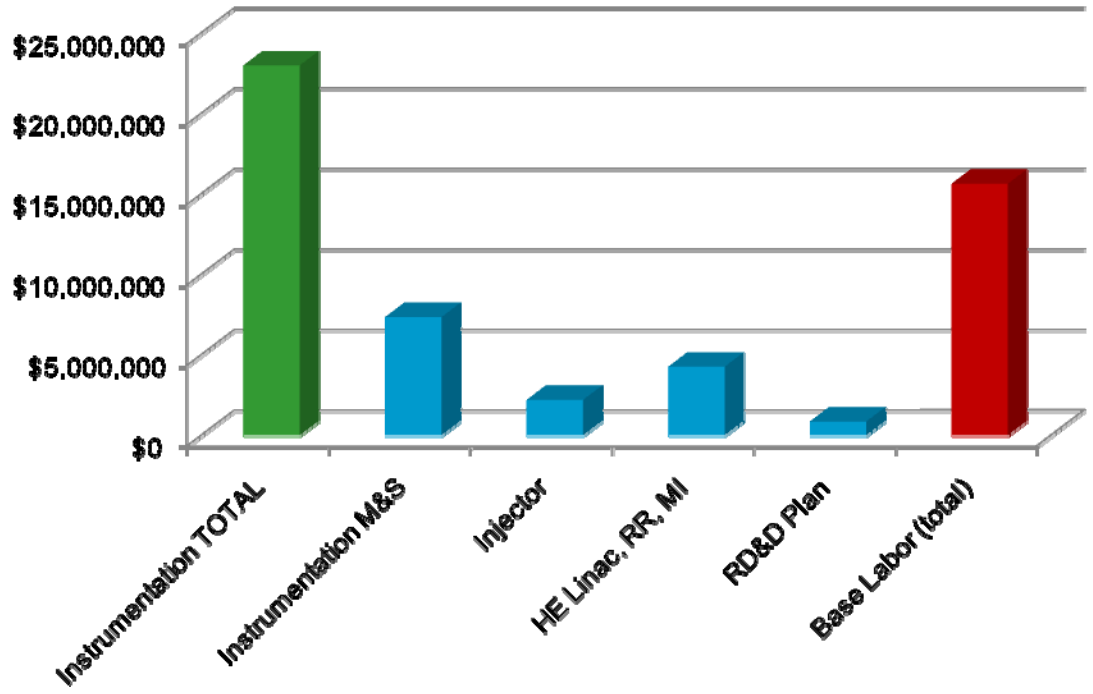
- A parametric spreadsheet summarizes the details of this cost estimate, arranged in four tables:
  - A Counts&Costs table lists15 different instrumentation systems, and their counts in the five Project X machine areas: Injector, 1.3 GHz Linac, Transport-line, Recycler (injection only), Main Injector (only add-ons). Summarizes all M&S costs.
  - A Components table lists all parts, and the M&S costs for each instrumentation system.
    - The cost estimation is done in more detail for the basic instruments, but simplified for supplemental and more exotic diagnostic systems.
  - A M&SCost_Area table sums the total M&S costs, and includes the expenses for the area specific infrastructure.
  - A Manpower table estimates the required FTEs per year under 4 different work categories

Basis of Estimate, cont.

- M&S estimates for individual components are based on
  - Recent purchases, quotes (2007, 2008), or prices available on the web.
  - Experience on recent development activities.
- Comments are added to some table cells, with some background information on the technology and/or details on the estimate.
- The costing assumes a four years construction period (CD-2 to CD-4), RD&D activities are estimated in a separate spreadsheet.
  - At CD-2 (FY12) all design and development activities are finalized.
- So-called “supplemental beam diagnostics” are estimated without a detailed breakdown structure.
- All exotic “other monitors” are summed and estimated as single item.

Cost Overview

- M&S estimates, plus manpower related costs sums to M$23.
  - Including spares, but no contingency, escalation, etc.



Technical Risks

- Regarding beam instrumentation, Project X profits from the experience at SNS and FLASH, as well as diagnostics developed at other laboratories (CERN, GSI, RAL, J-PARC), including Fermilab.
- All proposed Project X beam instruments are (well) known, or in an advanced development status at Fermilab or other laboratories.
- Nevertheless, some minor technical risks are still present:
  - Beam parameters during commissioning cannot be handled.
  - Beam-line layout issues or conflicts prevents the installation of optimal beam diagnostics.
  - Series production does not reach the quality of the prototype.
  - Engineering, development, and design errors (some may be hidden).

Technical Risks, cont.

- Failure or malfunction of major, mission critical systems (e.g. BPMs, BLMs, laser-based diagnostics) will have a substantial impact:
  - Delay machine commissioning/operation!
  - High additional M&S costs for resolving the problems!
- Problems with supplemental diagnostics may prevent to reach highest beam quality / minimize beam losses, however the M&S costs for improvement are probably moderate, BUT: delays operation!
- Mitigation of technical risks (examples):
  - A proposed RD&D program focuses on critical beam instruments, e.g. laser-based diagnostics, beam halo diagnostics, beam emittance monitors, e-beam scanner, e-cloud diagnostics, cold BPMs, etc.
  - Most RD&D activities include practical beam test.
  - Design reviews (also concepts) with internal and external colleagues.
  - Information exchange (workshops, conferences, meetings).
  - Allow for conceptual redundancy wherever possible.

Potential Technical Revisions

- Technical revisions are / may be required
  - Major change of beam parameters or requirements.
  - New insights from beam simulations, studies, R&D results, etc.
  - Conflicts in the layout of the beam-line or conventional facilities.
  - New safety rules / regulations.
  - New technologies, technology breakthroughs.
- Technical revisions do not always increase costs.

A general observation:

- Costs for metal hardware increase (vacuum components, cabling, crates & enclosures, RF connectors, precision mechanics, etc.)
- Costs for electronics decrease (components, boards, systems).

Collaborators

- Outside collaborators are welcome in frame of Project X beam instrumentation R&D
- Project X Collaboration Initiative (November 2008):
  - Expressions of interest on beam instrumentation collaboration projects from SNS, LBNL, and SLAC (Controls).
- SNS
  - Various advanced diagnostics systems (broadband Faraday-cup, e-beam scanner, MEBT beam instrumentation, Allison scanner, etc.)
  - Support, information exchange, RD&D help, visits, reviews, etc.,
- LBNL
  - Collaboration on e-Cloud measurements
  - EOI on the development of a mode-locked fiber laser system for laser-based longitudinal and transverse beam diagnostics.

Summary

- The cost estimation mythology for the Project X beam instrumentation is presented.
- The estimation is given for the
  - RD&D program between CD-0 to CD-2
  - Project X construction period CD-2 to CD-4
- The range and boundaries of Project X beam diagnostic systems are defined.
- Details and the basis of the cost estimate are discussed.
- The technical risks are expected to be low, and will be further reduced by an extensive RD&D program.
- Outside collaborators will play an important role throughout the Project X instrumentation RD&D program.