Accelerator Programs at Fermilab: (Past), Present, and Future

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Outline

- Strategic Framework
- Program Elements
  - The Energy Frontier Line
  - The Neutrino Line
- Aligning our Core Competencies
- Connections and Collaborations
- Organization: The role of the divisions

Strategic Framework:
Time Frames

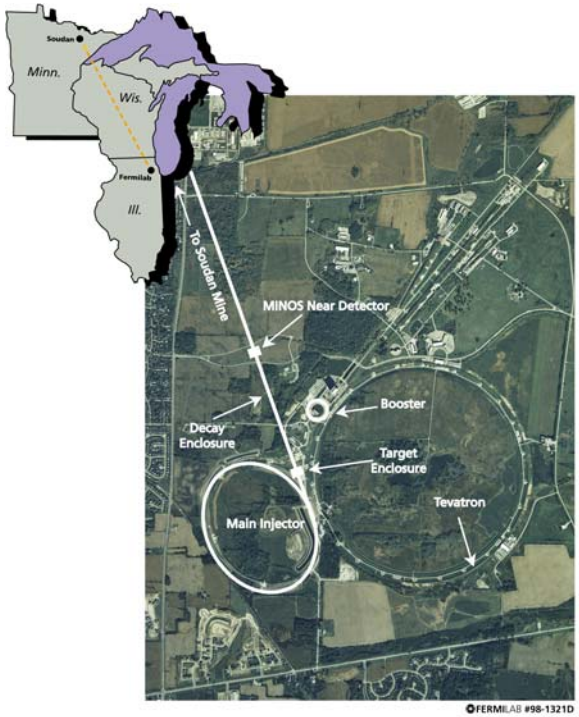
- In characterizing the elements of our accelerator program it is useful to think in terms of three natural time frames:
  - Short term: The Run II era
    - Collider operations, Run II Upgrade Program, NuMI, Proton Plan
  - Intermediate term: The post-Run II era
    - ILC, Proton Driver, LHC, Proton Plan II
  - Far term: Beyond the next generation
    - Neutrino Factory, VLHC, Muon Collider, new acceleration techniques

Strategic Framework:
The Present Reality

- Fermilab has operated the highest energy particle accelerator in the world since 1983. . .
  - This will change somewhere within the period 2007-09.

Strategic Framework:
The Present Reality

- Fermilab has now established the most advanced long-baseline neutrino program in the world. . .
  - J-PARC will become competitive in the 2010-2011 timeframe



To SuperKamiokande:
750 KW @ 50 GeV

Strategic Framework:
Building Blocks

- The basic building blocks out of which the post-Run II era can be constructed have been identified:
  - The decade of 2010: LHC, ILC, PP I, PD, PP II
  - Beyond 2020: Muons (neutrino factory, muon collider), VLCH, AARD

- The challenge is to determine how to assemble a world-leading program based on these elements in an era of uncertainty:
  - How much ($$) is the government willing to invest in HEP?
  - What is $\sin^2(2\theta_{13})$?
  - When is the LHC going to turn on and what will it tell us?
  - How do we prepare for the future without wrecking Run II in the process?

- Any strategic plan has to recognize the existence of these questions and provide flexibility as answers appear.

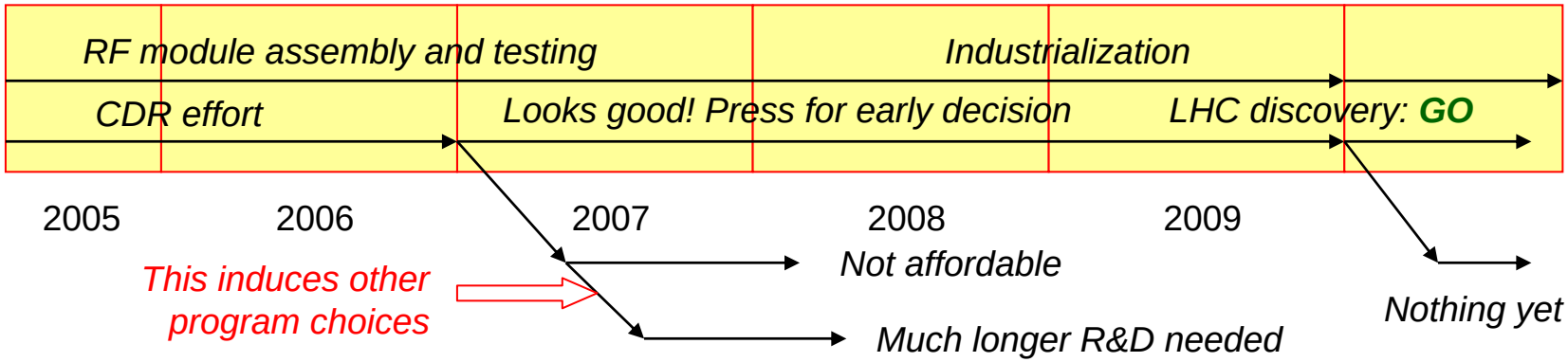
Strategic Framework:
The Vision

- The vision is that Fermilab remains the U.S. center for accelerator based research in High Energy Physics, and one of the (two) pre-eminent centers in the world for the foreseeable future.

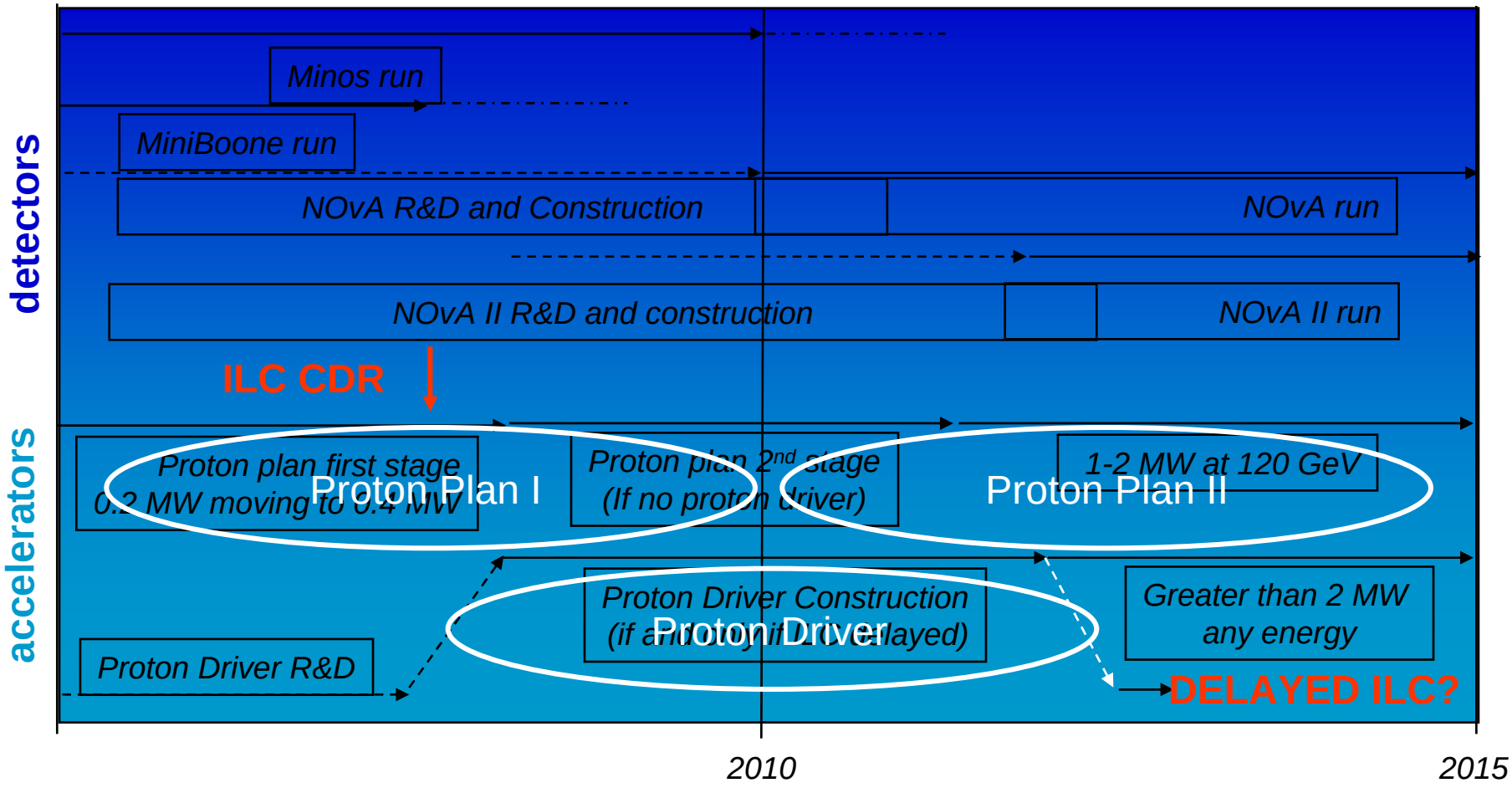
- The Fermilab Long Range Plan establishes the ILC as the primary goal, with a world-leading neutrino program if the ILC were delayed or constructed elsewhere.

- The ILC cold technology decision has allowed close alignment of Fermilab's R&D programs in support of these goals.

Strategic Framework:
The Roadmap: ILC Decision Tree



Strategic Framework:
The Roadmap: Neutrino Decision Tree

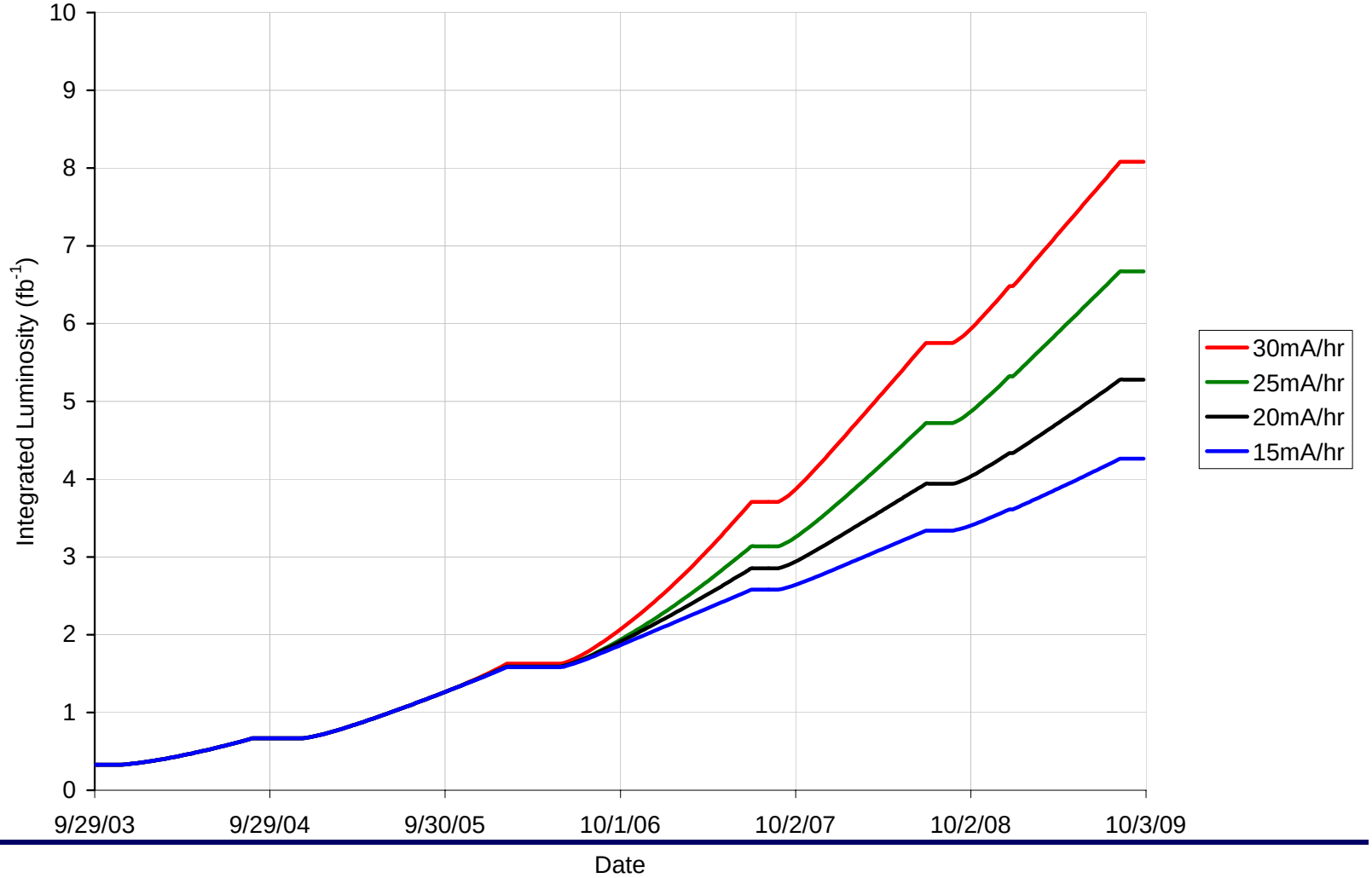


The Energy Frontier Line:
Run II

- Run II has been the lab's highest priority for the last several years. The entire laboratory, with AD in the lead, has done a magnificent job in establishing the current level of performance.
  - AD staff please take note: Your efforts on Run II have been as important as any at the laboratory in establishing Fermilab as the preferred U.S. host lab for ILC.

- Successful completion of Run II remains critical to our future.
  - "Design" and "base" profiles established several years ago @
    - D=8 fb^{-1}; B=4 fb^{-1} (through FY2009)
  - Upgrades are essentially complete in 2006
    - Resources devoted to Run II have already started to decrease, and will continue to do be redeployed through 2009.
  - Stacking rate is the last major battle
    - ~30 mA/hour should allow us to meet the design goal.

The Energy Frontier Line:
Run II



The Energy Frontier Line:
LHC

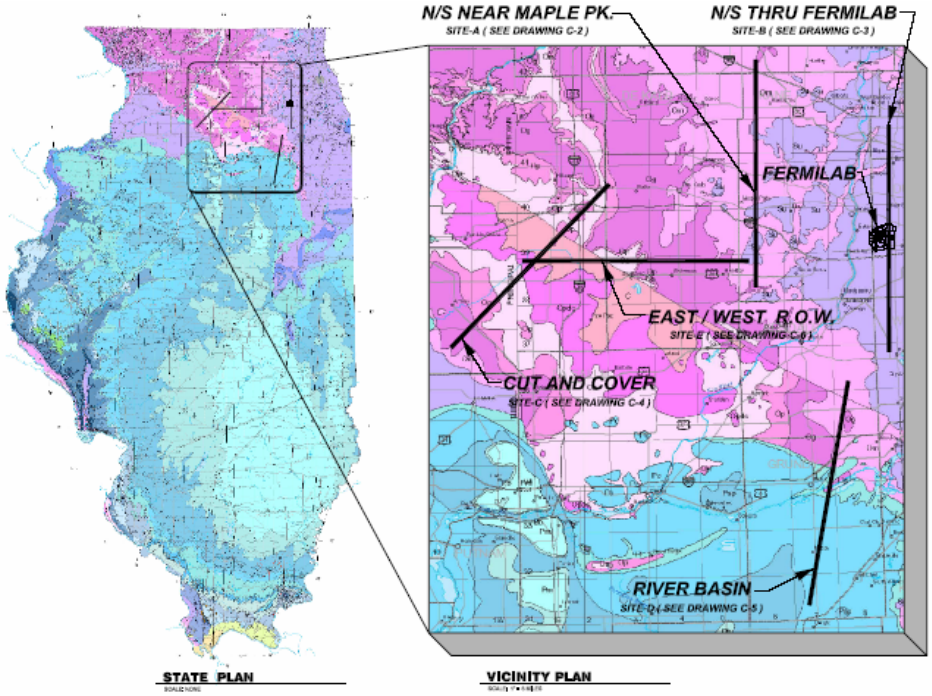
- U.S. contribution to the LHC accelerator construction has been executed as a inter-laboratory (FNAL, BNL, LBNL) collaboration.
  - The fabrication, testing, and shipment of low beta quadrupoles from Fermilab to LHC will be completed over the next three months.
- The LHC Accelerator Research Program (LARP) has been initiated to provide continued collaboration between the U.S. and CERN on the LHC accelerator.
  - Hardware commissioning
  - Beam commissioning
  - Instrumentation
  - Development of next generation (Nb_3Sn) quadrupoles for a luminosity upgrade (~2013?)
- Possible utilization of “low-field” magnets (developed within the VLHC program) for a 1 TeV injector into LHC?

The Energy Frontier Line:
LHC

The Energy Frontier Line:
ILC

Our goal is to provide the U.S. with the best possible host site for a prospective ILC bid, and to construct the ILC in northern Illinois.

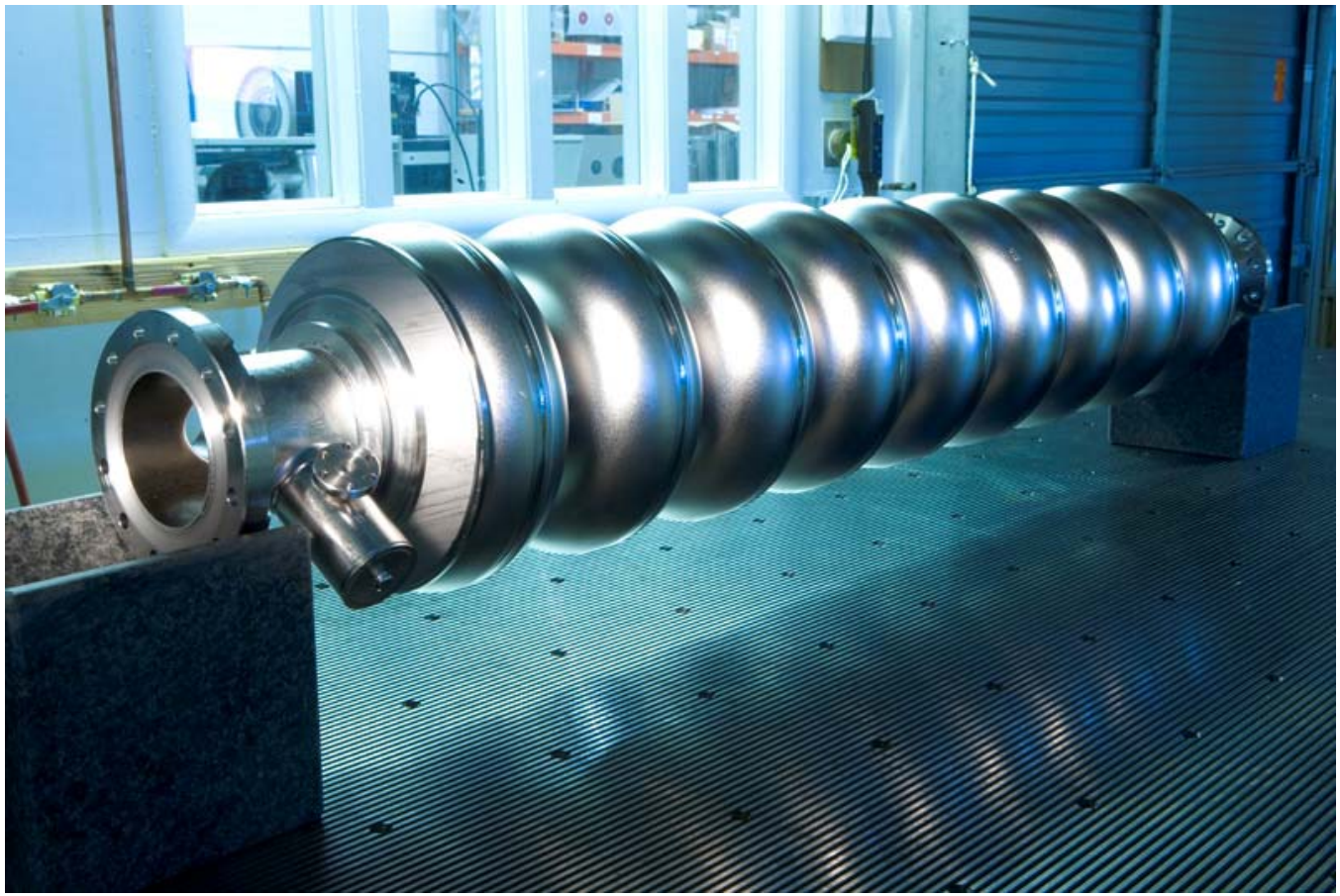
"The U.S. Department of Energy has expressed its interest in the possibility of hosting a linear collider, at Fermilab, subject to the machine being affordable and scientifically validated by physics discoveries at the LHC.“



The Energy Frontier Line:
ILC: Fermilab Goals

- Provide leadership of the America's regional effort in development of the SCRF technology base for ILC.
  - Fabrication and testing facilities @ Fermilab
  - Goal is to have a first U.S. assembled cryomodule ~1/1/07
- Provide leadership of the America's regional effort on the civil/siting design
- Engage strongly within the GDE in preparation of the RDR
  - Major involvement in costing, linac design, civil, communications
  - 6 km damping ring chosen the BCD
- Organize a lab-wide effort coordinated within the Directorate
  - Bob K. now assigned as ILC Program Director
- ILC Community Task Force formed

The Energy Frontier Line:
ILC



Accel 9-cell, 1.3 GHz cavity at IB-4

The Neutrino Line:
NuMI, MINOS, Noνa, and Proton Plan I

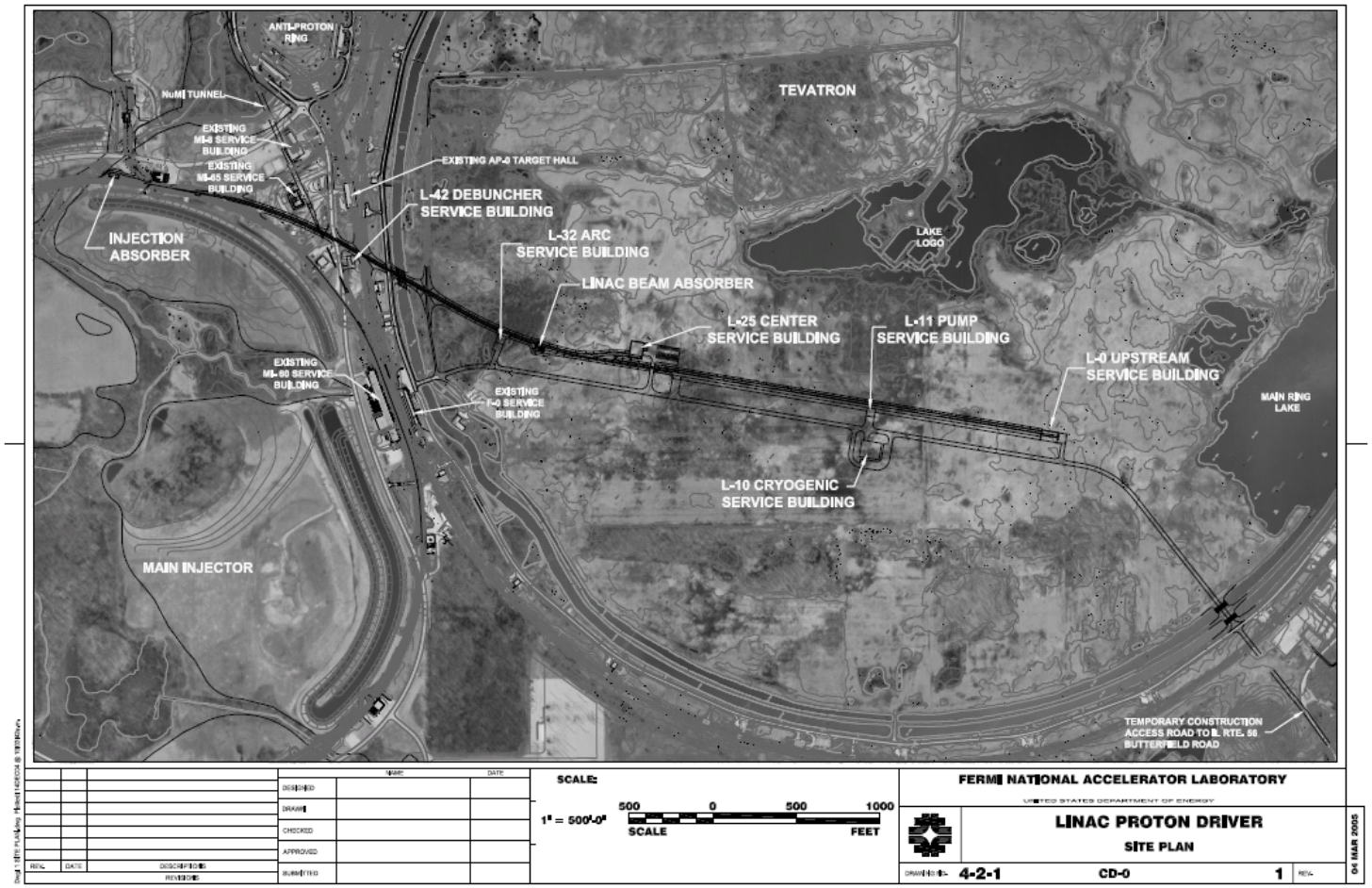
- NuMI is up and running, providing the highest performance long baseline neutrino beam in the world.
  - Design goal is 0.25 MW at 120 GeV
  - Proton Plan I goal is ~0.4 MW @ 120 GeV (4.3E13 @ 2.2 sec)
    (post-Collider) ~0.7 MW @ 120 GeV (5.2E13 @ 1.5 sec)

- The NuMI beamline is currently serving the MINOS experiment. Later in the decade it will simultaneously serve Noνa.
  - Noνa is designed to have a world-class capability at Proton Plan I design goals.
  - However, extension of the beam power on target to 1-4 MW range would keep Fermilab in a world leading position for in neutrino physics for decades, in addition to providing a base for a possible construction of a muon storage ring based “Neutrino Factory”

The Neutrino Line:
Proton Plan II and Proton Driver

- It is highly likely we will embark on a program of extending beam power beyond 1 MW independent of the fate of the ILC.
- If the ILC is delayed, or being constructed elsewhere, the preferred approach would be the Proton Driver.
  - 2 MW, upgradeable to 3-4 MW, throughout the range 30-120 GeV
  - Simultaneous delivery of 0.4 MW, upgradeable to 2 MW, at 8 GeV
  - Keeps the ILC technology development path alive
  - Potential base for future machines
  - Status: Expect CD-0 “soon”, preparing for CD-1 review this summer
    Forming a national collaboration
- If the ILC is identified as on a “fast track” we would most likely execute a program based on modifications to the existing complex (“Proton Plan II”, see e.g. Dave McGinnis presentation)
  - 1-2 MW at 120 GeV, power proportional to beam energy

The Neutrino Line:
Proton Driver



The Long Term

- The longer term future is represented by our efforts in the Muon , photoinjector, and superconducting magnet programs.
  - Muons
    - MTA, migrating into MICE
    - Long term: NuFact? Muon Collider?
  - Photoinjector
    - Will move to New Muon Lab in support of ILC + AARD
  - Superconducting magnets
    - LARP in the short/intermediate term
    - Long term: VLHC?

Establishing Core Competencies

- The two main branches within our future rely on superconducting radio frequency acceleration as a technology base.
  - ⇒ It is critical that Fermilab establish world leading expertise.
  - – Requires investment in both human and physical resources

- Fermilab has historically been a/the world leader in superconducting magnet technologies, a capability that was dissipated and then reconstituted at great effort in the mid-late 1990s. We need to continue the investment.

- Accelerator simulations are an increasingly important component in the design of large, state-of-the-art accelerator facilities
  - – CD/AD collaboration

Connections & Collaborations

- Collaborative efforts on large scale accelerator projects are clearly the wave of the future.
  - ILC is already internationalized, with the national scrf effort being conducted through a half-dozen major laboratories.
  - Proton Driver effort already involves ANL, BNL, LBNL, MSU, SLAC
  - Early industrial involvement is desirable /necessary on these projects

  ⇒ **We have to get comfortable with working in this mode.**
- Universities connections are becoming more important.
  - Major local universities with aspirations for degree granting in accelerator fields (UC, UIC, IIT, UIUC, NWU, NIU)
  - Masters program in rf engineering under discussion with NIU
- Many of these connections are forged through the state.
  - Illinois Accelerator Research Center (IARC) proposal
- The Public

Organizing the Fermilab Effort
The Role of the Divisions

- Collaborations need to exist also across division boundaries
  - Great progress on this within the Run II Upgrade Program
  - Good cooperation on ILC and PD
- At the end of the 1990s a conscious decision was made to grow the technology R&D capabilities of the Technical Division, most notably in resurrecting the sc magnet program and in establishing TD as lead division for Fermilab linear collider technology program.
  - This was done because we felt the AD would have its hands full with Run II
  - Not intended to be a permanent feature
  - Accelerator expertise did not diminish in AD, but focused on Run II
  - AD remains residence of the bulk of our accelerator physics and operations expertise

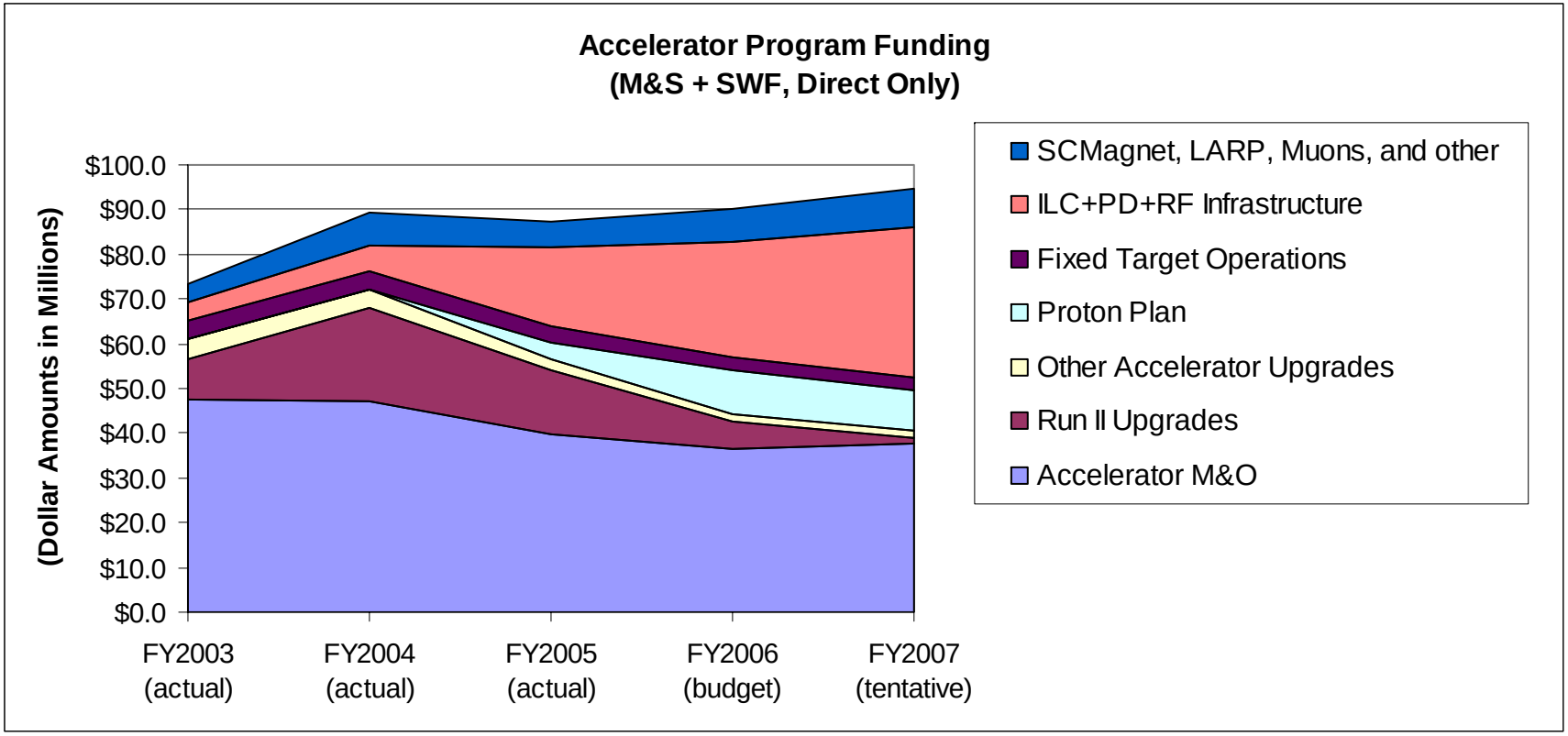
Organizing the Fermilab Effort
The Role of the Divisions

- I would claim that as a result the laboratory as a whole now has greater capabilities in accelerator physics and technologies relevant to our future than it did five years ago.
- However, it is now imperative that AD strongly engaged in the R&D towards are future.

  ⇒ This is our intention; our challenge is to do this without damaging Run II.

Following the Money

- Talk is cheap, the way to understand the priorities of the lab is to follow the money.



Summary

- The lab has done a great job on Run II, with AD providing critical leadership. The goal remains to meet or exceed the design curve.
- We need to confront the future and do so in a manner that does not snatch defeat from the jaws of victory on Run II.
  - Significant resources are going into preparing for the future. This trend will grow in the next couple years.
- Over the next ~15 months Fermilab R&D activities are <u>independent</u> of the final destination:
  - Develop superconducting rf capabilities, with domestic and international partners
  - Support GDE completion of ILC CDR with supporting R&D
  - Completion of Proton Driver CDR with supporting R&D
  - Participate in LHC commissioning and magnet R&D + muons + AARD
- <u>The next several years should be very interesting.</u>