Project X: Status, Strategy, Meeting Goals

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Project X Muon Workshop

November 8, 2010

Outline

- Project X Goals and the Reference Design
- RD&D Plan
- Strategy and Timeline

Our websites:

http://projectx.fnal.gov

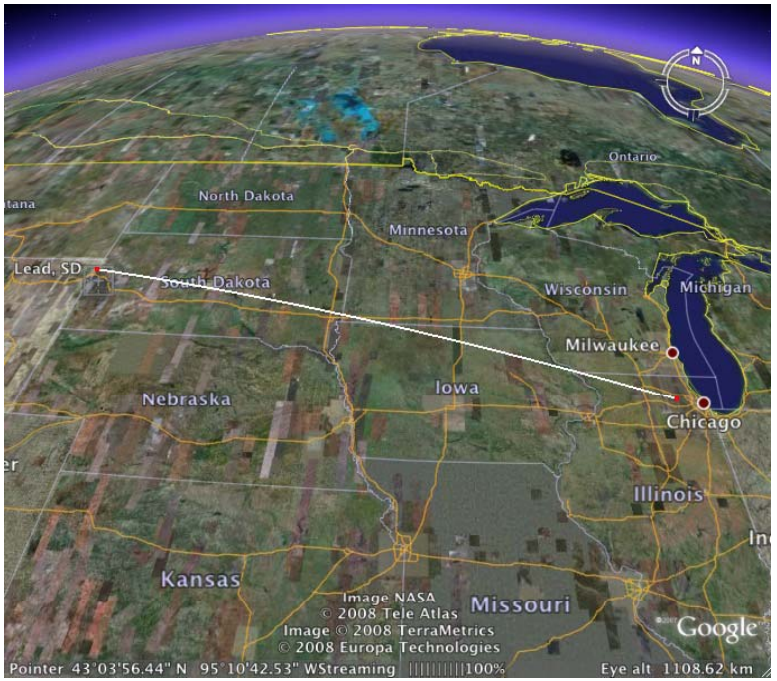
http://projectx-docdb.fnal.gov

Evolution of the Fermilab Accelerator Complex

- A multi-MW Proton Source, Project X, is the linchpin of Fermilab's strategy for future development of the accelerator complex.
- Project X provides long term flexibility for achieving leadership on the intensity and energy frontiers
  - Intensity Frontier:
    NuMI→ NOνA→ LBNE/mu2e→ Project X → Rare Processes → NuFact
    - Continuously evolving world leading program in neutrino and rare processes physics; opportunities for applications outside EPP
  - Energy Frontier:
    Tevatron → ILC or Muon Collider
    - Technology alignment
    - Fermilab as host site for ILC or MC

Mission

- A neutrino beam for long baseline neutrino oscillation experiments
  - 2 MW proton source at 60-120 GeV
- High intensity, low energy protons for kaon and muon based precision experiments
  - Operations simultaneous with the neutrino program
- A path toward a muon source for a possible future Neutrino Factory and/or a Muon Collider
  - Requires ~4 MW at ~5-15 GeV .



- Possible non-HEP missions under consideration
  - Nuclear physics and ADS development

Physics Requirements
November 2009 Workshop

	Proton Energy (kinetic)	Beam Power	Beam Timing
Rare Muon decays	2-3 GeV	>500 kW	1 kHz – 160 MHz
(g-2) measurement	8 GeV	20-50 kW	30- 100 Hz.
Rare Kaon decays	2.6 – 4 GeV	>500 kW	20 – 160 MHz. (<50 psec pings)
Precision K^0 studies	2.6 – 3 GeV	> 100 μA (internal target)	20 – 160 MHz. (<50 psec pings)
Neutron and exotic nuclei EDMs	1.5-2.5 GeV	>500 kW	> 100 Hz

Since the November 2009 Workshop

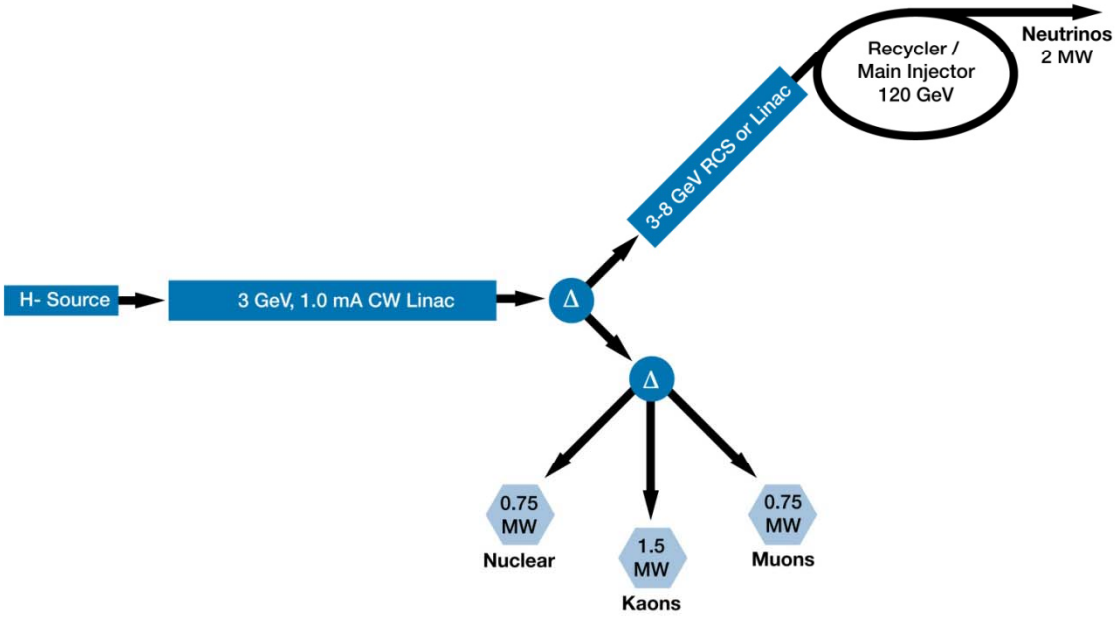
- 3 GeV established as a workable energy for the rare processes program
- Reference Design established
  - Based on 3 GeV CW linac, 3-8 GeV pulsed linac, Recycler/MI modifications
  - Functional Requirements Specification (FRS) released
- Updated RD&D plan, resource loaded schedule (RLS), and cost estimate corresponding to reference design
- Project X collaboration now includes four Indian Institutes
- Potential for nuclear physics and/or energy programs under investigation

Since the November 2009 Workshop

- DOE Science & Technology Review
  - "The Project X machine design is sufficiently well developed for the pre-CD0 stage."
  - "The physics program for Project X is not well defined at this time. The scientific community should be engaged in defining the potential program."
- Five Physics/Experiments Task Forces established
  - Neutrinos
  - Kaons
  - Muons
  - Nuclear Physics
  - Nuclear Energy

  Goal: define an initial experiment in each area
  Fall workshops
- ARRA
  - Significant investment in SRF infrastructure at Fermilab and development of domestic vendors
- New Fermilab Associate Director for Accelerators – Stuart Henderson

Reference Design



- 3 GeV, 1 mA, CW linac
- Greatly enhanced capabilities in the rare processes program
  - MW class beam power to multiple experiments with variable bunch configurations, simultaneous with neutrino operations
- Self-consistent concept for 3-8 GeV acceleration identified
  - Pulsed linac preferred to RCS due to long-term flexibility

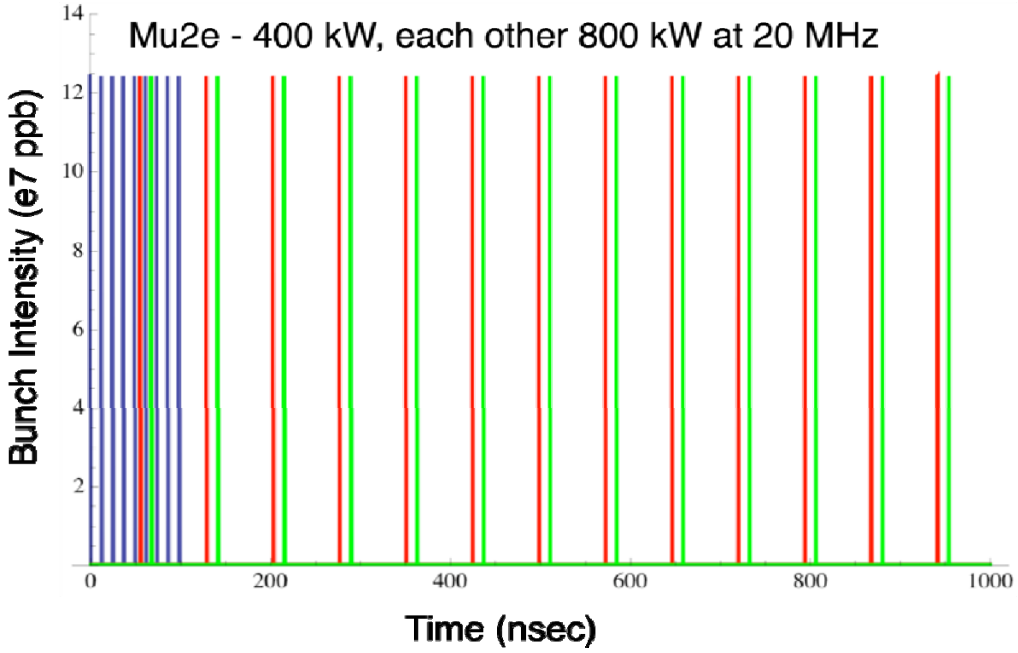
Project X Goals

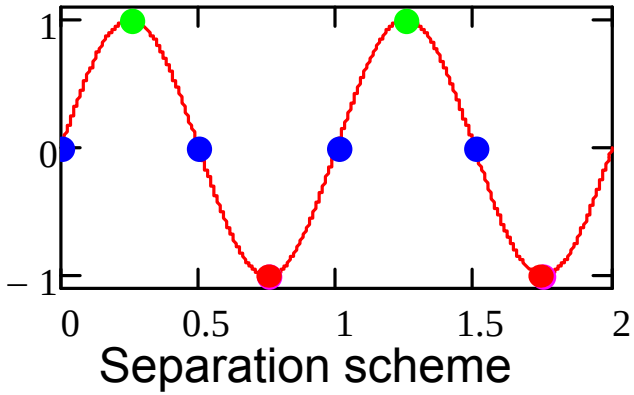
- Construct a 3 GeV continuous-wave superconducting H- linac, capable of delivering 1 mA of average beam current.
  - Supports rare processes and nuclear physics programs
  - Can support ADS development with beams energy <2 GeV
- Construct a 3-8 GeV pulsed linac, utilizing an ILC-style RF system, with total beam power delivered to 8 GeV ovf 300 kW.
  - Required for the neutrino program
  - Establishes a path toward a muon based facility
- Upgrade the Recycler and Main Injector to provide ≥ 2 MW to a neutrino production target at 60-120 GeV.
  - Supports the long baseline neutrino program
- Simultaneous operations of the rare processes and neutrino programs

Reference Design
Operating Scenario

1 μsec period at 3 GeV

mu2e pulse (9e7) 162.5 MHz, 100 nsec	400 kW
Kaon pulse (9e7) 27 MHz	800 kW
Other pulse (9e7) 27 MHz	800 kW





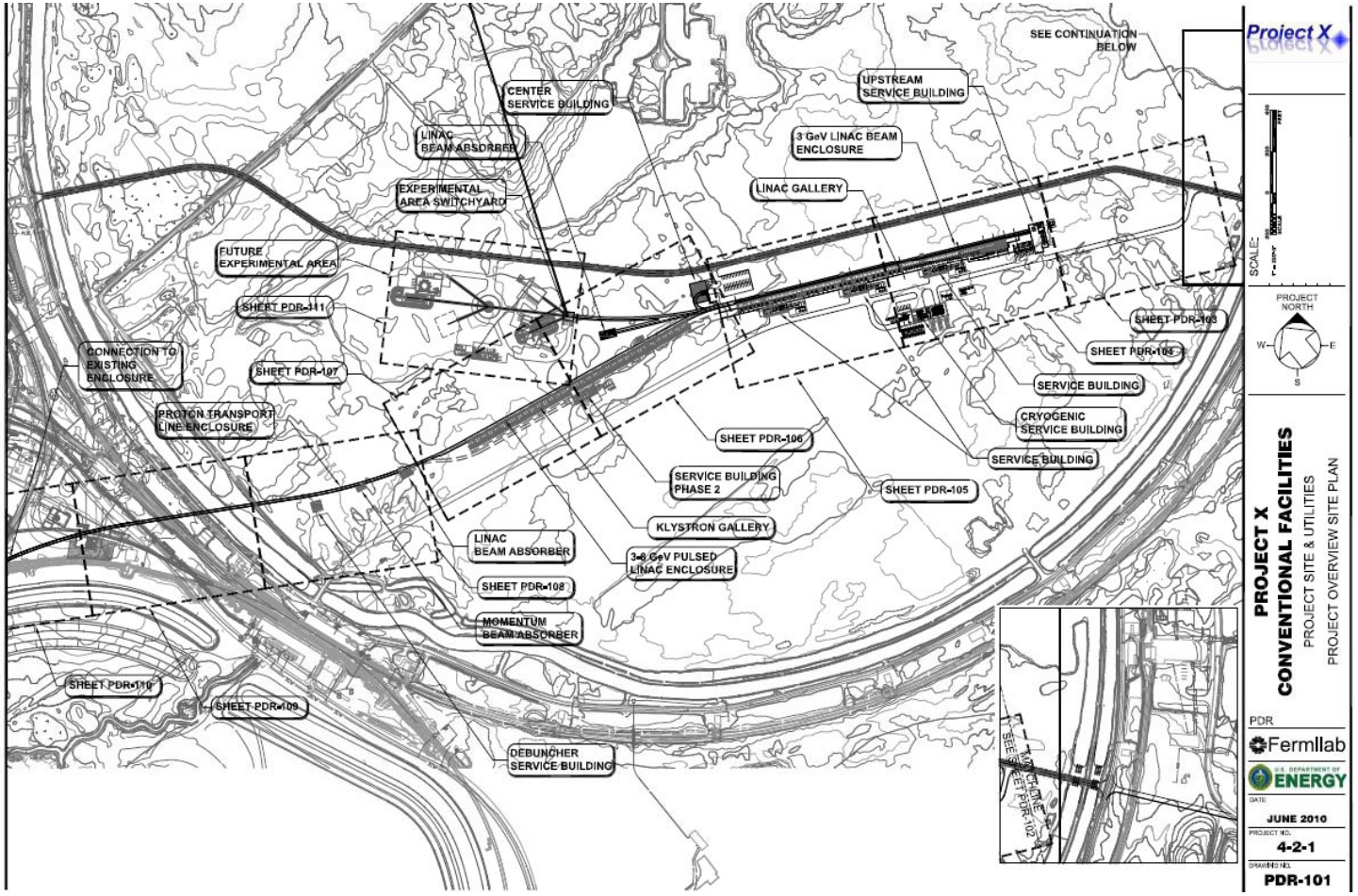
Functional Requirements

Requirement	Description	Value
L1	Delivered Beam Energy, maximum	3 GeV
L2	Delivered Beam Power at 3 GeV	3 MW
L3	Average Beam Current (averaged over >1 μsec)	1 mA
L4	Maximum Beam Current (sustained for <1 μsec)	10 mA
L5	The 3 GeV linac must be capable of delivering correctly formatted beam to a pulsed linac, for acceleration to 8 GeV	
L6	Charge delivered to pulsed linac	26 mA-msec in < 0.75 sec
L7	Maximum Bunch Intensity	1.9×10^{8}
L8	Minimum Bunch Spacing	3.1 nsec (1/325 MHz)
L9	Bunch Length	<50 psec (full-width half max)
L10	Bunch Pattern	Programmable
L11	RF Duty Factor	100% (CW)
L12	RF Frequency	325 MHz and harmonics thereof
L13	3 GeV Beam Split	Three-way
P1	Maximum beam Energy	8 GeV
P2	The 3-8 GeV pulsed linac must be capable of delivering correctly formatted beam for injection into the recycler (or Main Injector).	
P3	Charge to fill Main Injector/cycle	26 mA-msec in <0.75 sec
P4	Maximum beam power delivered to 8 GeV	300 kW

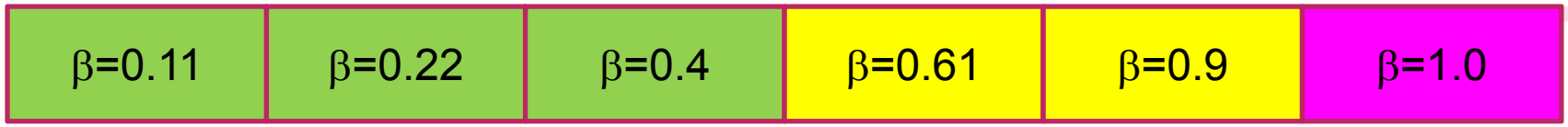
Functional Requirements

Requirement	Description	Value
M1	Delivered Beam Energy, maximum	120 GeV
M2	Delivered Beam Energy, minimum	60 GeV
M3	Minimum Injection Energy	6 GeV
M4	Beam Power (60-120 GeV)	> 2 MW
M5	Beam Particles	Protons
M6	Beam Intensity	1.6 x 10^{14} protons per pulse
M7	Beam Pulse Length	9.5 μsec
M8	Bunches per Pulse	504
M9	Bunch Spacing	18.8 nsec (1/53.1 MHz)
M10	Bunch Length	<2 nsec (fullwidth half max)
M11	Pulse Repetition Rate (120 GeV)	1.333 sec
M12	Pulse Repetition Rate (60 GeV)	0.75 sec
M13	Max Momentum Spread at extraction	2×10^{-3}
I1	The 3 GeV and neutrino programs must operate simultaneously	
I2	Residual Activation from Uncontrolled Beam Loss	<20 mrem/hour (average) <100 mrem/hour (peak) @ 1 ft
I3	Scheduled Maintenance Weeks/Year	4
I4	3 GeV Linac Operational Reliability	90%
I5	60-120 GeV Operational Reliabiltiy	85%
I6	Facility Lifetime	40 years
U1	Provisions should be made to support an upgrade of the CW linac to support an average current of 4 mA.	
U2	Provisions should be made to support an upgrade of the Main Injector to support a delivered beam power of ~4 MW at 120 GeV.	
U3	Provisions should be made to deliver CW proton beams as low as 1 GeV	
U4	Provision should be made to support an upgrade to the CW linac such that it can accelerate Protons	

Reference Design
Provisional Siting



CW Linac Technologies



325 MHz SSR
2.5-160 MeV

650 MHz Elliptical
0.16-2 GeV

1.3 GHz Elliptical
2-3 GeV

Section	Freq	Energy (MeV)	Cav/mag/CM	Type
SSR0 (β_G=0.11)	325	2.5-10	26 /26/1	SSR, solenoid
SSR1 (β_G=0.22)	325	10-32	18 /18/ 2	SSR, solenoid
SSR2 (β_G=0.4)	325	32-160	44 /22/4	SSR, solenoid
LB 650 (β_G=0.61)	650	160-520	42 /42/7	5-cell elliptical, doublet
HB 650 (β_G=0.9)	650	520-2000	96 /24/12	5-cell elliptical, doublet
ILC 1.3 (β_G=1.0)	1300	2000-3000	72 /9 /9	9-cell elliptical, quad

Maybe 650

Pulsed Linac

- A superconducting pulsed linac will be used for acceleration from 3 to 8 GeV
  - ILC style cavities and cryomodules
    - 1.3 GHZ, β=1.0
  - ILC style rf system
    - 5 MW klystron
    - Four cryomodules per rf source
  - Must deliver 26 mA-msec to the Recycler every 0.75 sec. Options:
    - 2 mA x 2.2 msec pulses at 10 Hz
      - Six pulses required to load Recycler/Main Injector
    - 1 mA x 2.2 msec pulses at 20 Hz
      - Twelve pulses required to load Recycler/Main Injector
    - 1 mA x 4.4 msec pulses at 10 Hz
      - Six pulses required to load Recycler/Main Injector
    - 1 mA x 26 msec pulses at 10 Hz
      - One pulse required to load Main Injector

RD&D Plan
Goals

- RD&D = Research, Design, and Development
- RD&D Plan corresponds to the Reference Design
  - Most recent version available at: http://projectx-docdb.fnal.gov:8080/cgi-bin/ShowDocument?docid=628
- Goals
  - Complete design of the Project X facility including all technical and conventional construction elements
  - Identification of key accelerator physics and engineering challenges and validation of performance of critical technology items
    - Simulations, experimentation, and prototype construction as appropriate
  - Development of an acquisition strategy for key technical elements, including development/qualification of vendors for critical components
  - Development of a technical/cost/schedule baseline for construction
  - Preliminary identification of performance upgrade paths

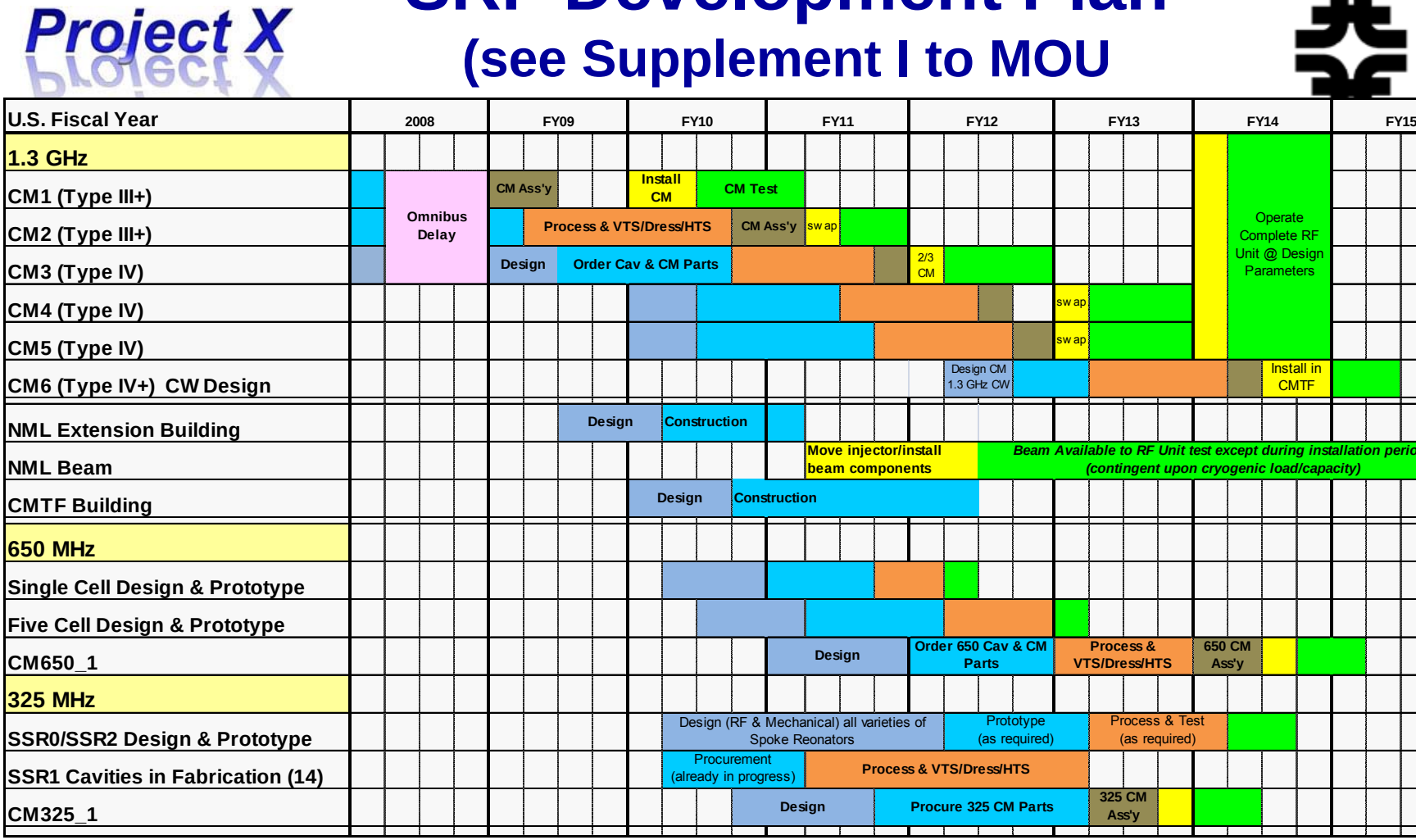
RD&D Plan
Scope/Deliverables

- Scope
  - All activities required to bring Project X from the Reference Design through final design (CD-3).
- Deliverables
  - All documentation required by the Department of Energy prior to authorizing construction
  - Supporting technical R&D required to validate the design and establish fabrication methods
- Assumed Critical Decision dates
  - CD-0: January 2011 — Approve Mission Need
  - CD-1: July 2012 — Approve Alternative Selection & Cost Range
  - CD-2: August 2013 — Approve Performance Baseline
  - CD-3: September 2014 — Approve Start of Construction
  - CD-4: September 2019 — Project Complete

Project X/ILC/SRF
Integrated Plan

- All srf programs at Fermilab are being integrated into a single, centrally managed program.
  - Effective FY2011
  - Brings all srf activities under the purview of the ILC/SRF Program Director
    - ILC and Project X management define requirements
- Discontinue the HIgh Intensity Neutrino Source (HINS) program as a stand-alone R&D program
  - Rescope the beam facility to support chopper and instrumentation development for Project X. Fund via Project X R&D
  - Retain low beta cavity development under the direction of the ILC/SRF Program Director
  - Eliminate HINS as a budget line item

SRF Development Plan
(see Supplement I to MOU



Design	Procure	Process & VTS Dress & HTS	Assemble	Install	Commission & Operate

Collaboration Plan

- A multi-institutional collaboration has been established to execute the Project X RD&D Program.
  - Organized as a “national project with international participation”.
    - Fermilab as lead laboratory
    - International participation via in-kind contributions, established through bi-lateral MOUs.
      - IIFC is the first international agreement
  - Collaboration MOUs for the RD&D phase outlines basic goals, and the means of organizing and executing the work. Signatories:

ANL	ORNL/SNS	BARC/Mumbai
BNL	MSU	IUAC/Delhi
Cornell	TJNAF	RRCAT/Indore
Fermilab	SLAC	VECC/Kolkata
LBNL	ILC/ART	

  - Collaborators to assume responsibility for components and sub-system design, development, cost estimating, and potentially construction.

Strategy/Timeline

- Next month: Complete all preliminary design, configuration, and cost range documentation for CD-0.
  - Functional Requirements Specification
  - Reference Design Report
  - RD&D Plan
  - Cost estimate/range
  - Resource Loaded Schedule
  - ⇒ Department of Energy briefing on November 16-17
- Continue conceptual development on outstanding technical questions
  - Baseline concept for the chopper
  - Concepts for marrying the 3-8 GeV pulsed linac to CW front end
  - Injection into the Recycler/Main Injector
  - Emphasis of srf development at all relevant frequencies
- The DOE has advised that the earliest possible construction start is FY2015
  - We are receiving very significant R&D support for Project X and SRF development (~$40M in FY11, not including ARRA (stimulus))
- Planning for a five year construction schedule

⇒Project X could be up and running in ~2020

Summary

- Project X is central to Fermilab's strategy for development of the accelerator complex over the coming decade
  - World leading programs in neutrinos and rare processes;
  - Potential applications beyond elementary particle physics;
  - Aligned with ILC, Muon Accelerators, and Nuclear Energy
- Project X design concept is well developed and well aligned with the requirements of the physics program:
  - 3 GeV CW linac operating at 1 mA: 3 MW beam power
  - 3-8 GeV pulsed linac injecting into the Recycler/Main Injector complex
- We are expecting CD-0 for Project X in early 2011
- Project X could be constructed over the period ~2015 – 2019