Slides extracted from Feb 18 OHEP talk

DOE Budget Briefing
ILC/SRF B&R Codes

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B&R Codes

- National HEP Program
  - KA 15 02 02-1 ILC Accelerator R&D
  - KA 15 02 02-3 Other Supporting R&D (GDE/ART)
- Core Technology R&D
  - KA 15 02 01-2 Superconducting RF
  - KA 15 02 01-1 General Accelerator Development
- Collectively these B&R's support all Superconducting RF development activities and ILC R&D at Fermilab

SRF an Enabling Technology

- SRF is an enabling technology envisioned for use in many new applications of interest to the Office of Science
  - Project X
  - International Linear Collider
  - Muon Collider
  - Lights Sources, ERL, ADS etc

- SRF R&D at FNAL began 1990's via the TESLA collab.
  - Design/construction of FNPL and 3.9 GHz cryomodule (collab with DESY)
  - FNAL effort was small (U.S. was pushing warm technology for ILC)

FY06 & FY07

- In FY06: The picture changed dramatically
  - Cold technology choice for ILC in Aug 05
  - FNAL plans for SRF based Proton linac (Proton Driver)
  - Requested funds to build SRF infrastructure (SMTF Proposal)
- In FY 07:
  - ILC R&D spending ramped up dramatically: SRF goals established
    - S0 >35 MV/m bare cavities
    - S1 31 MV/m dressed cavities in a ILC Cryomodule
    - S2 Beam test of full ILC RF unit (CM, klystron, modulator)
  - FNAL directed $ 24.7 M of core R&D funds towards construction of 1.3 GHz SRF infrastructure for ILC and/or Proton Driver
- HINS created to capture Proton Driver front end R&D

SRF B&R

- SRF B&R created in FY08:
  - Recognition that scope of required effort was large
    - e.g. DESY had spent 125 M euro in M&S (direct) on SRF by 2007
    - FNAL requested $ 25 M/yr for SRF program (in addition to ILC)
  - B&R created to capture the effort to build ILC/Px SRF infrastructure

- Not a "construction project" !
  - Rather an infrastructure/technology development program
  - Must respond to evolving project goals & technology changes
  - Indeed the scope and goals have changed several times

FY08

- FY08:
  - Plan was for ILC to ramp up further
  - Feb 08: ILC cost estimate released (shock to system!)
  - Dec 08: Omnibus Bill ! (& FY09 CR)
  - ILC and SRF R&D activities effectively stopped for ~ 1 yr
    - 145 FTE ILC/SRF workforce dispersed
    - HINS and 3.9 GHz Cryomodule activity continued
- OHEP "redefined" scope of SRF B&R
  - To include SRF: facility operations, cavity purchases, industrial development, and materials R&D
  - ILC time line acknowledged to be much later
  - New emphasis on Project X ICD-1 (pulsed 1.3 GHz linac)

FY09

- In FY 09:
  - ILC funding restored to $11 M, ~½ FY07 ($ 7 M for SRF)
  - SRF funding restored to $ 19 M still focused on 1.3 GHz pulsed
  - ~65% of previous SRF workforce recaptured
    - The rest remained assigned to other projects
- ARRA: $ 52.7 M of funds approved for SRF
  - Huge boost towards recovery from FY08 work stoppage
  - Advances schedule of planned FNAL infrastructure
  - Allows purchase and construction of previously unfunded NML refrigerator including a new building for CM test stands
  - Allows industrial cavity procurement, industrial EP, CM parts!
  - All M&S; Mostly industry; All focused on 1.3 GHz pulsed linac

FY10: Issues/Concerns/New Directions

- ILC /PX 1.3 GHz pulsed linac R&D continues
  - ILC R&D remains part of the national program and FNAL is playing a big role, Lots of technical progress! (more in a minute)
  - Pulsed 1.3 GHz linac still remains part of the Project X upgrade path to a high power proton source from the main injector
- But… the Project X design has changed:
  - ICD1, a 8 GeV pulsed linac ➔ evolved
  - ICD2, a 3 GeV CW linac for an enhanced rare decay program
  - Upgradable to 8 GeV via pulsed 1.3 GHz linac for neutrinos

FY10: Issues/Concerns/New Directions

- Realigning the HINS front end with PX
  - Evolving into PX chopper and instrumentation test facility
  - 325 MHz spoke resonators are still part of Project X
    - ➢ but now will operate CW at 1.8 K (vs pulsed at 4.5 K)
    - ➢ needs test and fabrication infrastructure (started by HINS)
- Project X now envisions 650 MHz cavities
  - Two new families of 650 MHz elliptical cavities Beta = 0.6 & 0.9
  - Operating CW at 1.8 K (CW better for rare decay program)
  - Cost effective; provides larger aperture; better transit time match
  - Much of the infrastructure we have built is useful
  - But some changes/additions are needed

FY11: Merge FNAL SRF efforts

- Project X
- HINS

SRF parts currently managed independently

- ILC R&D
- SRF Infrastructure

- FY11: Consolidate the SRF parts of these efforts
  - Personnel Management: Many personnel are shared
  - Technical Management: Optimized development & infrastructure
  - Financial Management: Manage SRF across 3 B&R's
  - Communication: Speak with one voice to SRF collaborators

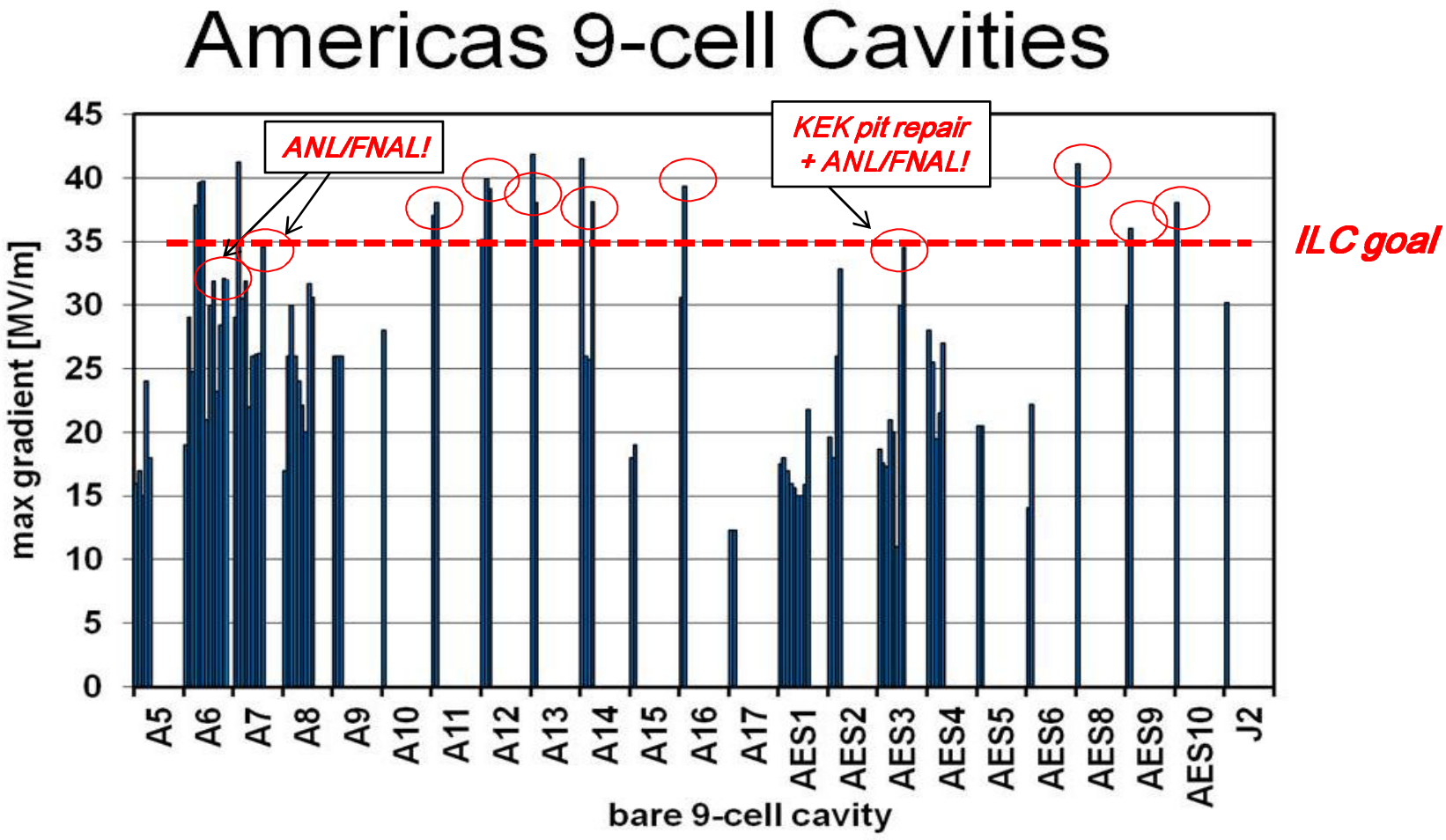
FY09: ILC/SRF Accomplishments

- **Steady progress on SRF infrastructure at FNAL**
  - Several new SRF facilities now in full operation
- **Vertical Test Stand; tests bare cavities**
  - Works! 60 tests so far, 40 in FY09 (achieved design test rate of 5/month)
  - Civil construction complete for 2 more VTS systems (325 and 650 MHz capability)
- **Cryomodule Assembly Facility**
  - Works! 2 CM assembled in MP9 & ICB: CM1(1.3 GHz) & FLASH(3.9 GHz)
  - Completed cavity dressing infrastructure ➔ dressed 7 cavities so far
- **Horizontal Test Stand**; tests dressed cavities (unique in U.S.)
  - Works ! Five 3.9 GHz tests + Five 1.3 GHz cavities tested so far (faster than DESY!)
  - Two high gradient (> 30 MV/m) dressed "S1-global" cavities shipped to Japan
- **ANL/FNAL Joint EP Processing; commissioning**
  - ~Works ! Excellent results with single and nine cells (two ~ 35 MV/m)
  - 6 nine cell EP cycles, 38 High Pressure rinse and assembly cycles!
- **Excellent progress on RF unit test facility at New Muon Lab**

FY09: ILC/SRF Accomplishments

- Cavities:
  - Using ANL and JLAB EP facilities “flat out” to process cavities
  - Tuning, cavity dressing, ½ VTS and all HTS tests at FNAL
  - Progress! In improving yield of high gradient cavities!
- Cryomodules:
  - CM1 being installed at NML
  - CM2 parts in hand, need 8 dressed cavities; assembly in FY10
  - Type IV CM design ~ complete and ordering parts with ARRA funds
- SRF Materials:
  - Improved diagnostics (thermometry, 2nd sound, optical inspection)
  - Understanding reasons for poor performers (e.g. weld pits)
  - Demonstrated 3 different cavity repair techniques, all successful!
    - tumbling, laser re-melt pit, local grinding, followed by EP, HPR

ILC Cavity Gradient



FY09: SRF Accomplishments: Industrialization

- Working to develop a U.S. Industrial base in SRF
- Cavities:
  - 22 ILC cavities built by two U.S. vendors (AES, Roark/Niowave)
    - ➢ 4 of 6 recent AES cavities now make ILC gradient! (> 35 MV/m)
  - New U.S. vendor: PAVAC opening a branch in Batavia!
  - 40 more ILC cavities being ordered with ARRA funds
- Surface Processing:
  - Engaging U.S. industrial vendors in surface processing (AES)
- Cryomodule parts:
  - Multiple vendors making parts (tuners, Ti He vessels, Ti bellows, vacuum vessels, cold mass parts, etc)

FY09: SRF ARRA Funds Accomplishments

- Huge boost! $ 52.7 M of funding
  - Including $ 8 M of funding for NML refrigerator (MIE)
  - Mostly M&S, and mostly to industry and collaborators
- $ 21.5 M (direct) obligated or RIPS by Feb 15
  - Ordered two new vacuum ovens (one large enough for 650 MHz)
  - Design study for Industrial EP facility (AES)
  - Design study for eco-friendly cavity processing development
  - Sent funds to JLAB for infrastructure upgrades, ANL for EP labor, SLAC for RF couplers and RF distribution systems
  - Placed order for first 20 cavities from industry, order the rest soon
  - Ordered $ 3.7 M of NML injector and beam line components
  - NML buildings and refrigerator procurements are in progress

ARRA funds

ARRA Task	Estimated Cost (K$)	Obligations plus RIP to Date (K$)
Cryogenics for NML Test Facility	$ 16,813	$ -
Vertical Test Stand Components	$ 2,330	$ 801
Vacuum Oven Components	$ 1,676	$ 1,155
NML RF Unit Test Area Components	$ 12,487	$ 3,733
Industrial Cavity Development	$ 4,120	$ 4,536
Horizontal Test Stand RF Components	$ 1,610	$ 488
Industrial Infrastructure and Electro-polish of Cavities	$ 2,160	$ 2,080
Fabricate Improved Cryomodule in Collaboration with Industry	$ 4,359	$ 1,808
Labor for Cavity Processing at ANL	$ 899	$ 899
Cavity Processing/Test/Infrastructure at JLAB	$ 897	$ 890
RF Distribution for Cryomodule at SLAC	$ 482	$ 482
Couplers for Cryomodules for FNAL & Value Engineering at SLAC	$ 2,543	$ 2,535
Components for 10 MW 1.3 GHz RF Power Source	$ 1,216	$ 1,138
Develop Eco-friendly Cavity Processing	$ 1,080	$ 1,000
Total	**$ 52,672**	**$ 21,543**

Original plan focused on 1.3 GHz, but making adjustments for 650 MHz cavities

FY09: Accomplishments: GenAccel Dev

- 325 MHz Spoke resonators (HINS)
  - Designed/built two SSR1 (beta = 0.21)
    - One built by Roark (U.S. Industry), one by Zannon (Europe)
    - Design =10 MV/m; Tested > 30 MV/m Eacc, a real achievement!
  - 1st SSR1 is being dressed
  - Two more SSR1 being fabricated in India, 10 on order from Roark
  - Built HTS facility to test dressed cavities at 4 K with pulsed 325 MHz RF
  - Design of spoke resonator cryomodule is starting
- 650 MHz Elliptical cavities (Project X)
  - Preliminary design of cavity shapes for Beta = 0.6 and 0.9
  - Single cell design close to complete, working on 5 cell design
  - Plan to order Nb and single cells in FY10

Reviews

- DOE Review of GDE ART in Apr 09
- DOE Review SRF in May 09
  - Included plan for use of ARRA funds
- FNAL Accelerator Advisory Committee
  - Review of SRF, Project X, and HINS programs

- Uniformly positive SRF comments at closeouts
  - Excellent technical progress!
  - Nice comments about FNAL contributions to ILC R&D
  - HINS technical progress (of course questions about PX alignment)
  - Effective collaborative activities (MOU's with 19 institutions!)

SRF R&D in the future

- Overarching goal of the SRF program remains
  - To develop the SC accelerating structures and associated infrastructure at Fermilab in support of future accelerators

- but… must revise our long term plan & goals to reflect:
  - Delays and uncertainty in ILC time line
  - The proposed technical changes in Project X
  - Delayed schedule for Project X construction
  - OHEP funding guidance

Approach to making a plan

- Although a SRF "R&D and technology development program", we manage the SRF effort with project-like tools (financial and planning) so given the changes we have to:
  - Establish new technical goals and scope of work
  - Write down a technically plausible schedule
  - Resource load the tasks by fiscal year (as best we can for R&D efforts)
  - Adjust the schedule to reflect funding guidance

High Level SRF Goals

- Revised ILC SRF Goals:
  - Retain the current ILC S0, S1, S2 goals
  - Recognize that a string test in NML with beam, will take longer
    - driven by availability of new ARRA funded refrigerator ~ 2013
- New Project X Goals:
  - Modify/test one Type IV 1.3 GHz cryomodule with CW
  - Construct/test a 325 MHz CW spoke resonator cryomodule
  - Construct/test a 650 MHz CW elliptical cryomodule
  - Build associated 325 and 650 MHz CW infrastructure
  - Industrial capability in place for Project X by ~FY15
- Create an integrated plan (in a minute)

Supported by 3 B&R codes

Level 2 SRF Goals

- 1.3 GHz (ILC and Project X)
  - Complete planned 1.3 GHz cavity/CM infrastructure
  - Fabricate/process/test a series of 1.3 GHz cavities and CM
  - Complete NML and achieve ILC S2 goal (operation of an ILC RF unit)
  - Explore CW operation for Project X (RF, couplers, cooling)
  - Develop U.S. industry (cavity and CM parts, surface processing)
- Materials R&D
  - Understand mechanisms that limit cavity performance
  - Demonstrate cavity repair techniques on multi-cell cavities
  - Cavity cost reduction (ALD, hydro-form, non-HF surface polish, TIG)

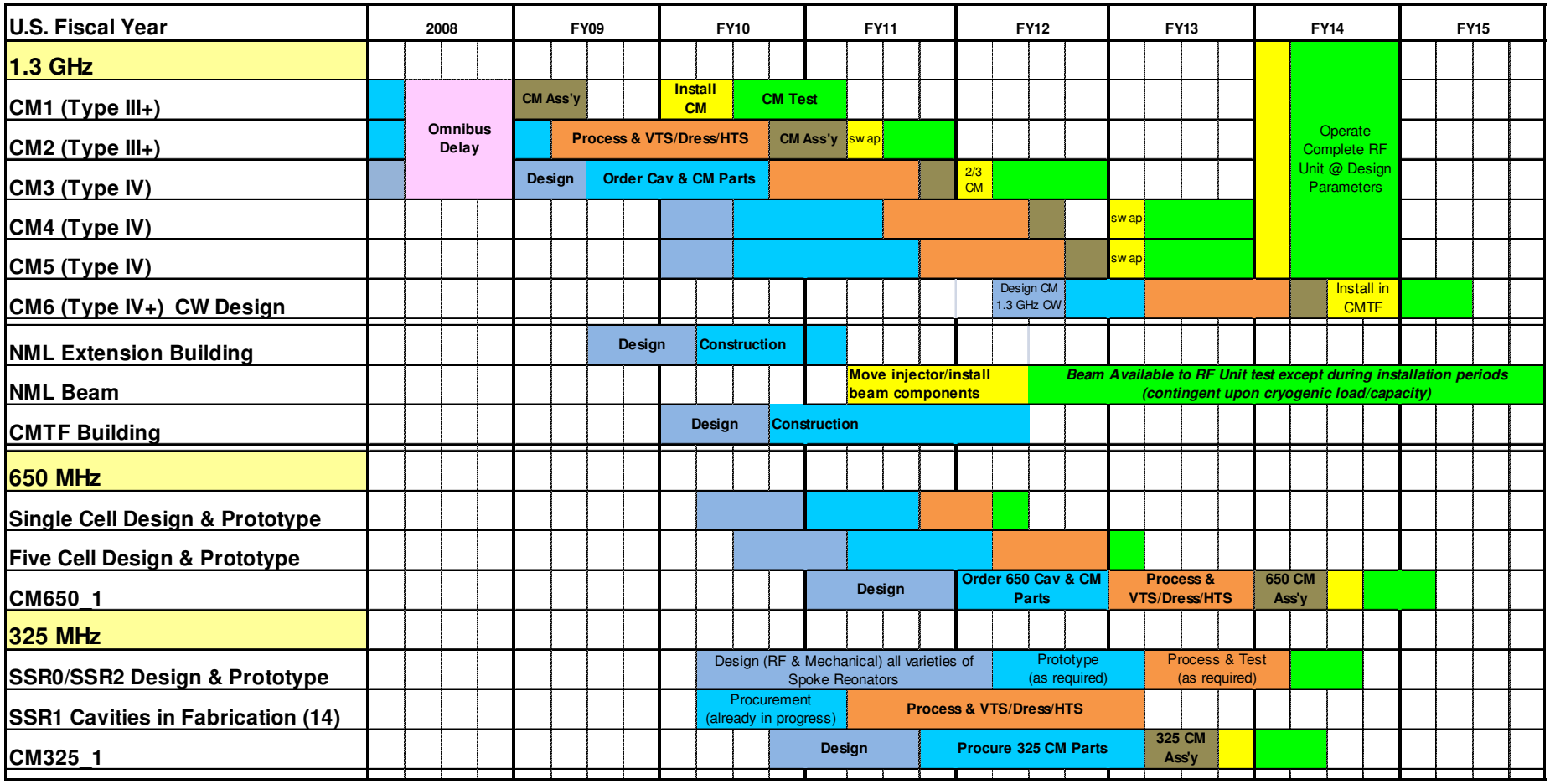
Integrated SRF Goals

- 325 MHz
  - Complete HINS 325 MHz HTS (designed for 4 K pulsed operation)
  - Test SSR1 dressed spoke resonator both CW and pulsed RF
  - Modify HTS and MDB cryo system for 1.8 K and test cavity
  - Upgrade/build new infrastructure to process spoke resonators
  - Design/build/test a 325 MHz cryomodule (incl. test stand)
- 650 MHz
  - Develop/fabricate new cavity designs (single + multi-cells)
  - Design/build 650 MHz RF systems
  - Modify/build processing facilities and HPR for 650 MHz
  - Test bare and dressed 650 MHz cavities
  - Design HTS 2 to allow 650 MHz CW testing
  - Design/build/test a 650 MHz cryomodule (incl. test stand)
- All of this in collaboration with our SRF partners!

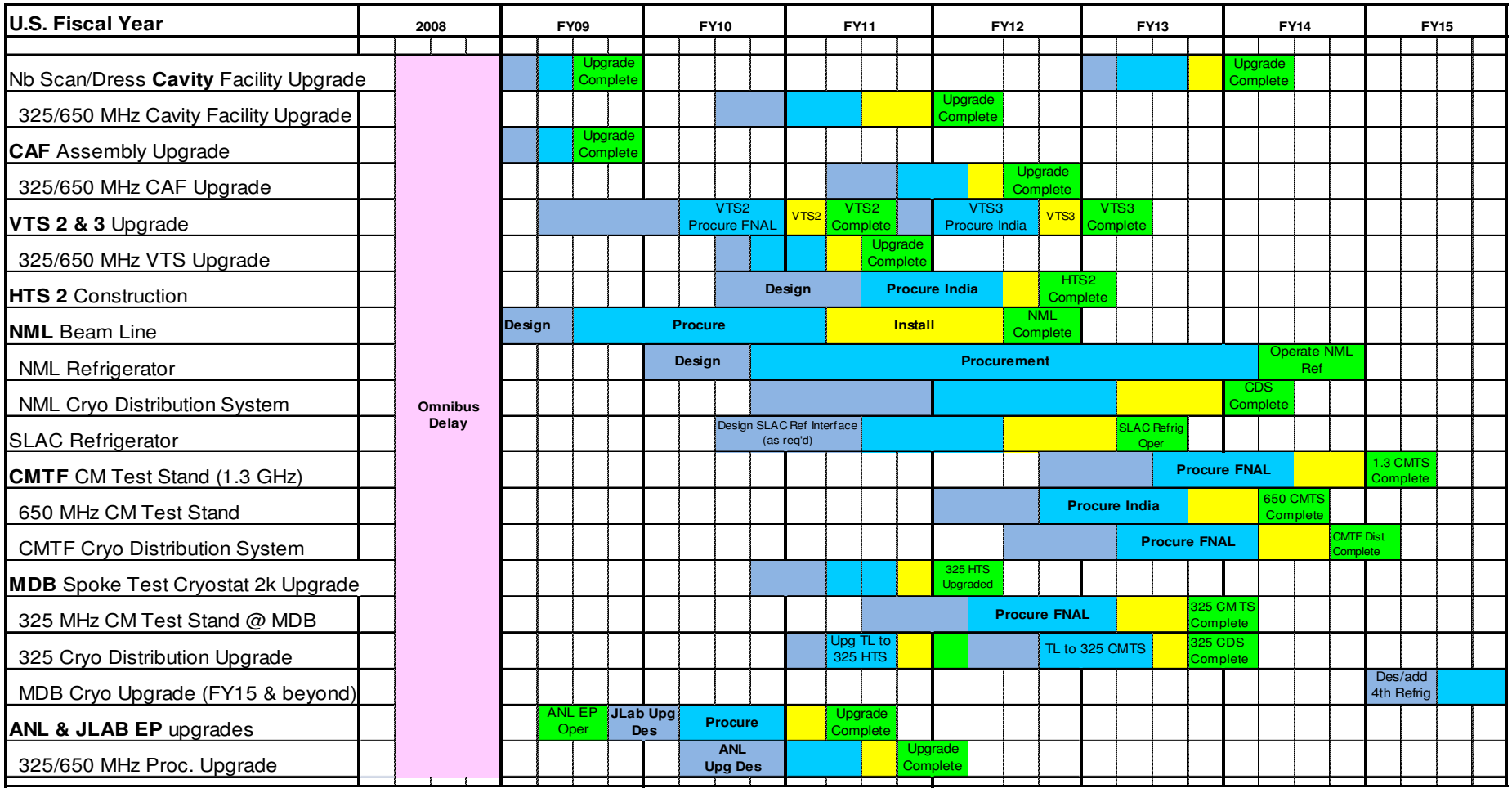
Integrated SRF plan

- Approach: make a plan assuming OHEP ILC and SRF guidance, redirect HINS SRF labor & M&S, planned PX SRF development funds in GenAccDev through in FY15
  - Write down the tasks, estimate the cost and duration
  - Assume plausible rate of technical success
  - Respect stated purpose of B&R, balance SWF and M&S within B&R
  - Progress paced by overall workforce size, technical issues, & funding
- Conclude: Made a plan that is technically achievable
  - Overall M&S funding is close to the need
  - Assumes ~constant workforce through FY13, may not support 650 MHz tasks
  - Overall schedule is plausible but optimistic to support a FY15 PX start
  - Issues: ILC funding for SRF beyond FY12, FY11 M&S for SRF operations given EBW MIE, achieving the 650 MHz timeline, keeping SRF industry engaged
  - Will speak to each of these in a minute

Integrated SRF Plan (Cryomodules)



Integrated SRF Plan (Infrastructure)



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

Resource Load Integrated Plan

Summary Tasks from a much larger spreadsheet (iterating)

	FY09 (incl. ARRA)	FY10	FY11	FY12	FY13	FY14	FY15
Management	2,632	2,726	2,453	2,832	2,334	2,365	2,395
1.3 GHz Cavity & Cryomodules	17,351	6,101	5,652	5,894	4,644	3,889	4,923
650 MHz Cavity & Cryomodules		3,304	3,011	4,245	2,920	4,421	8,006
325 MHz Cavity & Cryomodules		1,975	2,870	3,529	2,005	1,422	2,966
Processing Facilities	7,142	1,419	1,417	1,744	3,133	2,215	2,727
Cavity/Cryomodule Facility	1,060	2,451	5,161	2,110	3,494	1,588	3,165
Vertical Test Facility	5,704	2,808	2,561	2,702	1,817	1,843	2,195
Horizontal Test Facility	2,257	2,359	2,474	3,325	1,736	2,375	3,119
NML Beam Test Facility	24,866	10,571	11,328	11,211	4,575	2,995	2,091
New Refrigerator & Building	16,813						
Cryomodule Test Facility	0	658	1,284	2,385	10,445	16,539	5,324
Materials R&D	1,923	1,559	1,524	1,020	935	721	735
Other (Global Systems)	2,742	3,447	3,162	3,266	1,658	1,757	1,886
TOTAL Funding	82,490	39,378	42,897	44,263	39,696	42,130	39,532
KA 15 02 02-1 ILC Accelerator R&D	11,157	11,321	10,650	10,650	5,325	5,485	5,677
KA 15 02 01-2 Superconducting RF	18,661	20,500	24,379	23,877	24,515	25,171	17,026
KA 15 02 01-2 Superconducting RF - ARRA	52,672						
KA 15 02 01-1 GenAccDev (SRF part only)		7,557	7,868	9,736	9,856	11,474	16,829

GenAccDev thru FY13, then assumes additional Px R&D funds: Profile from Steve

Sum of yellow row is over $ 300 M in SRF funding!

Summary

- SRF effort at FNAL started 4 yrs ago at “square 1”
- Rapidly becoming a world class SRF lab
  - Built & operate some of the best SRF infrastructure in the world
  - Developing world class SRF scientific and engineering staff
  - Established strong collaborative connections
- Considerable technical progress and excellent reviews
- Significant contributions to global ILC program
- Extensive SRF Infrastructure constructed and in operation
  - Supports GDE SRF goals for ILC
  - Supports revised Project X baseline
  - Supports U.S. Industrialization of SRF technology
- Additional infrastructure under construction

Summary

Program Management:

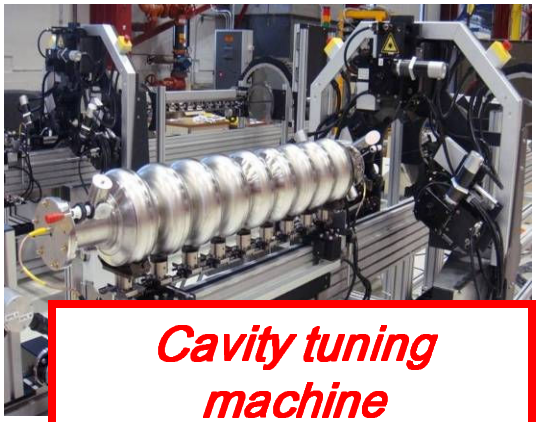
- Have demonstrated our ability to roll with the punches
  - Omnibus bill, workforce disruption, delayed ILC
  - ARRA funds!
  - Project X technical changes
- Plan Single point management of SRF effort in FY11
  - Will further improve efficiency and effectiveness of the program

- Future: Creating an integrated SRF plan
  - Supports both ILC and Project X R&D goals
  - Resources consistent with OHEP budget guidance.
  - All scenarios force technical delays of some PX tasks (e.g. 650 MHz)
  - Believe plan is achievable by FY15 within OHEP funding guidance

New FNAL SRF infrastructure


VTS


VTS


Cavity tuning machine


HTS


String Assembly


MP9 Clean Room

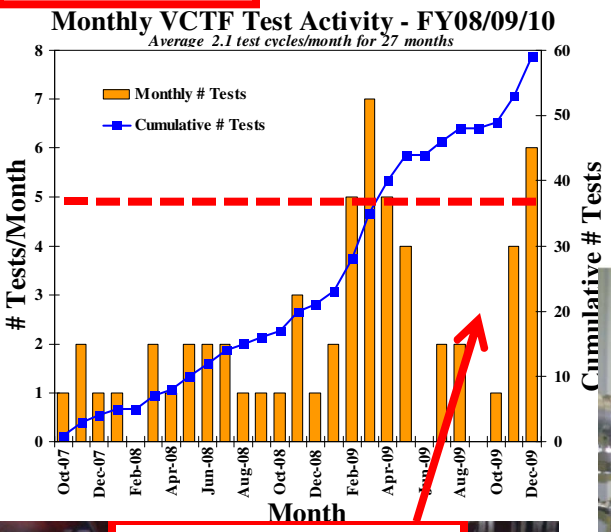

Final Assembly


1st U.S. built ILC/PX Cryomodule

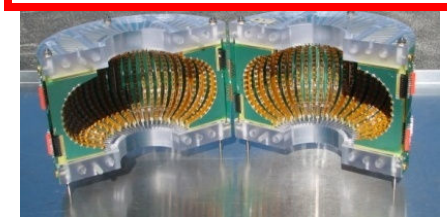

1st Dressed Cavity

SRF Progress

VTS 1 Tests



Thermometry



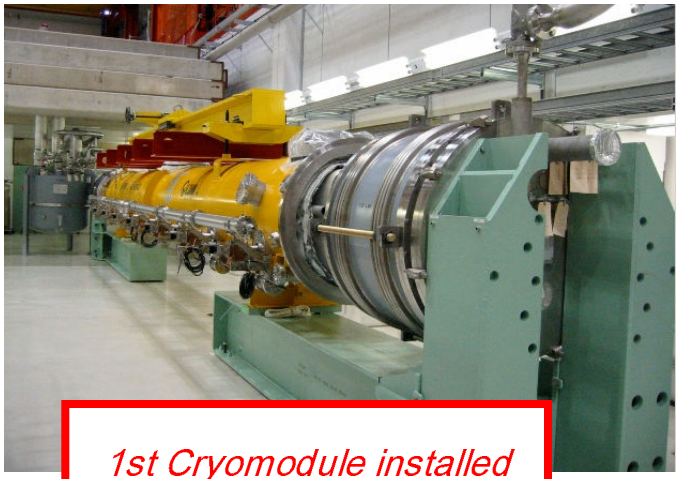
325 MHz spoke resonator

FNAL S1 global Cavities @ KEK

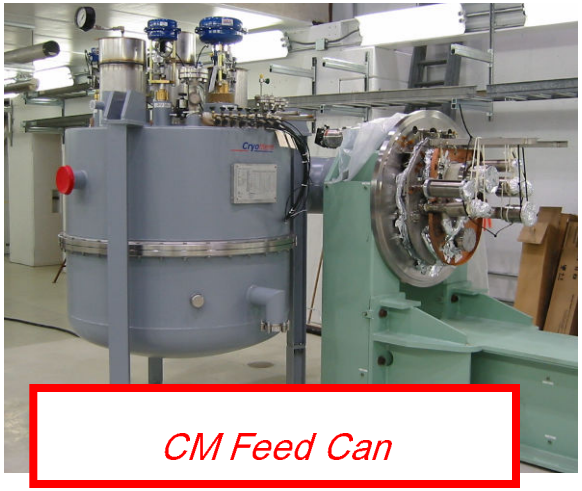
VTS 2-3 Civil construction

NML

Progress at NML



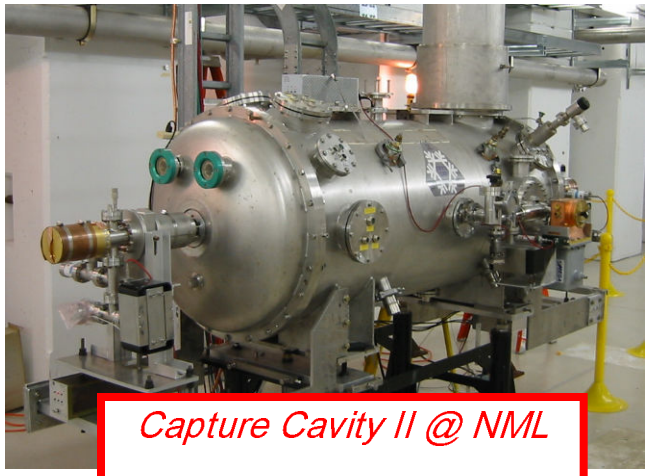
1st Cryomodule installed



CM Feed Can

Large Vacuum Pump

Control Room

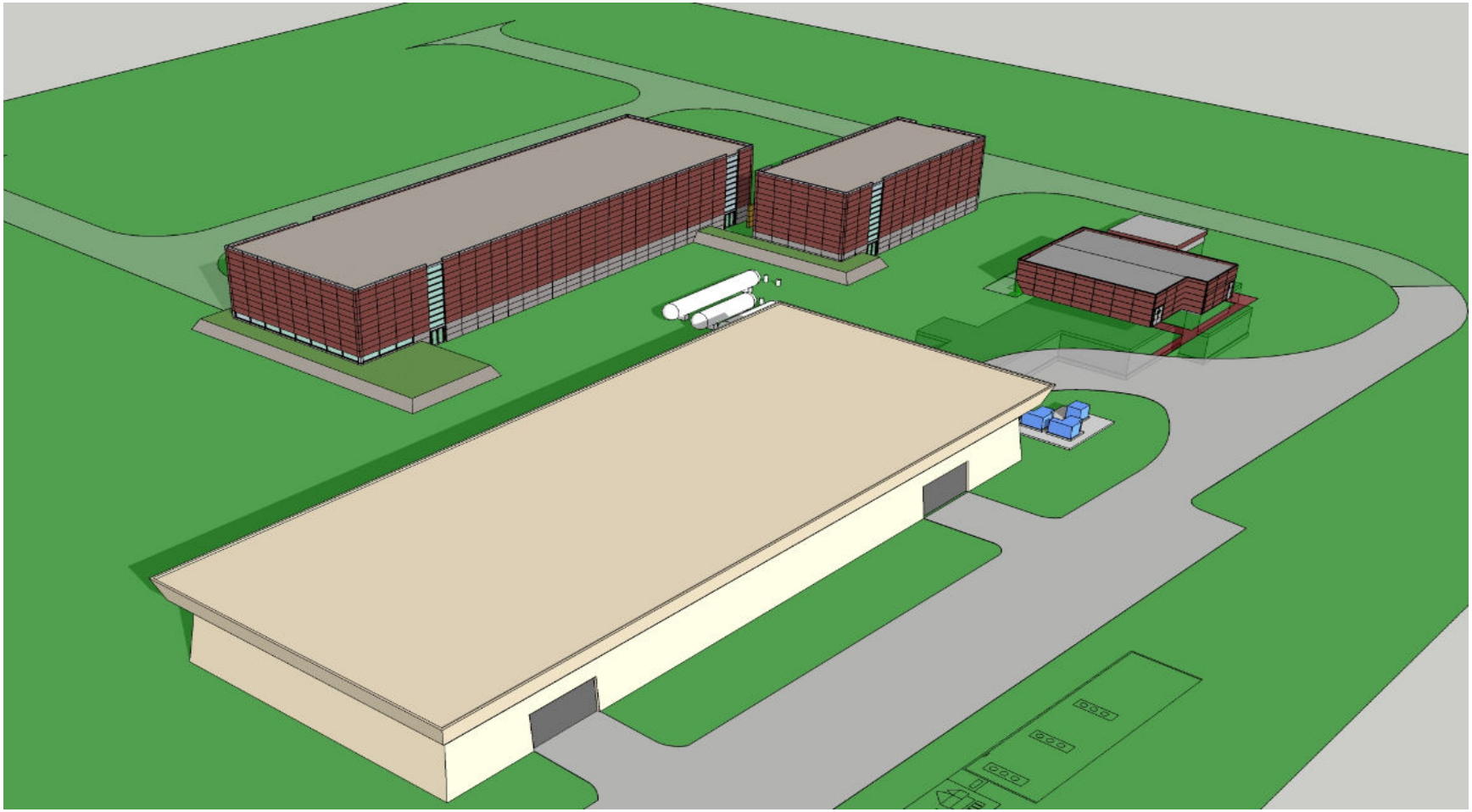


Capture Cavity II @ NML

Operating at 2K

He Refrigerator

New buildings and Refrigerator (ARRA)



Reaction from OHEP

- Dennis was in general complementary, supportive, positive
  - Accepts goals of the integrated SRF plan
- Has a hard time selling infrastructure plans or plans to build capability over many years to OMB➔ asks us to repackage into "tasks of finite duration with deliverables every few yrs"
  - ILC ramps down after FY12 (but not necessarily FNAL part)
  - Declare victory on SRF infrastructure and ramp that B&R down
  - Ramp up an SRF operations funding line in FY12
  - Ramp up General Acc Development (with PX SRF tasks)
- Steve and I made a revised funding plan by B&R that supports the overall integrated SRF plan. (Dennis is on board, need to coordinate with Harrison)
- Note: Integrated SRF plan funds only a portion of the SRF R&D goals (prior to CD3) described in the most recent PX R&D plan by FY15
- I am very happy with the continued support for SRF from OHEP

Remapping to B&R's

	FY 10	FY 11	FY 12	FY 13	FY 14	FY 15	FY 16
ILC R&D Total (wo/GDE)	11,321	10,650	10,650	5,325	5,485	5,677	0
New SRF Line	20,500	20,516	5,900	0	0	0	0
New SRF Operations	0	0	11,000	11,220	11,444	11,673	11,907
SRF Component of GAD	7,557	11,731	16,713	23,151	25,201	22,182	14,635
Total	39,378	42,897	44,263	39,696	42,130	39,532	26,542

- Relevant to you only in that it all fits into the lab's financial plan
- Will revise existing ILC/SRF organization to include 325 and 650 MHz
- Working towards more "project like" processes
  - Functional Requirements for each task (e.g. HTS-2, CMTS, SSR0 CM, 650 CM)
  - Technical requirements
  - Technical Design Reviews
  - Cost/schedule/resource estimates
  - Etc
- We (You!) have made a great start towards a new SRF machine!