FNAL SCRF Program Overview

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Outline

- Introduction
- R&D Goals and required infrastructure
- Why an generic SCRF R&D program vs ILC R&D or a DOE construction project?
- Organization and Financial Management
- FY06 Financials and technical achievement
- FY07 plan
- FY08 and beyond
- Conclusion

Introduction

- Superconducting Radio Frequency Technology (SCRF) has emerged as an important "enabling" accelerator technology
  - Think… "like SC magnets in 1980's"
- Many existing SCRF based accelerators or under const.
  - ATLAS (ANL)
  - CBEAF (TJNL)
  - SCRF cavities for LEP, KEK b factory, etc
  - SNS (ORNL)
  - TTFII/FLASH, XFEL (DESY)
- Remarkable improvements in the achievable accelerating gradients (~ 5→35 MV/M) over the last ~ decade or so
- → SCRF is the chosen technology for the International Linear Collider, the next new global High Energy Physics facility
- It is being considered for many other applications

Introduction

- **The uses of SCRF go far beyond the ILC**
  - **High Intensity Neutrino (ie proton) Sources (HINS)**
  - **Front end of neutrino factories or Muon Colliders**
  - **Spallation neutron sources (e.g. like SNS)**
  - **Light Sources (e.g. XFEL)**
  - **Energy Recovery Linacs**
  - **Rare Isotope Accelerators (RIA)**
  - **Medical Accelerators**
- **High Energy Physics has developed much of the accelerator technology used by Nuclear Physics & Basic Energy Sciences**
- **As the only National Laboratory (after 2009) dedicated to HEP, it is FNAL's natural role to be the steward of of SCRF technology**
- **If it wishes to be a viable host for ILC, FNAL should strive to become a <u>leader</u> in SCRF development**

Global SCRF Landscape

- Europe
  - DESY/INFN developed world class SCRF expertise and infrastructure as it built the Tesla Test Facility in support of the TESLA proposal.
  - Infrastructure is being expanded to support the XFEL
  - Strong industrial vendors involved: ACCEL, Zannon in cavity fabrication; some in processing
  - Previous experience with LEP SCRF cavities at CERN
- Japan
  - Several decades of SCRF R&D at KEK (Saito)
    - New cavity shapes and processing techniques
  - Experience with SCRF cavities for KEK B factory
  - Major effort to build STF facility (CM cold this year)
  - Strong working relationship with Industry

U.S. SCRF

- **U.S.**
  - **ATLAS machine at ANL**
  - **SCRF R&D at Cornell, MSU, ANL, TJNL, etc**
  - **CEBAF and SNS experience at TJNL**
  - **RIA R&D at ANL, MSU, TJNL**
  - **Most work done in labs and universities, no significant industrial participation prior to ILC.**
- **FNAL**
  - **Small SCRF program as part of TESLA collaboration for > 10 yrs**
    - **Built A0 FNPL photo-injector in parallel (twin of TTF I)**
    - **Supplied components to DESY (modulators, cryo parts)**
    - **Working to complete 3.9 GHz 3rd harmonic cavities for DESY**
  - **Until 2005 this was a small ~ $1-2 M/yr program**
  - **Moreover, OHEP did not want FNAL to grow the SCRF effort at FNAL, largely because the U.S. was focused on the warm technology for ILC**

U.S. SCRF

- FNAL and collaborators submitted the SMTF proposal in Feb 2005 to greatly expand U.S. SCRF infrastructure and capability
  - Much of the infrastructure we are discussing today to support ILC and HINS was requested in that proposal
  - For complicated reasons SMTF was not funded…
    - Multiple offices in DOE, multiple projects, etc.
- Change! Following August 2005 technology choice for the ILC
  - FNAL began a major program to build its SCRF capability, infrastructure, and expertise
  - Even though SMTF was not approved, we were encouraged to use “GDE recommended” ILC funds and lab core funds to start building the necessary SCRF infrastructure.
- Our rate of progress has been limited financially
  - More on FY06 finances in a minute

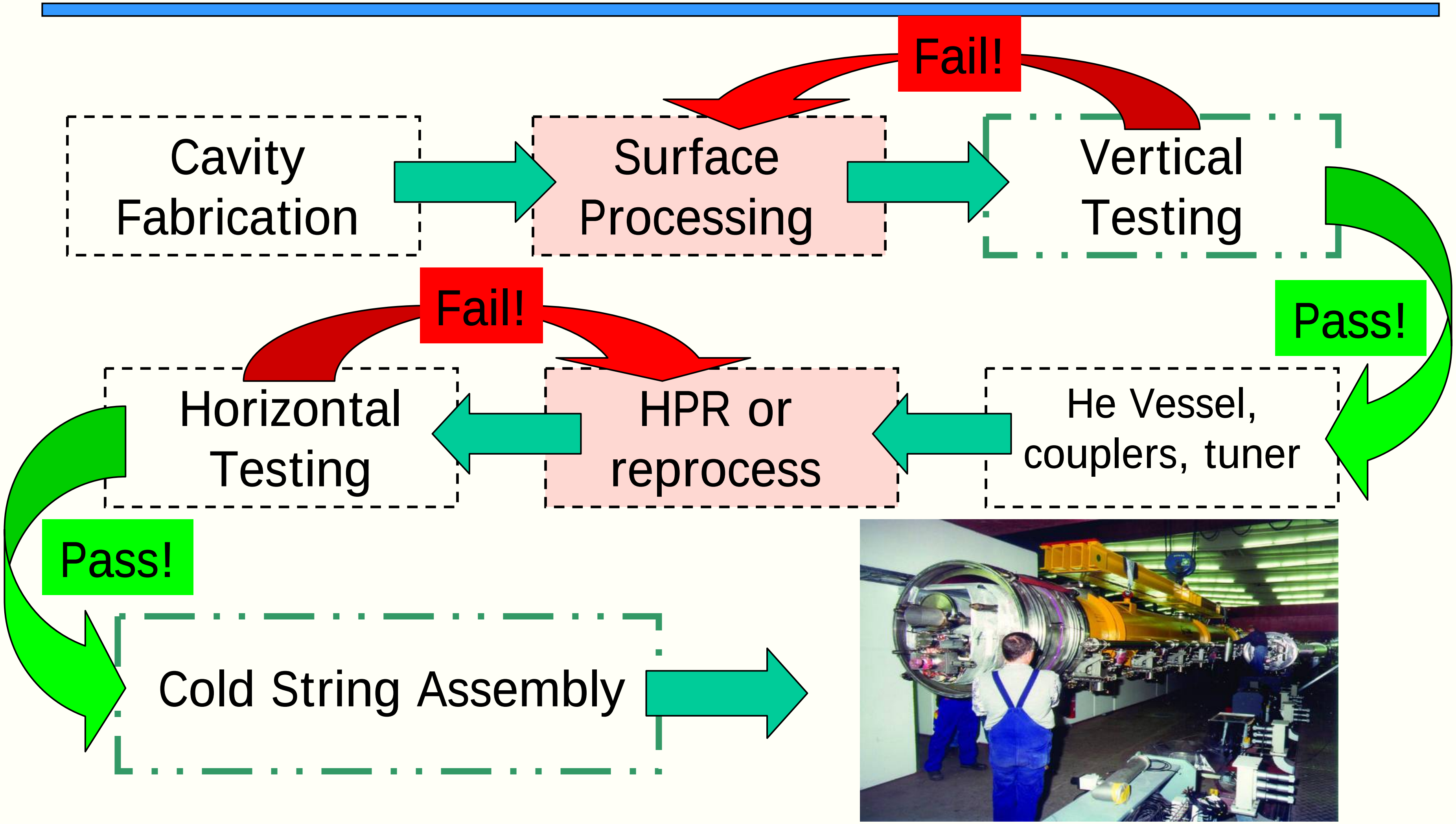
Current R&D Program

- We are pursuing 4 SCRF activities in Parallel
- Plan A: ILC
  - Our goal is to Work with the international community to carry our the R&D necessary to demonstrate the machine is technically feasible and affordable
  - We also want to prepare FNAL as a strong host candidate for the machine. Command of SCRF technology is essential
- Plan B: HINS
  - If the ILC is delayed or sited elsewhere, build an intense SCRF based proton source for long baseline neutrino physics
  - Such a project could serve to build up industry for a delayed ILC
- Generic SCRF development:
  - Mostly 3.9 GHz work in progress as part of the TESLA Technology collaboration and Materials R&D collaboration
- AARD:
  - So far this has been largely the FNPL Photo-injector effort
  - FNAL wishes to increase activities on Accelerator R&D and this can be a natural extension of our ILC and HINS plans (more)

This talk: focus on ILC goals

- A primary ILC R&D goal is to rapidly advance the intellectual understanding of SCRF surface physics and establish process controls to reliably achieve high gradient (35 MV/M) SCRF cavity operation needed for ILC (usually referred to as GDE S0 goal)
- Approach: Establish so called “tight loop” processing and test infrastructure
- Tight loop elements:
  - Cavity fabrication capability (U.S. vendors)
  - BCP & Electro-polish facilities
  - High purity water and High pressure rinse
  - Vertical test facilities
  - SCRF experts & materials program to interpret results
- SCRF materials program =FNAL,UW,NW,Cornell,TJNL,MSU, etc

Cavity process and testing



Plan… Develop in labs then transfer technology to industry

SCRF Infrastructure

- This process requires extensive infrastructure
- Bare cavities
  - Fabrication facilities (Industry: Electron beam welder, QC, etc)
  - Surface treatment facilities BCP & Electro-polish facilities (EP)
  - Ultra clean H_20 & High Pressure Rinse systems
  - Vertical Test facilities (Cryogenics + low power RF)
- Cavity Dressing Facilities (cryostat, tuner, coupler)
  - Class 100 clean room
  - Horizontal cavity & Coupler test facilities (RF pulsed power)
- String Assembly Facilities
  - Large class 10/100 clean rooms, Large fixtures
- Cryo-module test facilities
  - Cryogenics, pulsed RF power, LLRF, controls, shielding, etc.
  - Beam tests ➔ electron source (RF unit test facility at NML)
- The focus of this review is to describe to you our plans to build this infrastructure and develop SCRF expertise at FNAL

Why an SCRF R&D program?

- **Why NOT just an ILC R&D expense?**
- **Answer:**
  - **The ILC in many ways “sets the bar” for the needs**
  - **ILC funds are supporting some FNAL infrastructure construction and SCRF R&D.. but ILC is a global project.**
  - **The GDE has steered ILC R&D funds at the most pressing issues for the benefit of “project”.**
    - **➔ use existing U.S. SCRF institutions to get “quick” answers**
    - **Because FNAL does not have much SCRF infrastructure we are at a disadvantage to participate in this activity.**
  - **Known that existing SCRF facilities are inadequate for ILC R&D needs ➔new “generic” facilities with better process control and throughput are needed**
  - **The GDE does not have the responsibility for building generic SCRF capability at any laboratory or in any region**
- **This is the responsibility of the DOE.**
- **HINS or other U.S. SCRF projects will benefit from R&D aimed at high gradients and from this improved infrastructure**

Funding types

- It is important to recognize that SCRF efforts are funded from various sources
- ILC funding (ILC B&R… GDE recommends)
  - Funds actual machine design effort
  - ILC cavity fabrication, processing, CM parts, etc.
  - Only funds most crucial infrastructure
- HINS (lab core funds)
- SCRF infrastructure (lab core funds)
  - Funds the bulk of infrastructure
  - Funds efforts that are generic or that serve to "train" our staff… e.g. 3.9 GHz effort with DESY
  - Funds facility "operations" not paid for by ILC or HINS
- This review is focused on the last category…

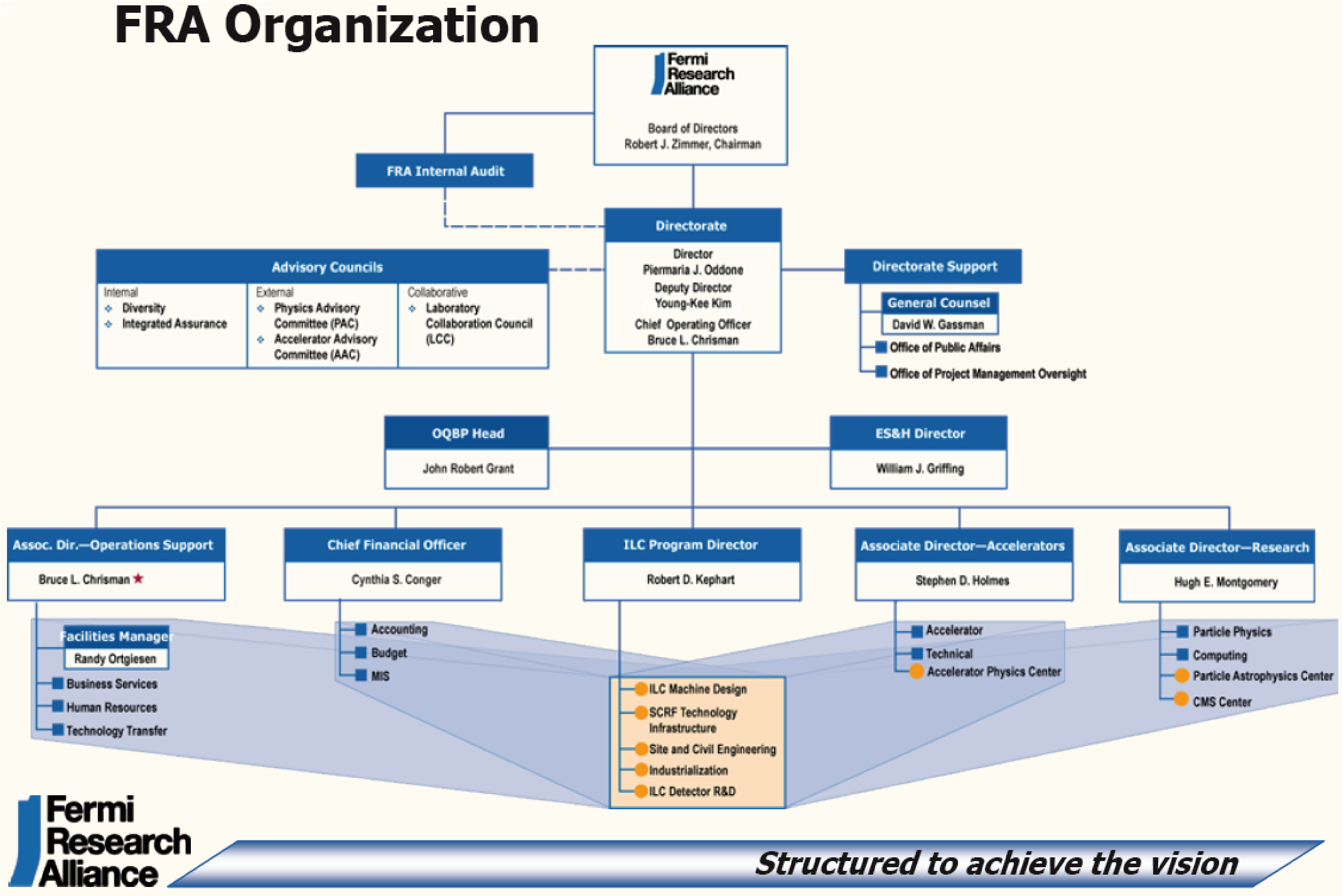
Why an R&D program?

- **Should the required SCRF infrastructure be built as a "construction project" in the DOE system ?**
  - **Answer No! We do not fully understand today the process steps to reliably produce high gradient cavities and CM**
  - **This is R&D! Can only partially specify the equipment and infrastructure that will be required.**
  - **Plans will evolve, so will the costs and milestones… they are dependent on the outcome of the R&D**
- **The framework of a DOE Project would waste lots of effort and not improve the outcome**
- **Of course it must be well planned and managed !**
- **We will present "next steps" and our best estimate of the associated costs and schedule for 2-3 yrs**

FNAL ILC/SCRF organization

- **For the next few years FNAL faces the difficult challenge of delivering on the existing program (especially Run II) while building the ILC effort**
  - **The lab also recognized that SCRF is an "enabling" technology that will be useful any of a variety of future projects in addition to ILC.**
- **We also recognize that success on the ILC requires the full resources of the laboratory**
  - **Technical, business, HR, FESS, etc.**
  - **Hence ILC is not organized as a project in a division**
- **In FY06 Pier chose to organize ILC and all SCRF efforts by creating an office in the Directorate**
- **Full budget authority, matrix management org**

FNAL ILC/SCRF organization



FRA Organization

Fermi Research Alliance
Board of Directors
Robert J. Zimmer, Chairman

FRA Internal Audit

Directorate
Director
Piermaria J. Oddone
Deputy Director
Young-Kee Kim
Chief Operating Officer
Bruce L. Chrisman

Advisory Councils

Internal	External	Collaborative
Diversity Integrated Assurance	Physics Advisory Committee (PAC) Accelerator Advisory Committee (AAC)	Laboratory Collaboration Council (LCC)

Directorate Support
- General Counsel — David W. Gassman
- Office of Public Affairs
- Office of Project Management Oversight

OQBP Head — John Robert Grant

ES&H Director — William J. Griffing

Assoc. Dir.—Operations Support — Bruce L. Chrisman ★
- Facilities Manager — Randy Ortgiesen
- Business Services
- Human Resources
- Technology Transfer

Chief Financial Officer — Cynthia S. Conger
- Accounting
- Budget
- MIS

ILC Program Director — Robert D. Kephart
- ILC Machine Design
- SCRF Technology Infrastructure
- Site and Civil Engineering
- Industrialization
- ILC Detector R&D

Associate Director—Accelerators — Stephen D. Holmes
- Accelerator
- Technical
- Accelerator Physics Center

Associate Director—Research — Hugh E. Montgomery
- Particle Physics
- Computing
- Particle Astrophysics Center
- CMS Center

Fermi Research Alliance

Structured to achieve the vision

FNAL ILC/SCRF organization

- Deputies
  - Shekhar Mishra
  - Sergei Nagaitsev
- Resource Manager – Rich Stanek
- Leaders in the Divisions and Sections
  - AD (Sergei Nagaitsev)
  - TD Marc Ross (as of Feb 1)
  - PPD Marcel DeMarteau
  - CD Steve Wolbers
  - FESS Vic Kuchler
- Detailed organization chart exists
  - Task Leaders responsible for deliverables
  - Workers may come from more than one Division
  - SWF in Division (labor agreement), M&S in Directorate
- Evolving… eg new strong additions (e.g. Marc Ross)
- Full WBS (Project 18 in FNAL financial system)
- Technical and Financial tracking in place

Financial Management

- Full WBS breakdown of tasks
  - ILC Division Leaders organize efforts in each Division
    - Task managers responsible for budget & technical progress
  - SWF is assigned to Divisions for scope of work
    - Essentially a scope of labor agreement
    - Guidance provided for FY 06, renegotiated as required
    - High level assignments made by Division Heads in consultation with ILC Director and Division leader
    - Mostly this worked fine, but a few cases where key personnel were reassigned without notice
    - This is new, so some task leaders not yet fully up to speed
  - M&S and management reserve held in Directorate
    - Division Leaders & Task leaders have signature authority
    - M&S in FY06 changed due to incremental funding by DOE
  - Seven separate funding changes in FY06!

Financial Management

- The ILC/SCRF effort was organized as a “Project 18” in the FNAL financial system
- 18.1 GDE directed activities
  - Deliverables and levels of effort specified in GDE MOU
  - All funding in ILC B&R category, we report on this
  - Contains all “ILC specific” work (accounting)
- 18.2 FNAL directed infrastructure and R&D
  - Efforts are arguably more general (e.g. SCRF = enabling technology with other applications, advanced controls system development benefits other projects, detector develop, etc)
  - Informed GDE about what we are doing (endorsement)
- 18.3 DESY collaborative 3.9 GHz effort
- 18.4 U.S. Bid to host ILC (small, mostly outreach)
- 18.5 ILC Americas (communicator support)

- Project 19: GDE Directors salary, office expense, travel
- This reorganization took effect ~ Jan 06 (25% thru fiscal yr)

Financial Management

- Role of ILC Resource Manager (Rich Stanek)
  - Interacts with Task Managers on budget and resource issues
  - Monitors ILC (GDE) vs. SCRF Infrastructure split to assure it is done correctly (Multiple funds transfers➔Serious Issue!)
  - Oversees MOUs and financial transfers to outside institutions
  - Produces monthly financial reports (with Budget Office)
  - With Program Engineers (Harry Carter & Jerry Leibfritz)
    - Developing a resource loaded schedule & milestones
    - Produce GDE quarterly technical & financial reports
  - With input from task managers, produce summary cost estimates for FNAL SCRF program in future years

GDE directed ILC R&D

- The vision of the GDE is that the ILC R&D program be proposal driven, prioritized, and optimized across the globe
  - U.S. DOE has asked the GDE Americas Regional Team (ART) Director for R&D funding recommendations
  - Some influence in U.K… less in Europe and Japan
- In the U.S. in FY06 and FY07 U.S. labs and universities made proposals for ILC R&D efforts
- The ART Director (Dugan now, soon Harrison)
  - Received guidance from OHEP on available funding for U.S. ILC R&D (funds in the ILC B&R code)
  - GDE research board assigned relative priority to tasks
  - ART Director consulted with RDB and EC then recommended funding by work package to the DOE

FY06 Funding

- **FY06 national funding for ILC R&D was $ 30 M**
  - **GDE recommended ILC R&D funding to FNAL was $ 13 m**
  - **Some of this funded the RDR work, but part funded cavity development and infrastructure of the highest priority to ILC**
  - **FNAL added $ 19 M in core funds to develop generic SCRF capability & infrastructure (includes ~$3 M for DESY collaboration)**
- **FNAL's total FY06 ILC/SCRF effort was $ 32 M**
  - **Numbers include salaries and overhead**
- **In FY06 the FNAL workforce (ILC + SCRF) ramped from 60 FTE to 150 FTE by year end**
  - **ie, a major increase in emphasis and effort**
  - **Rapidly evolving workforce and capability**

FY06 Funding

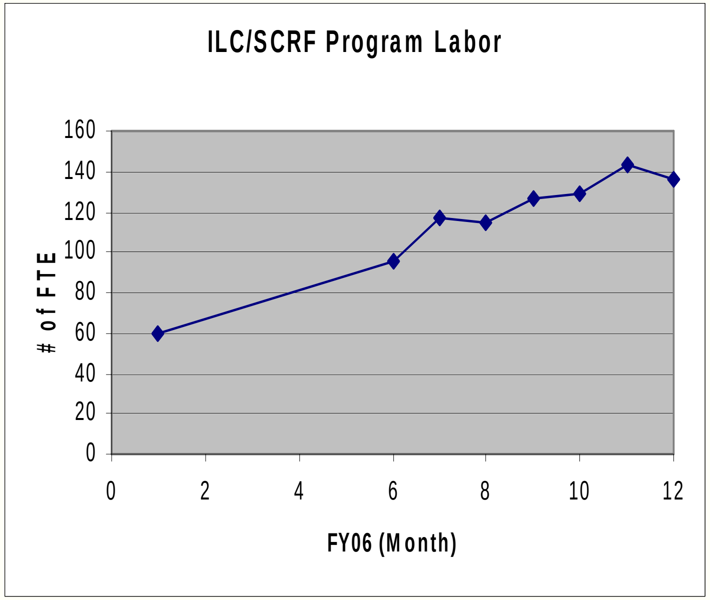
- Total FNAL spending on ILC/SCRF in FY06 was $ 25,545 K
  - Spending on just SCRF infra was $ 15,231 K

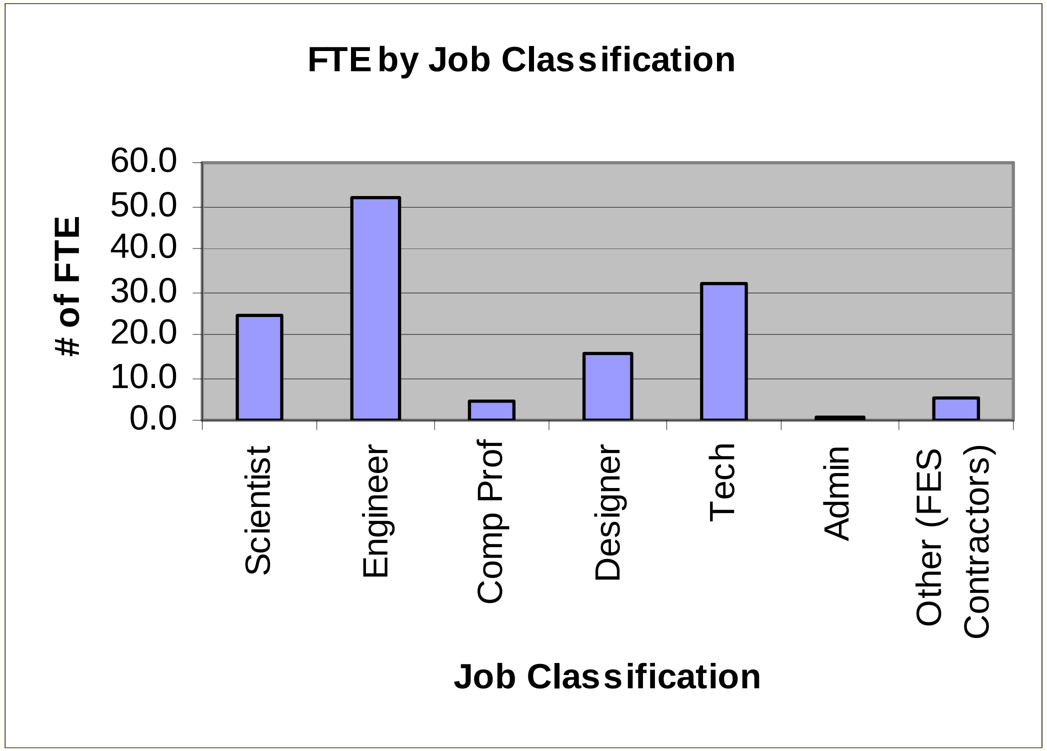
- Labor: FY06 spending on SWF was $ 12, 943 K
  - Steady growth of workforce through the fiscal year (next slide)
  - Workforce increased from 60 FTE to 150 FTE at EOY
  - 72% of this labor worked on SCRF R&D and building infrastructure

- M&S: FY06 spending in was $ 12,603 K
  - Most of this went into the SCRF R&D program and infrastructure

- Level of funding was very uncertain during the year
  - Numerous funding changes… with funds added late in the year
- Our progress was paced by available funding.

FY06 Workforce





ILC/SCRF Program (SWF)

	SWF Budget		SWF Actual
	Guidance	Revised	
AD	5250	4620	4719
CD	848	1217	1182
DIR	410	488	488
FES	0	0	9
PPD	2131	2226	2324
TD	4409	4228	4221
TOTAL	**13,048**	**12,779**	**12,943**

- **All Divisions contributing**
- **Full effort reporting in place**
- **Note: FES is chargeback organization so CFS work shows up as M&S expense**

06 Technical Accomplishments

- ILC Design:
  - FNAL made a large contribution to ILC RDR machine design and cost estimate
- DESY 3.9 GHz Collaboration
  - Fabricated, processed, & tested first 3.9 GHz cavities
  - Completed design of the CM and ordered parts
- Capture Cavity II
  - DESY supplied high gradient cavity intended for use with NML RF unit test facility
  - Completed MDB cryogenics modifications and demonstrated 1.8 K operations
- 300 KW klystron, LLRF, etc installed in MDB
- Operated Capture Cavity II at 31.5 MV/M

FY06 Accomplishments and status

- **Cavities:**
  - **Cavity Processing:** Purchased and received 4 nine cell TESLA cavities from ACCEL (Europe) to develop U.S. surface processing facilities (at TJNL and Cornell)
  - **Vendor Development:** Ordered 4 nine cell cavities from AES a U.S. vendor: first step in qualifying them to make ILC cavities, ordered single cells from Roark/Niowave
  - **Lab Development:** Ordered two standard 9 cell TESLA cavities from TJNL, experienced cavity fabricators. Goal is both processing development and as a bench mark
  - **Large Grain:** Ordered two large-grain Nb 9 cell TESLA cavities from TJNL to explore BCP processing as an alternative processing technique
  - **Populate cryomodules:** The best of these cavities will be used to populate the 2nd cryomodule we build

Current state of FNAL SCRF

- **Processing:**
  - Cornell: Funded Cornell to use existing BCP facilities to process an ACCEL cavity
  - TJNL: Funded TJNL to upgrade its facilities to EP process TESLA cavities and test them
    - 1st ACCEL cavity achieved 29.5 MV/ M
- **VTS**
  - Began construction of Vertical Test System in IB1
  - Civil done, ordered cryostat, power amp, etc
- **HTS**
  - Began construction of Horizontal Test System
  - Cryo connections in MDB ~done, cryostat in hand, will use same RF system as CCII
- **Cryomodules**
  - Slide on this
- **RF unit test facility**
  - Slide on this

Need to finish these slides

06 Technical Accomplishments

- Cryomodule Assembly Facility (MP9)
  - Large class 10/100 Clean room installed and operational
  - Large CM assembly fixtures fabricated and in hand
- Joint ANL/FNAL processing facility built and is coming into operation for BCP and EP
- Began cleanout of NML
  - CCM gone, Cryogenics installation under way
- Fabricated cavities at ACCEL, AES
  - 1 Processed at Cornell with BCP (26 MV/M)
  - 1 Processed at TJNL with EP (29.5 MV/M)
- Initiated extensive collaborative activities
- Much more about all of this in the talks that follow…

FY07 Initial Plan

- GDE assumed U.S. funding increase $30 → 60 M
- ART call for proposals in May resulted in $ 105 M of proposed ILC R&D activity (not much on EDR in this)
- FNAL FY07 Request: (without distinguishing between ILC and SCRF B&R categories) was:
  - SWF support for ~ 180 FTE incl. Detector R&D
  - $22 M of M&S
    - Not including site specific civil design
    - Not including industrialization activities
    - Not including EDR effort >> RDR
    - Our plan assumed ~ $ 4 M of M&S would go to other labs and universities, largely to cover cavity processing and collaborative activities
  - Total FNAL request was for $ 56 M

FY07: A key year for ILC R&D

- Cavity R&D:
  - Need to purchase enough cavities to measure yield (~50)
  - Need to develop processing technology and improve yield
  - Need infrastructure to dress cavities, test them, and put them in CM
- Cryomodule R&D:
  - Finish the Cryomodule fabrication infrastructure
  - Purchase parts for 2nd Cryomodule (1st with U.S. cavities)
  - Improve design and cost reduction (involve US Industry)
- RF Unit Test:
  - Prepare ILCTA_NM infrastructure to test DESY cryomodule by end of year, and eventually with beam
- SRF Infrastructure:
  - Start design and initial fabrication of cavity processing and test infrastructure needed for S0. Complete VTS, HTS, etc systems
- EDR Launch: Opportunity to take a major leadership role in ILC

FY07 Developments

- FY07 GDE recommendation to DOE was to support 68 FTE and $ 9.8 M in M&S at FNAL… $22.7 M total from ILC funds
  - A big increase, but far from supporting the existing workforce
  - Recommended additional support of staff & infrastructure from other funds, but no OHEP plan for these funds (funding depends on availability of lab's core funds for this)
- FNAL IFP (core funding) too low to support infra work
- Next: FY07 national ILC funding became uncertain
  - Presidents budget recommends $ 60 M (House also)
  - Senate recommended $ 45 M, but no bill passed
  - Awaiting Senate passage of the bill, resolution in conference
  - meanwhile… THE ELECTION… Democrats win ➔CR
- We now are told that the continuing resolution will be in force for the entire FY07 fiscal year ➔ SCRF budget is completely uncertain… very disruptive !!!

FY08 and beyond

- Clearly need to establish a “line” of funding so the required SCRF infrastructure can be built and so that long term planning is possible
- What is the scope of the overall effort required ?
  - DESY spent ~ $150 M of M&S to build TTFII and associated infrastructure.
  - The facilities we need are more advanced… higher gradients (cleaner) and higher cavity/CM throughput
  - But… many existing pieces of infrastructure at FNAL that we can be exploited (buildings, refrigerators, A0 photo injector parts, etc)
  - The infrastructure we plan in the next ~ 3 years is comparable in scope to DESY ~ $130 M

Question: Scope

- What sets the scope?
- The best cavity fabrication and surface processing can yield outstanding cavity performance (> 40 MV/m Eacc)
  - But the process yield is low for 9 cell cavities
  - Evidence points to one or more uncontrolled variables
  - Goal is to achieve clean smooth Nb surfaces
  - Particulates at the micron level lead to field emission, defects of 10s of microns lead to quenches
- Need adequate lab infrastructure to build, process, and test a large number of cavities to track down the sources of variability.
  - S0 ILC goal: > 100 cavities process/test cycles per year
  - TJNL ~ 30/yr, Cornell ~ 12/yr: both institutions have other plans beyond 2008 for their facilities
  - Clear need for new large facility

Other Questions

- What are the key R&D issues ?
  - Reliable achievement of high gradients (ie yield)
  - Cavity fabrication techniques, surface processing technology, process control, and cavity diagnostics and test facilities are all key elements
  - So is cost of fabrication and processing
  - Achieving high gradient cavity operation in cryomodules with beam is also crucial
    - Goals outlined in GDE S2 task force report
  - Additional goals associated with spoke resonators
- Will the facilities we plan be adequate to address key questions ? On what time scale.
  - Yes… our claim is that the facilities we propose will be
  - But… timescale depends on funding profile

Other Questions

- Laboratory Collaboration
  - Have we developed close collaboration with U.S. SCRF experts at universities and DOE labs (TJNL) ? We claim yes..
  - Extensive Collaborative activity with non-U.S. partners, and U.S.universities, and labs (next slide)
- Are we developing industry ?
  - No… not yet
  - Have started, but effort is limited by our own expertise to guide them and by available funding
- Is our plan prioritized so that it can be scaled back?
  - Yes… Priority set by 1) GDE goals, 2) FNAL desire to host ILC
  - Scale back ? Sure, but to the extent we do that we will never catch up with Europe and Japan on SCRF
  - Priorities and scope largely set by the needs of the ILC R&D program, but facilities can serve many other needs in the future

ILC Collaborations

Fermilab

- ANL: EP development and cavity processing
- Cornell: Cavity processing & test, materials R&D
- DESY: 3.9 GHz, cryomodule kit, TTF
- KEK: Cavity R&D, ATF II
- MSU: HPR, Cavity vendor development and cost
- TJNL: EP cavity processing and test
- INFN: tuners, HTS, NML gun cathodes
- Penn/Triumf: cavity tuners
- SLAC: RF power, klystrons, couplers
- CERN, DESY, KEK, INFN, etc: Type IV CM design
- India: Design, couplers, cavities, etc
- NW,UW/NHML,Cornell, DESY, KEK: Materials etc…
- Major Ramp up in planned collaborative efforts !

Cost Estimate Summary

- **Spread sheet here**

Conclusions

- I have described to you the importance of SCRF as and “enabling” technology for HEP.
- In the talks that follow we will:
  - Address the questions in the charge in more detail
  - Describe plans for the needed generic infrastructure
  - Present the estimated cost and schedule to build it
  - Describe an R&D program using that infrastructure to address the key R&D questions in HEP, primarily thos that face the ILC, HEP’s new planned flagship facility
- Hopefully we will convince you that this crucial enabling technology urgently needs significant investments and that FNAL is the place to make them.