

Cryomodule Assembly Facility (CAF)

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Outline



- **Goals for SRF Infrastructure**
- **Introduction**
- **CAF-MP9 & CAF-ICB Facilities Layout**
- **Cryomodule Assembly Workflow**
- **CAF-MP9 & CAF-ICB Infrastructure**
 - **Current Status**
 - **Future Plans**
- **Throughput Assumptions**
- **Cost Summary**
- **Conclusions**

Goals for SRF Infrastructure



- **To perfect U.S. fabrication & processing of SRF cavities and modules and to demonstrate performance with a full range of testing (including beam)**
 - Deploy ILC design / processing / assembly techniques
 - Establish process controls to reliably achieve high gradient cavity operation and module performance
 - Test cavities and modules at the component level and in a systems test to demonstrate yield, reproducibility and beam performance
- **To facilitate commercial production of SRF components and modules**
 - Train and transfer SRF technology to the US industry
 - Allow industrial participation and input to the process
- **To participate in SRF Research and Development**
 - Develop expertise in SRF technology and provide training base for construction and operation of future accelerators
 - Our attempt to fit into the world's SRF community

All of this work will be carried out with US/international collaboration

Development of Industry



Cryomodule Process	Starts with		Transitions to
Cavity Fabrication	Lab/Industry Collaboration	→	Industry
↓			
Cavity Processing	Lab/Industry Collaboration	→	Industry
↓			
Low Power Test (VTS)	Laboratory	→	Laboratory
↓			
Cavity Dressing	Lab/Industry Collaboration	→	Industry
↓			
High Power Test (HTS)	Laboratory	→	Laboratory
↓			
Cryomodule Fabrication	Lab/Industry Collaboration	→	Industry
↓			
Cryomodule Test (CTS)	Laboratory	→	Laboratory

The technology for cavity fabrication & processing, cavity dressing and cryomodule fabrication will be transferred to Industry.

Cryogenic testing of cavities and cryomodules along with beam tests will remain the responsibility of US laboratories.

US Laboratories Capacity



Fermilab

Program	FY07	FY08	FY09	FY10	Capacity Needed/yr by FY10
Cavity Processing (EP, HPR, Bake)	Jlab-30 Cornell-10	Jlab-40 Cornell-10 ANL-40	Jlab-40 Cornell-10 ANL-40 Fermilab-20	Jlab-40 Cornell-10 ANL-40 Fermilab-100	200
Vertical Testing	Jlab-30 Cornell-10 Fermilab-20	Jlab-40 Cornell-10 Fermilab-75	Jlab-40 Cornell-10 Fermilab-75	Jlab-40 Cornell-10 Fermilab-200	200
Horizontal Testing	Fermilab-6	Fermilab-24	Fermilab-24	Fermilab-72	72
Cryomodule Assembly	Fermilab-1	Fermilab-4	Fermilab-12	Fermilab-12	12
Cryomodule Test	Fermilab: ILCTA_NML	Fermilab: ILCTA_NML	Fermilab: ILCTA_NML	Fermilab: ILCTA_NML CMTS	12

Introduction

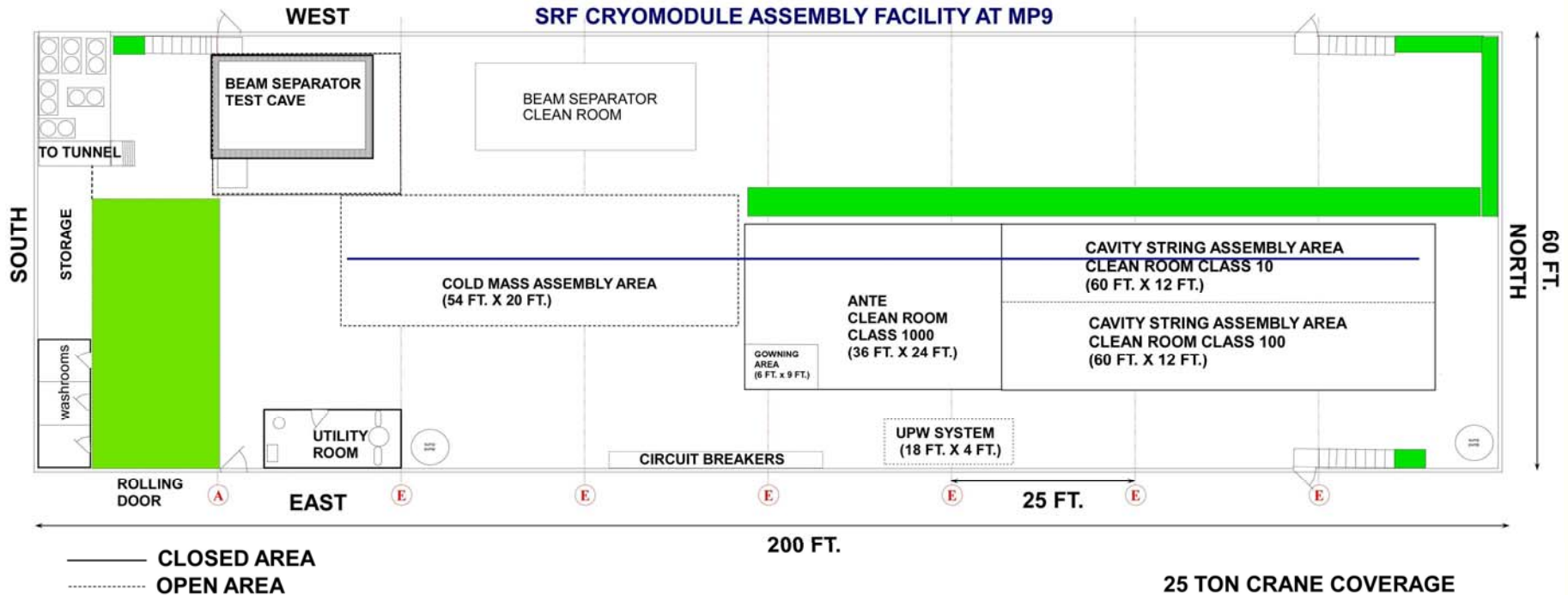


- CAF is an upgraded version of the infrastructure in DESY Hall 3 for cryomodule assembly:
 - Cavity String Assembly
 - Cold Mass Assembly
 - Vacuum Vessel Assembly
 - Final Assembly
- The plan is to assemble this facility in MP-9 building and the Industrial Center Building (ICB) in the Technical Division at FNAL.
- Cryomodule Assembly Facility (CAF) at Fermilab consists of 2 buildings: CAF-MP9 and CAF-ICB.
- The ultimate throughput of this infrastructure will be to assemble 1 cryomodule per month. (12 cryomodules per year).

CAF-MP9



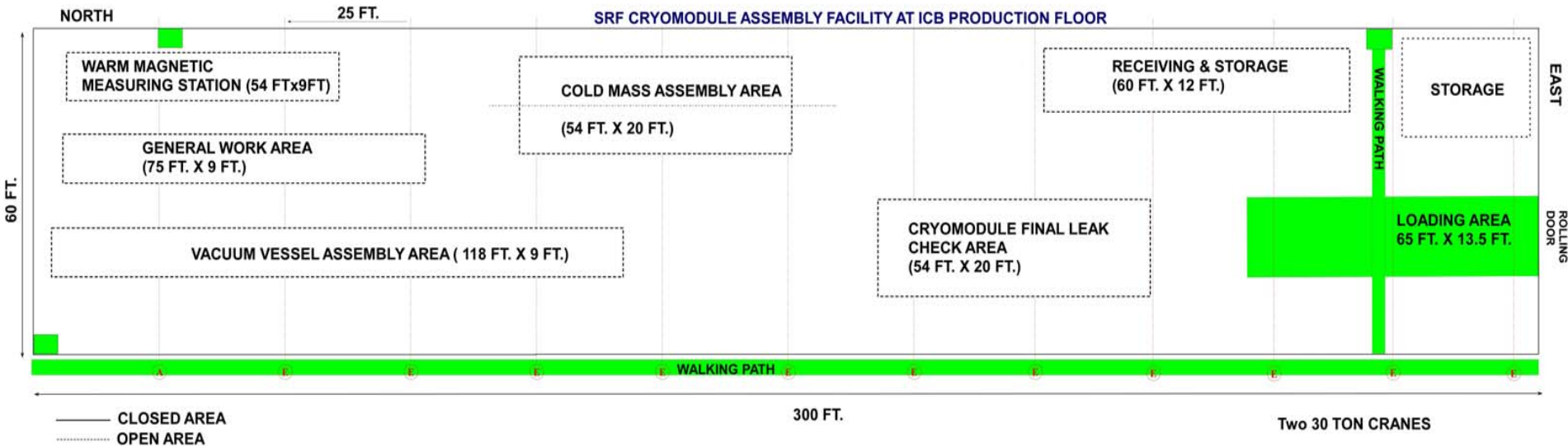
CAF-MP9 houses the string assembly clean rooms, the rail for string assembly under the clean room extending to the cold mass assembly area and the cold mass assembly fixture adjacent to the clean room.



CAF-ICB



CAF-ICB houses the Vacuum Vessel Assembly area and Final Assembly area including the Big Bertha Fixture.



Cryomodule Assembly Workflow



At CAF-MP9:

- Receive chemically processed bare cavities
- Dress cavities for horizontal dewar test:
 - Weld the titanium helium vessel to the bare cavity
 - Install cold part of the main coupler (clean room)
 - Install tuner and magnetic shielding
 - Send cavity for horizontal dewar test
- Received dressed cavities from horizontal dewar test: :
 - Proceed to string assembly if the desired gradient is achieved
 - High pressure rinse cavity if the desired gradient is not achieved
- **Assemble dressed Cavities to form a String in the Cavity String Assembly Area (Clean Room)**
- **Install String Assembly to Cold Mass in the Cold Mass Assembly Area**
- **Transport the Cold Mass to CAF-ICB**

At CAF-ICB:

- **Receive partially assembled cold mass from CAF-MP9**
- **Install the Cold Mass back to the Cold Mass Assembly Fixture in Cold Mass Assembly Area**
- **Align Cavity String to the Cold Mass Support**
- **Install the String assembly with the cold mass into the Vacuum vessel in the Vacuum Vessel Assembly area**
- **Ship Completed Cryomodule to NML for testing**

Assembly Workflow @ CAF-MP9

Receive dressed Cavities

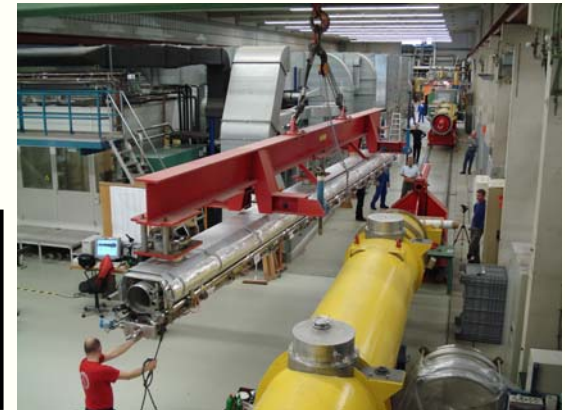
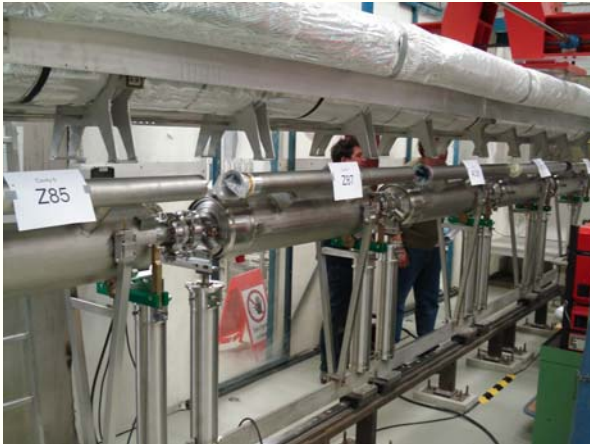
Receive peripheral parts



Assemble dressed Cavities to form a String in the **Cavity String Assembly Area** (Clean Room)



Install String Assembly to Cold Mass in the **Cold Mass Assembly Area**



Transport the Cold Mass to **CAF-ICB**

Assembly Workflow @ CAF-ICB

Install the Cold Mass back to the Cold Mass Assembly Fixture in **Cold Mass Assembly Area**



Align Cavity String to the Cold Mass Support



Install the String assembly with the cold mass into the Vacuum vessel in the **Vacuum Vessel Assembly area**



Ship Completed Cryomodule to **NML** for testing



CAF-MP9 Infrastructure

- Cavity String Assembly Clean Room
- A large clean room was specified and procured in FY05 and installed in FY06 at Fermilab for about \$ 1 M.
- The cavity string assembly clean rooms infrastructure consists of:
 - Class 1000 ante clean room for preparation of the dressed cavities for transportation into the assembly clean room.
 - Class 100 parts and assembly preparation
 - Class 10 assembly clean room where the cavities vacuum is vented to interconnect them with bellows.



CAF-MP9 Infrastructure (cont.)

Other infrastructure:

- String Assembly Fixtures
- Vacuum / Ultra Pure Gas Flow Equipment/ Hardware
- Ultrasonic Cleaner
- Ultra pure DI water
- Cavity Handling Cart / Fixture
- Cold Mass Assembly Fixture



CAF-MP9 Current Status

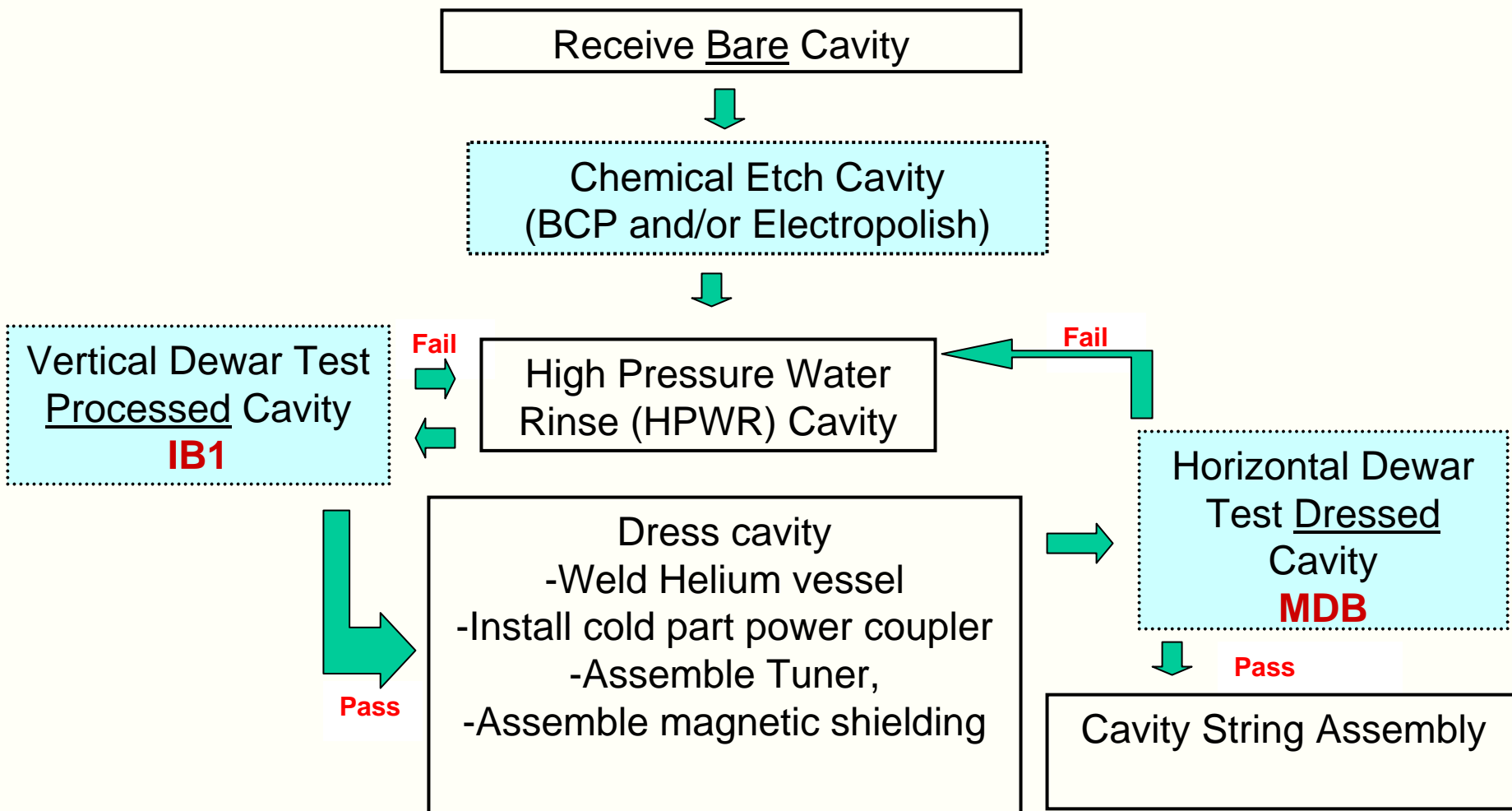


- Cryomodule Assembly Facility (CAF) in MP9 is now mostly complete.
- CAF-MP9 will continue to be the main CAF building for the assembly of the ILC cavity strings in the clean room in the coming fiscal years.
- After the installation of the horizontal test stand at Fermilab, the Joint BCP Facility at ANL and the planned Cavity Processing Facility (CPF) at FNAL, Fermilab plans to process and dress cavities. (Currently, bare cavities are purchased from industry and are processed at collaborating institutions.)

Cavity Preparation Workflow



Cavity Dressing & HPWR infrastructure will be done at CAF-MP9 until CPF is ready

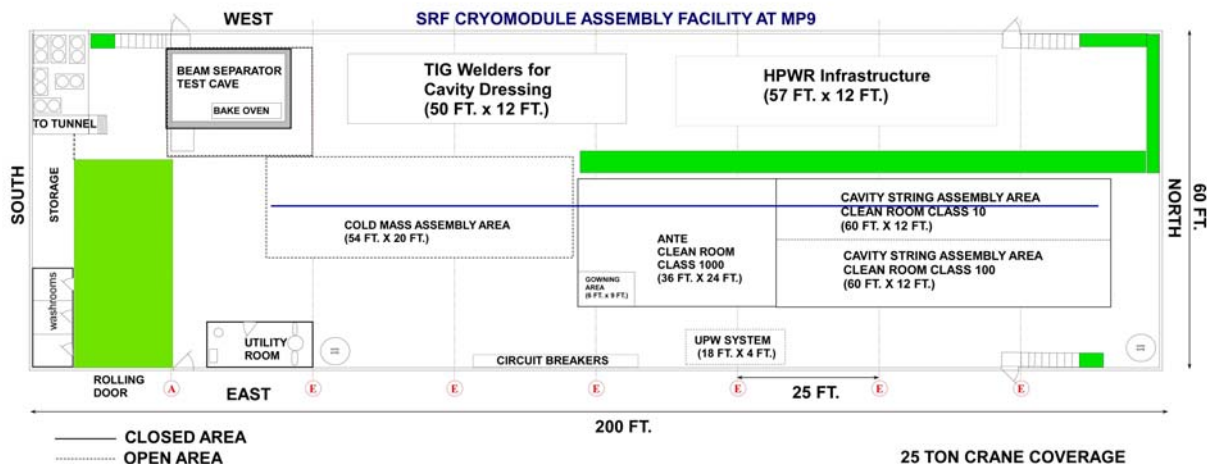


CAF-MP9 Future Plans



- Below is the additional planned infrastructure and the estimated cost of CAF-MP9 cavity dressing infrastructure:

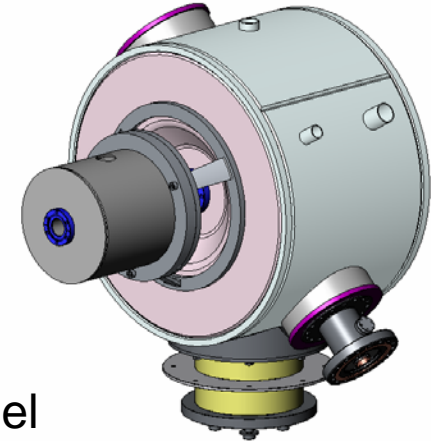
Expenditure Description	FTE-years	Labor (K\$)	M&S (K\$)	Total Cost Including Indirect (K\$)	Fiscal Year
HPR Infrastructure	0.5	67.5	200	257.5	FY08
TIG Welders			80	80	FY08
Welding Fixtures	0.25	33.75	50	79	FY08
Total		101.25	330	517.07	



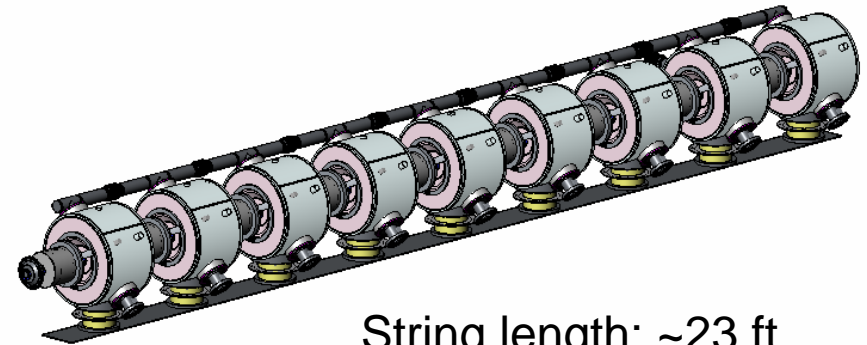
CAF-MP9 Future Plans (cont.)

There will be 3 spoke cryomodules (2-SSR1 and SSR2) needed to be assembled for HINS R&D Program (2007-2010):

- The first SSR1 will be assembled in summer 2009. The second SSR1 CM will be assembled by end-2009. The SSR2 CM will be assembled by summer 2010
- 9 spoke cavities and 9 solenoids in the SSR1 & 11 spokes cavities and 6 solenoids in the SSR2
- Cavities in their individual He vessel will arrive after processing (BCP+HPR) from ANL to FNAL
- They would be tested in Meson in the Test Cryostat
- Solenoids would be produced at FNAL/vendor
- String Assembly will be done at CAF-MP9
- Transport the assembled string from CAF-MP9 to CAF-ICB



Cavity with Helium Vessel and Solenoid assembled



String length: ~23 ft

CAF-ICB Infrastructure



- After the cavity string is picked up off the rail and partially assembled to the cold mass support, the cold mass assembly is transported to the Vacuum Vessel Assembly Area at CAF-ICB.
- Transport fixture will be required to move the cavity string from MP-9 to ICB. (under design review)
- Transport fixture will be required to move the completed cryomodule from CAF-ICB to NML.
- The major CM assembly fixture used in this assembly area is “Big Bertha”
 - a cantilever fixture used to support the cold mass for the remainder of the insulation and power coupler assembly and then slide the vacuum vessel on the assembled cold mass. (One was ordered in FY06 and a second is planned for FY08)
- Portable clean rooms for coupler assembly and specialized vacuum and leak detection equipment
- Various minor fixtures and tooling are necessary during the cold mass, vacuum vessel and final assembly.

CAF-ICB Current Status

- ICB building will be available by the end of February 2007 once the LHC HGQ magnet production is completed.
- ICB production floor will be prepared for CAF operations (~\$100K)
- The major infrastructure/ fixture and equipment outside of the clean room for the Cryomodule Assembly are funded in FY07. Our plans assume that we will have \$0.7 M total (direct) to complete these tasks in FY07.



CAF-ICB Future Plans



- CAF can also be used for small scale mass production assembly area for cryomodules. With the fixtures / tooling procured & installed in FY07, ILC R&D quantity Cryomodules can be assembled at CAF.
- If one wants to increase the assembly capacity to 1 cryomodules per month, then additional infrastructure will be needed for CAF, especially for CAF-ICB. (next slide)

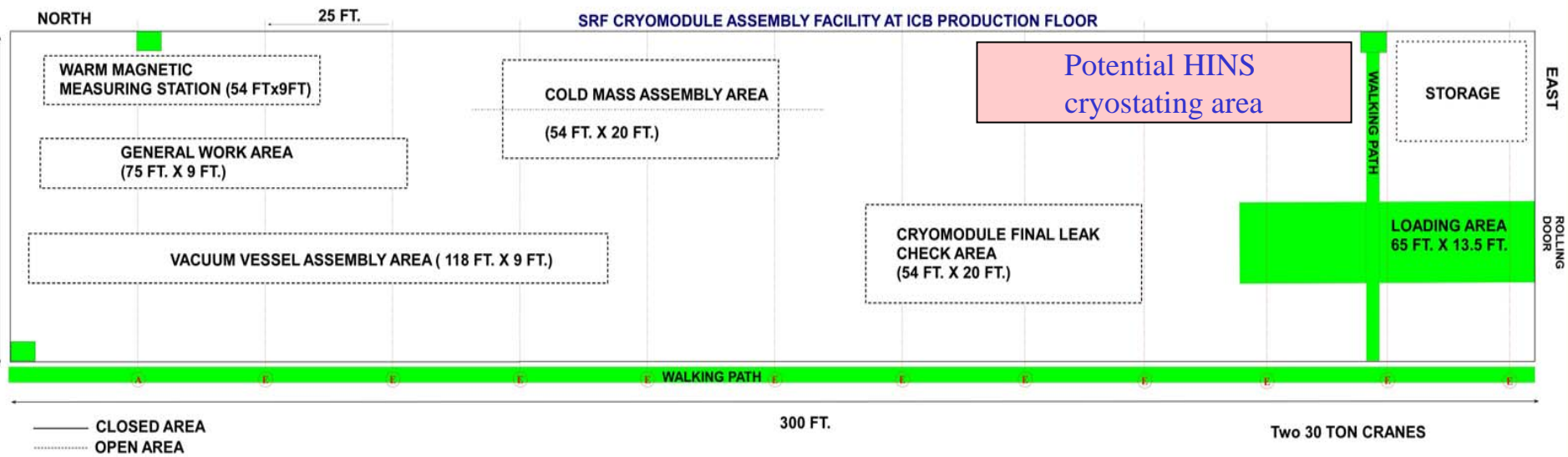
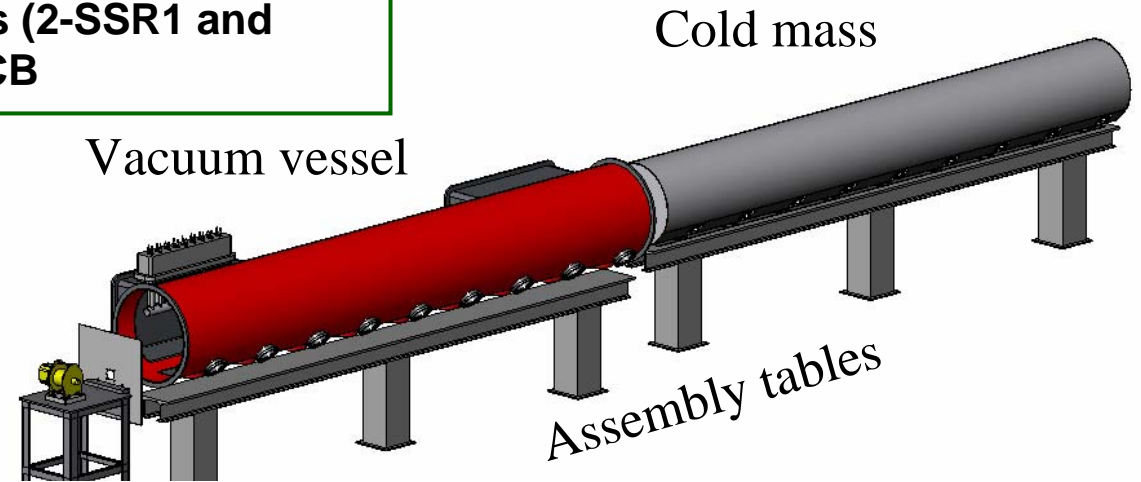
CAF-ICB Future Plans (cont.)



Expenditure Description	FTE-years	Labor (K\$)	M&S (K\$)	Total Cost Including Indirect (K\$)	Fiscal Year	Status
Cold Mass Assembly Fixture	0.2	33.75	2 x 35 = 70	94	FY09 & Beyond	2 extra fixtures for CAF-ICB
Vacuum Vessel Assembly Fixture (Big Bertha)	0.5	67.5	150	208	FY09 & Beyond	1 extra fixture for CAF-ICB
Rail System for Cavity Support	0.5	67.5	90	148	FY09 & Beyond	This maybe required to transport the string from CAF-MP9 to CAF-ICB
Misc. Fixtures / Tooling			50	50	FY09 & Beyond	
Total		168.75	360	640.43		

CAF-ICB Future Plans (cont.)

Cold Mass and Vacuum Vessel Assembly of the HINS spoke cryomodules (2-SSR1 and SSR2) will be done at CAF-ICB



Throughput Assumptions



- The current infrastructure installed at CAF-MP9 and at CAF-ICB has a throughput of R&D quantities cryomodule fabrication. (1 cryomodule per ~ 3 months)
- The ultimate throughput is to assemble 1 cryomodule per month at CAF facilities:
 - S0-S1-S2 cryomodule assembly capacity requirements per year:
 - 2007: 1 Cryomodule
 - 2008: 4 Cryomodules
 - 2009: 12 Cryomodules
 - 2010: 12 Cryomodules
- Currently at DESY Hall 3: (Total 33 work days)
 - It takes 10 work days to assemble a cavity string in the clean room.
 - It takes 13 work days to assemble the Cold Mass out of the clean room in the Cold Mass Assembly Area and 10 work days for the final assembly in the Vacuum Vessel Assembly Area.

Throughput Assumptions (cont.)



In order to achieve a throughput of 1 cryomodule per month:

- Work two shifts in the Cavity String Assembly Clean Room to assemble cavity string: (one assembly rail in the clean room)
 - This will assure 1 assembled string every 5 work days
- Transport the assembled string from CAF-MP9 to CAF-ICB. (preferably right after the string is rolled out of the clean room)
- Have two parallel Cold Mass Assembly Lines at CAF-ICB to receive assembled cavity strings. Work one shift:
 - This will assure 1 cold mass assembly every 7 work days
- Have 2 parallel Big Bertha Fixtures in the Vacuum Vessel Assembly Area at CAF-ICB. Work one shift:
 - This will assure 1 final cryomodule assembly every 5 work days

With the above assumptions, one can assemble 1 cryomodule in 17 work days. (This throughput assumes that the trained personnel are available as needed and the duplicated assembly fixtures are installed)

Required Funding



Infrastructure	M&S	SWF	Total with Indirect
Cavity Fabrication Infrastructure	\$ 3,000	\$ 675	\$ 4,380
Cavity Processing Facilities	\$ 11,100	\$ 4,590	\$ 18,945
Vertical Test Stand (VTS 2 & 3)	\$ 2,625	\$ 1,845	\$ 5,475
Horizontal Test Stand (HTS 2)	\$ 1,220	\$ 1,057	\$ 2,805
Cavity/Cryomodule Assembly Facilities (CAF_MP9 & ICB)	\$ 690	\$ 270	\$ 1,158
NML Facility (ILCTA_NML)	\$ 18,270	\$ 23,220	\$ 51,700
Cryogenics for Test Facilities	\$ 10,690	\$ 950	\$ 13,692
Cryomodule Test Stand	\$ 5,400	\$ 2,970	\$ 10,180
Material R&D	\$ 870	\$ 722	\$ 1,960
Illinois Accelerator Research Center	\$ 20,000	\$ 4,050	\$ 28,605
Grand Total (\$k)	\$ 73,865	\$ 40,349	\$ 138,900

Infrastructure	M&S (direct)	SWF (direct)	Total with Indirect
CAF Infrastructure	\$ 690	\$ 270	\$ 1,158

Conclusions



- CAF Infrastructure setup is progressing as planned. Major tooling / fixtures were designed, procured and installed.
- Tooling shake down and assembly procedures practice (learning curve) are under progress with the mockup cavities sent by DESY.
- Cryomodule Assembly plans in FY07:
 - **1st FNAL ILC Cryomodule Assembly:**
 - Assembly (~4 months): Start date depends when we receive the kit from DESY (July – October 2007) DESY colleagues will assist during the assembly at FNAL.
 - **3.9 GHz DESY TTF Cryomodule Assembly:**
 - Mock-up assemblies (March – May 2007)
 - String Assembly at CAF-MP9
 - Cold Mass & Vacuum Vessel Assembly at CAF-ICB & at DESY