Cryomodule Assembly Facility (CAF)

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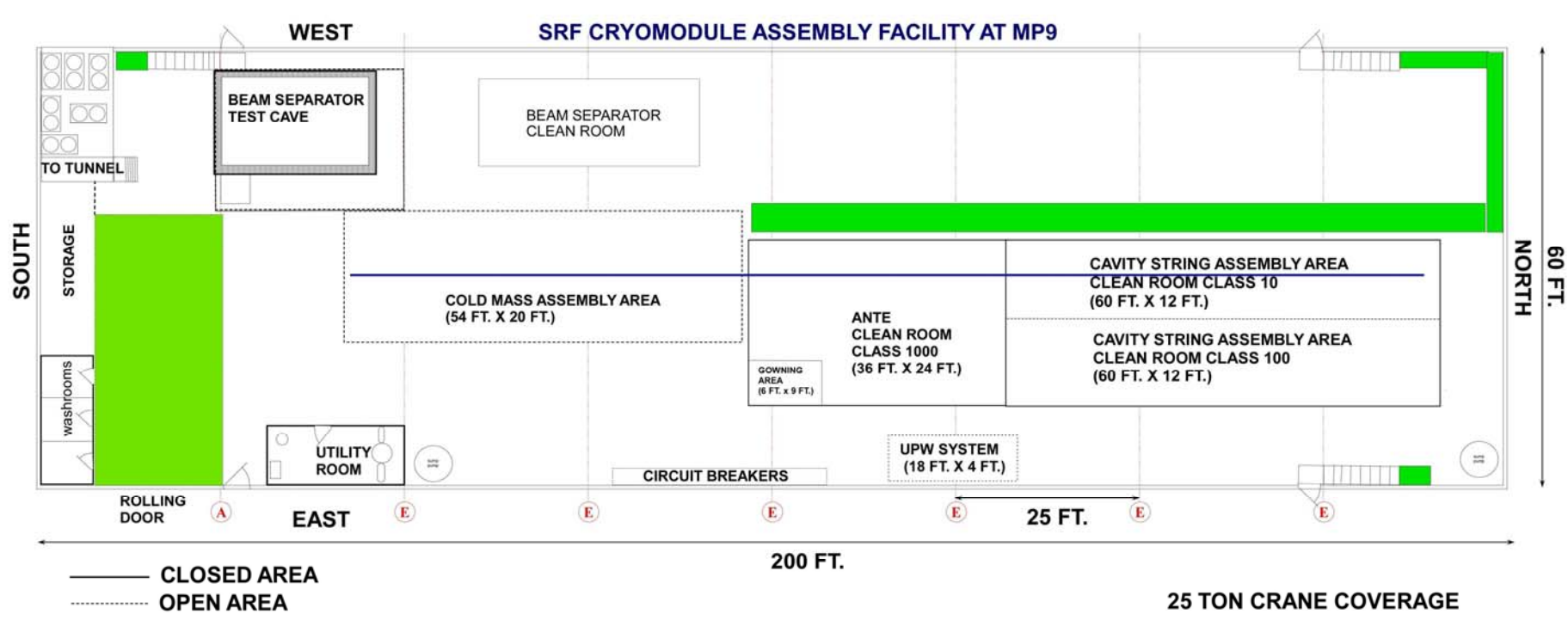
Introduction

- Our plan is to build an upgraded version of the infrastructure in DESY Hall 3 for cavity dressing, cavity string and cryomodule assembly.
- The plan is to assemble this facility in MP-9 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 one month. (12 cryomodules per year).

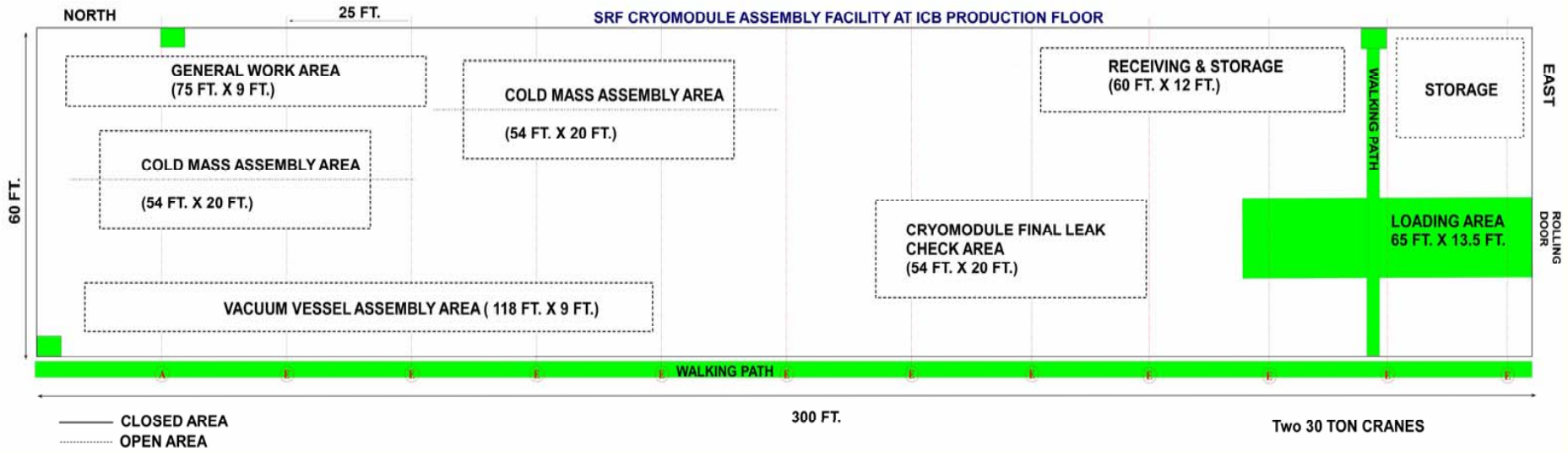
CAF-MP9

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

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At CAF-MP9:

- Receive chemically processed bare cavities
- Dress cavities for horizontal dewar test: (until Cavity Processing Facility [CPF] is ready)
  - Weld the titanium helium vessel to the bare cavity
  - Install cold part of the main coupler in the Class 10 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 at CAF-MP9
- Transport the Cold Mass from CAF-MP9 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 at CAF-ICB
- 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 (Big Bertha) area
- Ship Completed Cryomodule to NML for testing

Assembly Workflow @ CAF-MP9

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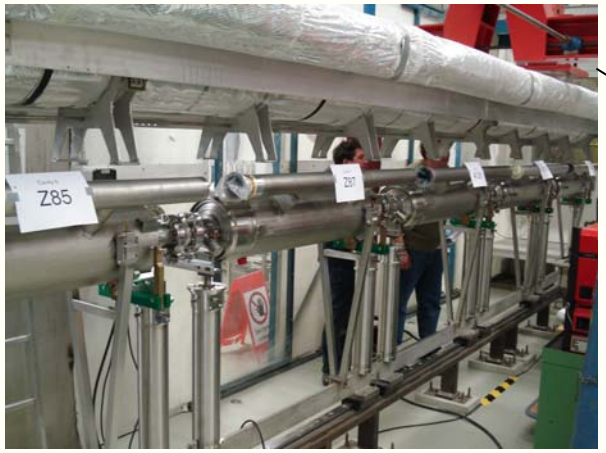
Receive dressed Cavities

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 from **CAF-MP9** to **CAF-ICB**

Assembly Workflow @ CAF-ICB

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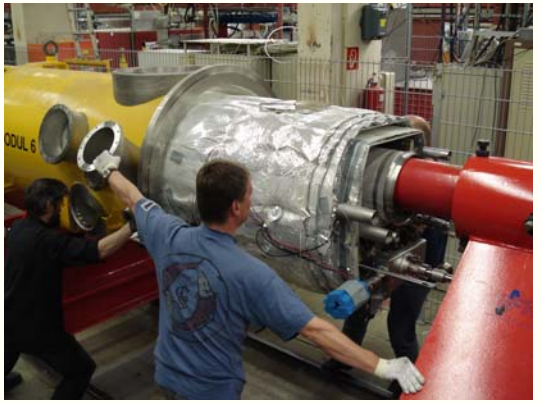
Install the Cold Mass back to the Cold Mass Assembly Fixture in **Cold Mass Assembly Area at CAF-ICB**

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



CAF-MP9 Infrastructure

- A series of clean rooms are needed to assemble dressed (welded with helium tank around the bare cavity), horizontal tested and qualified to gradient cavities into a cavity string.
- A large clean room was specified and procured in early part of FY06 at Fermilab for about $ 1 M.
  - The clean room has a Class 10 assembly area with the size of 60 ft long and 12 ft wide. This is needed to be able to assemble a cavity string (8 cavities, BPM/Quad package) that is approximately 36 ft long.
- 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 10 assembly clean room where the cavities vacuum is vented to interconnect them with bellows.

CAF-MP9 Infrastructure (cont.)

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Other infrastructure:

- *String Assembly Fixtures:* There are approximately 30 fixtures used to assemble a string. Major fixtures are cavity support stands, components alignment fixtures etc.
- *Vacuum / Ultra Pure Gas Flow Equipment/ Hardware:* The cavities need to be backfilled and argon flow is needed during interconnecting them with bellows. All the vacuum and gas handling equipment need to be clean room compatible, particle free in order not to contaminate the cavities during assembly.
- *Ultrasonic Cleaner:* It is necessary to clean outside surfaces of the cavities, fixtures and assembly hardware for particle reduction before they are transported into the Class 10 assembly area.
- *UPW Infrastructure:* Ultra pure, De-ionized water is needed for the ultrasonic cleaning of the parts.
- *Cavity Handling Cart / Fixture:* Dressed cavities needs to be transported as needed inside Class 10 assembly area. This cart needs to be clean room compatible.
- Cold Mass Assembly Fixture: A spreader bar lifting fixture is needed to assemble the cold mass and to transport it to Big Bertha Fixture

CAF-MP9 Current Status

- Cryomodule Assembly Facility (CAF) in MP9 is now largely complete.
- All of this equipment basically fills the MP9 building. 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.)

CAF-MP9 Future Plans

- We plan to procure and setup TIG welding stations at CAF-MP9 to dress cavities:
  - Receive chemically processed and Vertical Tested Bare Cavities at CAF-MP9
  - TIG Weld Helium Vessels to the Bare Cavities
  - Leak Check
- After the welding of the helium tank, the dressed cavities need to go through several cycles of high pressure rinsing (HPR). We plan to install 2 state of the art High Pressure Water Rinse systems at Cavity Processing Facility at FNAL. Until this facility is ready, we plan to install an HPR system at CAF-MP9.
- Then the dressed cavities will be moved into the Clean Rooms for the assembly of the cold part of the power coupler in preparation for the horizontal test. The assembly of the cold part of the power coupler requires venting the cavity inside to inert gas atmosphere so the assembly work needs to be done in the Class 10 Clean Room.
- After the assembly of the cold part of the main coupler, then dressed cavities will be moved out of the Clean Room and it will be further dressed for the horizontal test at CAF-MP9. The tuner and the magnetic shielding will be installed for the test. Then the cavities will be shipped to Meson Detector Building (MDB) where the horizontal test stand infrastructures reside.
- If the horizontal test result is successful and the desired operating gradient is achieved, then the dressed and qualified cavities will be brought back to CAF-MP9 for assemble of the cavity string.
- If the test result is not satisfactory, dressed cavities will go through several cycles of HPR at CAF-MP9 and it will be retested.

CAF-MP9 Future Plans (cont.)

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

Expenditure Description	FTE-years	Labor (K$)	M&S (K$)	Total Cost (K$)	Fiscal Year
HPR Infrastructure	0.5	57.5	200	257.5	FY08
TIG Welders			80	80	FY08
Welding Fixtures	0.25	29	50	79	FY08
Total		**86.5**	**330**	**416.5**	

CAF-ICB Infrastructure

- After the cavity string is picked up off the rail and aligned to the cold mass support, the cold mass assembly is moved to Vacuum Vessel Assembly Area at CAF-ICB.
- Transport fixture will be required to move the cavity string from MP-9 to ICB.
- 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 are other major equipment for vacuum and final assembly.
- Various fixtures and tooling are necessary during the cold mass, vacuum vessel and final assembly.

CAF-ICB Infrastructure (cont.)

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The cold mass assembly major steps are:

- Roll the cavity string out of the clean room
- Position / Align the string under the cold mass support
- Interconnect cavity helium supply pipes
- Install tuners on the cavities
- Install instrumentation on the cavities
- Install magnetic shielding on the cavities
- Lower the cold mass support to the cavity string
- Install the needle bearings and bearing housings
- Pick up the cavity string off the rail with the cold mass support through the needle bearings housing
- Align cavity string to the cold mass support

The cold mass assembly major steps at the Vacuum Vessel Assembly Area are:

- Move the cold mass assembly to Big Bertha Fixture
- Install and weld 4K aluminum shields
- Wrap 10 layers of MLI
- Install and weld 80K aluminum shields
- Wrap 30 layers of MLI
- Slide vacuum vessel onto the cold mass
- Align the cold mass inside the vacuum vessel
- Assemble the warm part of the power couplers
- Harness the instrumentation / read out wire, cables
- Install and solder power leads for Quad magnet

CAF-ICB Current Status

- As stated before, Cryomodule Assembly Facility at Fermilab consists of two assembly buildings: CAF-MP9 and CAF-ICB.
- CAF-MP9 will accommodate the string assembly and part of the cold mass assembly infrastructure.
- CAF-ICB will accommodate remainder of the cold mass assembly and vacuum vessel assembly infrastructure.
- 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 fixture/ tooling procured & installed in FY07, ILC R&D quantity Cryomodules can be assembled at CAF.
- If one wants to increase the assembly capacity to 1~2 cryomodules per 1 month, then the below additional infrastructure will be needed for CAF, especially for CAF-ICB.

CAF-ICB Future Plans (cont.)

Expenditure Description	FTE-years	Labor (K$)	M&S (K$)	Total Cost (K$)	Fiscal Year	Status
Cold Mass Assembly Fixture	0.2	24	2 x 35 = 70	94	FY08 & Beyond	2 extra fixtures for CAF-ICB
Vacuum Vessel Assembly Fixture (Big Bertha)	0.5	58	150	208	FY08 & Beyond	1 extra fixture for CAF-ICB
Rail System for Cavity Support	0.5	58	90	148	FY08 & Beyond	This maybe required to transport the string from CAF MP9 to CAF-ICB
Misc. Fixtures / Tooling			50	50	FY08 & Beyond	
Total	**1.2**	**140**	**360**	**500**		

Throughput Assumptions

- The current infrastructure installed at CAF-MP9 and planned to be installed 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 1 month at CAF facilities. This requires the below assumptions:
  - It takes 10 business days to assemble a cavity string in the clean room. This equals to 10 shifts. If two 8-hour shifts are worked, 1 cavity string per week (5 business days) could be assembled in the CAF-MP9 Clean Room. We have 1 rail system underneath the clean room; therefore having multiple string assembly lines is not a viable option to increase the throughput for the cavity string assembly.
  - It takes 12 business days to assemble the Cold Mass out of the clean room in the Cold Mass Assembly Area and 9 business days for the final assembly on the Big Bertha fixture in the Vacuum Vessel Assembly Area. These equal to 21 days, 21 8-hours shifts.

Throughput Assumptions (cont.)

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

- Work two 8-hour shifts in the Cavity String Assembly Clean Room to assemble cavity string. This will assure 1 assembled string every week (5 business days).
- Move the assembled string from CAF-MP9 to CAF-ICB as soon as possible (preferably right after the string is rolled out of the clean room) in order to have part / material transfer access to the clean room for the next string assembly.
- Have two parallel Cold Mass Assembly Lines at CAF-ICB to receive assembled cavity strings from CAF-MP9 every week.
- Work two 8-hour shifts in the Cold Mass Assembly Area. This will assure 1 cold mass assembly every 7 business days.
- Have 2 parallel Big Bertha Fixtures in the Vacuum Vessel Assembly Area at CAF-ICB.
- Work two 8-hour shifts in the Vacuum Vessel Assembly Area. This will assure 1 final cryomodule assembly every 5 business days

- **With the above assumptions, one can assemble 1 cryomodule in 20 business days (1 month) working 2 shifts in parallel assembly lines.**
- **This throughput assumes that the trained personnel are available all the time to assemble the cryomodules.**

Cost Summary

- Majority of the R&D quantity cryomodule assembly infrastructure was procured and installed in FY06.
- The remaining infrastructure is currently being procured in FY07.
- Cavity dressing infrastructure will be procured and installed at CAF-MP9 in early FY08 until the planned Cavity Processing Facility (CPF) is ready.

- Majority of the R&D quantity cryomodule assembly infrastructure is being procured and installed in FY07.
- ICB building will be available for CAF-ICB starting from February 2007 after the LHC magnet assembly is completed.
- Additional fixtures are needed to ramp up the throughput to 1 cryomodule per month and these additional fixtures will be procured in early FY08.

CAF-MP9	FY06	FY07	**FY08**
M&S	1,541	241	**330**
SWF	100	52	**86.5**
Total	$1,641	$293	**$416.5**

CAF-ICB	FY06	FY07	FY08
M&S	125	500	360
SWF		83	140
Total	**$125**	**$583**	**$500**

Cost Summary: (In $k) Request to finish

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Infrastructure	M&S (direct)	SWF (direct)	Total with Indirect
Cavity Infrastructure	$ 690	$ 227	$ 1,565

Conclusions

- **CAF Infrastructure setup is progressing as planned. Major tooling / fixtures were designed, procured.**
- **1st FNAL ILC Cryomodule Assembly Plans:**
  - **Cavity String Assembly Procedures & Fixtures Learning at DESY (February 20 –March 3, 06)** [Completed]
  - **CAF-MP9 Clean Rooms operational:** [Completed]
  - **Install Cold Mass Assembly Fixture at CAF-MP9:** [Completed]
  - **Cryomodule #6 Assembly Procedures Learning at DESY** [Completed]
  - **CAF-MP9 Infrastructure ready & operational [100%]:** (February 2007)
  - **Install Vacuum Vessel Assembly Fixture (Big Bertha) at CAF-ICB** (March 2006)
  - **Practice assembly procedures (learned at DESY during Module #6 assembly) with mockups and new installed infrastructure at CAF-MP9** (December 2006 – February 2007)
  - **Assemble 1st Cryomodule (4 months): Start date depends when we receive the kit from DESY** (July – October 2007)