Cryomodules: Status Report and Work Package Plan for the ILC Americas Region

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Outline

- Review of RDR work
- Present Status of Cryomodule Work
- Work Package Plan for ILC Americas
- EDR Cryomodule Plan

RDR Review for Cryomodules

- As we all recall, the BCD cryomodule was the TTF Type 3+ design. The ACD was the Type IV cryomodule and an additional alternate was to consider a separate cryostat for the quadrupole magnet.
- The RDR Cryomodule was the Type IV with the predominant features of:
  - A 26-cavity RF unit consisting of three cryomodules
    - Two cryomodules containing 9 cavities each
    - One cryomodule containing a centrally located quadrupole/corrector/BPM package and 8 cavities
  - Blade-style slow tuners with piezo fast tuners
  - Reduced cavity-to-cavity interconnect spacing
- Development of the Cryomodule section of the RDR was a joint effort between Carlo Pagani, Norihito Ohuchi, and myself, with editing by Nick Walker and Chris Adolphsen, and final review by Nan Phinney
- The bulk of the text relied heavily on the TESLA TDR
- Areas described as requiring further work were
  - Type IV Cryomodule design development
  - Improved fiducialization of cryomodules
  - Cryomodule cost reduction
  - Developing a plan for shipping cryomodules

RDR Review for Cryomodules: Types and Quantities

Location	Quantity	Multiplier	Total	Unit Breakdown	Notes
Main Linac	936	2	1872	624 standard 1248 standard	w/quad w/o quad
RTML	60	2	120	64 standard 56 standard	w/quad w/o quad
e- source	21	1	21	11 standard 4 special 6 special	w/quad 6 cavities + 6 quads 8 cavities + 2 quads
e+ booster	22	1	22	12 standard 4 special 6 special	w/quad 6 cavities + 6 quads 8 cavities + 2 quads
e+ keep alive	2	1	2	2 special	w/quad(s)
Undulator	13	1	13	9 standard 4 standard	w/quad w/o quad
Total 1300 MHz			2050	2050	1300 MHz
Damping Rings	32	3	96	96 special	650 MHz

Table developed by T. Peterson as part of Global Systems/Cryogenics

CM-Related Work Accomplished During RDR Period

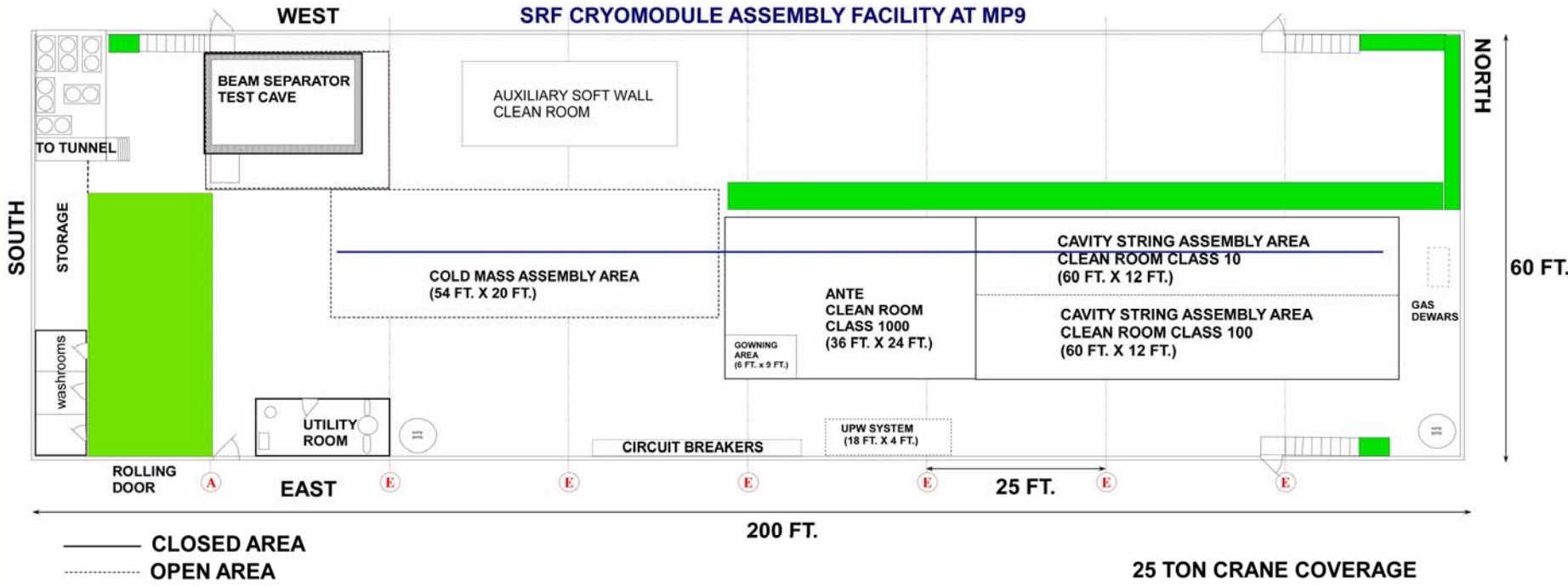
- **International Cryomodule Design Effort**
  - **Type IV CM design meetings held at:**
    - **CERN, January 2006---kickoff meeting**
    - **FNAL, July 2006---design status report and details development**
    - **INFN-Pisa, October 2006---detailed design meeting**
    - **FNAL, November 2006--- week long I-DEAS training class**
    - **INFN-Milano, May 2007---design review and status report**
    - **FNAL, July 2007---design review and status report**
  - **Goal: Complete engineering design package by October 2007 (now expect this to be end of CY07)**
- **Cryomodule Cost Studies**
  - **Industrial-based RF unit cost study led by AES (used LCFOA members)**
  - **FNAL-based study led by R. Stanek (members inc. JLab and SLAC)**
- **Industrialization**
  - **R. Kephart formed a study group (led by S. Mishra / P. Garbincius) charged with the development of a U.S. plan. Effort is ongoing with a report due before the end of this year.**

CM-Related Work Accomplished During RDR Period

- **Infrastructure Development at FNAL**
  - **Cryomodule Assembly Facilities:**
    - CAF-MP9---cavity string assembly and cold mass pre-assembly facility, cavity dressing area, and 1.3GHz cavity HPR **(until the CPF is operational)**
    - CAF-ICB---cold mass and cryomodule final assembly
  - **Cavity Processing and Testing Facilities**
    - BCP and EP Facility at ANL
    - VTS at IB1
    - HTS at MDB
    - IB4
  - **Cryomodule Test Facility**
    - ILCTA_NML (New Muon Laboratory)---RF unit test facility

Will be addressed in detail at DESY next week

Infrastructure at FNAL: CAF-MP9

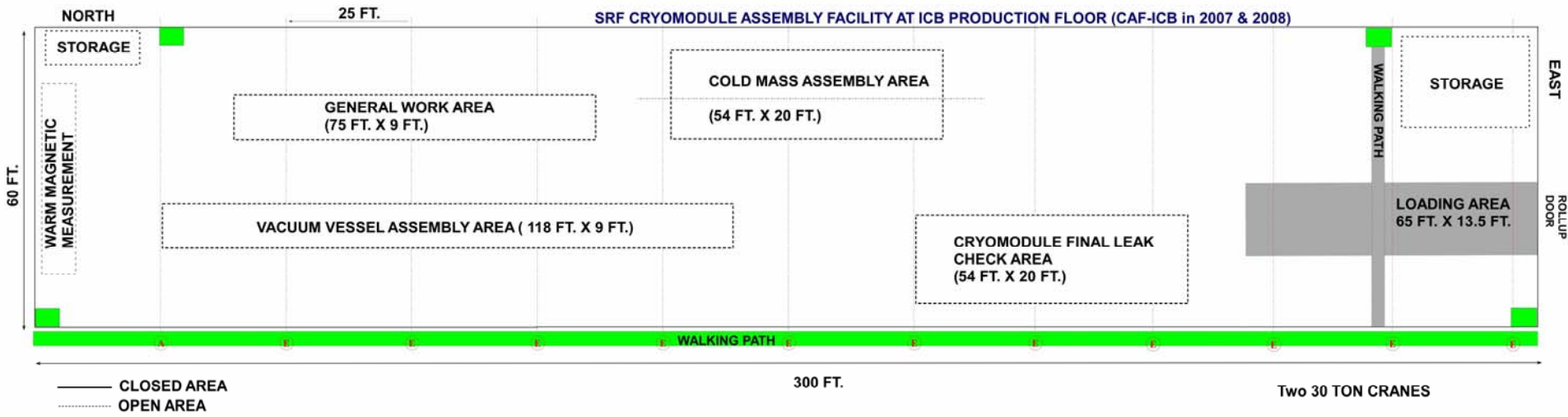


- **Functions:**
  - Cavity string assembly in Class 10 clean room
  - Roll out of cavity string
  - Upper cold mass pre-assembly
  - Prepare cold mass for transport to CAF-ICB

Infrastructure at FNAL: CAF-MP9

- Maximum throughput: 2 cavity strings per month
- Future/upgrades:
  - Dress cavities prior to horizontal testing (near term upgrade)
  - HPR

CAF-ICB



- **Functions:**
  - Receive cold mass pre-assembly from CAF-MP9
  - Complete cold mass assembly, including final alignment of cavity string
  - Insert cold mass assembly into vacuum vessel
  - Install warm part of power couplers
  - Leak final cryomodule assembly
  - Prep for shipping to ILCTA_NML

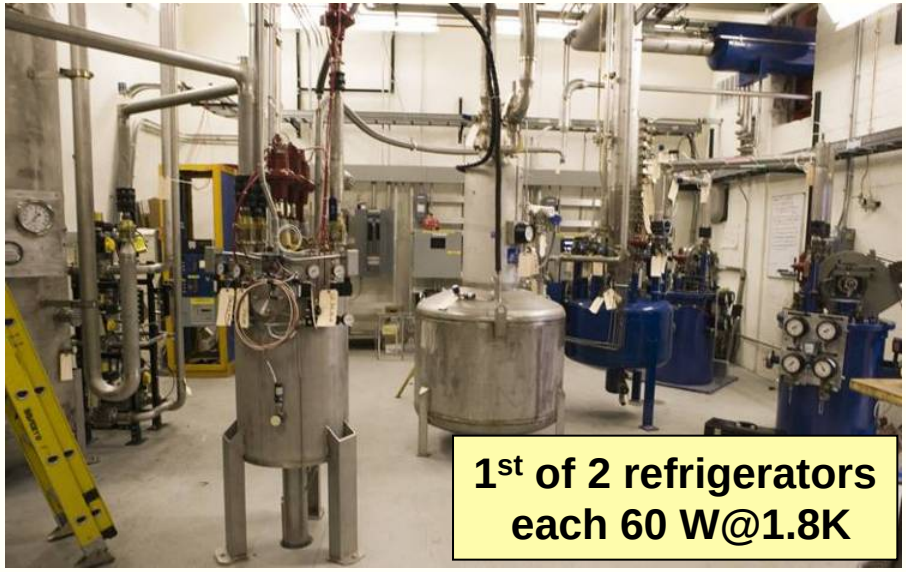
CAF-ICB

- **CAF-ICB maximum throughput is 2 cryomodules per month**

Vacuum vessel/cold mass assembly fixture at ICB

Cold mass assembly fixture (DESY)

ILCTA_NML



- **CM-Related Functions:**
  - Receive cryomodule assembly from CAF-ICB
  - Install cryomodule in NML test cave
  - Operate cryomodule as part of the NML test accelerator
  - Perform a complete RF unit test

FNAL Infrastructure: Future Plans

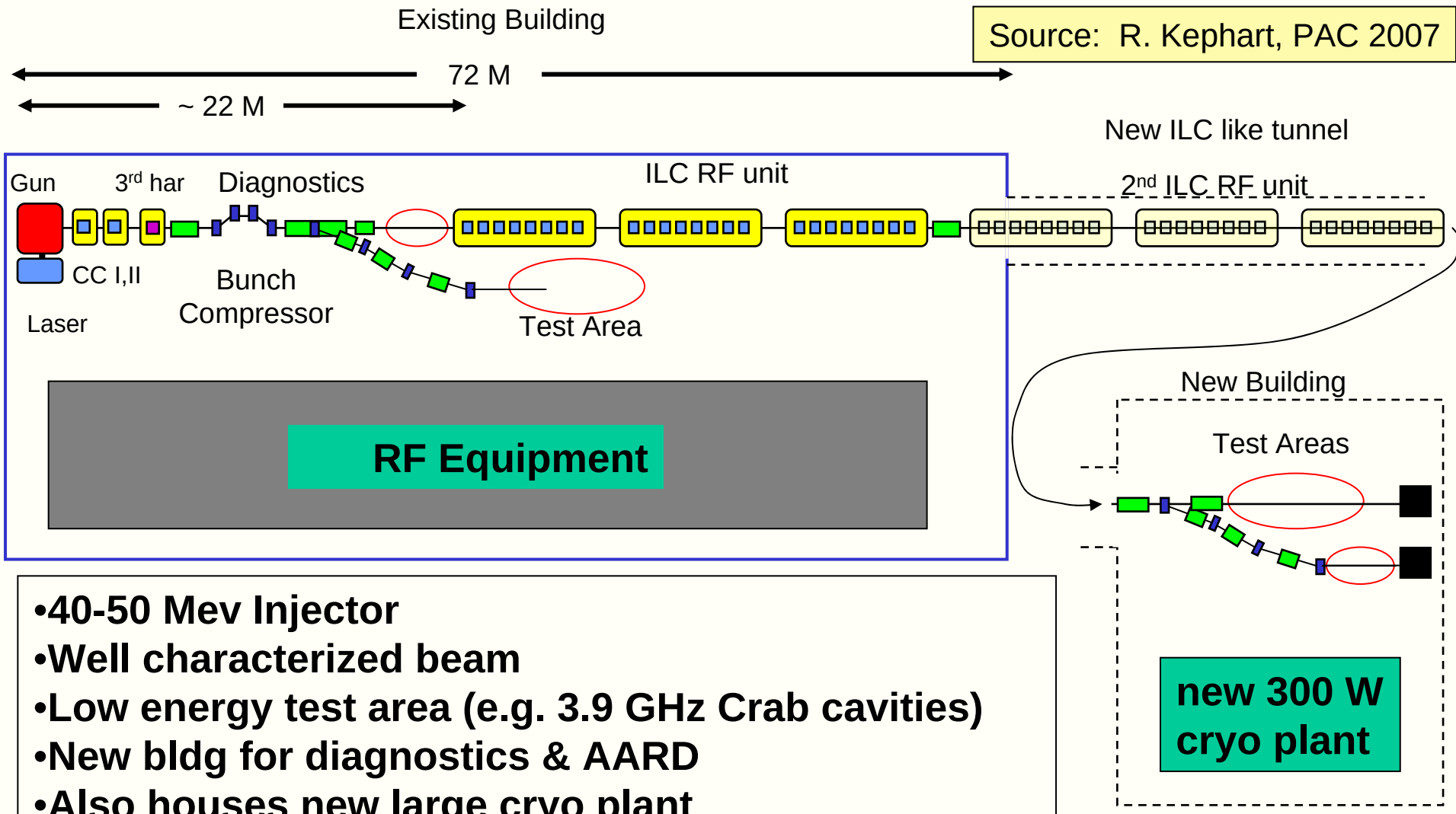
- **Vertical Testing System at IB1**
  - Increase from one to three test cryostats
  - Upgrade cryogenic system to support all testing at IB1
- **Horizontal Testing System**
  - Design and construct a second test cryostat (HTS-2) capable of simultaneously testing two dressed cavities or one cavity + quadrupole
- **Cavity Processing Facility (CPF)**
  - Design and construct a processing facility capable of performing 100 cavity processing cycles per year
- **Cryomodule Test Stand**
  - Using the test stand developed at DESY as a model, develop and construct a cryomodule test stand at FNAL

Infrastructure--Future Plans: ILCTA_NML

- Effort is funding limited requiring a phased approach
- Cryomodule delivery
  - 1st (Type 3+) cryomodule built from "kit" of DESY parts in late 2007
  - 2nd (Type 3+) CM – 2008 built with U.S. processed cavities
  - 3rd (ILC Type 4) CM – 2009 all U.S. components
  - Replace all three CMs with ILC Type 4+ in FY2010
- FY07: Start as a Cryomodule Test Stand
- FY08: move A0 photoinjector, start civil construction for new bldg
- FY09: 1st beam operation, 2-3 CM, low rep rate operations
- FY10: replace all 3 CM with ILC type CM
- FY11: install new refrigerator, ILC RF Unit operations
- Collaboration: DESY, INFN, ANL, Cockroft, NIU, Rochester, KEK

Source: R. Kephart, PAC 2007

Infrastructure--Future Plans: ILCTA_NML



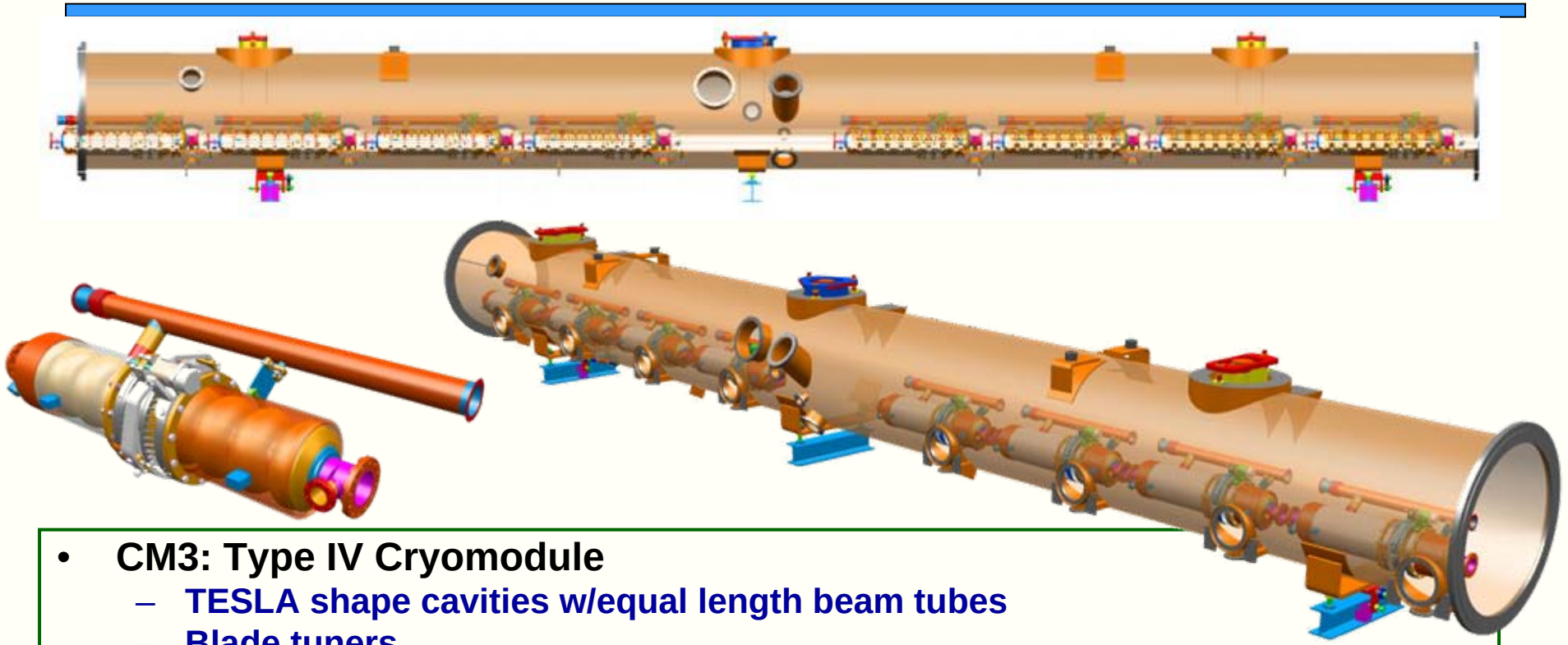
- 40-50 Mev Injector
- Well characterized beam
- Low energy test area (e.g. 3.9 GHz Crab cavities)
- New bldg for diagnostics & AARD
- Also houses new large cryo plant

Cryomodules: Status and Plans

- **CM1: TTF Type 3+ Design**
  - Comprehensive kit supplied by DESY
  - Standard TESLA style cavities w/unequal length beam tubes
  - Cavities use lever style tuner at end of cavity
  - Partial string of four cavities are assembled in MP9 clean room; other four cavities have been received at FNAL
  - Expect CM1 assembly to be completed by mid-November 2007
- **CM2: TTF Type 3+ Design**
  - Cavities from Accel and AES planned to be used
  - Cavities have equal length beam tubes
  - All cavities use blade tuners
  - Cavities will be dressed and horizontally tested at FNAL
  - Cold mass and vacuum vessel supplied by INFN-Milano
  - Expected to be completed by late Summer 2008

Concern is having enough dressed, tested cavities

Cryomodules: Status and Plans



- **CM3: Type IV Cryomodule**
  - TESLA shape cavities w/equal length beam tubes
  - Blade tuners
  - Revised helium vessel design inc. stainless steel 2 phase tube
  - Quad/corrector/BPM package in the center of the CM
  - Quad design suitable for operation at low beam energies at NML
  - Conductively cooled, LHC design, 100A magnet leads
  - Design work to be fully finished by end of CY2007
  - Procurement of major components to begin at start of FY08

ILC Americas Work Package Plan

From the ILC PMP (N. Walker)

- **During the ED period**
  - **Goals for SCRF Linac Technology include:**
    - **Complete the critical R&D as identified by the R&D Board Task Forces during the RDR phase.**
    - **Coordinate the industrialization efforts in each region (test facilities)**
    - **Identify a plan for reducing 'design variants', with a goal to consolidating finite resources on a single (or plug compatible) engineering solution (prototyping and DFM).**
    - **Identify key CFS cost-driving interfaces that require an early down-select of supported alternative solutions.**
    - **Identify (clarify) ways in which the maximum benefit can be obtained from the European XFEL project, including the industrialization effort.**

From the ILC PMP (N. Walker)

- **During the ED period**
  - **Milestones for SCRF Linac Technology include:**
    - completion of the 'S0' cavity processing R&D
    - development and test of a high -gradient cryomodule, 'S1'
    - phased completion of each region's SCRF test facilities: ILCTA_NML, STF, XFEL support systems
    - development of an ILC project cryomodule production plan including definition of cost -reduction and cost -containment design and R & D efforts
    - development and identification of qualified vendors for cavity and cryomodule production
    - beam testing in order to support ILC parameters and design choices, such as cryogenic load testing, higher-order-mode extraction and flexible, precise, high level RF controls

ILC Americas Cavity and Cryomodule Work Package Plan

- **ART Nomenclature**
  - **The Main Linac Cavity and Cryomodule plan: WBS X.9**
    - **WBS 1.9.1 Management WBS Level 2 Manager:**
      - **Shekhar Mishra, Hasan Padamsee, John Mammosser and Mike Kelly**
    - **WBS 2.9.1 Main Linac EDR: Cavity and Cryomodule**
    - **WBS 3.9.1 Cavity Fabrication**
    - **WBS 3.9.2 Cavity QC and Tuning**
    - **WBS 3.9.3 Cavity Processing and Vertical Testing**
    - **WBS 3.9.4 Single Cell Processing R&D**
    - **WBS 3.9.5 Cavity Horizontal Test**
    - **WBS 3.9.6 ACD Shape and Material**
    - **WBS 3.9.7 Cavity Failure and improvement of Manufacturing Yield**
    - **WBS 3.9.8 R&D on Cavity Processing**
    - **WBS 3.9.9 ILC Cryomodule**
    - **WBS 3.9.10 SCRF Material Research**
    - **WBS 5.9.2 Cavity HPR Systems**
    - **WBS 5.9.3 Upgrade to the Processing Facility**
    - **WBS 5.9.4 ILCTA_NML RF Unit Test Infrastructure**
    - **WBS 7.9.1 Industrial Development**
    - **WBS 7.9.2 Cavity and Cryomodule Processing and Testing Infrastructure**

ILC Americas Work Package Plan

FY07

- **The major projects that are assumed to take place in FY07 includes**
  - **Order 24 ILC Cavities from Industry**
  - **Order parts for the 2nd Type-III+ Cryomodule**
  - **Fully commission and operate of the Jlab and Cornell cavity processing and vertical test facilities**
  - **Cavity processing R&D using 1-Cell and 9-Cell cavities**
  - **Construct and commission the vertical and horizontal test stands at Fermilab**
  - **Construct and commission the electro-polishing facility at ANL**
  - **Commissioning of the Cryomodule Assembly Facility with the DESY Kit**
  - **Complete the cryogenic at the ILCTA_NML for cooling the 1st Cryomodule**
  - **Complete RF power (Modulator and Klystron), distribution and controls at ILCTA_NML for the 1st Cryomodule.**
  - **Complete engineering design of the ILCTA_NML electron source**

ILC Americas WP Plan: FY08-FY09 Summary

	FY05	FY06	FY07	FY08	FY09
Cavity and Cryomodule R&D					
Number of Cavities	4	23	16	30	60
Number of Cryomodule Parts		1	1	2	2
Cryomodules Assembled			1	2	2
Processing Capability (CY/yr)					
Jlab			30	40	50
Cornell			12	12	12
ANL/FNAL			20	50	50
FNAL					50
Cavity Failure Analysis					
LANL				4	4
MSU				4	4
1-Cell and ACD Program					
JLAB		X	X	X	X
Cornell		X	X	X	X
MSU				X	X
ANL/FNAL (1 Cell Only)			X	X	X
Infrastructure Development					
Jlab (Processing)		C			
Cornell (Processing)		C			
ANL (EP/HPR)			C		
LANL (HPR/Testing)			C		
MSU (HPR/Testing)				C	
FNAL Program					
VTS-1			C		
VTS-2 & 3				DC	C
HTS-1			C		
HTS-2					DC
CAF			C		
CPF (With Industry)			D	DC	C
ILCTA@Fermilab					
Cryomodule-1 (Type-III+)				IC	
Cryomodule-2 (Type-III+)				IC	
Cryomodule-3 & 4 (Type-IV)					IC
Cryomodule-4 & 5 (Type-IV)					XX

X: Planned, C: Commissioned, D: Design, DC: Design and Construct, IC: Install and Commission

ILC Americas Work Package Plan

- **FY08 and FY09 plans address many of the milestones set forth in the ILC PMP including:**
  - **work toward completion of the critical R&D identified during the RDR phase.**
  - **completion of the 'S0' cavity processing R&D**
  - **work on the development and test of a high -gradient cryomodule, 'S1'**
  - **phased completion of the ART SCRF test facilities: ILCTA_NML support systems**
  - **development and identification of qualified vendors for cavity and cryomodule production**

EDR Cryomodule Development

- **Cryomodule Design Effort:**
  - **The T4CM effort is laying the groundwork for the ILC CM Design**
    - **Well organized and tasks shared across the regions**
- **The next generation CM (ILC Prototype?) must**
  - **Utilize an agreed upon set of technical standards (ANSI/ASME, etc.)**
  - **Be developed from a set of clear requirements that lead to a design specification**
  - **Incorporate value engineering and design for manufacture**
- **We need an EDR Review and Decision mechanism**
  - **An EDR CCB?---we need a to establish an approved baseline design as well as including a limited set of approved alternatives**
- **We need to establish control mechanisms**
  - **Reviews and approvals**
  - **Documented requirements**
  - **Engineering & production design packages**
  - **Quality assurance**
  - **Integration**
  - **Testing standards**

Some Key Questions for EDR phase

- Is the goal to build IDENTICAL CMs all regions ?
- Are CMs that are “plug compatible” good enough ?
- Should completed CMs be shipped to the ILC site or should final assembly and test occur at the end use site ?
- Should we consider RF units, or even whole sections of the linac as deliverables from a region ?
- Do we agree on what must be done to the current CM design ?
- How important is it to lower the cost ?
- What is the “time scale” for changes ?
- What is the criterion for a “better CM design” ?
- How do we manage industrialization ?

Conclusions

- Significant work was accomplished by ART during the RDR development phase
- In FY08 and FY09 ART stands ready to meet many of the milestones set forth in the ILC Project Management Plan
- Development of the EDR CM requires a clear, concise specification as well as an agreed upon set of technical standards that must be met
- A set of key questions must be answered in order to effectively plan the EDR CM effort. Some have been presented---no doubt many more exist
- Coordination of efforts in the three regions is essential in order to minimize duplication of effort where it is not warranted