CM Industrialization in the Americas

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EDR CM KOM
KEK, Sept 07

EDR Cryomodule Plan

- **The development of ILC cryomodules during the EDR phase will have three main elements**
  - **Cryomodule Design Effort**
    - **Goal: Meet ILC technical objectives**
    - **Goal: Cost Reduction via design improvements**
  - **Cryomodule R&D and Testing Program**
    - **Develop components and improved CM prototypes**
    - **Development of regional CM test facilities**
    - **Tests of CM to VALIDATE performance & reliability**
  - **An industrialization plan**
    - **Laboratory-built prototypes → industrial production**
    - **Educate industry, then learn from them about mass production**
    - **Programs needed in all 3 regions (different… eg XFEL)**

These elements are strongly correlated

Cryomodule Design

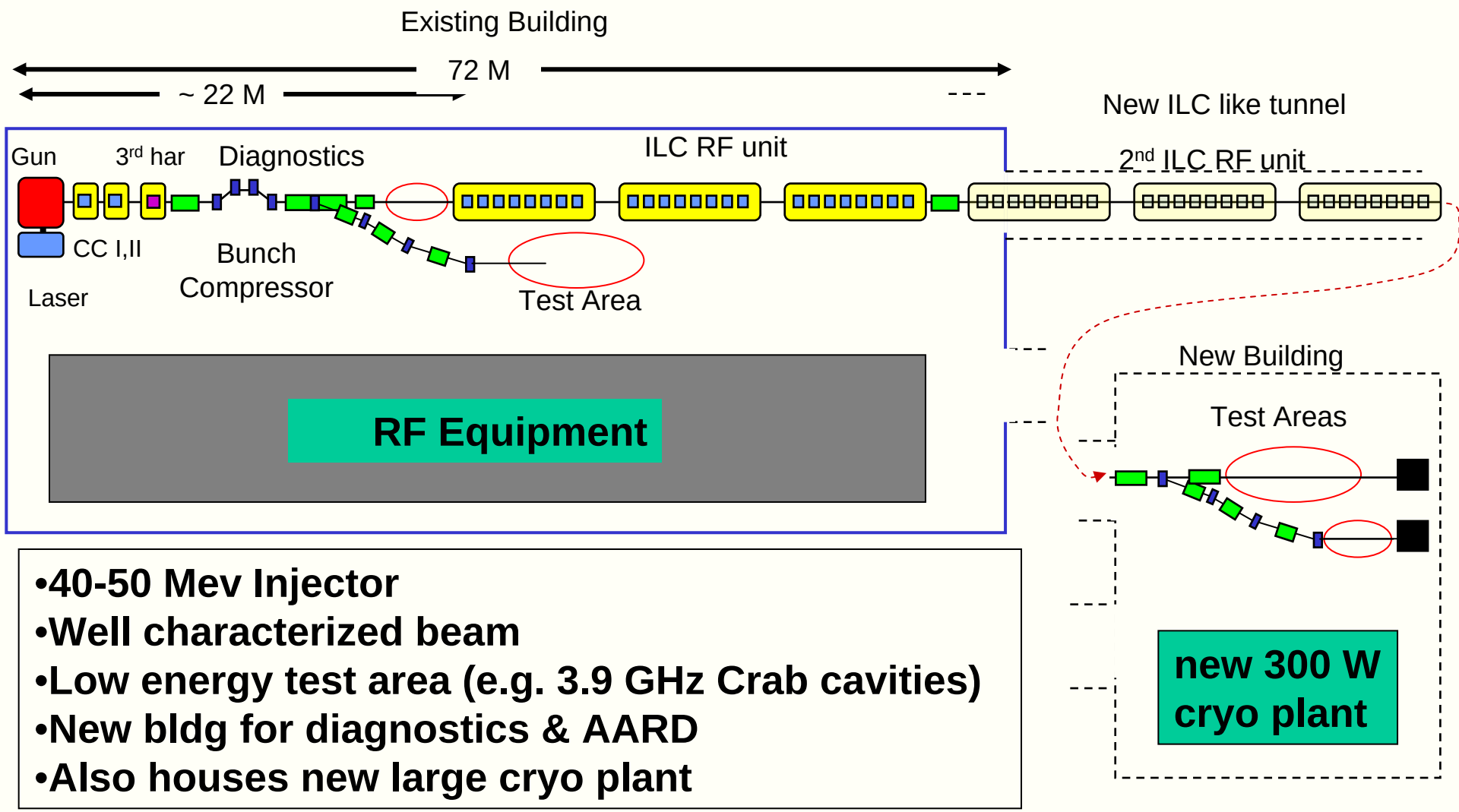
- The U.S. coordinates the T4CM collaboration
  - Start = FNAL effort to convert DESY CM drawings for U.S. Industry
  - Evolved into the design of next generation of the baseline TESLA Cryomodule intended for ILC
  - Well organized and tasks shared across the regions. (good!)
- Type IV design finished by ~end of year
  - Date set by U.S. need to order parts in industry
- Design group needs guidance on what to do next
  - Clear requirements (optimize cost ? Performance ?)
  - Need to establish the time scale for the next step remembering that it takes a long time to build and validate a CM design
  - Plan for down selects on tuner design, cavity shape, etc
  - We need to include industry as part of "value engineering"
- We need mechanisms to keep us in sync.
  - Written specifications
  - Review and approval process
  - Regular meetings (incl webex)

Cryomodule R&D and Testing

To build Cryomodules we must have cavities

- **Develop of cavity fabrication and processing capability**
  - **Cavity issues will be addressed at the DESY KOM**
  - **ART plan through FY08 supports GDE S0/S1/S2 goals**
  - **Cavity processing and test**
    - **JLAB (30-40 cavity process and test cycles per year)**
    - **Cornell (~ 10 cycles per year)**
    - **ANL/FNAL (~ 40 cycles per yr starting in fall of FY07)**
    - **Designing new processing facility (CPF) ~ 100-200 cycles/yr**
- **Must also have region cavity and CM fab & test facilities**
  - **VTS operational at JLab, Cornell, and soon FNAL (+ upgrades)**
  - **HTS at FNAL being commissioned**
  - **FNAL Cryomodule Assembly Facility operational (MP9 + IB1)**
  - **ILCTA_NML "RF unit" test facility: under construction**
- **Cavity fab, EP will be in Industry. CM assembly? Test in Labs**

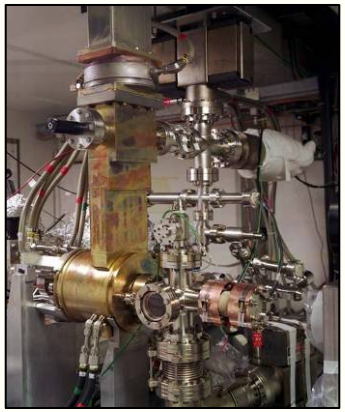
ILCTA_NM (FNAL)



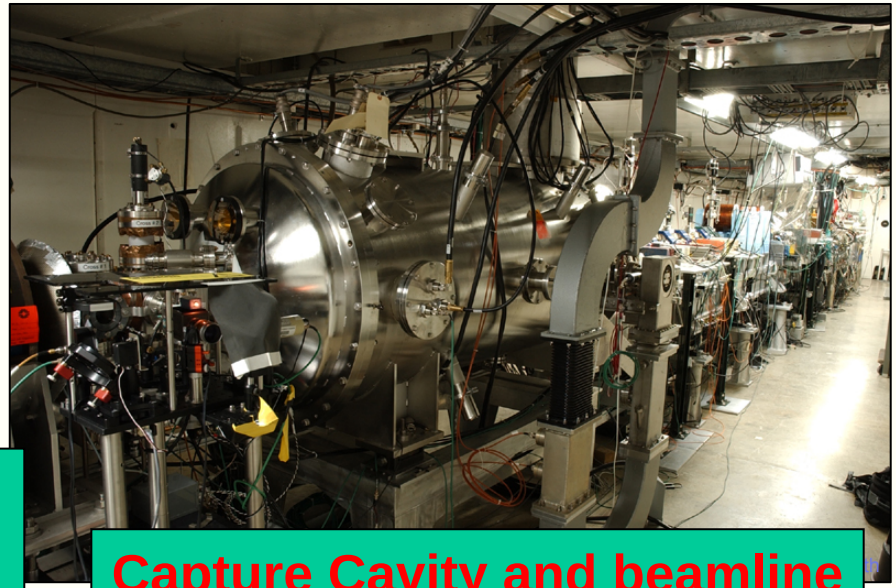
- 40-50 Mev Injector
- Well characterized beam
- Low energy test area (e.g. 3.9 GHz Crab cavities)
- New bldg for diagnostics & AARD
- Also houses new large cryo plant

A0 Photo Injector

- The A0 Photo Injector built in collaboration with DESY as part of the TESLA collaboration (essentially a copy of TTFI)
- In operation since late 90's
- Two klystron-based RF systems power the RF Gun & Capture Cavity
- Built a second capture cavity (CCII) using high gradient DESY cavity
- A0 RF assets and CCII will be moved to NML in 2008



RF Gun prior to solenoid installation



Capture Cavity and beamline

Capture Cavity-II

ILCTA Plans

- Effort is Funding limited➔ 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 FY2010-11 (Industry ???)
- 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
- FY10-11: replace all 3 CM with ILC type CM
- FY11: install new refrigerator, ILC RF Unit operations
- Collaboration: DESY, INFN, ANL, Cockroft, NIU, Rochester, KEK…
- Stand alone CM test stand ~ 2010
- This is where we will test 1st industrially produced Cryomodules

ILCTA_NML and CM picts

NML Building

NML: Aug 07

Cavities for 1st CM @ FNAL

1st of 2 refrigerators each 60 W@1.8K

DESY CM kit being assembled at FNAL

FNAL Clean Room & CM assembly Area

Industrialization in Americas

Basic Strategy

- Learn how to build cavities & cryomodules at labs/universities
- Develop vendors in U.S. industry for materials, components, and processes
- Collaborate with industry to optimize the cryomodule design for high volume low cost production
- Develop cavity and CM test facilities at labs: Why ?
  - RF and cryogenic equipment➔ specialized expertise
  - Too expensive for industry to develop before a “project”
- Teach industry how to assemble CM in partnership with labs
- Develop a model for how ILC CM in Americas will be built
  - Distribution of CM work (lab vs industry) and funding
  - Industry responsibilities vs lab responsibilities
  - Requirements, testing, handoffs, QC, and validation before and during mass production
  - Funding profiles, infrastructure, and labor requirements for the project

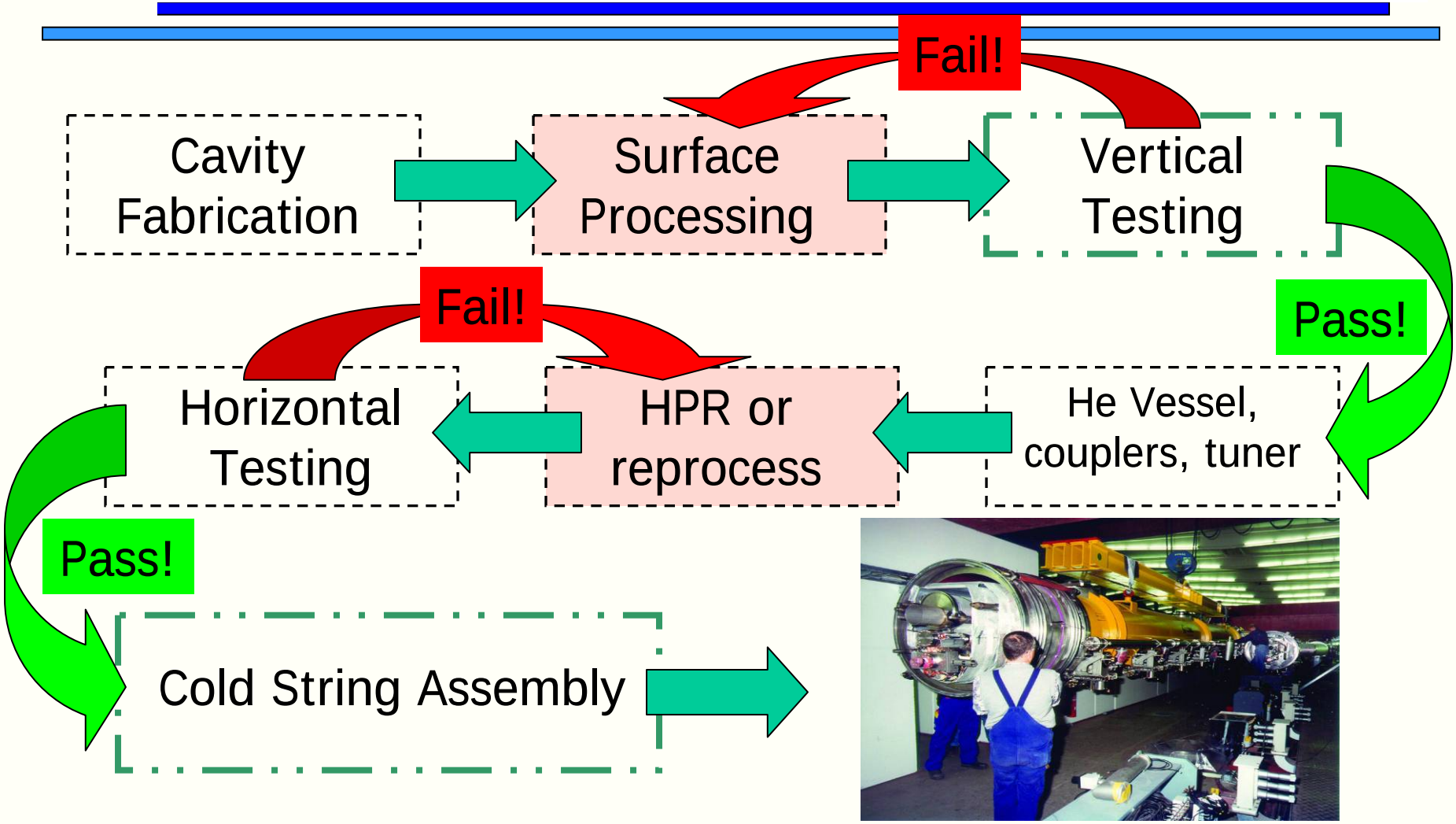
Development of Industry

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.

It seems likely that cryogenic testing of cavities and cryomodules along with beam tests will remain the responsibility of US laboratories.

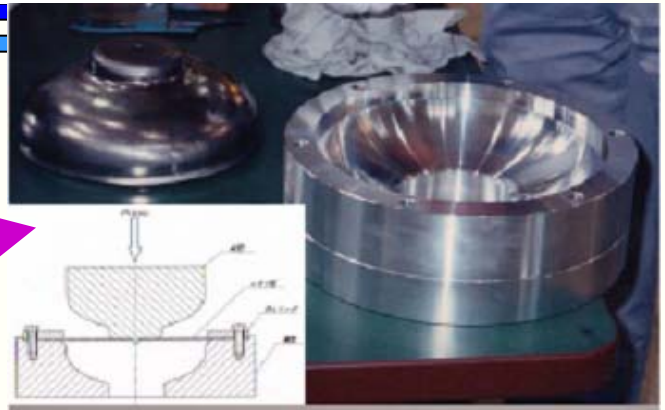
Cavity/CM process and Testing



Plan… Develop in labs then transfer technology to industry

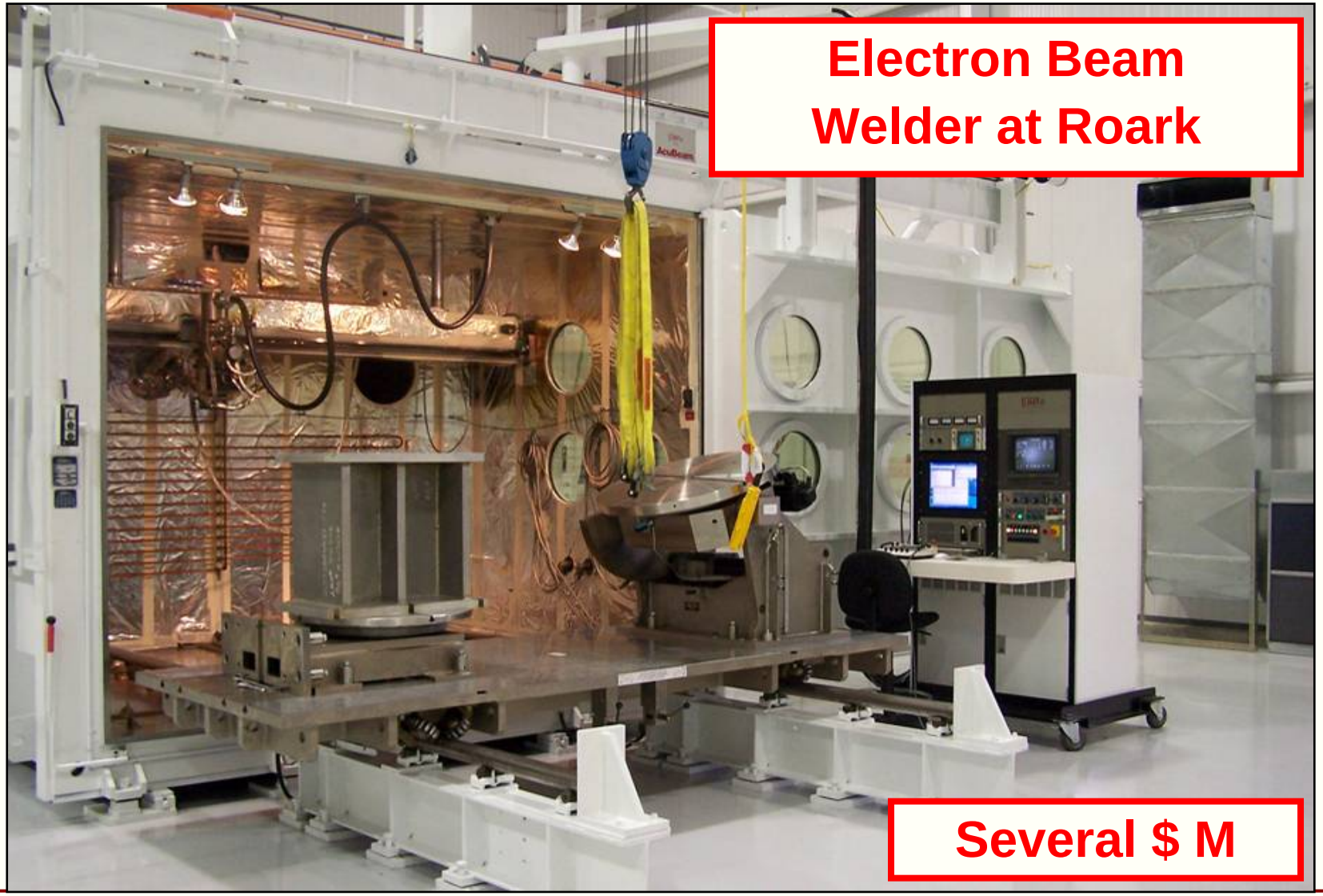
Cavity Fabrication

- Sheet Nb is eddy current scanned (QA to eliminate defects) Now done at labs
- Half cells are formed by deep drawing sheets then annealed
- BCP cleaned prior to welding
- Half cells →"dumb bells" via electron beam welding
- End groups assemblies are fabricated via EB welding: contain HOM and ports for main coupler
- Entire 9 cell cavity is assembled by EBW
- Intent is that this is all done in INDUSTRY



AES

Significant Infrastructure



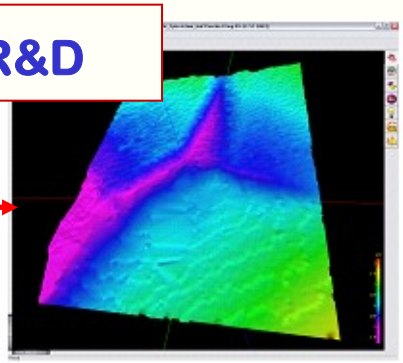
Control of Fabrication Processes

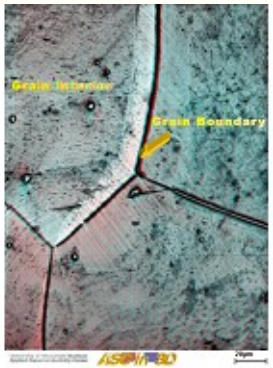
- Quality of Nb sheet from vendors
  - Material composition (RRR, chemical composition, etc)
  - Surface properties: oxides, inclusions, and scratches via eddy scanning of Nb sheet from vendors
  - Measure Nb mechanical properties (ie crystal structure)
- Machining and forming of parts
  - Avoid inclusions and or contamination of Nb
  - Avoid overheating during machining operations
- Electron Beam Welding
  - Weld preparation: machine surface, clean, BCP, protect prior to weld
  - Good vacuum (< 10-5 torr) during EBW
  - Weld parameters: full penetration, no holes or voids, smooth weld on inner surface, no overlaps, no contamination or degradation of RRR

Nb Materials R&D

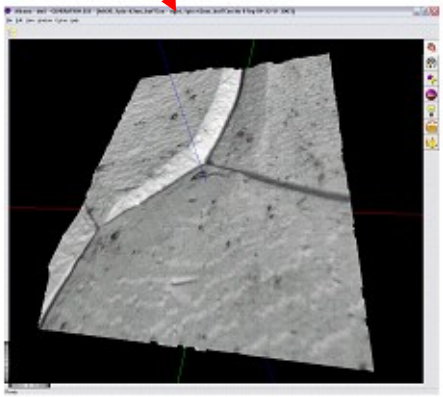
Quality Control – Material R&D

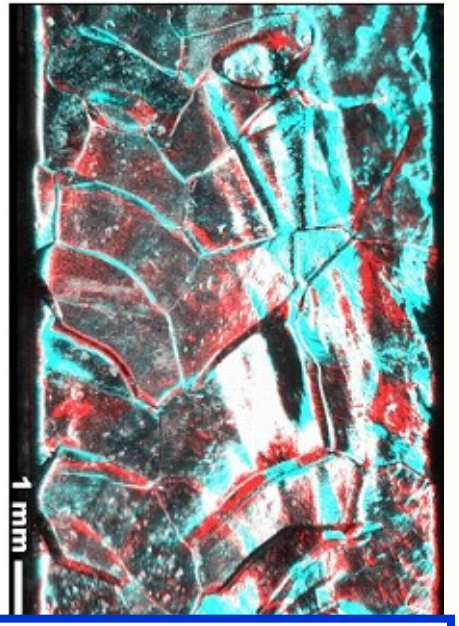
Microscopy

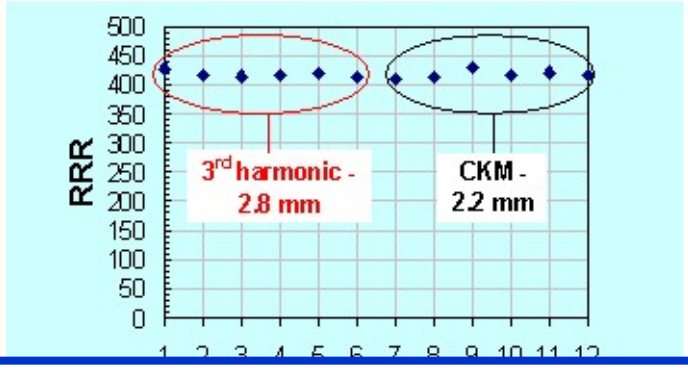




RRR - measurements

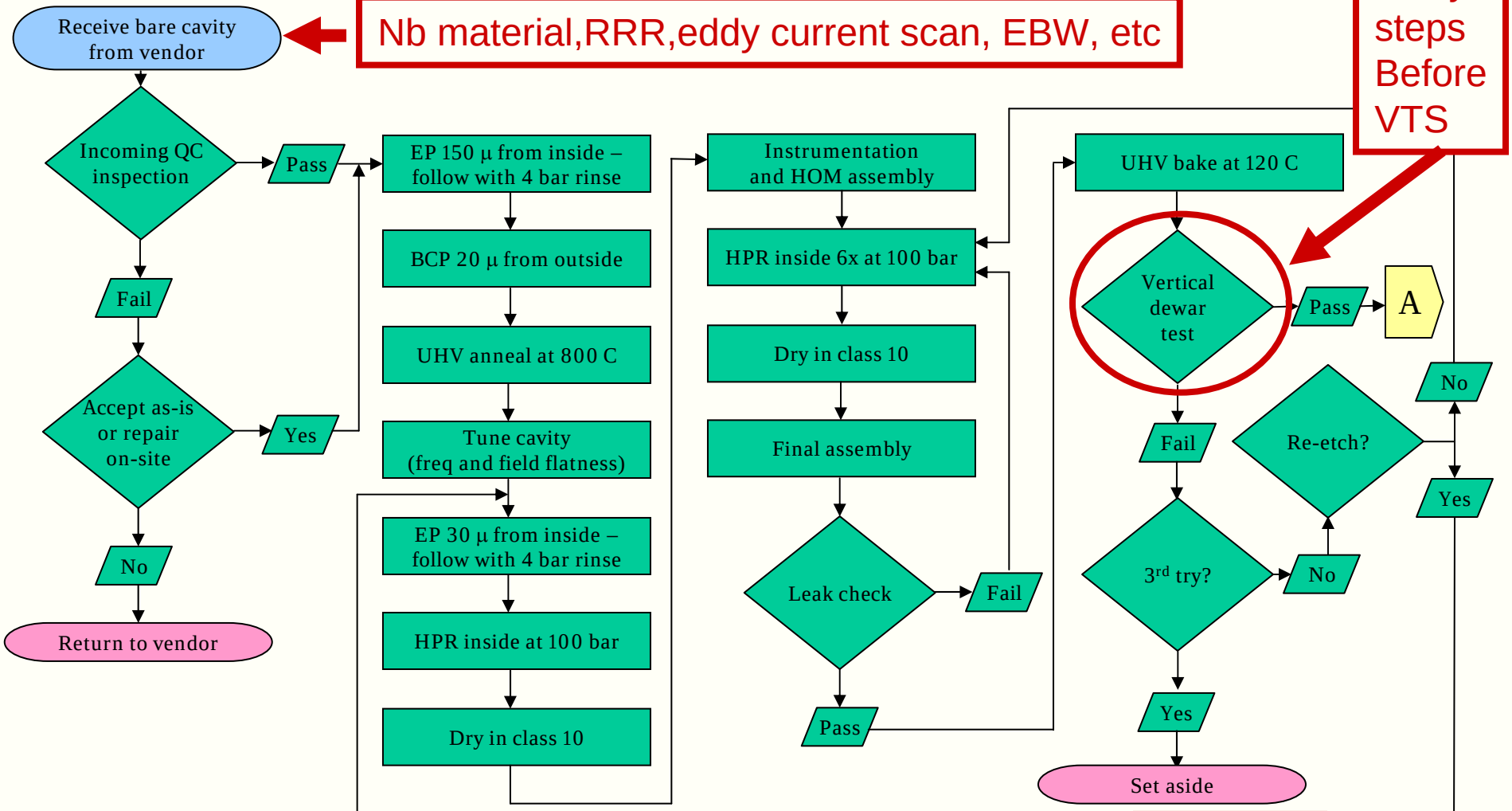






Purity, grain structure, and surface defects matter!

Cavity processing



Control of Surface Processing

Cavity Prep. (XFEL Industrial Production)

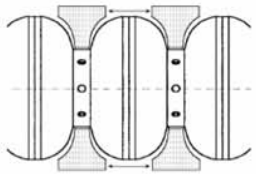
Courtesy: R. Brinkmann, DESY

EP 150 µm (inside)

4 bar rinse

BCP 20 µm (outside)

UHV 800°C annealing

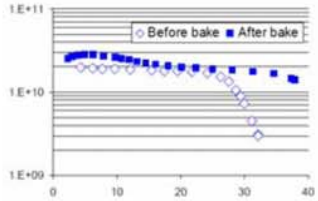


freq./ field flatness tuning

EP 30 µm (inside)

100 bar HPR

inst. pick-up / HOM



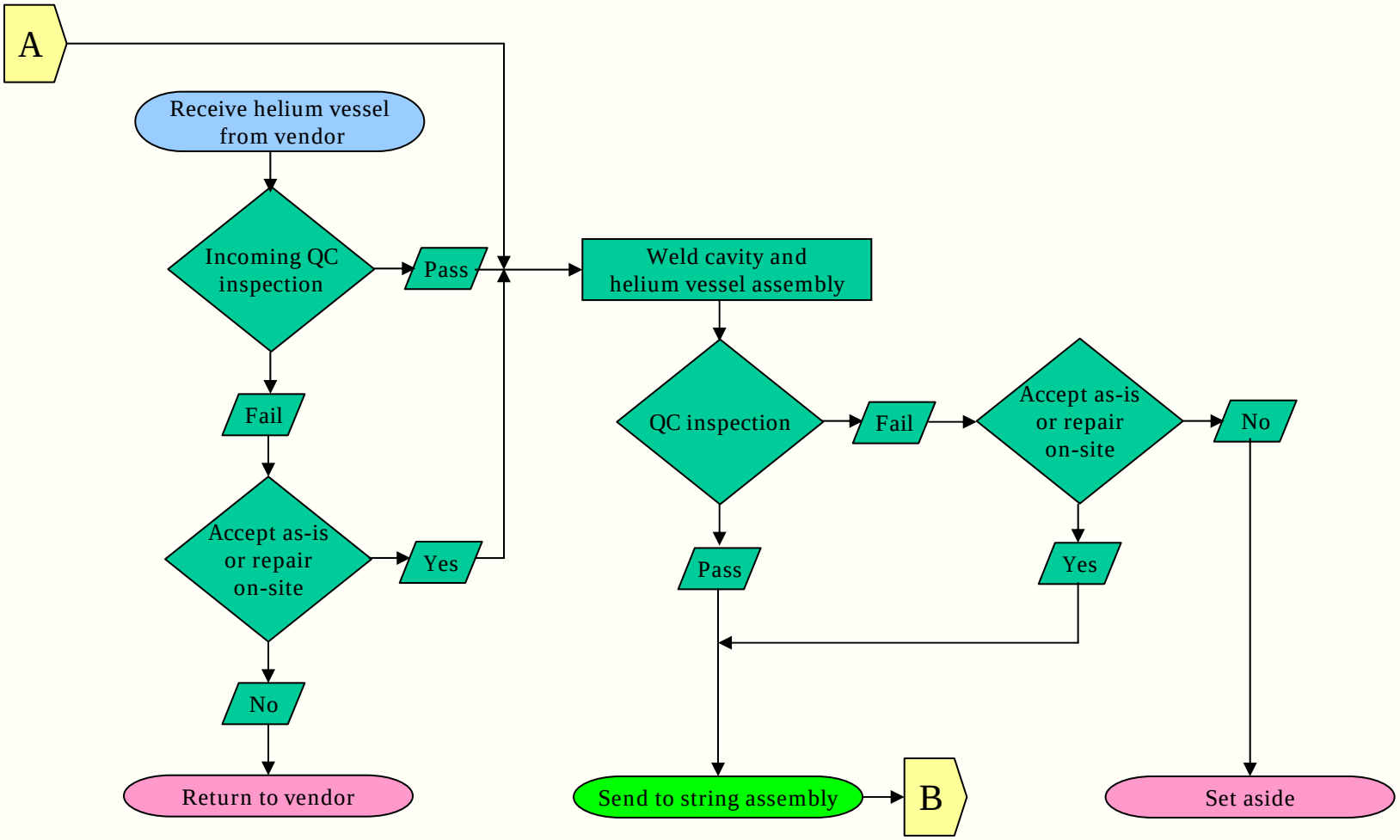
UHV 120°C baking

100 bar HPR (6 ×)

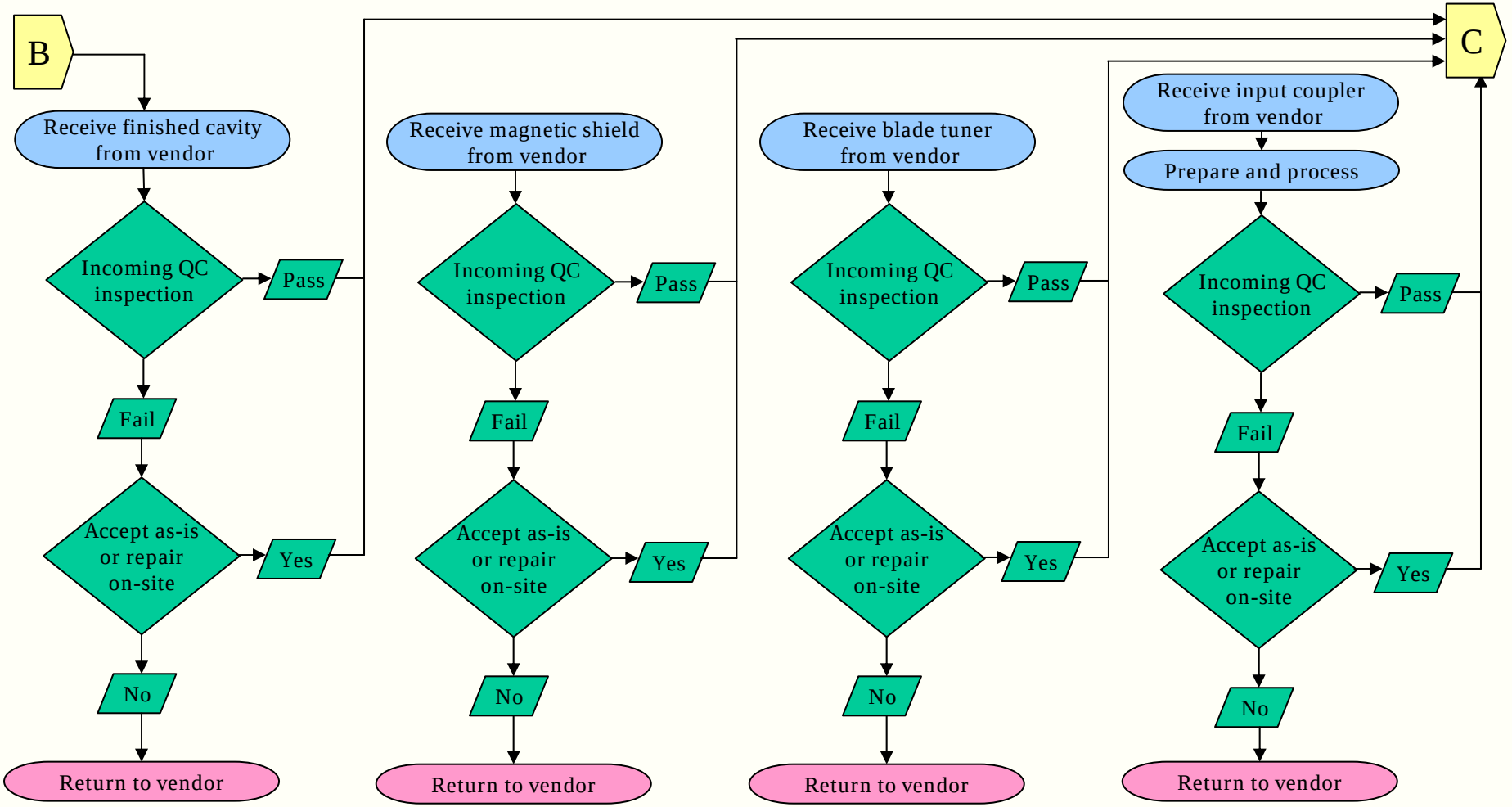
These 5 plus evacuation are the critical ones!

Mastering them is an essential precondition for optimizing EP!

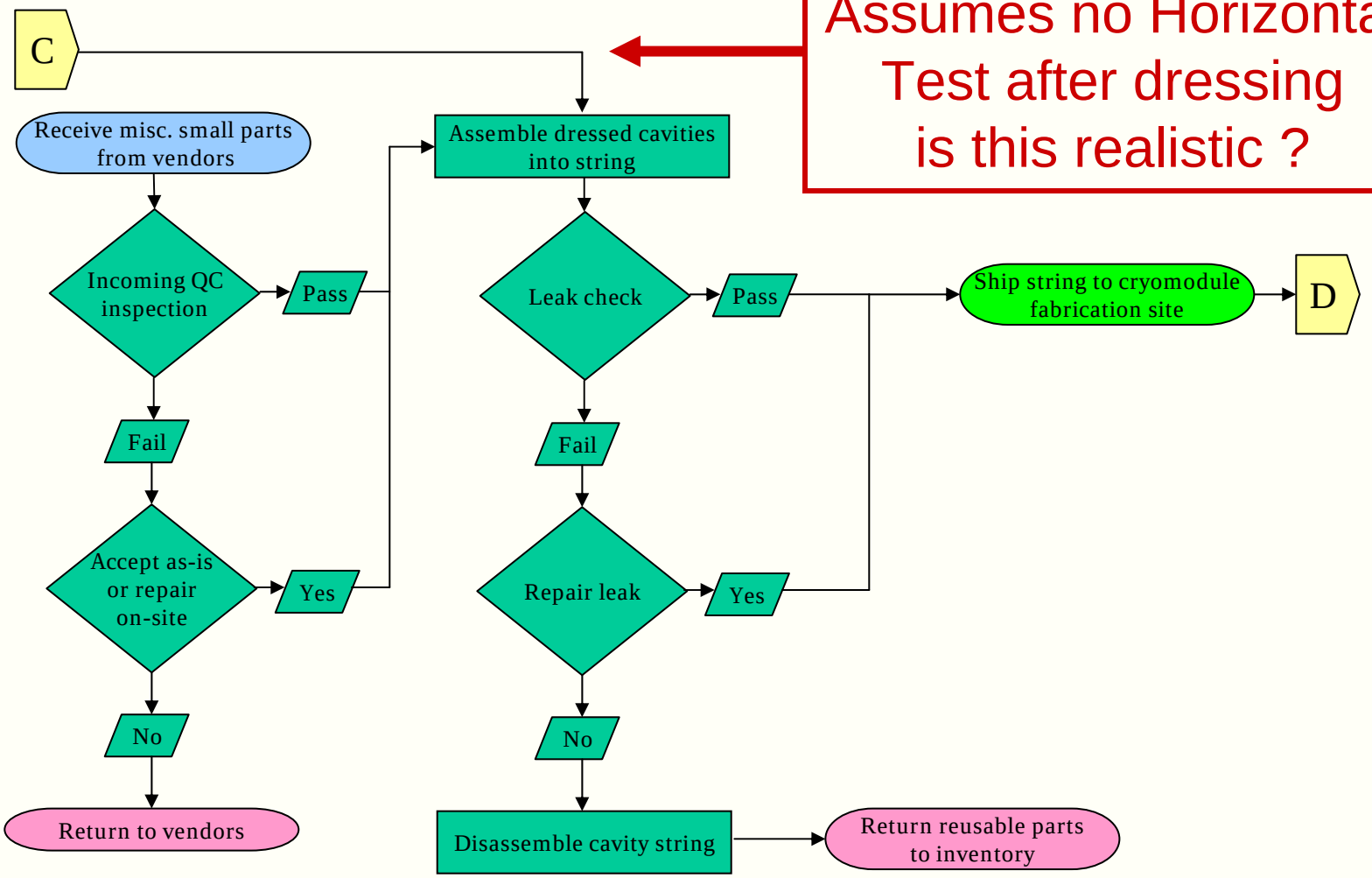
Dressed cavity assembly



Dressed Cavity assembly



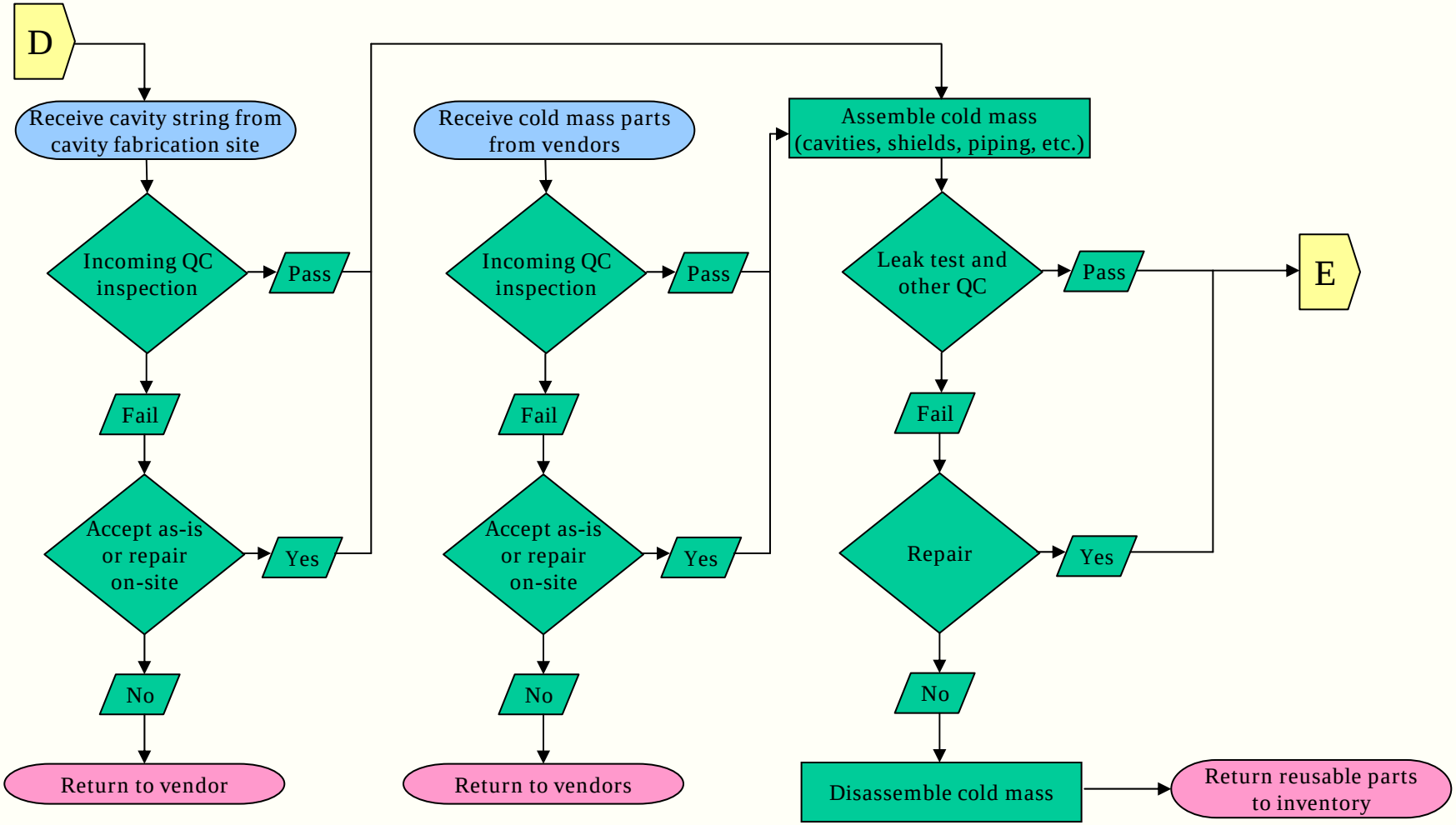
Cavity string assembly - continued



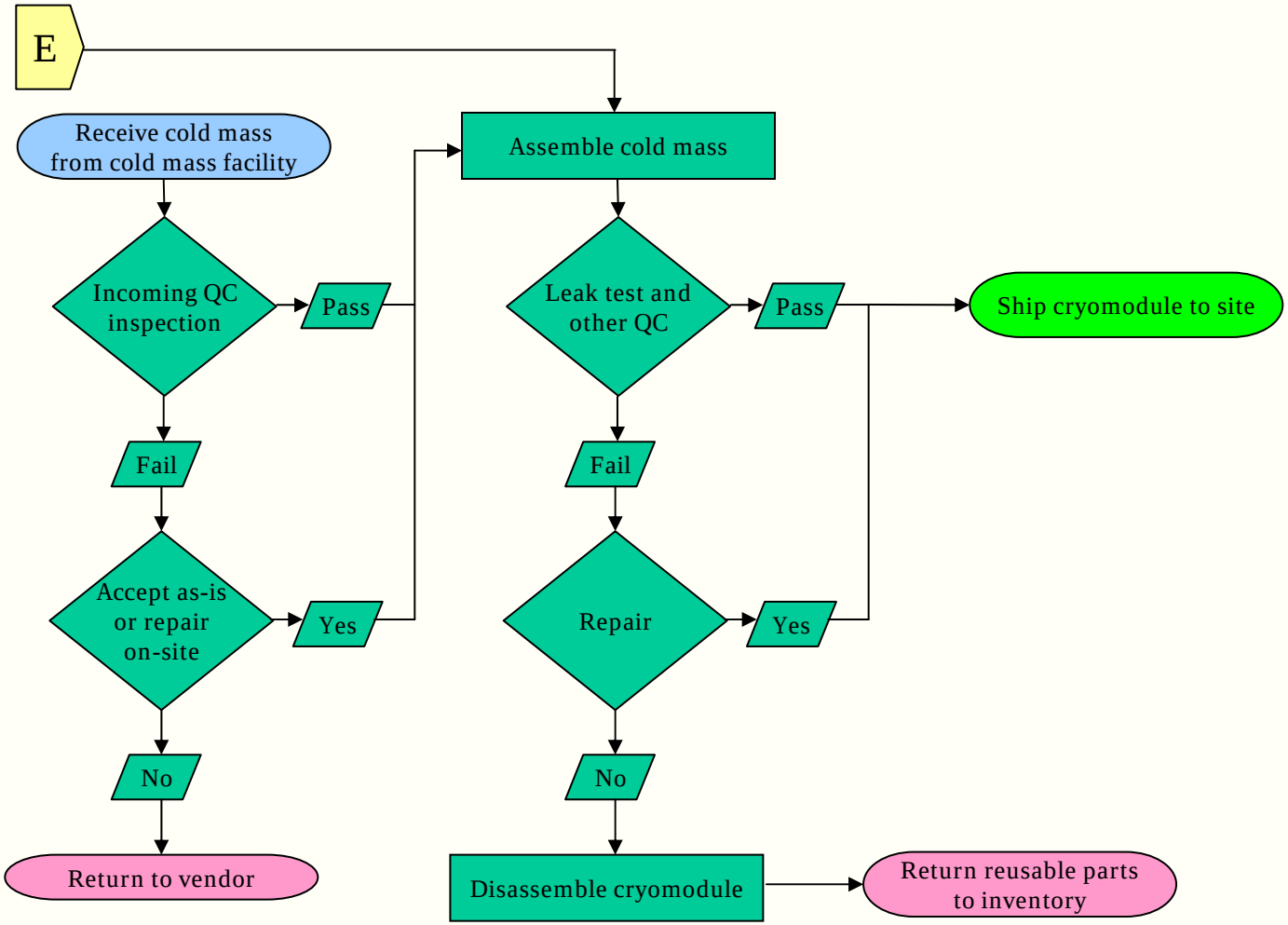
Control of Clean Room Assembly

- Goal: Assemble cavity string but avoid contamination of cavities with particulates
- Clean Room air quality
- Good procedures and fixtures
- Good seal designs
- Clean Vacuum and leak check equipment
- Cleaning of parts before entry into clean room
- Training of workers
- Good QC and QA procedures

Cold mass assembly



Cryomodule assembly



Cryomodule Test and Validation

- Goal: Validate that Cryomodule is ready for installation in machine
- Check manufacturing steps and CM performance
- Develop acceptance tests
- Test all CM cold and with RF➔ test stands
- Test subset of CM with beam ➔ beam test facilities
- NOTE: There is ample evidence that says that FINAL design (no small changes!) must be fully tested before mass production in industry starts.
  - There is a huge risk to project if you do not do this
  - It may take several years to build and validate a design
  - This is likely to be on the critical path for project

Vendor Development Strategy

- Difficult to interest “large” companies in U.S. until the ILC project becomes more real
- Strategy: Qualify smaller vendors with the assumption that if/when ILC becomes real they will partner with larger companies in the Americas
- Realize that although we make a plan, most large companies will have their own ideas about how to mass produce cryomodules

Vendor Development

- Nb vendors:
  - Wah Chang,
  - LCFOA: soon two more
- Cavity vendors:
  - AES (making 9 cells)
  - Niowave/ Roark (making 1st single cells)
  - PAVAC: Canadian company near TRIUMPF
- Surface Processing
  - ABLE (EP of 1st single cells)
- Couplers
  - CPI
- Cryomodule Parts (cold mass, tuners, etc)
  - Many potential vendors: Develop with Type IV
  - Meyer tool + others (CM assembly)
- Industrial Cost Studies and Value engineering: LCFOA

Conclusions

- Plan for industrialization in the Americas is under development… but much yet to do !
- Closely coupled to our R&D and design activities
- Charged a committee to create a plan for U.S.
  - Report by end of year
- Overall effort is limited by available funding
- Industrialization may be driven by the needs of other U.S. SRF projects (beyond ILC)
  - E.g. Project X = 8 GeV Proton Linac at FNAL for Neutrino physics would need ~ 40 ILC Cryomodules
  - SNS upgrades
  - 12 GeV upgrades at TJNL
  - ERL, FEL's, etc.