Status of U.S. Cavity & Cryomodule Industrialization

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Introduction

- In this talk I review the current status and plans for:
  - North American industrial fabrication of 1.3 GHz elliptical cavities
  - Industrial fabrication of cryomodule parts
  - Development of an industrial cavity processing capability

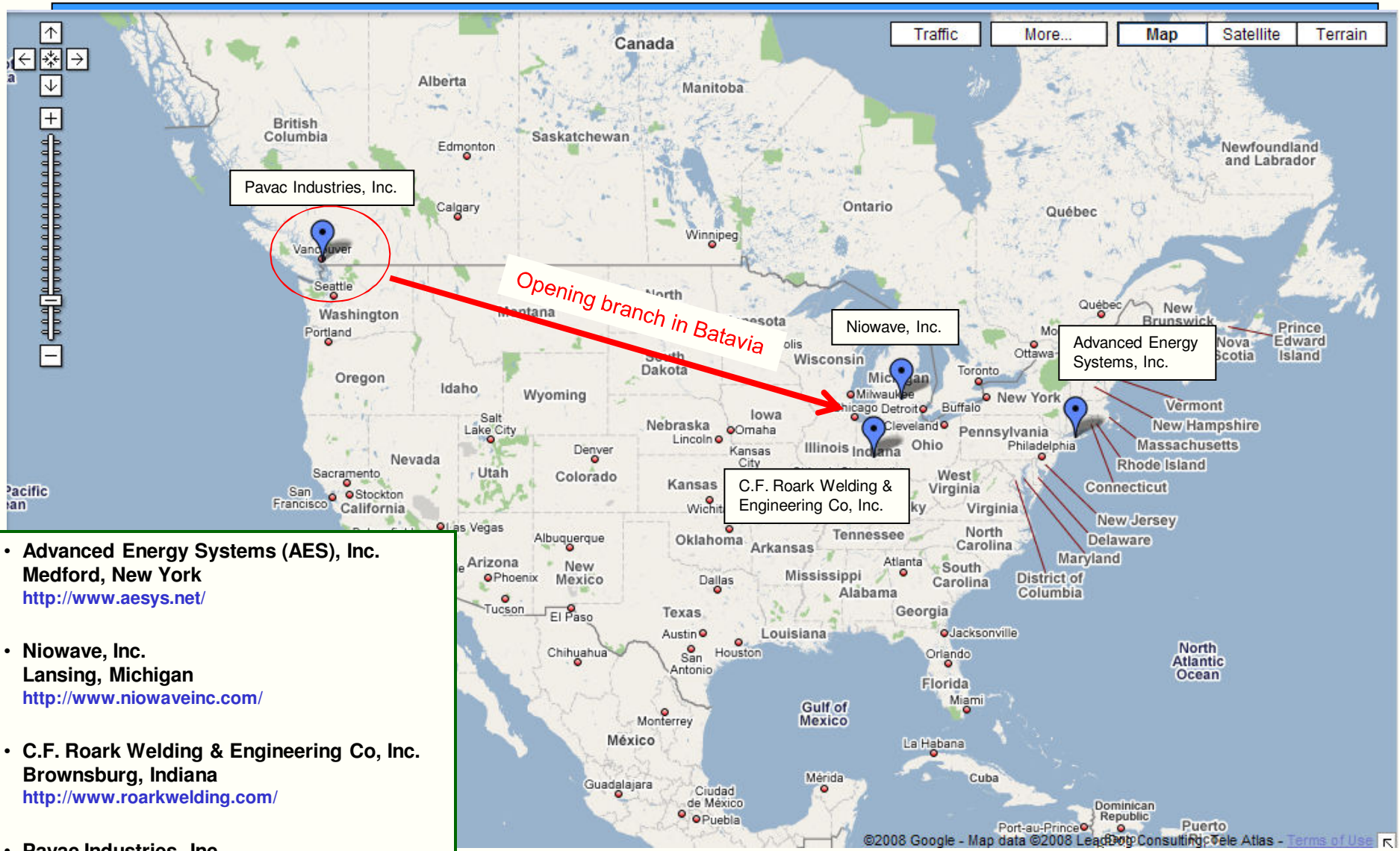
- 1.3 GHz cavity and CM procurements support
  - Cavity R&D towards the ILC S0 goals (FNAL, ANL, JLAB,Cornell effort)
  - Construction of cryomodules to attempt to meet ILC S1 & S2 goals
  - Development of qualified cavity and CM parts vendors
- Currently plan to purchase Cavities with the "TESLA" shape
- Cryomodules parts are being ordered in U.S. industry
  - cold mass parts, He vessels, tuners, couplers, etc
- Also working to develop an industrial cavity processing capability in North America
- Most U.S. industrialization is funded with SRF and ARRA funds (generic vs ILC funds)

Introduction

- **Motivation for Industrial Development:**
  - **Promotes competition which should lead to improved performance of SRF components and lower prices for future accelerators (ILC or Project X)**
  - **Multiple qualified vendors will ensure product availability in case one vendor ceases operations or has other large contracts**
  - **Promotes increased industrial capacity in preparation for the construction of projects**
  - **Part of our mission as a DOE laboratory**

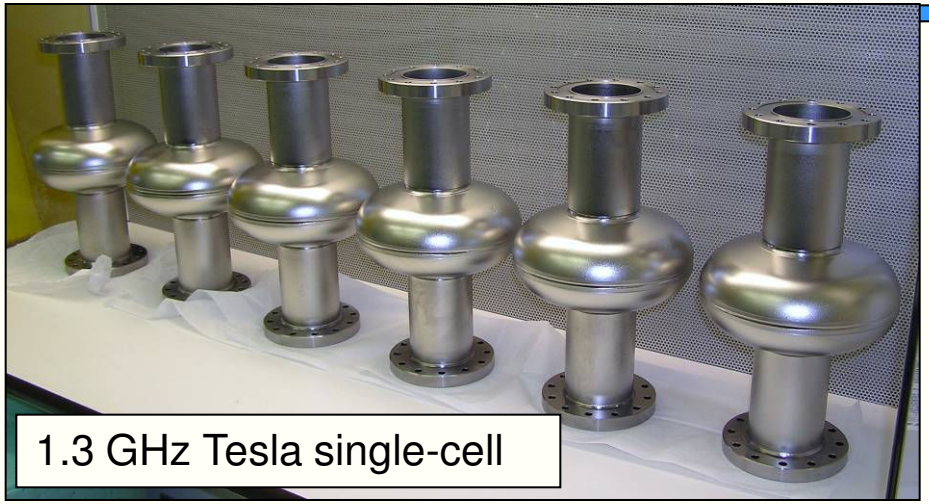
- **One concern is the timing for industrialization**
  - **Project timescales (PX and ILC) are still uncertain**
  - **Once an industrial capability is created it atrophies if not used**

North American Cavity Vendors

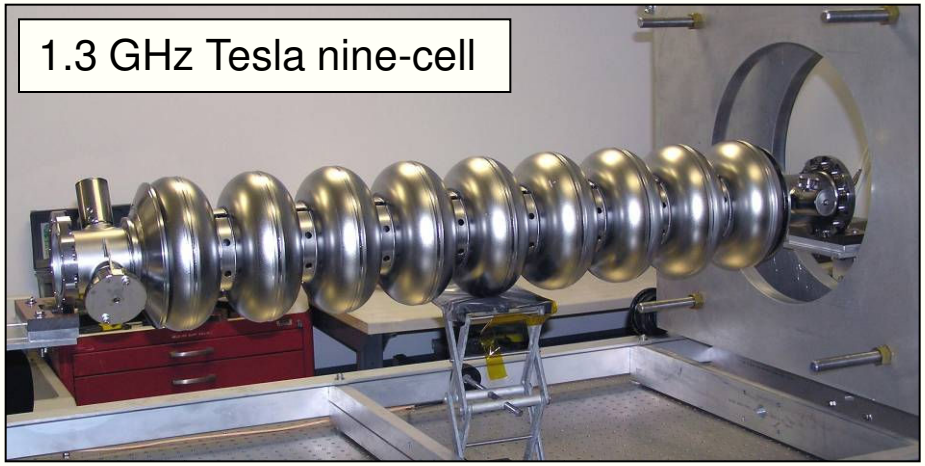


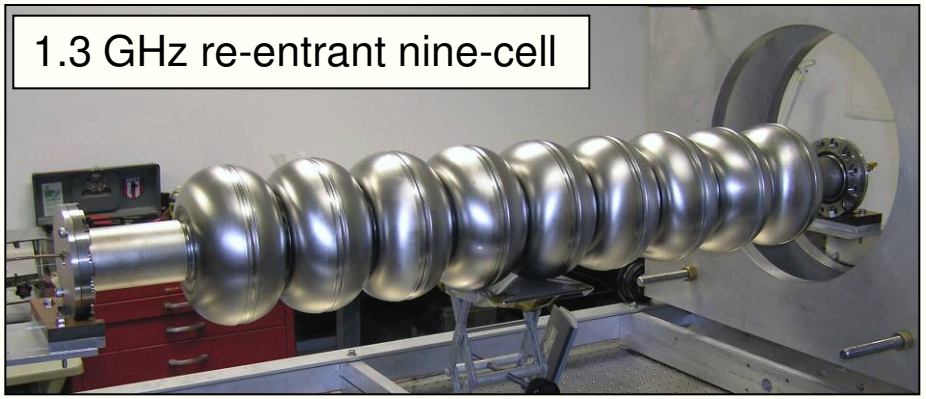
- **Advanced Energy Systems (AES), Inc.**
  Medford, New York
  http://www.aesys.net/
- **Niowave, Inc.**
  Lansing, Michigan
  http://www.niowaveinc.com/
- **C.F. Roark Welding & Engineering Co, Inc.**
  Brownsburg, Indiana
  http://www.roarkwelding.com/
- **Pavac Industries, Inc.**
  Richmond, British Columbia
  http://www.pavac.com

AES has complete production capability on-site
10 nine-cells delivered; 6 more in April, 20 more ordered (ARRA)

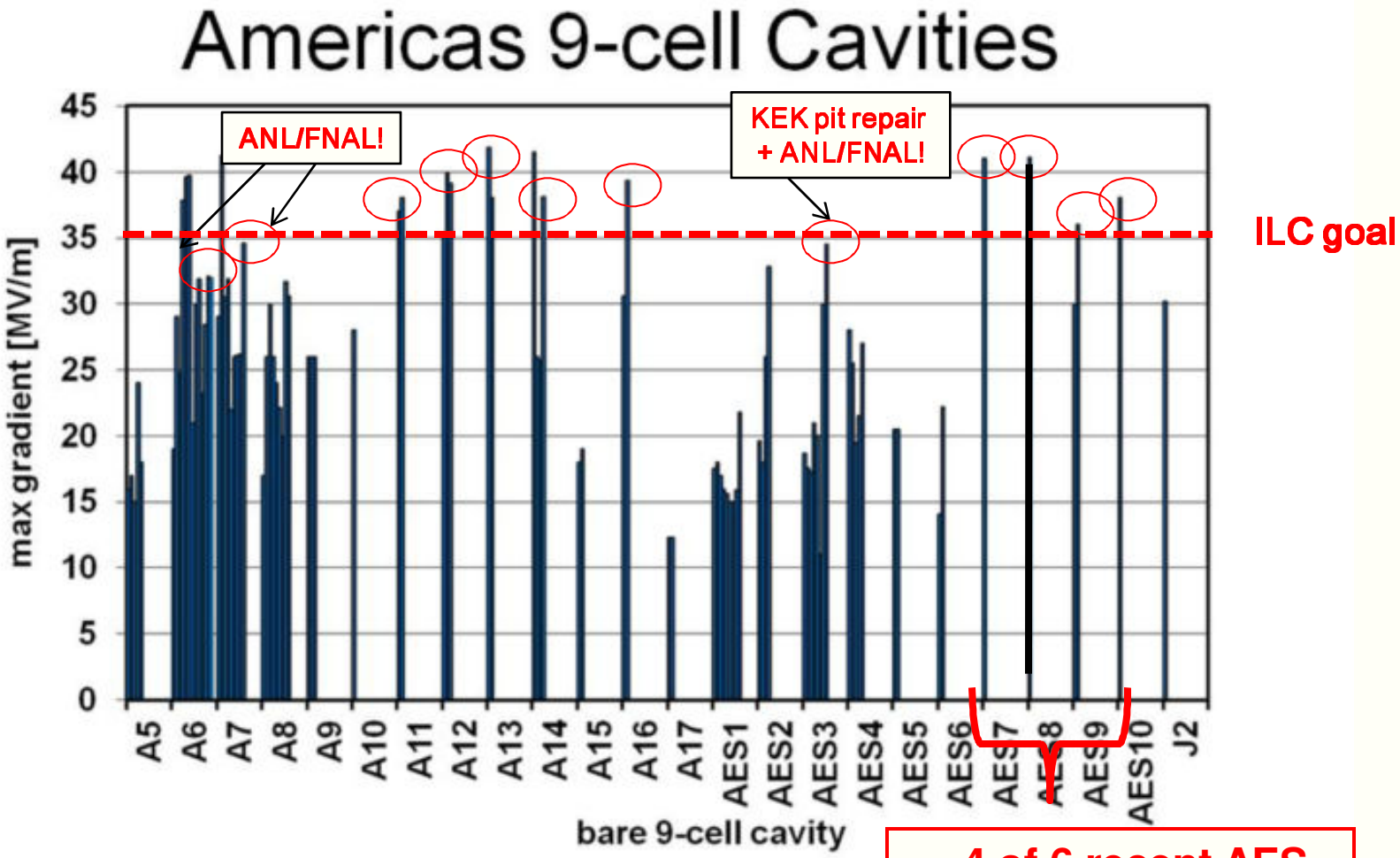

1.3 GHz Tesla single-cell

Electron-beam welding facility


1.3 GHz Tesla nine-cell


1.3 GHz re-entrant nine-cell

Performance of AES 9-cell cavities



4 of 6 recent AES cavities exceed 35 MV/M at JLAB

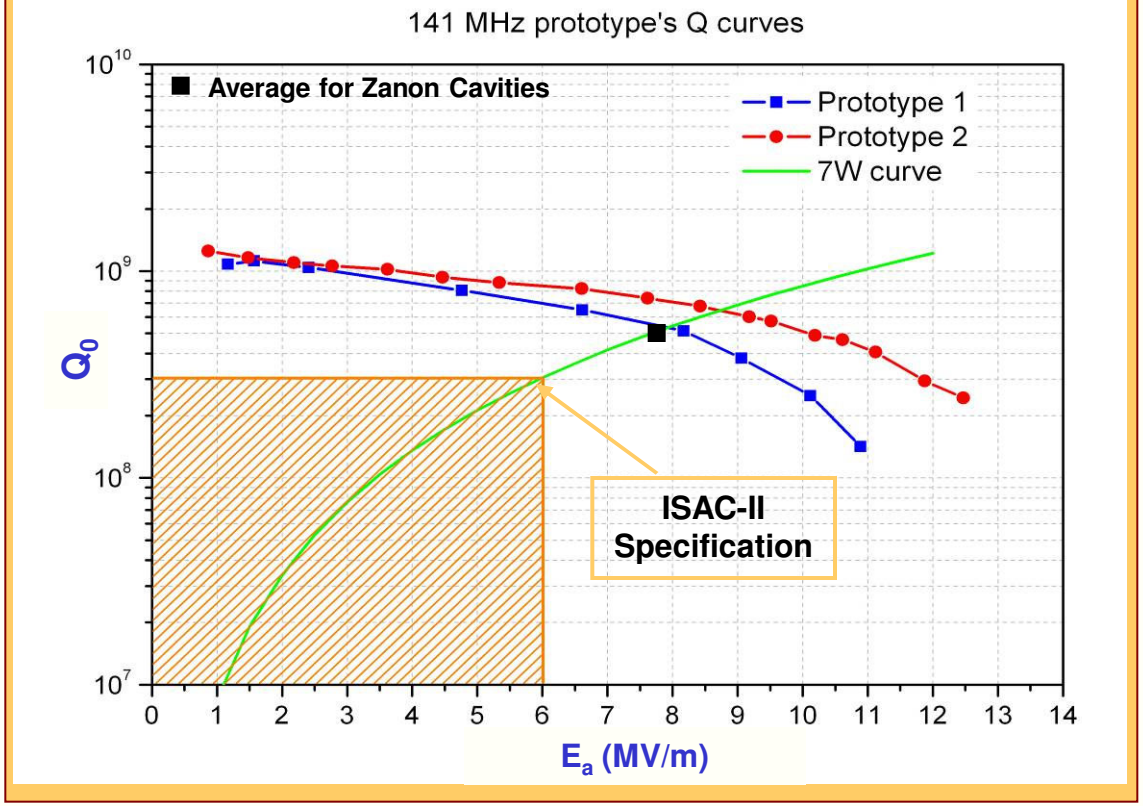
Niowave & Roark collaborate on 1.3 GHz cavities
Roark is working independently on low-beta structures

- 6 Single-cell cavities deliver Jun 08
- Performed well
- 6 nine-cell cavities in fabrication
- Expect delivery of 1st 2 in April
- Evaluating bid on ARRA cavities

- Roark 325 MHz beta=0.22 single-spoke cavity
- Delivered Summer 2008
- Design = 10 MV/M @ 4K
- Exceeded 30 MV/M @ 2 K
- Ordered 10 more for Project X

PAVAC is producing 20 coaxial resonators in collaboration with TRIUMF for the ISAC-II Phase-II extension

- Two prototypes manufactured and tested; production under way.
- Both prototypes perform significantly above ISAC-II specifications; average values of E_a=8.2MV/m, Ep=40MV/m cw (specification 6MV/m)
- Pavac is fabricating 6 1.3 GHz single cell cavities, Evaluating bid on ARRA 9-cell cavities
- Excellent expertise in EB welders… NEW! Opening a branch in Batavia




Beta = 0.11 resonator

U.S. Cavity inventory and planned procurements

Description	No. Cavities	Status
AES 1-4	4	Tested: AES2 at 32 MV/M, AES3 at 34 MV/m after repair
AES 5-10	6	Tested: 4 of 6 tested at over 35 MV/m
AES 11-16	6	Due April 2010
AES 17-36	20	Ordered Feb 2010 with ARRA funds
Accel 6-9	4	Tested: 2 of 4 above 35 MV/m at one point, degraded in subequent tests
Accel 10-17	8	Tested: 5 of 8 over 35 MV/m. (ACC12 and ACC14 damaged)
RI 18-29	12	Testing just started, 6 with bulk EP at RI, 6 delivered
Jlab fine-grain 1-2	2	Fabrication complete at JLAB; J2 at 30 MV/M, J1 usable?
Niowave-Roark 1-6	6	Due April 2010, 3 finished ready to ship, 3 close
Additional ARRA	20	Evaluating bids from Roark/Niowave and PAVAC
Total	**88**	
	36	Cavities received by end of March 2010
	23	Processed and tested
Tesla-shape single-cell cavities		
Description	**No. Cavities**	**Status**
AES1-6	6	tested at Cornell; further testing in progress
Accel 1-6	6	received Dec 2008; further testing in progress
Niowave-Roark 1-6	6	tested at Cornell; further testing in progress
PAVAC	4	in fabrication
Total	**22**	
Already Received	18	

Cavity design capabilities at Fermilab

- **FNAL now has the personnel & software tools to design new cavity shapes:**
  - **Two good examples: the 3.9 GHz cavities and the 325 MHz single-spoke cavity (beta=0.22)**
  - **Electromagnetic, multi-pacting, mechanical, and thermal computations performed mainly in the Technical Division / SRF Development Dept.**
  - **Beam dynamics computations performed mainly in the Accelerator Physics Center**
  - **Mechanical design and design/drafting performed in Technical Division and Accelerator Division**
- **Plan to develop two new 650 MHz elliptical cavity designs for Project X**
  - **Beta=0.6, Beta =0.9**
  - **Design in collaboration: e.g. lots of expertise at JLAB, Cornell, etc**
  - **Fabricate in Industry (and perhaps single cells at JLAB)**
  - **Process in Industry & labs (ANL/FNAL , JLAB, Cornell)**
  - **Test at labs**

U.S. Plan for Cavity Vendor Development

- The vendors learn through experience, so in general they will improve their manufacturing processes over time
- But, feedback from the laboratories is key to obtaining performance improvements
  - Careful QA and optical inspection of incoming cavities
  - Process & test cavities quickly
- Relatively small cavity orders allow for feedback between productions
  - AES made substantial improvements in tooling and installed an electron-beam welder after their first production of 4 nine-cell cavities
- Larger orders will allow us to better understand costs
- Close communication and regular visits
- Assistance from experts at Cornell and JLab
- Stimulus procurements will give cavity vendors a big boost

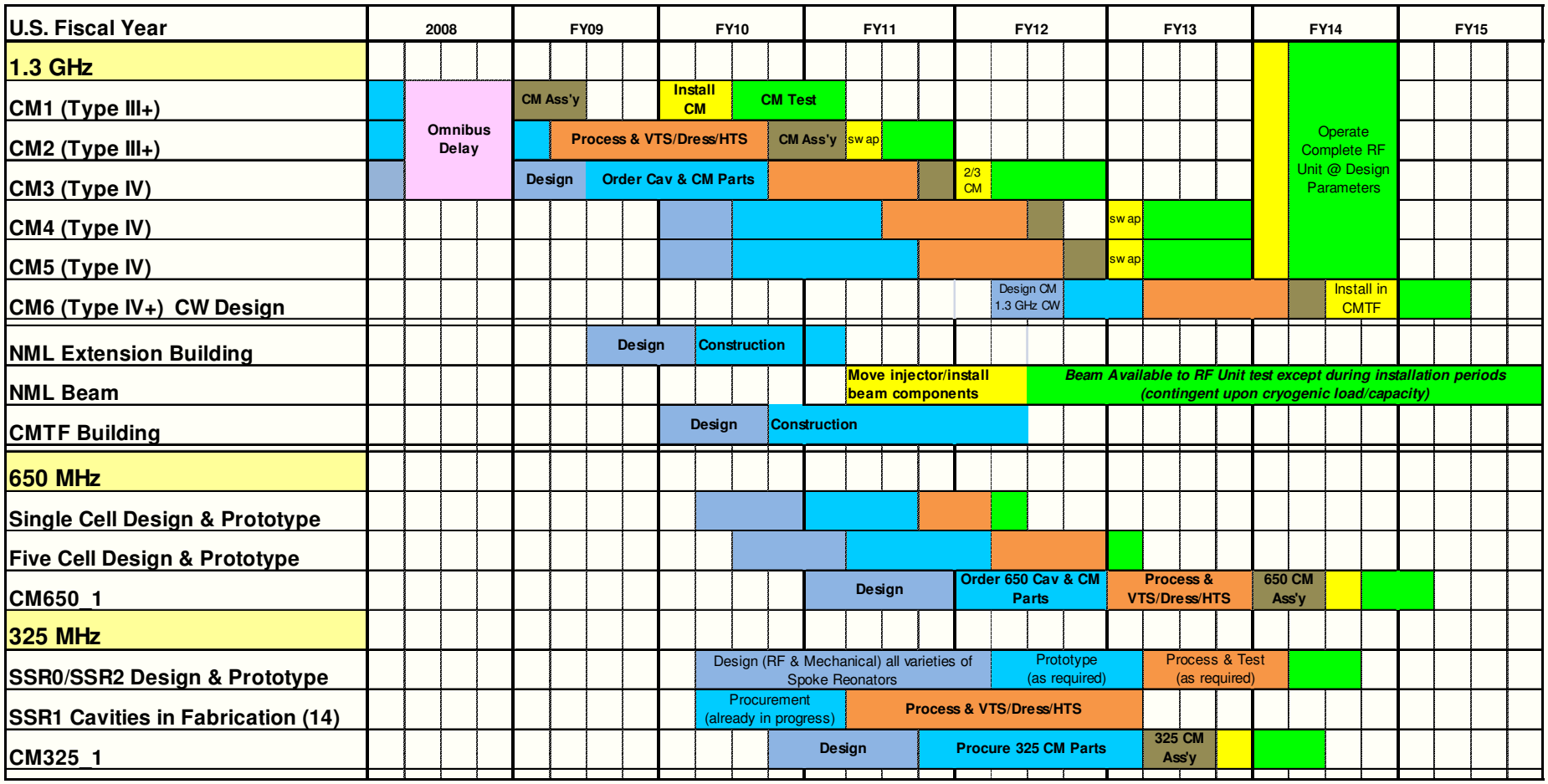
U.S. Industrialization of Cryomodules

- **Strategy on Cryomodule Industrialization**
  - **The value added during CM assembly is < 10% the value of the cryomodule.**
  - **The number we will assemble over the next few years is very small ➔ have no plans to train industry to do assembly of ILC CM**
    - **Any training likely to be lost… without follow on work**
    - **Not even clear this would make sense for Project X volumes**
- **Strategy is to design CM at labs and order parts from industry**

U.S. Industrialization of Cryomodules

- **CM1: is a TTF Type III+ and was assembled at FNAL in our CAF facility from a kit of parts provided by DESY/INFN**
  - Dressed cavities from DESY
  - DESY style lever tuners
  - Magnet package located at end of cavity string (but no magnet)
  - DESY and INFN provided assistance in assembly
- **CM2: will be built in 2010 at CAF.**
  - Another Type III+
  - Cold mass parts were procured in Europe with help from INFN
  - Populate with U.S. processed and dressed cavities
- **CM3-CM6:**
  - Type IV ILC/Project X design (larger pipe sizes)
  - Magnet package can be located in positions 2,5,8 (5 = center of CM)
  - Cold mass parts ordered in U.S. industry with ILC and ARRA funds
  - Populate with U.S. processed and dressed cavities
  - CM6 will be a CW cryomodule for Project X
- **Cryomodules will go to NML: will try to meet ILC S1 and S2 goals**

Integrated ILC/PX SRF Plan (Cryomodules)



Design	Procure	Process & VTS Dress & HTS	Assemble	Install	Commission & Operate

Cryomodule activities at FNAL

CM1 String Assembly

MP9 Clean Room

Final Assembly

CM1

Move to NML

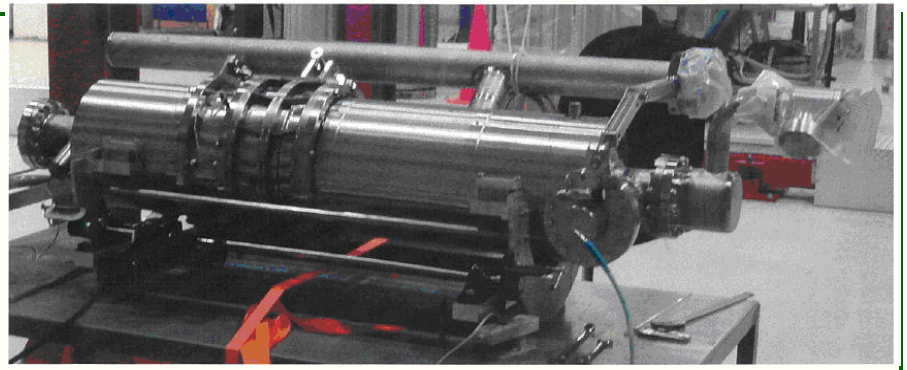
CM1 installed

Dressing cavities for CM2

FNAL S1 global Cavities @ KEK

U.S. Industrialization of Cryomodules

CM3-6 Parts



- **He Vessels:**
  - **Fabricated of Titanium (like XFEL)**
  - **20 already procured from Hi-Tech (4637 N. 25th Ave., Schiller Park, Il 60176)**
  - **40 more being procured with ARRA funds**
    - **Likely vendors Hi-Tech, INCODEMA (www.INCODEMA.com), Titanium Fabrication Corp. (110 Lehigh Drive, Farifield, N.J. 07004), and Titan Metal Fabricators Inc. (835 Flynn Rd. , Camarillo, CA. 93012)**
- **Tuners**
  - **For CM2 and beyond we will use Blade tuner developed by INFN**
  - **CM2 and S1-Global: 12 tuners provided by INFN, built in Europe**
  - **CM3-CM6: Tuners made by U.S. industry (ARRA)**
    - **20 Ti blade tuners from INCODEMA; 20 from Hi-Tech**

U.S. Industrialization of Cryomodules

CM3-6 Parts

- **Couplers**
  - Vendor is Communications and Power Industries, CPI, (150 Sohier Road, Beverly, MA. 01915-5595)
  - 12 couplers delivered for S1 global and CM2;
  - 20 more ordered via SLAC (using ARRA funds)

- **Cold mass parts and Vacuum Vessels**
  - 4 cryomodules worth of Type IV parts on order
  - Vendor is PHPK Technologies (2111 Builders Place, Columbus, OH 43204)

Industrial Surface Processing

- **Industrial Electro-polish**
  - ARRA funds make it possible for us to develop Electro-polish capability in U.S. industry
    - Competition to perform design study; AES won the bid
  - AES will make a proposal for a horizontal EP facility
    - Capable of processing 1300 and 650 MHz elliptical cavities
    - Benefits from existing clean room, HPR, and chemistry infrastructure funded at AES by Brookhaven National Lab
- **Eco-friendly Surface Processing**
  - Funded with ARRA funds
  - Goal is to produce smooth clean cavity surfaces without using HF and other toxic chemicals
  - 3 companies have bid for design study
    - Will select 1 or 2
  - Fund best to demonstrate performance with single cells

Summary

- Cavity procurements are needed for cavity R&D, cryomodule fabrication, and vendor development
- Fermilab is engaged in vendor development with three North American cavity vendors:
  - AES, Niowave/Roark, and PAVAC
- We are also engaged in industrialization of cryomodule parts and cavity surface processing
- Industrialization is being funded by ARRA funds
  - but one time infusion of funds
- In the longer run, Project X or other similar project are the likely path to U.S. SRF industrialization for a future ILC project