ILC Marx Modulator R&D Status

ILC GDE Meeting

IHEP, Beijing, PRC February 6, 2007

Ray Larsen

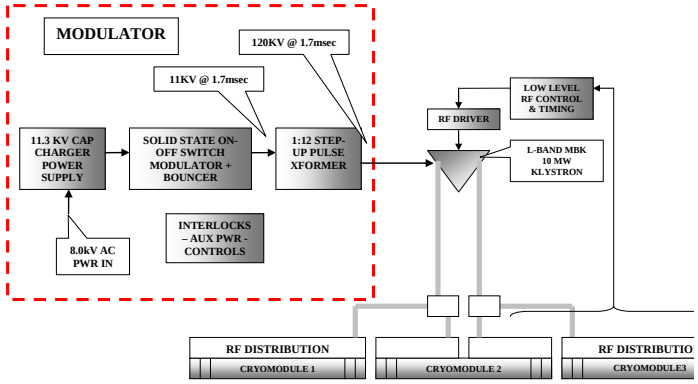
Stanford Linear Accelerator Center

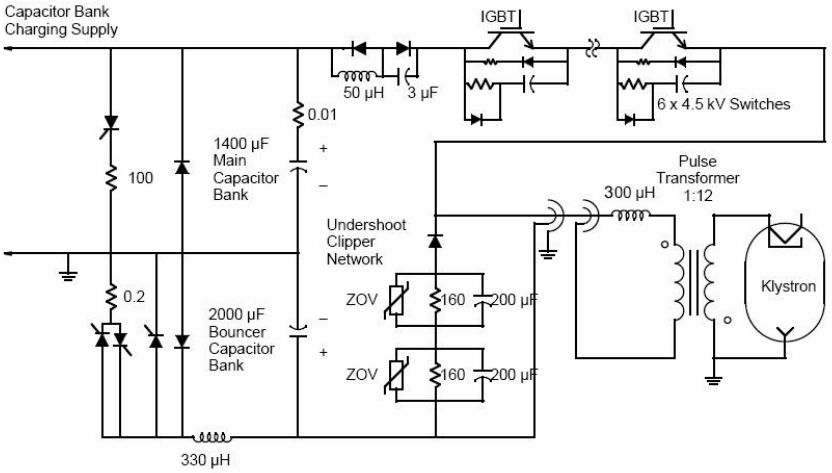
Outline

- I. Baseline Design
- II. Alternate Design: Marx
- III. Progress Report: G. Leyh
- IV. Preliminary Schedule
- V. Summary
- VI Acknowledgment

I. Baseline Design

- 3 large packages: 150 kW Charger, Capacitor-Switch-Bank-Bouncer Modulator and Pulse Transformer






A

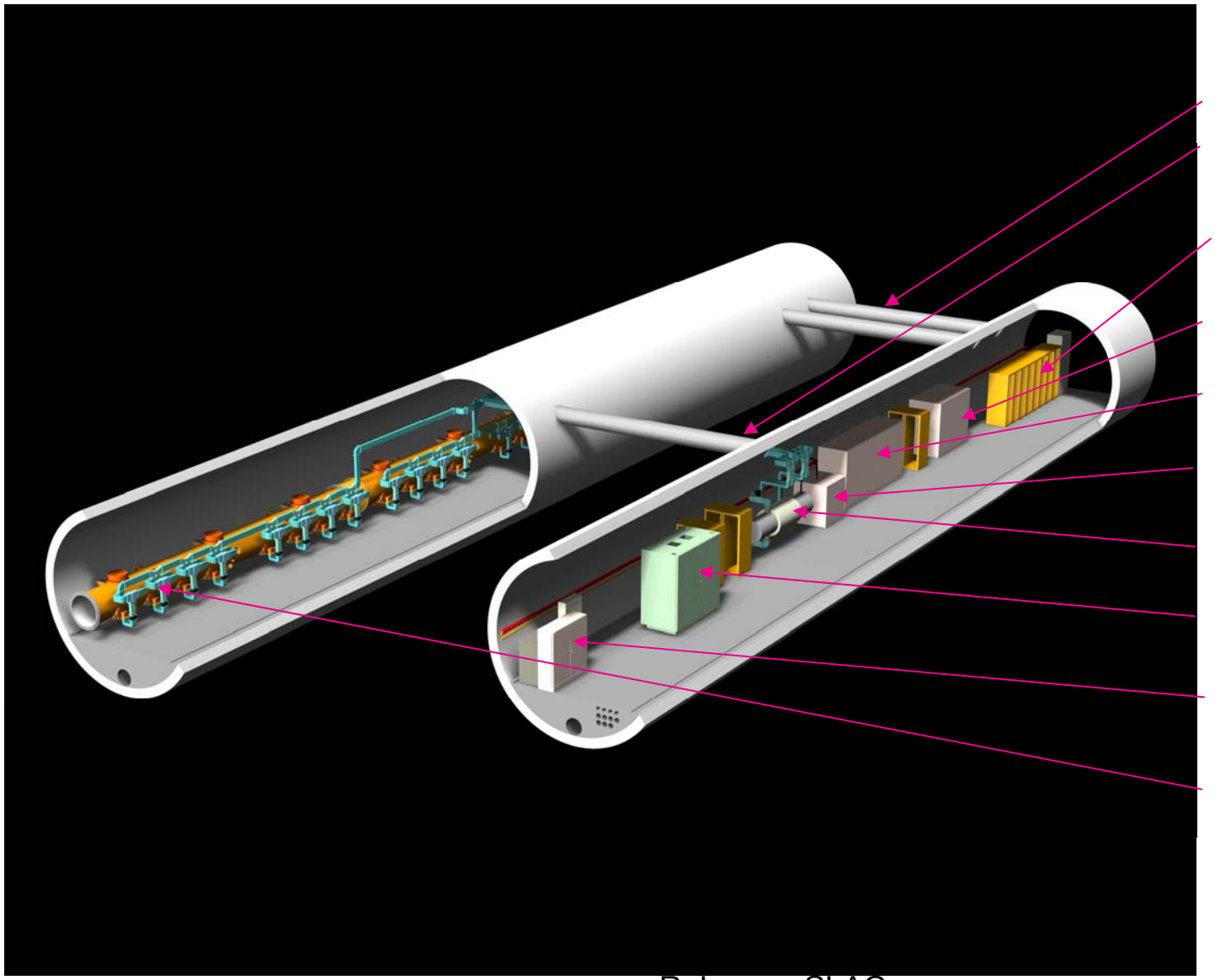

B


C


D

A. Capacitor Stack, B. Dual IGBT Switch, C. Bouncer Filter Chokes, D. Pulse Transformer
-Bouncer smoothes pulse top to +/- 0.5%
-8-10 units built by FNAL/DESY

ILC Baseline: 38m 10 MW Linac RF Station



Penetrations:
Cable & Plumbing
Waveguide

LLRF, Controls,
Protection Racks

Charger

Main Modulator

HV Pulse Transformer

Horizontal Klystron

LCW Chiller

HV Supply Switchgear

Waveguide
Distribution
System

Courtesy: J. Liebfritz, FNAL

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II. Marx Modulator

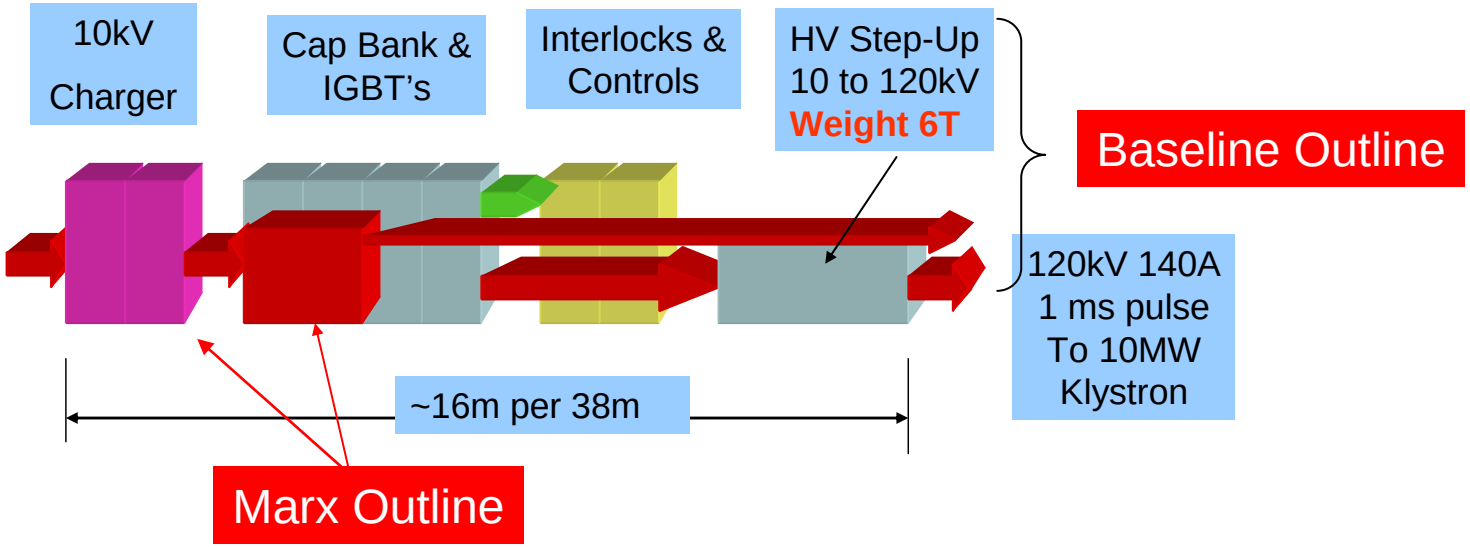
- Being investigated as alternate design to present switched cap "Bouncer" design

Goals:

Reduce size, weight, space by 3-4X
Reduce cost by >2X
Increase efficiency
Demonstrate operation in 2007.

Specifications:

120 kV, 140 A, 1.63 ms, 5 Hz
125 kW output power to klystron
Efficiency from wall-plug ~90%

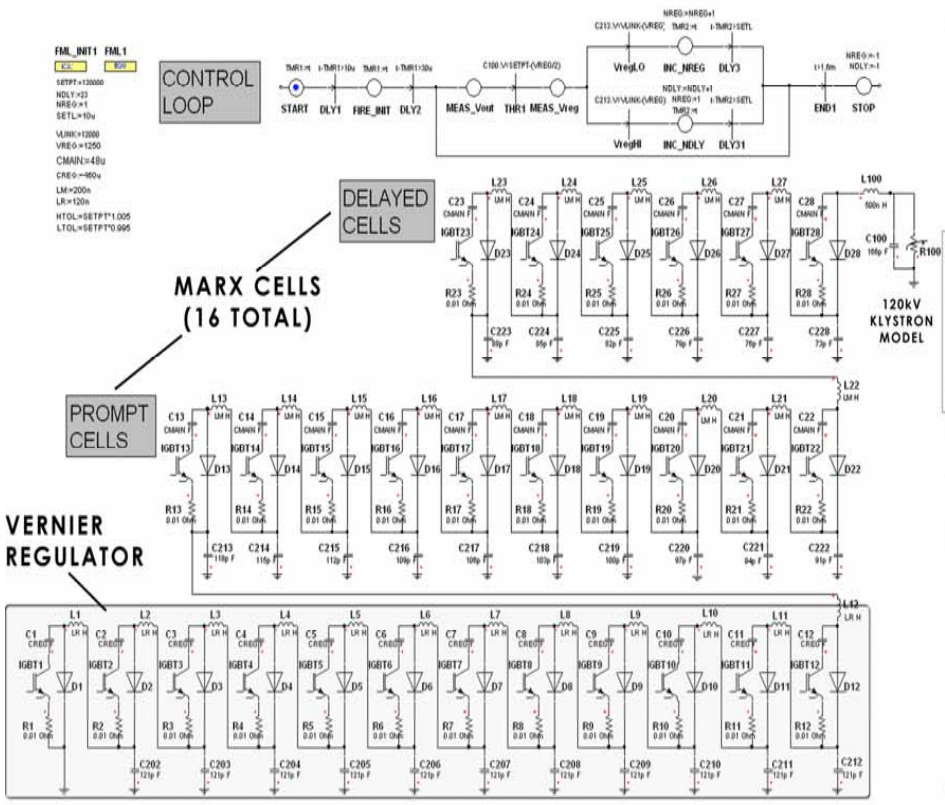


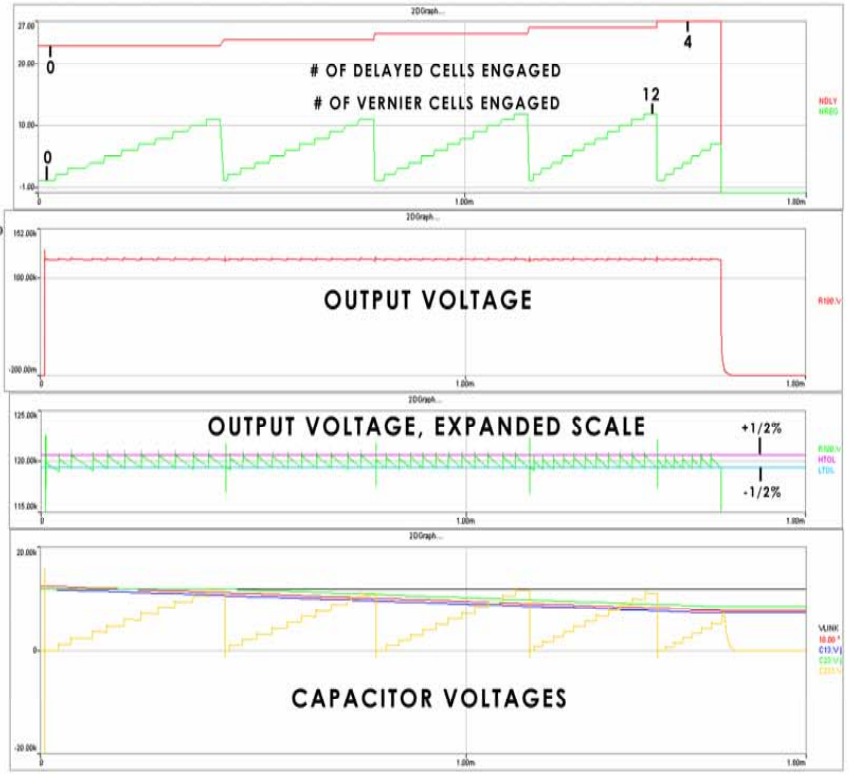
II. Alternate Design Motivation

- Generate HV by stacked switched cells DC coupled; smooth pulse by digitally controlled elements (Vernier); air cooled
- Eliminate oil-filled multi-ton Pulse Transformer
- Reduce total foot print by ~3X, Cost by ~2X
- Modular design with N+1 Cell redundancy for higher Availability, shorter Mean Time to Repair (MTTR)
- N+1 Redundancy at 12 kV cell level, charge and discharge switch level, capacitor level
- Cells air-cooled inside water-cooled enclosure; easier maintenance handling, replacement, off-line repair
- Charge directly from 34.5:8 kV distribution transformer; simple buck regulator cell; eliminate oil-filled charger transformer

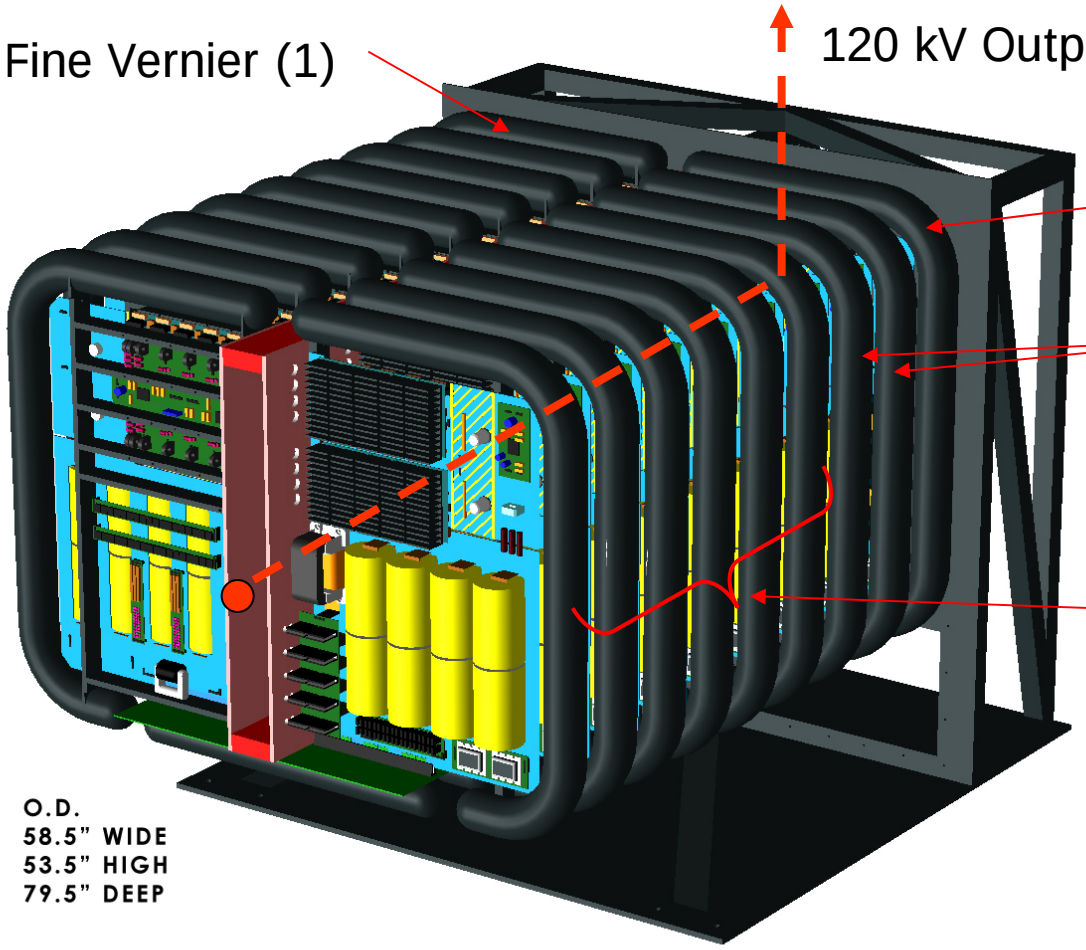
[Note: Charger topology may be redesigned further to solve power factor / phase load balancing issues.]

II. Marx Conceptual Circuit Design





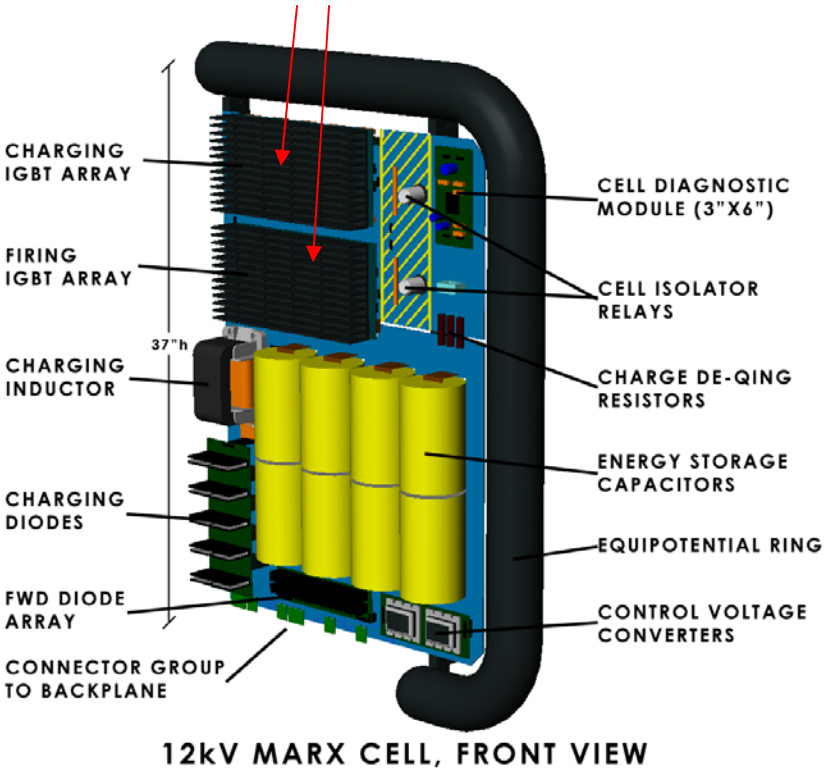
II. Marx Assembly Overview



DETAIL, MARX MODULATOR CORE

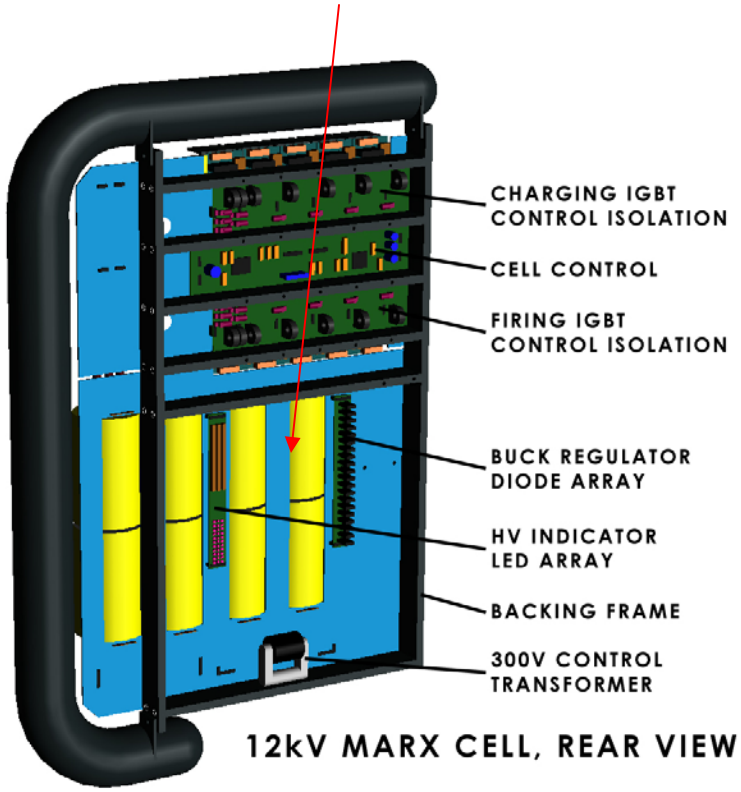
II. 12 kV Cell Detail

4+1 Redundant Switch Arrays for charge, discharge



12kV MARX CELL, FRONT VIEW

6+2 Redundant Capacitors

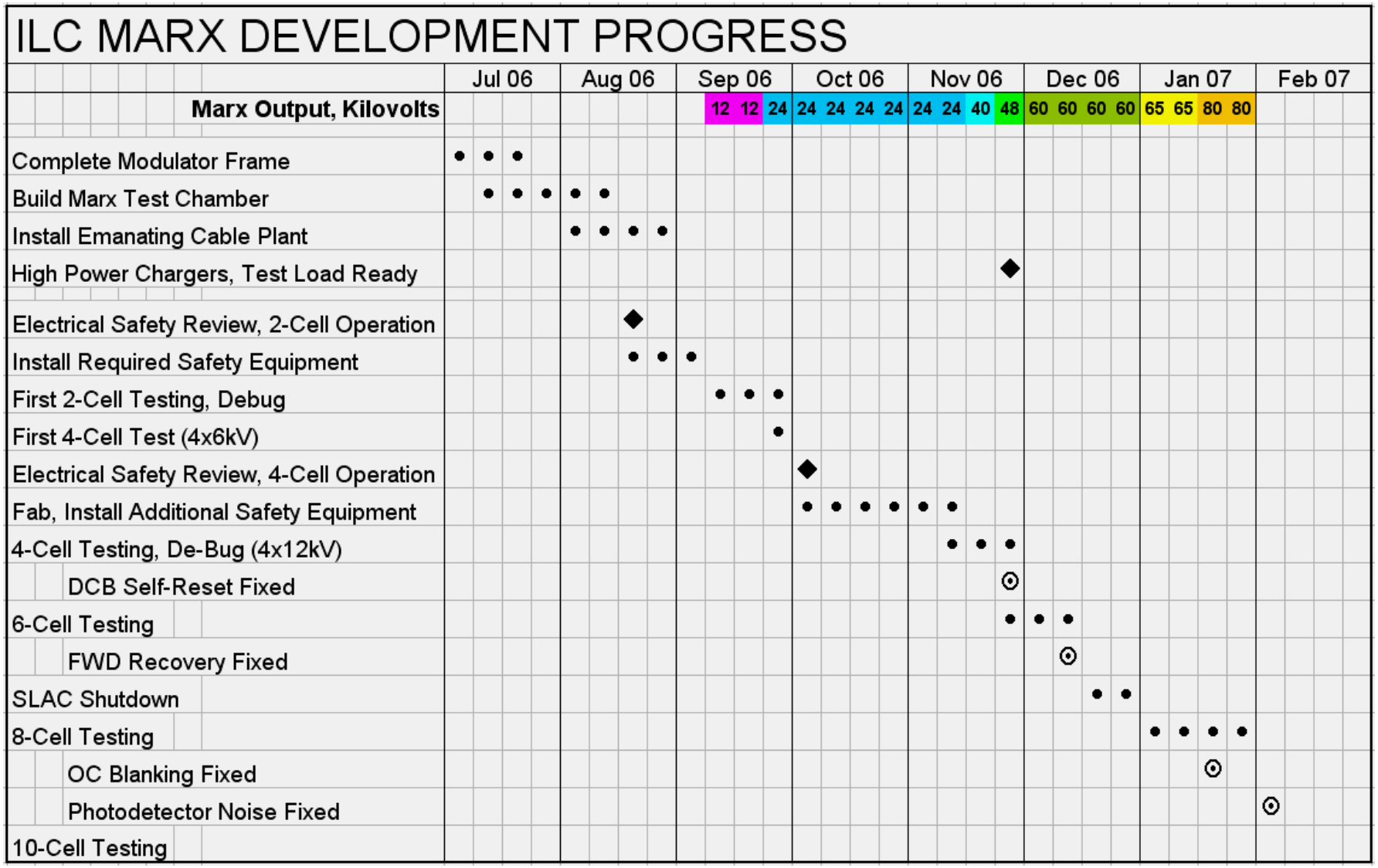


12kV MARX CELL, REAR VIEW

III. ILC Marx Modulator Progress Report

G.E. Leyh, SLAC 29 January 2007

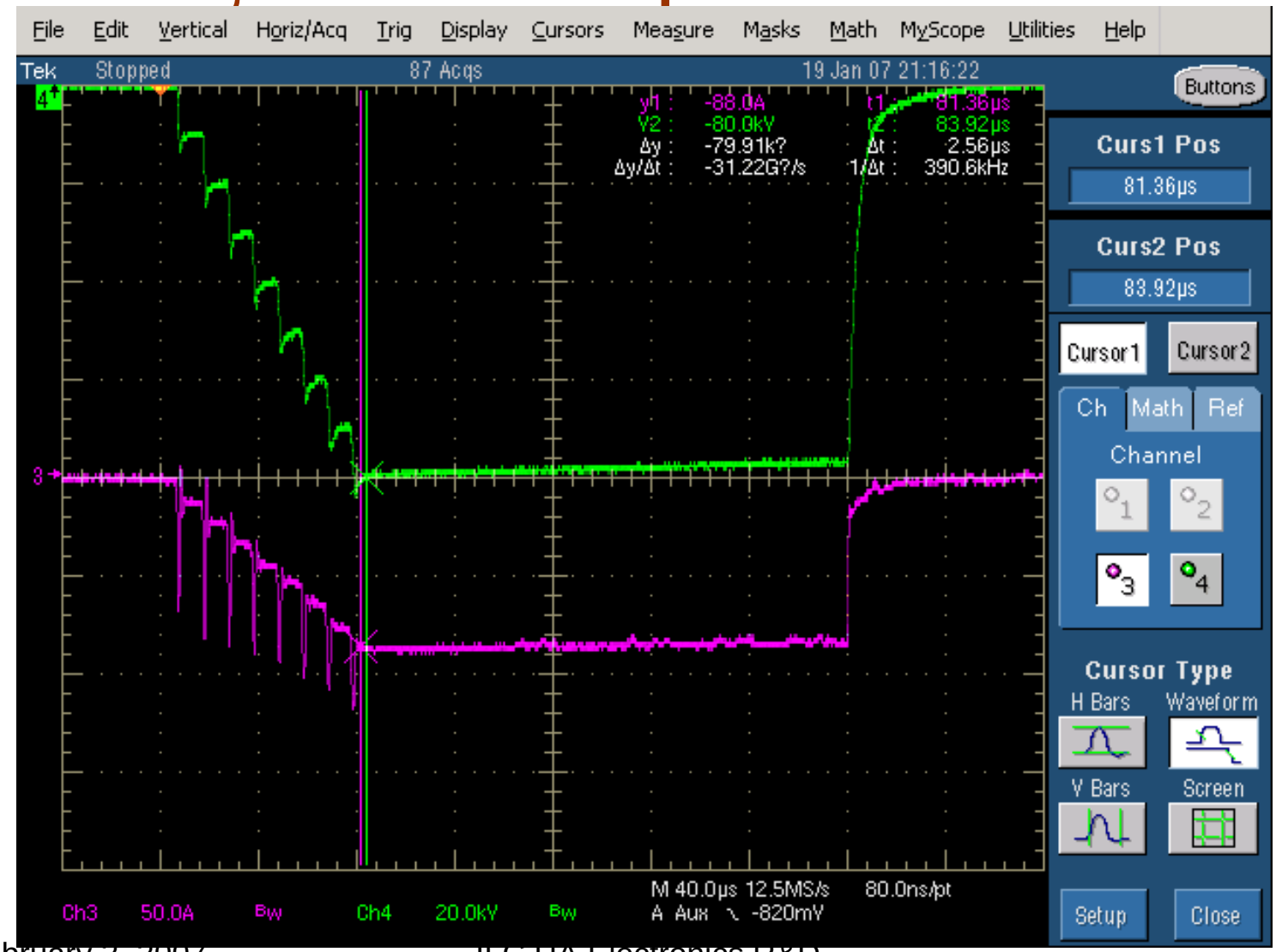
ILC MARX DEVELOPMENT PROGRESS

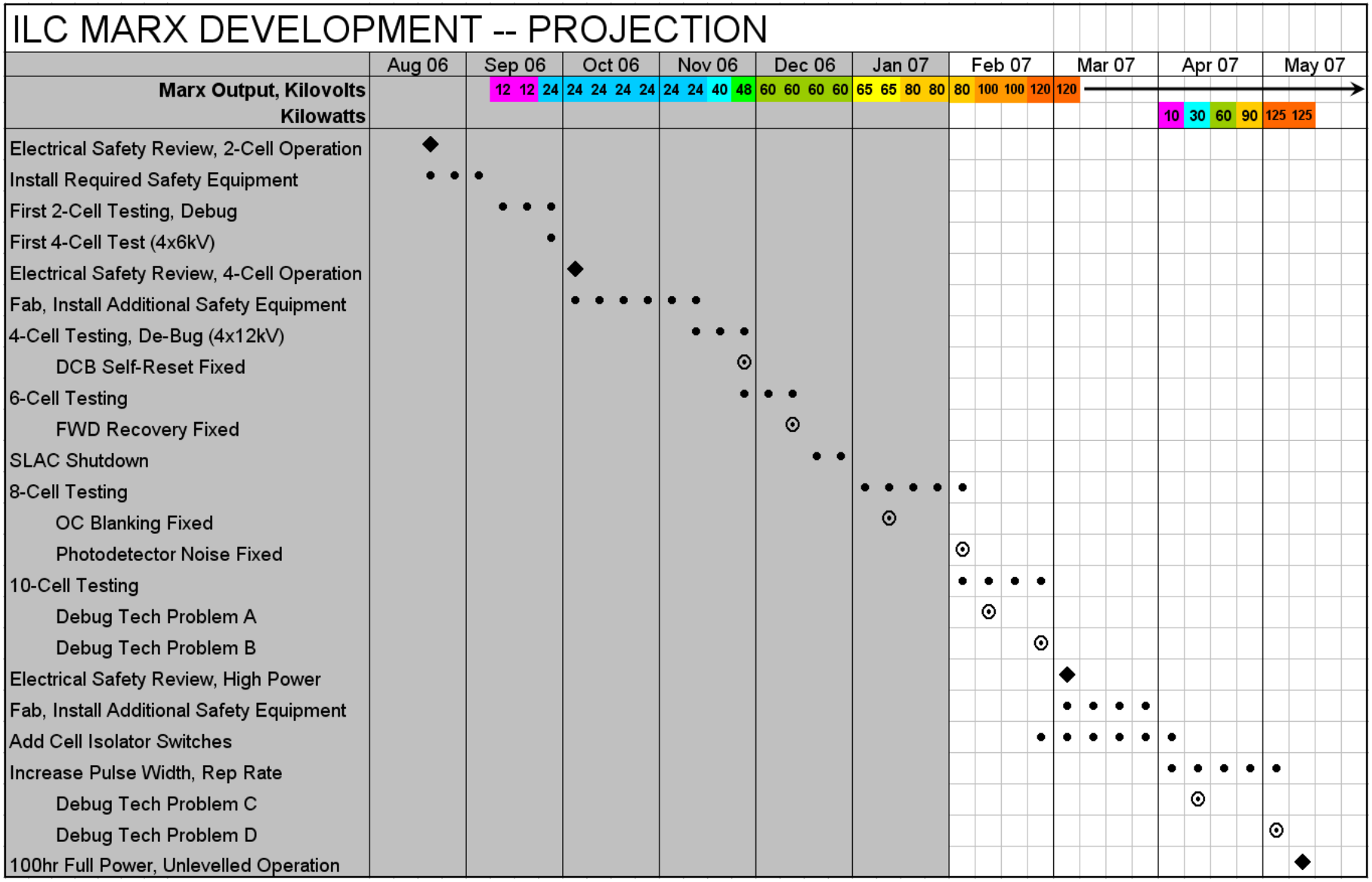


Performing Measurements

- Single cell on test stand.
- Capacitor safety shorting device, long handle
- Long wait period before handling after shorting.
- Probe suspended, repositioned for point-to-point measurements
- Very slow process – automated test, maintenance fixtures & procedures need to be developed

8-Cell, 80kV Output Waveforms

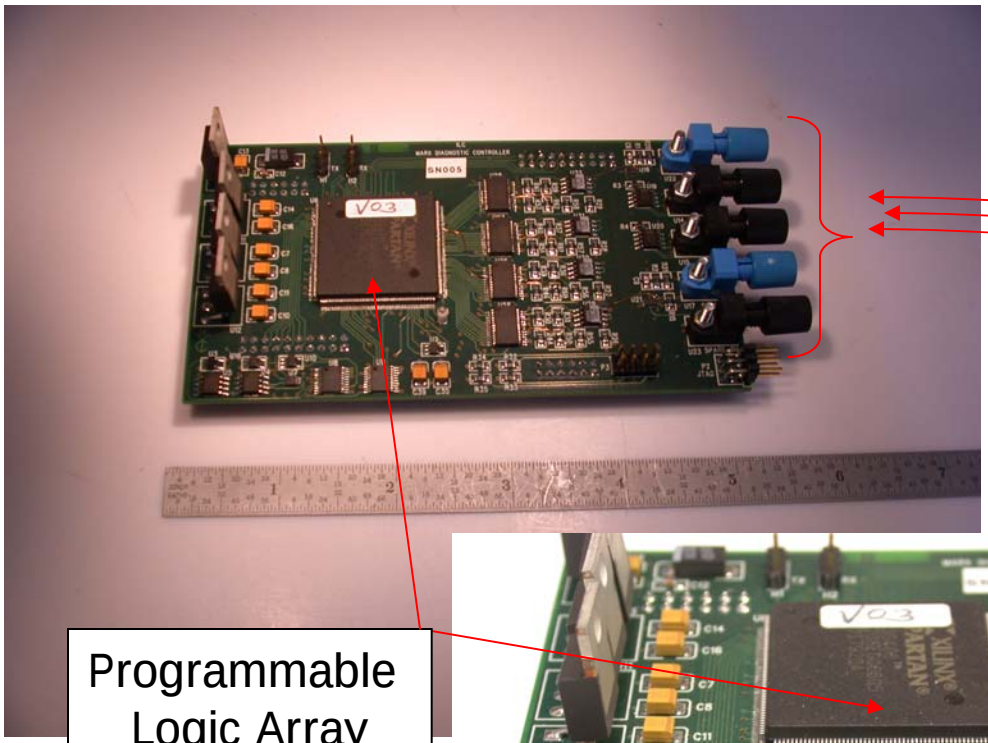



ILC MARX DEVELOPMENT -- PROJECTION
Aug 06
Sep 06
Oct 06
Nov 06
Dec 06
Jan 07
Feb 07
Mar 07
Apr 07
May 07
Marx Output, Kilovolts
12 12 24 24 24 24 24 24 24 40 48 60 60 60 60 65 65 80 80 80 100 100 120 120
Kilowatts
10 30 60 90 125 125
Electrical Safety Review, 2-Cell Operation
Install Required Safety Equipment
First 2-Cell Testing, Debug
First 4-Cell Test (4x6kV)
Electrical Safety Review, 4-Cell Operation
Fab, Install Additional Safety Equipment
4-Cell Testing, De-Bug (4x12kV)
DCB Self-Reset Fixed
6-Cell Testing
FWD Recovery Fixed
SLAC Shutdown
8-Cell Testing
OC Blanking Fixed
Photodetector Noise Fixed
10-Cell Testing
Debug Tech Problem A
Debug Tech Problem B
Electrical Safety Review, High Power
Fab, Install Additional Safety Equipment
Add Cell Isolator Switches
Increase Pulse Width, Rep Rate
Debug Tech Problem C
Debug Tech Problem D
100hr Full Power, Unlevelled Operation

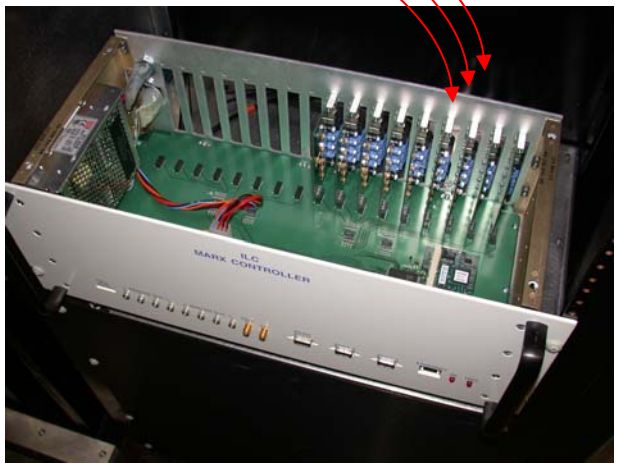
Other Accomplishments

- Additional Tasks Completed
  - *Diagnostic Controller system*
  - *150 kW Charger Supply and Resistive Load*
  - *Air-water cooled enclosure*
  - *Second Level Vernier correction box (LLNL)*

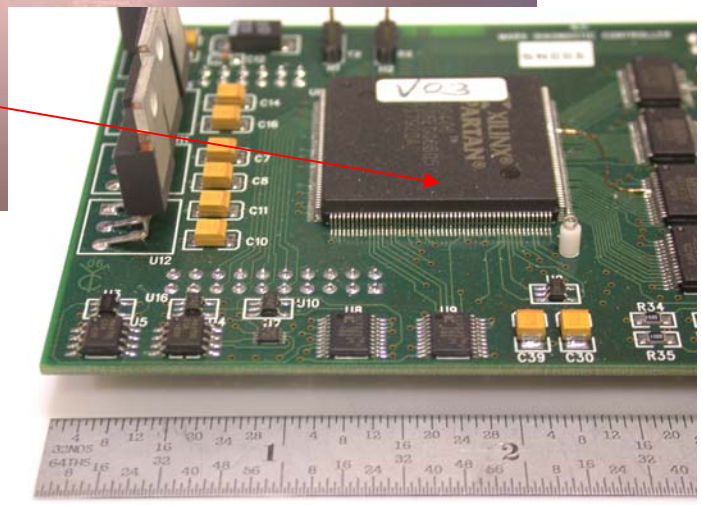
Diagnostic Controller Details



Dual Fiber Optic Timing & Data Links



Programmable Logic Array



Duplex Timing & Data Channels Each Cell (Mounted on Rear)

16 Ch Ground Station

150 kW Air-Cooled load

Disc Resistor Stacks (2)

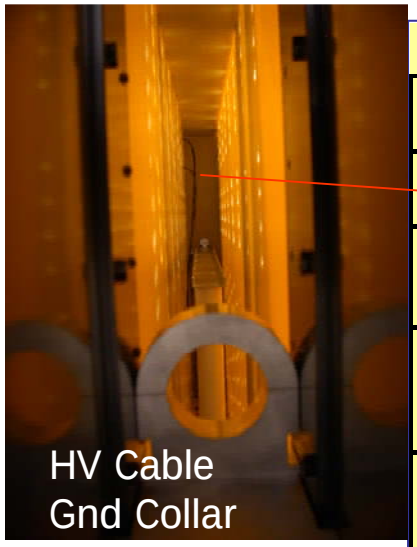
120 kV Input Cable

Rear View Axial Fans

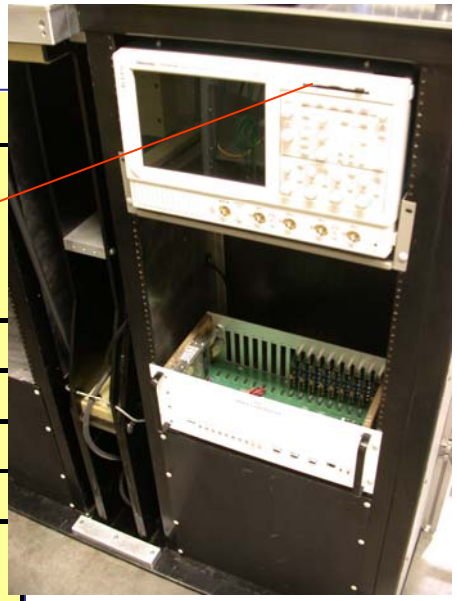
Disc Resistor & Cooling Fin Stacks

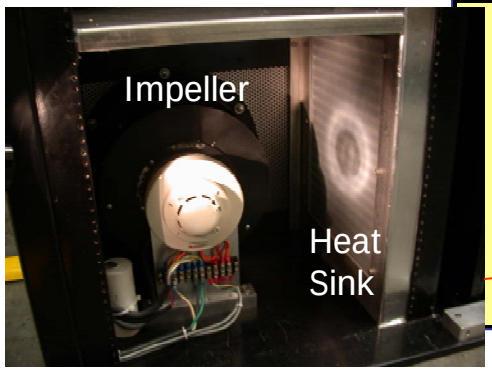
Integrated Instrument Rack

Layout - Front View



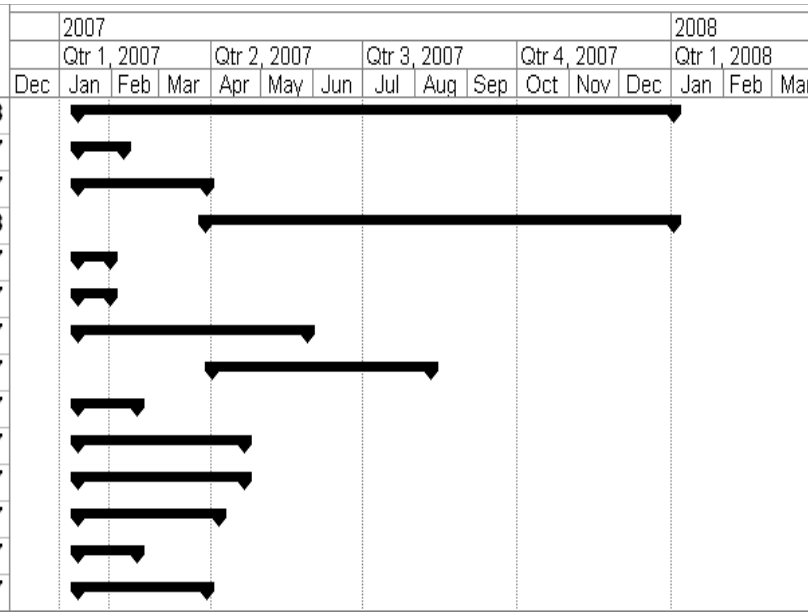
RACK 'A'	LEVEL	RACK 'B'
AC POWER DIST	19 18 17	TEK 4-CHANNEL OSCILLOSCOPE
INTLK, UTIL SUMMARY	16 15 14	
BUCK REGULATOR CONTROLLER	13 12 11	OPTO DIAG 1
	10	OPTO DIAG 2
FAST ANALOG REG	9 8 7	KEYBOARD
	6	300VDC CTRL PS
GROUND STATION EXT	5 4 3 2 1	GROUND STATION
BLOWER & HEAT EXCHANGER 1		BLOWER & HEAT EXCHANGER 2





IV. Preliminary Schedule

ID	Task Name	Duration	Start	Finish
1	DEMONSTRATION INITIAL OPERATION	254 days	Fri 1/12/07	Wed 1/2/08
2	Full Power Demonstration (Unlevelled)	19 days	Fri 1/12/07	Wed 2/7/07
11	100 Hour Test	55 days	Fri 1/12/07	Thu 3/29/07
21	2000 Hour Test (Phase 1 - B15)	200 days	Thu 3/29/07	Wed 1/2/08
31	CELL COMPLETION	13 days	Fri 1/12/07	Tue 1/30/07
32	Cells 11-14 Assembly & Test	13 days	Fri 1/12/07	Tue 1/30/07
41	VERNIER CELL	97 days	Fri 1/12/07	Mon 5/28/07
54	BUCK REGULATOR CELL	95 days	Mon 4/2/07	Fri 8/10/07
73	TOOLING	25 days	Fri 1/12/07	Thu 2/15/07
75	PACKAGED UNIT FOR ESB INSTALLATION	71 days?	Fri 1/12/07	Fri 4/20/07
76	Package Assembly	71 days?	Fri 1/12/07	Fri 4/20/07
84	Site Preparation	60 days	Fri 1/12/07	Thu 4/5/07
89	Safety Reviews & Documentation	25 days	Fri 1/12/07	Thu 2/15/07
94	Control System Integration	55 days	Fri 1/12/07	Thu 3/29/07



Note – Preliminary to show remaining tasks, not optimized.

V. Summary

- Original schedule aiming for HV demonstration by end FY06 and Vernier demonstration by end CY06 not met due to:
  - *Initial delays in parts deliveries (IGBTs)*
  - *Design and implementation of safety features*
  - *Safety documents, reviews, authorization to proceed*
  - *Charger design delayed so implemented alternate commercial unit system.*
  - *Noise problem in DCB limited to 40 kV (fixed).*
  - *Protection diode problem failure (fixed).*
- Subsequently made tests up to 60 kV at low power prior to year end and to 80 kV in January 07
  - *Blanking pulse added to CPLD to eliminate noise trips (fixed).*
  - *Additional problem encountered at 80 kV with noise in opto-isolators (being fixed).*
  - *HV measurements painstakingly slow*

Summary-2

- Next Steps:
  - *Continue debugging to 120 kV at low power*
  - *Perform short power test (100 hrs) with full charger supply, load*
  - *Modify design to include new capacitor discharge switches, begin 2000 h test.*
  - *In parallel Complete Vernier, Buck Regulator Boards. When ready install, test.*
  - *Complete Full Power 2000 h test on Resistive Load*
  - *In parallel, prepare End Station infrastructure*
  - *Install tested unit in air-water cooled enclosure (parts on hand)*
  - *Move to End Station and install on 10 MW klystron load.*

VI. Acknowledgment

- The key players in development of the Marx are:
  - *Project Engineer, G. Leyh, Power Conversion Dept*
  - *Associates: Piotr Blum and Alfred Viceral*
  - *Diagnostic Controller design: J. Olsen, Controls Dept*
  - *Vernier Board design: Craig Burkhart*
  - *2nd Level Vernier design: E. Cook, LLNL*
  - *150 kW Air cooled Resistive Load: C. Brooksby LLNL, detailed design and R. Cassel & Co., construction*
  - *150 kW Charger system: A. deLira, design & R. Cassel & Co., design & construction*