Marx Modulator Status Report

C. Burkhart
SLAC Power Conversion Dept.
for the Marx Team
April 24. 2008

Presentation Overview

- Marx Development Program
- P1-Prototype Development Status
- Vernier Regulator Development Status
- Cost Estimate Review

Marx Development Program

- Prototype (P1) Modulator
  - Demonstrate efficacy of Marx topology for ILC Klystron modulator application (thru FY08-Q3)
  - Power 10 MW klystron for ESB life/performance testing (start FY08-Q4)
- 2nd Generation Prototype (P2) (FY09 & 10)
  - Modify to conform to revised tunnel design
  - Improve manufacturability
  - Improve reliability/availability

P1-Prototype Status

- Operated at Full Voltage (120 kV), Current (140 A) and Pulse Length (1.6 ms) with Coarse Flattening
  - 16 Cell at 11 kV, 11 prompt and 5 delayed
  - Load variations → >150 A
  - Vernier Regulator for 0.5% regulation under development
- Operated at Near Full Power (135 kW)
  - Maximum of ≥100 kW, limited by 11 kV source and load
- Operated at Full PRF (5 Hz)
- Operated for Several Days without Intervention
- BUT Have Not Achieved All Simultaneously

Marx Output with Coarse Flattening

Voltage: 20 kV/div

Current: 50 A/div

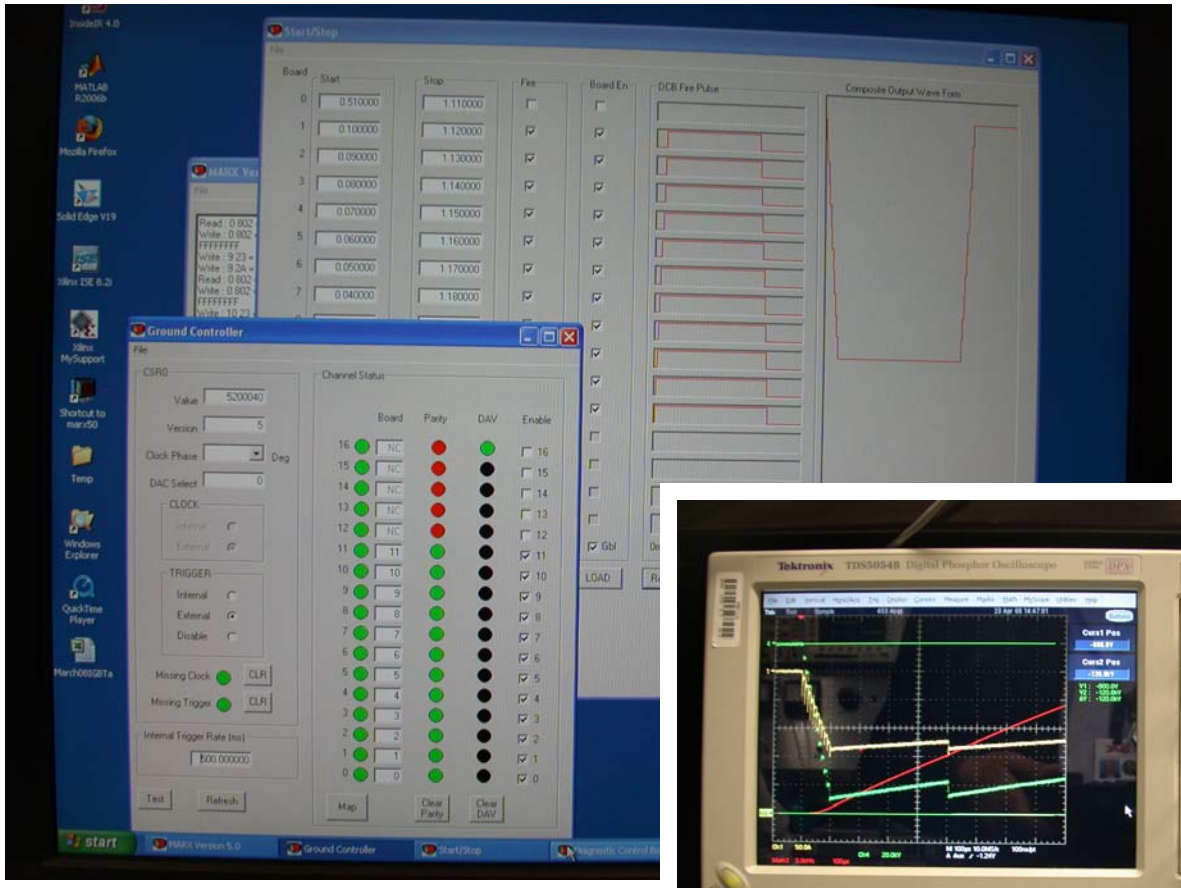
Energy: 4.5 kJ/div

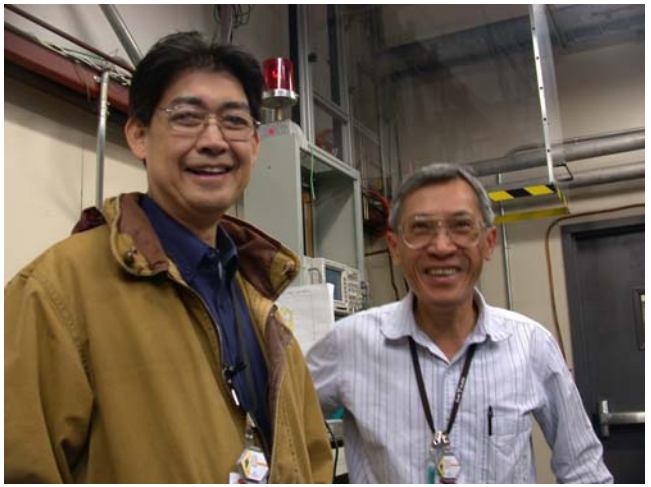
P1-Prototype Development Challenges

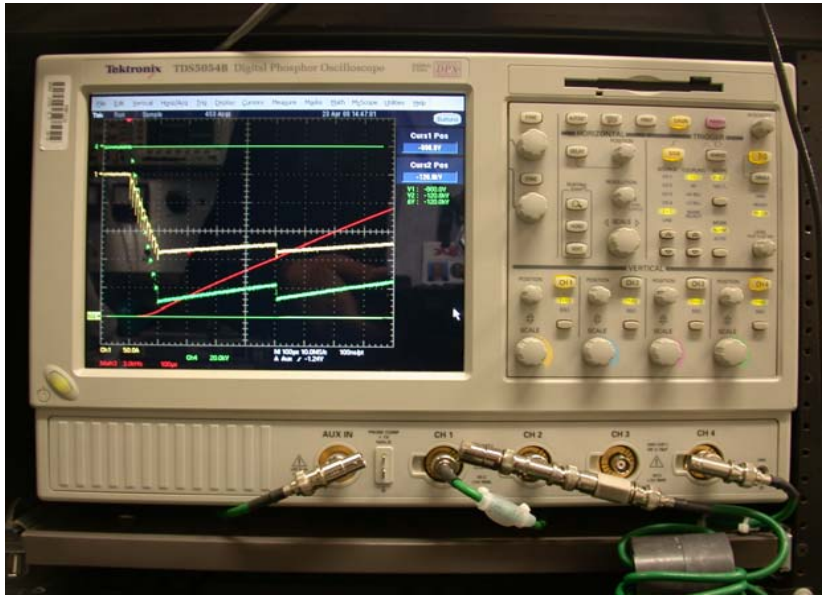
- (Too) High Voltage Stress on IGBTs, Scale Back to Improve Robustness to a Suitable Level of this Application
  - V_{OP} /$V_{(BR)CES}$ ~0.67
  - Small/No snubbers or MOVs
  - Over Voltage protection active: device turn-on delay
- Extended Operation to Evaluate “Subtle” Effects
- Fault Testing: Simulate Klystron Arc
- Prime Power/Load Limitations/Failures
- Control System Upgrades: EPICs Support
- Packaging for ESB Operation
- Vernier Regulator

Marx Water Load & Charger

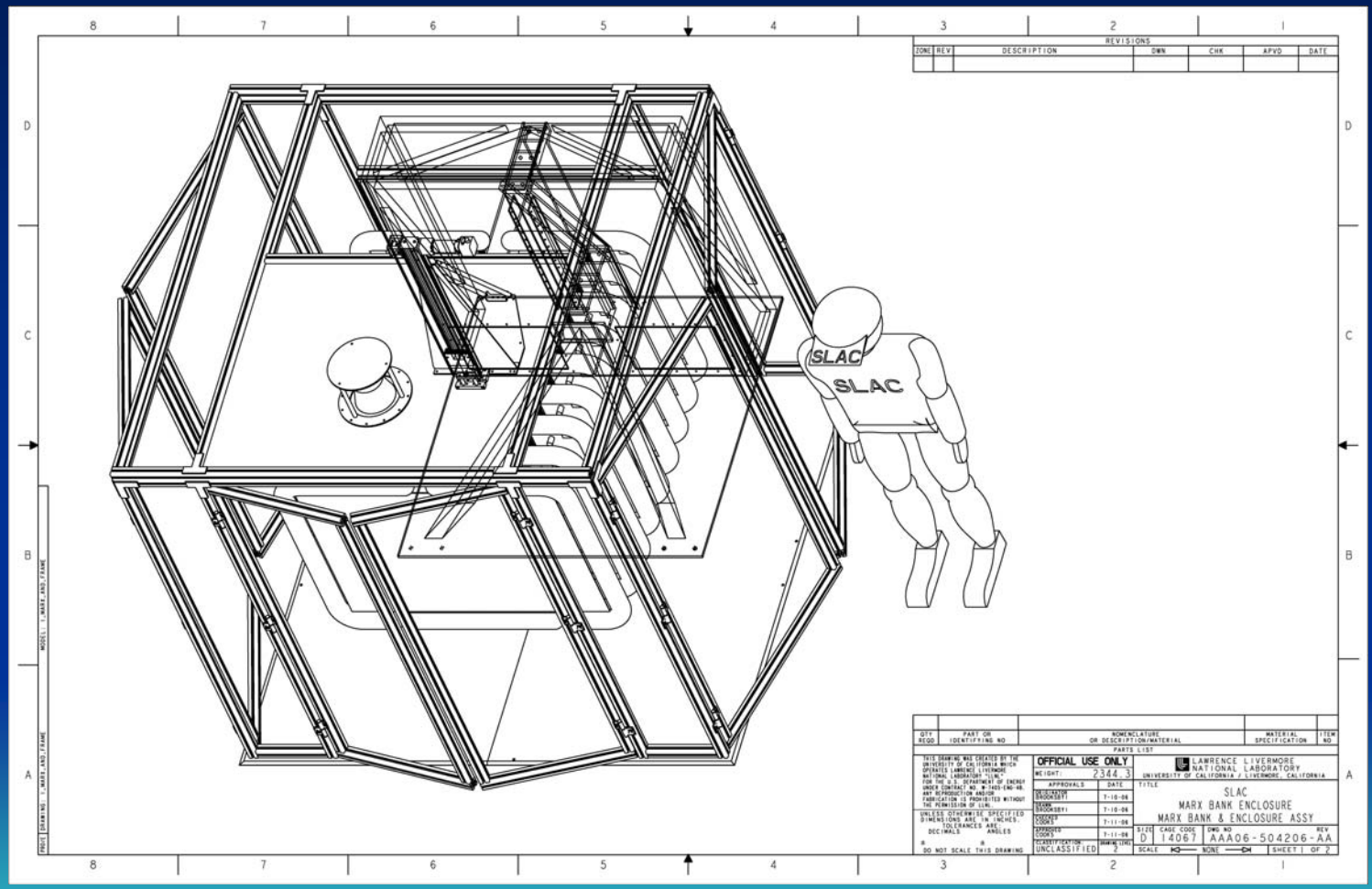
Marx Waveforms & Control Screen







ESB Enclosure

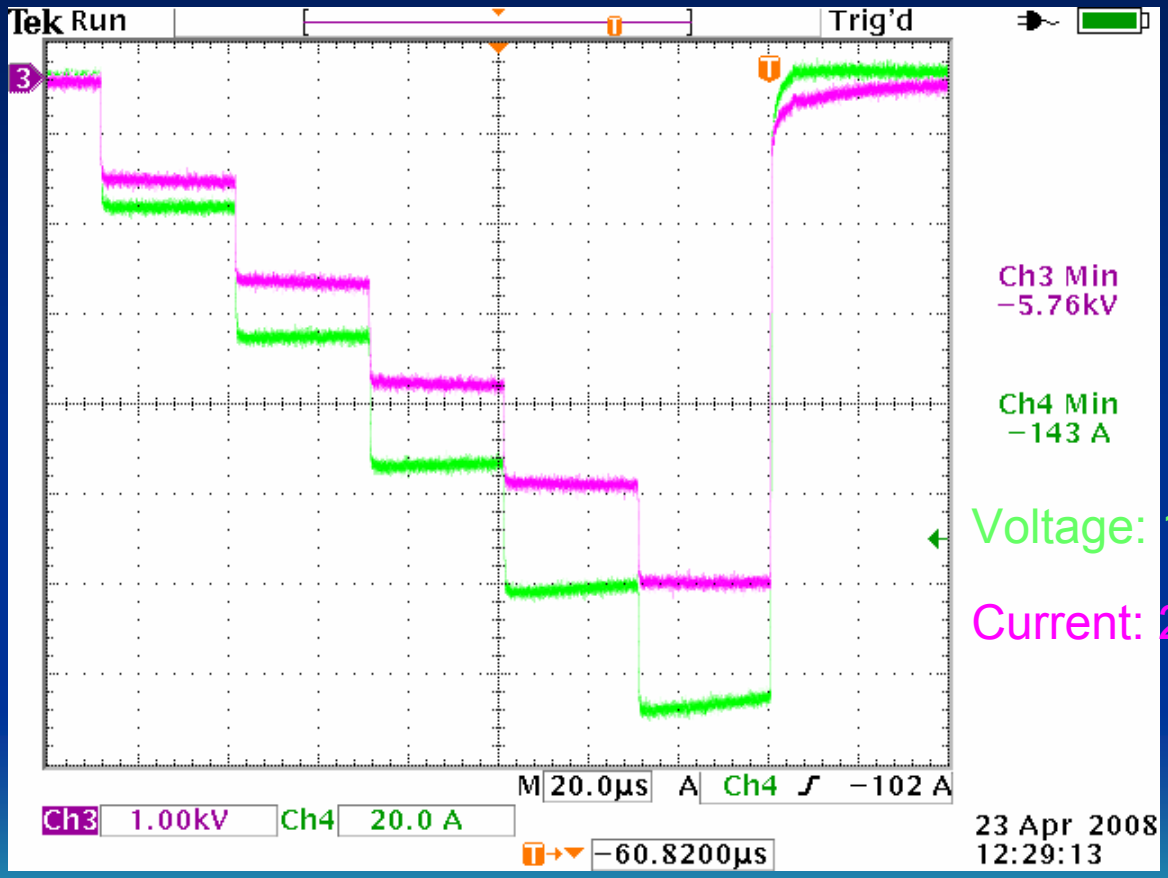


Vernier Regulator

- 16-Cell "Mini-Marx", 1.2 kV Cells
- Multiple Erections of Marx to Generate a Series of Voltage "Ramps" to Offset Droop (Sawtooth) in Coarse Pulse Flattening
- 2nd Generation Cells Successfully Operated, 5-cell Stack
- 3rd Generation Cell Design Complete
- Motherboard/Aux Board Designs Nearly Complete

5-Cell Vernier Test Set-up

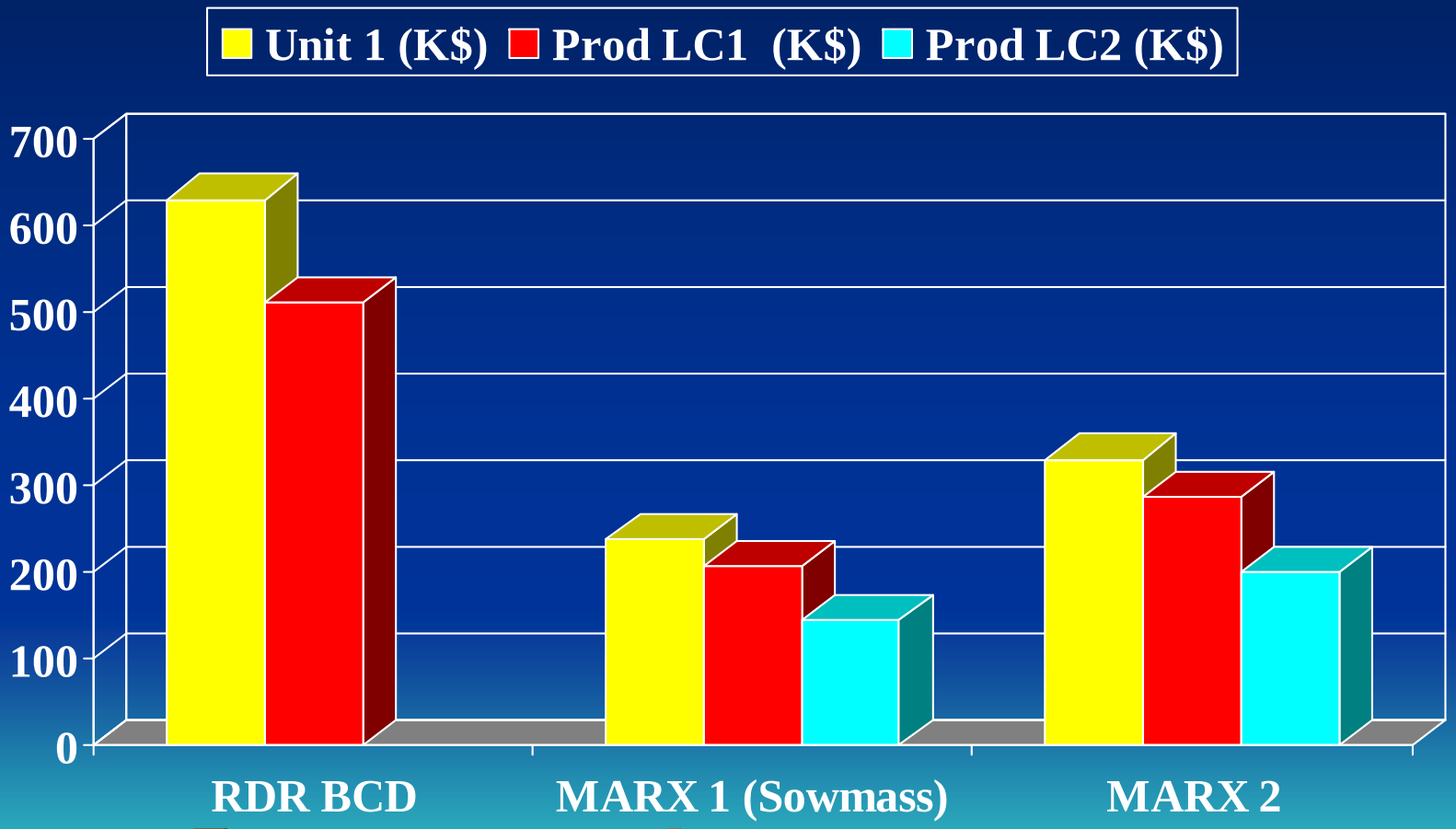
5-cell Vernier Output



Cost Estimate Revisited

- Bulk of original components, costs remain unchanged since model shown at Snowmass '05.
  - Same architecture of cells, housing
  - Major cost drivers (IGBT's, capacitors) ~same
- 2008 adjustments
  - Charger Supply
    - Earlier estimate assumed bulk regulator at 12 kV built onto single cell; did not included distribution or phase load balancing
    - New estimate made for 6-Pack high availability power distribution (R. Cassel) added $60K per modulator
  - Cell voltage reduction
    - Originally designed to run at 12 kV per cell, insufficient margin for protection
    - Now operating at 11 kV/cell, which means should add ~8% to cost for same level of cell redundancy
  - Results shown in next slide.

Snowmass '05 Updated



Marx Cost Summary

Including 8-Pack Charger & AC Distribution, Extra Cell

Rev. 042408

MARX Modulator						
Item	**Cost Basis**	**M&S**	**Labor**	**Total k$/$**	**Profit 15%**	**Total Cost**
Main Unit	M&S Quotes, Labor Eng. Estimate			**(*1.08)**		
Marx Cells		131.0	10.0			
Modular Enclosures		8.4				
Overall Enclosure		2.5				
Cooling Main Unit		4.0				
Internal Wire/cable		1.6				
Diagnostic Cntrlrs		6.0				
PLC Controls		2.0				
Cntrl Sys Interface		0.5				
Other labor			15.0			
Subtotal Main Unit		***156.0***				
Protection Units		1.5				
Charging Supply	Cassel HA System w/ distribution	67.2				
Miscellaneous		10.9	5.0			
Subtotal, Misc		***79.6***				
Subtotal Prod.Unit 1		***235.6***	**30.0**			
Total Cost Full Unit 1 (k$)				**286.8**	**43.0**	**329.9**
Avg Cost 572 Units [1]	Conservative LC (95%M&S, 95% Labor)			**248.8**	**37.3**	**286.1**
[1] Includes 20% ED&I in LC	Aggressive LC (90% M&S, 85% Labor)			**174.4**	**26.2**	**200.6**

Marx Program Summary

- P1-Prototype Nearing Completion (FY08-Q3)
- Integrate P1 into L-band Facility (FY08-Q4) Initiate Life Testing of Marx and MBK
- Complete Vernier Regulator and Integrate into P1 (FY08-Q3/4)
- Nth Unit Cost Re-examined: $200k - 290k, ~30% Increase from Snowmass ’05 Estimate
- P2-Prototype Development FY09-10

The Marx Team
Past, Present, (Future?)

- D. Anderson
- P. Bellomo
- P. Blum
- C. Brooksby (LLNL)
- C. Burkhart
- R. Cassel
- R. Chestnut
- E. Cook (LLNL)
- A. de Lira
- R. Larsen
- G. Leyh
- D. Moreno
- M. Nguyen
- J. Olsen
- P. Shen
- A. Viceral