Proton Plan
201 Mhz. Low Level RF Replacement and Quad Power Supply Upgrade for The Low Energy Linac
Directorate Review
August 2005

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Agenda

- Low Level RF(LLRF) Technical Description
- LLRF Goals
- LLRF Management
- LLRF Risk Analysis
- LLRF Critical Path Analysis
- LLRF Conclusions
- Quad Power Supply(QPS) Goals and Technical Description
- Q P S Management and Risk Analysis
- Q P S Critical Path Analysis
- Q P S Conclusions

What We Have Now For Low Level RF

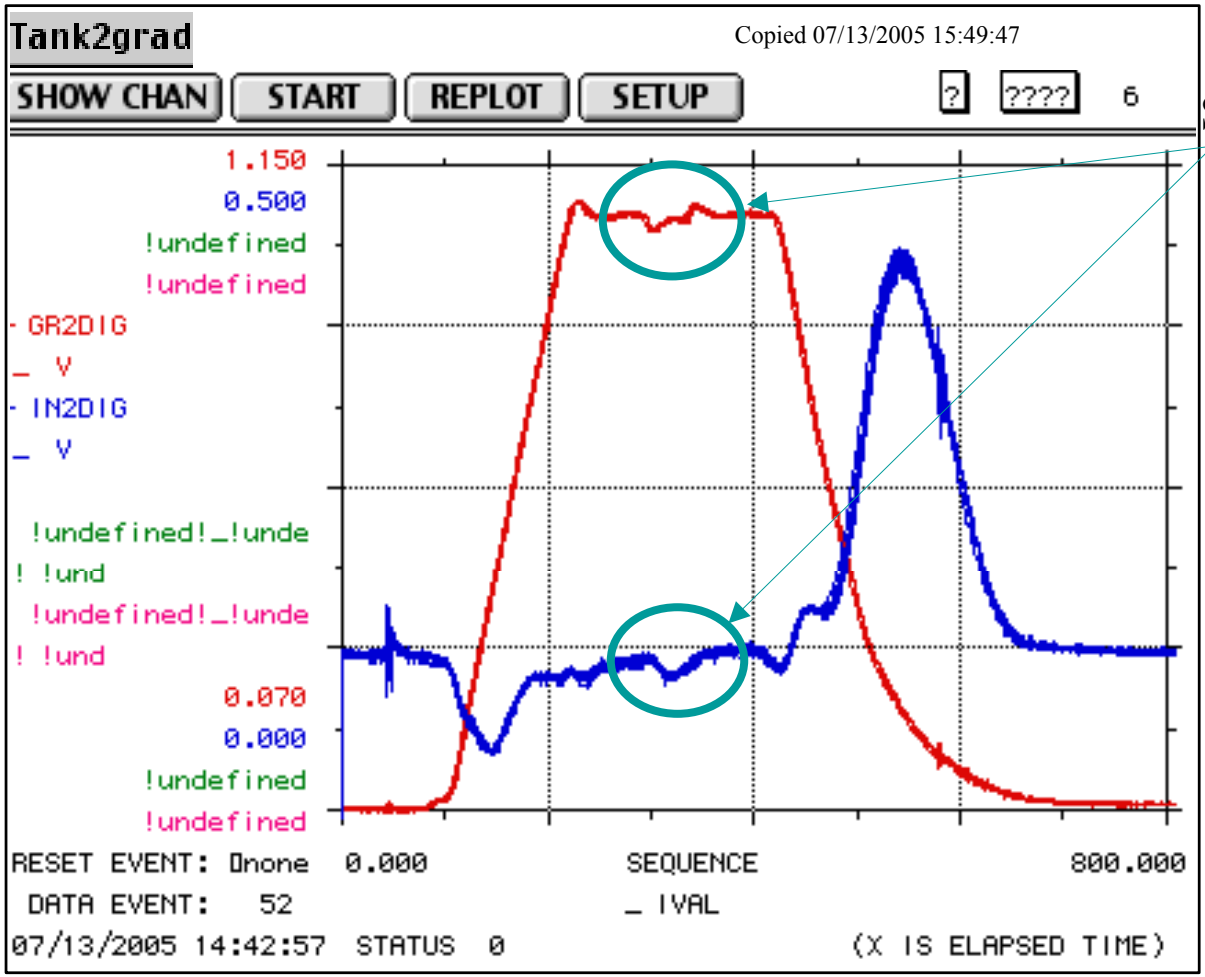
- Current Low Energy Linac(LEL) LLRF system was designed in the late sixties with a minor upgrade in 1994.
- Phase is controlled by the LLRF drive signal and amplitude is controlled by the modulator.
- There is no phase measurement relative to any reference line.
- There are two phase control loops.

What We Have Now For LLRF

- The Modulator receives a reference waveform from its LL system and attempts to make the RF amplitude in the cavity match that by modulating the 7835 anode voltage.
- Under most circumstances the RF amplitude and phase require more than 10 μsec to settle in.
- The result of this is that the first 10 μsec of beam is unacceptable and will be thrown away.

What We Have Now For LLRF

RF Amplitude Envelope and Intertank Phase Signal From LRF2

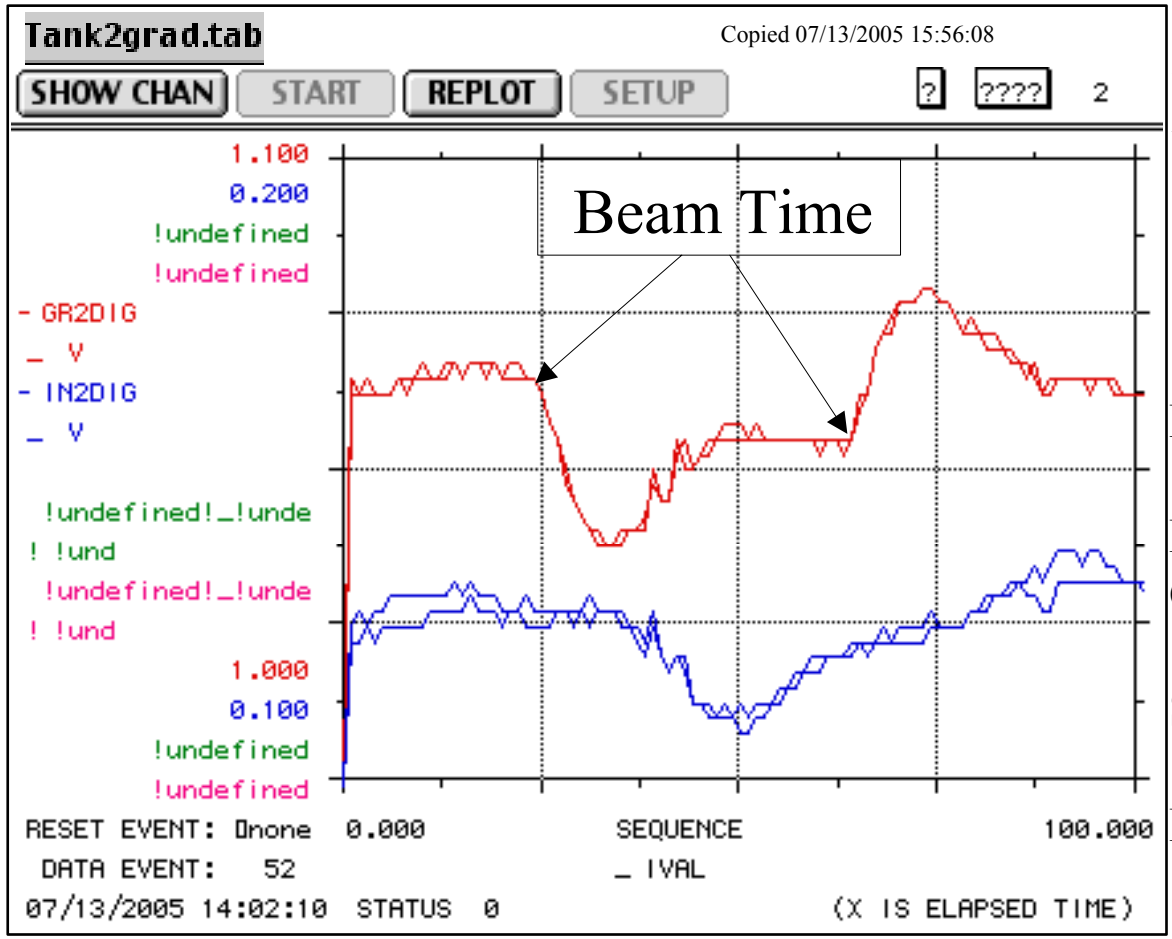


Scale Expanded In Next Slide

Typical Gradient and Intertank Phase Signal

X Axis in µsec.

What We Have Now For LLRF



RF Amplitude Envelope And Intertank Phase Signal with Expanded Scale

Pk. Beam Loading 2.7%

Beam Loading After Gradient Settles 1.0%

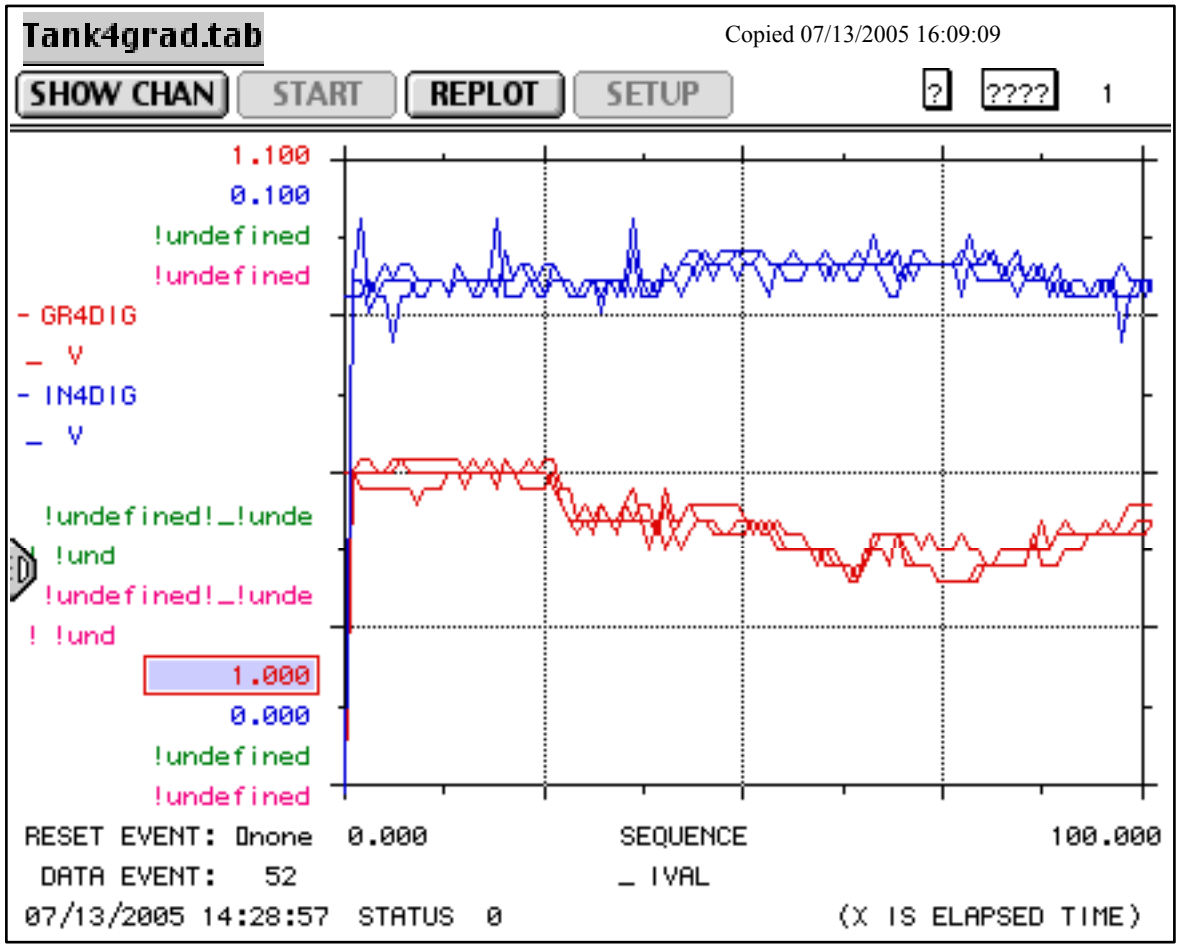
Settle Time 21 µsec

Difference 1.7%

Same Gradient and Phase Signal Blown Up

X Axis µsec

What We Have Now For LLRF



LRF 4 Gradient and Intertank Phase

Amplitude and Phase of LRF 4

Beam Loading Not As Severe But Never Settles Out

Why We Want better LRF System

- By reducing the settle time to 2 μsec we reduce the beam pulse length by 8 μsec. reducing linac beam losses by at least 22% at the highest booster intensity we currently expect.

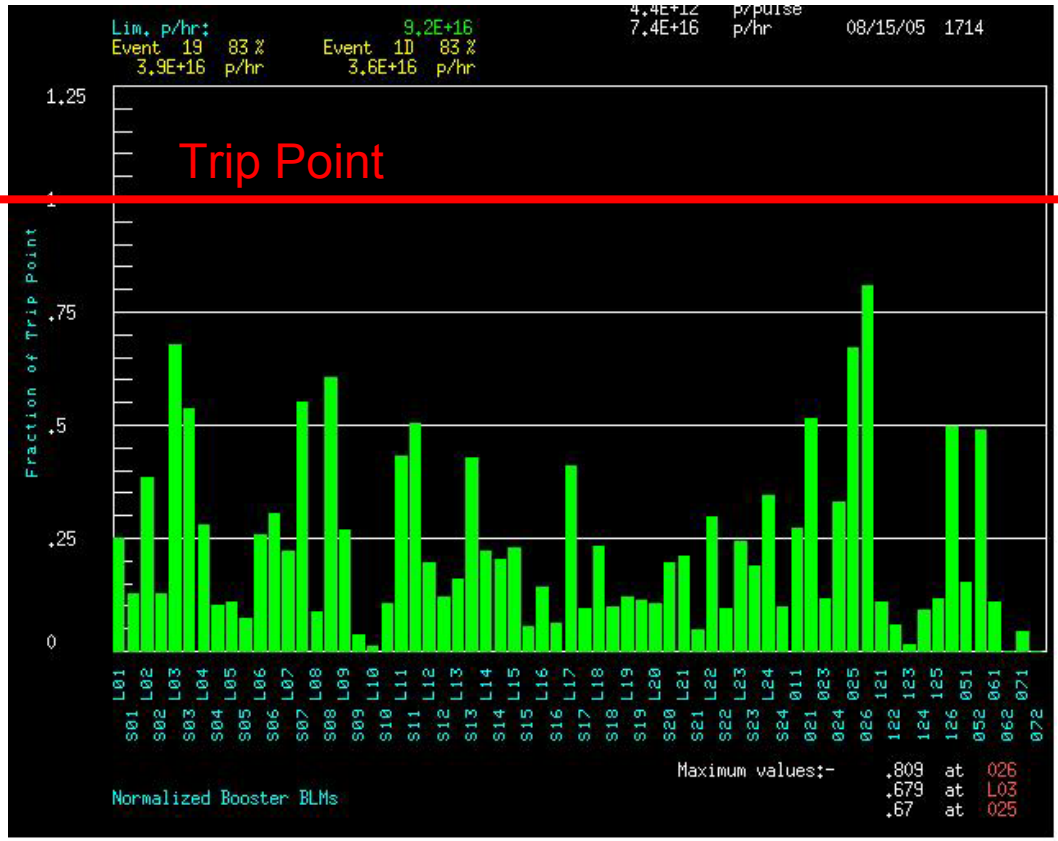
- Under the best of circumstances, Low Energy Linac Modulators do not have sufficient bandwidth to control RF amplitude to 1%.

- We often need significant slopes on the 805 Mhz RF amplitude and phase to buck out changes in the linac energy

Why We Want better LRF System

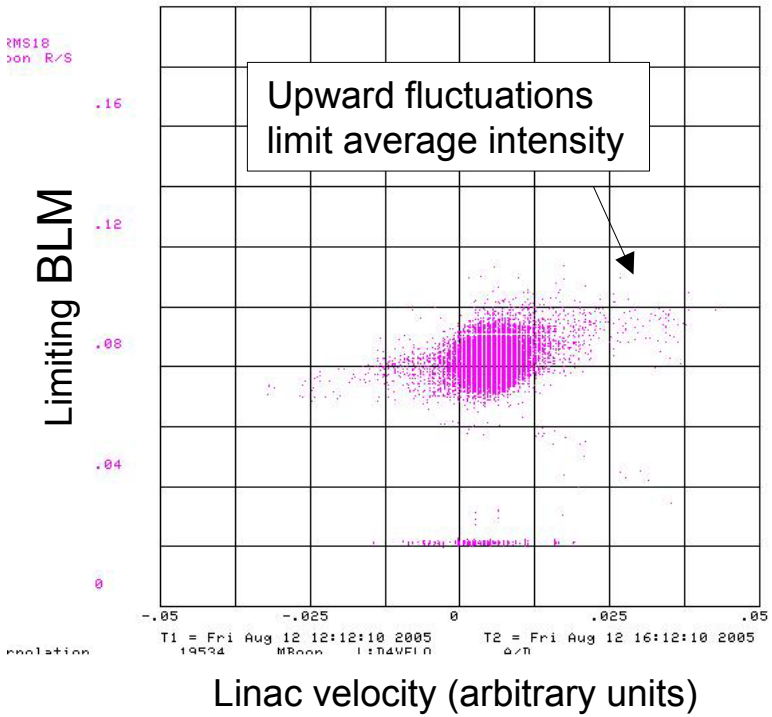
- At the end of the 400 MeV Line there is one to two mm of movement both horizontally and vertically, pulse to pulse and within the pulse.
- This is due in at least in part to the momentum drifting.
- Reducing the RF phase and amplitude variations will reduce the momentum shifts and make beam more acceptable to Booster.

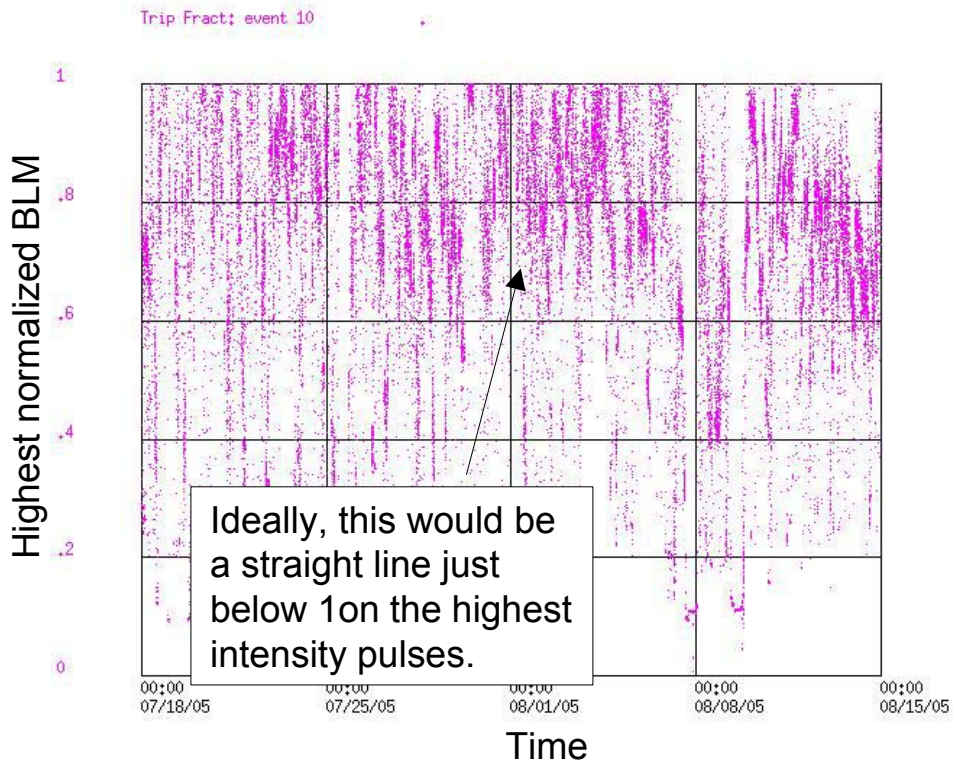
LLRF Benefit to Booster



- Total Booster throughput limited by set of ~60 loss monitors
- Beam loss instabilities prevent us from running very close to trip point.
- Beam loss instabilities primarily due to Linac energy fluctuations.
- Energy fluctuations most likely caused by phase instability in the LLRF of the LEL.

LLRF Benefit to Booster (cont'd)





- Based on observed fluctuations in the limiting BLM's, we estimate that we could potentially deliver 5 to 10% more integrated beam with an improved LLRF in the Low Energy Linac.

What We Want For LLRF

- Phase and Amplitude of the entire system regulated to ±.2 %
- Settle Time 2μsec or less.
- Output power and phase controlled either locally or via computer.
- New LLRF System will work in concert with the Modulator to control amplitude, getting the final 1 to 2 %, during beam time, from the Driver.
- Phase will be measured from each cavity to the reference line instead of cavity to cavity.
- The project is to new for there to be a design.

Management and Schedule

- It is to Early for a Production and Quality Assurance Plan
- We propose that the project to be built by The RF Department with help from the Linac Group.
- Linac Group will provide one Electrical Engineer to model the system .
- Linac Group will provide another Electrical Engineer and technician to help with design and construction.

Management and Schedule

- Cost estimates are based on the original 805 Mhz LLRF project

- Preliminary Cost Estimate

WBS	Name	Esc SWF	Esc M&S	Cont
1.1.4	**200 Mhz LLRF Upgrade**	**$547,909**	**$131,970**	**100%**
1.1.4.1	**200 Mhz LLRF Engineering**	**$387,537**	**$0**	**100**
1.1.4.1.1	200 Mhz LLRF Modeling	$68,194	$0	**100%**
1.1.4.1.2	200 Mhz LLRF Engineering	$319,343	$0	**100%**
1.1.4.1.3	200 Mhz LLRF Design Review	$0	$0	**0%**
1.1.4.2	**200 Mhz LLRF Procure/Assy/Test/Install**	**$136,560**	**$131,970**	**100%**
1.1.4.2.1	200 Mhz LLRF Procurement	$1,201	$131,970	**100%**
1.1.4.2.2	200 Mhz LLRF Assembly	$80,959	$0	**100%**
1.1.4.2.3	200 Mhz LLRF Testing	$29,710	$0	**100%**
1.1.4.2.4	200 Mhz LLRF Installation	$24,691	$0	**100%**
1.1.4.3	200 Mhz LLRF Commissioning	$23,811	$0	**100%**
1.1.4.4	200 Mhz LLRF Installation Complete	$0	$0	**0%**

Management and Schedule

Uniq	WBS	Name	St	Fin	%	Float
459	1.1.4	LLRF Upgrade	9/ 1/ 05	7/ 11/ 07	0%	59 d
460	1.1.4.1	LLRF Modeling	9/ 1/ 05	3/ 6/ 06	0%	185 d
468	1.1.4.2	LLRF Engineering	10/ 3/ 05	9/ 29/ 06	0%	59 d
712	1.1.4.3	LLRF Procurement	10/ 2/ 06	2/ 5/ 07	0%	59 d
713	1.1.4.4	LLRF Assembly	2/ 6/ 07	4/ 2/ 07	0%	59 d
714	1.1.4.5	LLRF Testing	11/ 30/ 07	5/ 31/ 07	0%	59 d
715	1.1.4.6	LLRF Installation	8/ 6/ 07	8/ 31/ 07	0%	59 d
718	1.1.4.7	LLRF Commissioning	9/ 4/ 07	10/ 1/ 07	0%	59 d
716	1.1.4.8	LLRF Install. Compl.		10/ 1/ 07	0%	59 d

Risks

- The Cavities May not easily respond in 2μsec.
  - We have begun studies of this on the RF Test Station
- The Operation of the RF System may not support using the driver to make up the final 1 to 2% amplitude regulation
  - The Modeling will address this and we have begun studies of this on the RF Test Station

Conclusions

- This project will enhance linac performance and increase booster output by 5 to 10 %.
- At the intensities being run today by the Linac and Booster any change in linac energy or energy spread is seen as a booster loss.
- Linac is accelerating more beam than Booster is using therefore making unnecessary linac losses.
- The new LLRF system will reduce both effects.

Q PS Goals and Technical description

- Over the last year a study was done to cost and design a new Quad Power Supply for the Low Energy Linac.
- After reevaluating the cost/benefit of the new supply it was decided scale the project back and only update the control cards in the current QPSs.
- Linac Quad Power Supplies account 5% of the linac downtime.
- Most of the incidents involve the PC cards that control the supply

QuickTime™ and a
Photo - JPEG decompressor
are needed to see this picture.

P5 Timing Card and P7 Input Card

Q PS Goals and Technical description

- It has been decided to replace seven cards. We will design and have the cards fabricated one at a time starting with the Timing Card.
- Timing of the current pulse moves with changes of Amplitude. New timing card will address this problem and reliability issues
- Newer technology will provide better amplitude regulation
- Order of upgrades for other cards not yet decided. Looking at reliability data.

QPS Management and Risk Analysis

- We propose that the upgrades be designed by a combination of EE Support and Linac Group personnel.
- Cards will be fabricated by an outside vendor.
- Preliminary Cost Estimate and Schedule

WBS	Name	Start	% Finish	Float	Compl	Esc/Burd Labor	Esc M&S	
1.1.2.2	QPS Update	9/1/05	8/17/07		0%	$161,508	$155,208	Cont. %
1.1.2.2.1	QPS Design	10/3/05	6/7/06	72 d	0%	$98,636	$0	100%
1.1.2.2.2	QPS Drafting	2/2/06	7/7/06	72 d	0%	$36887	$0	100%
1.1.2.2.3	QPS Procurement	4/3/06	11/28/07	72 d	0%	$0	$191,124	100%
1.1.2.2.4	QPS Test	12/18/06	12/14/07	72 d	0%	$22,399	$0	100%
1.1.2.2.5	QPS Install	01/23/07	1/18/08	72 d	0%	$3,586	$0	100%
1.1.2.2.6	QPS Completion		1/18/08	72 d	0%	$0	$0	0%

QPS Management and Risk Analysis

- Because of the work done on the design for a new power supply and limited scope of the upgrades, we don't expect any undue risks.

- We will build spares to account for failures.

Conclusions

- Replacing the control cards in the Linac Quad Power Supplies will provide two improvements.
  - Reliability will be enhanced as most of the QPS failures are due to the control cards.
  - Performance will be enhanced because there will be improvements in timing and amplitude stability.