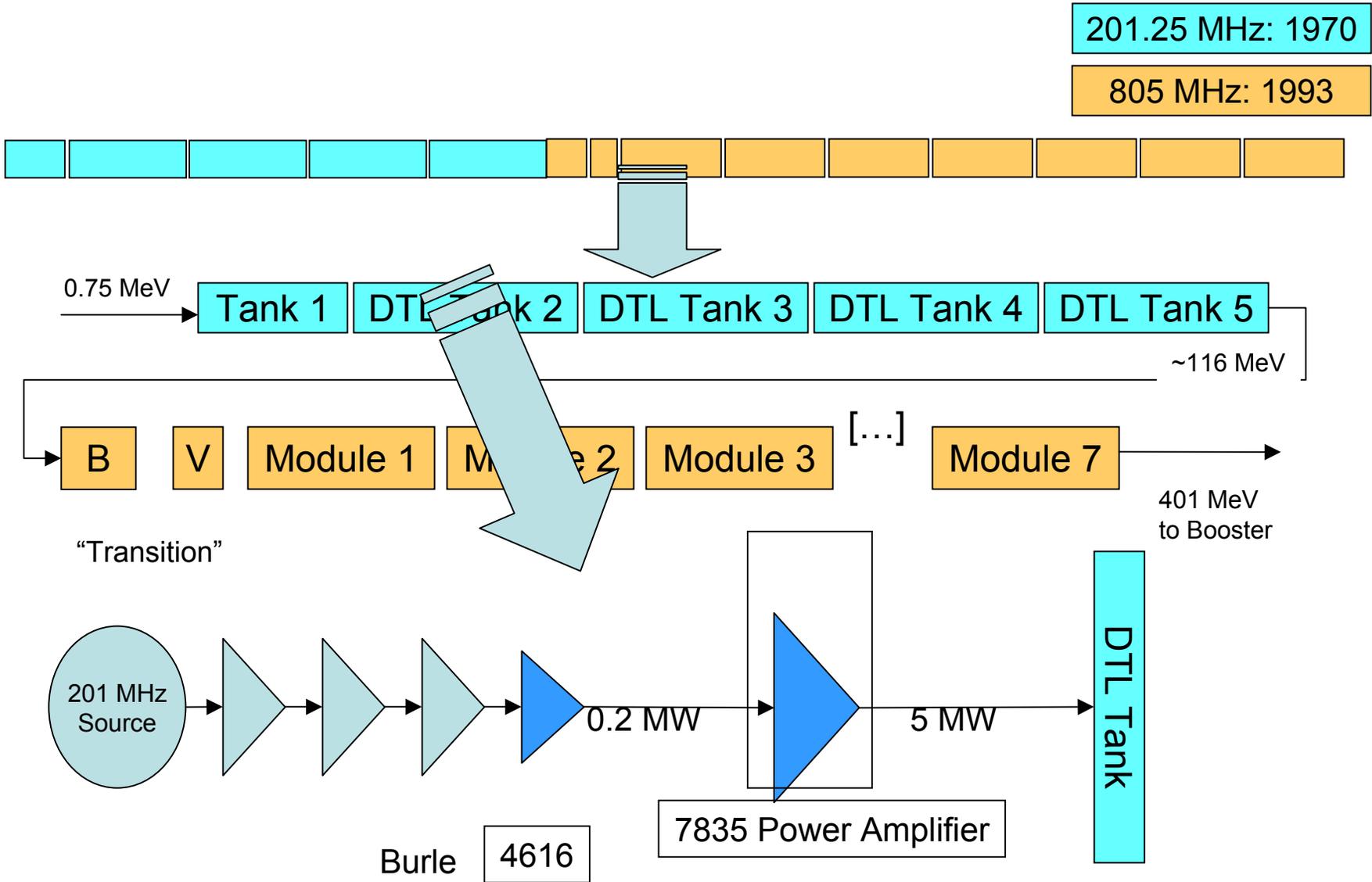


# 7835 Vulnerability

By  
Rich Andrews

- The Motivation
- Phase 1 of the Charge
  - Tutorials and Discussions
  - Burle Plant visit
  - Recommendations
- Phase 2 of the Charge
  - Replacement Linac
  - Development of an alternate tube.
  - Recommendations
- Conclusions
  - Describe the three options
  - Explain the drivers of each
  - Lab needs
    - RF Engineering



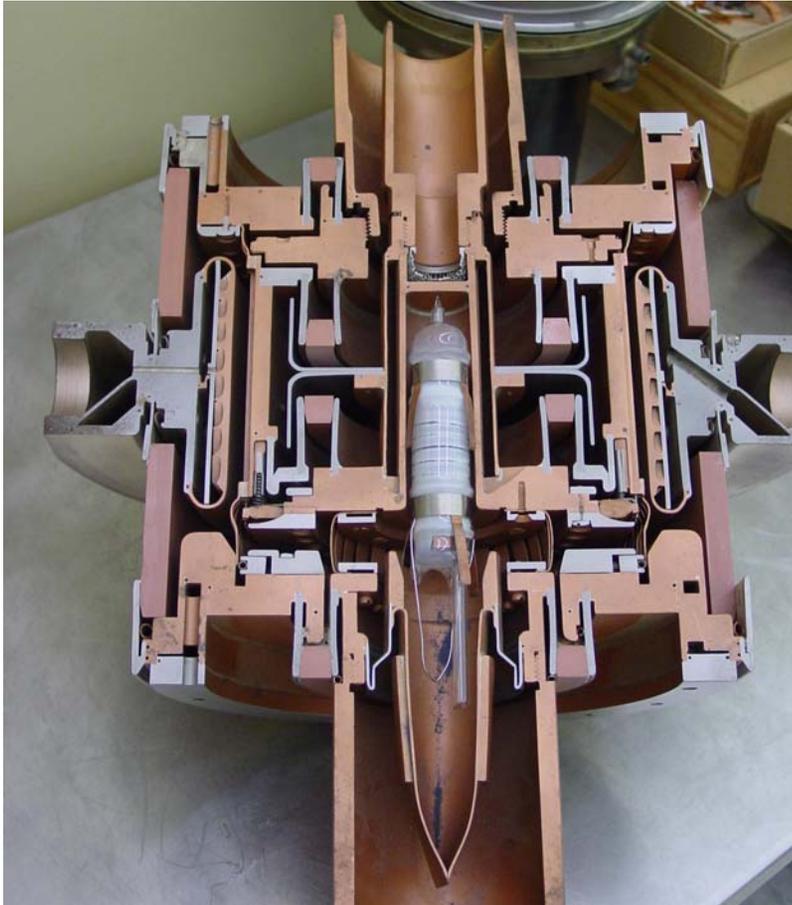
- The lifetime of the 7835 Vacuum Tube has diminished over the last several years.
- The manufacturer, Burle Industries Inc., has had an uncertain future
- There is no replacement tube for the existing RF System
- From the Proton Plan: “... The availability of replacement tubes has remained critical since the start of Run II. This lack of spares is a serious vulnerability, both in the immediate future and for the long-term viability of the experimental program”, and recommends to build up an inventory in the mid-term, and a study to recommend a specific plan of action for the long term

- Richard Andrews AD (Chairman)
- Dave Carlson BSS
- Paul Czarapata AD
- Elliott McCrory AD
- Joe Morgan BSS
- Ralph Pasquinelli AD
- Vincent LoDestro BNL

# Phase I

(or what's the problem with the  
7835 PA Tubes?)





- 5 MW, 201.25 MHz Power Amplifier, Model 7835
  - Matched 1 MW driver, model 4616
  - Original model 4617
    - Difference: Thoriated filament
- Burle Industries, Lancaster, PA
  - Spun off from RCA in 1987
- Remember: An average year is 8766 hours

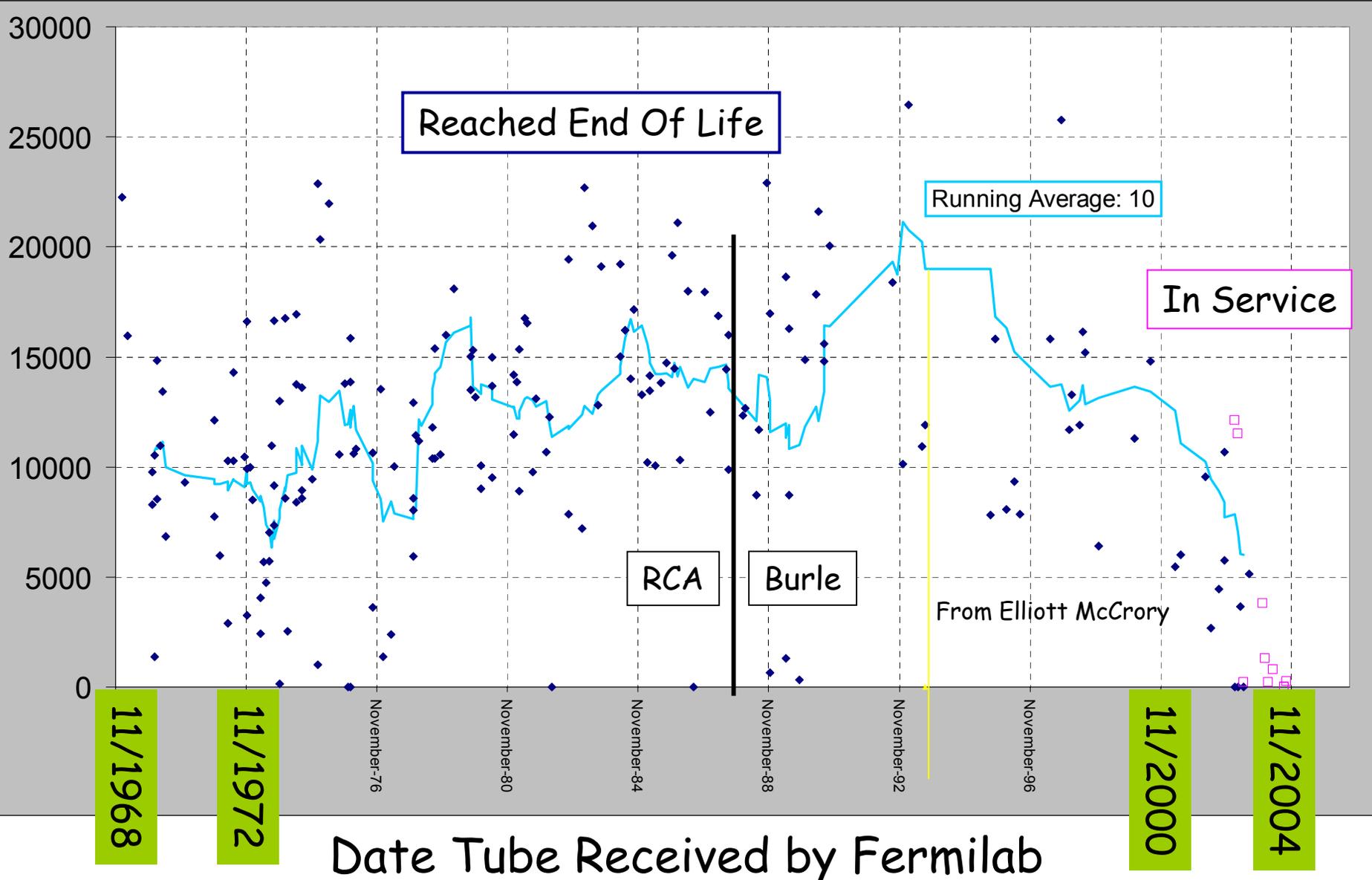
From Elliott McCrory

- First Meeting to initiate the Task Force (22DEC04)
- 3 More Meetings of Discussions and Tutorials
- Burle Plant visit (20JAN05)
- Two more meetings of discussions and creating a Preliminary Report
- Preliminary Report submitted (09FEB05)
- Fermilab acts on the recommendations (21FEB05)

- Costs
  - New: \$155,000
  - Rebuild: \$50k to \$120k
    - Num rebuilds: Have seen R9
  - Rebuild as good as new
  - ~1/5 attempts to rebuild fail
    - More or less independent of rebuild number
- Failures
  - Half fail due to emission limit
  - Half fail for other reasons
    - Water leaks
    - Irreparable sparks
      - We can repair some sparks locally
    - Vacuum failure

From Elliott McCrory

# Date Received vs. Hours to EOL



- Fermilab
  - 5 sockets; 8000 hours/year
- Brookhaven Lab
  - 9 sockets; ~4000 hours/year
- Argonne
  - 1 socket; <1000 hours/year
- Los Alamos
  - 5 sockets; ??
- Kwajalein Islands (DOD)
  - 4 sockets; 8000 hours/year??
  - 4617 model tube

From Elliott McCrory

- 20 Tubes In House:
  - 6 are installed in the Linac (1 in Cavity#7)
  - 2 are in Standby (installed in cavities)
  - 5 on the shelf spares (one w/ 11,542 hrs.)
  - 3 failed (2 at Burle for evaluation)
  - 4 at Burle in rebuild (3 in TC&A)
- 15 Tubes on Order:
  - 2 Operational Spares (due Jul and Aug)
  - 12 for Inventory (Insurance against Burle's uncertainty)
- Future Operational Needs:
  - 3 to be ordered near the end of the calendar year

- Burle has made a significant capital investment to improve their facility.
- Improved cleanliness and discipline in following procedures and specifications
- Notable improvement in equipment being used
- Updating of the technology being used in the process.
- Re-hired one of their very senior staff members
- Documenting all of the steps of production  
    Implement quality control measures
- Cross train individuals in each step of the process.

# Exhaust Station



This unit runs 24 hours/day and 7 days/week making it the limit in Burle's production rate of 2 tubes/month. They have procured most parts for a second station, but still must procure the controls. With a large order for 7835's, they will procure the parts and begin the assembly (likely date of completion: June of 2005.)

- Fermilab should purchase 8 tubes + option for 4 more
  - (FNAL placed an order for 12 tubes.)
- Require Burle to build the 2<sup>nd</sup> Exhaust Station as a condition of this contract.
- Give efforts to improve tube performance a priority with machine operations as follows:
  - Install the line conditioner on the first station
  - Accurately measure the current to the filament
- Address our own manpower issues
  - Testing
  - RF Engineering
- Make a follow up visit to Burle.

- Too early to tell for sure, but
- They are delivering close to their schedule,
- The Exhaust Station will be ready in late 2005
  - (initial estimate was: complete in June '05)
  - Concerned that this might affect 12 tube delivery
- Rebuild of the Lindbergh Furnace
  - Repairs further delayed when vendor delivered wrong heaters.
  - Heaters were re-ordered, and repairs are expected to be completed by the end of July 2005 (now Aug'05)

- BURLE was acquired by a French company called Photonis Holding SAS, earlier this month.
  - The Power Tube group will continue to remain as a business unit within this company. There are no anticipated changes regarding Power Tube and this acquisition.
  - Everything will be the same in Lancaster for the foreseeable future.
- The head of the Power Tube business unit, Ron Minnier, and Bob Rutherford plan on visiting Fermilab within the next two weeks to explain the acquisition and answer any questions.
  - Bob will let us know when they would like to visit.
  - Ron has been with the company for 35+ years and has been running our factory for a significant portion of that time.

Test stand Date	7835 Serial #	Pulsed Eanode KV	Pulsed lanode Amps	7835 Z Ohms	Ion Pump current uAmps	7835 Power out MegaWatts	RF7 Condition time HRS	Total Filament HRS	7835 Filament AMPS	Power input (calculated) MegaWatts	Comments [location]
06-12-91	A2R3	22.5	220	102.3	-	3.50	?	17973		4.95	Cannot find original data to support this tube
09-30-92	X2R5	22.0	218	100.9	-	3.50	?	?		4.80	Cannot find original data to support this tube
02-23-93	X12R7	22.0	210	104.8	-	3.80	?	1296		4.62	Cannot find original data to support this tube (This tube was gassy & sent back)
05-17-93	J3R2	25.0	210	119.0	-	3.50	?	10116		5.25	Cannot find original data to support this tube
02-24-94	P2R2	23.6	225	104.9	-	4.00	?	26466		5.31	Cannot find original data to support this tube
09-14-94	C2R3	22.6	225	100.4	-	3.50	?	10914		5.09	Cannot find original data to support this tube
02-22-95	A1R6	23.0	223	103.1	-	3.50	?	11914		5.13	Cannot find original data to support this tube
03-04-98	X2R6	30.3	269	112.6	-	5.00	417	15782	6800	8.15	
04-15-98	C2R6	31.0	265	117.0	-	5.00	?	13264	6690	8.22	
07-01-98	A27R5	29.6	270	109.6	-	4.90	524	25773	6668	7.99	
08-25-98	N16R7	31.3	271	115.5	-	5.00	826	12513	4684??	8.48	
03-05-99	A1R7	31.4	272	115.4	-	5.00	370	6410	6800	8.54	
04-29-99	P1R2	32.0	262	122.1	-	5.00	?	11896	6570	8.38	
12-21-99	A20R7	32.0	260	123.1	-	4.94	?	18611	6650	8.32	
07-19-00	X12R8	30.3	241	125.7	-	4.52	84	15202	6620	7.30	
08-01-00	P2R3	30.0	266	112.8	-	5.00	848	11305	6600	7.98	
07-27-01	N14R6	30.5	250	122.0	-	4.80	418	14807	6715	7.63	
09-04-01	S10R6		230		-		140	5586	6800		Taken for service RF3 before prescribed break-in was completed
09-17-01	P7R8	30.0	290	103.4	-	5.10	333	5918	6700	8.70	
04-09-02	K7R2	28.5	260	109.6	-	4.50	189	9540	6725	7.41	
06-11-02	J2R5	28.0	260	107.7	-	4.40	123	2664	6700	7.28	
09-06-02	Y3R9	26.0	225	115.6	-	3.70	110	4425	6740	5.85	
11-26-02	Y2R7	30.0	246	122.0	-	4.40	317	5842	6752	7.38	
12-16-02	A1R8	27.7	270	102.6	-	4.50	437	11149	6710	7.48	
04-08-03	A27R6	28.0	260	107.7	-	4.50	73	11542	6750	7.28	[spare]
06-24-03	BK1	28.7	253	113.4	1.1	4.50	211	214	6600	7.26	[at Brookhaven] This tube has ODD tuning. Awaiting testing at Brookhaven
09-04-03	BK3	26.0	240	108.3	8.6	4.00	36	6828	6600	6.24	[at Burle] Never finished conditioning because shutdown & no water (installed RF5)
11-17-03	P2R4	28.0	270	103.7	2.9	4.60	182	6000	6700	7.56	
02-10-04	N16R8	30.0	257	116.7	0.5	4.70	106	8814	6750	7.71	[in RF2]
02-25-04	A30R6	30.0	238	126.1	16.5	4.50	180	6404	6750	7.14	[in RF1]
06-11-04	A2R4	30.0	280	107.1	25.7	4.87	202	6368	6700	8.40	
11-03-04	BH4 *	25.7	253	101.6	2.0	4.00	382	5761	6750	6.50	[in RF3] First tube without a getter
12-03-04	S10R7 *	26.8	250	107.2	4.0	4.00	602	603	6750	6.70	[spare]
01-19-05	BH5 *	27.9	281	99.3	1.1	4.70	169	2540	6750	7.84	[in RF5] Notes indicated tube needed further conditioning but was installed because it was needed
02-09-05	N27R8	28.5	245	116.3	51.0	4.20	62	62	6750	6.98	[spare]
02-16-05	AZ4R1 *	27.0	276	97.8	28.0	4.50	348	348	7000	7.45	[spare] Tube appears weaker than some
03-16-05	N14R7	30.0	238	126.1	45.0	4.00	216	364	7010	7.14	[in RF4] This wimp has a getter, it sucks anyway. This was the highest power we pushed
05-25-05	BV2	28.5	302	94.4	32.0	5.00	84	85	6750	8.61	[at Argonne] A wonderful mistake was made, this tube has balls, best one in years
06-13-05	A20R8	30.6	245	124.9	15.0	4.12	220	219	6800	7.50	[spare] Tube looks like another wimp
07-15-05	BV3	29.0	296	98.0	3.5	5.06	212	212	6750	8.58	[in RF7] This is another wonderful mistake. Not as good as BV2, but still good.

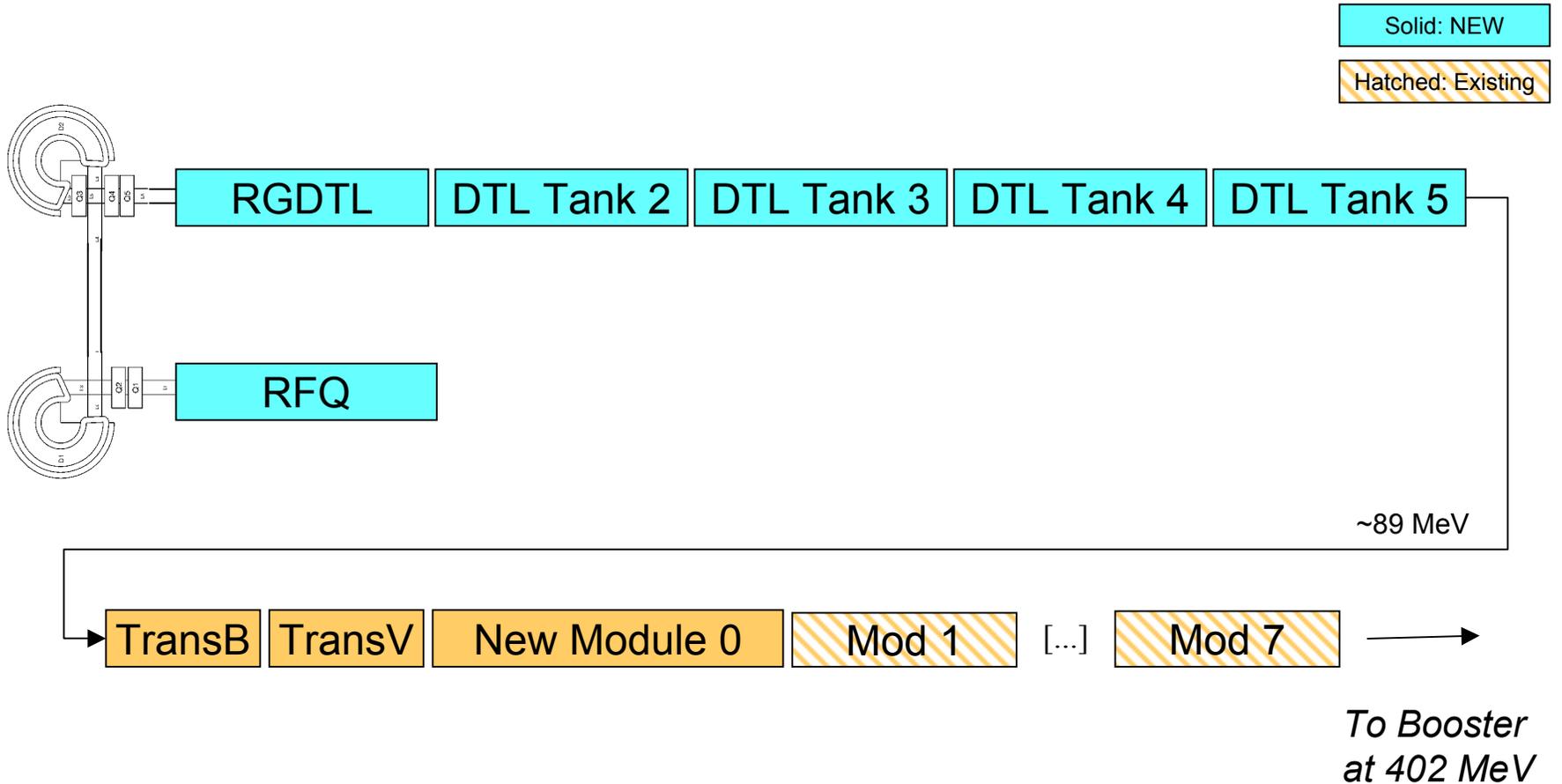
All readings taken from Fermilab 7835 conditioning log book. Ultimate lifetime can be found in Ray's Operating Tube reports.  
 There was no established data recording before 1999, so some readings may be missing, or data may not be able to be correlated properly.  
 Data entries in this document were [mostly] complete to the point of comparison with other tubes.  
 Some tube data was omitted entirely. Logbook test entries were extensive and not included except for summary comments. (Sarcasm extra)  
 In cases where NO ion pump current is indicated, prescribed time duration conditioning process was used.  
 \* denotes NO GETTER

- The 7835 needs continuous oversight including:
  - Hold Burle to their schedule
  - Give feedback to Burle about performance and testing results
- Periodically install one of the newly delivered tubes that has passed the inspection testing to measure performance improvements.

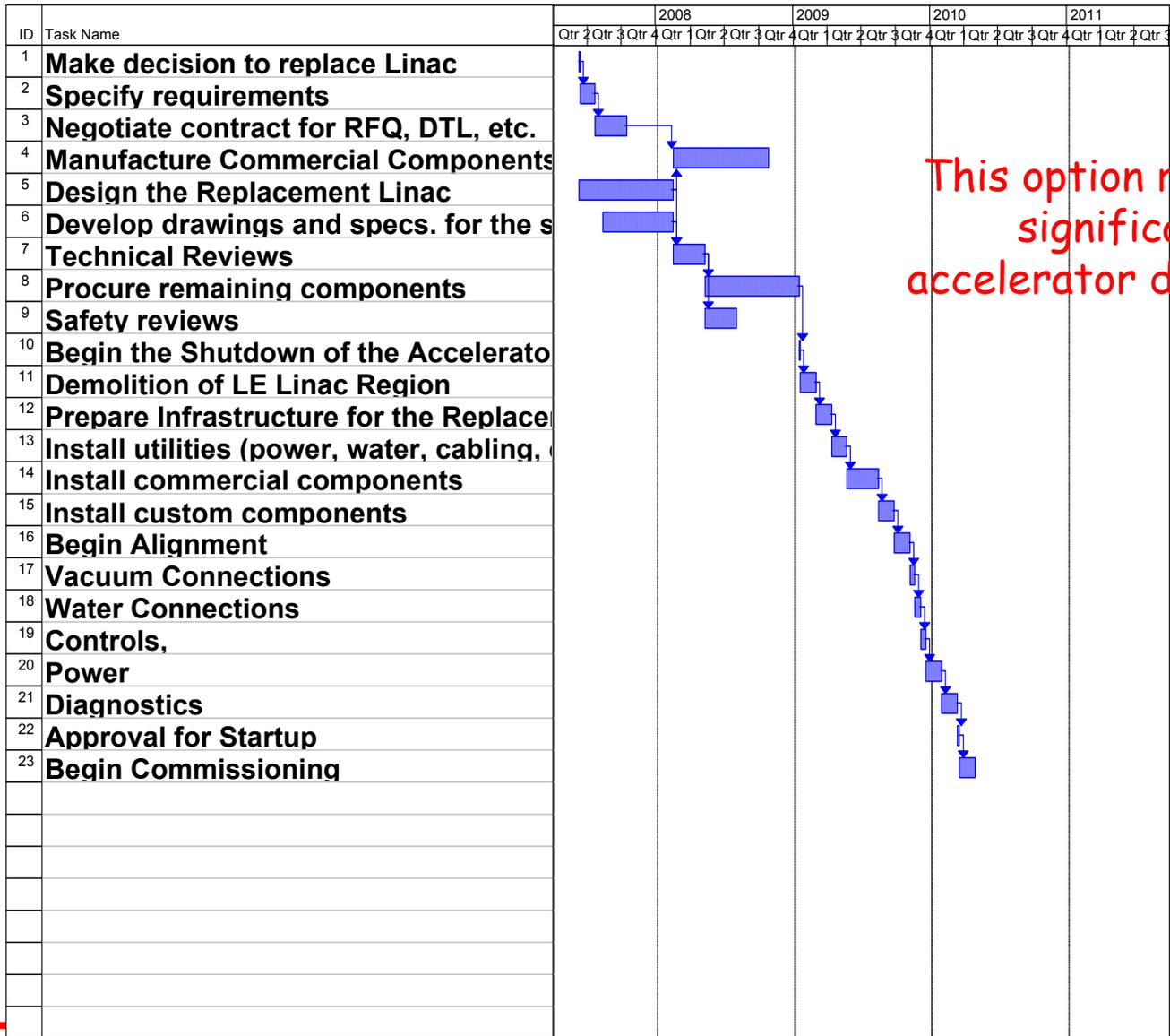
## Phase II

(or what do we do if Burle tubes are no longer an option?)

# Replace the Low Energy Linac



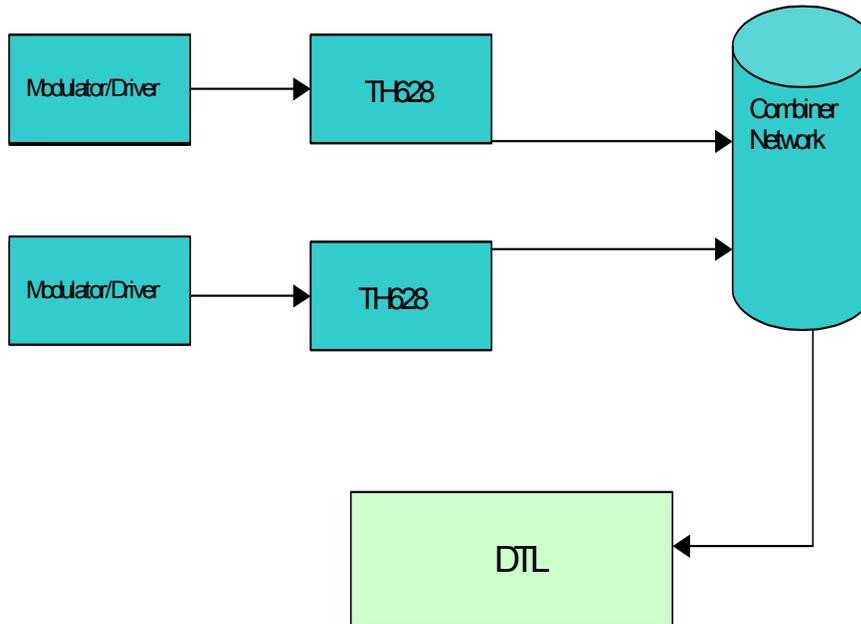
"Silver" version of Low-Energy Linac Upgrade									
Item	Unit\$	Num	Cost	Base w/ Indirects			Contingency	Total	Notes
				M&S (17%)	Labor (40%)	Total			
R&D Contract with AccSys	\$ 100	1	\$ 100	\$ 17		\$ 117	20%	\$ 140	FY04 R&D on this idea
AccSys RFQ	\$ 750	1	\$ 750	\$ 128		\$ 878	25%	\$ 1,097	Standard PL-7 Linac from AccSys
AccSys RGDTL	\$ 750	1	\$ 750	\$ 128		\$ 878	25%	\$ 1,097	Standard PL-7 Linac from AccSys
MEBT, including double alpha	\$1,000	1	\$ 1,000	\$ 170		\$ 1,170	30%	\$ 1,521	Physicist Estimate
402 MHz DTL cavities	\$1,900	5	\$ 9,500	\$ 1,615		\$ 11,115	35%	\$ 15,005	Extrapolation from AccSys cost estimate
402 MHz RF Systems	\$1,400	7	\$ 9,800	\$ 1,666		\$ 11,466	35%	\$ 15,479	Based on AccSys data
SCC Matching Section modules	\$ 375	0	\$ -	\$ -	\$ -	\$ -	30%	\$ -	Based on 1993 actual costs, escalated
805 MHz RF systems for Transition	\$1,500	0	\$ -	\$ -	\$ -	\$ -		\$ -	Reuse existing transition RF systems
New SCC module(s) to 116 MeV	\$1,500	0	\$ -	\$ -	\$ -	\$ -	50%	\$ -	Based on 1993 actual costs, escalated
New SCC module(s) at 400 MeV	\$1,500	0	\$ -	\$ -	\$ -	\$ -		\$ -	Silver version: No additional tanks
New 805 MHz rf systems	\$1,500	0	\$ -	\$ -	\$ -	\$ -	50%	\$ -	Based on 1993 actual costs, escalated
Controls, diagnostics, infrastructure	\$1,000	1	\$ 1,000		\$ 400	\$ 1,400	50%	\$ 2,100	SWAG, but based on 1993 experience
Pre installation			\$ 1,000		\$ 400	\$ 1,400	50%	\$ 2,100	Using experience gained from 1993
Installation & Commissioning			\$ 3,000		\$ 1,200	\$ 4,200	50%	\$ 6,300	Physicist Estimate
Removing old 201 MHz Tanks			\$ 1,000		\$ 400	\$ 1,400	50%	\$ 2,100	Physicist Estimate
Building modifications			\$ 500	\$ 85		\$ 585	50%	\$ 878	Physicist Estimate
<b>Total, FY 2002\$</b>		3	<b>\$ 28,300</b>			<b>\$ 34,491</b>		<b>\$ 47,677</b>	<b>FY 2002 \$</b>
EDIA			\$ 1,415			\$ 35,906		\$ 49,092	FY 2002 cost w/ EDIA
Inflation/year		4%	\$ 31,834			\$ 40,389		<b>\$ 55,221</b>	Scale to FY05 \$ (4% inflation)



Replace this:

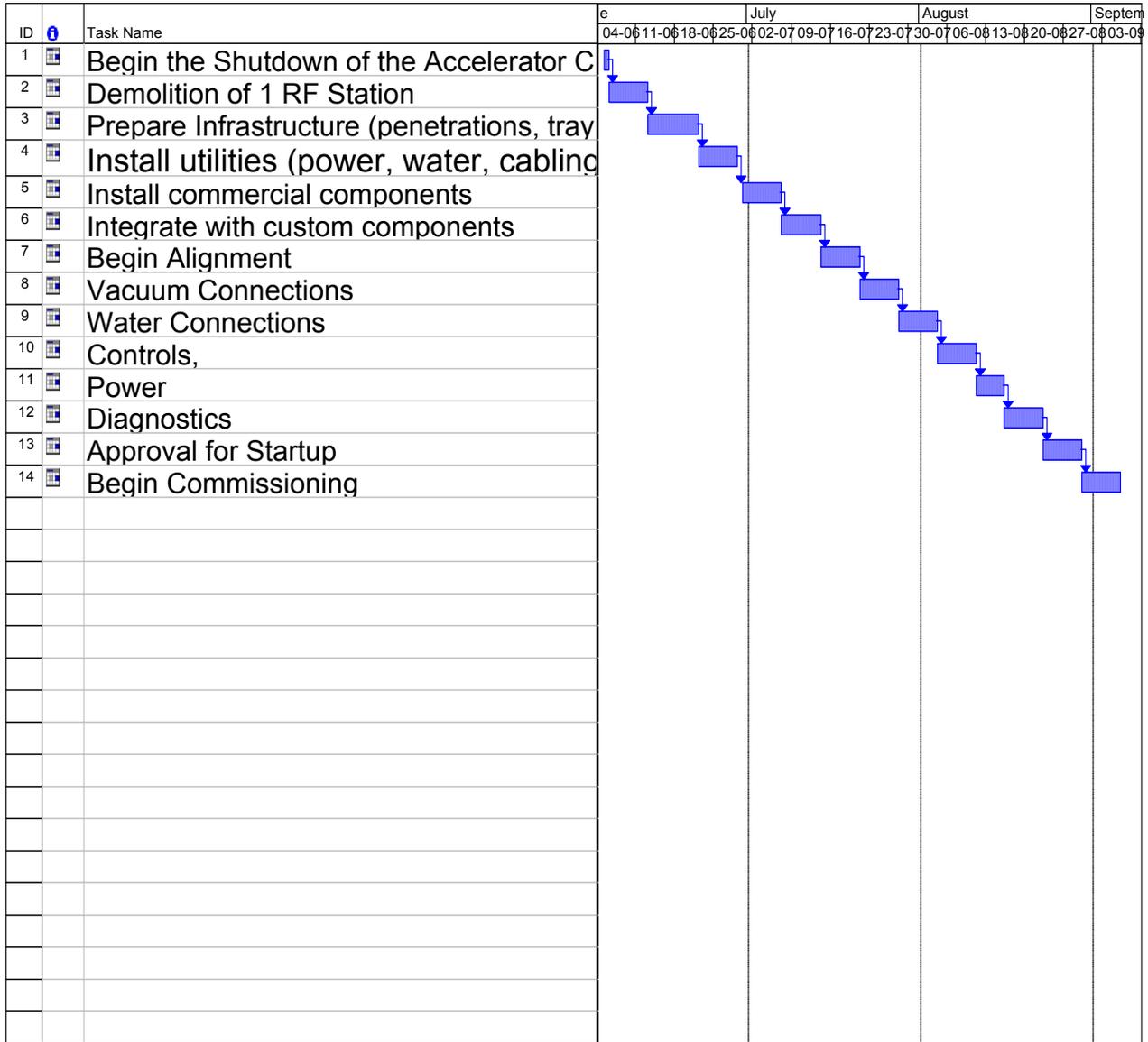


With this:

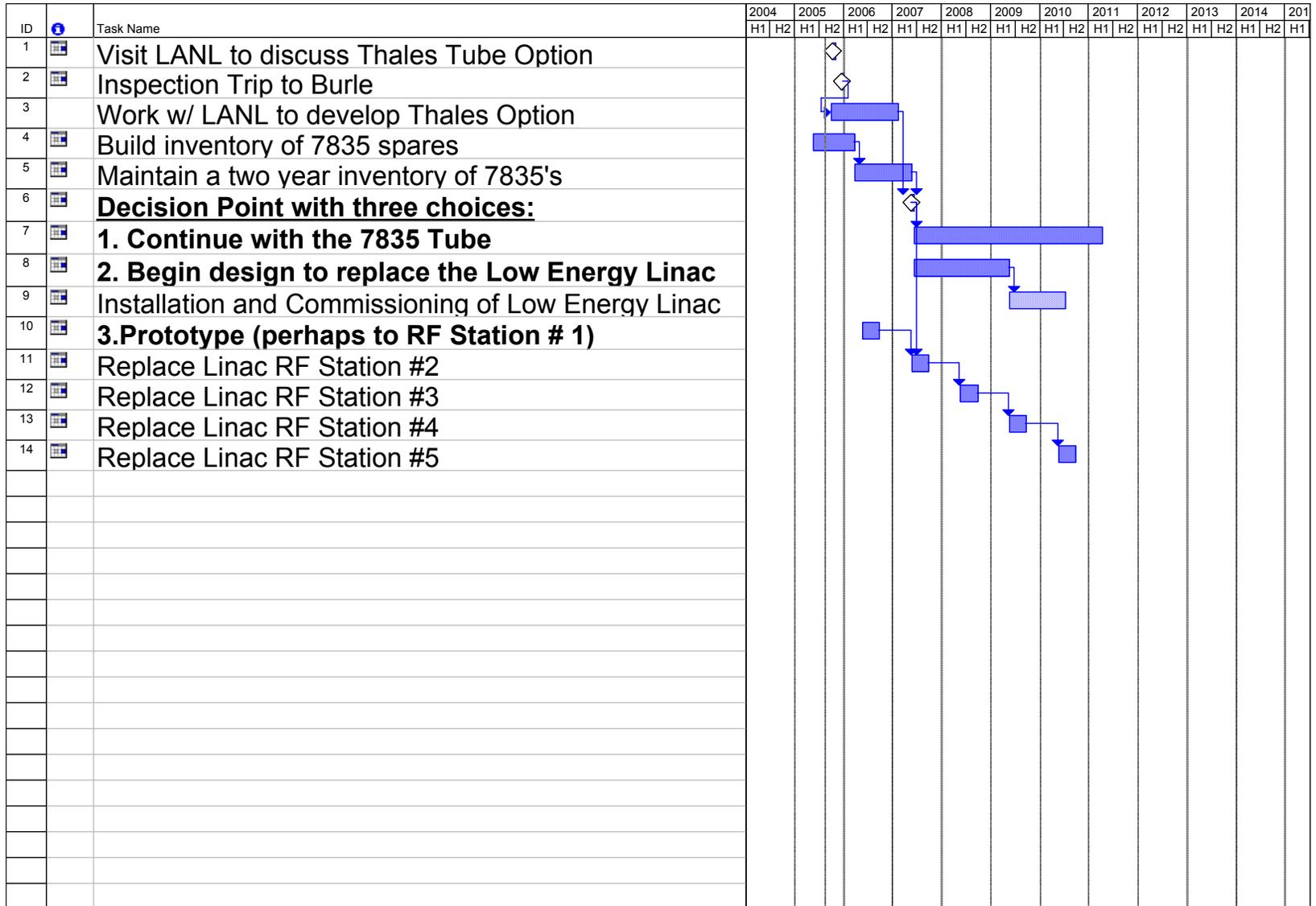


Thales Tube Replacement (TH628)									
Item	Unit(K\$)	Num	Cost	Base w/ Indirects			Contingency	Total	Notes
				M&S (17%)	Labor (40%)	Total			
Modulator/Power Supply	500	10	5000	850		5850	40%	8190	Discussion w/ Elliott
Drivers	500	10	5000	850		5850	40%	8190	Discussion w/ Elliott
Thales Tube (TH628)	175	10	1750	297.5		2047.5	30%	2661.75	Vendor Quote
Combiner Network	100	5	500	85		585	30%	760.5	Vendor Quote
Controls, Diagnostics and other infrastructure	1,000	1	1000		400	1400	50%	2100	Engineering Estimate
Installation and Commissioning			1,500		600	2100	50%	3150	Engineering Estimate
Removing old driver system, building modifications	500	1	500		200	700	50%	1050	Engineering Estimate
<b>Total, FY 2002\$</b>		3	<b>\$ 15,250</b>			<b>\$ 18,533</b>		<b>\$ 26,102</b>	<b>FY 2002 \$</b>
EDIA			\$ 763			\$ 19,295		\$ 26,865	
Inflation/year		4%	\$ 17,154			\$ 21,704		<b>\$ 30,219</b>	Scale to <b>FY05 \$ (4% inflation)</b>

# Replace RF Station



# Decision Points



- The #1 choice by far, is to rely on the 7835 tube
- Continued close monitoring of Burle regarding the delivery of 7835's is a requirement
- Continued studies and modifications as necessary to improve tube lifetime.
- For assurance that we have a complete plan for continued operation of the Linac through 2010, Fermilab should work with LANL to develop an alternative Vacuum Tube solution.
- If the Accelerator Complex is to run well beyond 2010 for continued Neutrino Physics, the Low Energy Linac should be replaced. Assuming the ILC becomes operational for Physics by 2015, one would consider this choice, as it would assure reliable operations for Neutrino Physics to at least 2020.
- If there is a Proton Driver in Fermilab's future, then it may be prudent to replace the power tubes only for efficiently phasing to the new machine.

- Phase I (now through 2005)
  - Organize a smaller Task force to explore the Thales Tube option.
  - Can we develop an equivalent RF system with the Thales TH628 tube?
    - One tube/station or two tubes?
  - Can we work with LANL in a collaborative effort?
  - Objective (at this point) develop:
    - Feasibility
    - Budget and schedule
- Phase II (2006)
  - Build a prototype
  - Some money has been allocated, but needs the work of Phase I to determine the actual cost.

- Vinnie will speak to your engineers regarding the testing of BK1 at Brookhaven. The device still remains at BURLE.
- BK3 will ship in August.
  - It should leave BURLE by late next week (~19AUG05).
- Two new 7835's are also shipping in August.
  - This is PO 561089.
  - Parts delivery issues from a vendor made the delivery date slip. This has been corrected.
- TC&A's for C2R6 and N49R8 were completed a few weeks ago, and proposals forwarded to you.
  - To date, we do not have an order to rebuild either of these 7835's.
- 4616 S/N U8022R3 will ship in September.
  - There was a sub-assembly that required additional time to rebuild.
- Deliveries on the 12 piece order will start in October.
  - Some parts from vendors were late. This prevented us from starting in October.

- Lindberg Furnace Repair –
  - The company that was repairing the furnace had ordered incorrect heaters, then they ordered the incorrect quantity.
  - All of the correct heaters were received this week.
  - The repair company will complete the job next week (week of August 15<sup>th</sup>).
- Exhaust station –
  - The full stand and associated vacuum system and supplies have been completed and are in place...
  - The plumbing will be starting within the next two weeks,
  - The electrical work will begin by mid-September. The switching mechanism will then be installed so that manual mode operation can begin by the end of October.
  - The automation equipment is being finalized and that will be installed by the end of the year. The schedule for this exhaust station will not impact the delivery of your 7835's.

Joe,

Responding to your requests for Delivery Status on several orders, here is the latest info. –

1. PO 562585 – SN BK3            In-pro repair failure. Currently re-scheduled for Sep. 2005 delivery.
  2. PO 561069 – New Tubes        Two (2) tubes scheduled for Aug. 2005 delivery.
  3. PO 544985 – SN BK1            Will be shipped to BNL for testing when BNL is ready.
  4. PO 562967 – SN U8022R2      Delivery scheduled for Sep. 2005 or sooner, if possible.
  5. PO 562585 – SN A1R8            Delivery is now scheduled for Jul. 2005.
  6. PO 561069 – New Tube          One (1) tube is scheduled for Jul 2005 delivery.
  7. PO 562028 – 12 New Tubes      Deliveries are currently scheduled at 2 per month starting in Oct. 2005.
  8. PO 563829 – SN C2R6 and N49R6    Tubes received 29-Jun-2005. TCA(s) scheduled to be completed in July 2005.
  
  9. Lindberg Furnace Repair        Repairs further delayed when vendor delivered wrong heaters. Heaters re-ordered and repairs are expected to be completed by the end of July 2005.
  
  10. Sale of BURLE                    You should expect an official announcement very shortly.
- Robert J. Hatch  
Senior Contract Administrator