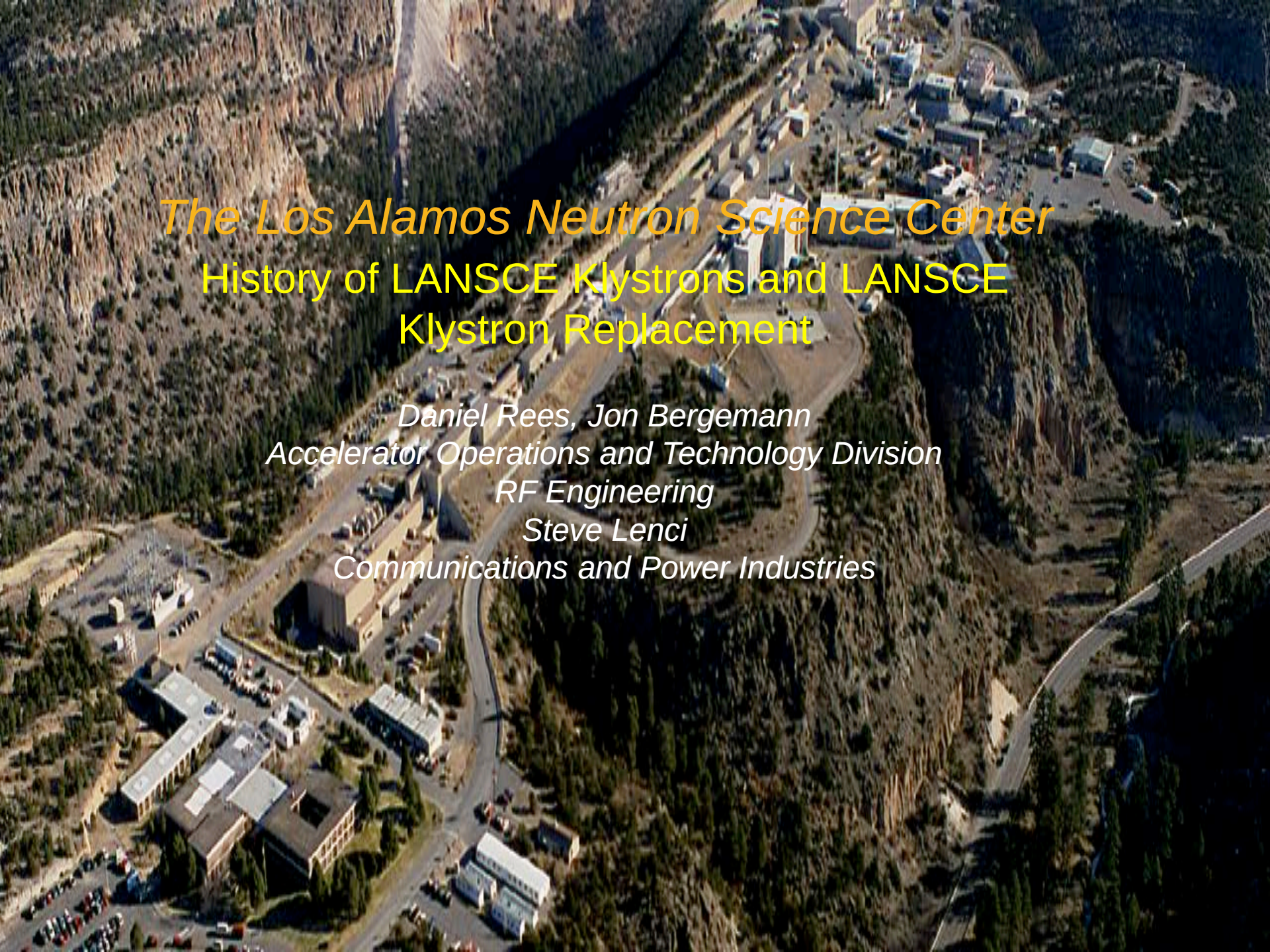

The Los Alamos Neutron Science Center

History of LANSCE Klystrons and LANSCE Klystron Replacement

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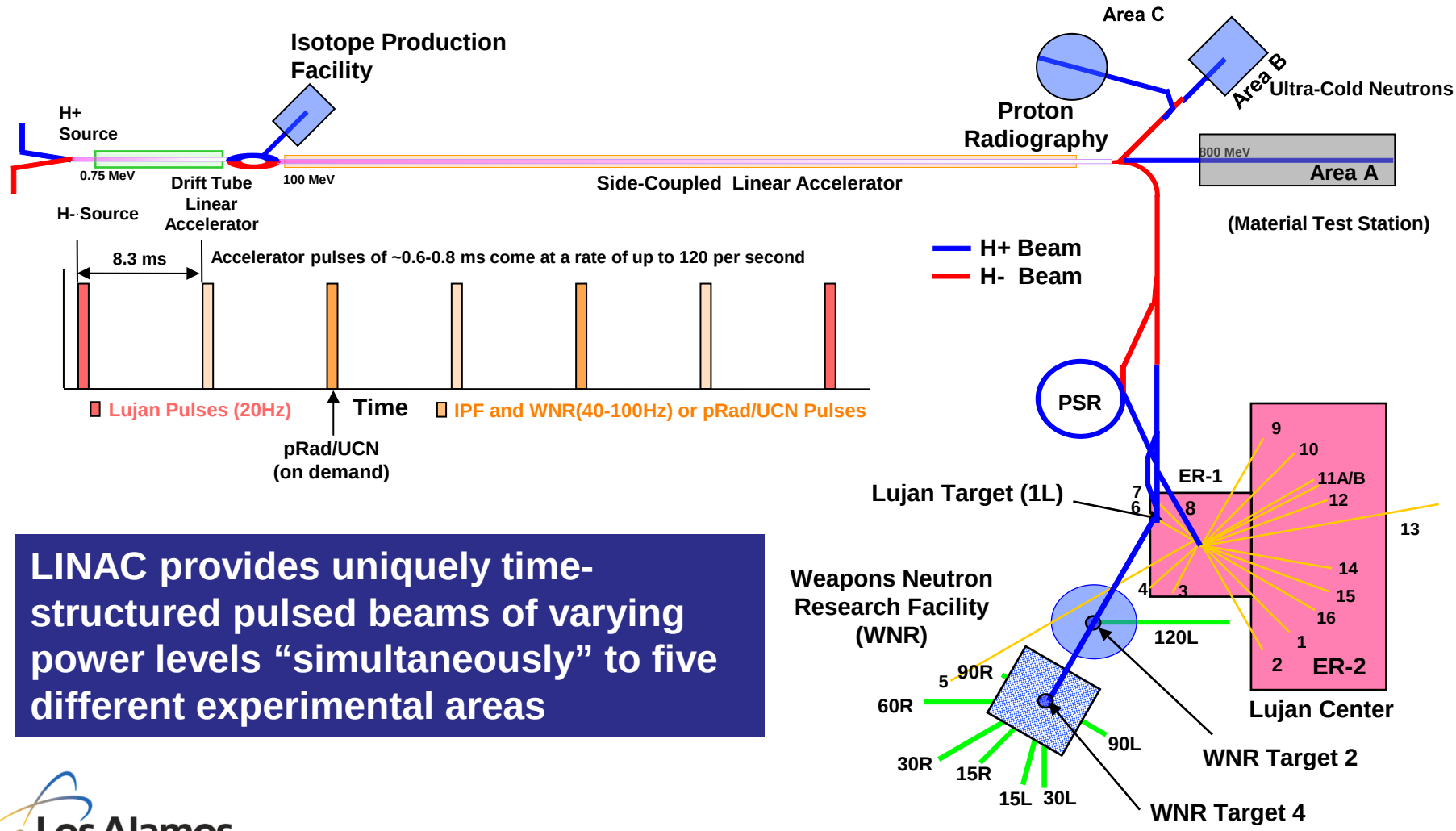
Outline

- LANSCE
- Klystron specification
- Original klystron order
- Bridging the gap to the 2009 klystron order
- 2009 klystron order
- 2009 klystron order results
- Current LANSCE klystron statistics

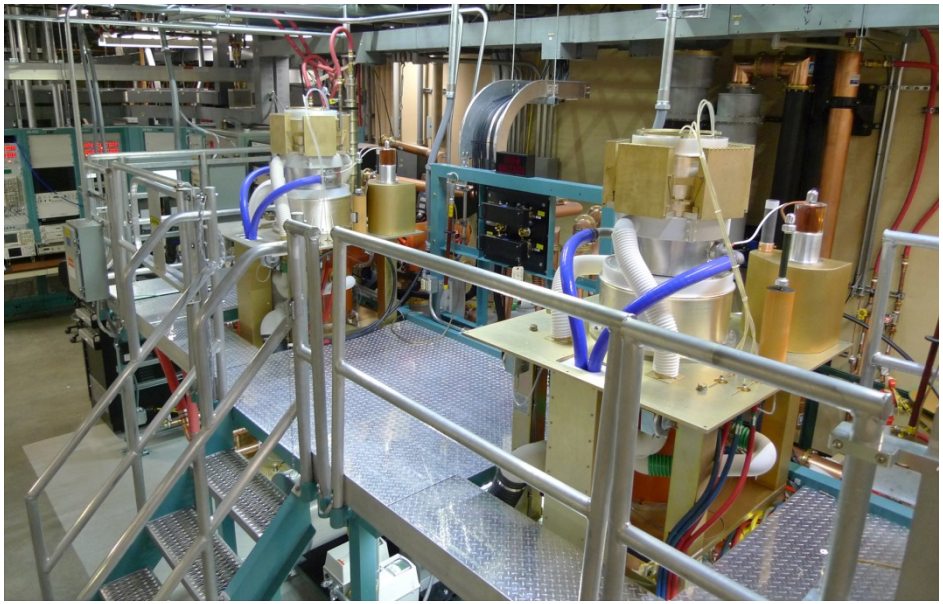
The heart of LANSCE is a very flexible 800-MeV proton linear accelerator (LINAC)



LINAC provides uniquely time-structured pulsed beams of varying power levels "simultaneously" to five different experimental areas

LANSCE RF Systems

4 – 201 MHz, 3.4 MW Gridded Tube Systems



44 – 805 MHz, 1.25 MW Klystron Systems

LANSCE Nominally Operates 120 Hz, 825 usec RF Pulses, 625 usec Beam Pulses

Klystron Specification

- 1.25 MW
- 805 MHz
- 120 Hz pulse repetition frequency
- 1000 usec pulse width
- 86 kV peak cathode voltage
- 33 A peak cathode current
- 44% minimum efficiency (purposefully low to allow stable operation without a circulator)
- 50 dB gain
- Power a resonant load with a Q of 20,000 and a steady state VSWR of 1.1:1 without a circulator

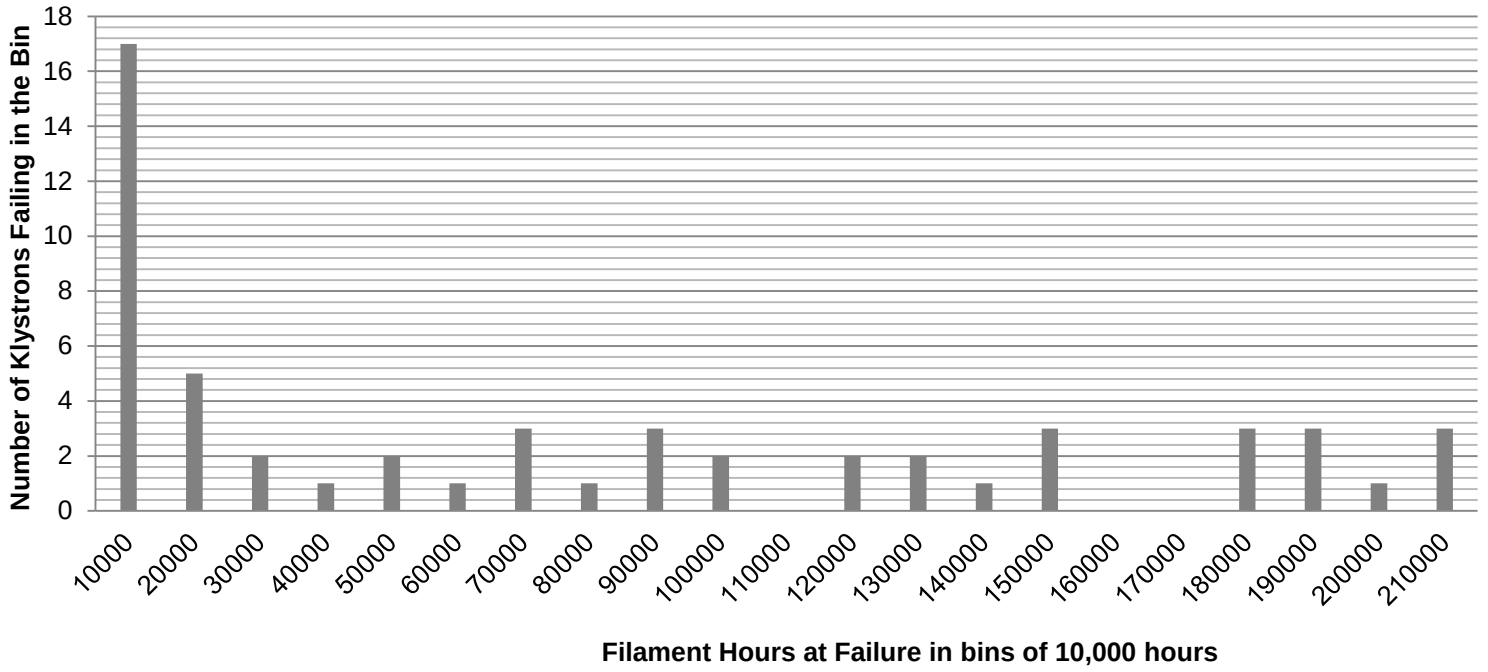
Original Klystron Order

- **Two Vendors**
- **Vendor A**
  - Delivered 70 klystrons
- **Vendor B**
  - Delivered 28 klystrons
- **Although built to the same specification, each klystron type has a unique transmitter requirements and output waveguide flange location.**
  - Our klystron gallery is spread across 7 building, each containing 6 or 7 klystrons
  - One building contains only vendor B klystrons
  - The others contain vendor A klystrons
  - Both klystrons use the same magnet

Bridging the gap - Our starting point for the 2009 order

- **2006 (operational) klystron statistics - when we proposed the order**
  - Average filament hours of the installed klystrons – 124 khr
  - Average filament hours of spare klystrons – 79 khr
  - 23 installed tubes with over 141 khr filament hours
- **Klystron statistics projected to the delivery of the first new klystron – projected at 2012**
  - Assumed 5 good rebuilds during the 2009 order process
  - Average filament hours of installed klystrons – 115 khr
  - Average filament hours of spare klystrons – 151 khr
  - 2 original spares left when we take delivery of the first new klystron

Vendor A Klystron Failures Binned in 10,000 hour Increments (old plus new) – Start of a Bathtub Curve



Average hours on failed klystrons – 71,712 filament hours
Average hours on failed klystrons, if the klystron survives first 13,000 hours – 110,000 filament hours

We have rebuilt all the excellent and good candidate tubes – future rebuilds will be on "low probability of success" klystrons

Good Candidates

Poor Candidates

Item	SN	B	LOC.	STAT	FIL HRS	HV HRS	LAST ACTION	COMMENTS	LANL Rebuild	Vac Failure	Emission/Arcing	RF Problem	Witnessed 8/05	Window Sleeve	Category	Comments	CPI Repair
1	219	0	p01	5	111904	94842	8/19/1999	one fil open,7, possible emergency use			X		X	SST	1	Reported to have lost vacuum at LANL. May have been a bad pump supply.	Gun, I/P Cav, Window 8/24/05
2	249	0	p05	5	53701	46269	8/10/1984	VAC FAILURE		X			X	K	1		Down to oil leak in Cav 1 bellows, at CPI
3	232	0	p03	5	87757	78491	4/16/2003	1,7, damaged by arc (concave cath button, vac leak), Hi lion, MA k arcs, possible emergency use		X			X	K	2	"Concave button" refers to heater cup on baseplate	Gun Rebuilt10/10/06
4	237	0	p07	5	98000	76000	8/21/1991	VAC FAILURE,		X			X	SST	2	Opened for leak check	Repl Gun, Window 11/10/06
5	**243**	0	p08	5	4405	3813	8/27/1991	VAC FAILURE, kovar,7?		X			X	K	2	Recd 7/08, Gun bent	
6	**247**	0	p08	5	45683	38219	11/18/1985	VAC FAILURE, kovar,7?		X			X	K	2	Recd 7/08	
7	**252**	0	p07	5	50000	40000	12/1/1989	VAC FAILURE,7?		X			X	K	2	Recd 7/08	
8	306	0	p02	5	63773	46536	4/13/1996	VAC FAIL, CATHODE BUTTON		X					2		Gun Window, 2/20/07
9	250	1	ts2	4	7691	7397	7/16/2004	rebuilt by CPI, vac problem		X			X	CU	2	Reported to have lost vacuum at LANL	Gun Window 4/24/2003
10	203	0	p10	5	124501	97720	2/21/1997	low gain, melted input connector,7				X	X	K	3		
11	208	0	p11	5	89832	74773	8/3/1997	cav 1 damaged or tuner broken,7				X	X	K	3		
12	216	0	p07	5	115831	92474	10/25/1994	VAC FAIL, MAG SHORTED,7?		X			X	SST	3		
13	231	1	p06	5	500	310	11/4/1996	LOW Perveance, ARCS,7	X		X		X	CU	3	Leak in weld at 5th cav - vac sealed?, Window replaced, Perv bad	
14	304	2	p03	5	42225	32931	5/7/2003	never recovered from col vane cleaning, vac fail while hi potting	X	X					3		
15	251	0	p05	5	8000	6000	12/5/1989	leak c1 water to vac, gun on 307		X			X	K	4	Opened, gun removed	
16	227	1	p11	5	119209	94472	11/19/1998	filament intermittant,7, possible emergency use	X		X		X	K	4		
17	101	2	p04	5	1246	818	10/16/1990	HI X-RAY,BURNS INPUT CABLE'7?	X			X	X	K	4		
18	103	2	p05	5	90501	65228	9/1/1994	VAC FAILURE, BURNED CATH,7?	X	X			X	K	4		
19	105	2	p11	5	1248	1161	11/1/1999	60 cycle problem,M/A CBs	X		X		X	K	4		
20	202	2	p05	5	36700	31750	12/17/1993	vac fail	X	X			X		4		
21	207	2	p10	5	11000	8000	6/18/2003	vac failure, cav 1 water passage	X	X			X	?	4		
22	210	2	p04	5	2495	1925	12/22/1982	LO EMISSION,2ND HARM CAVS,7?	X				X	SST	4		
23	233	2	p08	3	75614	65443	1/7/2004	marginal emission, 12.8v fil, low gain, lion 10ua,	X		X		X	K	4		
24	222	5	p09	5	2400	1560	9/2/2003	LOW GAIN, GLITCHES,7, possible emergency use if DC fil supply used, see ET2 log 9-2-03	X			X	X	?	4		
25	206	1	CPI	5	65966	60648	9/1/2004	being rebuilt at CPI, filaments opened in shipping							N/A	Returned 8/05, tested good	Gun 2/21/2003

Tube Life as a Function of Rebuild Number Vendor A – Original Order

- **These statistics include both failed and operating tubes, so the average life continues to increase**
- **Initial Life – Average 111,859 Filament Hours**
  - 20 Operating, 69 Failed
- **First Rebuild – Average 35,683 Filament Hours**
  - 7 Operating, 24 Failed
- **Second Rebuild – Average 63,780 Filament Hours**
  - 1 Operating, 14 Failed
- **Third Rebuild – Average 27,267 Filament Hours**
  - 1 Operating, 4 Failed
- **Based on this data and the cost of a rebuild, it is hard to make a life cycle cost justification for a rebuild if your budget allows for a bulk tube order.**

2009 Klystron Procurement Goals

- **Non competitive procurement**
- **Single Vendor – Based on life cycle costs**
- **Maintain the amazing life expectancy of the original design**
- **Fix problems with the original design**
  - Heater hum
- **Address evolutionary safety issues with the new procurement**
  - Engineered x-ray shielding
  - BeO RF window

Non Competitive Procurement (sole source) – Based on Risk Reduction and Life Cycle Costs

- **Limited to the original 2 vendor with well known, proven designs**
- **Source selected based on life cycle cost comparison**
  - Vendor A
    - 55% of the original klystron order still supports operations
    - Average demonstrated filament life of 102,105 hours
    - 26% of the currently operating tubes have had a major repair that involved vacuum
  - Vendor B
    - 21% of the original klystrons order still support operations
    - Average demonstrated filament life of 38,962 hours
    - 67% of the currently operating tubes have had a major repair that involved vacuum
- **Vendor A was selected**
- **The selected vendor was not told it was a sole source procurement during the bid process**

Preserving the reliability of the historical design

- **Specification limited the suppliers ability to change the design**
- **New tubes were built to the original drawing package**
- **New tubes have to run in the original solenoids**
- **Changes were allowed for outdated manufacturing techniques**
  - Heater wire replaced
  - Pinch off tube size changed
- **Design changed had to be reviewed and approved by the customer**
- **Design changes were required for the RF window and xray shielding**
- **Design changes were allowed that benefitted overall design**
  - Rubber hoses on body cooling changed to copper
  - Removed bronze from collector manifold
- **Testing requirements were expanded from the original specification**

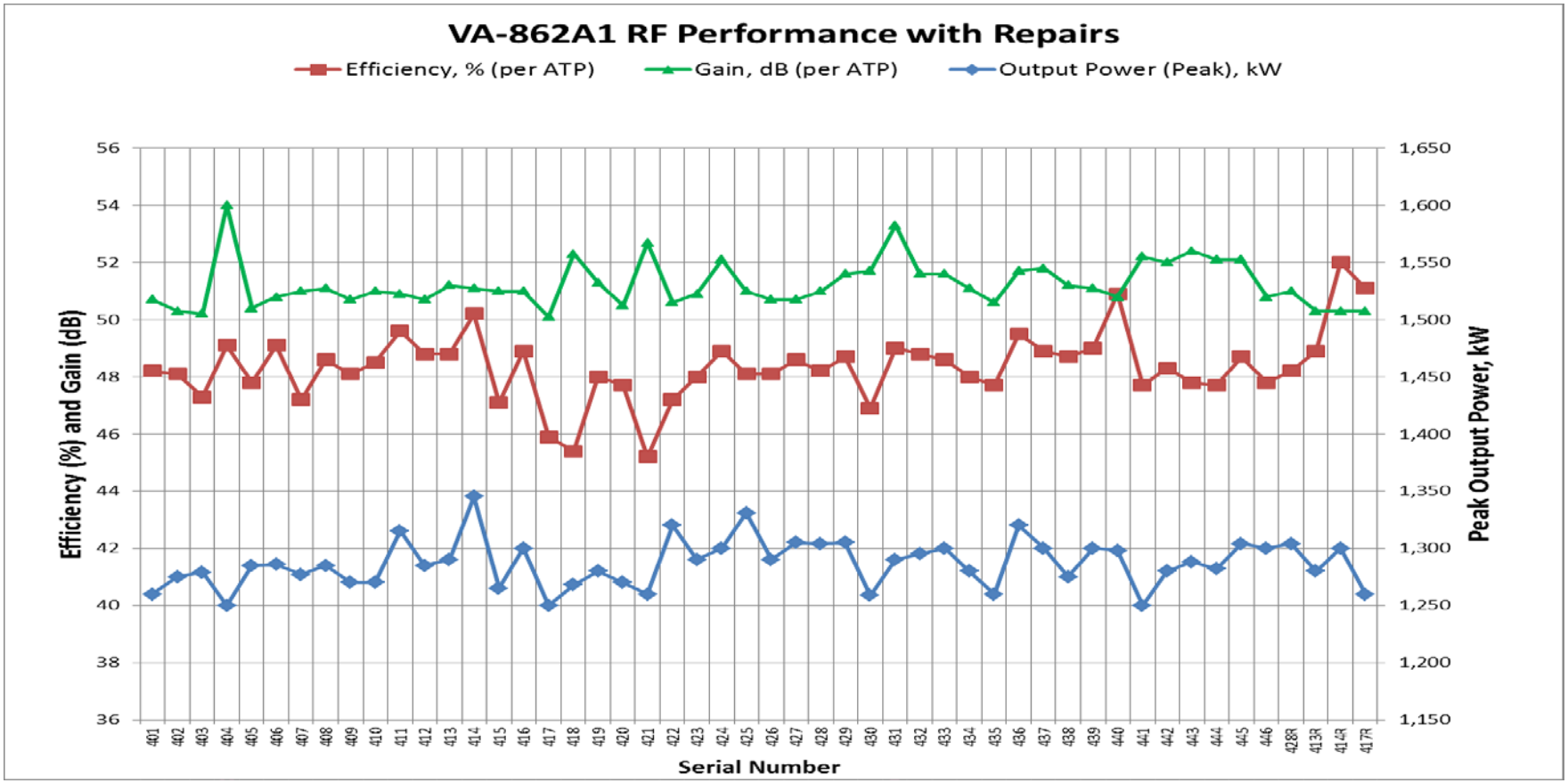
Schedule

- **Procurement took LANL buyer 13 months**
- **Prototype requested – 12 months ARO**
- **45 Production – 8 months ARO at a rate of 2 per month**
- **Prototype – Completed October 2011**
- **First Production – Complete January 2012**

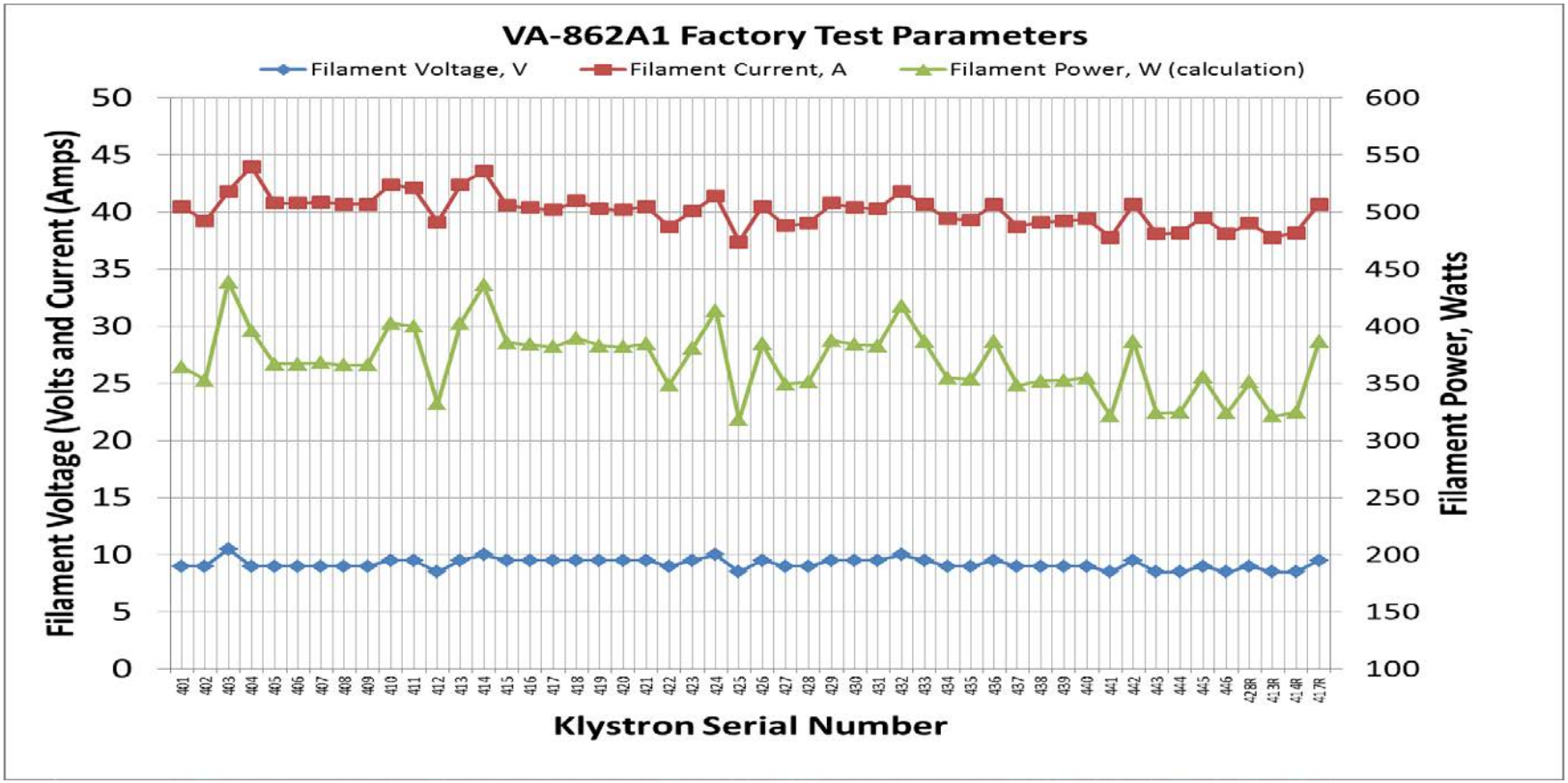
Observations Reguarding the Procurement

- The new klystrons are almost identical to the 1970's era klystron
- The 1970's klystron order lost 10 klystrons to infant mortality (< 7000 filament hours) – Around 15% mortality
- The latest order has had around 10% infant mortality which are being rebuilt under warranty
- Three of the new klystrons now have > 15,000 filament hours
- We are going to run the old klystrons till they drop then replace them with new

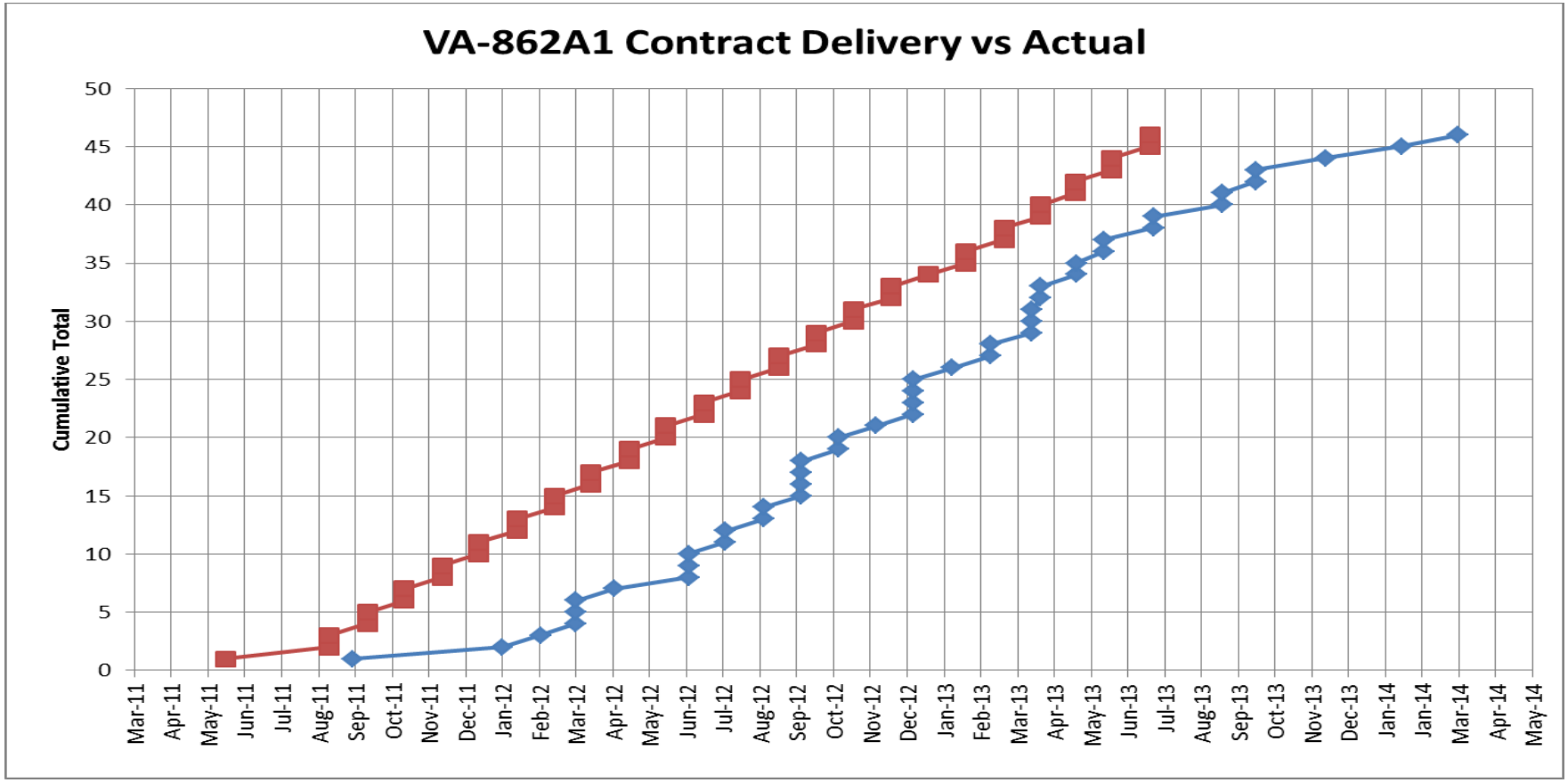
RF Consistency across the production



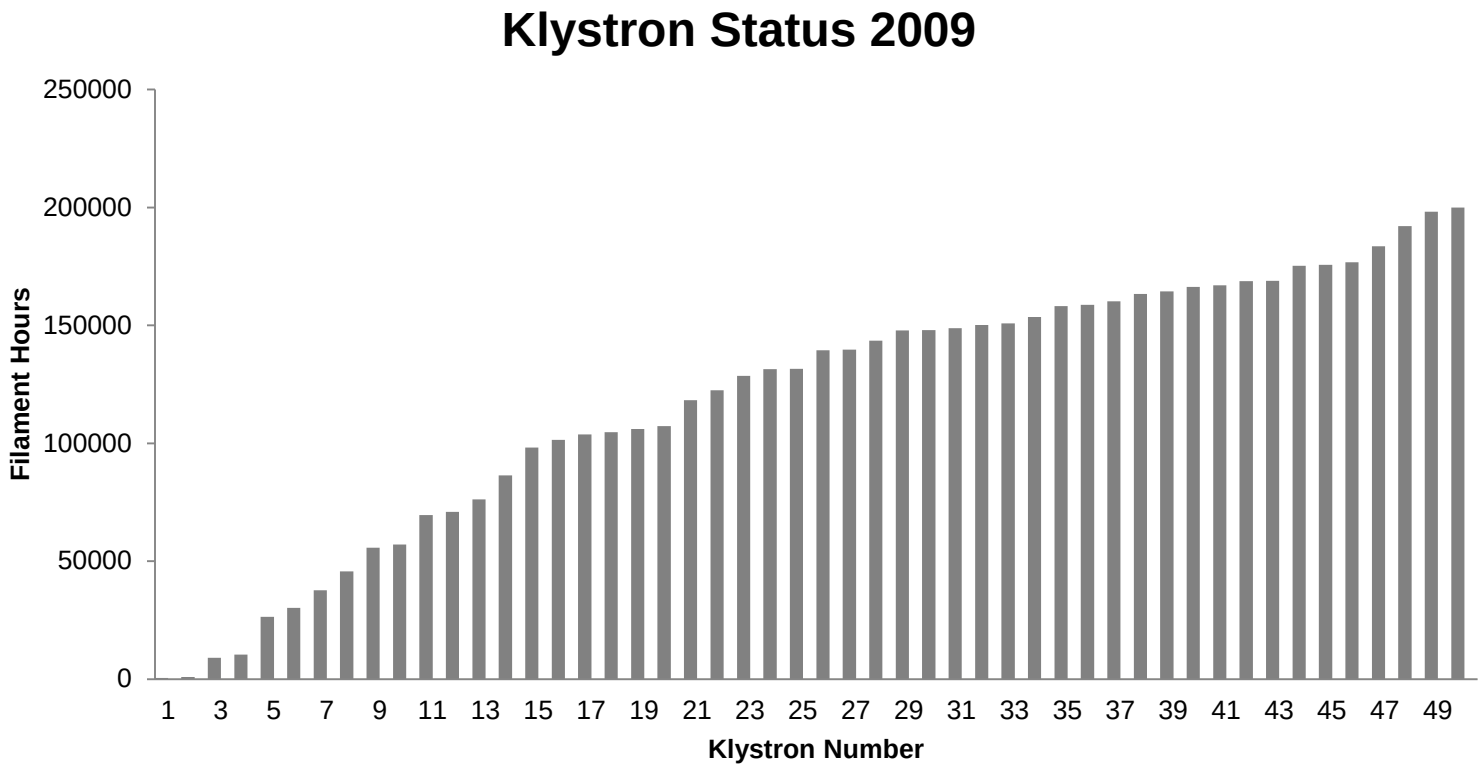
Production Klystron Filament Characteristics



Production Klystron Schedule

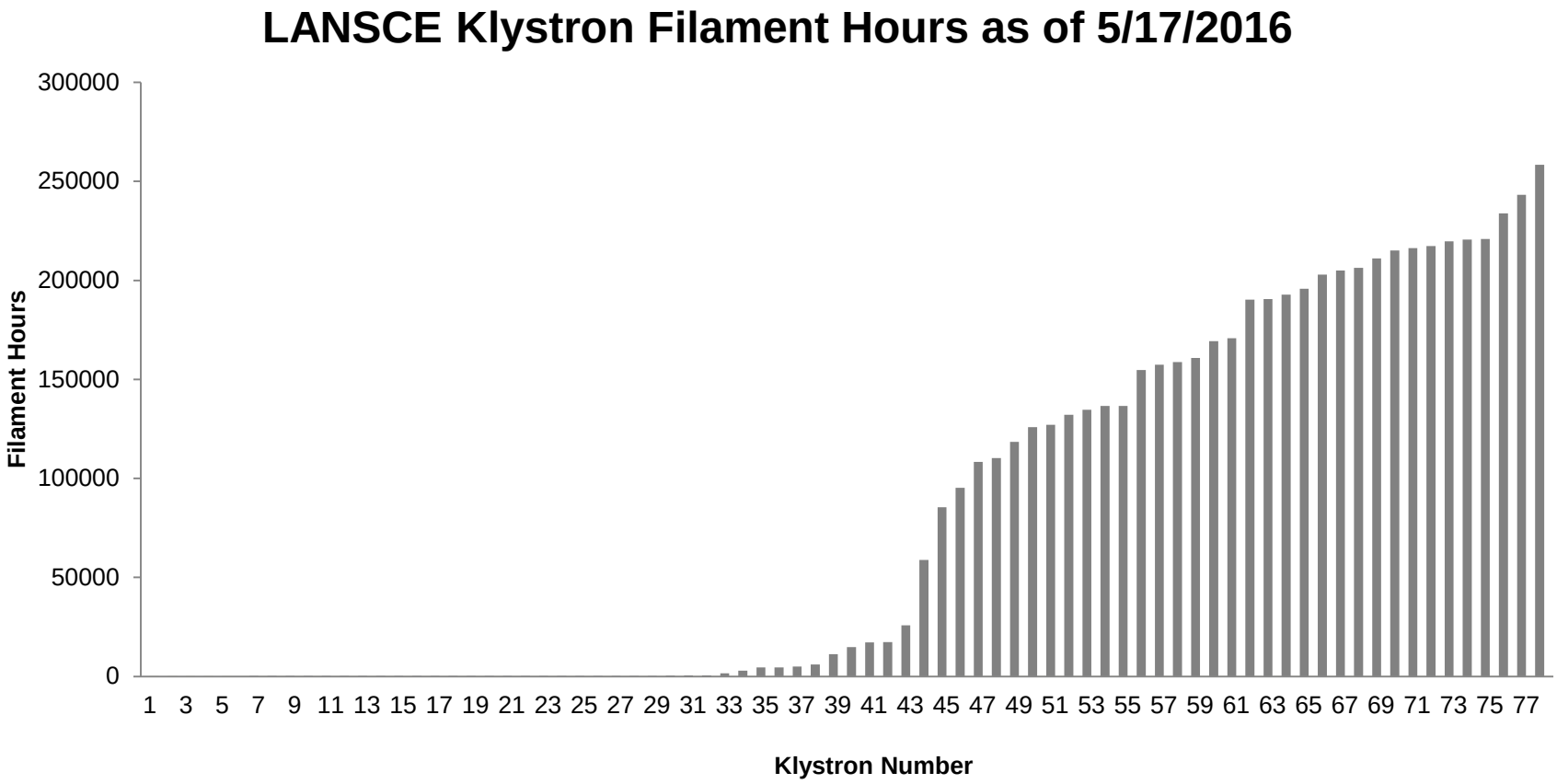


Klystron Status at the Start of the Order



6 Spare Klystrons, Average Filament Hours 118538

Current Klystron Statistics



34 Spare Klystrons, Average Filament Hours 78190

20 Klystrons, never rebuilt, from the original order are still in service

- All from Vendor A
- 10 have > than 200,000 filament hours
- Average filament hours of these klystrons – 185395 hours
- Average HV hours of these klystrons – 158186 hours

Current klystron statistics – Original tube, never rebuilt, still in service, greater than 200,000 filament hours

Vendor	Serial Number	Filament Hours	HV Hours	Module
Vendor A	239	258367 (29.4 Yr)	222357	5
Vendor A	218	243247	203542	19
Vendor A	225	233908	196071	11
Vendor A	209	219656	188787	23
Vendor A	234	217295	191012	41
Vendor A	201	216347	179469	42
Vendor A	240	215161	186898	30
Vendor A	211	211139	181189	31
Vendor A	301	206378	162907	6
Vendor A	213	204964	172318	24

LANSCE just had its 44 year anniversary

Conclusions

- **LANSCE has a complement of spare klystrons that should enable several more decades of operation.**
- **It takes almost as long to get the order through are procurement organization as it does for the klystron vendor to deliver the first klystron.**
  - This time must be included in planning
- **We executed the new klystron procurement in a way that will hopefully preserve the demonstrated lifetime of the original tube order.**
- **Our statistics show that rebuilds are not a desirable path to maintaining klystrons spares.**
- **I believe there is benefit to data trending in a large klystron order, and will hopefully figure out how to incorporate this into our next procurement specification.**