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Strategic Maintenance Planning for Aging Accelerator Facilities

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Outline

- Motivation: An attempt to start a discussion on Strategic Maintenance Planning for Aging Facilities
- Why “Strategic Maintenance Planning”? – The case of the Los Alamos Neutron Science Center (LANSCE)
- Some thoughts on SMP – Please chime in!

Motivation: Start a Discussion on Strategic Maintenance Planning

- Many facilities have to deal with
  - Tightening budgets
  - Reduced staffing
  - Aging equipment
  - Increased user needs (“Do more for less!”)
- Pressure to do maintenance more effectively.
- Need for more preventive maintenance, less corrective maintenance.

The LANSCE accelerator provides uniquely flexible time-structured beams from 100 to 800 MeV that serve various user facilities.

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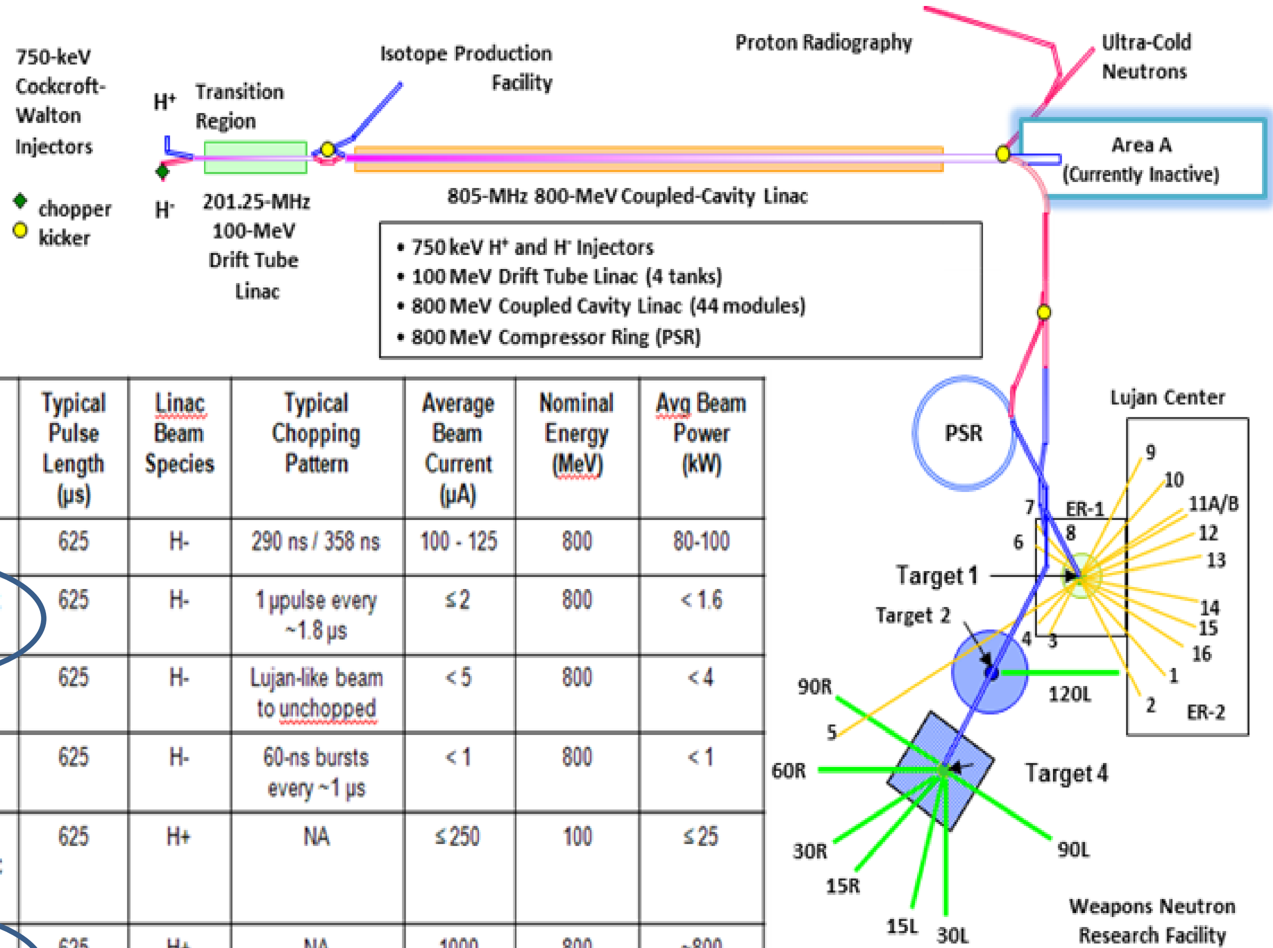
Return in 2014 to 120-Hz increased beam to WNR and will enable a return to multi-beam/high-power 800-MeV operations.

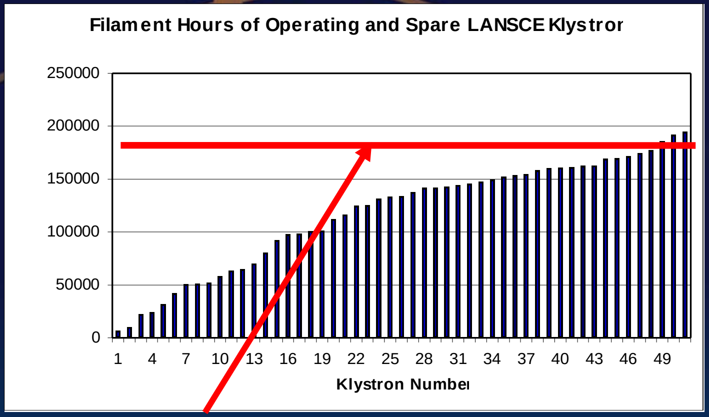


Area	Typical Repetition Rate (Hz)	Typical Pulse Length (μs)	Linac Beam Species	Typical Chopping Pattern	Average Beam Current (μA)	Nominal Energy (MeV)	Avg Beam Power (kW)
Lujan	20	625	H-	290 ns / 358 ns	100 - 125	800	80-100
WNR Tgt 4	≤ 40, present 100, future	625	H-	1 μpulse every ~1.8 μs	≤ 2	800	< 1.6
UCN	20	625	H-	Lujan-like beam to unchopped	< 5	800	< 4
pRad	~1	625	H-	60-ns bursts every ~1 μs	< 1	800	< 1
IPF	≤ 100 pulsed or DC mode	625	H+	NA	≤ 250	100	≤ 25
Area A Inactive	≤ 100	625	H+	NA	1000	800	~800

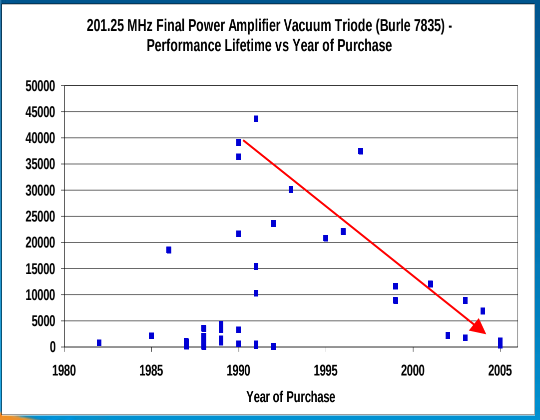
Why did we loose 120-Hz capability?

- 201 MHz DTL Final Power Amplifier (Burle/RCA,7835 Triodes) designed in late 1950s.
- Contain large number of intricate parts; manufacturing process labor intensive with skilled workers; original engineering staff gone.
- High duty factor at 120 Hz (10-12%) meant high thermal stress and tube emission failures.
- In 2005 reduced overall DF by half.

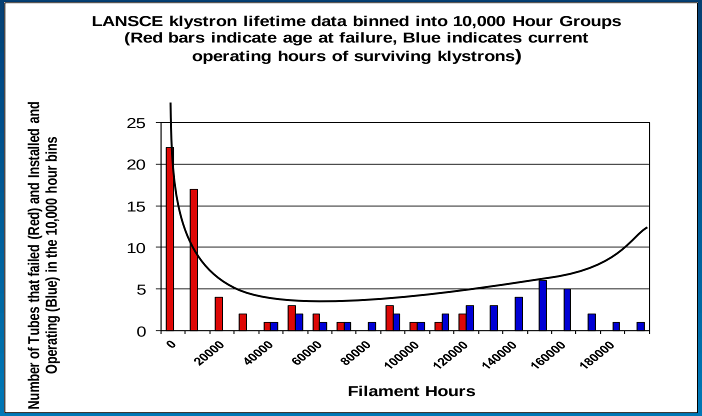
Risk from increasing obsolescence:



A ceramic fracture from a tube that failed after ~8,000 operating hours when 20,000 hours are expected. Each tube is very costly (~$400k fully burdened including initial testing costs at LANSCE)

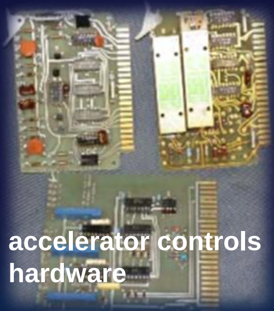


Expected klystron lifetime calculated from a Weibull distribution fit to LANSCE klystron failure data

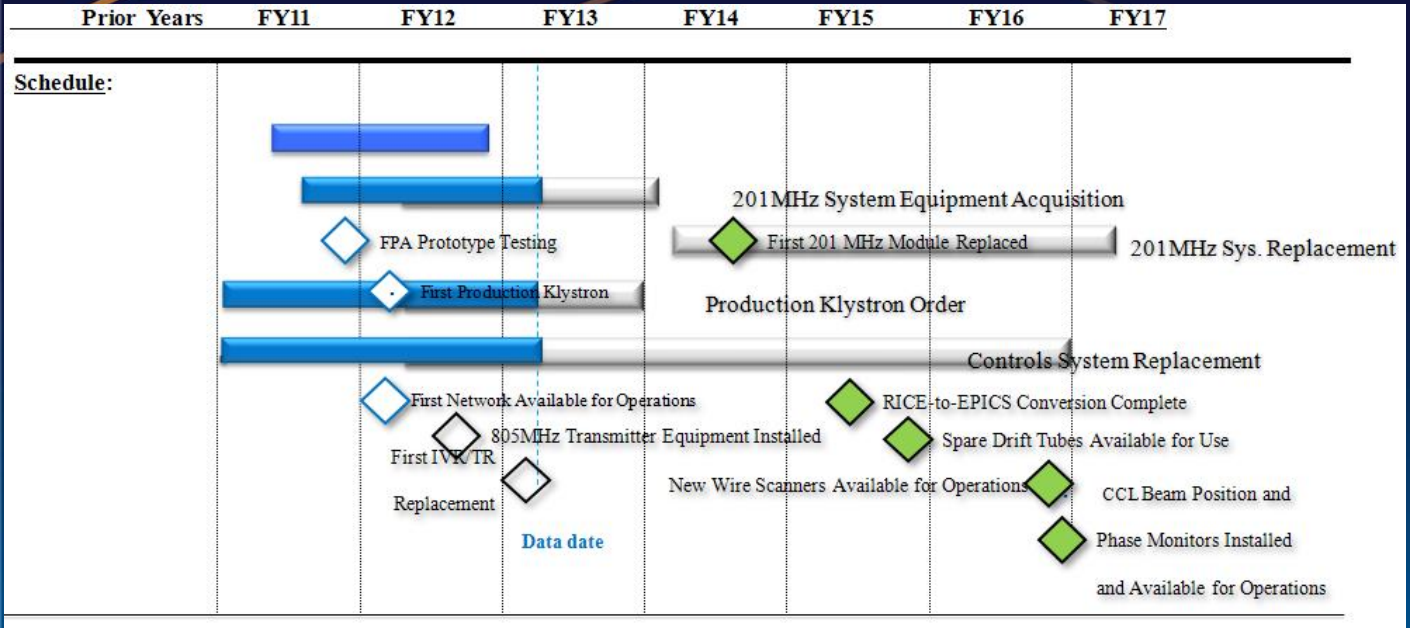


The klystron failure and lifetime data are beginning to exhibit end-of-life features on the “bathtub” curve

Obsolete Systems, difficult to maintain.



Linac risk-mitigation efforts have enabled a return to 120-Hz operations in 2014.



Work is being integrated with operations to ensure continued programmatic research and a robust user program during upgrades.

Linac risk-mitigation (L-RM) efforts designed to:

- Refurbish the 201 MHz and 805 MHz RF systems to regain reliable RF power system operation (may not be completed).
- Remediate accelerator structures, supporting equipment and power supplies.
- Implement modern, maintainable EPICS-based instrumentation & controls.
- Refurbish beam transport and front-end injector systems (RFQs)

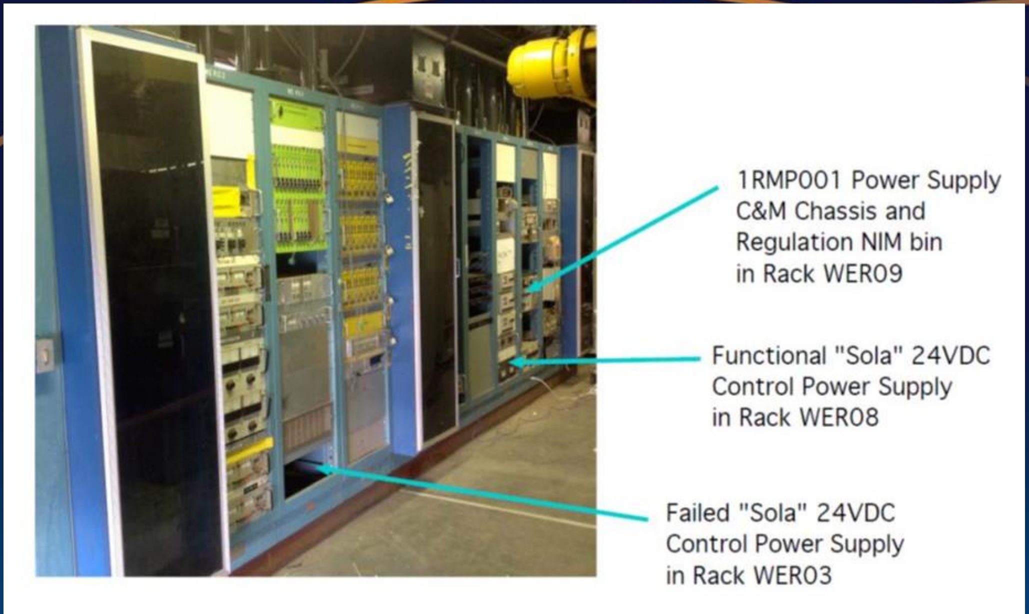
Multi-Year Effort & Funding: FY09-FY11 $40.3M, FY12-FY14 $20M, FY15 $10M, FY16+ ?

- **Long-term sustainability is in question!**

- Operations budgets are stagnant at best.
  - Buying power is decreasing.
  - Cost of labor continues to go up, staffing goes down.
- L-RM efforts have to compete with other critical maintenance.
- Many systems are "run to failure".
- Increased risk of catastrophic failures and major downtimes. *Example on next slide …*

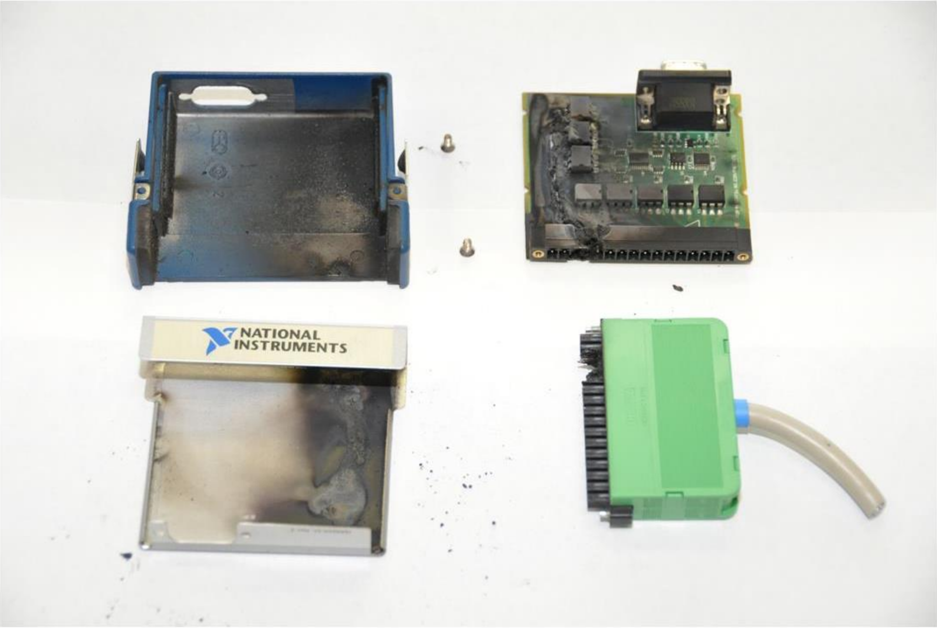
Catastrophic Magnet Failure

- During 2014 maintenance outage, in a 24 V power supply installed around 1970, a 120 VDC wire shorts to both positive and negative 24 VDC buses. *These power supplies were planned to run to failure.*
- Negative bus was connected to a similar supply in another rack. *Why? Somebody might know…*
- As a result the Computer I/O module for the power supply for a 30º bending magnet ("1RBM01") to WNR was damaged.



Racks with the two 24 V supplies.

Damaged I/O module.



- As a result of the damage to the I/O module interlocks were bypassed and the magnet was turned on and ramped up to ~1800 A, without cooling water.
- Coils overheated, melting insulation and Plexiglas enclosure and activated sprinkler head.
- Arcing caused localized temperatures in excess of 1000 ^{o}C. The coils were beyond repair.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- *Spare coils* could not be located. Most likely they were accidentally disposed off during a major site cleanup effort. New coils were ordered, but were not available in time for startup.
- A solution involving two magnets was devised, and, thanks to the enormous efforts of LANSCE personnel and crafts, successfully put in place in time for beam delivery to WNR.
- Estimated cost for the repair: ~ $1M

Some thoughts on Strategic Maintenance Planning (SMP)

Based on discussions with R. Garnett, who had addressed the subject with K. Jones at LANSCE in 2008/09.

- SMP has to be within constraints of facility's age, complexity, user requirements (beam time vs. outage time) and budget.
- **Q:** Will formalizing maintenance lead to higher reliability and availability by minimizing need for corrective maintenance?

- For an SMP to be successful, Roles & Responsibilities need to be defined (Maintenance Manager, Budget person, Scheduler, etc.).
  - System owners need to be involved, but someone needs to be in charge of integrating activities AND prioritizing.
- Make maintenance more effective to minimize costs.
  - Improve tool and/or spares storage (1RBM01!).
  - **Q:** Other ideas on how to make maintenance more effective?

- How to prioritize?
  - Top Ten list? Who determines priorities, if not owners?
  - Need data on costs and reliability of systems.
  - What are most critical areas? *LANSCE-LRM tries to address our most critical areas*. Need to direct resources towards these areas (may need higher-level direction/integration, above GL level).
  - Where do we compromise?
- Need a formal maintenance strategy, as opposed to fixing things as they fail.
  - <u>Are we missing correcting high-risk issues?</u>
  - What metrics to identify highest-risk issues?

- Objectives need to be defined, with help from customers, such as availability, reliability, # of downtimes by duration (shorter duration of experiments means shorter downtimes become more of an issue) and systems analyzed to determine how to meet goals.
- Try to get away from operating equipment past its useful lifetime. *Goal of L-RM.* Try to avoid "Obsolescence Cliff".

- Do we have a preventive maintenance plan? Beyond system level?
  - Does outage schedule qualify?
  - Is preventive maintenance planned into short outages (source recycle, unexpected downtime)?
  - Could operators be used more effectively, for example to do preparatory work for maintenance? ***Will be hard as control room staffing is down, too.***
- Do we measure split between preventive and corrective maintenance?
  - Changing ratio over time in favor of PM would be a sign that SMP is working.

- Is our “operating pattern” (run time vs. outage) optimized to allow us to do maintenance necessary to achieve/maintain reliability, etc. goals?
  – Outages were extended to accommodate L-RM work, but user demands tend to take some of that extra time out again.
  – *I can barely remember when we actually followed an annual schedule without extending a run, start (part of the machine) earlier than planned, etc.*

- Do we do routine maintenance inspections and trend monitoring?
  - If we increased monitoring efforts, would that affect the PM/CM ratio? Would we reduce the number of systems that are presently operated to failure?
  - Can we afford to increase efforts (cost, staffing limitations)?

- **Q to audience**: Do other facilities have an SMP?
  - How successful is/was it?
  - Are parts of the plan (or the whole plan) applicable to an aging facility under severe budget stress (not likely to improve soon), such as LANSCE?
- **Q to audience**: How important is subject of Strategic Maintenance Planning to you?
  - Would it warrant separate discussions, and to what extent?

Summary … let's discuss!

- Tightening budgets, aging equipment, reduced staffing, etc. make it increasingly hard to maintain reliability and availability to satisfy user needs.
- Pressure is on to perform maintenance more effectively, with more emphasis on preventive rather than corrective maintenance.
- Goal is to maintain capabilities and to minimize unscheduled downtimes.
- Formalizing and strategically planning maintenance might help, but how to do it?