Approach to Reliable Operation

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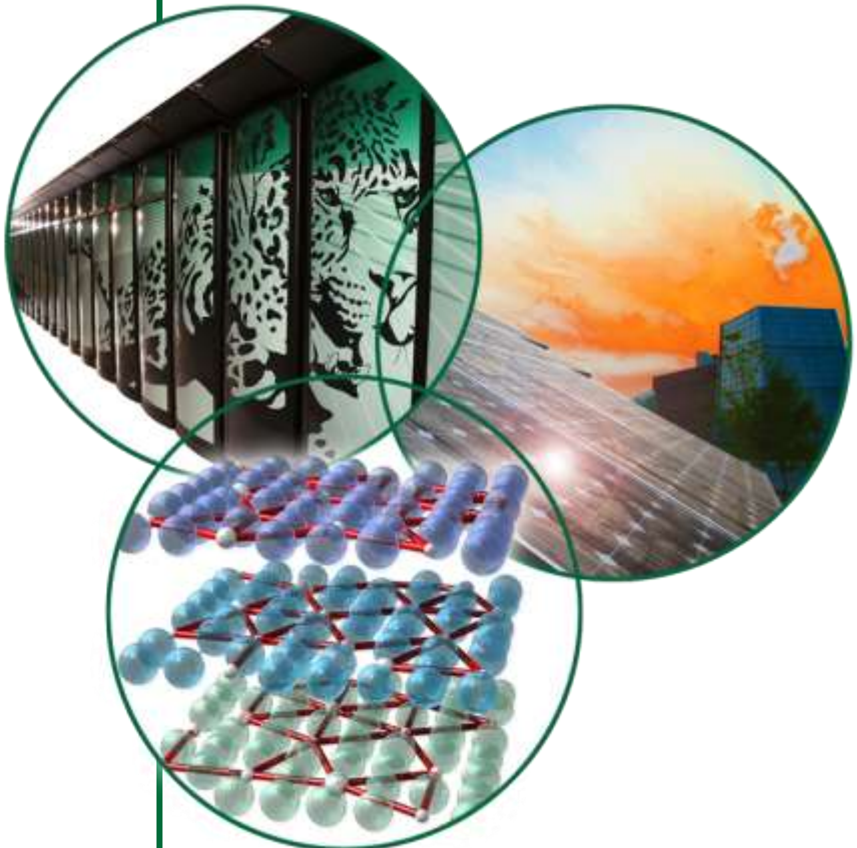

U.S. DEPARTMENT OF ENERGY

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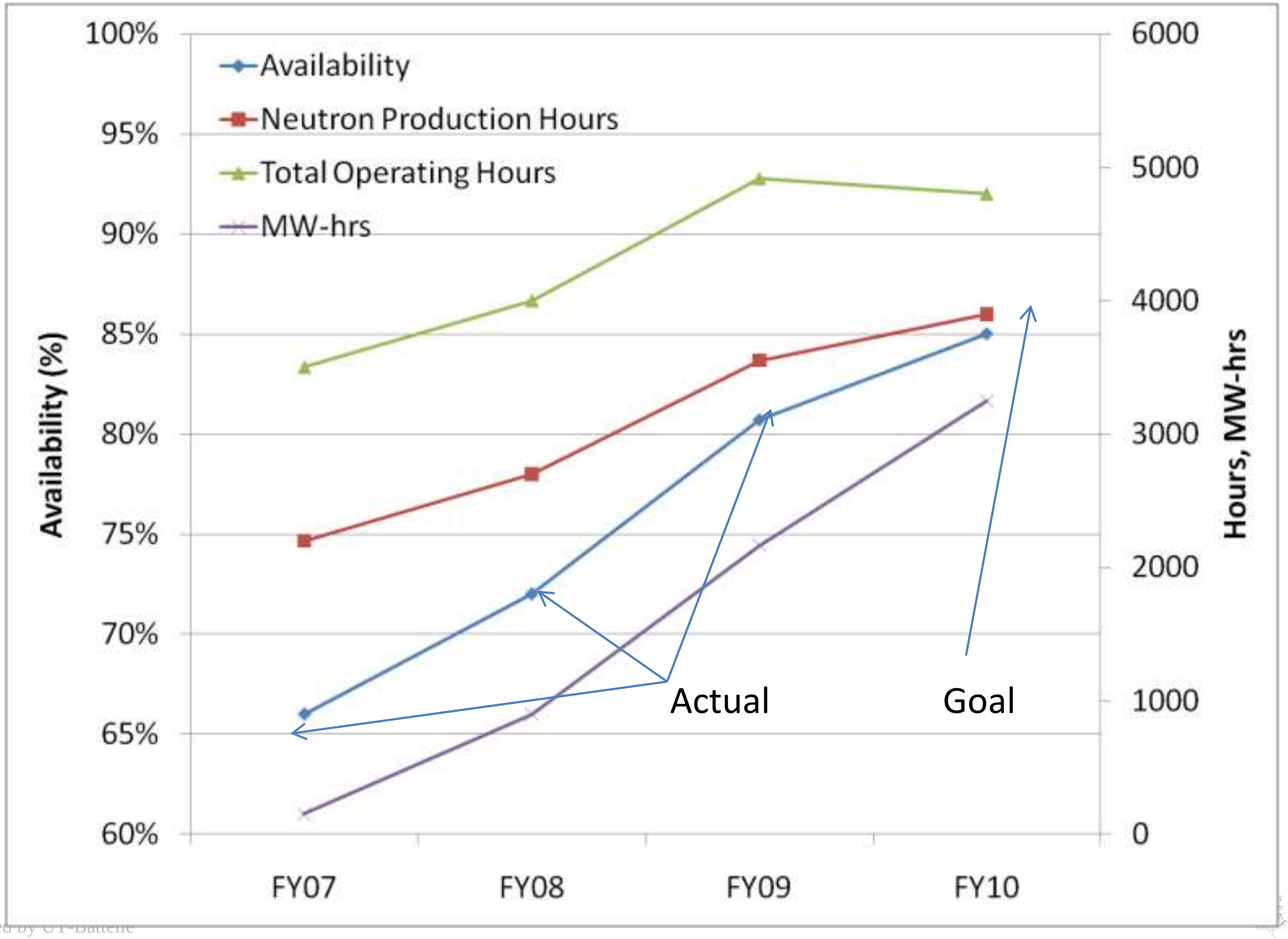
SNS Availability
85% looks achievable but for >90% a plan is needed



Approach to Reliable Operation

1. Create a Plan for 95% Availability
   - Set downtime goals for 90% and 95% Availability
     - Downtime apportioned by group, system as appropriate
   - Evaluation of the major sources of downtime
     - Use performance data to determine largest downtime contributors by Group, System, Sub-System, Sub-Sub-System….
     - Determine root causes of equipment failure
     - Determine actual Failure Rate (MTBF) and Mean Time to Repair/Recover Time (MTTRR) and compare with RAMI Model
     - Formulate downtime reduction strategy
       - ➢ Tailored approach: address the biggest downtime contributors first and "low hanging fruit" along the way
       - ➢ Incorporate in 95% Availability Plan
       - ➢ Can we repair failed systems faster?
       - ➢ Predictive maintenance and proactive equipment replacement
     - Complete an Operations Vulnerability Analysis

Approach to Reliable Operation (cont'd)

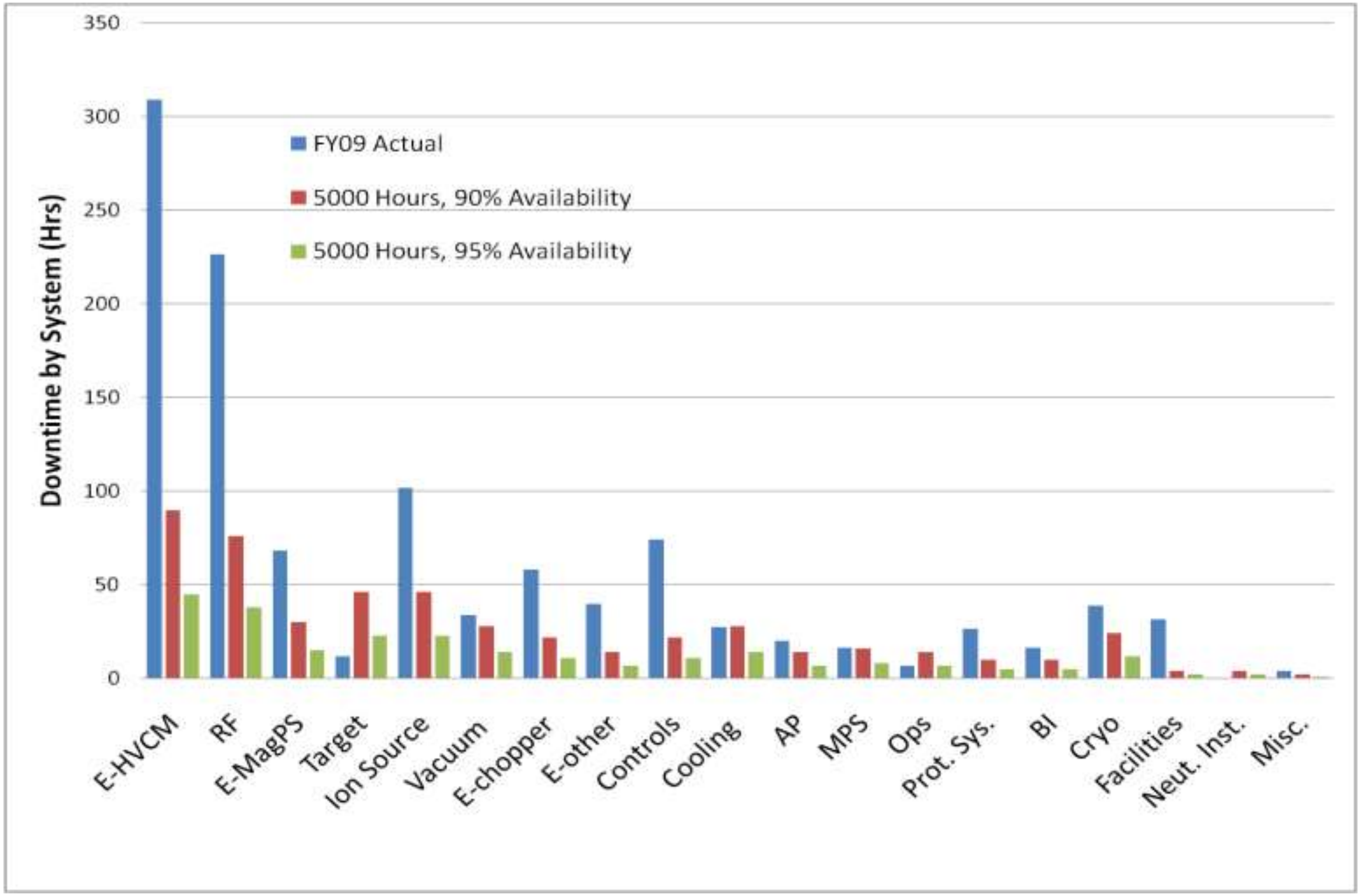
2. **Develop spares plan**
   - Determine appropriate number of spares based on
     – Number of installed units, MTBF, Mean time to acquire new or repair broken,
     – Acquire spares so that we are not limited by spare parts availability

3. **Configuration Control**
   - Ensure that new designs and design changes are handled properly
   - Ensure systems documentation as-built's are captured and updated
   - Ensure assets are tracked and managed in Datastream

95% Availability Plan

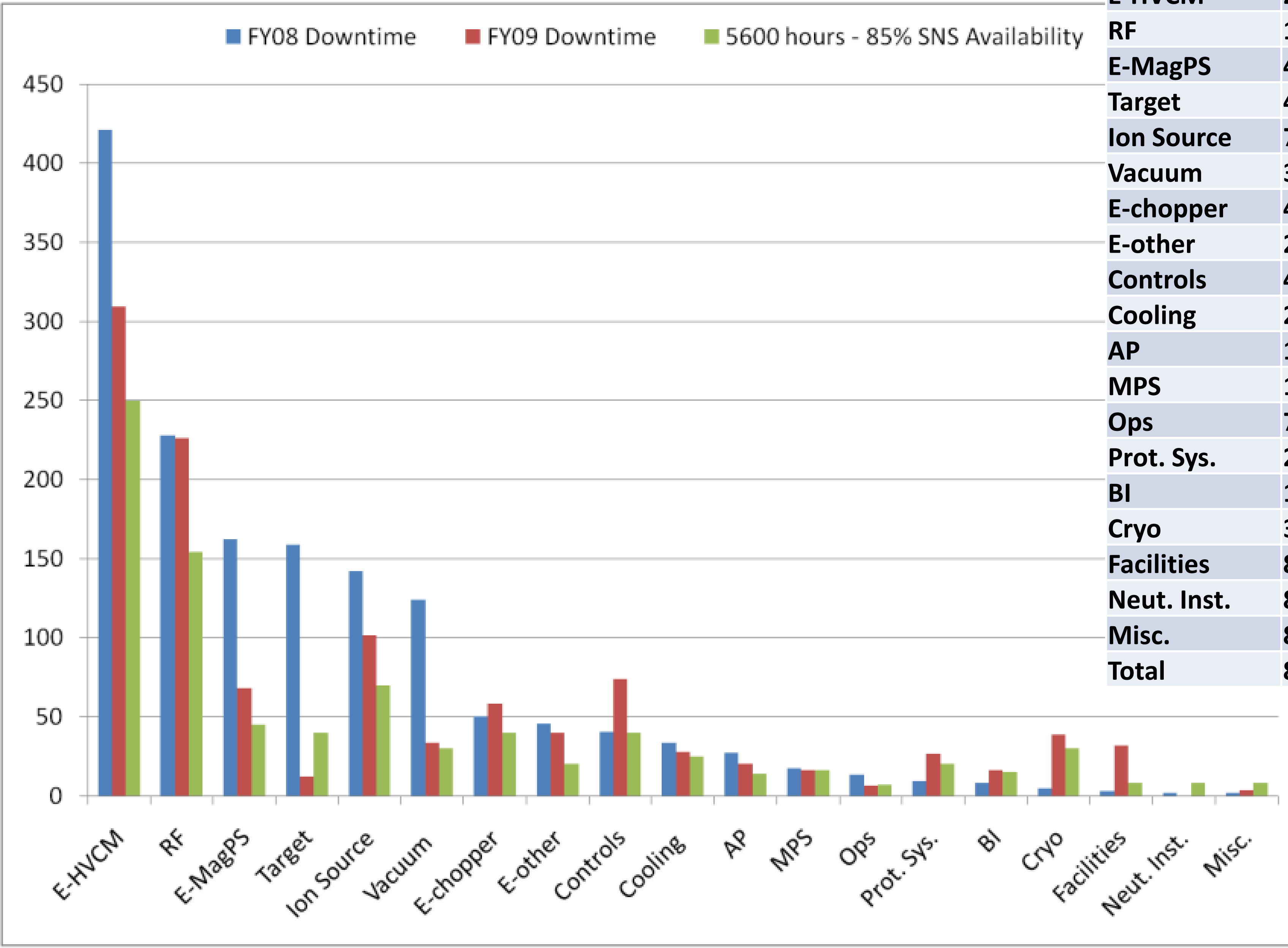
- Develop a plan for each system
- System Plans will be combined into an overall availability plan
- We will formulate a plan using 95% as a “design point” to assess scope, cost and schedule for required improvements
- Continue to emphasize that 95% availability is a long-term target for SNS availability, not a promise

Downtime Goals by System for 90% and 95% Availability



System	FY08 Downtime	5000 hours- 95% SNS Availability			5000 hours - 90% SNS Availability		
		Downtime Fraction	Hours	Availability	Downtime Fraction	Hours	Availability
E-HVCM	421.2	18%	45	99.10%	18%	90	98.20%
RF	227.7	15%	38	99.24%	15%	76	98.48%
E-MagPS	162.2	6%	15	99.70%	6%	30	99.40%
Target	158.9	9%	23	99.54%	9%	46	99.08%
Ion Source	142.2	9%	23	99.54%	9%	46	99.08%
Vacuum	124	6%	14	99.72%	6%	28	99.44%
E-chopper	50.3	4%	11	99.78%	4%	22	99.56%
E-other	45.6	3%	7	99.86%	3%	14	99.72%
Controls	40.7	4%	11	99.78%	4%	22	99.56%
Cooling	33.7	6%	14	99.72%	6%	28	99.44%
AP	27.3	3%	7	99.86%	3%	14	99.72%
MPS	17.3	3%	8	99.84%	3%	16	99.68%
Ops	13.4	3%	7	99.86%	3%	14	99.72%
Prot. Sys.	9.4	2%	5	99.90%	2%	10	99.80%
BI	8.4	2%	5	99.90%	2%	10	99.80%
Cryo	4.7	5%	12	99.76%	5%	24	99.52%
Facilities	3.1	1%	2	99.96%	1%	4	99.92%
Neut. Inst.	2	1%	2	99.96%	1%	4	99.92%
Misc.	2	0%	1	99.98%	0%	2	99.96%
Total		100%	250	95.00%	100%	500	90.00%

FY10 Downtime Goals



System	Downtime Hours
E-HVCM	250
RF	154
E-MagPS	45
Target	40
Ion Source	70
Vacuum	30
E-chopper	40
E-other	20
Controls	40
Cooling	25
AP	14
MPS	16
Ops	7
Prot. Sys.	20
BI	15
Cryo	30
Facilities	8
Neut. Inst.	8
Misc.	8
Total	840

Management Information Systems for Downtime Reporting and Equipment Tracking (identify largest sources of downtime)

- Downtime is assigned using the Shift Closeout page in the Operations Administration System (OAS), an ORACLE application.
- Downtime is reported by Group, Sub-Group, Sub-Sub Group….
  - The structure is as deep as it makes sense to use in tracking.
  - The OAS reporting structure is being created as a duplicate to the Equipment Structure in the Equipment Tracking/Maintenance Management System Datastream 7i (Infor)
  - The two systems will eventually be linked for direct tracking of downtime by position and asset

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Evaluations of Beam Downtime > 12 Hrs

- For beamtime loss > 12 Hours we hold an Evaluation done in accordance with SNS OPM 6.B-1"SNS Neutron Beam Production Downtime Evaluation Process". This
- The Evaluation includes:
  - A description and timeline of the associated events including System Response.
  - A summary of the root-cause of the failure.
  - An evaluation of the risk/likelihood that similar events may occur in the future.
  - A summary of suggested improvements that can mitigate this risk.
- The Evaluations are on the RAD SharePoint Site

Determine the Root Cause of the Failure (Example)

- In the HVCMs the IGBT Switchplate capacitors failed at ~20% of their expected lifetime
- Fit failure data to Weibull distribution to determine where in the distribution they are failing (infant, random, wear-out)
- The capacitors were overheating
- Tried several different types of replacements
- Settled on the TPC solid capacitors
  - Run much cooler
  - Successfully tested for 9 months of operation
- Compare with RAMI Expectations
  - Model prediction is MTBF of 27,000 Hrs for HVCMs MTBF
  - Create plan for 10,000 Hrs with current design
  - Improve design to achieve 27,000 Hrs

Goals for Electrical Systems (Example)

Downtime budget for 90% and 95% availability of Electrical Systems for 5000 operating hours are as follows:

For 90% availability:

Modulators	90 hours
Power Supplies	30 hours
Choppers	22 hours
Other	14 hours
Total	156 hours

For 95% availability:

Modulators	45 hours
Power Supplies	15 hours
Choppers	11 hours
Other	7 hours
Total	78 hours

Experience Based Plan (Example)

High Voltage Converter Modulators

- MTTR for failures outside of the tank averages 3 hours
- MTTR for failures inside the tank averages 12 hours
- Inside to outside tank failures occur at a ratio of about 10:1.

- For 90% availability, the budget is 90 hours or 2 inside tank and 22 outside tank for 24 total failures. This is a system MTBF of 208 hours. For each of the15 systems it means and average MTBF of 3125 hours.

- For 95% availability, the budget is 45 hours or 1 inside tank and 11 outside tank for 12 total failures. This is a system MTBF of 416 hours. For each of 15 systems a MTBF of 6250 hours. A MBTF of 6000 hours was reached (albeit at very low duty cycles) before the onset of capacitor problems, so in principal, this goal is also within reach.

Experience Based Plan (continued)

The short term goal is to reach 10,000 hours MTBF for the Modulators. These improvements include:

Capacitors (TPC)	$1M	AIP(14)	4KV Bypass Caps, cables etc.
SLAC Gate Drivers	$1.8M	AIP(02)	
IGBTs	$3M	$1M components and $2M NFDD R&D	
System Controller		PAIP(04)	

Dual, redundant oil pumps and external heat exchangers $300K

Longer term improvements for even longer MTBF include:

Series HV Disconnect Switch

Redundant H Bridge

Long term improvement for short MTTRR

Hot-Swappable Spare HVCM

Can we Repair Failed Systems Faster?

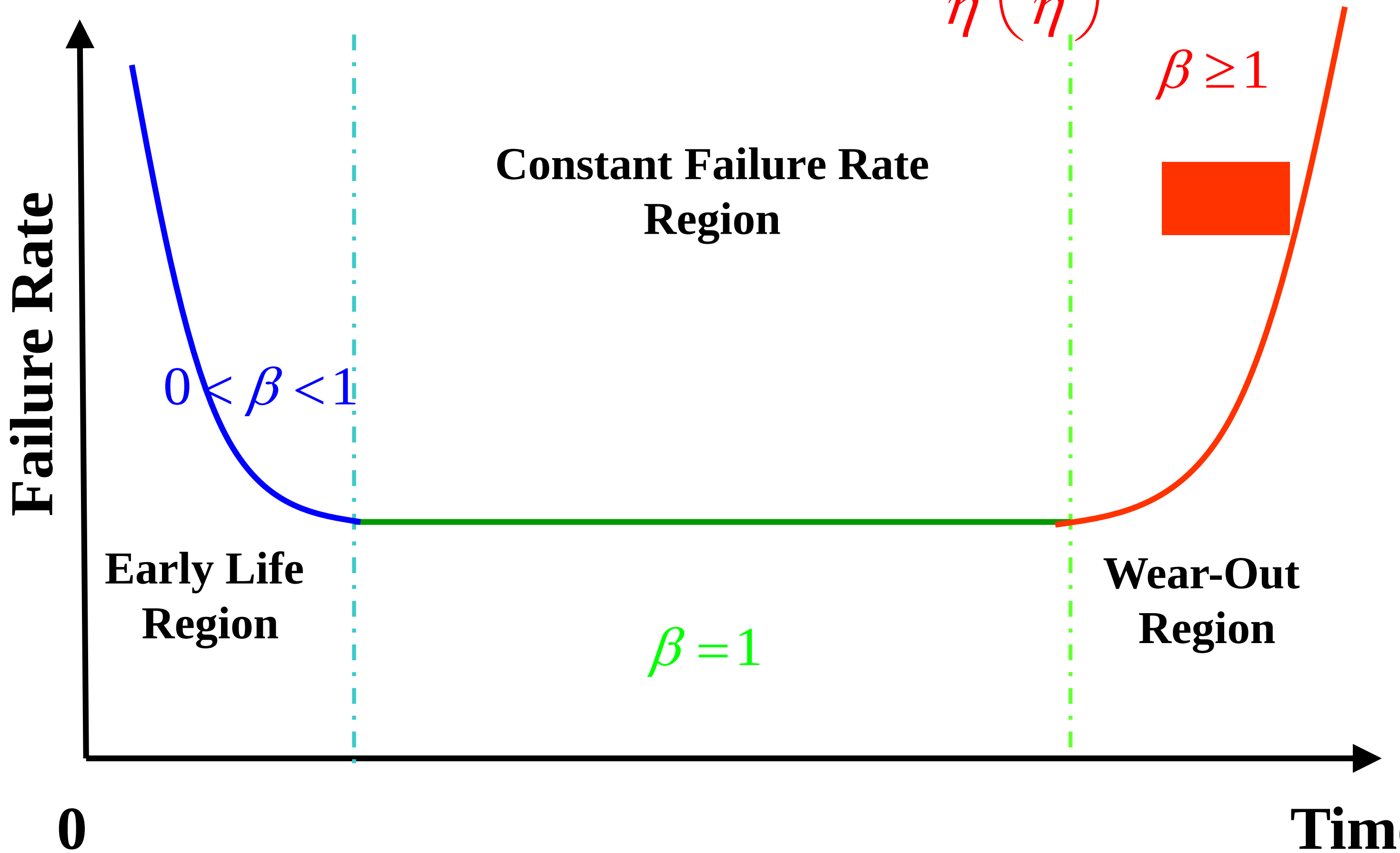
- Accelerator Operations personnel reset but do not replace failed systems.
  - We do not currently have onsite 24/7 technical support
- Phone-in to repair personnel arrival is on the order of ~1 hour. Technician/Engineer phone-in is accompanied by Research Mechanic phone-in.
- Can we reduce this number? If so, at what cost?
- For the HVCMs:
  - Assuming a the previous numbers for repair times on 24 failures per year for 90% availability and 12 failures per year for 95% availability.
  - If we went to 24/7 coverage (one technician and one research mechanic(electrical) – 8 total positions @ ~ $1.6 M/year), this would cut about one hour from each off-hour repair. About 76% of repairs are off-hour.
  - This would save 18 hours of downtime in the 90% model and 9 hours of downtime in the 95% model.
- The technician and research mechanic would also be available to repair other systems.

Predictive Maintenance and Proactive Replacement

- Predict the onset of failure and replace unit during planned maintenance periods
  – Measure klystron perveance
  – Measure vibration spectra from rotating equipment
- Replace equipment at a predetermined point in pre-failure
- Some equipment fails without warning
  – Once accurate MTBF has been determined, agree to replace at a fixed percent of the equipment lifetime
- Some equipment has a reasonable service life considerably shorter than the MTBF.
  – PLCs have a MTBF of 100 Year

Track the failure rate of equipment and compare with a Weibull Model

Failure Rate: $\lambda(t) = f(t) / R(t) = \frac{\beta}{\eta}\left(\frac{t}{\eta}\right)^{\beta - 1}$



Spares Plan

- **Determine appropriate number of spares based on**
  - **Number of installed units**
  - **MTBF**
  - **Mean time to acquire new or repair broken (can create a "blended average")**
  - **Inventory Status**
    - » **All installed at the same time**
      - Use predicted lifetime and purchase spares for complete change at end of life and wait for service start times to randomize (adjust lifetime with failure data)
    - » **Randomized start of service times**
      - Use SparesCalculator to predict Mean Time to Stock Outage and establish a "reasonable" goal.
- **Acquire spares so that we are not limited by spare parts availability**

Configuration Control

- Configuration Control Policy and Procedures
  - Section 9.A. Design Control and Configuration Management
    - 9.A-1 NFDD/RAD Configuration Management Policy

- To document previous history (when available) and present configuration including the status of compliance of an item to its physical and functional requirements.
- To ensure that we have correct, accurate, and current documentation.
- To ensure that new designs for systems, structures, components and software utilize best engineering practice, follow from an approved set of specifications, and are appropriately documented.
- To ensure that changes to existing systems, structures, components and software utilize best engineering practice, follow from an approved design change, and are appropriately documented.
- To ensure that the deployment of a new system or a change to an existing system is authorized.
- To ensure that the impact on performance due to the deployment of a new system or a change to a system is fully understood, and that the risks associated with the deployment are considered.

Configuration Control (cont'd)

- Configuration Control Policy and Procedures (cont'd)
  - Section 9.A. Design Control and Configuration Management
    - 9.A-2 NFDD/RAD Design Development Procedure
    - 9.A-3 NFDD/RAD Design Change Procedure
      - Detailed procedure including conceptualization, design, review, fabrication, testing, pre-installation review, installation, commissioning, documentation, maintenance requirements and tracking

N+1 Redundancy

- In the past, the path to high system availability was large MTBF for each component
- Most current thinking centers around N+1 redundant systems (continue operation and fix on a Maintenance Day – effectively takes the MTTR to 0)
  - Water Pumps – this has been done for years 4 to make 3
  - Power Supplies: 2 to make 1, 3 to make 2
  - HV Switches: for switches that fail shorted, 2 in series
- Apply where the cost is not too high and the systems are more failure prone.

Conclusion

We have an approach to achieving high availability. It involves:

- Developing a plan for high Availability Hardware and Fault Tolerant Software. We have some elements of this now.
- Development of a Predictive Maintenance plan to compliment our existing Preventative Maintenance Plan
- Development and execution of a Spares Plan
- An existing Configuration Control Policy and Procedures