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Reliability of the Operational Power Supplies of APS

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Advanced Photon Source

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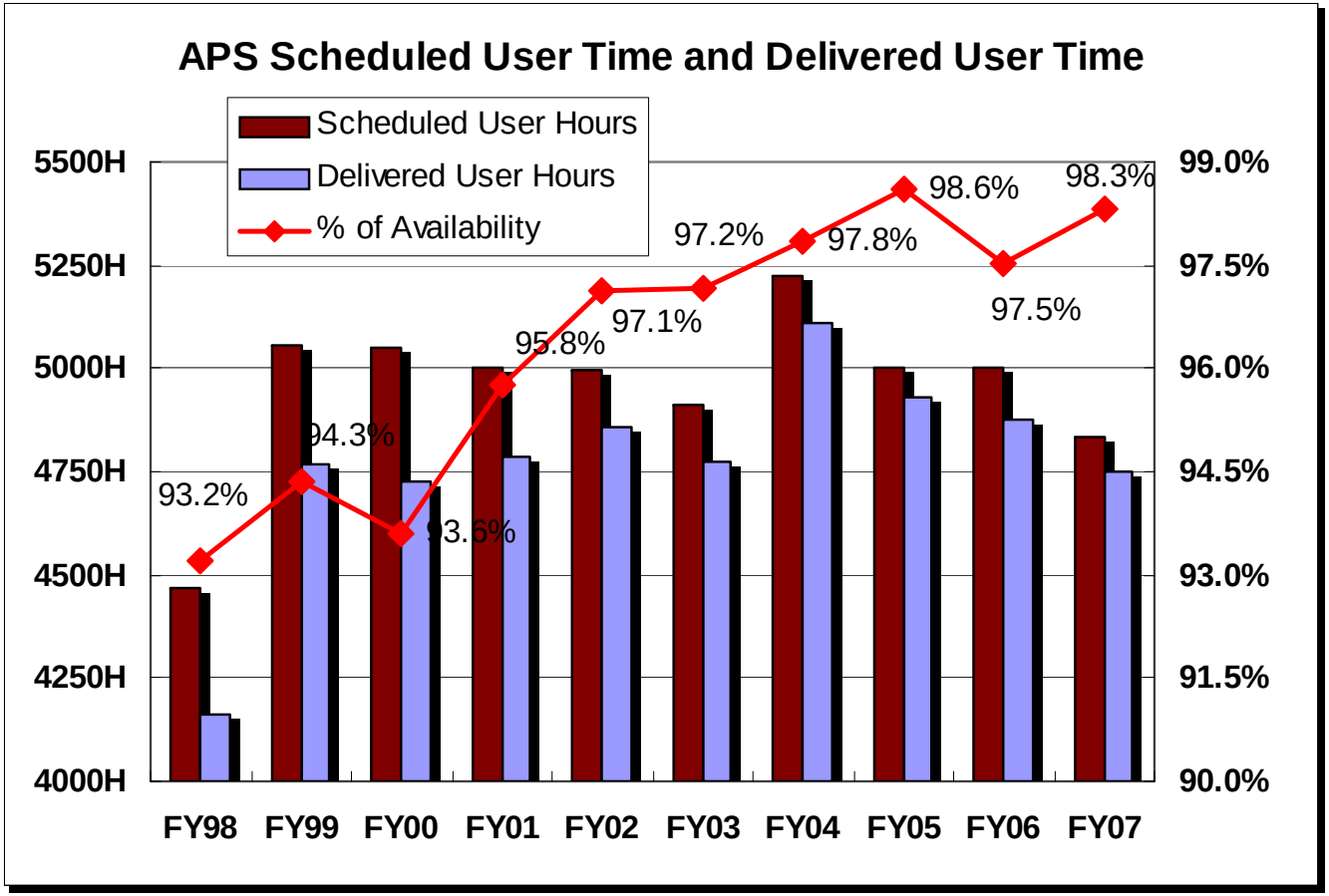
Outline

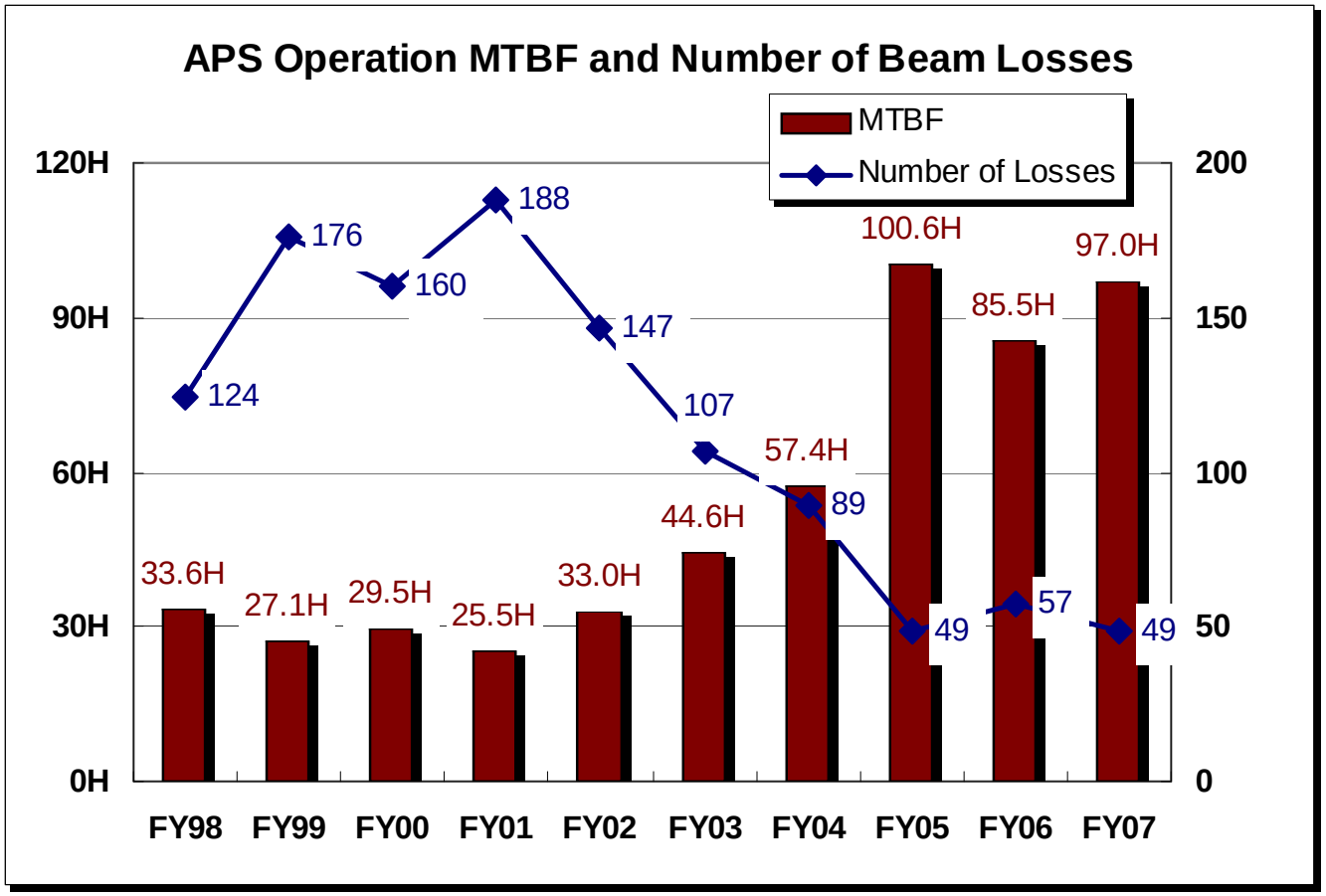
- APS Operation Statistics
- Introduction to APS Power Supplies
- APS Power Supply Operation Statistics
- Power Supply Reliability Upgrades
- Power Supply Maintenance
- Quality Assurance Program
- Challenges/Issues
- Summary

APS Operation Statistics



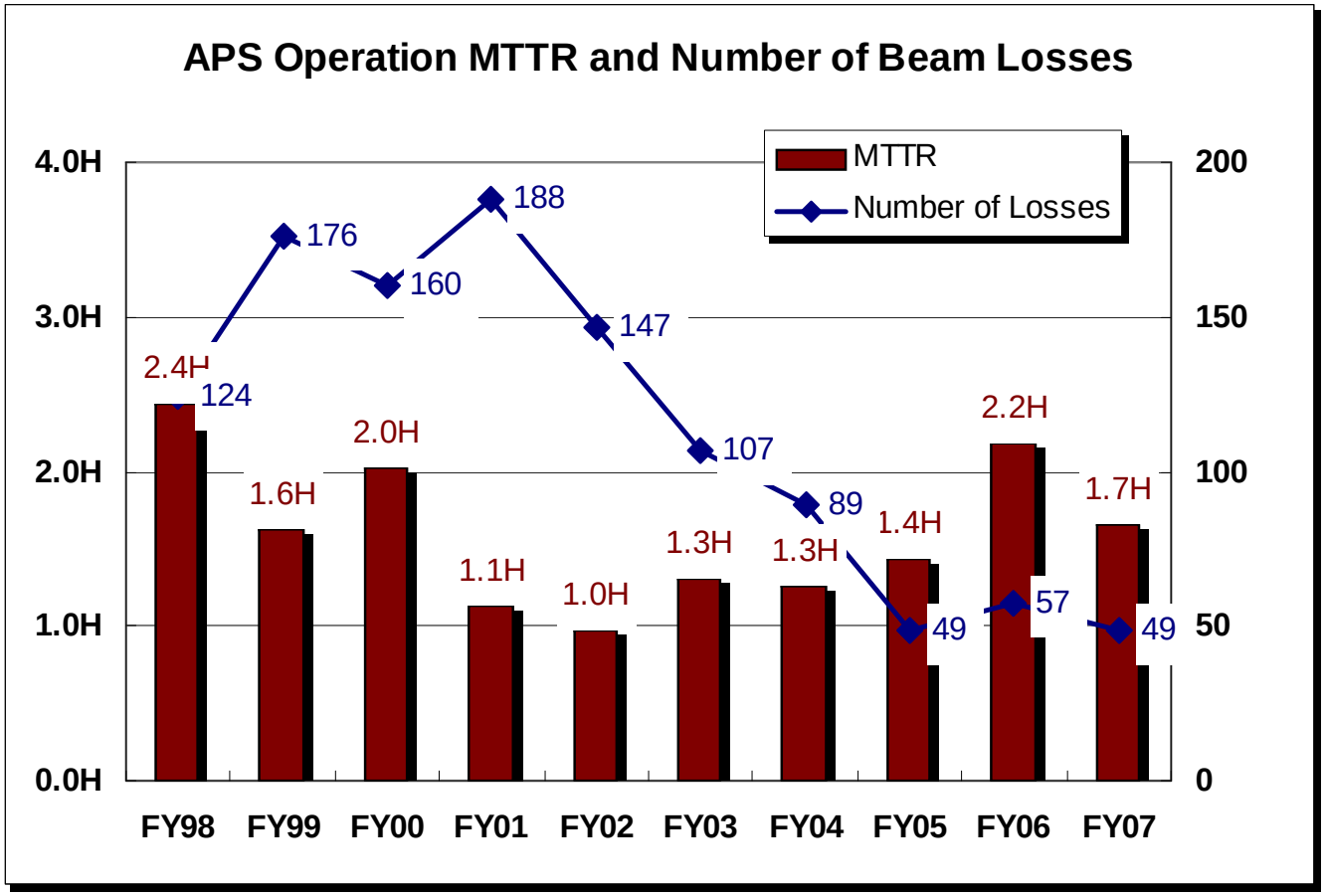
* The availability goal has been 95%, will likely increase soon.

APS Operation Statistics

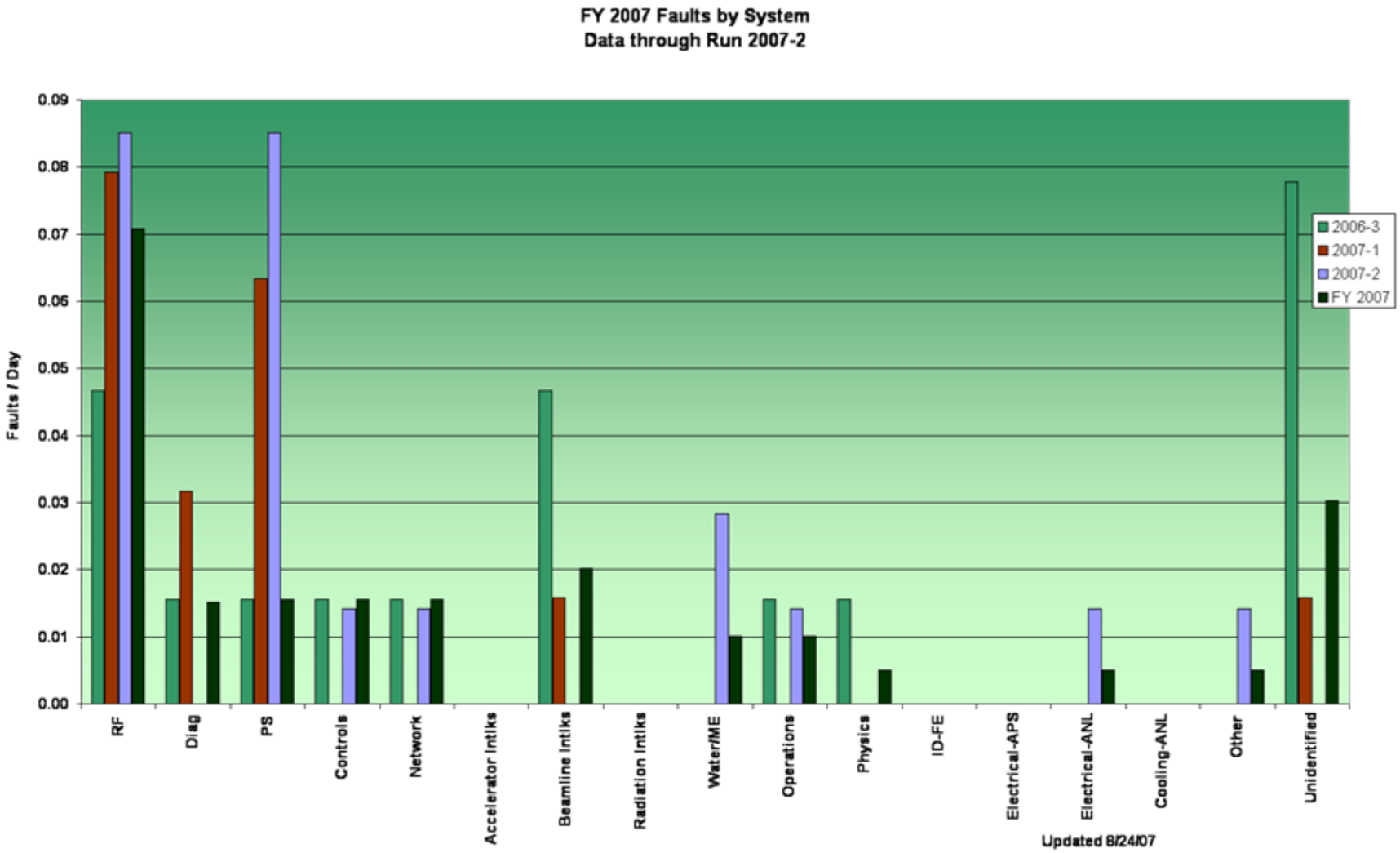


* The MTR goal has been 50 hours, will likely increase soon.

APS Operation Statistics



Typical Fault/Day by Systems

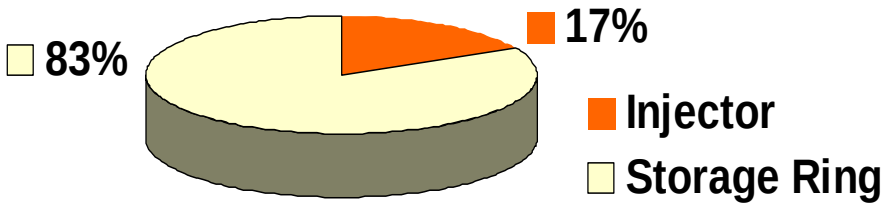


APS Power Supplies

400 quadrupole converters, 0 – 460 amps
280 sextupole converters, 0 – 250 amps
636 correctors, +/- 150 amps

We have …

- 1746 power supplies
  - Storage Ring: 1441
  - Injectors: 305
    - *Booster – 93*
    - *PAR – 37*
    - *Linac – 103*
    - *Transport Lines – 72*

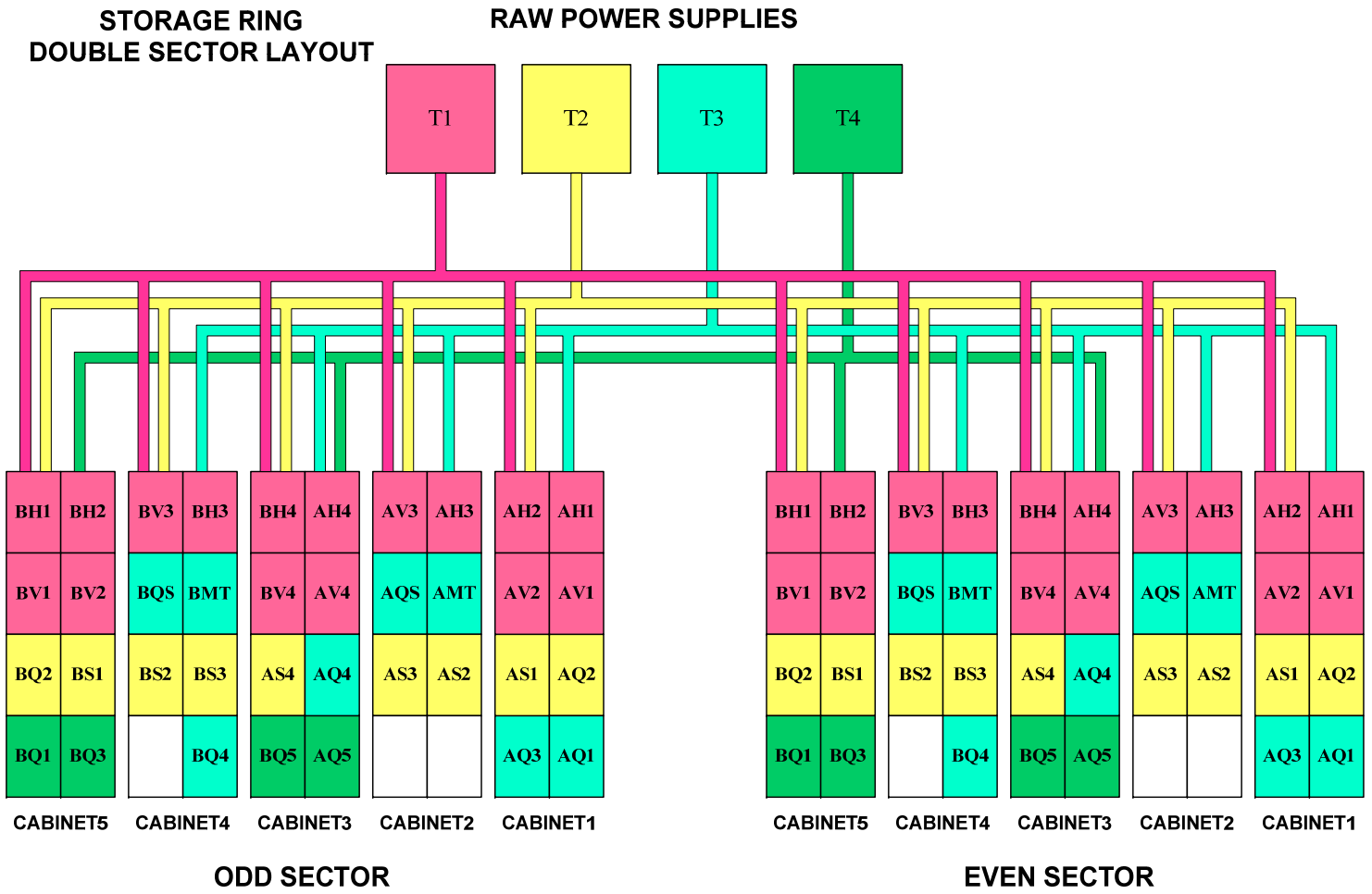


- Of all the supplies
  - 99% AC/DC or DC/DC supplies
  - 1% special supplies for pulsed and ramping magnets
- 269 power supply control units

Every storage ring magnet, except for dipoles, has its own power supply

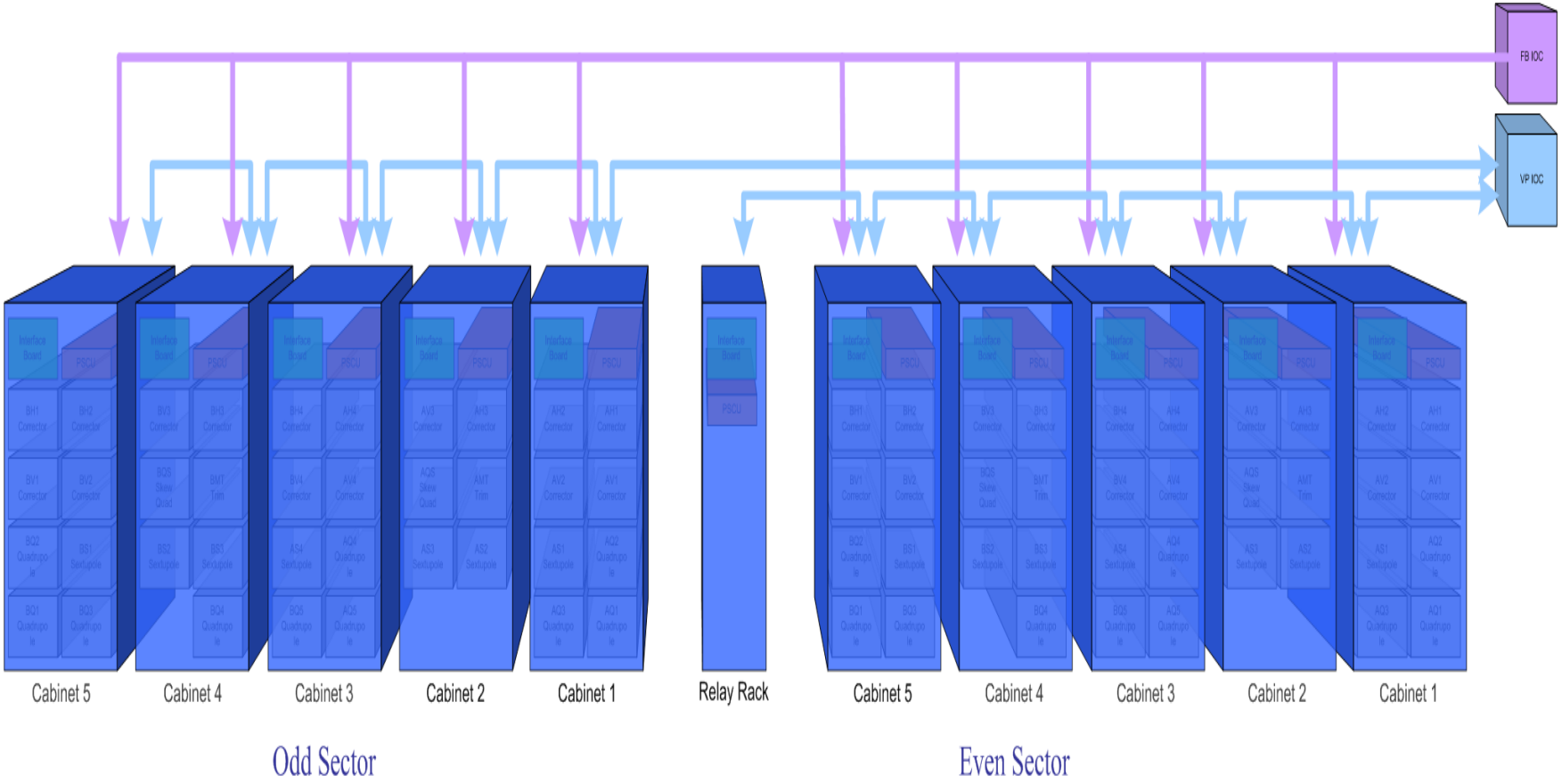
- Great flexibility for orbit configurations
- Great challenges and headaches to power supply people

APS Storage Ring Power Supply Configuration



* There are 20 double sectors.

APS Storage Ring Power Supply Control Configuration

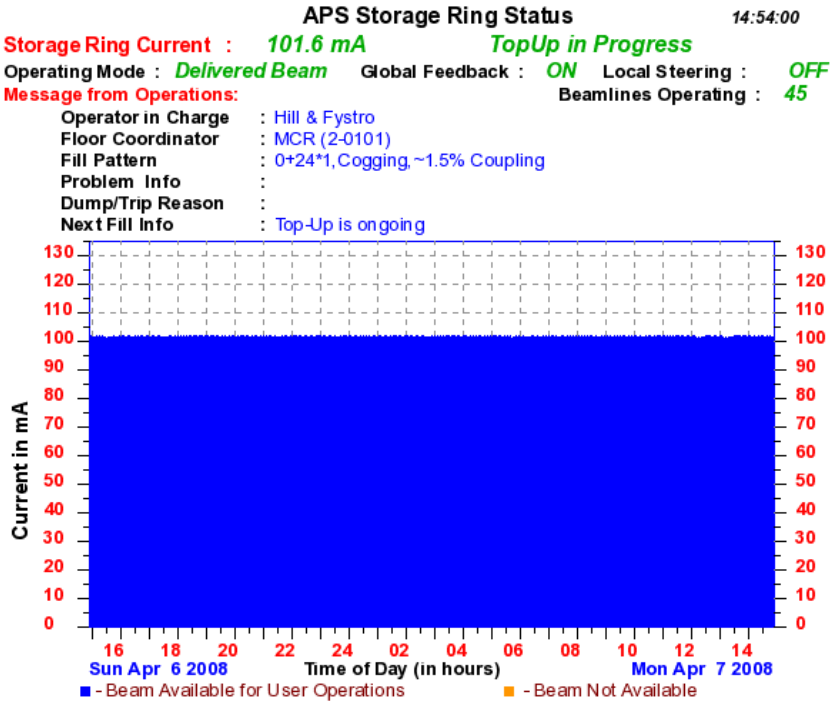


VP IOC controls static converters and reads back monitored points.
FB IOC controls converters for fast correctors

APS Power Supply Reliability Requirement

Power Supply Reliability Budget

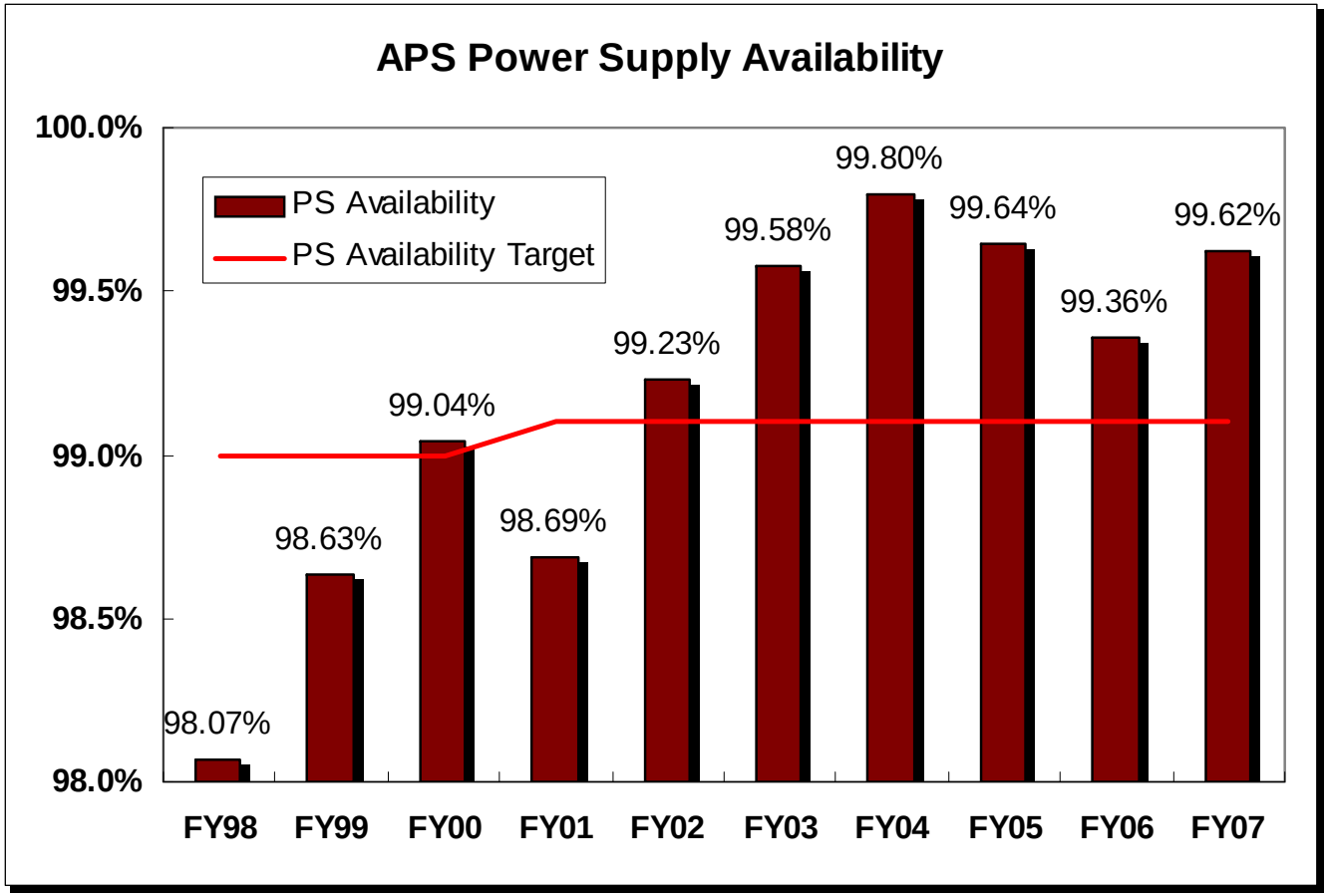
- Before 2002
  - MTBF 200 hours
  - Downtime 1% (99% availability)
- Since 2002
  - MTBF 240 hours
  - Downtime 0.9%
- Soon to be 357 hours and 0.56%?



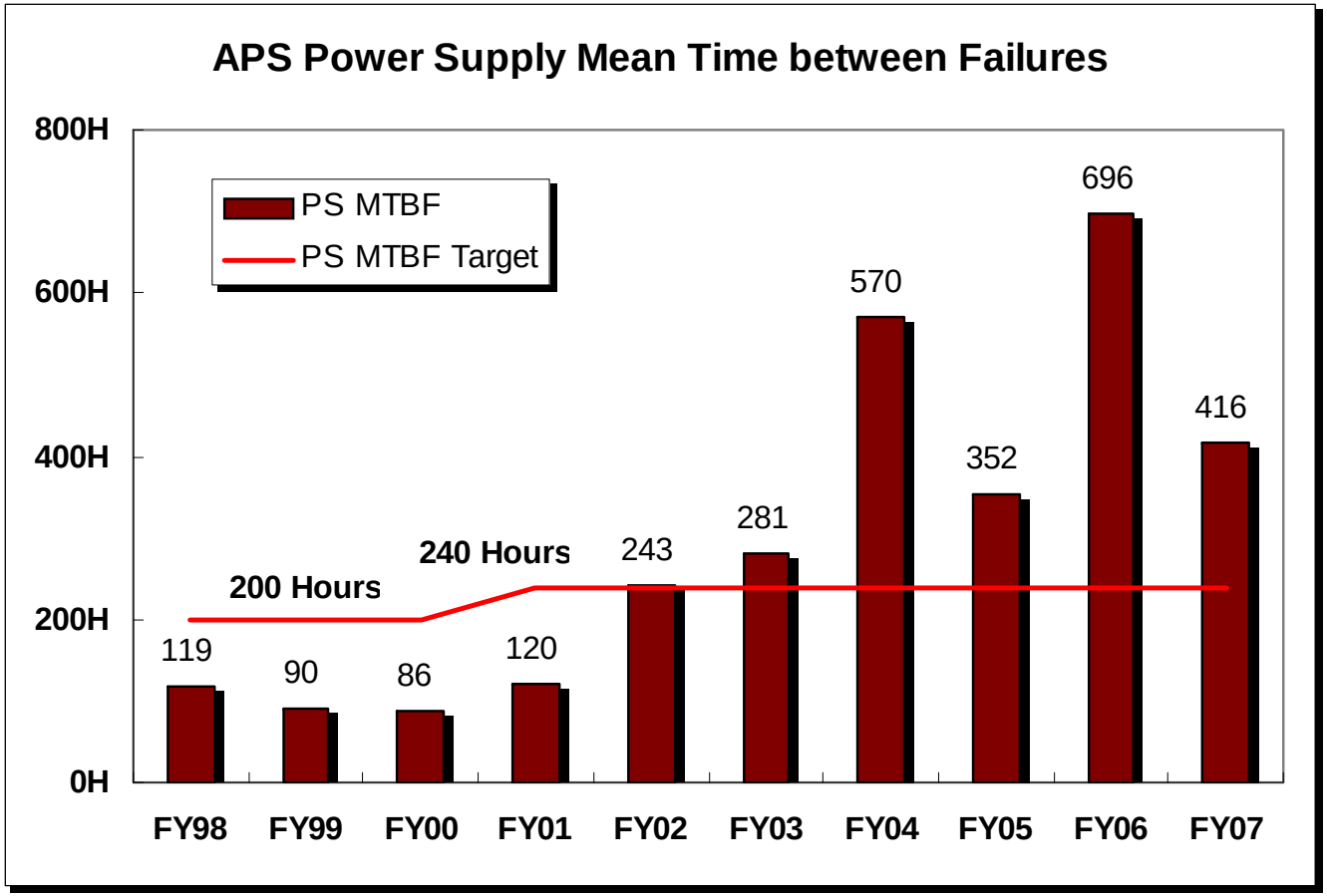
Power Systems Group Staffing and Operational Support

- Staffing
  - Five Engineers (include the group leader)
    - *Two specialized in power electronics*
    - *Three specialized in electronics*
  - Seven Technicians
    - *One chief tech*
    - *Six Sr. techs*
      - Divided into two crews, three for the Storage Ring and three for the injectors
- Operational Support
  - 24/7 support
  - One engineer and two techs on call
  - Typical response time is one hour
  - Trained operators for converter swap

APS Power Supply Availability for Operations

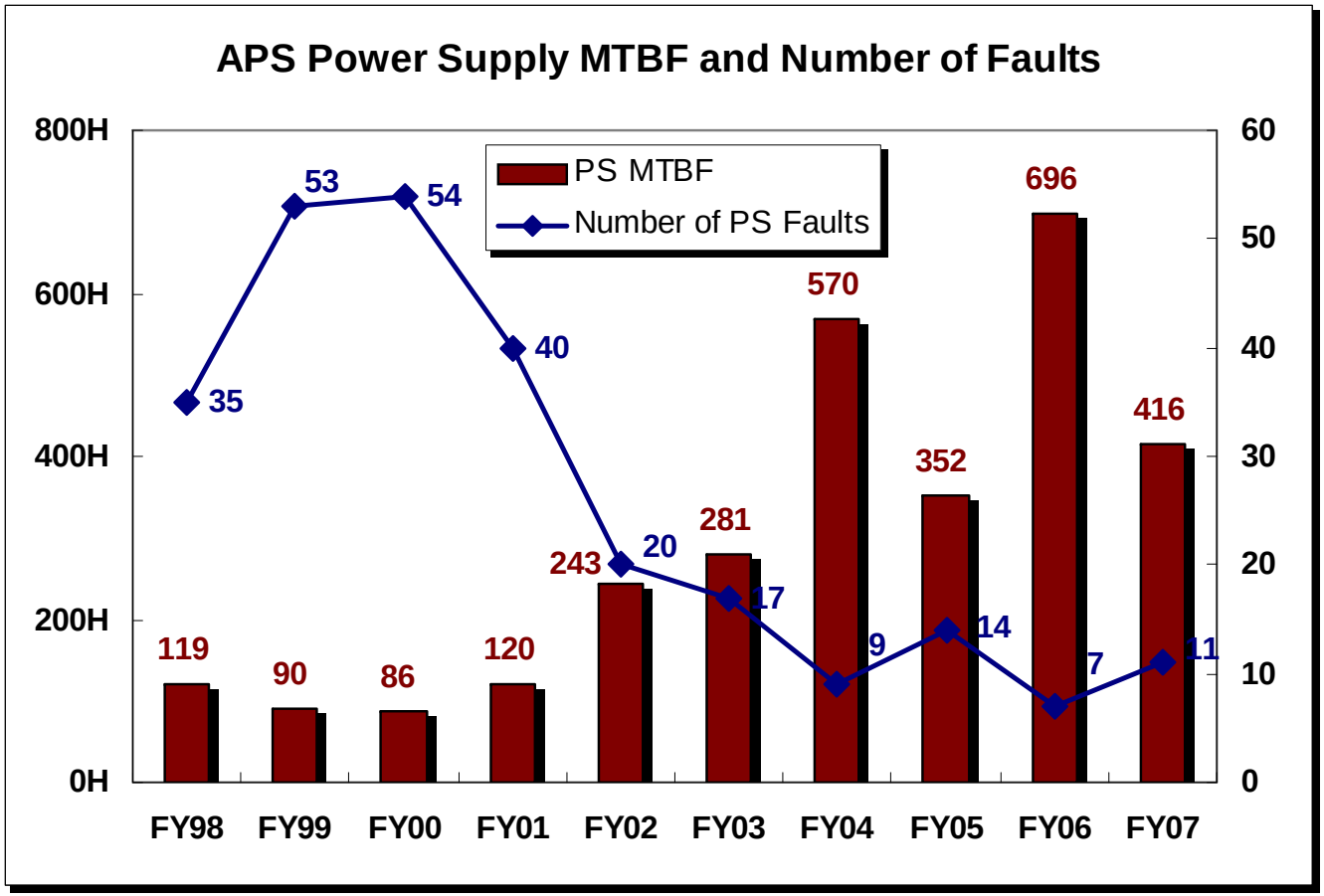


APS Power Supply Mean Time Between Failures*



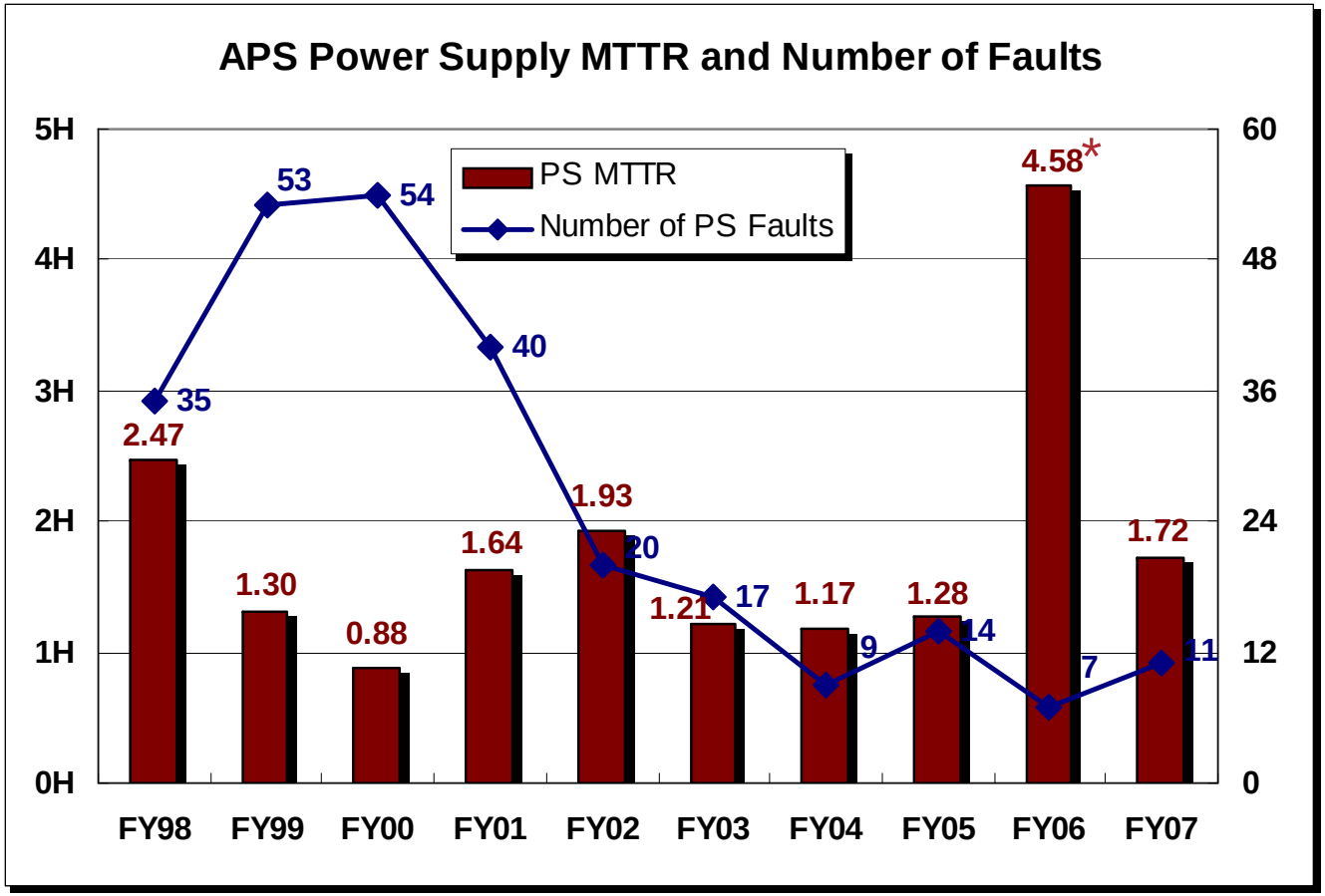
* Failures that caused machine downtimes.

APS Power Supply MTBF and Number of Faults*



* The number only includes faults that caused machine downtimes.

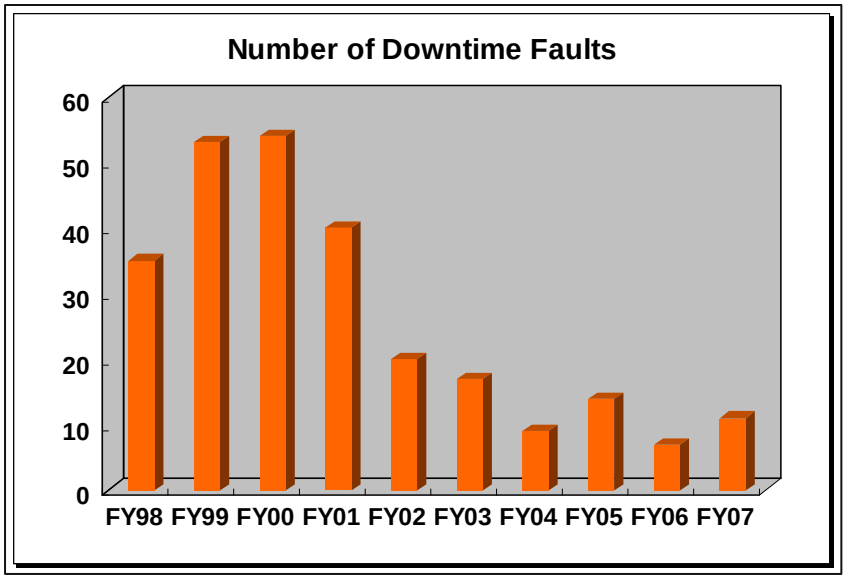
APS Power Mean Time to Repair for Operations



* A single fault in the Booster dipole supply costed more than 18 hours.

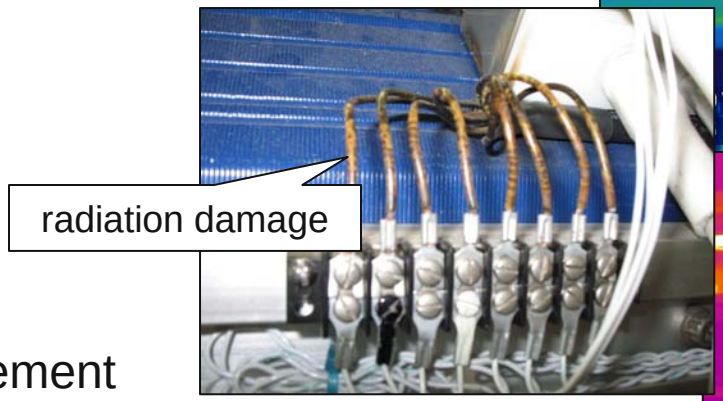
Reliability Improvements

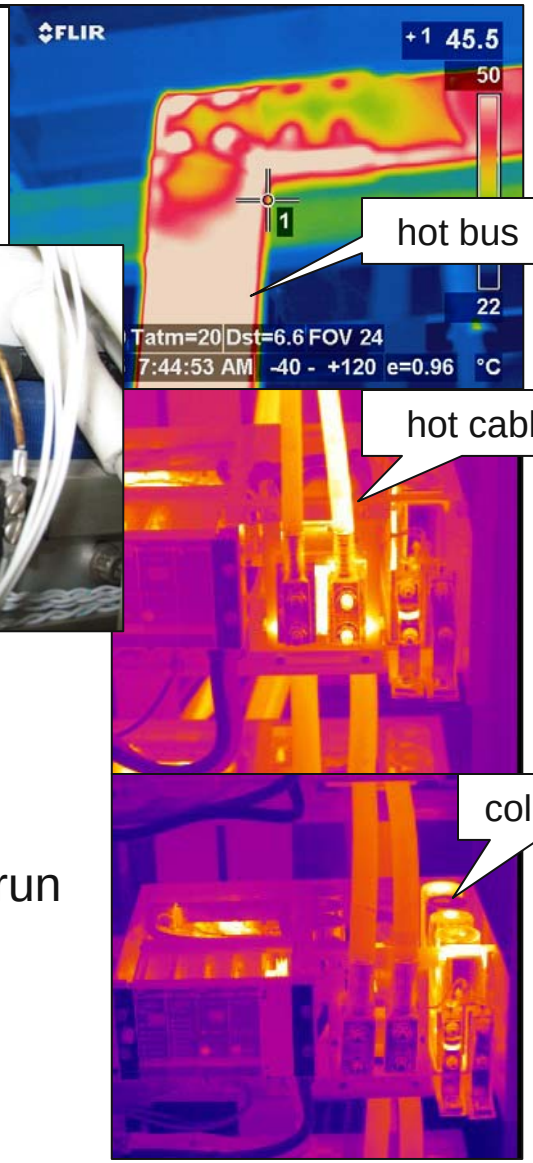
- Document, Analyze, Develop Solutions …
- Hardware/Software Upgrades
- Machine Recovery Procedure Change
  - Change from three resets to zero rest
- Proactive Maintenance
- Quality Assurance



Reliability Improvements – Proactive Maintenance

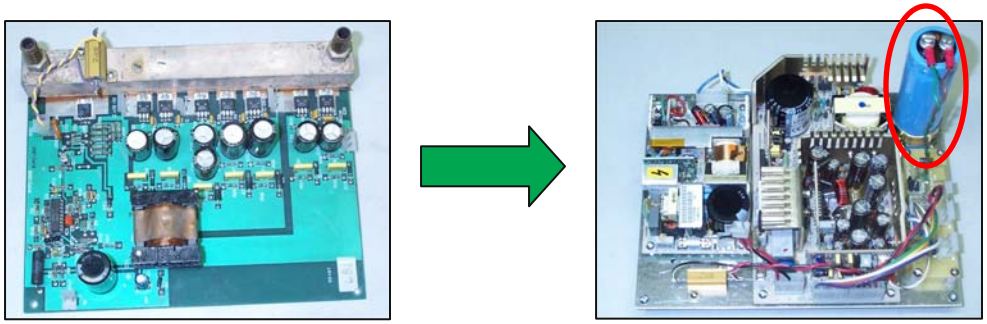
- Thoroughly analyze faults and develop remedies
- Identify, improve, or replace weak components
  - Visual inspection
  - Thermal imaging
    - *Capacitors*
    - *Connections*
    - *Fuses*
  - Preventive replacement
    - *Capacitors*
    - *Fuses*
    - *Water hoses*
- Systematically test all the equipment before each run
  - Performance test
  - Thermal test
  - Stress test



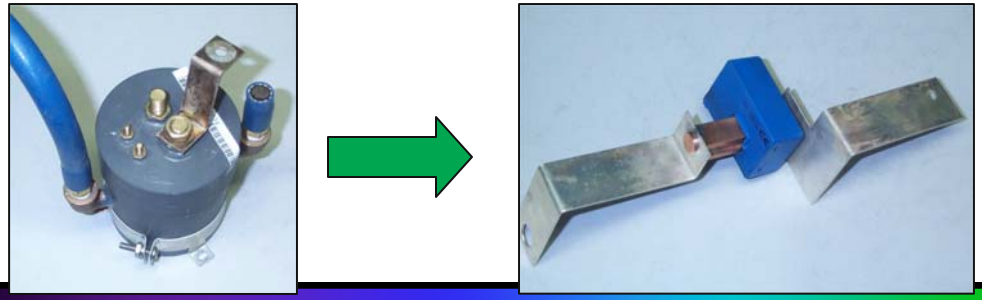


Reliability Improvements - Hardware Upgrades

- Control Power Supply Upgrade
  - Replaced in-house designed fly-back supplies with commercial supplies



- IGBT Protection Against Power Outages
  - Energy dumping resistors to DC raw supplies
  - Large capacitor on the control power supplies
- Replaced Water-cooled Shuts with LEMs

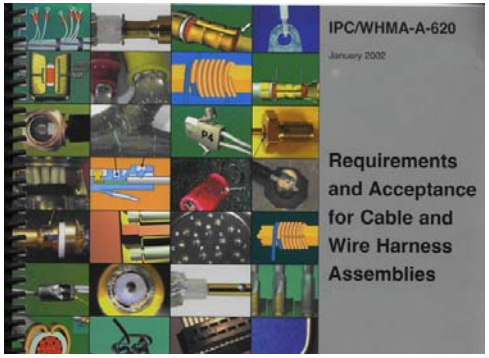


Reliability Improvements - Software Upgrades

- Send set point only when there is a change
- Change the way correctors receive their set point to minimize glitches
  - Old design reads the old set point from DAC, calculates the difference between the new and old set points, and sends count up or count down pulses to change the set point
  - New design sends the complete new set point through synchronized Clock and Data lines

Reliability Improvements – Quality Assurance

- Trained group members in 2003 for
  - IPC electronics assemblies and wiring standards
- Developed an official QA program in 2005
- Expanded QA to print circuit board design in 2007
- The QA program uses IPC standards
  - Acceptability of Electronic Assemblies (IPC-A-610C)
  - Requirements and Acceptance for Cable and Wire Harness Assemblies (IPC-A-620)
  - Acceptability of Printed Boards (IPC-A-600F)
  - Generic Standard on Printed Board Design (IPC-2221)
  - Sectional Design Standard for Rigid Organic Printed Boards (IPC-2222)
  - Guidelines for Printed Board Component Mounting (IPC-CM-770E)
  - Component Packaging and Interconnecting with Emphasis on Surface Mounting (IPC-SM-780)



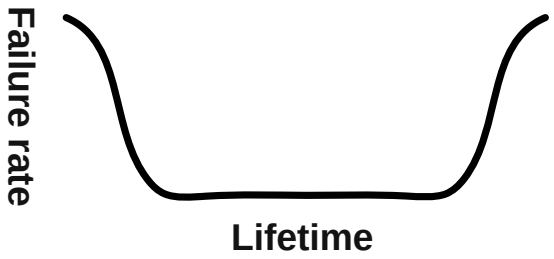
IPC—Association Connecting Electronics Industries®

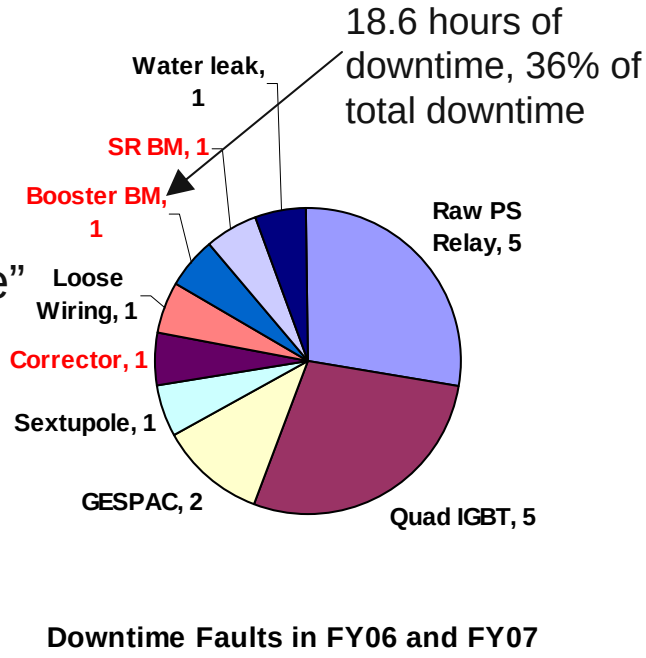
Reliability Improvements – Quality Assurance

- The QA Program Defines
  - Objective
    "The purpose of this quality assurance (QA) program is to maintain and improve (where feasible) the high reliability and performance of the APS by ensuring that any work performed on PSG equipment is done consistently and using the best known practices at the time."
  - Responsibilities and Authority
  - QA Process
    - *Work Flow*
      - New design and builds
      - Rework or repair
    - *Inspection*
      - No equipment can be put in service without passing the QA inspection

Challenges/Issues

- Faults with large and unique power supplies
  - Long trouble shoot time because of little experience or difficult to repair, typically takes more than four hours to recover
  - No hot-spares
- Non-reproducible faults
  - Converters taken out of service, but could not reproduce the fault on test stand
- Equipments are getting old
  - Approaching the end of the “bathtub curve”
  - Upgrade is hindered by poor budgets





Downtime Faults in FY06 and FY07

Summary

- Achieved a remarkable reliability record in last 10 years, greater than 99% availability and more than 350 hours MTBF
- Understand most of the remaining problems and have solutions
- Have a working QA program to ensure high reliability equipments
- Face more challenges as the machine gets old