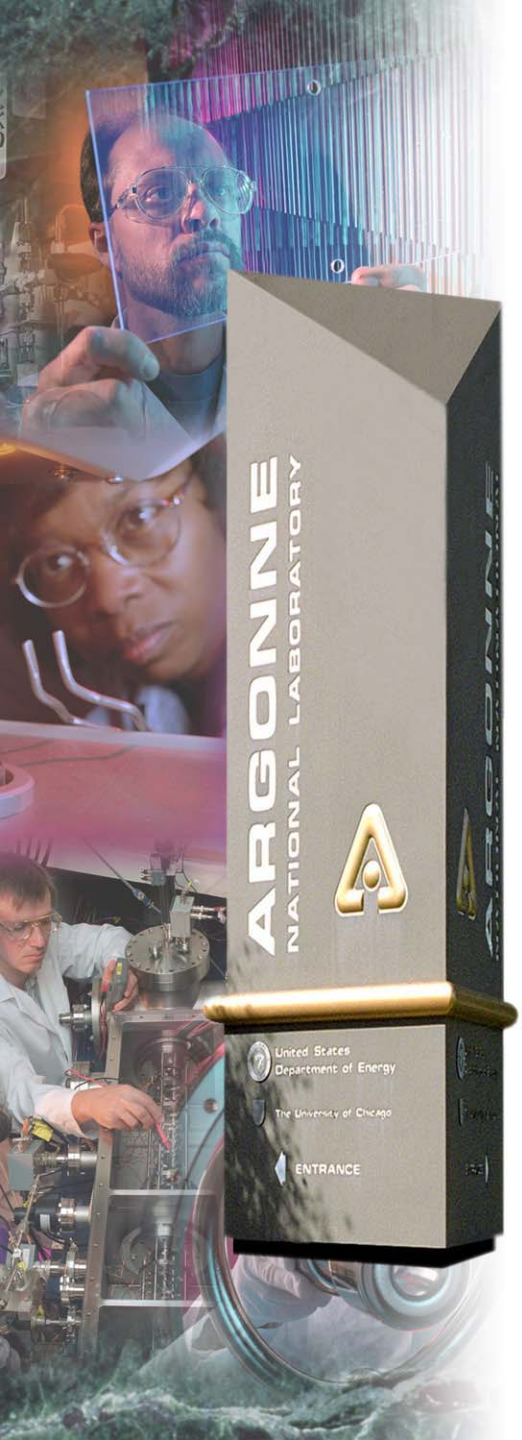


Accelerator Reliability and Enhancement at the APS

Rod Gerig

The University of Chicago Review
for the Advanced Photon Source
at Argonne National Laboratory

September 17-19, 2003

Office of Science
U.S. Department of Energy

A U.S. Department of Energy
Office of Science Laboratory
Operated by The University of Chicago

Outline of Presentation

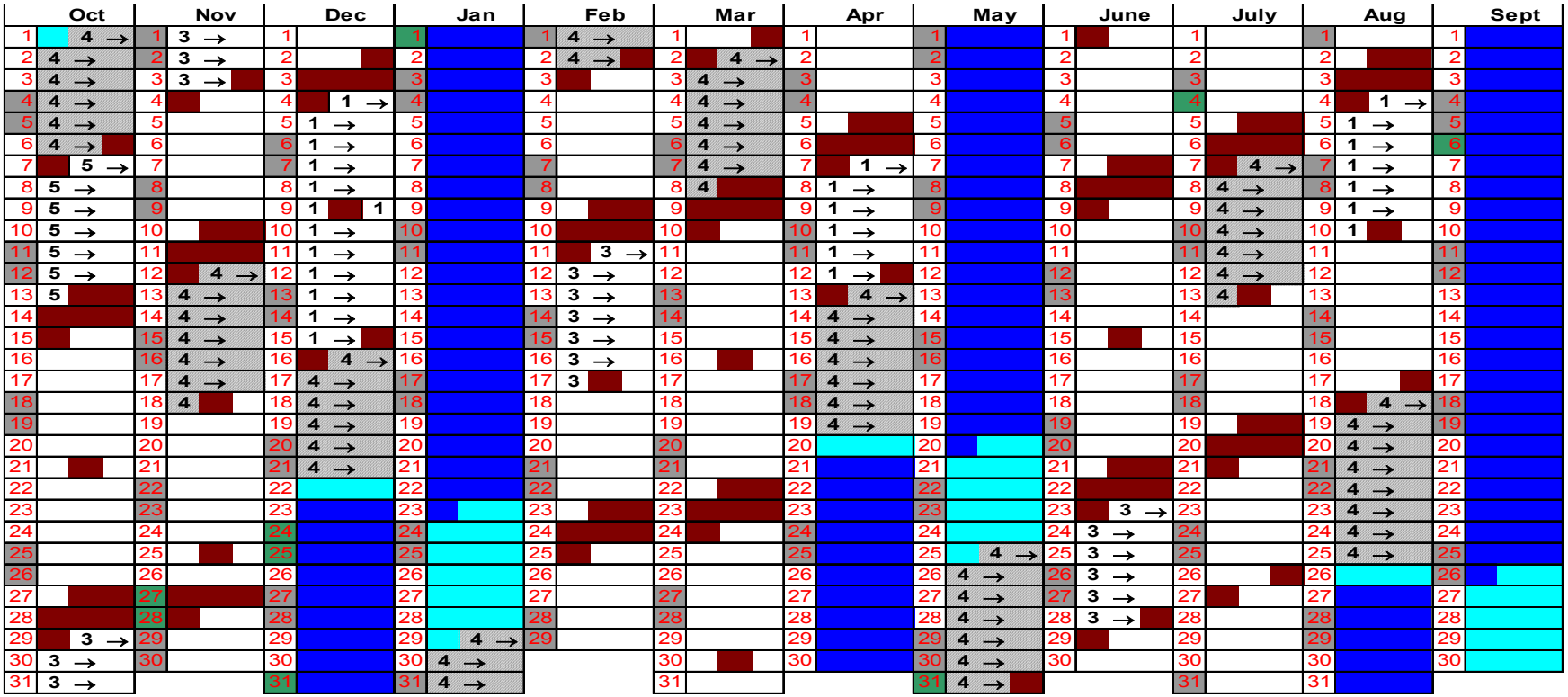
- **Accelerator Scheduling**
  - Special Operating Modes
- **Availability and Reliability Statistics**
- **Approaches to Accelerator Availability Improvements**
- **Approaches to Accelerator Performance Enhancements**

APS Operational Schedule for FY2004

APS FY 2004 Long Range Operations Schedule
(October 2003 – September 2004)

Tentative

Run 2003-03 | *Run 2004-01* | *Run 2004-02*



Top-up User Operation in low emittance mode
Non top-up User Operation
Fill pattern is 24 singlets unless otherwise indicated

SOM Periods
1 Hybrid Fill - (singlet)
2 Hybrid Fill - (triplet)
3 110 mA - Low E. singlets
4 324 Singlets - Low E. Fill
5 23 Singlets - Low E.

Machine Studies
Maintenance
Shifts set aside for Studies/ Machine Intervention as Needed

Weekends
Lab Holidays

Routine Top-Up User Operation

- **Fill pattern:**
  - 24 singlets (single bunch) with a maximum current of ~4.25 *mA* and a spacing of 153 *nanoseconds.* (Until FY2004, this mode was 23 singlets with 306 *nanosecond* gap between last and first bunch. The 23-bunch mode is now called **SOM5**).
- **Lattice configuration:**
  - Low horizontal emittance operation with a nominal effective emittance of 3.1 *nm-rad* and coupling of ~2.5%.
- **Refill schedule:**
  - Continuous top-up with refills occurring at a minimum of two minute, or a multiple of two minute, intervals - (i.e., 2, 4 or 6 minutes between refills).
- **Occasionally will use this mode with ~115 mA (SOM3).**

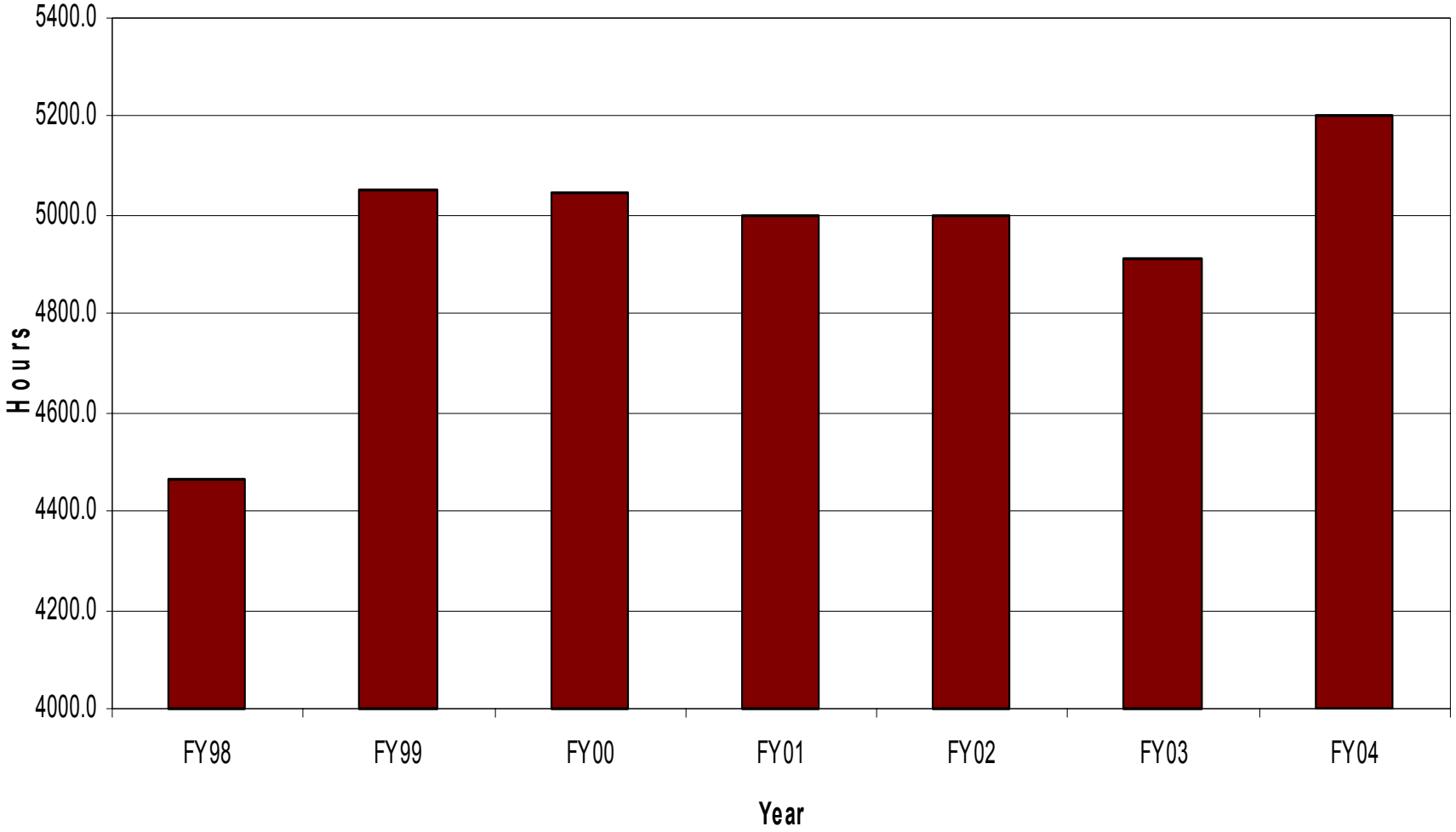
Special Operating Mode 1 (SOM1) – Hybrid Fill (Singlet)

- **Fill pattern:**
  - A single bunch containing a maximum of 5 *mA* isolated from the remaining bunches by symmetrical 1.59 *microseconds* gaps. The remaining current is distributed in 8 groups of 7 consecutive bunches with a maximum current of 12 *mA* per group and a spacing of 48 *nanoseconds* between groups.
- **Lattice configuration:**
  - Low horizontal emittance operation with a nominal effective emittance of 3.1 *nm-rad* and coupling of ~0.5%.
- **Refill schedule:**
  - Continuous top-up with refills occurring at a minimum of two minute, or a multiple of two minute, intervals - (i.e., 2, 4 or 6 minutes between refills).

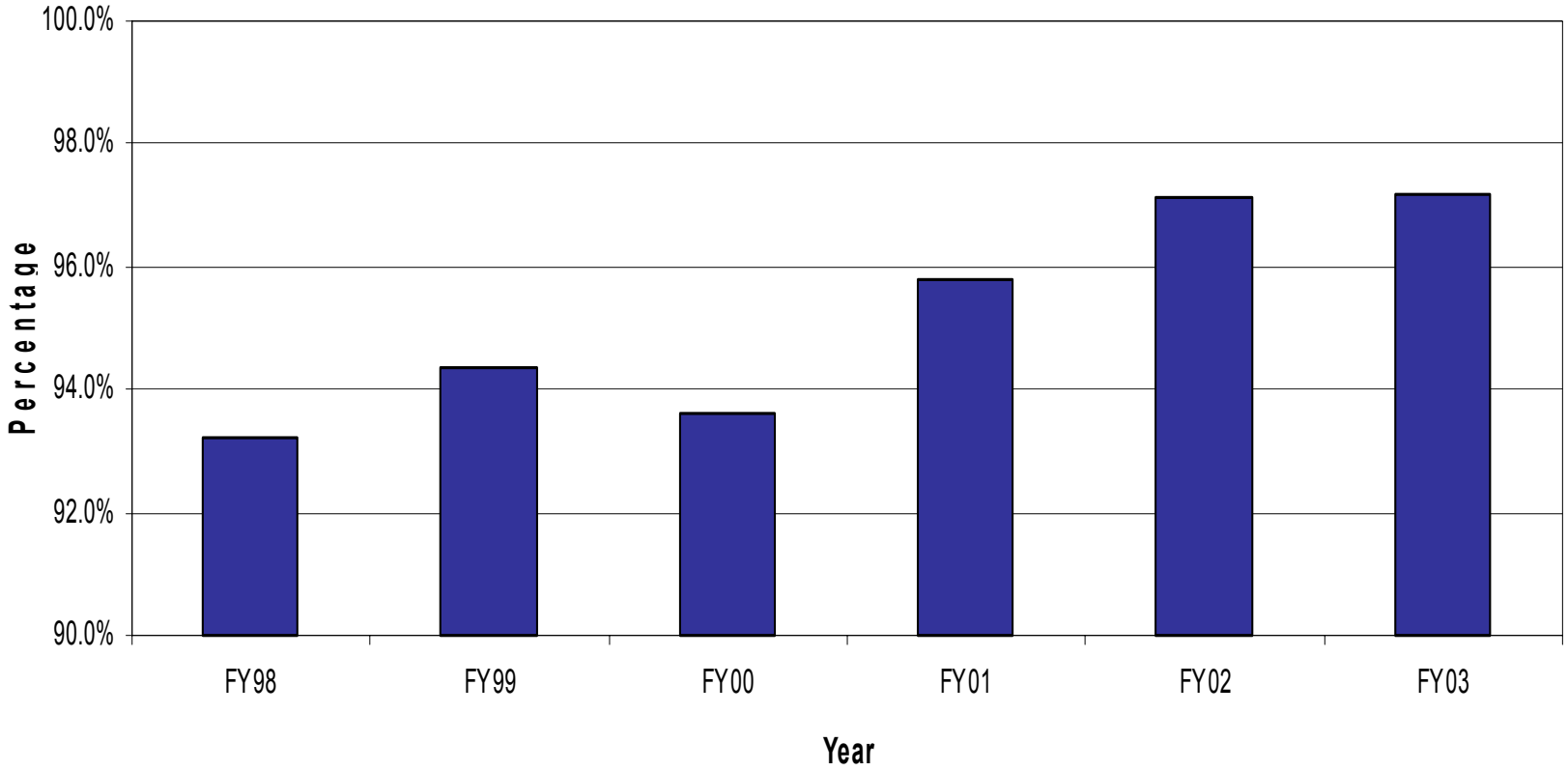
Special Operating Mode 4 (SOM4) – Low-Emittance Fill

- **Fill pattern:**
  - 324 uniformly spaced singlets with a nominal current of 0.31 mA, and a spacing of 11.37 *nanoseconds* between singlets.
- **Lattice configuration:**
  - Low horizontal emittance operation with a nominal effective emittance of 3.1 *nm-rad* and coupling of ~ 2.5%.
- **Refill schedule:**
  - Fill-on-fill two times per day, nominally at 7:45 AM, 7:45 PM. Lifetime is expected to be > 75 hours. There should be > 85 mA remaining at the time of each refill.

APS Scheduled User Hours

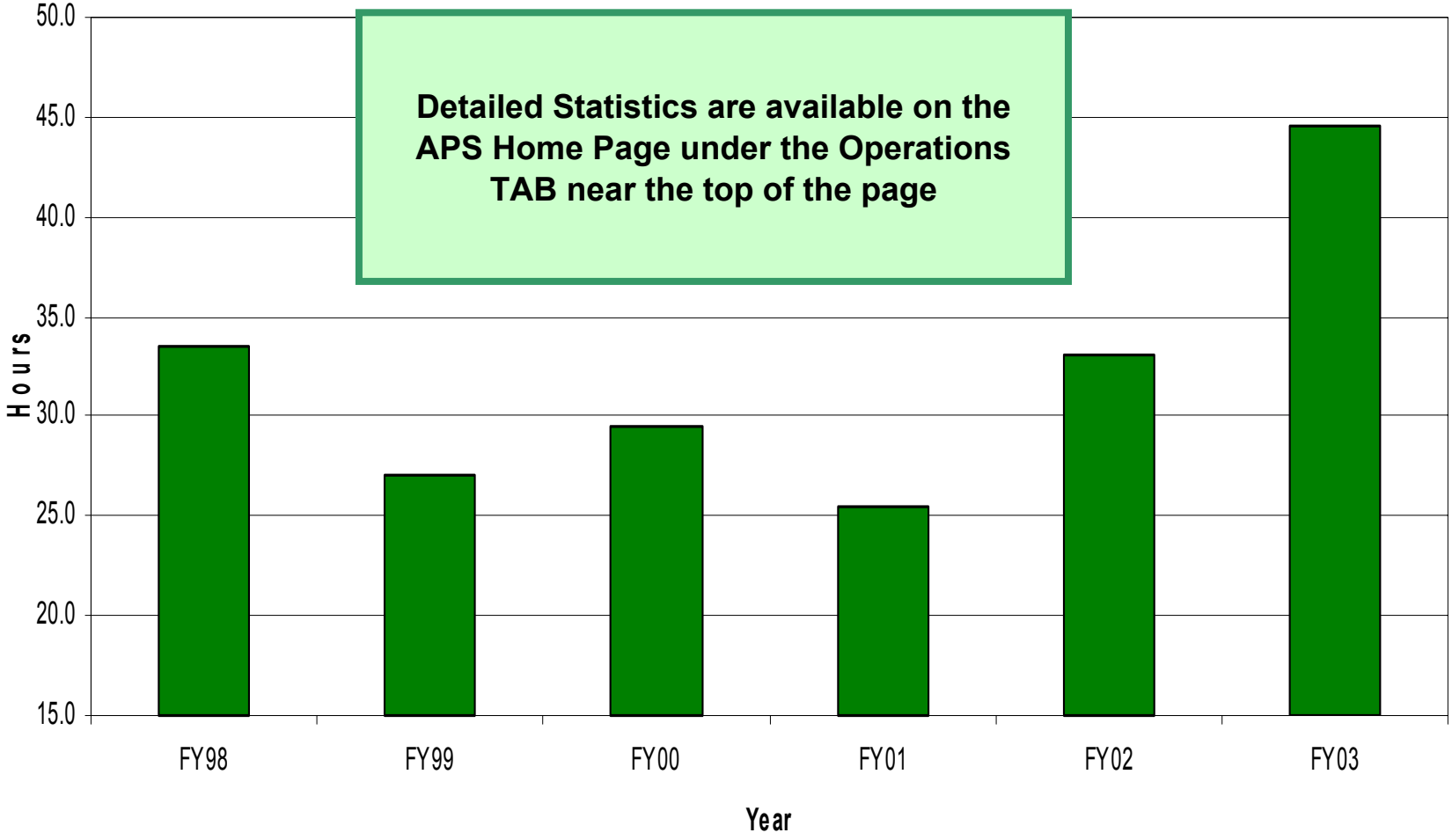


APS Run History Operational Statistics
X-ray Availability
Data from FY1998 through Present



Through the end of FY03

APS Run History Operational Statistics
Average Fill Duration Without a Fault (MTBF)
Data from FY 1998 through Present



Through the end of FY03

Availability Strategy

- **Mean Time to Recovery is approximately 1 hour (median time to recovery is less than .5 hours). Therefore, the only substantial improvements that impact scientific output are those that reduce the fault rate.**
  - Increased effort to identify root causes of faults, both system-wide (goal of no “Unknown Beam Loss”) and improved hardware diagnostics to identify problematic component
  - A change has been made (2003) in our strategy; we now replace tripped components upon first trip
- **Concurrently, we focus on the prevention of catastrophic failures.**

Fault Reduction (Run 2003-1 as Example)

Fill Number	Time of Fault		Fault text	Fault Group	
# 1	01/30 07:44	23.75	Correct P0 Err.	[CTL]	module failed (cold solder joint found later), replaced with spare
# 40	02/26 16:48	5.71	IOCRFTime problem	[CTL]	Caused by GPIB link/devices that are no longer used in operation.
# 41	02/26 23:49	6.14	IOCRFTIME problem	[CTL]	Devices and GPIB link removed
# 64	03/12 15:54	7.9	VacValve VM-39-VV02	[CTL]	Normal valve trip. The chassis for this particular valves
# 73	03/29 09:50	59.28	S39:VV01 Valve trip	[CTL]	will be replaced this shutdown.
# 23	02/15 11:09	75.16	1ID BPLD trip	[DIAG]	
# 25	02/15 11:28	0.04	1ID BPLD trip	[DIAG]	Debate with rf group over trips, improve rf diagnostics??
# 26	02/15 14:26	2.58	1ID BPLD trip	[DIAG]	
# 89	04/15 15:40	7.65	iocs31bpm reboot	[DIAG]	MPS card in IOC, so power down to reset IOC breaks timer to MPS
# 90	04/15 18:02	1.85	2ID BPLD fault	[DIAG]	
# 93	04/16 17:57	8.24	2ID BPLD fault	[DIAG]	
# 94	04/17 11:58	17.33	2ID BPLD fault	[DIAG]	All during 324 bunch operation, improve BPLD
# 96	04/17 21:23	8.96	2ID BPLD fault	[DIAG]	
#103	04/20 21:46	14.8	2ID BPLD fault	[DIAG]	
# 31	02/19 02:52	10.86	S9BQ2 failure	[ES]	Converter replacement, solder joint problem
# 57	03/10 01:28	65.56	S32B:Q5 converter	[ES]	Water header backflushed
# 65	03/17 01:25	105.26	S33B:V1 problem	[ES]	Converter noisy near zero; new design, underway, will solve
# 69	03/21 12:26	26.04	2ID PSS trip	[ES]	UPS failure, major UPS upgrade underway
# 72	03/26 21:22	13.37	S15B:MT trip	[ES]	TBD
# 86	04/09 11:34	3.55	15ID PSS fault	[ES]	Replaced control power supply with larger capacity unit
# 91	04/16 08:31	13.62	ACIS relay fault	[ES]	Unknown
# 98	04/20 05:27	51.92	S36AQ5 failure	[ES]	Converter Swapped, failure not understood
# 4	02/02 02:28	58.41	18ID Rad. Mon. Trip	[HP]	
# 74	04/01 04:25	66.19	Spurious RadMon.trip	[HP]	
# 80	04/05 16:13	54.94	5ID Rad.Mon.failure	[HP]	
# 87	04/13 09:30	92.82	10ID Rad.Mon. Err.	[HP]	
# 43	03/01 12:17	18.42	Rad.mon.trip @inj.	[OPS]	
# 55	03/07 07:44	19.38	Bunch purity	[OPS]	
# 81	04/06 14:02	19.73	Rad.trip @ refill	[OPS]	

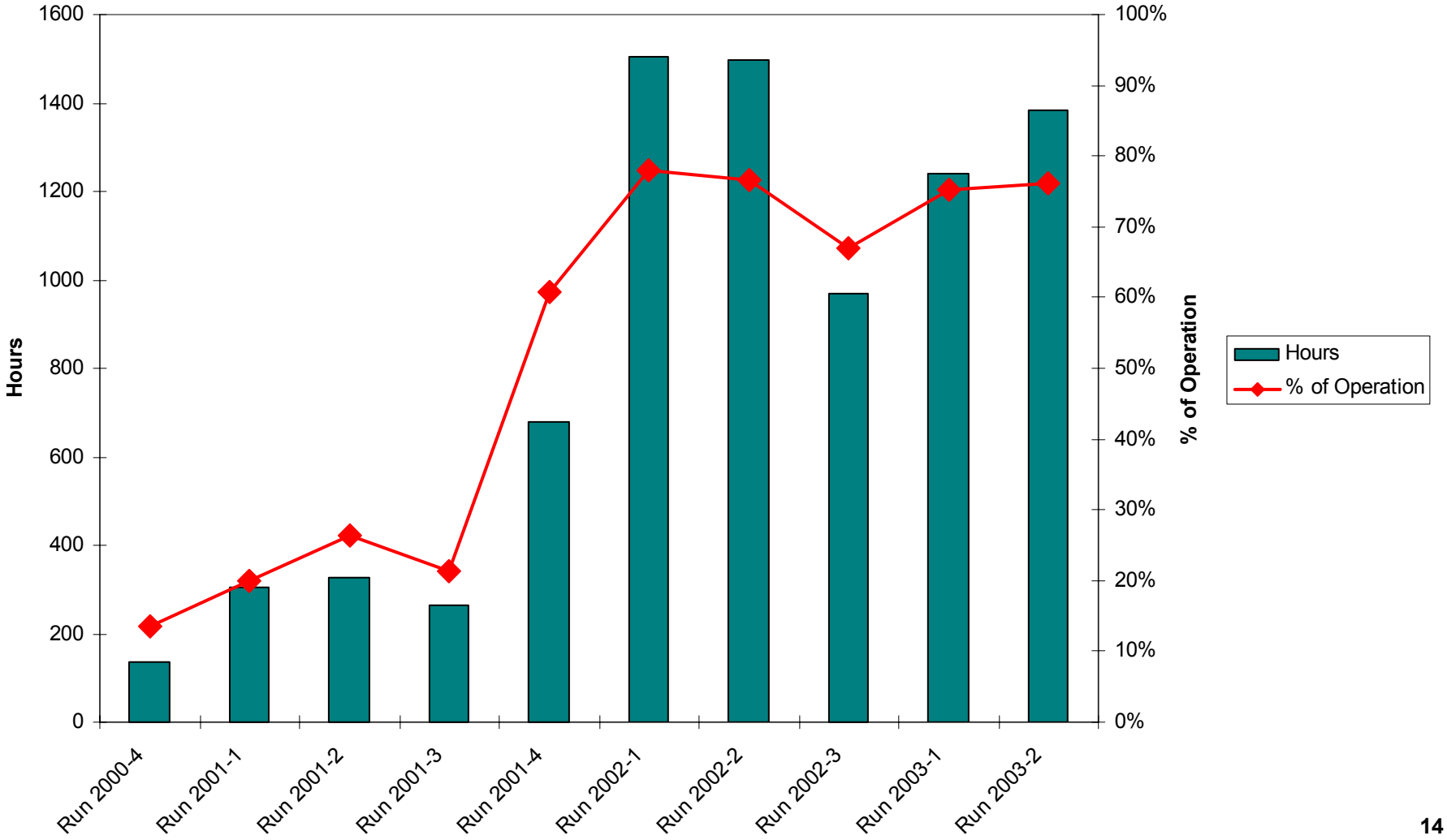
Fault Reduction - Continued

# 3	01/30 13:59	5.38	line power bump	[OTHER]	Both trips due to salt contamination	
# 50	03/06 11:22	51.36	Power bump	[OTHER]	on a ComEd 138kV transmission line	
# 15	02/07 08:34	72.38	rf4 Vac trip	[RF]		
# 16	02/07 16:19	7.02	rf4 llrf trip (was vacuum)	[RF]		
# 18	02/09 13:36	43.48	rf4 Vac trip	[RF]		
# 27	02/15 15:44	0.91	S37 Cav. Vacuum	[RF]		
# 28	02/15 18:14	1.77	RF4 sideband	[RF]	Vacuum trip due to cavity venting	
# 29	02/15 18:36	0.06	RF4 sideband	[RF]		
# 35	02/24 00:21	30.4	S40 Cav.Vac. trip	[RF]		
# 70	03/22 04:07	15.08	RF4 cav.Vac.Flt	[RF]		
# 77	04/02 16:38	22.25	S40 cav.vac trip	[RF]		
# 32	02/20 05:39	25.56	RF2 crowbar trip	[RF]	Faulty di/dt circuitry (fixed on 3/4/03).	**Done**
# 17	02/07 17:25	0.73	Beam Instability	{RF]		
# 33	02/22 17:20	59.45	RF2 crowbar trip	[RF]	Faulty di/dt circuitry (fixed on 3/4/03).	**Done**
# 34	02/22 17:41	0.04	RF2 crowbar trip	[RF]		
# 38	02/26 09:50	1.83	RF3 loss due to RF2	[RF]	Faulty di/dt circuitry + power monitor fault (fixed on 3/4/03)	**Done**
# 39	02/26 10:55	0.55	RF3 loss due to RF2	[RF]		
# 42	02/28 17:27	41.36	RF3 loss due to RF2	[RF]	Faulty di/dt circuitry + power monitor fault (fixed on 3/4/03)	**Done**
# 48	03/03 09:18	37.37	RF3 HVPS trip	[RF]	RF2 Power monitor fault turned off RF3 too fast. Fixed	**Done**
# 68	03/20 10:06	42.1	RF4 Power loss	[RF]	RF4 Power monitor major fault - changed PM on 04/07.	**Done**
# 78	04/03 09:04	15.73	RF4 lost power	[RF]	RF4 Power monitor major fault - changed PM on 04/07.	**Done**
# 10	02/02 05:45	0.77	22ID BPLD trip	[UKN]		
# 45	03/01 18:54	6.27	22ID BPLD trip	[UKN]		
# 47	03/01 19:45	0.62	Unknown beam motion	[UKN]		
Red Text: Faults occurred within one hour of previous fill and did not count in overall MTBF						

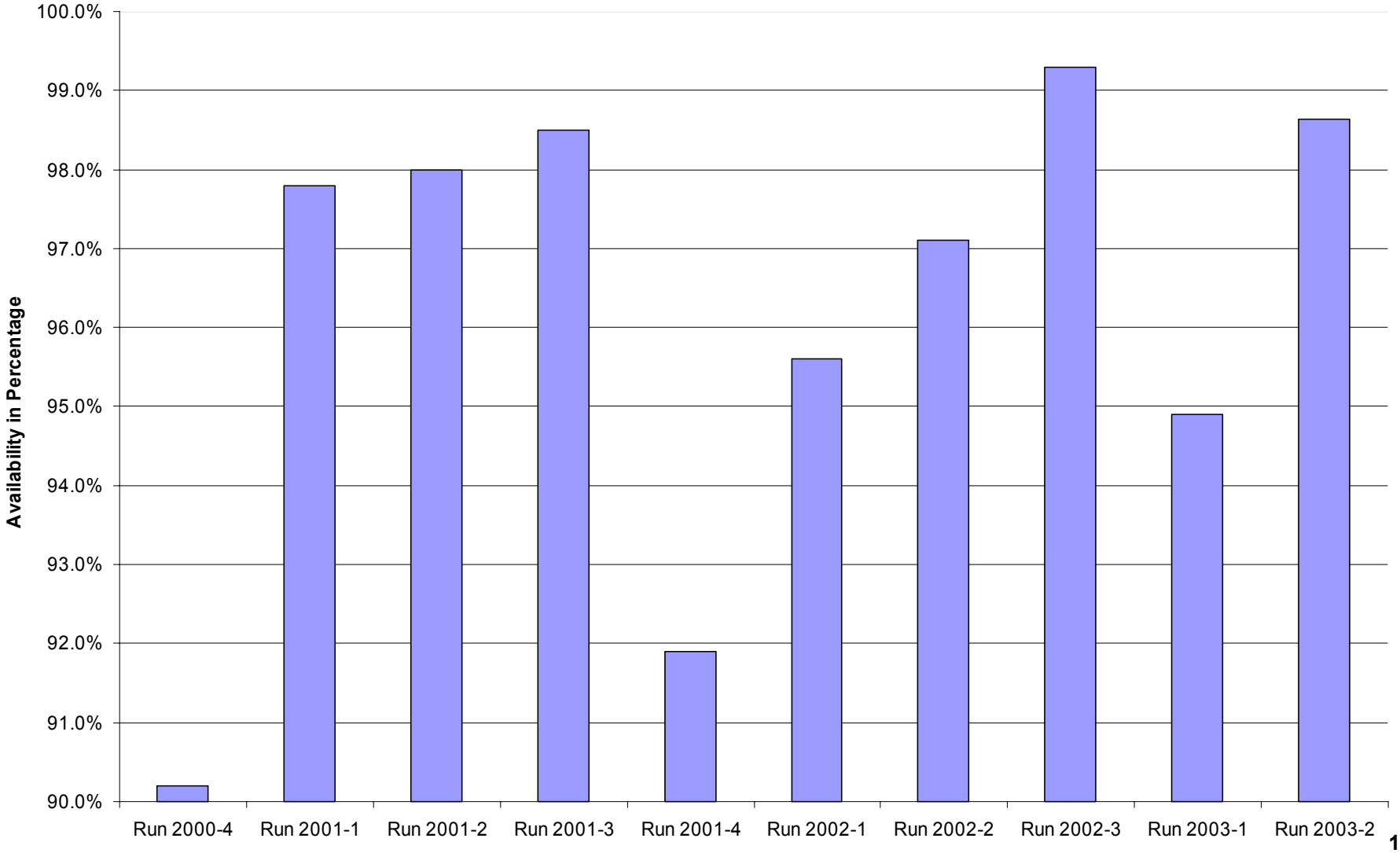
Reliability – Availability Initiatives

- Storage ring rf test stand – Test and condition components before installation in ring (poster sessions)
- Continuous improvement on SR rf systems
- PS converter improvements (poster)
- Replacement of vacuum valve controllers
- Replace / upgrade radiation monitors
- PAR obviation (see poster on “Direct Injection to Booster”)
- Robustness in power bumps
- Improvements to beam position interlock system (poster)
- Improved hardware diagnostics

Hours of Top-Up Operation



Injector Availability During Top-Up Operation



Accelerator Enhancements

Implemented: 1996 - Present

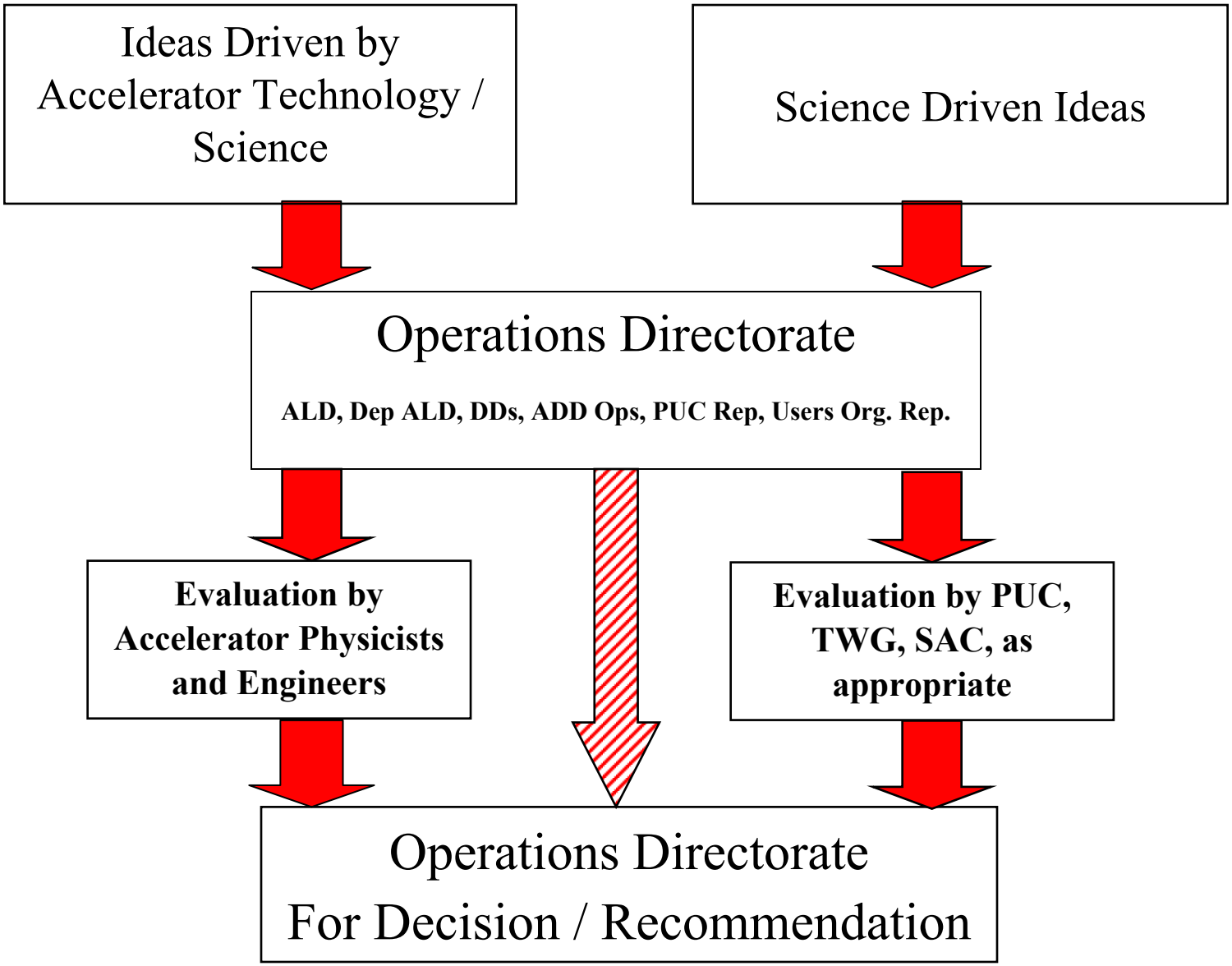
- **Top-up operation**
- **Reduced beta lattice for small-gap ID chambers**
- **Reduced natural emittance (8.0 nm-rad → 2.5 nm-rad)**
- **Canted undulator design allowing two beams from single straight section**
- **Beam stability**

Future Enhancements

- **Process has been developed to identify and prioritize accelerator enhancements to best address needs of scientific community.**

- **Accelerator enhancement ideas come from:**
  - Accelerator community
  - User community

- **Accelerator enhancements can improve scientific capability for some users while reducing it for others.**


Ideas Driven by Accelerator Technology / Science
Science Driven Ideas
Operations Directorate
ALD, Dep ALD, DDs, ADD Ops, PUC Rep, Users Org. Rep.
Evaluation by Accelerator Physicists and Engineers
Evaluation by PUC, TWG, SAC, as appropriate
Operations Directorate
For Decision / Recommendation

Enhancements Under Consideration or Implementation

- **Higher current**
- **Longer straight section implementation (IXS)**
- **Increase single-bunch current (poster session)**
  - Flexibility in fill pattern
- **Shorter x-ray pulses**