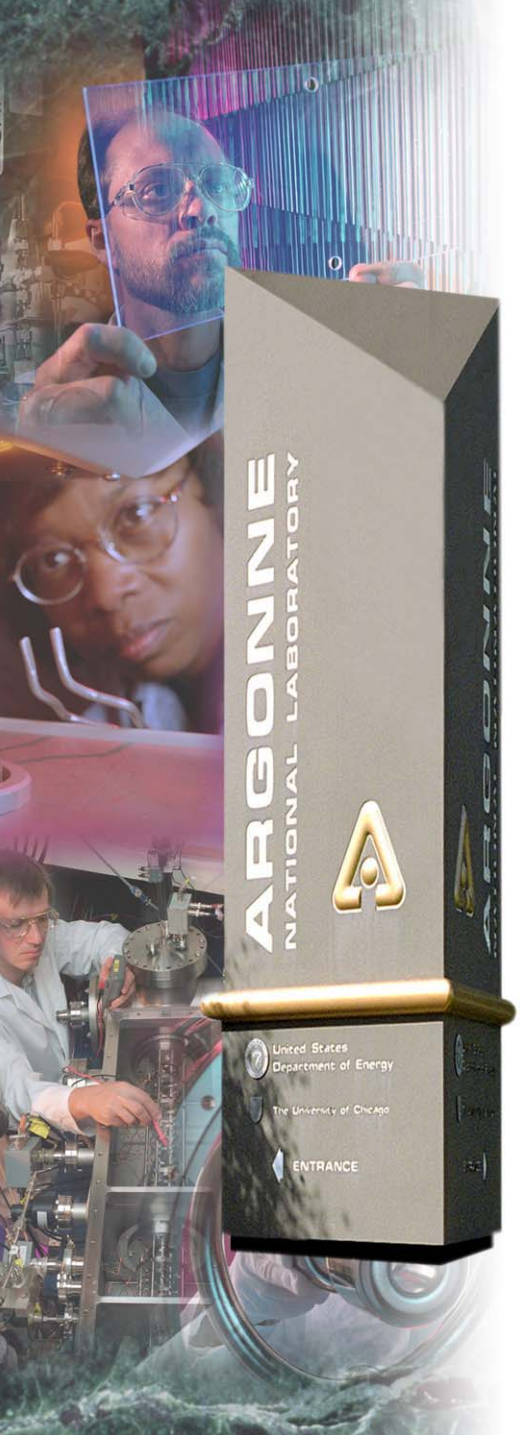


APS Operational Efficiency and Challenges

Rod Gerig

Three-way Meeting

June 2, 2003

Argonne National Laboratory

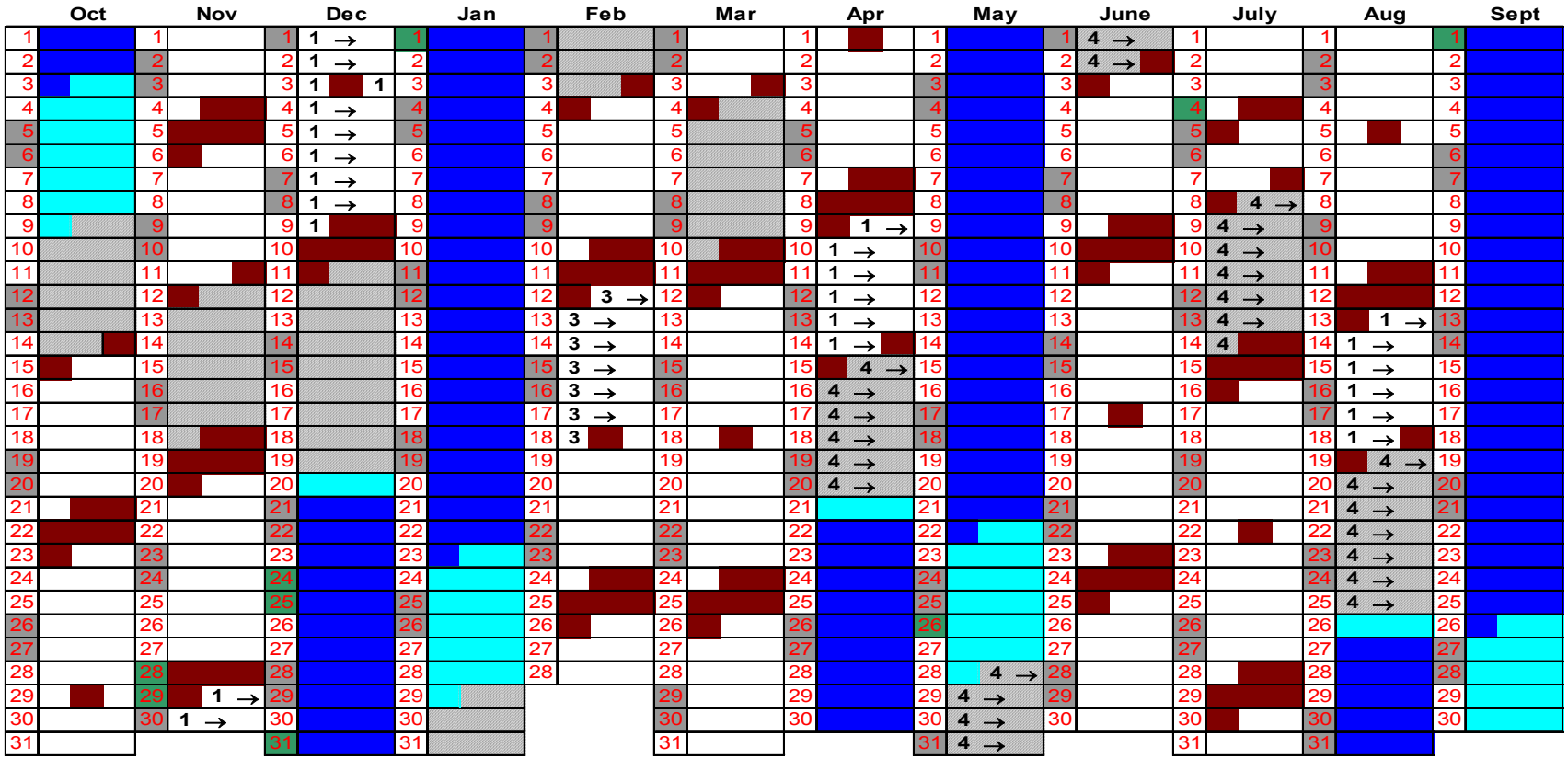
Office of Science
U.S. Department of Energy

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

APS Operational Schedule for FY2003

APS FY 2003 Long Range Operations Schedule
(October 2002 – September 2003)

Run 2002-03 | *Run 2003-01* | *Run 2003-02*



Top-up User Operation in low emittance mode
Non top-up User Operation
Fill pattern is 23 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

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

Weekends
Lab Holidays

Routine Top-up User Operation

- **Fill pattern:**
  - 23 singlets (single bunch) with a maximum current of ~4.5 *mA* and a spacing of 153 *nanoseconds* between singlets followed by a 306 *nanosecond* gap.
- **Lattice configuration:**
  - Low horizontal emittance operation with a nominal effective emittance of 2.9 *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)**

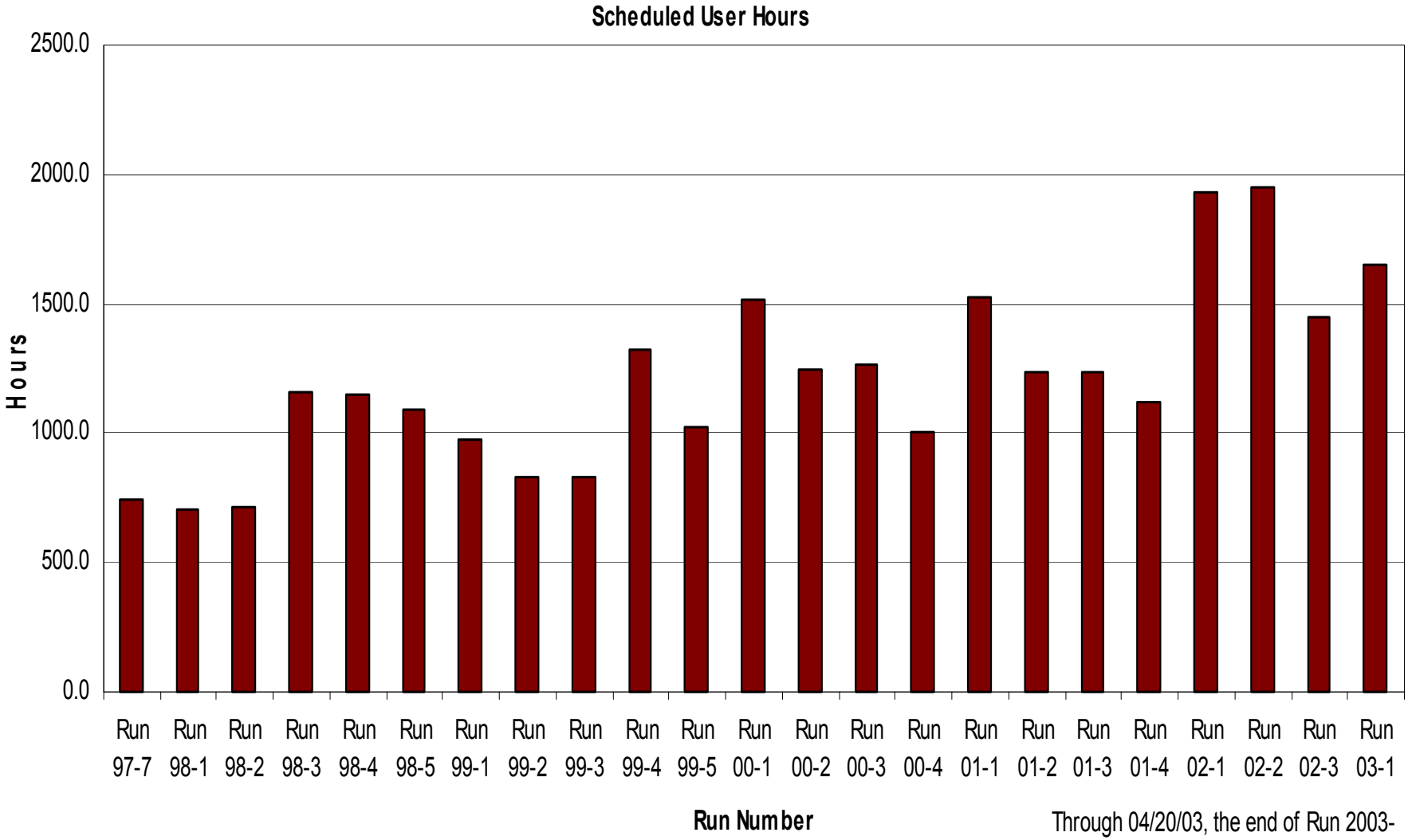
Special Operating Mode 1 (SOM1) - Hybrid fill (singlet)

- **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 2.9 *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)

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 2.9 *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 Run History Operational Statistics

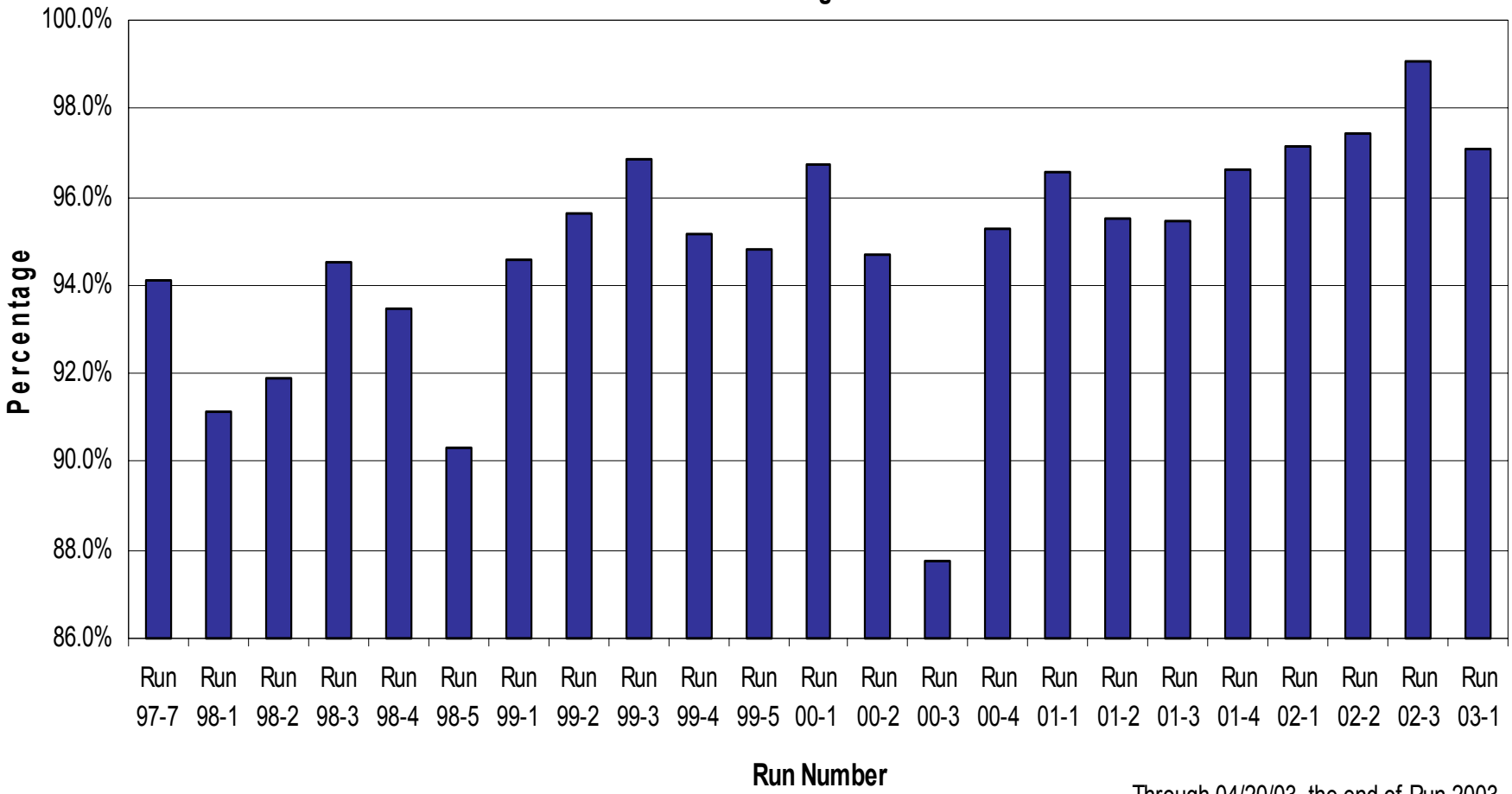


Through 04/20/03, the end of Run 2003-

Availability – Reliability Methodology

- **Schedule driven**
- **Beam is ‘available’ only when there is beam in the SR, and the MCR has granted a shutter open permissive**
- **When we inject with shutters open, we count the time available**
- **If a problem occurs necessitating the opening of all insertion devices, that time is subtracted, but it is not considered a fault**
- **If we run into a shutdown or machine intervention period, we increase the numerator and denominator**
- **A fault is counted any time the beam is lost. The exception is if the fault is within one hour of the most recent refill; if so, the fault is not counted, and the preceding time is considered unavailable (I.e, no fill of less than one hour is counted)**

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

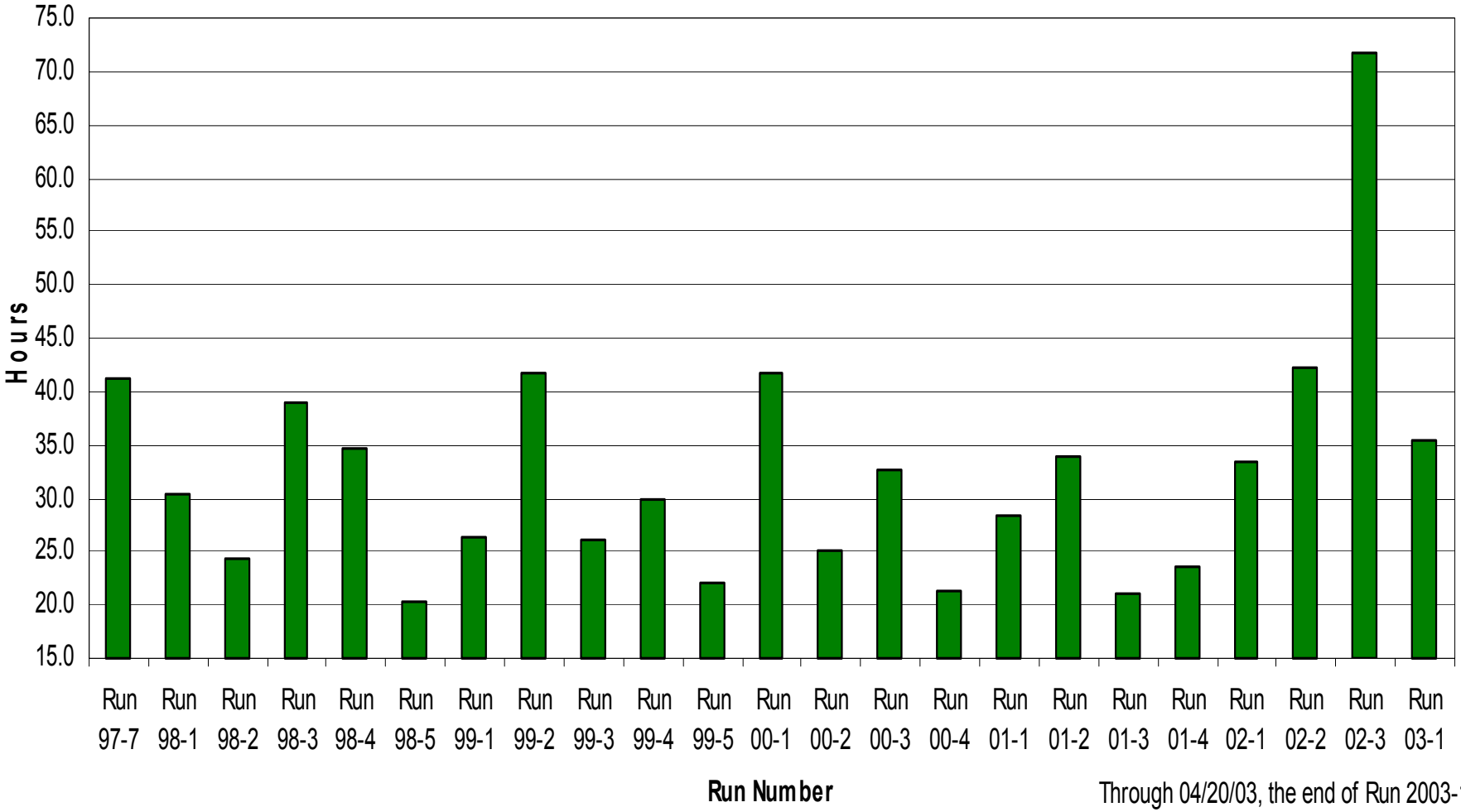


Through 04/20/03, the end of Run 2003-

APS Run History Operational Statistics

Average Fill Duration Without a Fault (MTBF)

Data from FY 1998 through Present



Through 04/20/03, the end of Run 2003-1

Statistics Overview

	CY2001				CY2002
Run Number		Run 02-1	Run 02-2	Run 02-3	
Start		1/23/2002	5/29/2002	10/9/2002	
End		4/29/2002	9/3/2002	12/19/2002	
Total Hours Scheduled (h)	5120.2	1927	1952	1449	5328
Beam Available for Users (h)	4917.1	1871.9	1902.2	1434.6	5208.7
Beam Availability	96.0%	97.1%	97.4%	99.0%	97.8%
Total Downtime (h)	203.1	55.1	49.8	14.4	119.3
Average Current (mA)	87.8	97.4	97.6	95.0	96.8
Number of Faults	189	56	45	20	121
Mean time Between Faults (h)	26.0	33.4	42.3	71.7	43.0
Mean time to Recovery (h)	1.1	0.98	1.11	0.72	0.99
Injector Availability		96.0%	96.5%	99.3%	97.1%

Availability Strategy

- **Mean time to Recovery is less than 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 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

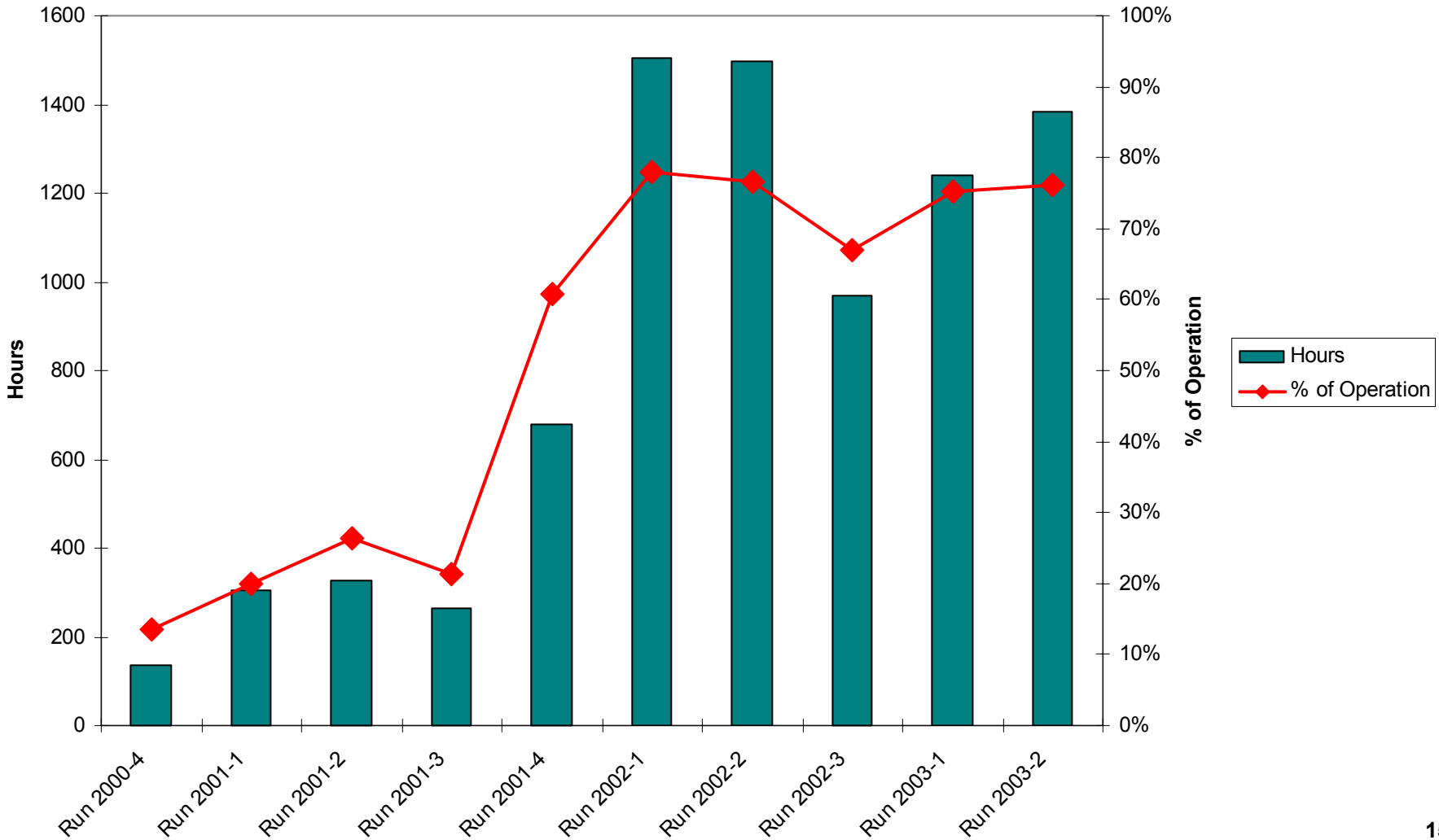
# 3	01/30 13:59	5.38	line power bump	[OTHER]	Both trips due to salt contamination	
# 50	03/06 11:22	51.36	Power bump	[OTHER]	on a ComEd 138kV transmission line	
# 15	02/07 08:34	72.38	rf4 Vac trip	[RF]		
# 16	02/07 16:19	7.02	rf4 llrf trip (was vacuum)	[RF]		
# 18	02/09 13:36	43.48	rf4 Vac trip	[RF]		
# 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

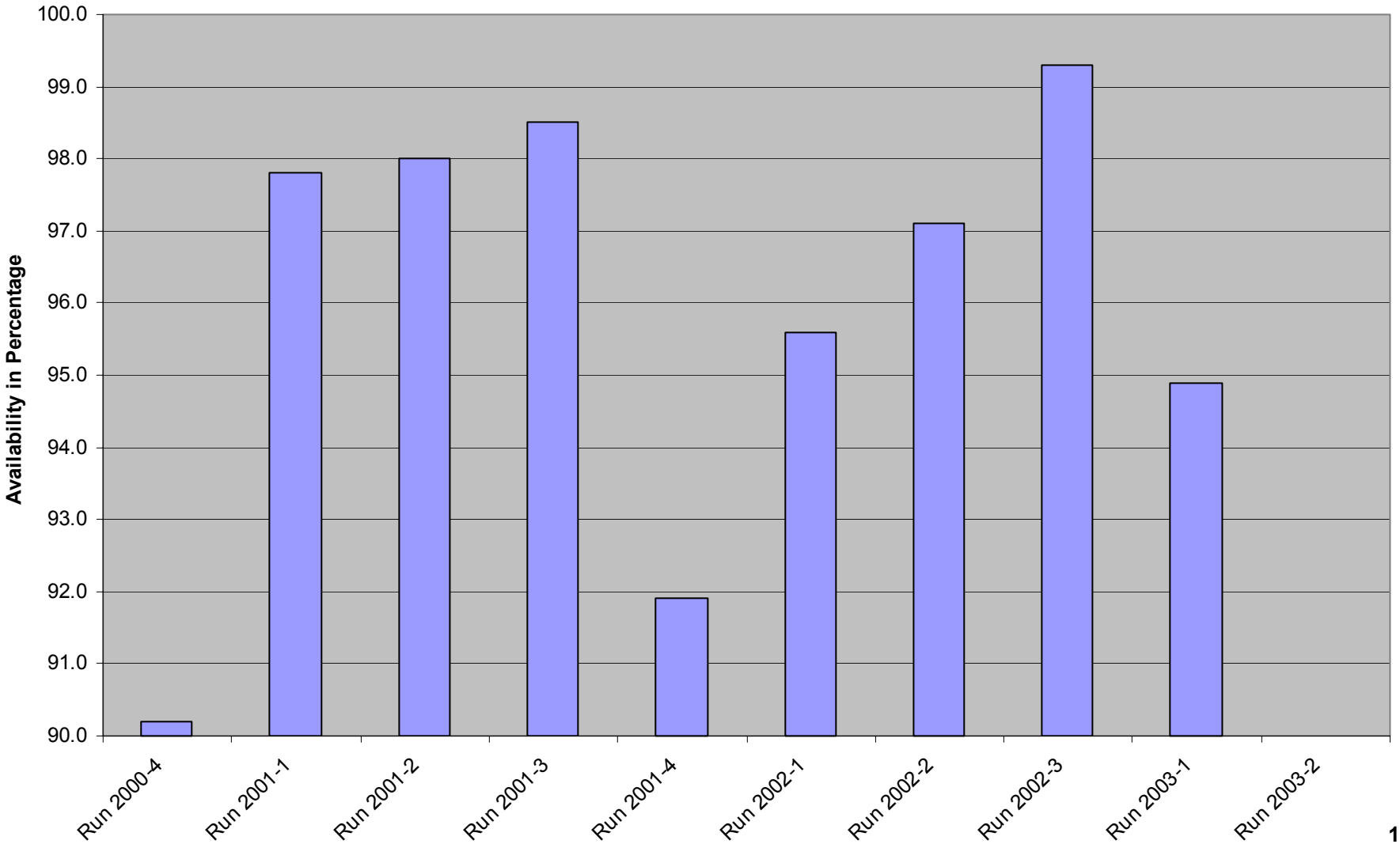
Reliability – Availability Initiatives

- **Storage Ring RF Test Stand – Test and condition components before installation in ring**
- **Continuous improvement on SR RF systems**
- **PS Converter improvements**
- **Replacement of vacuum valve controllers**
- **Replace / upgrade radiation monitors**
- **Improved hardware diagnostics**

Hours of Top-Up Operation



Injector Availability During Top-Up Operation



APS Running Statistics; FY98 to Present

	Scheduled User Hours	Storage Ring Availability (hours)	Storage Ring Availability (%)	X-ray Availability (hours)	X-ray Availability (%)	Faults	Average Fill Duration without a Fault (hours)	Faults Per Day of Delivered Beam	Delivered Integrated Current (A-hr)	Average Current (ma)
Run 97-7	741.9	722.6	97.4%	698.2	94.1%	17	41.1	0.58	52.9	75.8
Run 98-1	703.1	668.0	95.0%	640.6	91.1%	21	30.5	0.79	48.7	76.1
Run 98-2	714.5	683.3	95.6%	656.4	91.9%	27	24.3	0.99	50.3	76.6
Run 98-3	1154.2	1110.2	96.2%	1091.1	94.5%	28	39.0	0.62	85.1	78.0
Run 98-4	1152.2	1100.6	95.5%	1076.9	93.5%	31	34.7	0.69	84.2	78.2
Run 98-5	1093.6	1014.8	92.8%	987.4	90.3%	49	20.2	1.19	79.3	80.3
Run 99-1	976.6	941.2	96.4%	923.6	94.6%	35	26.4	0.91	75.3	81.5
Run 99-2	831.2	806.3	97.0%	794.9	95.6%	19	41.8	0.57	65.1	81.9
Run 99-3	832.0	812.6	97.7%	805.6	96.8%	31	26.0	0.92	58.5	72.6
Run 99-4	1320.0	1269.6	96.2%	1256.2	95.2%	42	29.9	0.80	102.5	81.6
Run 99-5	1024.0	983.0	96.0%	970.8	94.8%	44	22.1	1.09	82.0	84.5
Run 00-1	1511.0	1474.0	97.6%	1461.8	96.7%	35	41.8	0.57	119.5	81.7
Run 00-2	1248.0	1198.7	96.1%	1181.7	94.7%	47	25.1	0.95	99.5	84.2
Run 00-3	1264.2	1161.0	91.8%	1109.5	87.8%	34	32.6	0.74	89.2	80.4
Run 00-4	1000.1	963.6	96.4%	953.0	95.3%	45	21.2	1.13	79.2	83.1
Run 01-1	1528.2	1487.7	97.4%	1475.2	96.5%	52	28.4	0.85	124.9	84.7
Run 01-2	1240.0	1195.4	96.4%	1184.3	95.5%	35	33.8	0.71	101.5	85.7
Run 01-3	1232.0	1187.6	96.4%	1176.2	95.5%	56	21.0	1.14	104.2	88.6
Run 01-4	1120.0	1094.6	97.7%	1081.4	96.6%	46	23.5	1.02	101.3	93.7
Run 02-1	1927.0	1891.0	98.1%	1871.9	97.1%	56	33.4	0.72	182.2	97.4
Run 02-2	1952.0	1911.0	97.9%	1902.2	97.4%	45	42.3	0.57	185.6	97.6
Run 02-3	1449.0	1439.6	99.4%	1435.3	99.1%	20	71.8	0.33	136.3	94.9
Run 03-1	1646.9	1616.3	98.1%	1598.8	97.1%	45	35.5	0.68	157.3	98.4
TOTAL	22613.8	21765.7	96.2%	21396.65	94.6%	750	28.5	0.88	1785.5	83.4

Updated 5/20/03

Through 04/20/03, the end of Run 2003-1