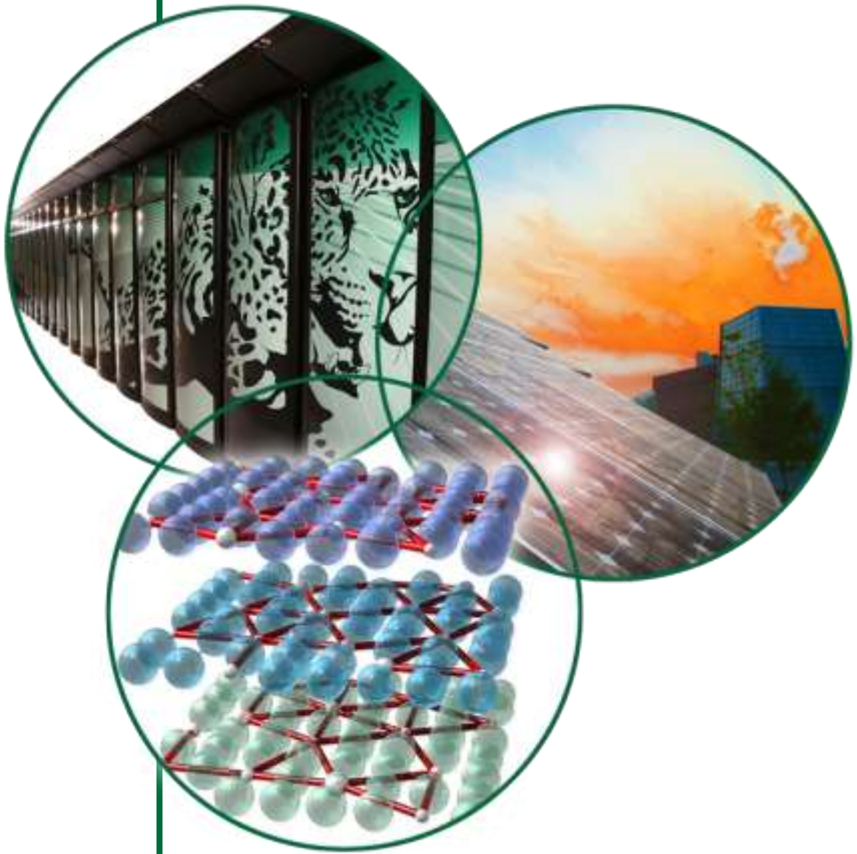
Accelerator Systems Overview and Plans



Stuart Henderson, Director
Research Accelerator Division

February 2, 2010

U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Outline

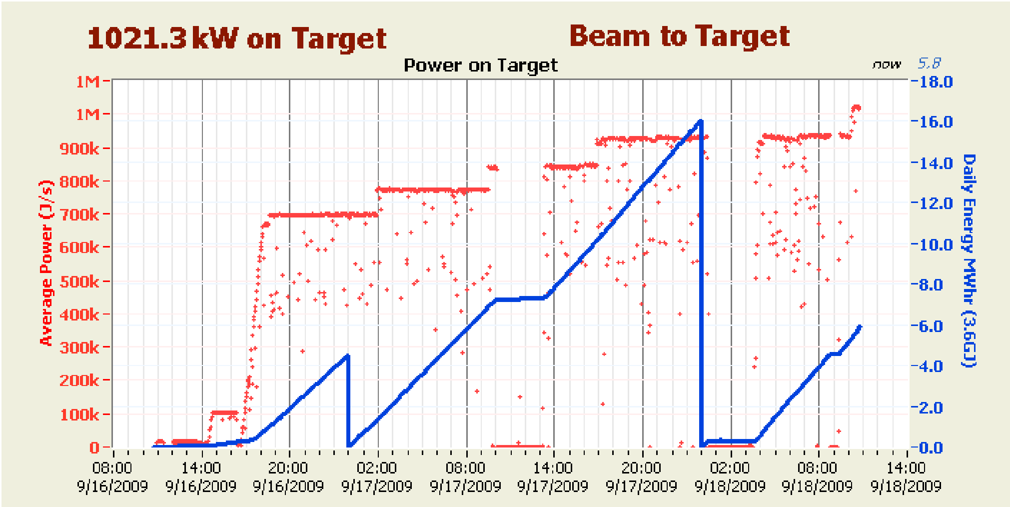
- SNS Overview and Design Parameters
- Performance History
- System Performance Highlights and Limitations
- Performance Goals and Ramp Up Plans

Accelerator Highlights

Since the last AAC meeting

- We have reached a peak beam power of 1 MW and peak integrated beam power >22 MW-hrs in a day
  - 1 MW delivers the capability outlined in the SNS Project Execution Plan
- We have increased the beam availability from ~72% (FY08) to ~85%
- We have operated as high as 42 mA Ion Source current in production (design is 38 mA)
- We have increased the linac beam energy from ~860 MeV to ~930 MeV and operated with 80 out of 81 cavities powered
- We have made significant progress on the two most problematic modulator failure modes
- We operated the entire last run (~3 months) with a single stripper foil
- We set another world record for proton intensity stored and extracted from a storage ring (1.55×10^{14} ppp)
- Modulator test-stand is complete and in routine operation for modulator development and the RF test-stand is in operation for conditioning/qualifying RF components

1 MW Beam Power Achieved!



Neutron facility achieves 1-megawatt power

By Duncan Mansfield
Associated Press
Posted Sep 21, 2009 @ 09:00 AM

DOE gives UT-Battelle all 'A' grades in review

By Frank Munger
Posted December 17, 2009 at midnight

Spallation Neutron Source first of its kind to reach megawatt power

Dream delivered: SNS pushes past one megawatt

Stuart Henderson said he was ready to get some sleep. Whether he meant for the first time since April 28, 2006, he didn't say. But the director of the Research Accelerator Division was obviously relieved.

The Spallation Neutron Source, which is supported by Stuart's division, on September 18 became the first spallation neutron source to break the one-megawatt barrier. SNS is now the most powerful spallation neutron source in the world, topping the continuous-beam SINQ at the Sherrer Institute in Switzerland, which currently runs at 900 kilowatts.

Much as the day the SNS was first turned on in April 2006, the milestone came with a control-room whoop as the power reading on the instrument panel rolled over to seven figures.

The SNS was ramping up for its latest operational run following a maintenance shutdown that included the installation of a brand new target module to replace the original target, which outlasted most expectations of service life.

"It's been a long time in the making and the dream of a lot of people to make a megawatt-class pulsed spallation neutron source, and today we've finally delivered on that dream," said Stuart just after the deed was done.

(See MEGAWATT, page 5)

Michael Plum (sitting) and Viatcheslav Danilov (standing) react as the SNS beam power readout goes to seven figures.

Research Accelerator Division

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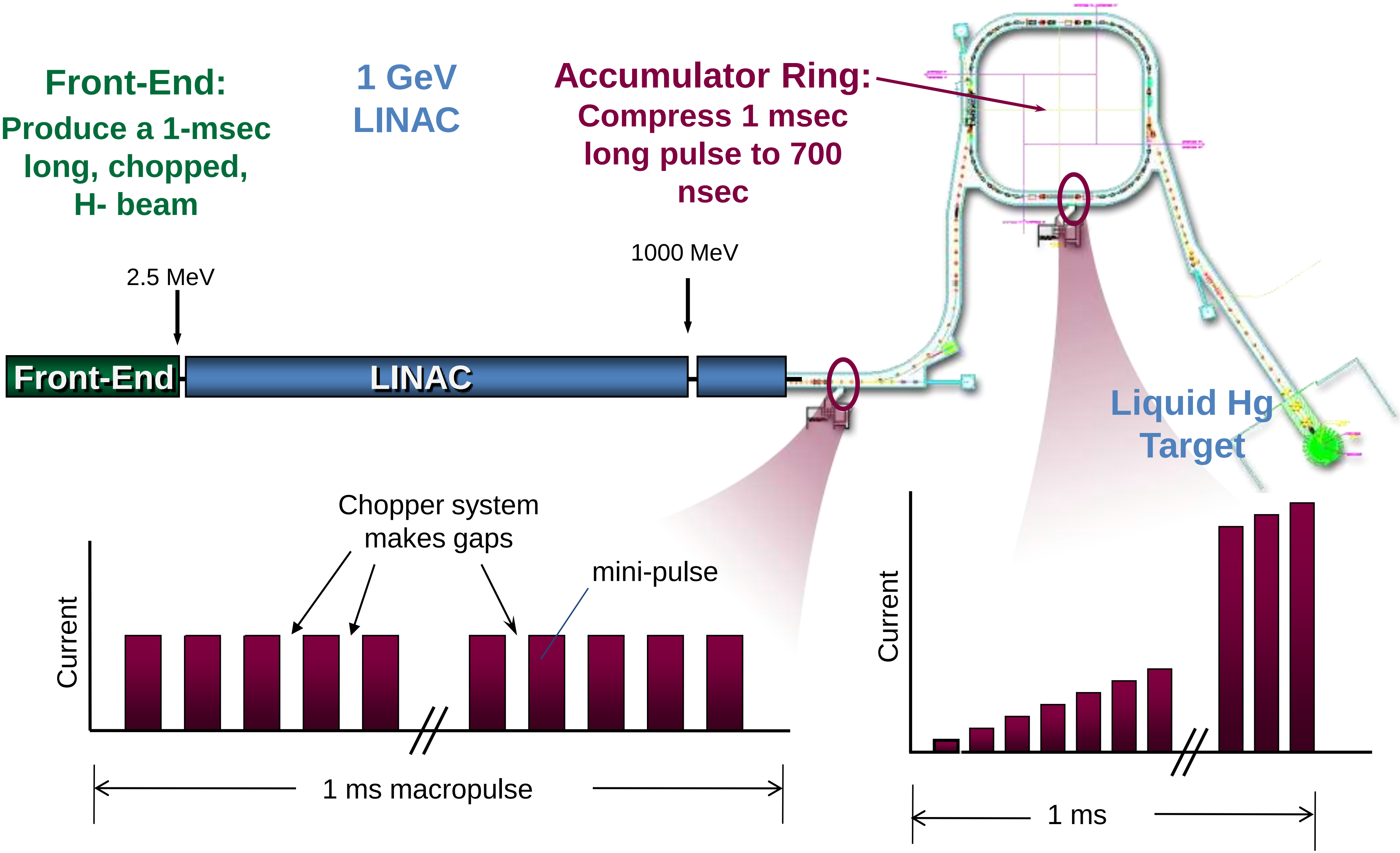
Group Leader

SNS Accelerator Complex



SNS Design Parameters

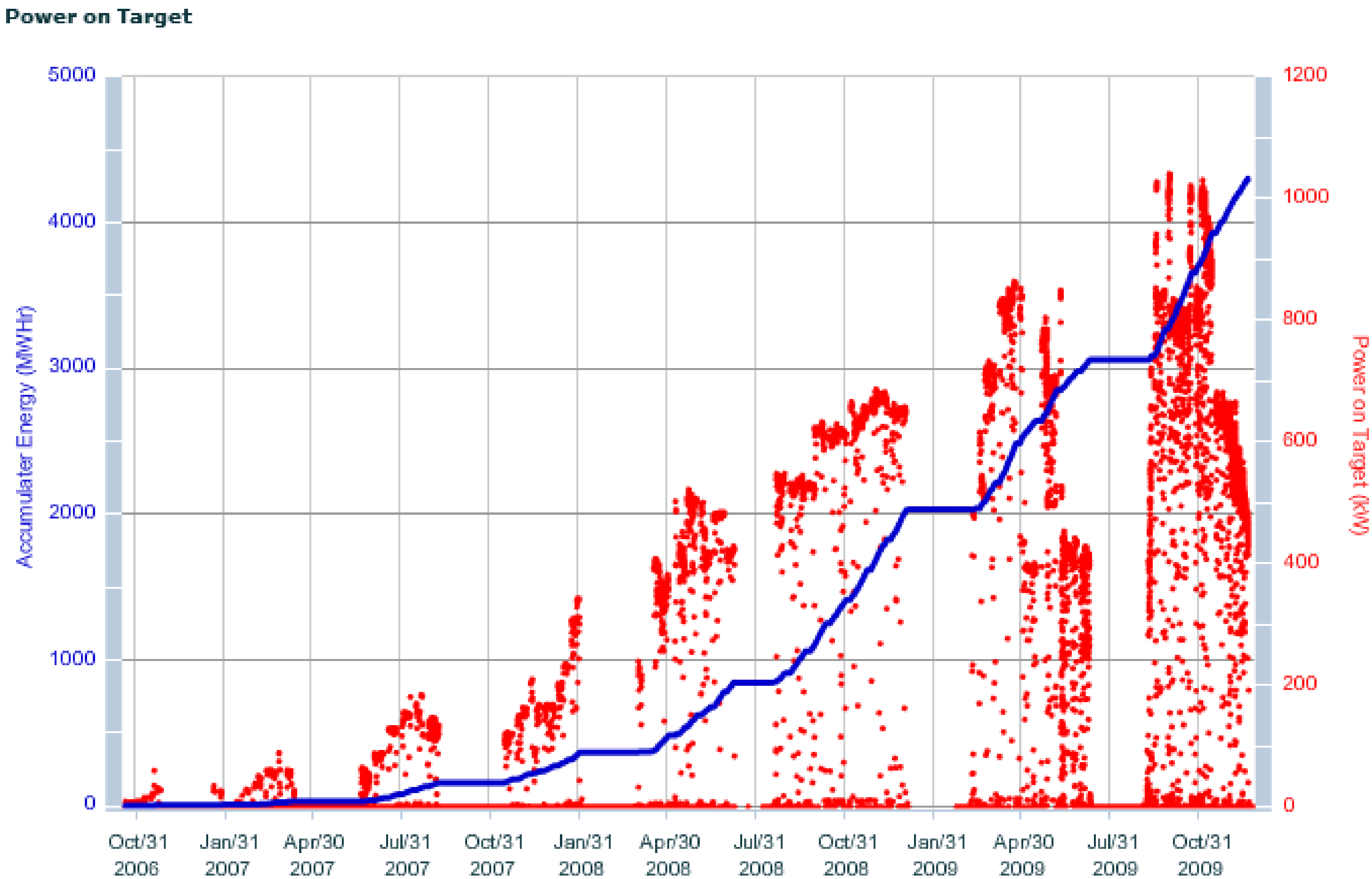
Kinetic Energy	1.0 GeV
Beam Power	1.4 MW
Linac Beam Duty Factor	6%
Modulator/RF Duty Factor Spec.	8%
Peak Linac Current	38 mA
Average Linac Current	1.6 mA
Linac pulse length	1.0 msec
Repetition Rate	60 Hz
SRF Cavities	81
Ring Accumulation Turns	1060
Peak Ring Current	25 A
Ring Bunch Intensity	1.5×10^{14}
Ring Space Charge Tune Spread	0.15

Performance History

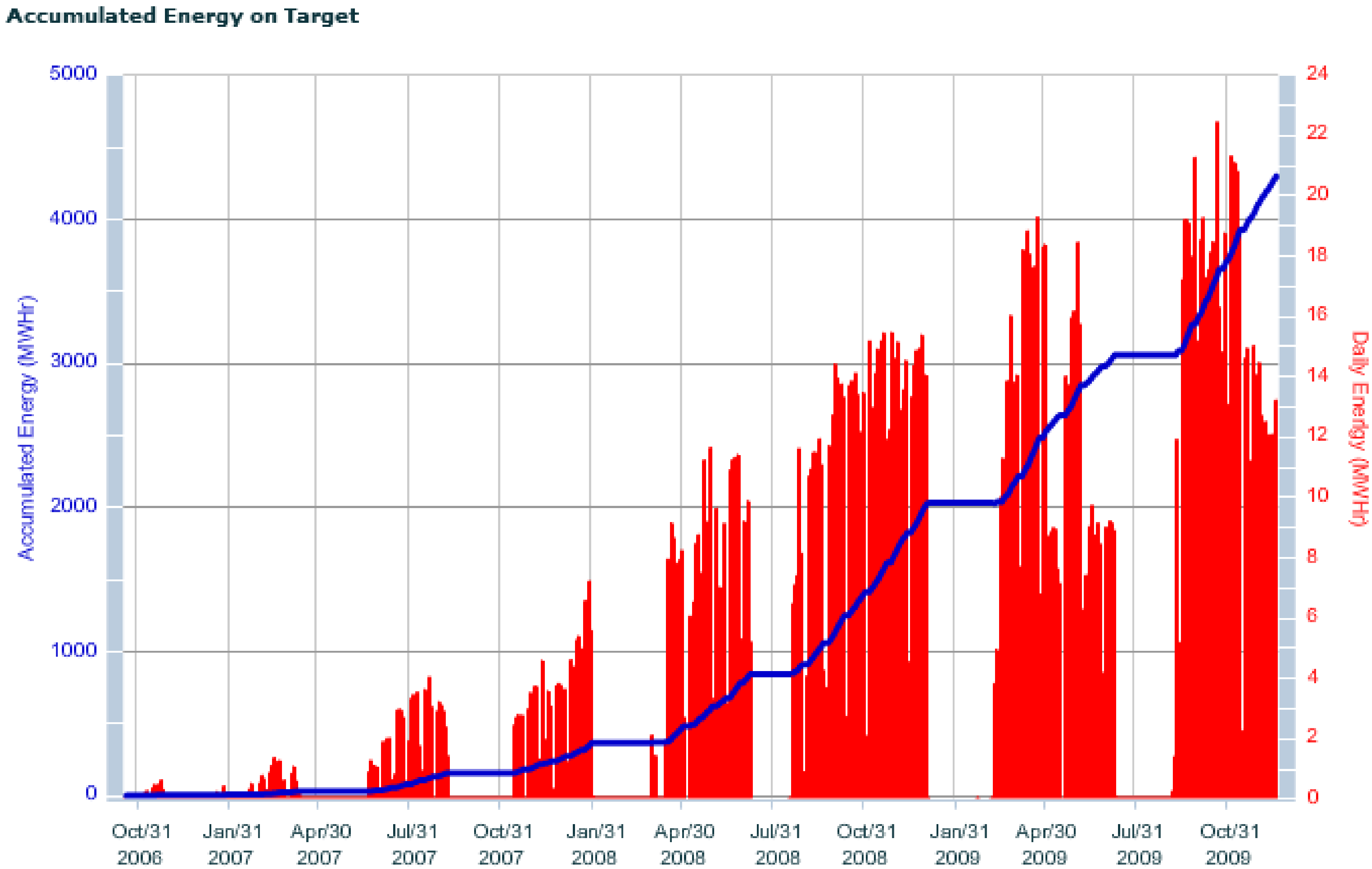
SNS Performance Relative to Design

	Design	Best Ever	Routine Operation
Kinetic Energy [GeV]	1.0	1.01	0.93
Beam Power [MW]	1.4	1.03	1.03
Linac Beam Duty Factor [%]	6	5	5
Modulator/RF Duty Factor [%]	8	7	7
Peak Linac Current [mA]	38	42	42
Average Linac Current [mA]	1.6	1.1	1.1
Linac pulse length [msec]	1.0	1.0	0.80
Repetition Rate [Hz]	60	60	60
SRF Cavities	81	80	80
Ring Accumulation Turns	1060	1020	825
Peak Ring Current [A]	25	26	18
Ring Bunch Intensity	$1.5x10^{14}$	$1.55x10^{14}$	$1.1x10^{14}$
Ring Space Charge Tune Spread	0.15	0.18	0.12

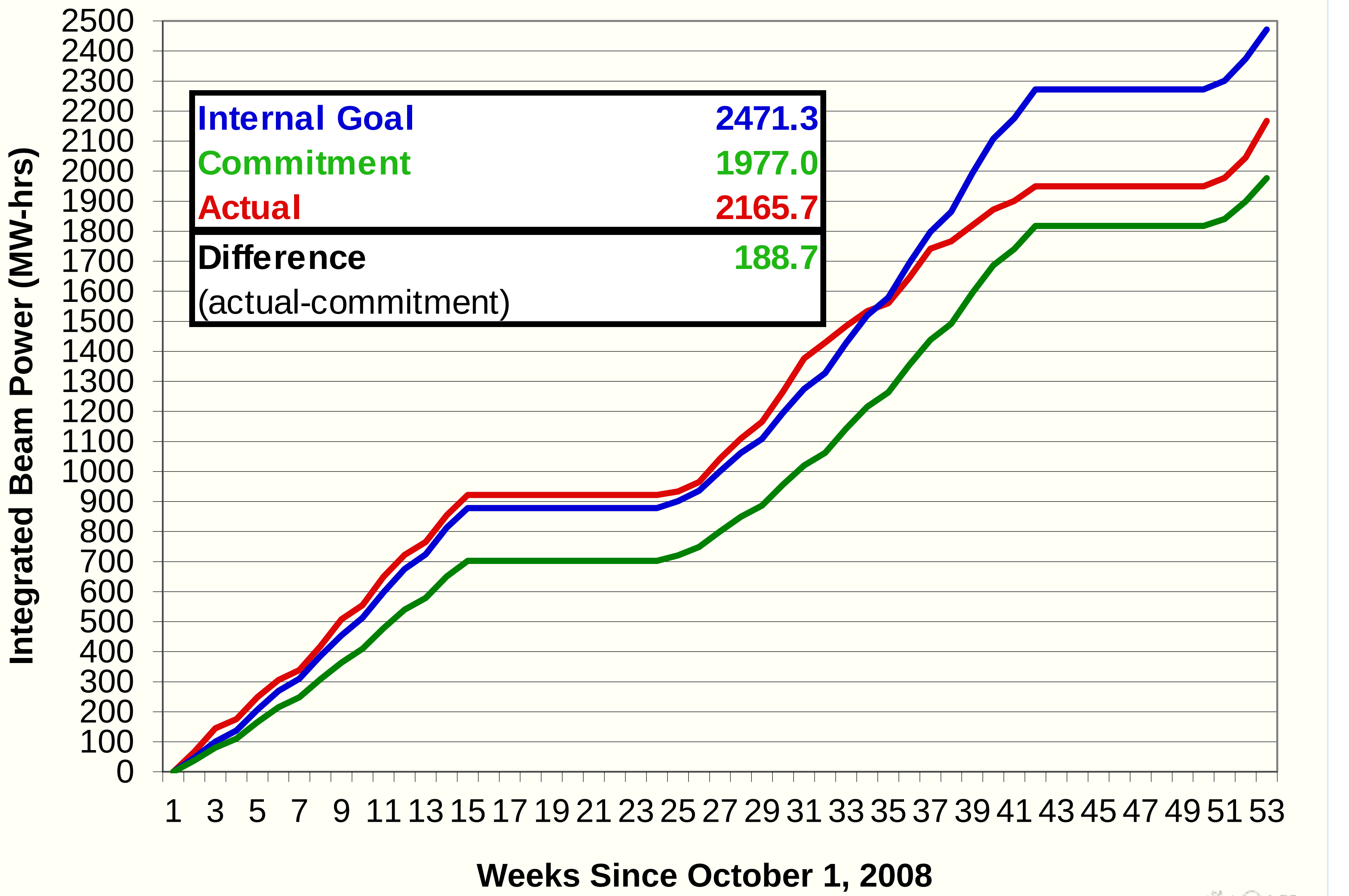
Beam Power on Target History Since October 2006



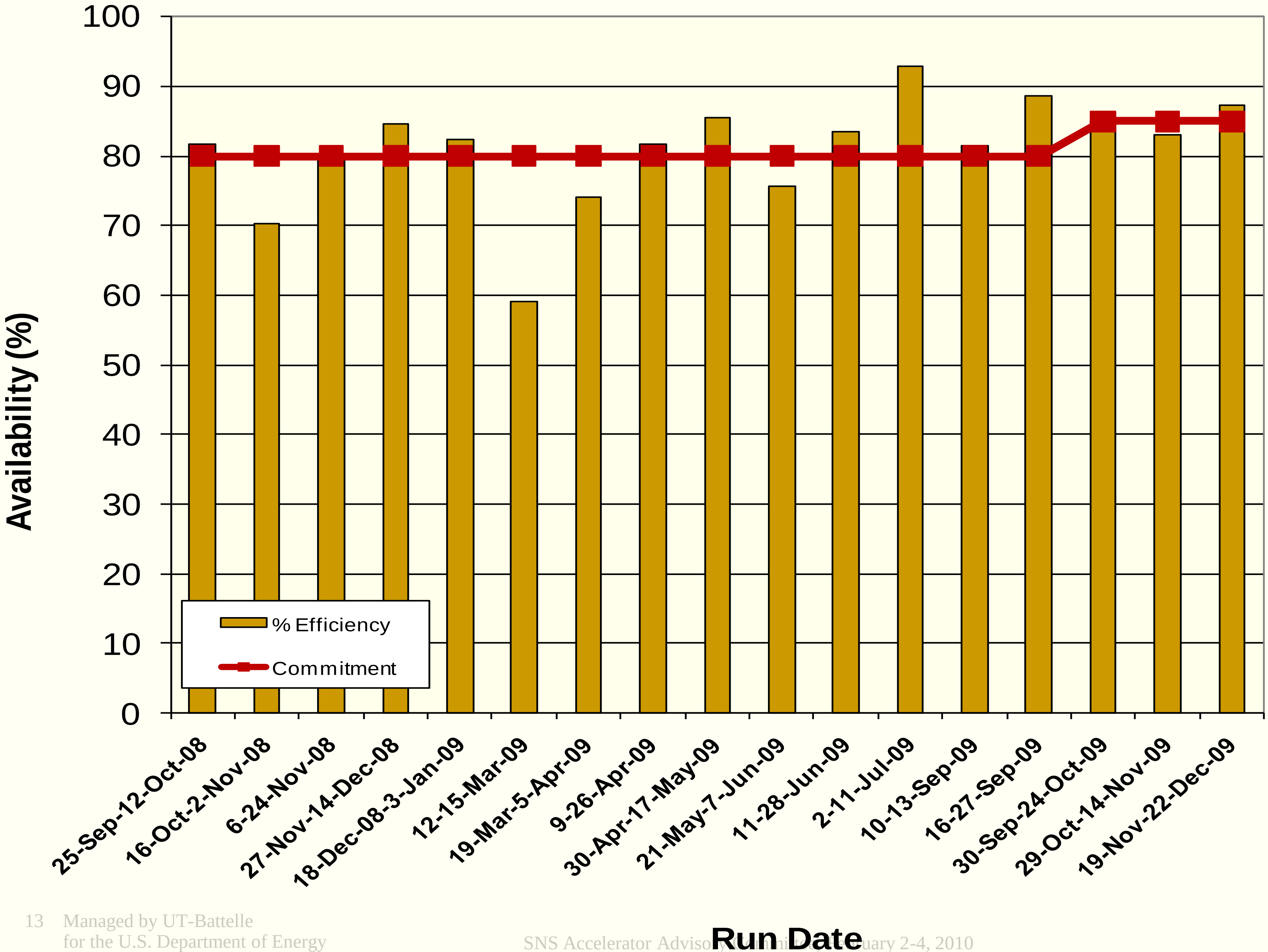
Integrated Beam Power on Target History



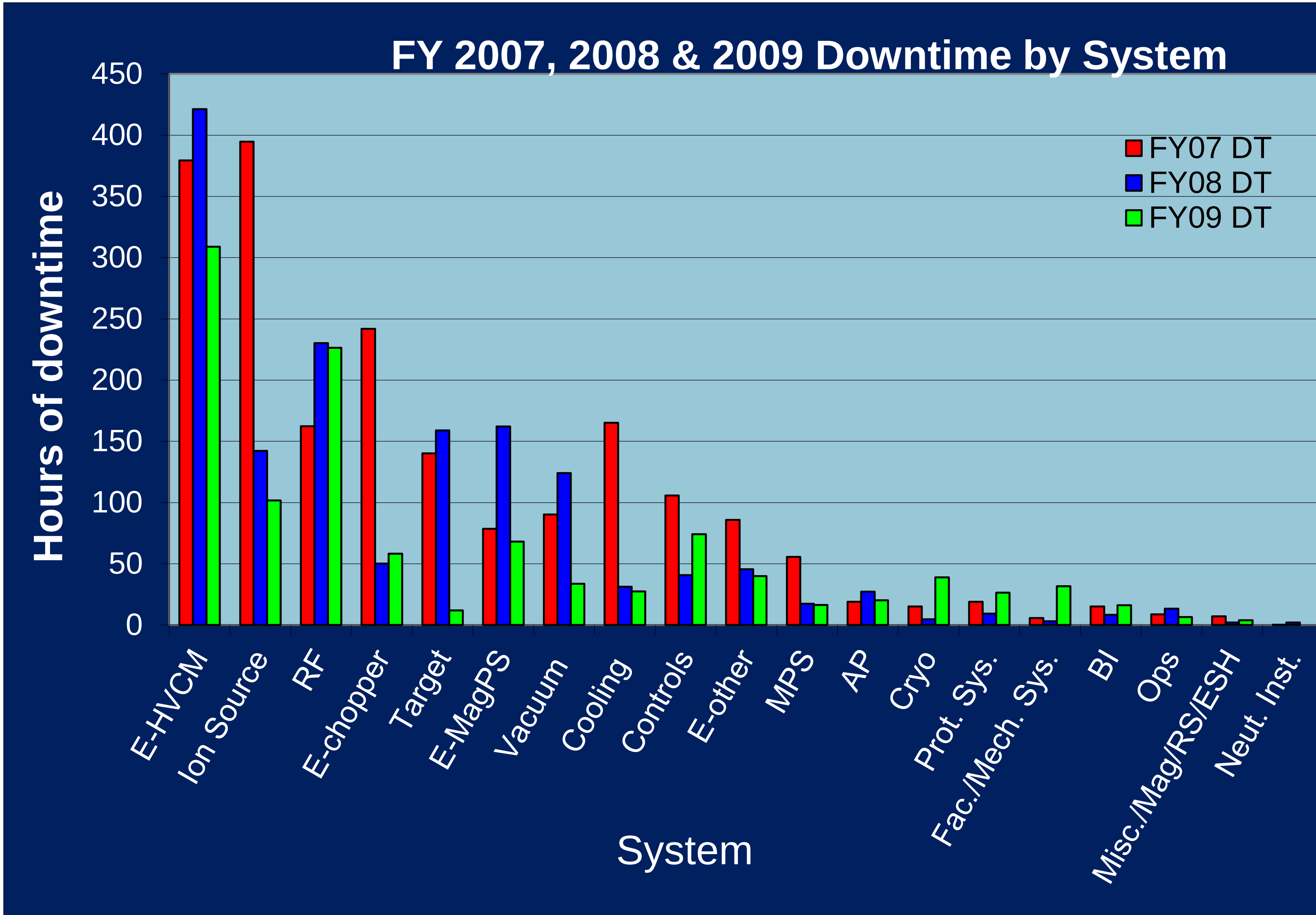
Power delivery goals for FY09



Neutron Production Availability by Mini-Run



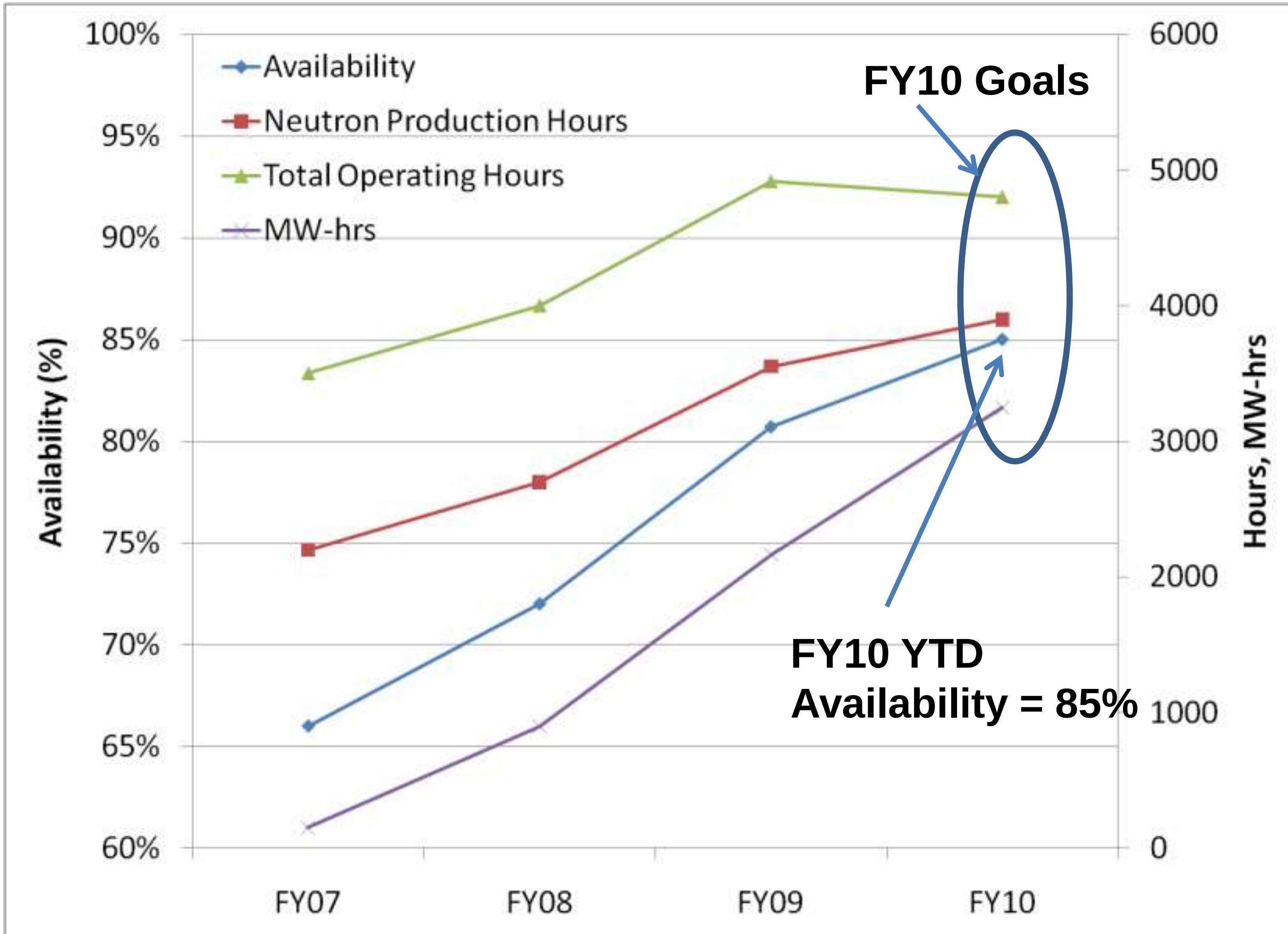
Downtime Statistics



Performance Goals vs. Actuals FY07-FY09

	FY07 Goal/Actual	FY08 Goal/Actual	FY09 Goal/Actual
Neutron Production Hours	1500/2113	2700/2807	3500/3553
Total Operating Hours	3500/3779	4000/4032	4500/4916
Neutron Production Availability	75%/66%	82.5%/72%	80%/81%
MW-hrs to Target Commitment	117/159	887/945	2031/2166

SNS Operational History



System Performance Highlights and Limitations

Dominant Performance Issues in the Past Year

- Charge-Exchange Injection
  - Experienced a rash of stripper foil and foil mounting failures which limited beam power in Spring/Summer
- High-Voltage Converter Modulators
  - Dominated FY09 downtime and continues to dominate in FY10, even as much progress was made in mitigating problematic failure modes
  - We were forced to reduce duty factor in November due to rash of failures
- RF Systems
  - MEBT Rebuncher RF Power Amplifiers tripping wall breakers, blowing fuses in first half of FY09; practically eliminated the issue by summer downtime
- Ion Source
  - RF System unreliability and degradation in output RF power
  - Deployed external antenna source; backed out due to unreliability
- Superconducting Linac
  - Forced to lowered gradients on two cavities
- Controls
  - Discovered problem with Machine Protection System that results in turn-off times much greater than specification on many channels

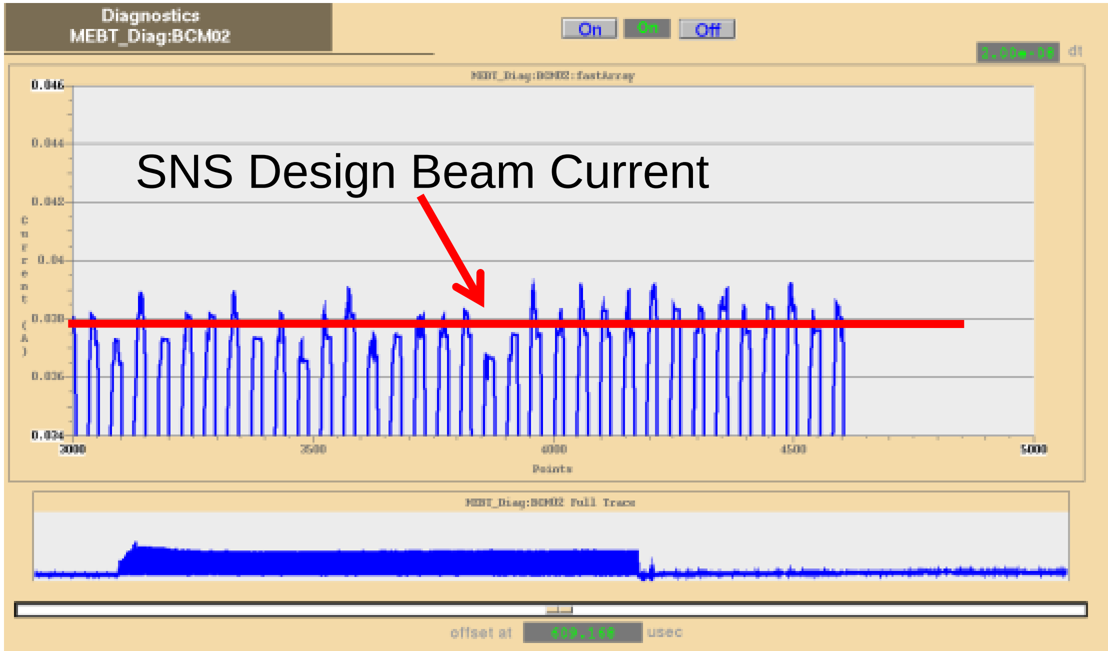
Ion Source and LEBT Performance

Highlights:

- **Delivered 42 mA peak current in production, which is sufficient for 1.4 MW at 930 MeV**
- **Increased source usage from 3 to 4 weeks**
- **LEBT HV arc rate is extremely low**

Issues

- **2 MHz RF amplifier reliability**



Development Activities:

- **Building a 2 MHz RF system operating at ground, coupled through HV isolation transformer**
- **Building a 2-solenoid magnetic LEBT with the expectation that it will give reliable high-power operation**
- **Constructing a second Ion Source test-stand to support R&D program**
- **Continuing to develop external antenna ion source to improve availability**

Front-End System Performance

- **RFQ:**
  - We have not experienced further RFQ detuning events since improving protection and resizing chiller
  - S. Kim led team to diagnose and correct RFQ resonance control issues; operated with 0.9 msec RF flat-top
  - We have received and are evaluating responses to our RFQ solicitation to produce a spare with the same beam dynamics design, but improved mechanical design
- **Chopper Systems**
  - The LEBT chopper system is performing reliably; downtime reduced
  - A new LEBT chopper pulser system with better protection against HV arcs, better risetime and more flexibility is undergoing testing (AIP Project)
  - The stripline MEBT chopper system is operational, although it doesn't always help reduce losses
- **MEBT**
  - Installed scraper system that has improved losses

SCL Performance and Plans

Operations

- Just prior to the last meeting we installed a refurbished CM H01 in slot 19, and an additional modulator
- Since then we have operated at ~930 MeV, with higher average gradients, and with 80, 79 and 78 cavities operational (out of 81)
- In November/December we were forced to reduce gradients in two cavities, following episodes of excessive errant beamloss deposited in the SCL
- We recently discovered longer than specified "within a pulse" Machine Protection System turn-off response in some MPS channels
- This is the result of an unintended consequence of noise-filtering added starting in commissioning and continuing through 2007
- Very good cryogenic system availability

Development and Upgrades

- We are beginning construction of the first spare high-beta cryomodule at SNS, following successful cavity preparation and qualification at Jlab
- We are working hard on outfitting SRF Facilities that support spare CM construction and testing, and Power Upgrade Project needs
- We are assembling a test-bed for plasma processing development

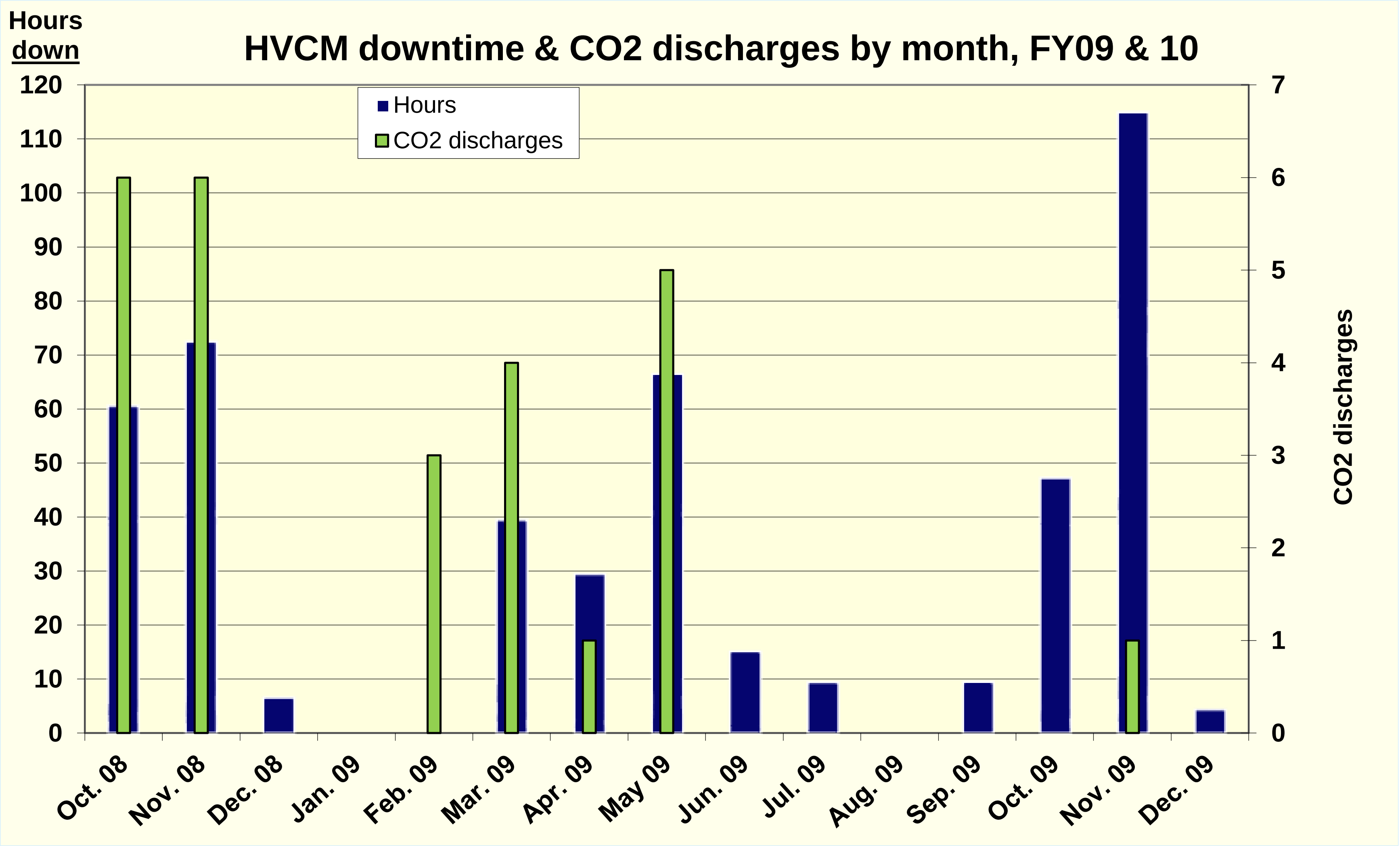
High-Voltage Converter Modulators

- Since the last AAC Meeting
  - Improved IGBT turn-off to limit overvoltage greatly reducing failures (by a factor of 20)
  - Completed replacement of flammable dielectric caps, failure of which had led to fires contained in the enclosure; several have since failed
  - Selected final replacement 4 kV capacitor and completed replacement (this week)
  - Added an additional modulator to allow SCL klystron operation at design voltage
  - Completed Modulator test-stand, now in routine operation in support of development activities

High-Voltage Converter Modulators (cont'd)

- **Additional, new failure modes have impacted availability and duty factor**
  - Reduced duty-factor in November
- **Developments and Improvements under way (or planned)**
  - Replace in-tank components with insufficient margin
  - IGBT Gate Drive Upgrade
  - Modulator pulse-droop compensation
  - 20kHz/40 kHz ripple reduction
  - New controller with advanced capabilities and diagnostics
  - Exploring new IGBT devices, ….

HVCM downtime and CO2 discharges by month, FY 2009 and 2010



RF Systems

- **Last year, MEBT RF Power Amplifier trips and subsequent blown fuses were a major source of downtime**
- **We purchased and installed one solid-state 25 kW amplifier to test. We have 3 more units on order to completely replace hard-tube units (AIP Project)**
- **Meanwhile, replaced DC supplies with charging supplies and reduced MEBT RF downtime by factor of 10-20**

Tomco Solid State Amplifier

- **We installed a new HVCM and reworked the RF distribution to populate "10-packs" and "11-packs" (AIP Project)**
  - **This allows us to reliably operate SCL klystrons at design voltage (75 kV)**
  - **Provides sufficient RF power for design beamloading and for reduction in cavity fill time**
- **We are beginning a program of spare klystron/window/coupler conditioning and qualification on our RF Test Stand**

Ring Highlights and Issues

- **This time last year, I said:**
  - ***"During production we have never had a foil failure. Last foil survived for ~700 MW-hrs at > 600 kW"***
- **That changed May 3rd, when we entered a period plagued by foil failures, foil holder melting/failure, and subsequent reduction in beam power**

- **A Foil Task-Force was formed to understand the myriad issues, and to implement fixes and mitigation**
- **That effort was successful; we ran the entire September-December production run on a single foil**
- **HEBT Collimation is important; Momentum Dump which failed April 2008 has been redesigned and is being installed (AIP Project)**
- **A system for beam-on-target profile measurement was constructed and is being commissioned**
- **We reached full design beam intensity (1.55e14 ppp); beam was stable using only Ring RF to control the e-p instability.**

Beamloss

Uncontrolled beamloss in nearly all regions of the accelerator is in line with expectations (< 1 W/m) at ~1 MW operation

We have not been limited by beam loss for ~2 years

- Substantial reduction in SCL Losses was achieved following
  - repair of CCL4 vacuum leak
  - Modification of SCL lattice
- Lost particles in the SCL are at the 10^{-5} – 10^{-6} level
- SCL laser-wire diagnostic is operating routinely with improved performance, improving understanding of SCL beam dynamics
- Over the last year the SCL activation is not increasing, even though the accelerated charge increased; average "warm section" activation ~30 mRem/hr
- Meanwhile, we continue to see that the injection region is the most sensitive region as regards beamloss
  - Injection region beamloss responds to collimation in MEBT and HEBT
  - Hottest spot is near the stripper foil, as expected

Performance Goals and Ramp Up Plans

Operations Strategy

- We are focusing on beam availability during Neutron Production; this is the highest priority for user program
  - If necessary, we will sacrifice beam power for availability
- Our near-term plan is to regain high-availability operation at 1 MW for the remainder of FY10, increasing the beam power to 1.2 MW during the fall run
- Central to this plan is shoring up the modulator performance
  - We held a one-day mini-workshop yesterday, with involvement from Dick Cassel, Craig Burkhardt, Chris Jensen, to evaluate and advise on HVCM development program
- We are working on shoring up availability of many, many other systems
- We have enhanced our rigor in deployment of changes to the accelerator system (Configuration Control)

FY 2010-FY 2012 Availability and Hours Goals

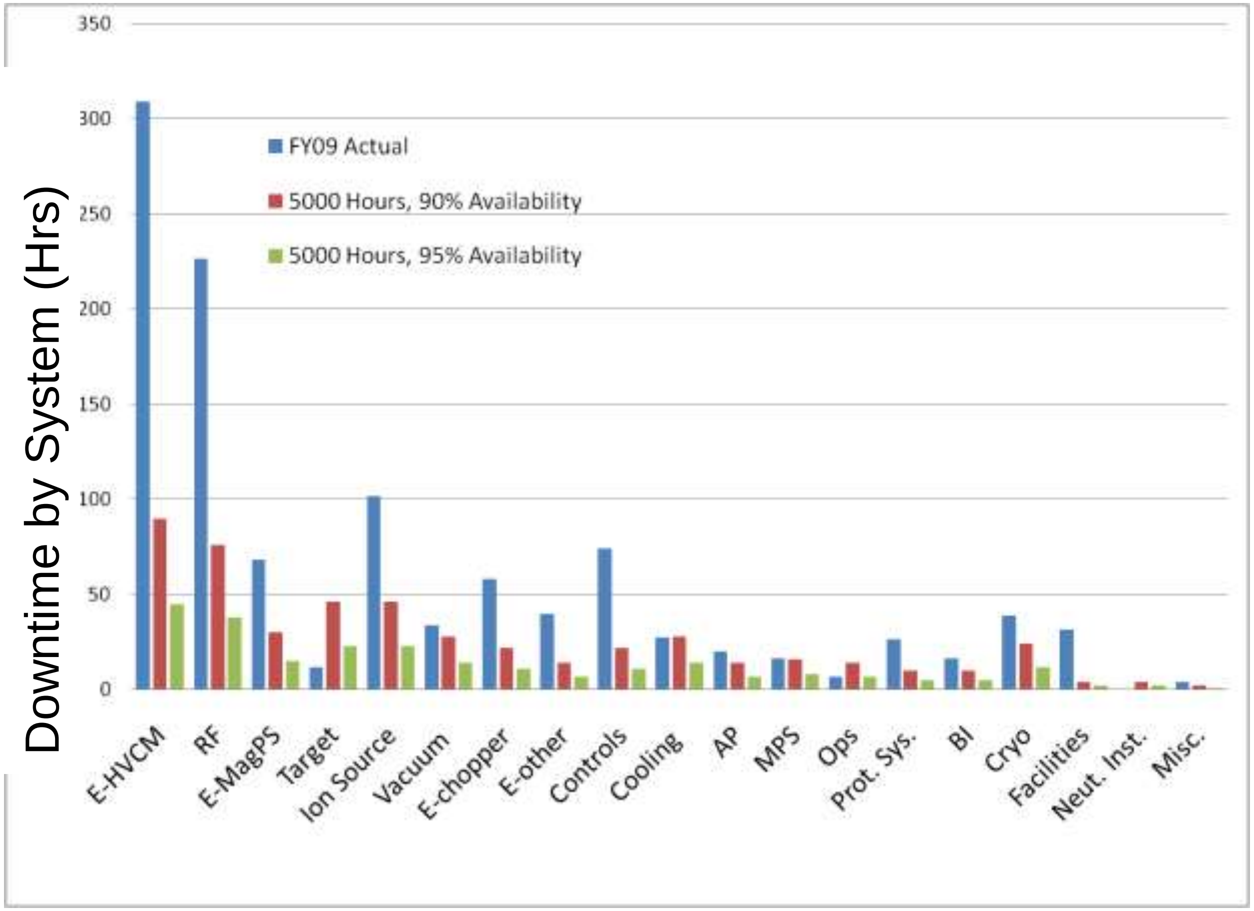
Year	Availability Commitment	Neutron Production Hours	Total Operating Hours
FY 2010	85	3900	4800
FY 2011	88	4300	5000
FY 2012	90	4500	5000

Reaching 1.4 MW Design Beam Power

	Dec 2008	Oct 2009	Oct 2010	Oct 2011
Beam Energy [MeV]	870	930	930	960
Peak Current [mA]	36	38	38	38
Pulse Length [msec]	0.62	0.80	0.85	0.95
Chopping Fraction [%]	60%	64%	68%	68%
Beam Power [kW]	700	1030	1180	1360

High Availability Assessment

- We have emphasized that 95% availability is a long-term target for SNS availability, not a promise
- We are using 95% as a "design point" to assess scope, cost and schedule for required improvements



Conclusion

- It has been a year of successes and challenges
- 1 MW has been achieved in routine operation
- Availability has increased to 85% (YTD)
- Performance was limited in the last year by stripper foil issues and modulator failures that limited duty factor; both issues, we believe, have been mitigated
- Our focus now is on increasing availability and stabilizing operation at 1 MW
- These achievements are thanks to the hard work, dedication and talent of the SNS staff