Accelerator Systems Management and Overview

Kevin W. Jones

Research Accelerator Division

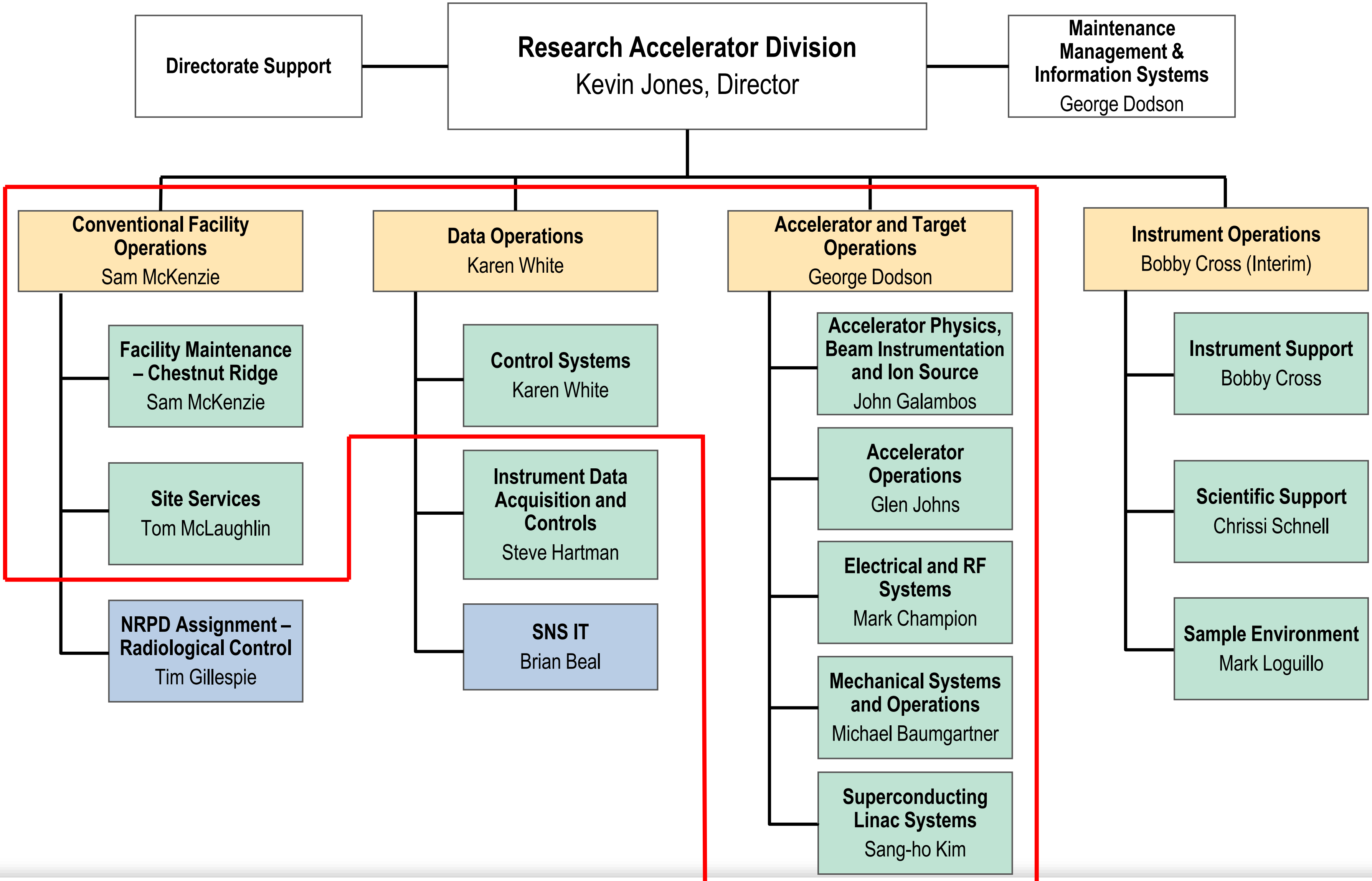
SNS Accelerator Advisory Committee
May 7-9, 2013

The Neutron Science organization is unchanged

Associate Laboratory Director
Kelly Beierschmitt
Herb Mook, Sr. Corporate Fellow
Jeanine Webber, Executive Secretary

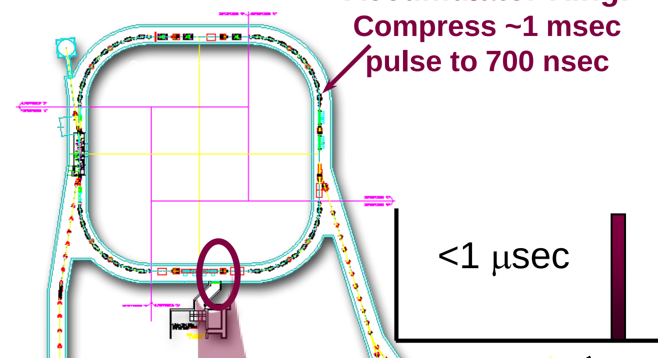
- **Joint Institute for Neutron Sciences** – Takeshi Egami
- **Matrix Support**
  - Bonnie Hébert, HR Manager
  - Lorie Hickey, Business Manager
- **Directorate Operations** – Crystal Schrof
- **User Programs and Outreach** – Laura Morris Edwards
- **Quantum Condensed Matter** – Stephen Nagler
- **Biology and Soft Matter** – Paul Langan
- **Chemical and Engineering Materials** – Mike Simonson
- **Neutron Data Analysis and Visualization** – Thomas Proffen
- **Research Reactors** – Ron Crone
- **Instrument and Source Design** – Ron Crone (Interim)
- **Research Accelerator** – Kevin Jones

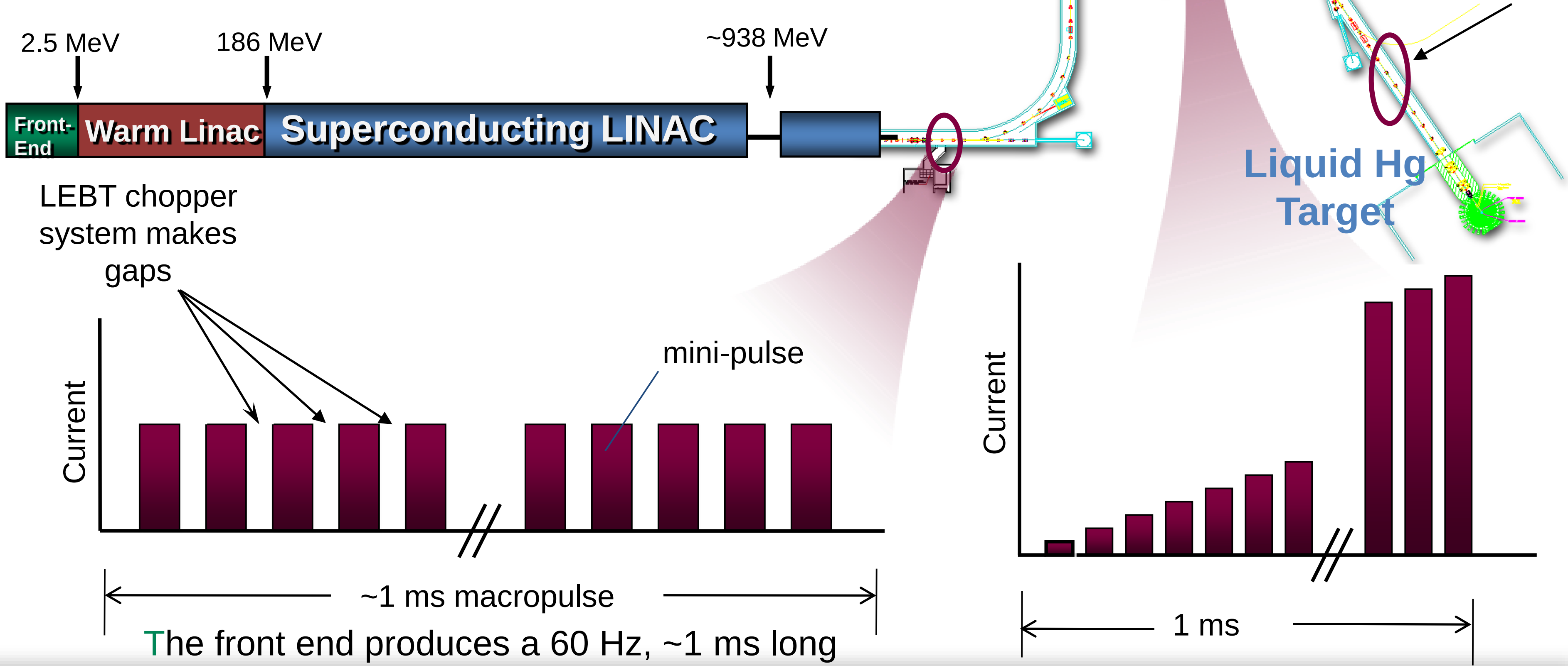
The Research Accelerator Division mission is the safe, reliable and efficient operation of the SNS neutron source, instruments and enabling technologies



A strong, committed and competent team operates, maintains and improves the SNS accelerator complex

- SNS is the highest power pulsed neutron source in the world
- The machine has over 100,000 control points and cycles ~5.2 million times a day
- Power (and base neutron flux) is the product of:
  - Beam Energy
  - Peak Current
  - Chopping Fraction
  - Pulse Length
  - Repetition Rate





The front end produces a 60 Hz, ~1 ms long chopped H- beam

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SNS design parameters

Kinetic Energy	1.0 GeV
Beam Power	1.4 MW
Linac Beam Duty Factor	6%
Modulator/RF Duty Factor Specification	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

SNS performance relative to design

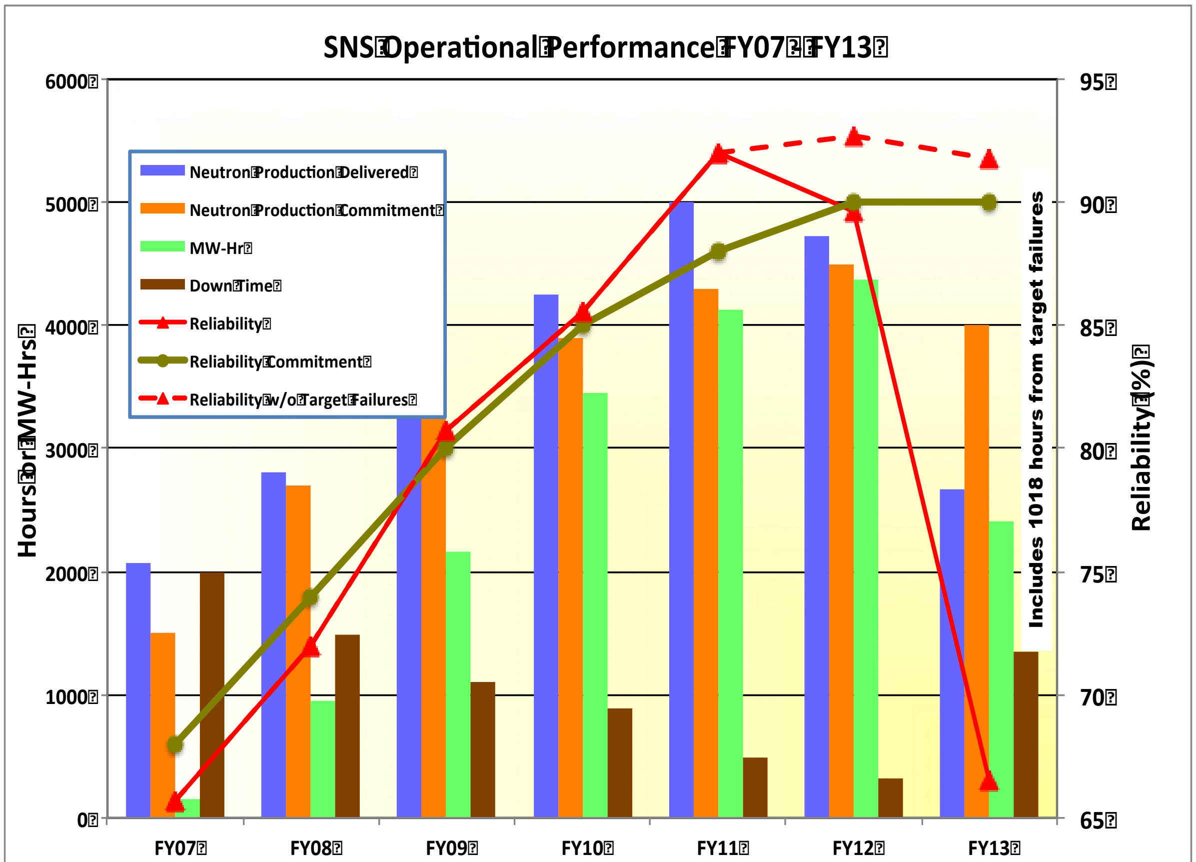
	Design	Best Ever	Routine Operation
Kinetic Energy [GeV]	1.0	1.01	0.938
Beam Power [MW]	1.4	1.089	0.8-1.07
Linac Beam Duty Factor [%]	6	5	5
Modulator/RF Duty Factor [%]	8	7	7
Peak Linac Current [mA]	38	42	38
Average Linac Current [mA]	1.6	1.1	1.1
Linac pulse length [msec]	1.0	1.0	0.80
Repetition Rate [Hz]	60	60	60
SRF Cavities	81	80	79-80
Ring Accumulation Turns	1060	1020	825
Peak Ring Current [A]	25	26	18
Ring Bunch Intensity	1.5×10^{14}	1.55×10^{14}	1.1×10^{14}
Ring Space Charge Tune Spread	0.15	0.18	0.12

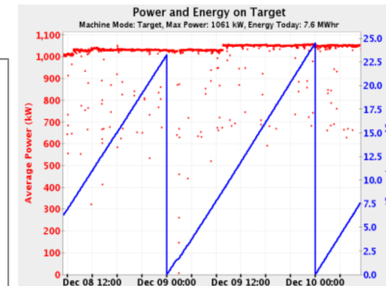
The SNS neutron source has achieved stable 1MW operation capability for 4500 hours at ≥90% reliability

Since FY09 the SNS neutron source has met or exceeded all operational commitments

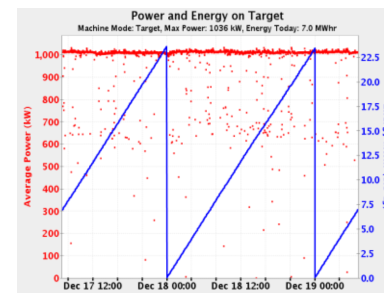
Consistent reliability of ≥90% in FY11 and FY12 is remarkable

Success derives from having the right people, sound processes, rigorous maintenance planning and management, spares management, obsolescence mitigation, configuration management and focused improvements

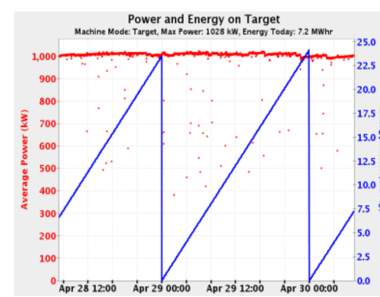




December 2010

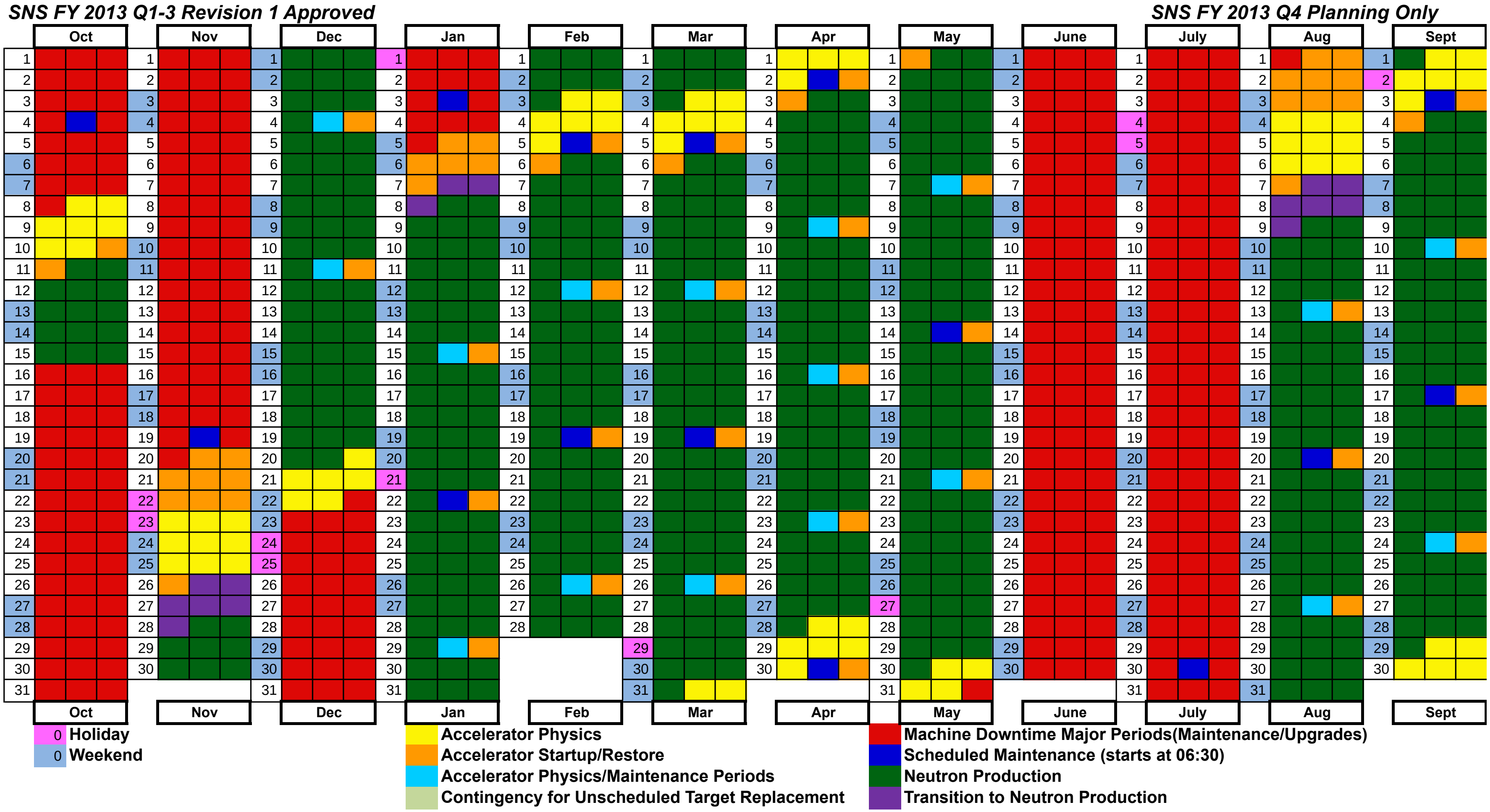


December 2011



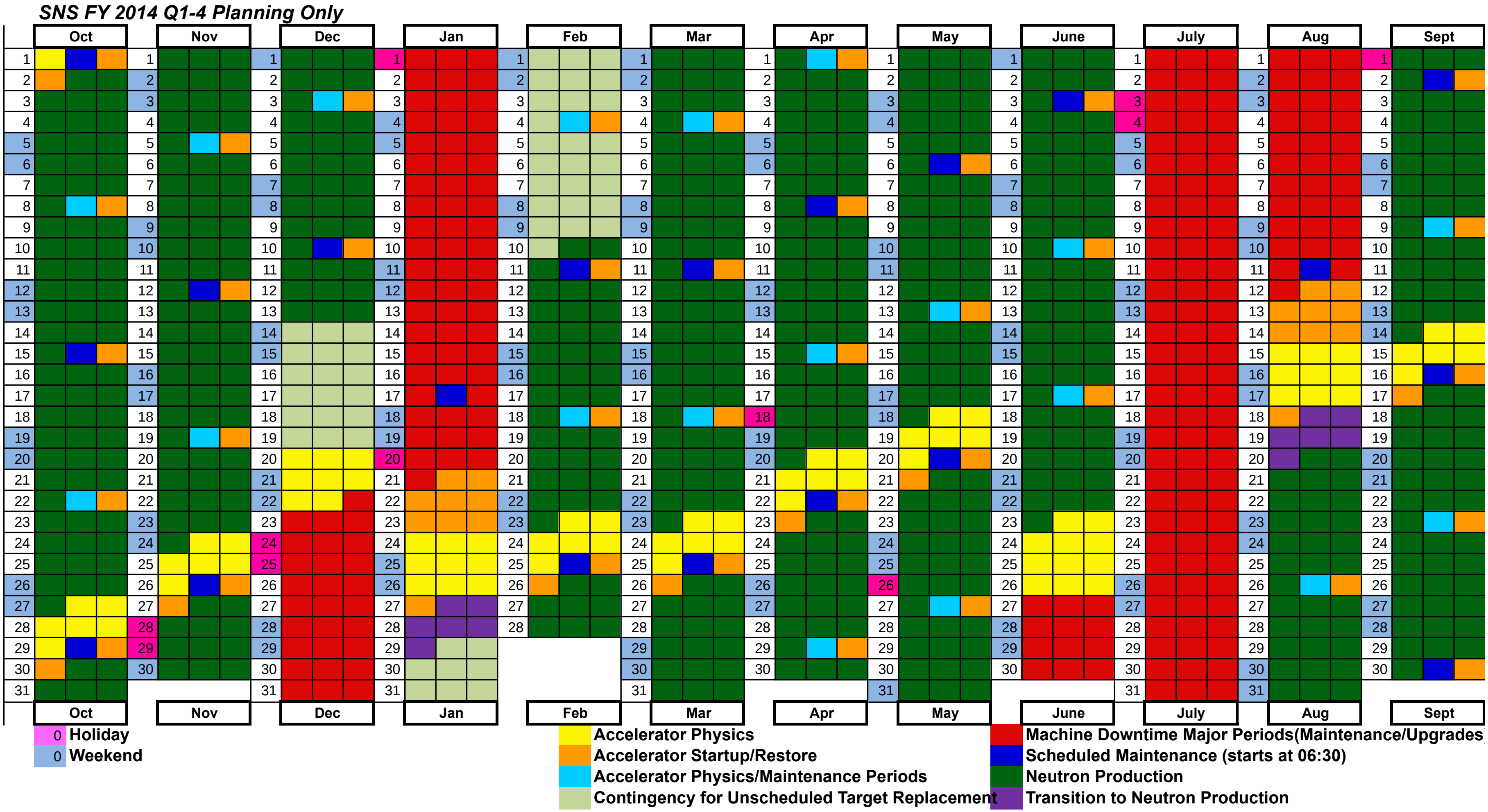
April 2012

The SNS FY13 operating schedule required substantial modification to respond to the two target failures in Fall 2012



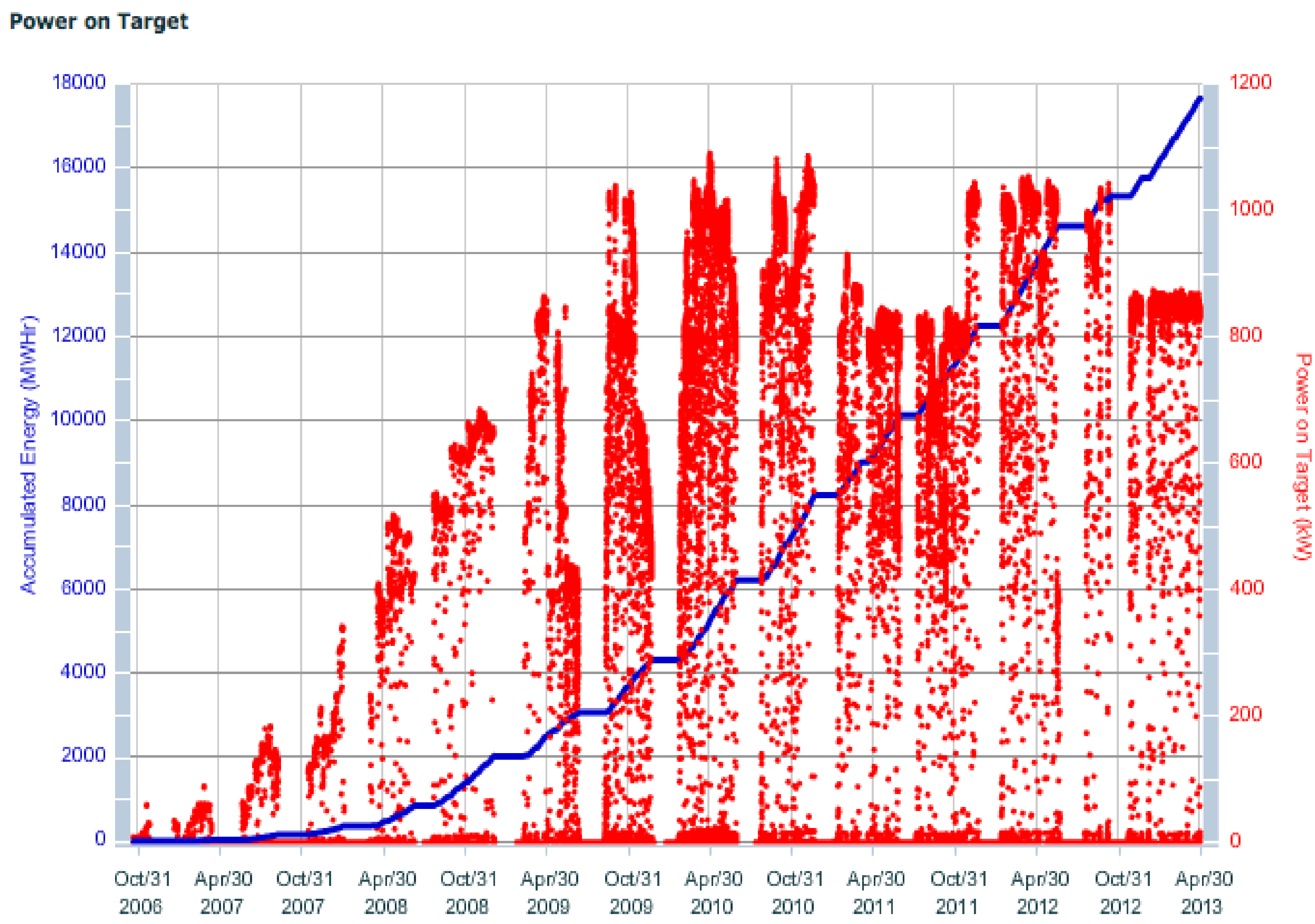
- Maintained minimal December/January outage to facilitate utility tie-in for Chestnut Ridge Maintenance Facility
- Shifted maintenance and upgrades to 2-month summer 2013 outage
- Recovered about half of the time lost due to target failures in October/November 2012
- Continued two full maintenance days every 4 weeks to optimize the maintenance strategy
- Now publish schedule for official DOE accounting by quarter, about 1 month in advance
- Operate at 850 kW to preserve target lifetime

The FY14 schedule is also affected to accommodate decision to run present target to failure



- Shorten the FY14 winter outage (impact assessment underway)
- “Plan” for unscheduled target change in fall 2013 by allocating contingency time for neutron production around winter outage
- Return to delivering 4500 hours of neutron production in FY14

Energy and power on target reflect management decisions to assure target operability



Machine study time and related upgrades have significantly enhanced availability and improved beam loss management

Beam Physics and Loss Management

- Intra Beam Stripping ($H^- + H^- \rightarrow H^- + H^0 + e$) determined to be cause of higher-than-expected beam loss in SCL, ~10x higher losses compared to H^+ beam mitigated by change in transverse focusing lattice strengths
- Overall beam loss reduction of ~25% in ring by tuning and scraping (new HEBT momentum dump) essential for hands-on maintenance and to minimize radiation damage
- Installed and commissioned new ring injection dump beam line with new BPMs and larger aperture to manage waste beams and reduce failure vulnerability
- Changed to fixed frequency operation to improve neutron instrument choppers and veto rate

Convertor Modulator Performance Improvement

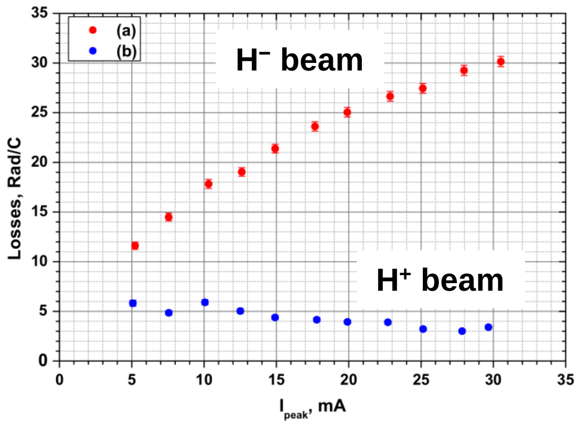
- Improved High Voltage Converter Module performance by a factor of 4 through focused investment of Accelerator improvement Project (AIP) and operating funds

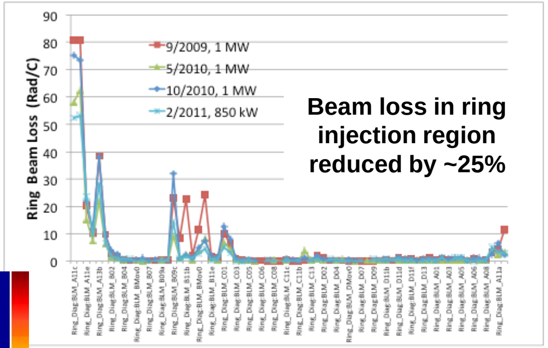
Diagnostic Enhancements

- Routine use of laser- based diagnostics for high power beams
- Implemented a quantitative imaging system for beam on target

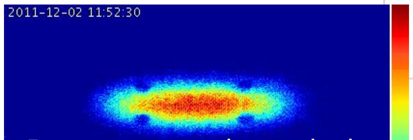
Ring Stripper Foil Improvements

- Stripper foil failure modes identified and mitigated (reflected convoy electrons, in-vacuum breakdown)
- Improved foil lifetime through materials engineering (corrugation, corner trim, boron doping)





Beam loss in ring injection region reduced by ~25%



Beam on target image in the control room

Longest-lived stripper foil (Spring 2010)

Beam loss management, particularly in the SCL and at higher powers in the ring, remains a significant concern

H⁻ Source and LEBT performance has stabilized but challenges remain

Peak Current Capability

- Current decay problem on Sources 2 and 4 resolved
- Three sources now reliably support high-power accelerator operation

Source Service Cycle

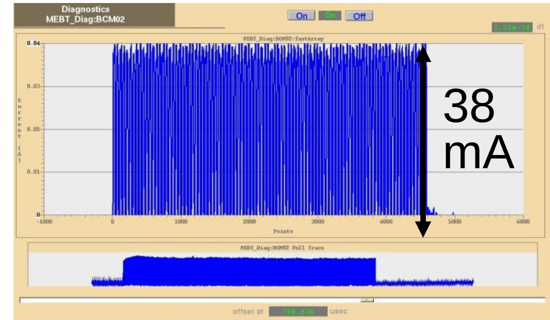
- Several sources reliably perform for 6-week cycles without performance degradation
- RF Antenna infant mortality problems are actively managed through quality assurance and contribute to this success

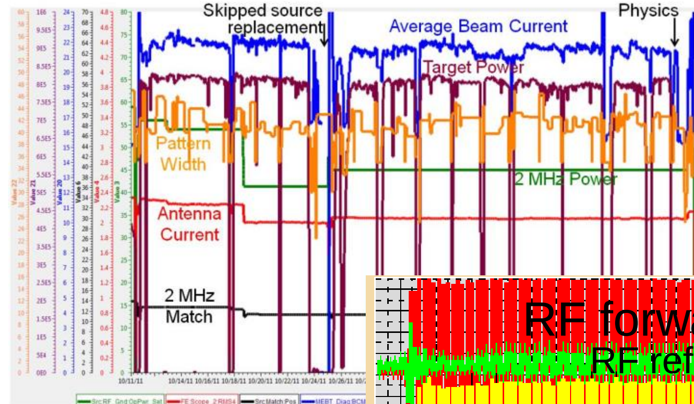
Plasma Outage Management

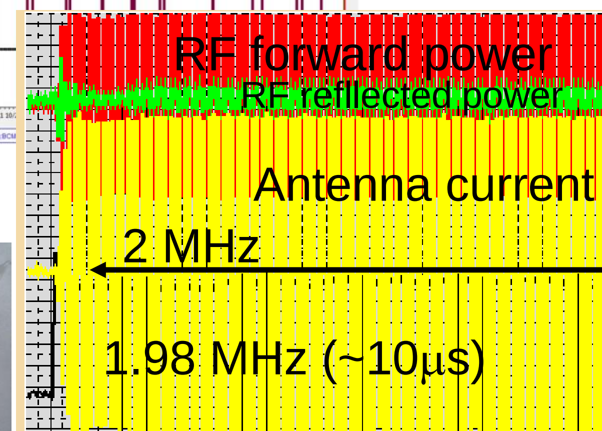
- Introduced frequency hopping in the 2MHz antenna drive to avoid plasma outages near the end of long service cycles

Cesium Consumption Management

- Reduced Cesium consumption from 0.5 mg/day to 0.1 mg/day
- High efficiency Cs consumption if ~4000 times less normalized to duty factor when compared with other cesiated H- ion sources



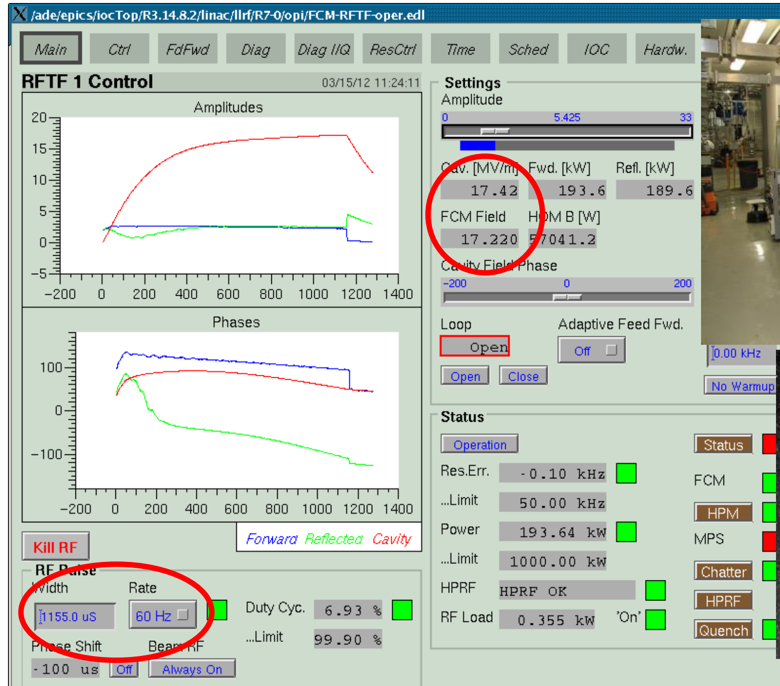


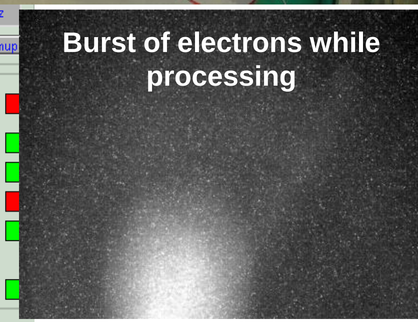


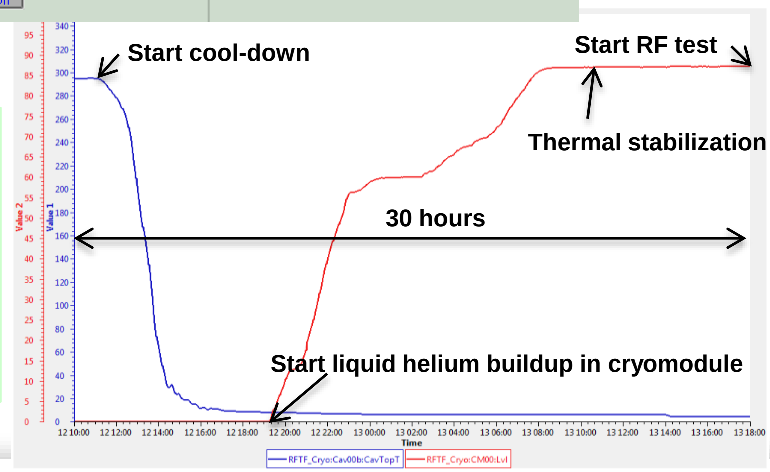
Three of the five ion sources can now predictably support 1MW operation for up to 6 weeks

Initial testing and subsequent installation of the first spare high-beta cryomodule with pressure vessel code stamp designed and built at SNS indicated excellent performance

- Leverages significant investment in cryogenic SRF test facilities
- Major design changes of helium circuit and vacuum vessel to meet the pressure vessel code requirements
- First time using central helium liquefier (CHL) system while running SNS linac at 2 K
- All four cavities in the spare cryomodule tested in the RFTF test cave with fully integrated control and diagnostic systems
- Individually and collectively tested cavities at 60Hz full duty



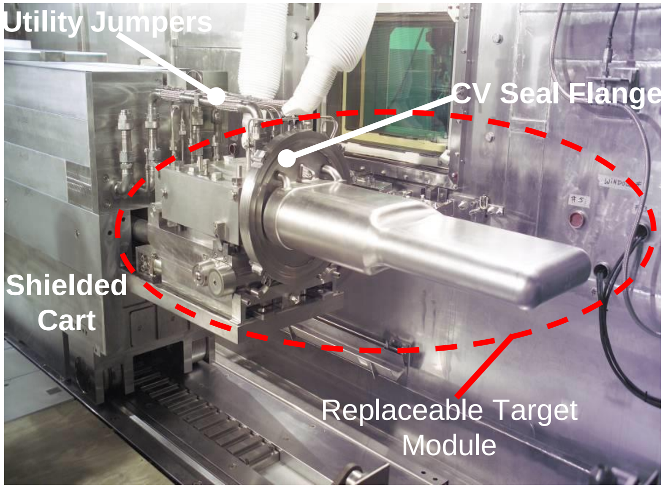




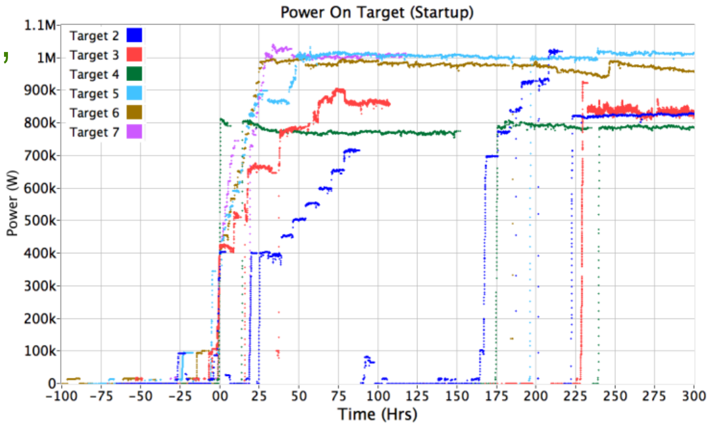
In-service high beta cryomodule gradients remain a significant operational issue – ongoing investments in SRF infrastructure are essential to maintaining and improving accelerator capability

SNS Target Modules 6 and 7 experienced unexpected and sequential early failure

- The first five devices lived for an average exposure of ~2900 MW-hrs with only one end-of-life condition (T3 at 2791 MW-hrs)
- T6 indicated failure at ~690 MW-hrs and T7 indicated failure at ~100 MW-hrs
- Possible causes:
  - Sensor malfunction (common mode) – ruled out
  - Operational issue (beam density, beam position, energy, etc.) – ruled out
  - Material issue (material specification, material processing, etc.) – none identified
  - Installation issue (bolt torques, seal integrity, etc.) – initial evaluation indicates ruled out, more analysis undertaken
  - Manufacturing issue (weld integrity, tolerances, etc.) – clearly identified issues in the same location on both T6 and T7

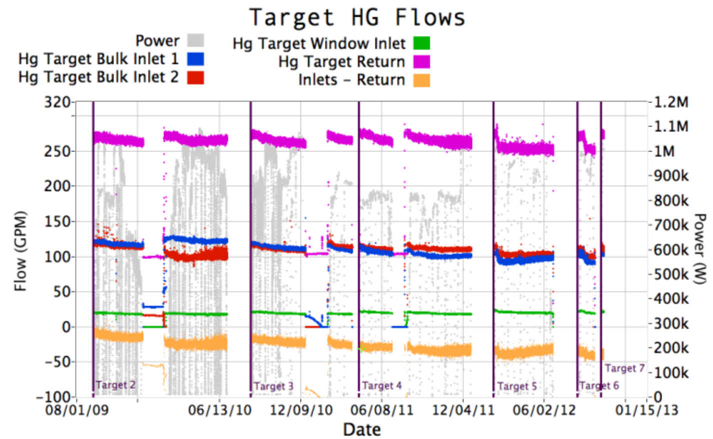


SNS Target Module on Cart – Retracted Position



Were there changes to procedures or operations that caused these failures?

- Evaluated a substantial amount of data for the installation and operation of Targets 1-7
- Identified four significant changes:
  - Fixed frequency operation (60 Hz asynchronous with respect to line voltage) beginning on February 14, 2012 (Targets 5-7) – no correlations identified
  - Changes in mercury loop pump differential pressure and system flows a few hundred hours after initial operation (Targets 5 and 6) – correlated with increase in upper knife edge seal pressure leak rate, which is in turn correlated with knife edge seal integrity, which in turn is correlated with installation procedures and bolt torque values – not a causal factor
  - Increased torque used to bolt the target module to the target carriage (Targets 6 and 7) – analysis indicates that T6 soft iron seal was partially compromised (installation) and that T7 best correlated with the only known metal-to-metal seal condition (T1) – not a causal factor
  - Reduced beam energy from 925 MeV to 895.5 MeV (removed Cryomodule 6 for repair) (Targets 6 and 7) – beam energy will be restored to ~920 MeV with installation of Cryomodule 6, and no obvious significant changes related to energy deposition with this small change in energy



Item	Change Description	Type	Implementation
1	Hardware developed to enable leak testing of mercury loop with Carriage retracted	Tooling	Target #2
2	Carriage Brake Pin retraction process altered to ensure pins are free	Procedural	Target #3
3	Counterweight Lift Fixture Stand utilized to hold fixture vertical	Tooling	Target #3
4	Maxi-Break Hiltap torque wrenches introduced to enable easier torque verification	Tooling	Target #3
5	Throat openings on open-end wrenches increased slightly to enable easier installation onto nuts	Tooling	Target #3
6	15 foot flex hose utilized to replace cumbersome 30 foot hose	Tooling	Target #3
7	Initial knife edge seal test performed prior to remaining jumper installation	Procedural	Target #3
8	Began utilization of PT1A wrench for target bolt torquing	Tooling	Target #3
9	Thru-the-wall manipulators used for N2/He line installation due to better access than the servo	Tooling	Target #3
10	Target orientation was reversed on Transfer Bay cart to provide clearance for nose while in the Transfer Bay	Procedural	Target #3
11	Hand tools were visibly marked to indicated sizes for better identification	Tooling	Target #3
12	Nose boot attachment arm modified to enable easier attachment to spent targets	Tooling	Target #3
13	Inflatable seal preparation procedure modified to remove travel-limiting screws	Tooling	Target #3
14	Heavy counterweight installation point moved to before jack bolt lowering	Procedural	Target #3
15	Window flow orifice remove from Seal Plate	Tooling	Target #3
16	"Installation Cans" used for water and mercury reflange seal rings to ease installation into hubs	Tooling	Target #4
17	Leak testing of water loop with Carriage retracted instituted	Tooling	Target #4
18	Delayed removal and inspection of water/mercury seal rings until full Carriage retracted to allow better servo access	Procedural	Target #4
19	Use of "IN" and "OUT" Carriage flags eliminated for all Carriage movements other than full retraction and full insertion	Procedural	Target #5
20	New nose spacer incorporated that includes handling features for easier removal	Tooling	Target #5
21	Installed new upper/lower knife edge seal nitrogen lines to repair line and relocate pressure transmitters to eliminate Carriage interference	Tooling	Target #6

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Since FY2009 there has been significant investment in SNS facilities

State Investment

- Joint Institute of Neutron Sciences Facility – $8.7 Million

Institutional Investment

- JINS and Guest House Parking Lot Expansion - $ 2.46 Million
- CLO 5th Floor Collaborative Offices - $2.1 Million
- Chestnut Ridge Maintenance Shops - $9.6 Million (FY12/13 – Under Construction)

SNS Programmatic Investment

- ORNL Guest House – $8.9 Million
- CLO 2nd Floor Labs – $4.8 Million
- Klystron Gallery Gap Build-out – $1.12 Million
- SRF Laboratory HVAC and Mezzanine – $0.65 Million
- Target Building Chilled Water System Upgrades – $0.59 Million
- CLO Central Control Room and Equipment Room Emergency Generator and UPS – $0.58 Million

Development is needed to increase source performance to 1.4 MW

Beam Energy

- Improve high beta SRF cavity performance – Plasma processing R&D and in-situ implementation (~$2.3M)
- Superconducting RF facilities and capabilities – Spare medium beta cryomodule, test facility development, Kinney pump, horizontal test facility, cavity chemistry (~$7.9M)
- Cryomodule rework – Two each high and medium beta cryomodules (~$1.0M)

Duty Factor

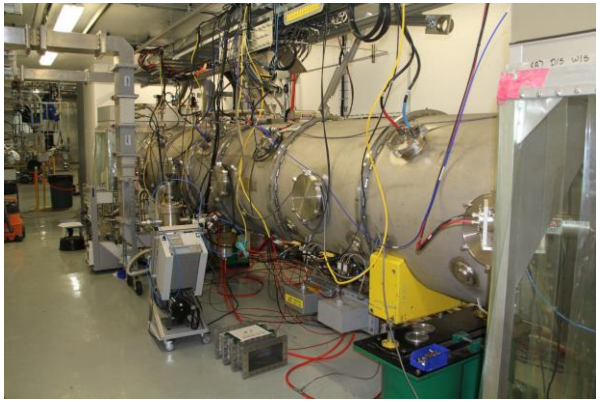
- For High Voltage Convertor Modulators - Pulse ripple reduction, controller upgrades, IGBT snubbers, HVCM cooling, and alternate topology (~$2.55M)
- Re-engineer all warm linac RF couplers ($0.8M)

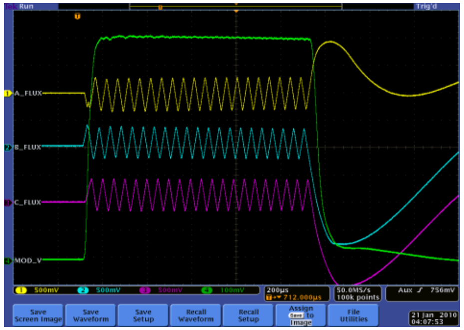
Peak Current

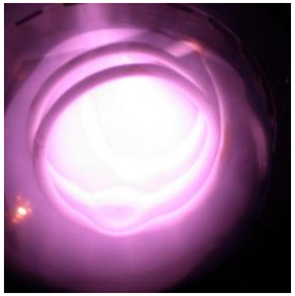
- External antenna development
- Ion source performance development (~$0.3M)

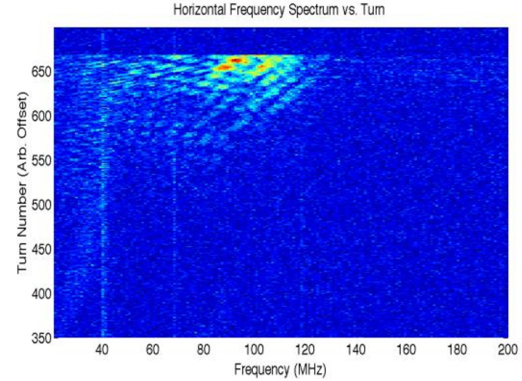
Beam Stability

- Damping system for e-p instability, 10µs laser stripping demonstration ($1.5M)









We have made good progress in closing items you identified last year

Area	Total	Closed	Open
General Remarks	1		1
RAD Re-Organization, current operations and ramp-up plans	1		1
Superconducting Linac Performance	2	1	1
High Voltage Converter Modulators	4		4
RF Systems	3		3
Superconducting Linac cryomodules and cryogenics	2		
HEBT/Ring/RTBT, Foil Development, Laser Wires and Laser Stripping	3	1	2
Ring beam dynamics	2	2	
Target development	3	3	
Moderator and reflector improvements	2	2	
Proton beam window	1	1	
Beam instrumentation systems	3	1	2
Reliability Modeling, Vulnerability Analysis and Spares Management	1	1	
Power Upgrade Project	2	1	1

Summary

- We can operate reproducibly with beam power ~ 1 MW and availability ~ 90%
- While we meet or exceed operating commitments many significant challenges remain
- Our immediate focus is on sustaining availability and continuing operation at ~1 MW (subject to target limitations)
- Our medium term effort will achieve reliable 1.4MW operation by 2017, lay the foundation for 3MW capability and maintain the potential to carry out the Second Target Station project
- Institutional commitment has been essential to our success

The hard work, dedication and talent of the SNS staff enable these achievements