SNS RAD Plan for 1.4 MW Operation

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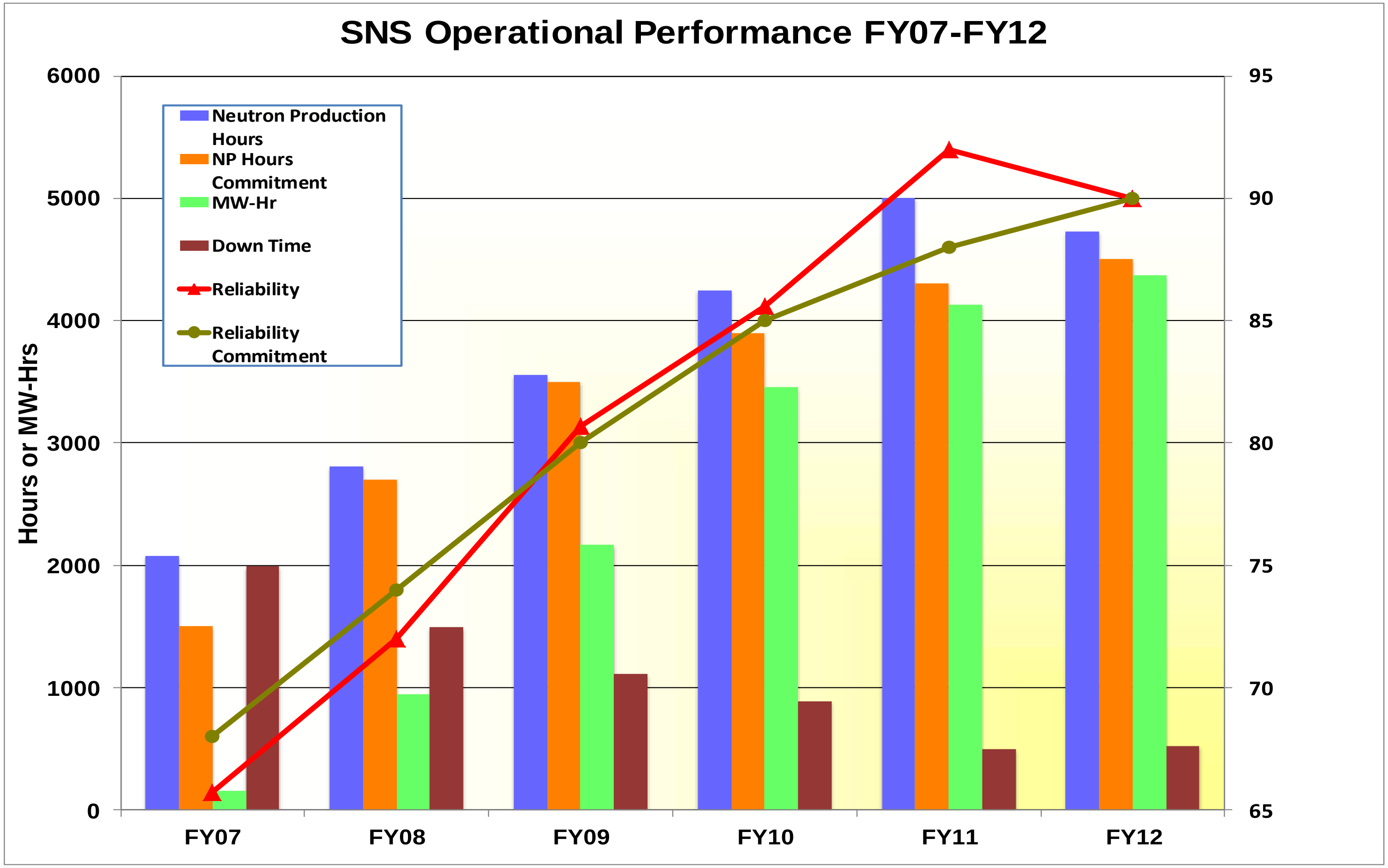
Introduction

Since FY 2009 SNS met or exceeded its operational commitments to DOE in neutron production hours delivered, beam power delivered, reliability and total operating hours.



A number of technical challenges remain to achieve 1.4 MW operation

- The SNS accelerator has operated for extended periods at a beam power of ~ 1 MW and is designed for 1.4 MW
- The first 5 years of operation (2007-2011) addressed many of the impediments to meeting 1MW operation at ≥90% reliability but some key challenges remain. These include:
  - Beam-induced superconducting radiofrequency (SRF) cavity damage and high beta SRF cavity performance
  - Warm Linac RF couplers and iris reliability
    High Voltage Converter Modulator (HVCM) performance at extended pulse length
  - Ion Source lifetime and performance
    Ring Injection stripper foil lifetime

Increasing the beam power to the full 1.4 MW design capability involves increasing three primary parameters

- Pulse Length
- Beam Current
- Beam Energy

	Average Beam Current (mA)	RF Pulse length (mS)	Energy (GeV)	Power (MW)
Present	22.8	0.825	0.925	1.0
+ 75 us pulse	22.8	0.900	0.925	1.1
+ 150 us pulse	22.8	0.975	0.925	1.2
Current increase	25.4	0.975	0.925	1.3
Energy increase	25.4	0.975	1.0	1.4

Increasing beam power cannot compromise our other goals – sustainable, high reliability operation is key to success

Our sponsors expect us to maintain operational performance in operating hours and reliability

Goal	FY13	FY14	FY15	FY16	FY17
Total Operating Hours (Goal)	4500	5000	5200	4500*	5200
Neutron Production Hours (Goal)	4000	4500	4600	4000*	4600
Neutron Production Hours (Commitment)	4000	4500	4500	3900*	4500
Reliability (Commitment)	≥90%	≥90%	≥90%	≥90%	≥90%

The current path towards 1.4MW is shown below and reflects funding constraints and target supply chain challenges.

	FY13	FY14	FY15	FY16	FY17
Plan	1.0MW	1.1MW	1.2MW	1.3MW	1.4MW

SNS Power timeline at sustained 90% reliability

Element 1 - Pulse Length Increase

- A primary vulnerability in this step is equipment stress with:
- Increased duty factor on the HVCMs
- RF system components
- The Ion Source.
- Even though the HVCM systems were designed for the planned 1-mS beam pulse length, these systems are first-of-a-kind, and carry associated uncertainties. During the initial power ramp-up to 1 MW (825 µs RF pulse length), increases in the operational duty factor revealed unanticipated equipment deficiencies. As a result, the HVCMs were operated at reduced performance levels until the necessary solutions were identified and implemented. Additional deficiencies must be overcome in order to reliably exceed 825uS of beam pulse length.
- The Drift Tube Linac and Coupled Cavity Linac RF couplers, as well as other RF components are marginal at 825 µs pulse length.
- Ion source antenna lifetime issues may re-occur at increased duty factor.

Pulse Length Increase Details - HVCM

Additional modifications to the HVCMs are required to increase the RF pulse length to the 975 µs for 1.4MW. These include:

- Pulse droop reduction – The HVCMs currently run open-loop. The pulses currently droop to below the limit for RF regulation at the full pulse width. This regulation can be achieved with an improved pulse controller.
- Pulse ripple reduction - At full pulse width, the pulse ripple is beyond the ability of the RF control system to compensate. The reduction can be achieved with an improved pulse controller.
- Improved transient over-voltage protection - New snubbers will reduce this leading cause of IGBT failure.
- HVCM Cooling - At present the heat exchangers in the HVCMs are insufficient to dissipate the heat for 975 µs pulse width operation.
- Capacitor lifetime issues (possibly related to overheating).

Pulse Length Increase Details – DTL-CCL

- The RF system components that are marginal at 825 μs pulse length will likely have to be improved for reliable 975 μs pulse length operation. These components include the RF couplers for the Drift Tube Linac and Coupled Cavity Linac.
- The Warm Linac vacuum systems are in serious need of an upgrade. They all leak air at some level which leads to degradation of the ion pumps. The ion pumps will be replaced by large turbomolecular pumps.

Pulse Length Increase Details – RFQ and Ion Source

- The ion source lifetime issues at increased duty factor will need to be addressed for the internal antenna source. This can be done on the test stand but further ion source antenna development is needed. We anticipate that the External Antenna source will play an important part in the upgrade. We will develop both approaches until the best approach emerges.

- RFQ stable operation at long pulse length and high current has not been demonstrated for a long period

Element 2 - Peak Current Increase - Ion Source and RFQ

Initially we thought that this would come exclusively from increased current from the ion source. However, a recent evaluation of the RFQ operating parameters revealed that we were not transporting the entire current from the ion source. Evaluations are underway to improve the efficiency of the ion source-RFQ.

The integrated charge from the BCM02 and BCM11.

The current increased by 25% for 0.4 amplitude from the 0.353 for production

From the parameter list we were only looking for ~11% more.

Element 3 – Beam Energy Increase (1)

The SNS beam was designed to operate at 1,000 MeV with an energy reserve of 25 MeV.

- **The beam is currently operating at 937 MeV with minimal reserve. A 6.3% beam energy increase is required to reach 1.4 MW reliably, and an additional 2.5% increase is required to provide the desired energy reserve.**

Element 3 – Beam Energy Increase (2)

- The achievable operating gradients in the high beta SRF cavities are lower than the design value, mainly due to the heating effect by electron emission and damaged parts/sub-equipment in the cryomodules. To reach the design output energy with an energy reserve more than 25 MeV, a ~15% increase in the average field gradient of the High Beta SRF cavities is needed.
- The preferred path to achieve and maintain the increased gradient is to develop and implement an in-situ processing surface treatment to reduce electron activity, which will address mild surface contamination or imperfection.
- In-situ plasma processing is one of the most promising solutions based on preliminary studies done in 2009 at SNS. This is a new technique that requires some R&D to optimize the processing parameters.
- If the R&D produces an applicable solution for the in-situ processing, it will take about 2 years to accomplish in-situ processing of cavities in the accelerator tunnel.

Plan by Year

FY 2013

- Operate with high reliability at 1.0MW – subject to Target supply limitations [key recent decision to remain at 0.85 MW for foreseeable future to conserve spare target(s) and minimize target changes]
- Demonstrate current increase with higher operating power on RFQ and retune RFQ
- Execute a several week run at the end of the Spring-Summer operating cycle at 1.1MW [deferred until target spare situation improves]
- HVCM Improvements
  - Prototype Cooling System Upgrade
  - Complete Snubber deployment
  - Develop Controller
- Develop External Antenna Ion Source
- Begin design of new RF Couplers
- Develop Plasma Processing – R&D with 3 cell cavity

Plan by Year

FY 2014

- Operate with high reliability at 1.1MW
- HVCM
  - Deploy HVCM Cooling Upgrade
  - Test Prototype Controller
- Develop External Antenna Ion Source
- Prototype and test new RF Couplers
- Develop Plasma Processing – R&D with 6 cell cavity and HTA
- Execute a several week run at the end of the Spring-Summer operating cycle at 1.2MW

Plan by Year

FY 2015

- Operate with high reliability at 1.2MW
- HVCM
  - Deploy New Controller
- Test External Antenna Ion Source
- Fabricate and install new RF Couplers
- Develop Plasma Processing – R&D with full Cryomdule

Plan by Year

FY 2016

- Operate with high reliability at 1.2MW and begin to operate at 1.3MW
- HVCM
  - Deploy New Controller
- Test External Antenna Ion Source
- Fabricate and install new RF Couplers
- Deploy Plasma Processing of in-situ Cryomodules

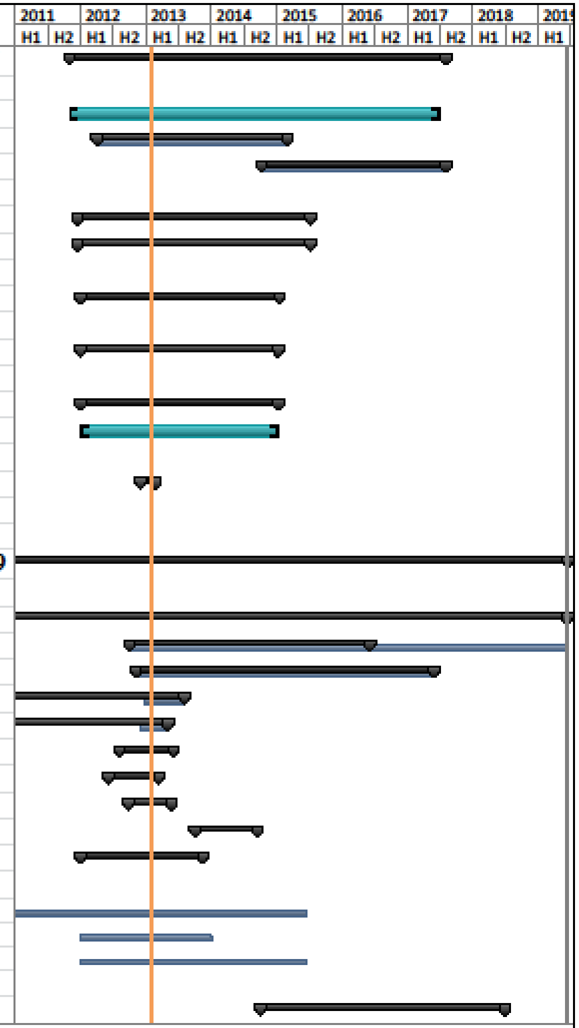
Plan by Year

FY 2017

- Operate with high reliability at 1.3MW and begin to operate at 1.4MW
- HVCM
  - Complete HVCM Upgrades
- Operate with External Antenna Ion Source
- Complete fabrication and installation of new RF Couplers
- Complete Plasma Processing of in-situ Cryomodules

Element 4 - Address Beam Stability, Injection Region and Sustainability concerns

ID	WBS	Task Name	Duration	Start	Finish
1	1	SNS Accelerator 1.4MW Plan	1502 day:	Tue 11/1/1]	Wed 8/2/17
2	1.1				
3	1.2	Beam Energy	1479 days	Tue 11/1/11	Fri 6/30/17
4	1.3	Plasma processing R&D	760 days	Mon 4/2/12	Fri 2/27/15
10	1.4	in-situ plasma processing	738 days	Mon 10/6/14	Wed 8/2/17
17					
18	1.5	Beam Pulse Length	928 days?	Fri 12/16/11	Tue 7/7/15
19	1.5.1	High Voltage Modulators	928 days?	Fri 12/16/11	Tue 7/7/15
39	1.5.2				
40	1.5.3	RF Systems	794 days	Sun 1/1/12	Thu 1/15/15
49					
50	1.6	Beam Current	788 days?	Sun 1/1/12	Wed 1/7/15
51					
52	1.6.1	Ion Source	788 days	Sun 1/1/12	Wed 1/7/15
53	1.6.1.1	Antena Development	789 days	Sun 1/1/12	Wed 1/7/15
54					
55	1.6.2	RFQ Transmission	56 days?	Sat 12/1/12	Mon 2/18/13
60					
61					
62	2	SNS Accelerator Sustainablity Plan	2529 day:	Mon 10/5/0	Thu 6/13/19
63					
64	2.1	Superconducting Linac and Cryogenics	2529 days	Mon 10/5/09	Thu 6/13/19
65	2.1.1	Medium Beta Spare Cryomodule	960 days	Mon 10/1/12	Fri 6/3/16
71	2.1.2	Cryomodule repair	1193 days	Mon 11/5/12	Wed 5/31/17
77	2.1.3	CTF	998 days	Mon 10/5/09	Wed 7/31/13
86	2.1.4	VTA	676 days	Fri 10/1/10	Fri 5/3/13
93	2.1.5	HTA	215 days	Mon 8/6/12	Fri 5/31/13
97	2.1.6	HPR	204 days	Mon 6/4/12	Thu 3/14/13
100	2.1.7	Vacuum furnace for small parts	175 days	Mon 9/24/12	Fri 5/24/13
104	2.1.8	Cavity surface polishing system	250 days	Tue 10/1/13	Mon 9/15/14
107	2.1.9	Test cavity	490 days	Mon 1/2/12	Fri 11/15/13
110					
111	2.2	Ring Systems			
112	2.2.1	Laser Stripping			
114	2.2.2	e-P Instability			
116					
117	2.3	Warm Linac Vacuum	977 days	Wed 10/1/14	Thu 6/28/18



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Upgrade	FY13 ($K)	FY14 ($K)	FY15 ($K)	FY16 ($K)	FY17 ($K)	Total ($K)
HVCM	408	1220	400	400	0	2428
Cryo Test Facility	1148	600	200	0	0	1948
Medium Beta Spare Cryomodule	0	0		1500	1500	3000
Cryomodule Rework-Processing	250	250	950	550	550	2550
Ring systems	0	0	536	204	536	1276
Warm Linac Vacuum	0	0	450	450		900
Primary Stripper Foil	0	0	0	1,000	0	1000
TOTAL	$1,806	$2,070	$2,536	$4,104	$2,586	$13,102
Operations Funding	$250	$250	$950	$2,050	$2,050	$5,550
AIP Funding	$1,556	$1,820	$1,586	$2,054	$536	$7,552

Summary

- Path forward is technically clear and well-defined, and must be accomplished within allocated operating budgets and AIP funding
- We are ready to demonstrate sustained operation at 1.1MW
- Key limitations on progress are
  - Directorate funding distribution
  - Target supply chain
- Positioned to execute the plan describe above – estimated completion in FY17 if we can resume high-power operation in the Summer of 2014
- Incremental increases in power as different elements are completed and consistent with a conservative, sustainable approach to operation that supports sponsor requirements