Power Upgrade and Second Target Station Update

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Accelerator Advisory Committee Meeting

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A Brief History of the Power Upgrade Project (PUP)

- SNS was designed from the outset to accommodate doubling the SNS proton beam power and adding Second Target Station (STS)
  - Both efforts ranked very-high priority in 2003 DOE future facility ranking

Power Upgrade Timeline

- Nov. 2004: CD-0, Double power, beam energy and current increase, CD-4 in 2012, $160 M
- Jan. 2009: CD-1, same cost as before
- July 2011: PUP “indefinitely postponed”, effort bundled with second target
- Jan. 2010 – July 2011: PUP organization formed, CD-2 basis developed, cost = $131M
- 2008: PUP changed to energy increase only ($90-96M), current increase through AIP
A Brief History of the Second Target Station

2007: STS workshops + study group, recommended long pulse option.

2008-2010: small internal effort, rotating target, site considerations, accelerator parameters

Jan. 2009: CD-0, mission need approval

Mid 2011– present: re-evaluate short pulse / long pulse, option from the user perspective + source moderator optimization

2013 BESAC facility prioritization: STS absolutely central, scientific/engineering challenges to resolve before initiating construction.

STS Time-line
STS Studies over the Past Two Years Concentrated on the Neutron Source

- 10 Hz, long wavelength neutron source
  - Moderator / target / reflector system optimized for high flux
  - Short pulse
  - 300 – 500 kW beam power
  - Similar to the strategy taken at the ISIS second target station

- This power level requires ultimate single pulse intensity from accelerator
Second Target Station

- A second target station is planned for SNS. Will probably require 300 – 500 kW, short pulse from ring (< 1 us)
Second target station and instrument suite fits well onto SNS site
Primary PUP Impact Areas

**Tunnel:** fill in empty drift sections with cryomodules

**Extraction:** fill in empty space with kickers

**Klystron gallery:** fill in area provided with high power RF equipment
PUP Superconducting Cavity Gradient Requirements Are Modest

- SCL requirements: 8 cryomodules to reach 1.3 GeV
  - There are 9 empty slots available, one for spare
    - Tech note PUP0-300-TR0001-R00
  - Long term SNS power upgrade impacts included
    - Tech note STS02-21-TR0001-R00

7 cryos: aggressive required gradient
8 cryos: conservative required gradient

- 8 cryos: very aggressive required gradient

6 cryos: very aggressive required gradient

<table>
<thead>
<tr>
<th>Gradients</th>
<th>MV/m</th>
</tr>
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<tbody>
<tr>
<td>Present high beta</td>
<td>12.8</td>
</tr>
<tr>
<td>Present range</td>
<td>7.7-15.4</td>
</tr>
<tr>
<td>Original SNS design</td>
<td>15.6</td>
</tr>
</tbody>
</table>
Cryomodules are a Large Part of the Power Upgrade

- PUP SCL cryomodules are based on spare cryo-module design (see M. Howell’s talk)
  - Required accelerating gradients are low for upgrade (spare cryomodule averaged higher, ~ 16 MV/m)
  - Simplify the design based on lessons learned (no Higher Order Mode couplers, no piezo tuners, etc.)
  - Pressure vessel code compatible
Ring / Transport Lines Upgrade Needs

• Most of the transport and Ring are 1.3 GeV capable
  – TEST: the Ring systems at 1.3 GeV – some cooling system upgrades will be included

• Injection region needs upgrade
  – 2 new chicane magnets + injection dump septum

• Extraction line needs 2 extra kickers

We have experience upgrading the Ring Injection area
Klystron Gallery Layout Based on Experience

- Layout of RF equipment based on HVCM experience
  - One additional modulator needed relative to original expectations
  - Addition to the klystron gallery has been added for this

Klystron gallery “bump-out” finished, will accommodate additional space needs
“Chases are Full” Problem Represents a Major Scheduling Headache

- During the original construction project, corners were cut
- Some upgrade RF chases (klystron gallery to tunnel) were filled with cables
  - These need to be properly re-routed
  - Have a plan for staged clean-up during normal 2x/year extended outages
- Now is an opportune time to address this problem

Example chase, tunnel side with high voltage cables
STS Accelerator Ongoing Activities

AAC 2012: “At a low level of effort, the design concepts for a power upgrade to 3 MW should continue to be refined, so that a final design can be more quickly developed when the funding environment improves”

• The funded STS efforts do not involve accelerator studies
  – Need to define the neutron source requirements first

• But some specific accelerator developments that impact support for the STS are ongoing
  – HVCM, RF, ion source development

• Looking at alternate applications for the SNS accelerator
Path to 3 MW: Basic Parameters are Known

At 60 Hz

<table>
<thead>
<tr>
<th></th>
<th>$\langle I \rangle$ (mA)</th>
<th>Pulse Length (ms)</th>
<th>Energy (GeV)</th>
<th>Linac Power (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present</td>
<td>23</td>
<td>0.82</td>
<td>0.935</td>
<td>1.1</td>
</tr>
<tr>
<td>Design</td>
<td>26</td>
<td>1</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>Energy Upgrade</td>
<td>26</td>
<td>1</td>
<td>1.3</td>
<td>2.0</td>
</tr>
<tr>
<td>Energy + Current Upgrade</td>
<td>42</td>
<td>1</td>
<td>1.3</td>
<td>3.2</td>
</tr>
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</table>

Need to push on energy, pulse length and beam current to reach 3 MW
Beam Current Increase Option

- Original plan was to develop a 60 mA peak ion source, with ~30% chopping to get 42 mA average
- But intelligent chopping can reduce needed peak current
  - Simulations show may be able to use 80-85% of beam current
  - Original design is 67% un-chopped
Long Term Plan Includes a 2 source Front End for Reliability

- Having a hot spare source has been a long term plan for reliable source operation
- Requires transitioning to a magnetic LEBT
  - Integrated Test Stand with RFQ will include magnetic LEBT
STS Gradient Strategy: Equalize Cavity Power

Tailoring the cavity gradients...

Results in constant power: eases modulator and RF requirements
Currently planned upgrades plus others should support STS power levels
- Snubbers, controller, new gate drivers and alternative bus to achieve higher voltage and a flat pulse with current system reliability levels – also supports 1.4 MW
- Alternate topology and possible redundancy to improve STS HVCM design with improved reliability

JEMA modulator specified to meet STS requirement to drive $12 \times 700$ kW CPI klystrons (85 kV, 160 A)

Factory acceptance testing scheduled for mid-May through June, delivery early August
With a 10 Hz 300-500 kW STS, Where Will all the Power Go?

- LINAC
  - 3 MW
  - 1.3 GeV
  - 60 Hz

(Power split is not finalized)

- up to 2 MW, 50 Hz
- 300 – 500 kW, 10 Hz
- 500 – 700 kW, other use

First target station
Second target station (presently being considered)
Other applications

With the power upgrade, the accelerator has potential to drive additional applications.
The Injection “Waste Beam” can be Used

• Presently we send ~ 50-75 kW beam to the Ring injection dump (not fully stripped)
  – Can easily divert most of this to another facility
  – Can easily increase this beam power by small movements of the foil
  – Pulse structure = 60 Hz x 1 ms (long-pulse)

Normal operation: ~ 5% of the beam power to the dump

Few mm of foil movement could allow 100’s of kW to the dump
Example of diverting beam from the injection dump

- New magnet diverts \( \text{H}^- \) beam to exp
- Normal beam to inj dump
- Existing injection dump

Diagram showing the new transport line and the new magnet:

- Existing injection dump
- New transport line
- Ring
- New magnet

Graph showing the amplitude (AU) vs. position (mm) for the \( \text{H}^- \) and \( \text{H}^0 \) beams.

- \( \text{H}^- \) beam
- \( \text{H}^0 \) beam
- ~ 15 cm separation

Table showing the position (mm) and amplitude (AU) for \( \text{H}^- \) beam:

<table>
<thead>
<tr>
<th>Position (mm)</th>
<th>Amplitude (AU)</th>
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<tbody>
<tr>
<td>~ 15 cm</td>
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Example site plan at the SNS - large space is available in the ring injection area.

Possible Additional Applications:
- Single Event Upset (FAA)
- ISOL
- Fusion / fission materials irradiation
Parasitic Application, No STS Impact: Neutrino Physics

- The SNS spallation target is an excellent source of low energy DAR neutrinos due to the high intensity, extremely low duty factor beam
  - Well defined, intense $\nu_u$, $\bar{\nu}_e$, and $\nu_e$, with very high background rejection due to short duty factor are desirable
  - Requests for sterile neutrino searches, cross section measurements for $\nu$-nucleus interactions to understand supernova nucleo-synthesis and $\nu$-nucleus scattering for supernova interpretation
  - Snowmass intensity frontier capability workshop identified the SNS beam as one of the desired proton beam capabilities

(Courtesy W. Louis / OscSNS)
Summary

• There is a nominal path forward for the power upgrade

• Funded STS activity is on the neutron source development
  – Need to “activate” the accelerator upgrade effort

• Alternate applications of the SNS proton beam are being pursued