APS Upgrade Status

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October 29, 2014

APS Upgrade Goal and Strategy

- APS Upgrade Goal: Build the **world's leading high-brightness hard x-ray storage ring**, incorporating advanced beam line, optics, detector and data technologies to enable breakthrough mesoscale science and the ability to explore real systems in real time in real environments

- Strategy: Upgrade the APS with **state-of-the-art technology to maintain world leadership**
  - Rebuild the storage ring with a multi-bend achromat design and high stability to provide the U.S.'s first 4th generation storage ring X-ray source
  - Deploy next-generation undulators to produce the highest x-ray brightness from the low storage ring emittance
  - Develop advanced beamlines that fully exploit the high-brightness source

Our plans enable the U.S. to establish a world leadership position in storage-ring x-ray sources, even in the face of stiff international competition, which was a central them in the July 2013 BESAC Report

Comparison of APS-U to other light sources worldwide in early 2020s

Parameter		APS	APS Upgrade		ESRF-II	SPring8-II	Petra-III	NSLS-II	MAX-IV	Sirius
		Present	Hi-Bright	48 Bunch						
Energy [GeV]		7	6	6	6	6	6	3	3	3
Current [mA]		102	200	200	200	100	100	500	500	500
Emittance, Horizontal [pm]		3113	67	48	142	99	1000	800	302	275
Brightness (*)	8 keV	1	88	51	61	43	4.1	3.7	13.9	22.7
	20 keV	1	336	144	164	137	2.9	0.8	5.2	8.1
	80 keV	1	382	152	154	127	1.0	0.01	0.4	0.3
Flux Density (*) (#)	8 keV	1	4.6	4.1	3.9	1.8	1.8	0.4	2.0	1.7
	20 keV	1	10.4	9.1	7.7	4.1	1.4	0.1	0.6	0.5
	80 keV	1	10.4	9.0	7.5	3.9	0.1	0.0	0.0	0.0
Coherent Flux	8 keV	9.3	813	472	562	398	38	34	129	211
(10^{11} ph/s)	20 keV	0.6	198	85	97	81	2	0	3	5
Single Bunch Brightness @ 8 keV (*)		1	6.5	25.5	1.5	5.1	0.3	0.1	1.9	3.1
Flux for 10 nm focus @ 20 keV (*)		1	336	144	164	137	2.9	0.8	5.2	8.1

(*) Relative to present APS performance

(#) Flux Density is through a 0.5 x 0.5 mm aperture at 30 m

No light source now operating or under construction can match all of APS-U's technical capabilities

Moving APS-U Forward – Three Elements

- Science Case
  - Articulation of visionary science and mind-blowing possibilities to strengthen the stump speech, building on a tremendous amount of development work by the community
  - Development of high-impact scientific opportunities (“killer apps”) through a science and beamline development process
  - Community engagement and support

- R&D Progress to develop and prove the concept
  - Refining and optimizing the conceptual design
  - Progressing on critical R&D and prototyping

- Develop, and validate, the Project to get ready for CD-1
  - Work towards CD-1 readiness in Q2 FY15
  - External validation of the APS-U approach, challenges and their solutions

Path Forward: Science Case

- In August we formed a Team with responsibility for working with the community to further develop and articulate the Science Case
- These members are reaching out to and working with the community to develop the case
- We will be developing a process inspired by the LCLS First Experiments approach, and seek the SACs guidance on that process
- It is essential that we effectively articulate the transformational opportunities enabled by the Upgrade, and convincingly explain why there is urgency around APS-U

Path Forward: FY15 R&D Plan

- Primarily technical efforts to drive the basis of the MBA design to a more quantitative basis:
  - Beam physics design and integration toward an ‘engineered’ machine design
  - Prototype vacuum hardware
  - Pre-prototype magnets and measurements (ANL, FNAL, BNL + Industry)
  - Support structures R&D
  - Beam Stability / Real Time Feedback in Sector 27
  - Power Supply stability
  - Fast pulsers / Kickers
  - High Harmonic Cavity / Bunch Lengthening System
  - Detectors

- FY15 Effort Request Agreements are in place, totaling ~67 FTEs

Path Forward: Getting “CD-1 Ready”

- While developing the scientific case for APS-U, we must further mature the conceptual design, advance the R&D program, cost estimate, resource loaded schedule, risk analysis, etc., to
  - develop the best possible project and gain confidence in our design and our plans
  - make the APS-U case bullet-proof…and do it with urgency

- We are beginning to stand up our advisory committee structure and plan for a complete set of top to bottom reviews

- The Machine Advisory Committee will review the technical basis of the accelerator design
  - Forming committee now with review in next 2-3 months

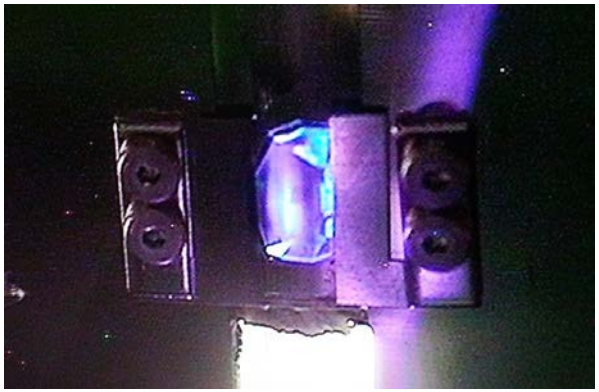
- Working through charters of other Project advisory committees and will start forming them

Project Status: Next Steps

- We are working with DOE/BES to provide the Business Case for the Upgrade so that they can move the project to the next step
- It is our understanding that CD-0 will be revised, based on this input
- Once that has been done, we will have a better timeline for CD-1
- Meanwhile, we are focused on further developing and refining the conceptual design and carrying out R&D
- We are seeing enthusiasm from DOE, and expect to move forward once we have delivered what is needed

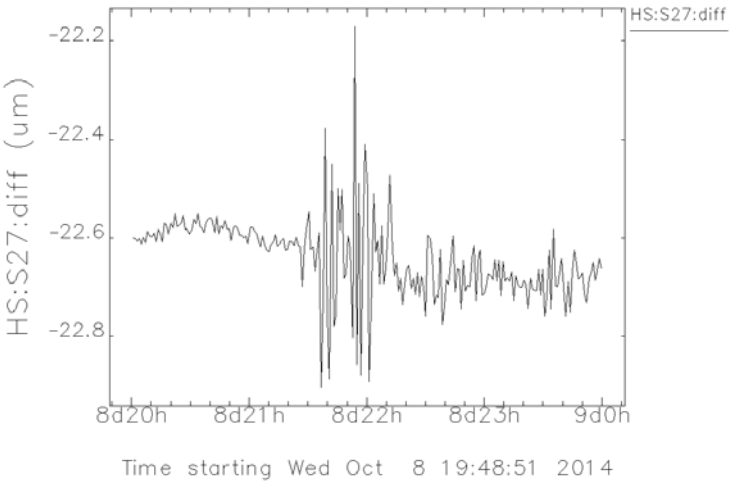
Meanwhile we are making good technical progress

- New RIXS Beamline 27-ID
  - All beamline components in first-optics enclosure commissioned in run 2014-2
  - Performance compares very favorably with existing beamlines w.r.t. flux, divergence and throughput
  - First RIXS experiments expected in second half of current run 2014-3
  - All RIXS work will be complete (on time, on budget) in the December shutdown



Diamond under x-rays in high-heat load monochromator

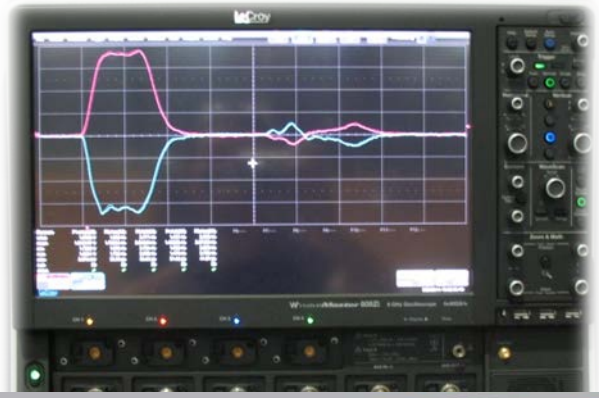
- Mechanical motion monitoring system
  - Stability and drift requirements for the Upgrade are at the micron level
  - Sector 27 has been outfitted with a system to monitor floor motion & BPM motion
  - Preliminary results show detection of floor and chamber mechanical movements at the 20 nm level



Magnitude 6.0 earthquake off the coast of Chile

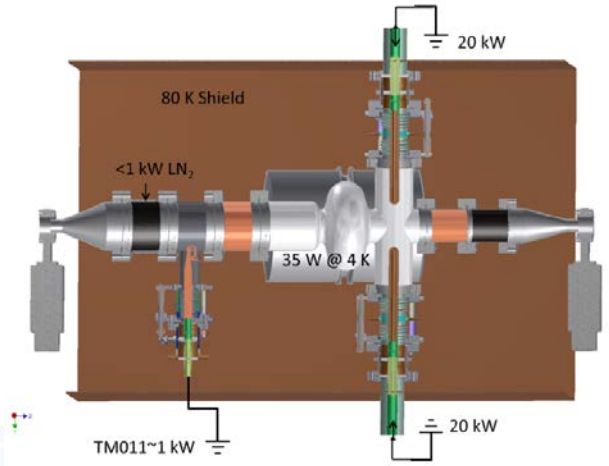
Meanwhile we are making good technical progress

- Injection pulser system
  - The APS-U concept calls for bunch swap-out via on-axis injection
  - Commercial pulser received and undergoing testing; meets specifications and initial reliability is encouraging; long terms tests in progress



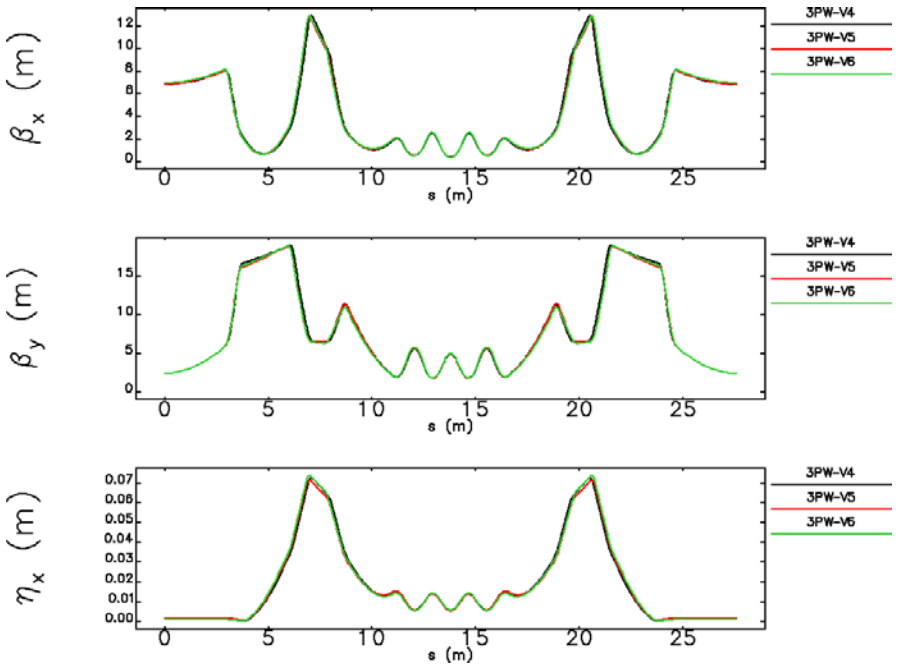
- Magnet development
  - Some non-conventional magnets are required to achieve low-emittance
  - Starting to prototype these magnets beginning with a longitudinal dipole

- Harmonic cavity development
  - Need to lengthen the bunch longitudinally for good lifetime
  - A superconducting radio-frequency cavity system is under development with cavity prototyping commencing



APS MBA Lattice Optimization (M. Borland)

- We have been working towards a lattice design which is further optimized from an engineering point of view
- Version 6 lattice released; performance very similar to earlier versions
- Benefits of new lattice:
  - reduces the number of different magnet designs (lengths) and number requiring expensive pole tip material, thereby reducing project cost
  - Optimizes special M1 magnet longitudinal field gradient
  - Adjust and optimize space between magnets to meet vacuum, diagnostics, corrector needs
- Version 6 lattice provides a solid basis for an engineering design. Optimization will continue.



	v5	v6
# Quad designs	8	3
# Sext designs	3	1
# VP Quads/sector	6	6
# VP Sexts/sector	6	2

Upcoming Events

- Upcoming Workshops and Events
  - APS Scientific Advisory Committee, November 5-6, 2014
  - Diffraction Limited Storage Ring Workshop, Nov. 19-21, 2014
  - Beam Dynamics and Magnets, Dec 1-4, 2014
  - APS Machine Advisory Committee Meeting
  - Full Field Imaging, Jan 19-20, 2015
  - Twenty Years of the APS, March 26, 2015

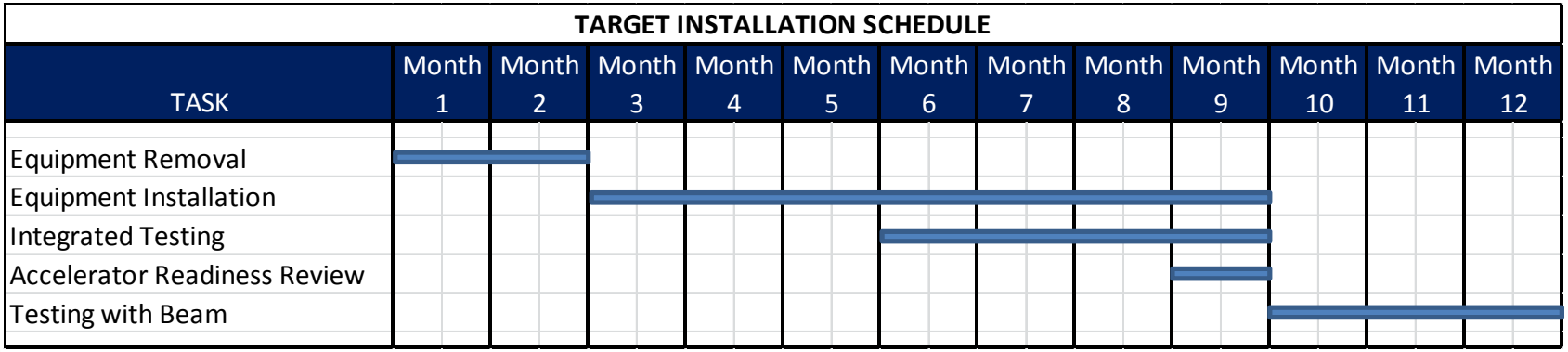
Finally,

What I would ask of the User Community

- Let your voice be heard
- Continue to make the case that the US needs an internationally competitive synchrotron x-ray source…and that you need it to carry out your science
- Take any opportunity you have to make the case for an Upgrade of APS
- Remember that there is a lot at stake
- If you need information, ask us
- We will be counting on your support as we continue to make the case that an upgraded APS is an essential tool for 21st century science

APS-U removal and installation plan

- Current planning calls for a 12-month shutdown and testing period, prior to resumption of operations
- Plan has substantial detail for this stage of the Project
  - Multi-shift, multi-crew operations
- Risk mitigation includes additional shifts, additional workdays
- Given central importance of minimizing APS unavailability, installation and testing requires a very different approach from typical installations, with all equipment in-hand, tested and ready to go, and adequate space
- SPEAR 3 is a proof of principle: same duration, 1/5th the size
- APS-U's preliminary removal/installation plan has been externally reviewed:
  - '…the committee members believe that the…plans are well developed and achievable'; 'The schedule of 9 months appears aggressive, but reasonable…'



High-Level Parameter Comparison: APS today vs MBA Upgrade*

Quantity	APS Now	APS MBA Timing Mode	APS MBA Bright. Mode
Beam Energy [GeV]	7	6	6
Beam current [mA]	100	200	200
Number of bunches	24	48	324
Bunch duration [ps]	34	70	18
Bunch spacing [ns]	153	77	11
Bunch rep. rate [MHz]	6.5	13	88
Emittance ratio	0.013	1.0	0.1
Horizontal emittance [pm-rad]	3100	46	67
Horizontal beam size [μm]	275	17.8	21.2
Horizontal beam divergence [μrad]	11	2.6	3.1
Vertical emittance [pm-rad]	40	46	7
Vertical beam size [μm]	10	10.2	4.0
Vertical beam divergence [μrad]	3.5	4.3	1.6

*H7BA-TwoSector-nux95-nuy36-3PW-Version4
Courtesy M. Borland