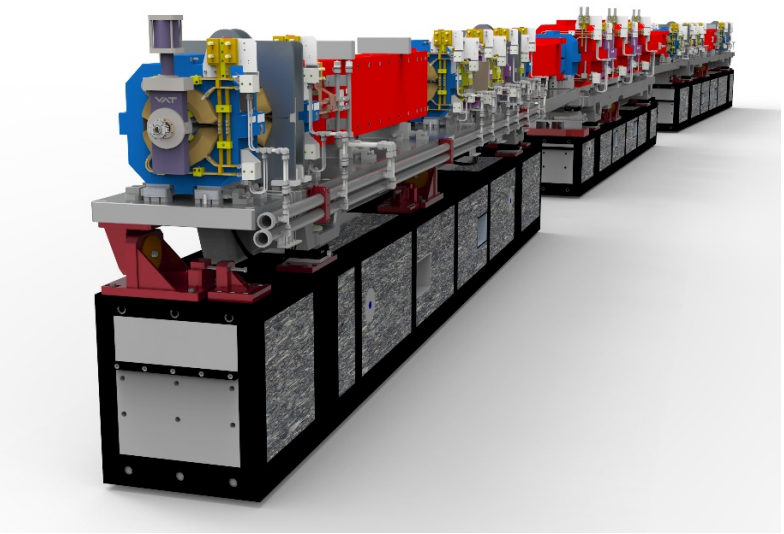
APS-U UPGRADE UPDATE
JANUARY 22, 2020

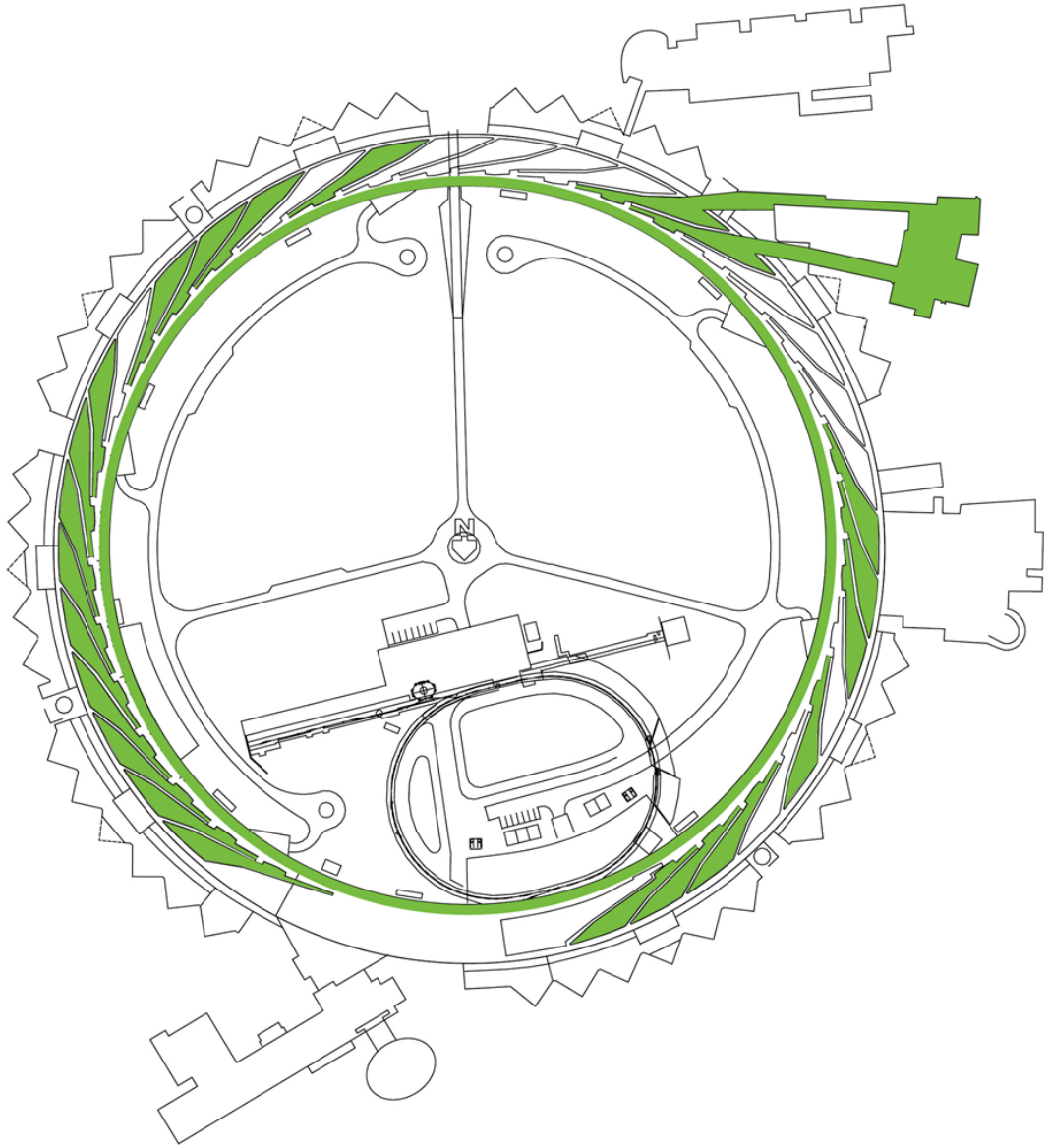


BOB HETTEL
APS Upgrade Project Director

APS-U SCOPE

815M$ project to update and renew the facility

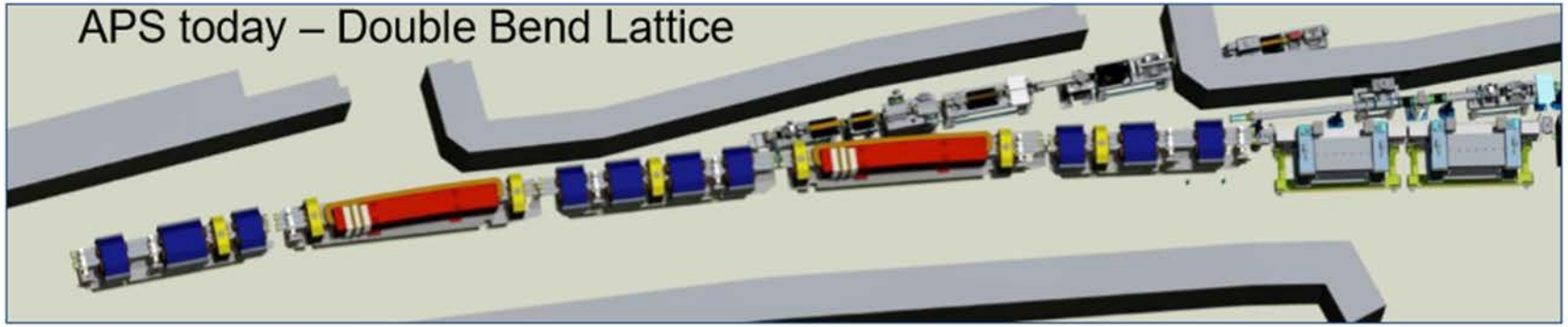
Re-uses 1.5B$ in existing infrastructure

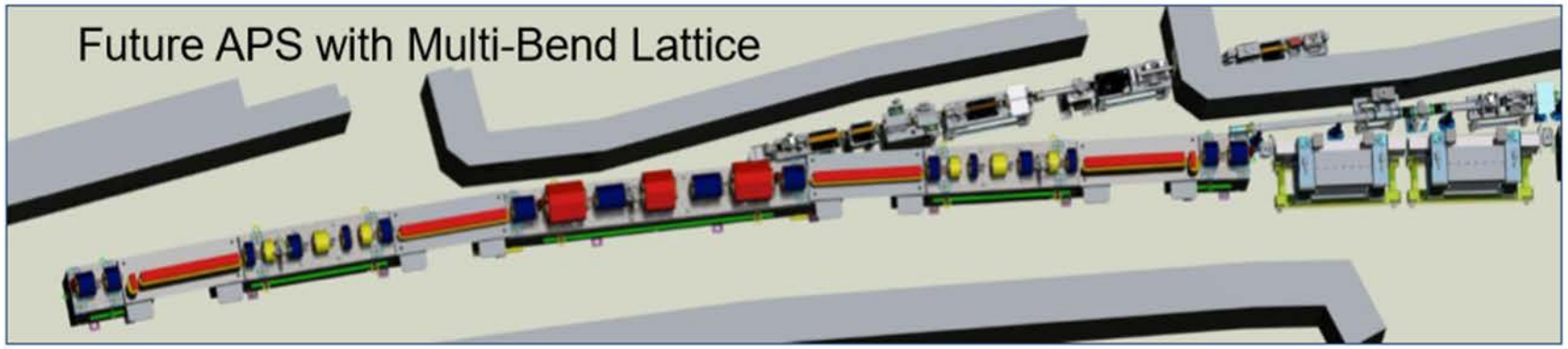


- Completely new storage ring, **42 pm** emittance @ 6 GeV, 200 mA
- New and updated insertion devices
- Combined result in brightness increases of up to 500x
- 9 new feature beamlines
- 15 enhanced and improved beamlines
- Exploit high performance computing, AI

APS-U LATTICE REPLACEMENT

~70-fold reduction in horizontal emittance

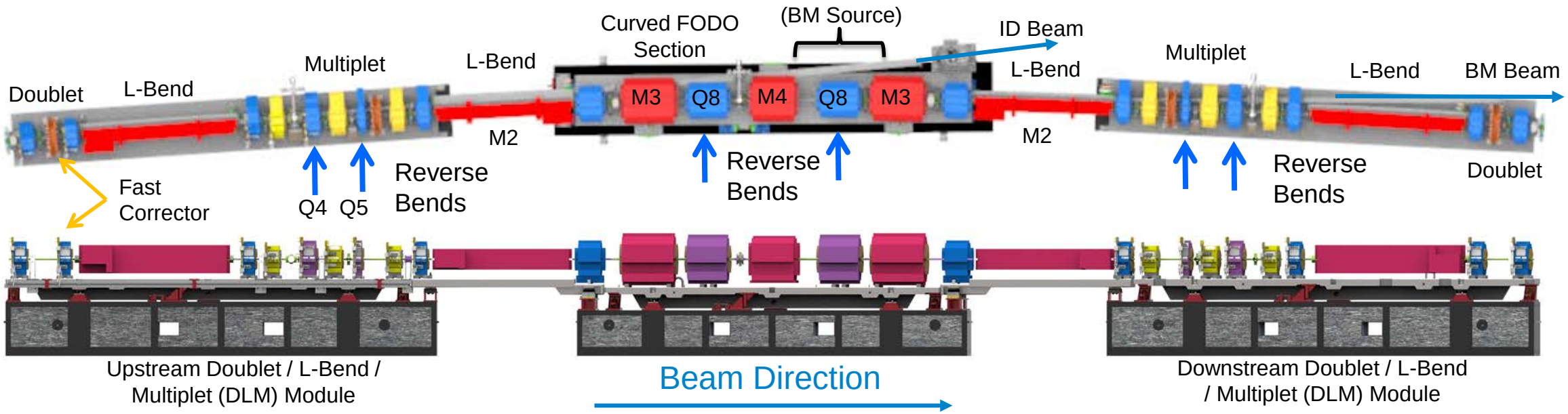




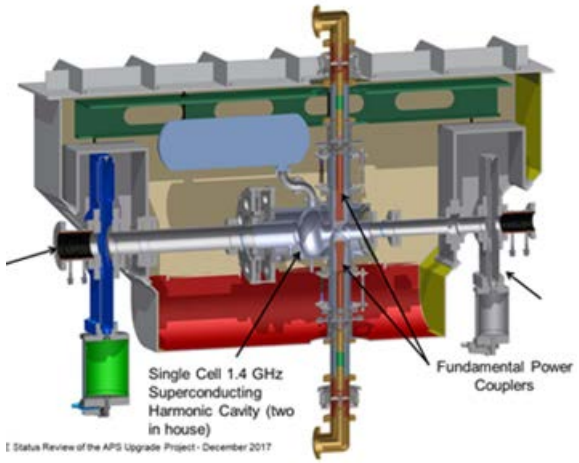
$$\varepsilon_x = C_L \frac{E^2}{N_D^3}$$

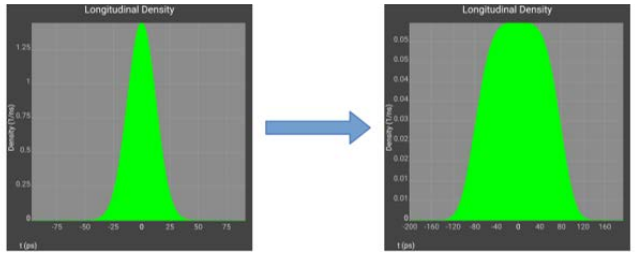
E = Beam energy (E = 6 GeV for APS MBA)
N_d = Number of dipoles per sector (N_d = 7 for APS MBA)

APS-U IMPLEMENTATION



SC bunch lengthening





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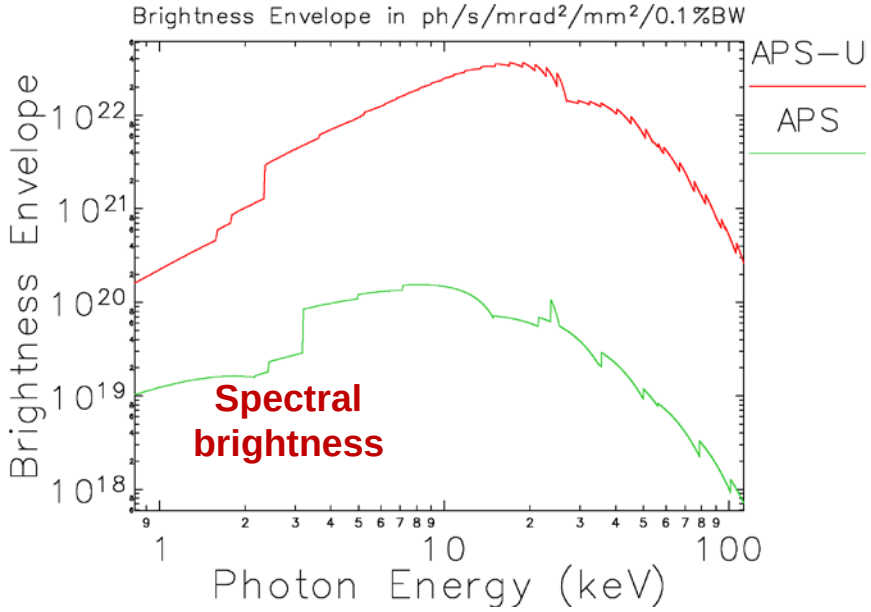
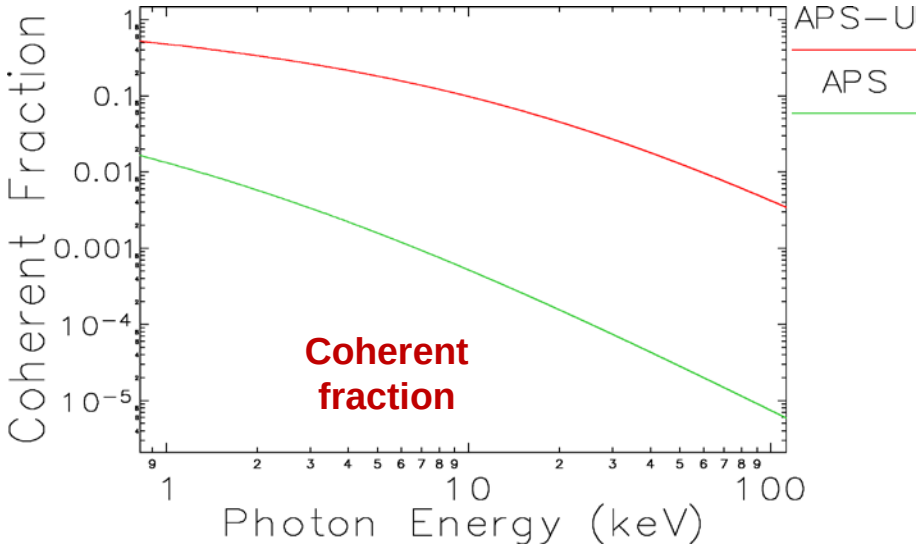
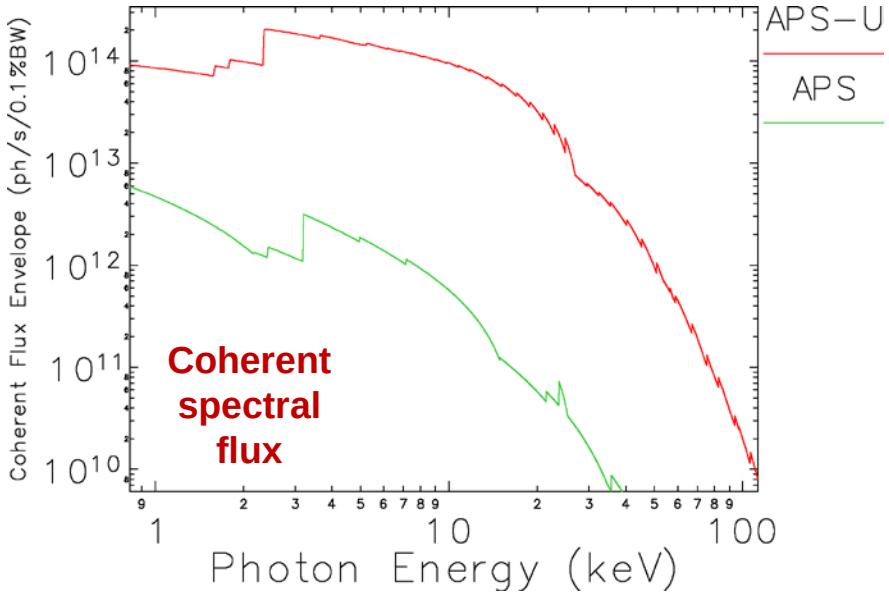
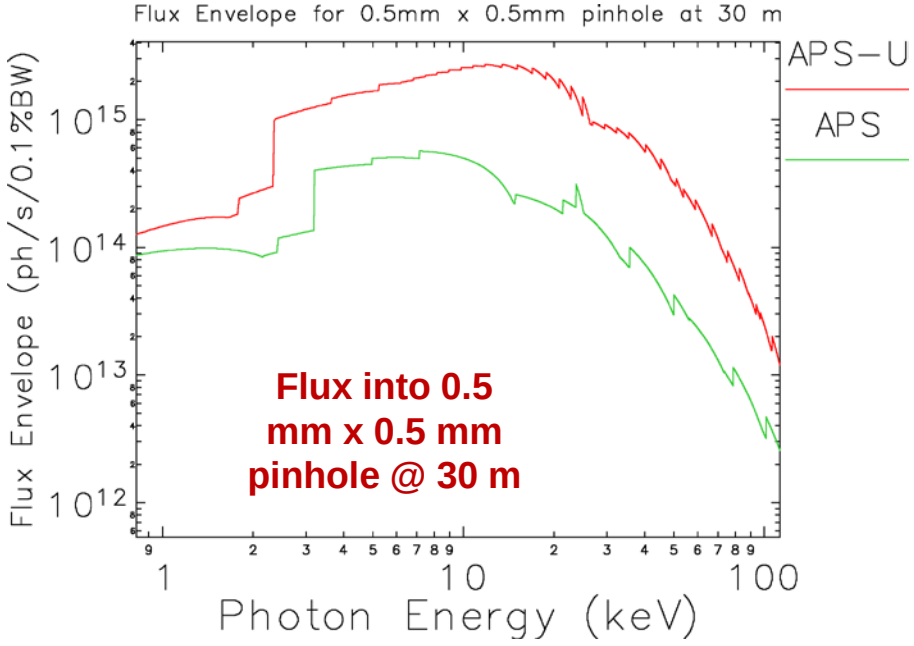
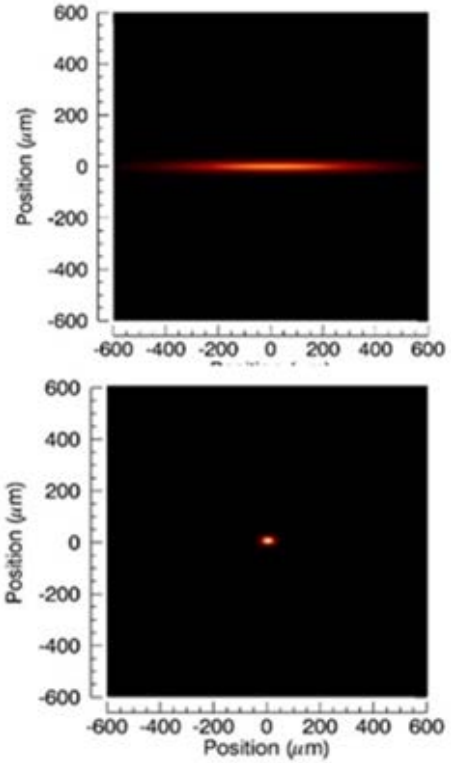
APS-U BRIGHTNESS AND COHERENCE

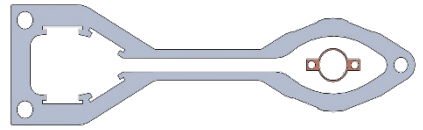












APS and APS-U chambers

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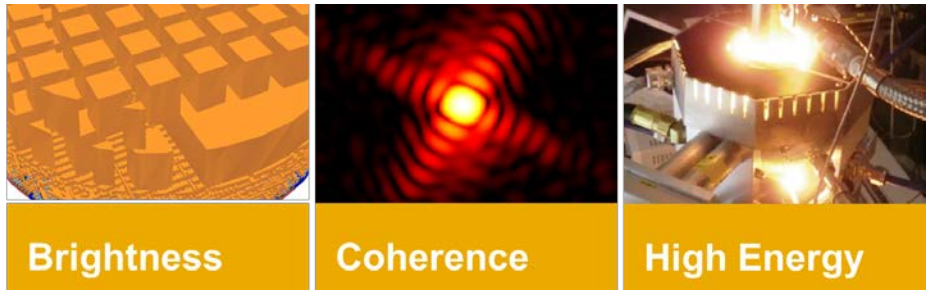
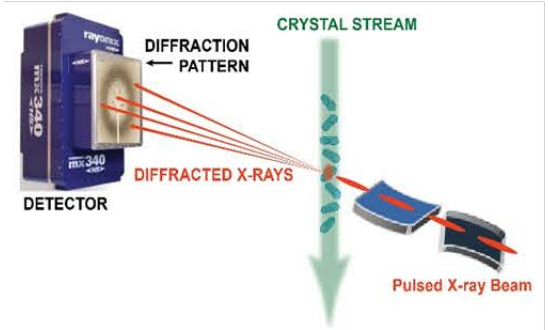
APS-U WILL ENABLE PIVOTAL RESEARCH ACROSS DISCIPLINES



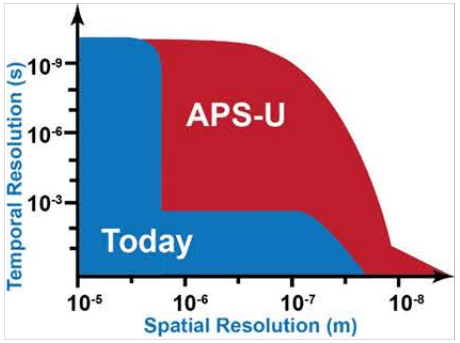
Small-Beam Scattering & Spectroscopy

- Nanometer imaging with chemical and structural contrast; few-atom sensitivity
- Room-temperature, serial, single-pulse pink beam macromolecular crystallography



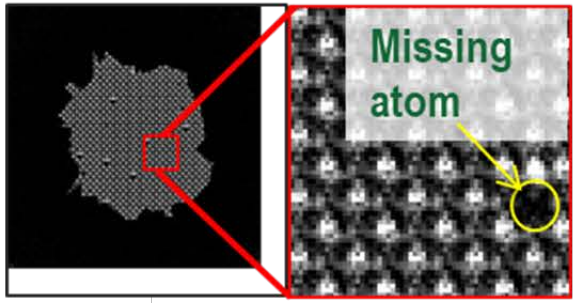
Resolution with Speed

- Mapping all of the critical atoms in a cubic millimeter
- Detecting and following rare events
- Multiscale imaging: enormous fields of view with high resolution



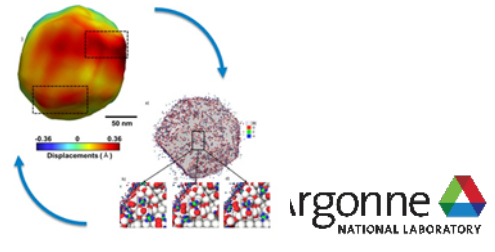
Coherent Scattering & Imaging

- Highest possible spatial resolution: 3D visualization; imaging of defects, disordered heterogeneous materials
- XPCS to probe continuous processes from nsec onward, opening up 5 orders of magnitude in time inaccessible today,

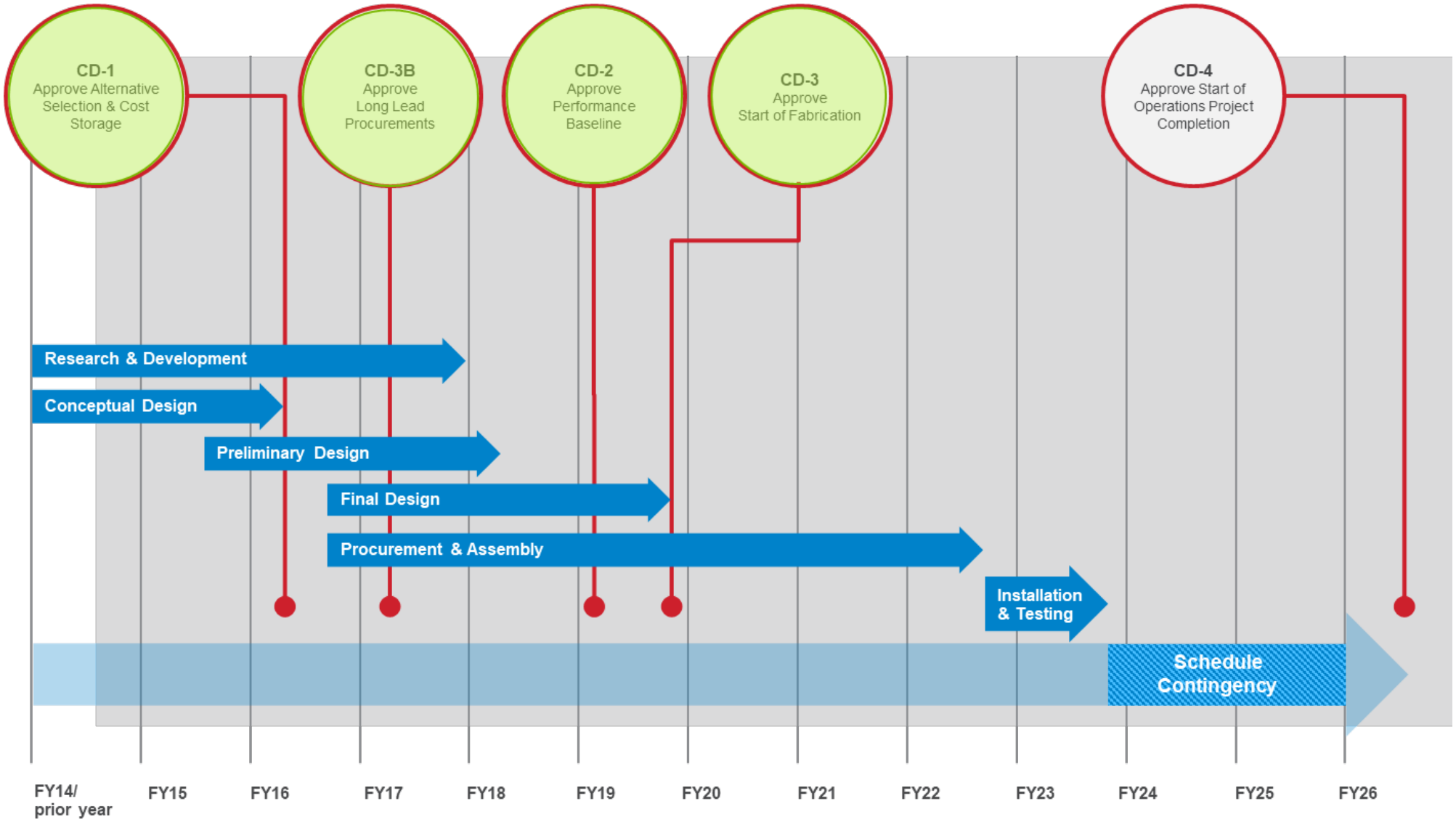


Exploit high performance computing, artificial intelligence

Automatic control of experiments, high volume data acquisition, analysis and reconstruction



APS-U PROJECT SCHEDULE



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THE APS-U OFFICIALLY ACHIEVED CD-3

Advanced Photon Source Upgrade Project at
Argonne National Laboratory
CD-3, Approve Start of Construction

Recommendations:

The undersigned "Do Recommend" (Yes) or "Do Not Recommend" (No) approval of CD-3, for the Advance Photon Source Upgrade at Argonne National Laboratory as noted below.

Ronald C. Pasco — 7/25/2019 — Yes X No ___
ESAAB Secretariat, Office of Project Assessment — Date

___ — Yes ___ No ___
Representative, Office of Budget — Date

___ — Yes ___ No ___
Representative, Environment, Safety and Health — Date

Yes ✓ No ___
Representative, Infrastructure (Field Safety, Security and Infrastructure) — 7/25/19 — Date

Earl Hinfey — 7/25/19 — Yes ✓ No ___
Representative, Security (Field Safety, Security and Infrastructure) — Date

Ben Brown by BJH — Yes ✓ No ___
Representative, Non-Proponent SC Program Office — Date

Hanley — 7/25/19 — Yes ✓ No ___
Representative, Non-Proponent Federal Project Director — Date

Concurrence:

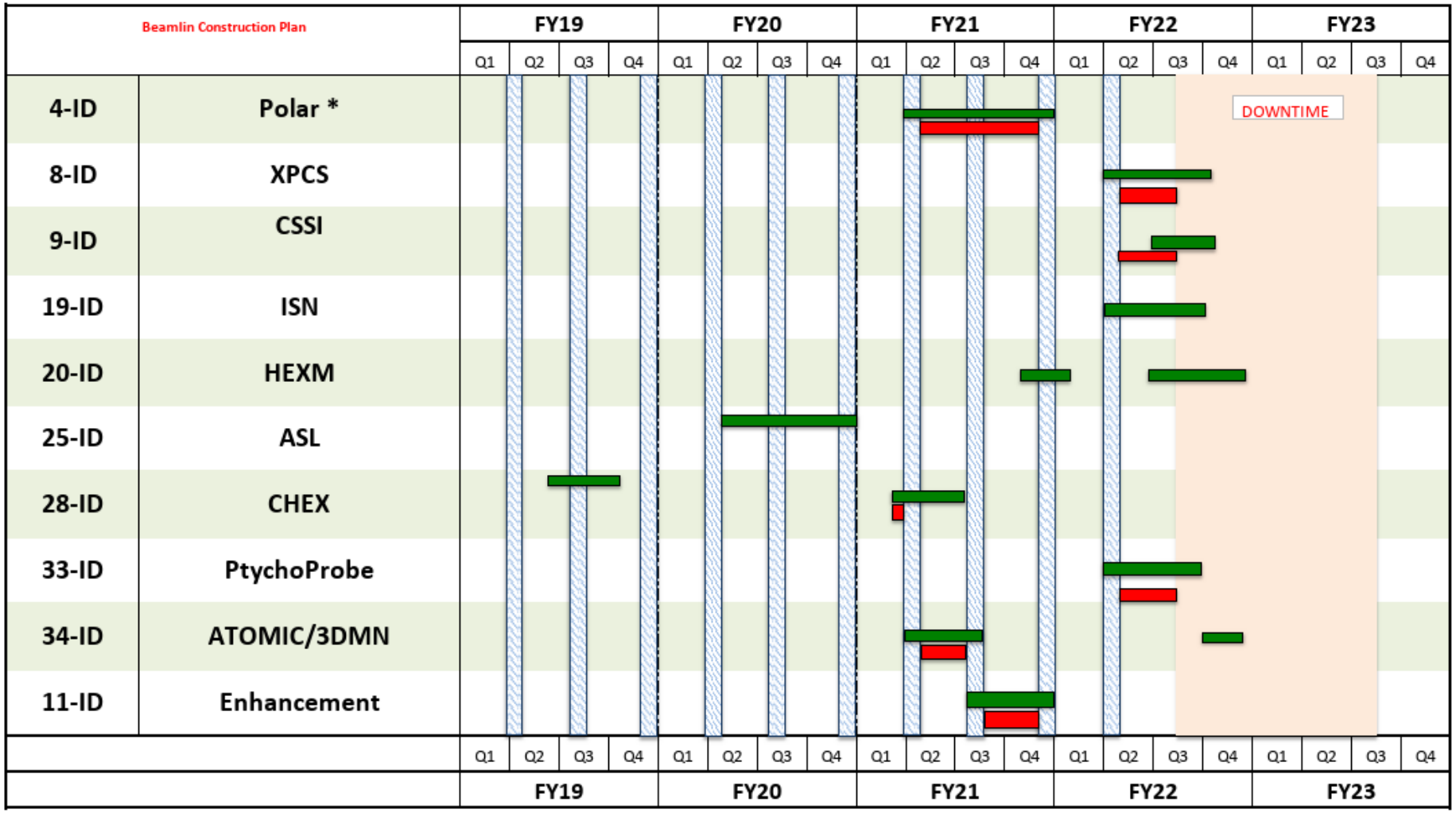
J S Binkley — 7/25/19
J. Stephen Binkley — Date
Deputy Director for Science Programs
Office of Science, DOE

Approval:

Based on the information presented above and at this review, Critical Decision-3, Approve Start of Construction, is approved for APS-U.

7/25/19
Chris Fall, Project Management Executive — Date
Director
Office of Science, DOE

NOTIONAL ENCLOSURE INSTALLATION SCHEDULE



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KEY PERFORMANCE PARAMETERS

Key Performance Parameter	Thresholds (Performance Deliverable)	Objectives
Storage Ring Energy	> 5.7 GeV, with systems installed for 6 GeV operation	6 GeV
Beam Current	≥ 25 mA in top-up injection mode with systems installed for 200 mA operation	200 mA in top-up injection mode
Horizontal Emittance	< 130 pm-rad at 25mA	≤ 42 pm-rad at 200mA
Brightness @ 20 keV[1]	> 1 x 10^{20}	> 1 x 10^{22}
Brightness @ 60 keV[1]	> 1 x 10^{19}	> 1 x 10^{21}
New APS-U Beamlines Transitioned to Operations	7	≥ 9

[1]photons/sec/mm^2/mrad^2/0.1%BW

Transition to Operations Plan – advanced draft in place

BEAMLINE TRANSITION TO OPERATIONS PARAMETERS

- Brightness measurement required for each new beamline.
- For completion of beamline transfer to operations: Threshold TTOP must be met or exceeded; key equipment is verified to be in place and working.

Beamline	TTOP Thresholds (Performance Deliverable)	Energy Range (keV)	Description
Polar	Brightness @ 9 keV > 4.9 x 10^{19}	2.75 – 27	Magnetic spectroscopy beamline designed to take advantage of novel undulators developed for the APS-U storage ring. Nanofocused, polarized beams will be used to study materials in extreme conditions.
XPCS	Brightness[1] @ 20 keV > 4.2 x 10^{19}	8 – 25	X-ray photon correlation spectroscopy beamline with instruments for small- and wide-angle scattering, designed for maximum coherent flux.
CSSI	Brightness[1] @ 20 keV > 4.2 x 10^{19}	6 – 30	Coherent surface scattering imaging beamline to explore the structure and dynamics of low dimensional, mesoscale, heterogeneous systems.
ISN	Brightness[1] @ 20 keV > 4.2 x 10^{19} Focused beam < 50 nm (FWHM)	4.8 – 30	A scanning nanoprobe optimized for large working distances and in situ experiments
HEXM	Brightness[1] @ 60 keV > 5.1x10^{18}	35 – 120	High-energy x-ray microscope for experiments on in situ environments for materials science and engineering applications.
CHEX	Brightness[1] @ 20 keV > 3.9 x 10^{19}	5 – 60	One tunable and three fixed-energy beamlines designed for coherent, high-energy x-ray in-situ diffraction studies of materials synthesis and chemical transformations.
Ptycho	Brightness[1] @ 10 keV > 1.3 x 10^{20}	5 – 30	Ultimate spatial resolution, ultra-fast scanning nanoprobe with ptychography for extremely high-resolution structural measurements.
ATOMIC	Brightness[1] @ 20 keV > 3.8 x 10^{19}	5 – 30	Bragg coherent diffraction imaging to study materials with spatial resolution of one nm or better. Zoom optics allow variable spot sizes so that the x-ray probe can be matched to the needs of individual experiments.
3DMN	Brightness[1] @ 20 keV > 2.5 x 10^{19}	5.3 – 30	3D diffraction nanoscope using both pink and monochromatic x-rays to study materials structure and mechanical behavior.

[1] Brightness = photons/sec/0.1% BW/mm^2/mrad^2 @ > 5.7 GeV, ≥25 mA, <130 H/65 V pm-rad, 20% high β_x (6.24 m) and β_y (2.88 m) with 8-mm η_x and 4-mm η_y leakage at source ; brightness measurements inferred by measurements of central cone spectral flux, β_x, β_y, η_x, η_y at source point.

PREPARATION FOR ACCELERATOR READINESS REVIEW

- Purpose of ARR: Assess compliance with DOE Order 420.2C, Safety of Accelerator Facilities, prior to commissioning the APS-U accelerator
- ARR addresses 6 main areas:
  - Safety Analysis Document (SAD) and Accelerator Safety Envelope (ASE) document
  - Unreviewed Safety Issue (USI) Process
  - Roles and Responsibilities
  - WPC for Credited Controls including safety systems and shielding
  - Conduct of Accelerator Operations
  - Contractor Assurance

  Both APS and lab-wide ANL processes and procedures are subject to scrutiny.
- Have created working group to assess status of ARR readiness, identify gaps and plan how to fill them.
- Have contracted an experienced person to lead the writing of the SAD and ASE.
- The radiation safety plan (shielding, radiation monitors, interlocks) is a large component of accelerator readiness. A team of radiation safety experts is working on this plan

SCHEDULE TO REACH KPPS (ESTIMATED)

Begin dark time (accelerator removal, install new systems)	T_0-12 months
Begin ring tests with beam	T_0 - 3 months
Initial ring operation (threshold KPPs: 25 mA, >5.7 GeV, <130 pm)	T_0
Initial feature beamline operation (25 mA, 6 GeV, threshold TTOPs)	T_0 + 6 months
100 mA, 6 GeV, 42 pm (Run 3)	T_0 + 8 months
200 mA, 6 GeV, 42 pm (ring objective KPPs, Run 4)	T_0 + 12 months
Feature beamline brightness (objective KPPs, TTOPs, Run 5)	T_0 + 16 months

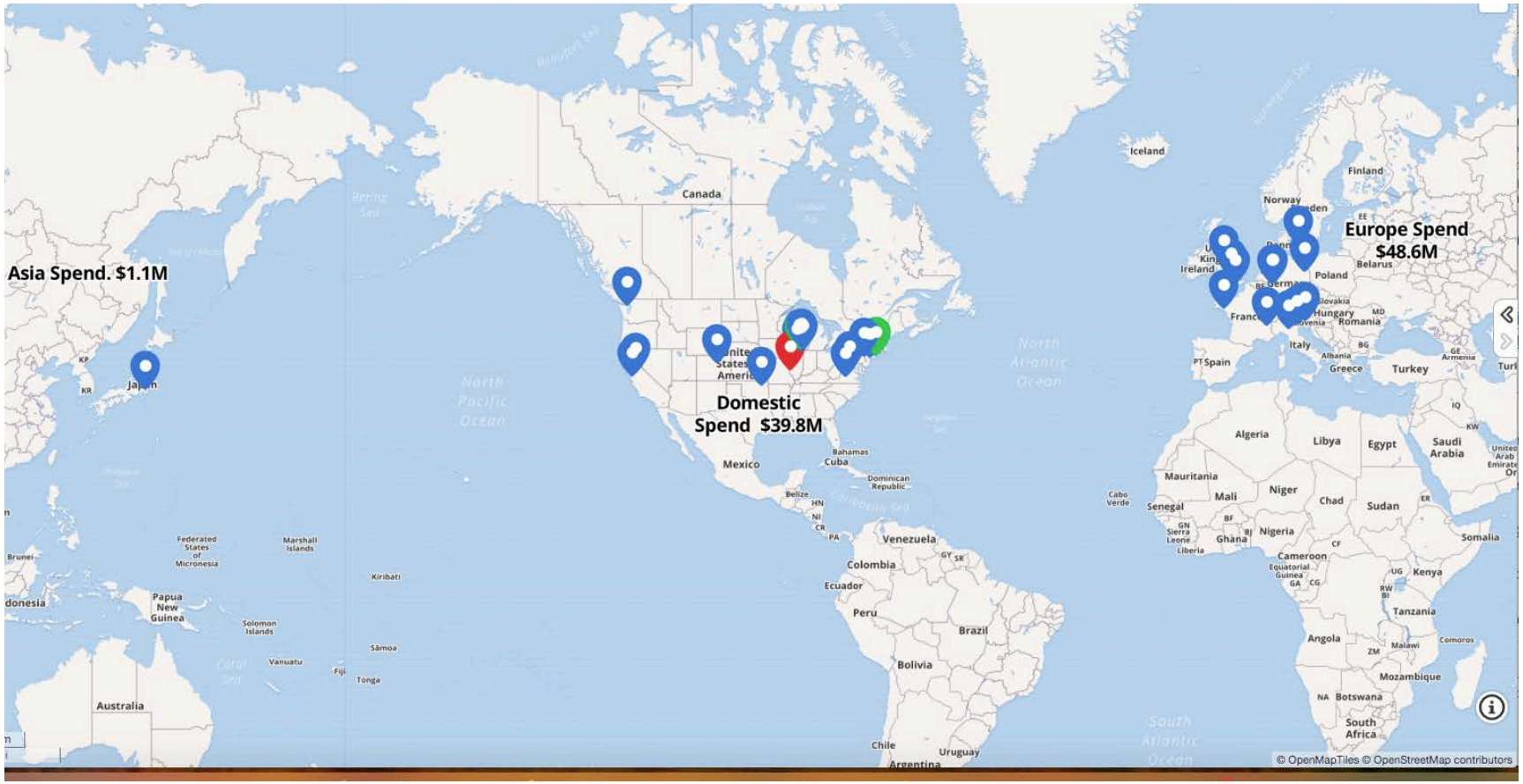
- ISN and Ptycho are most difficult feature beamlines. Reaching full operational capability (involving a combination of flux density on the sample and spot size) depends on optics and operational development extending to T_0 + ~3-5 years.
- Within the T_0 + 6-month period, various operational bunch patterns will be developed, including 25 mA in 48 bunches. Most challenging pattern for higher current is 48 bunches when operating with more than 150 mA. This requires operating the injector chain with higher bunch charge than presently possible. APS Operations has an investment plan to develop this capability with a targeted completion before the ring shut-down dark period (T_0 – 12 months).

PROJECT STATUS

- FY19 funding was 130 M$; FY20 President's budget was 150 M$, but 170 M$ delivered
- With a performance baseline funding of 677 M$ (+ 138 M$ contingency = 815 M$ TPC), have costed 215 M$ and current obligations of 67 M$;~30 M$ of other procurements in process
- ~32% complete on costs; ~42% on cost + obligation
- Plan to spend ~10 M$/month over next year
- Next DOE/OPA status review will happen around June 2020

APS-U PROCUREMENTS

- Upgrade is ~2/3rd industrial procurements.
- Vendor oversight will be key in coming years



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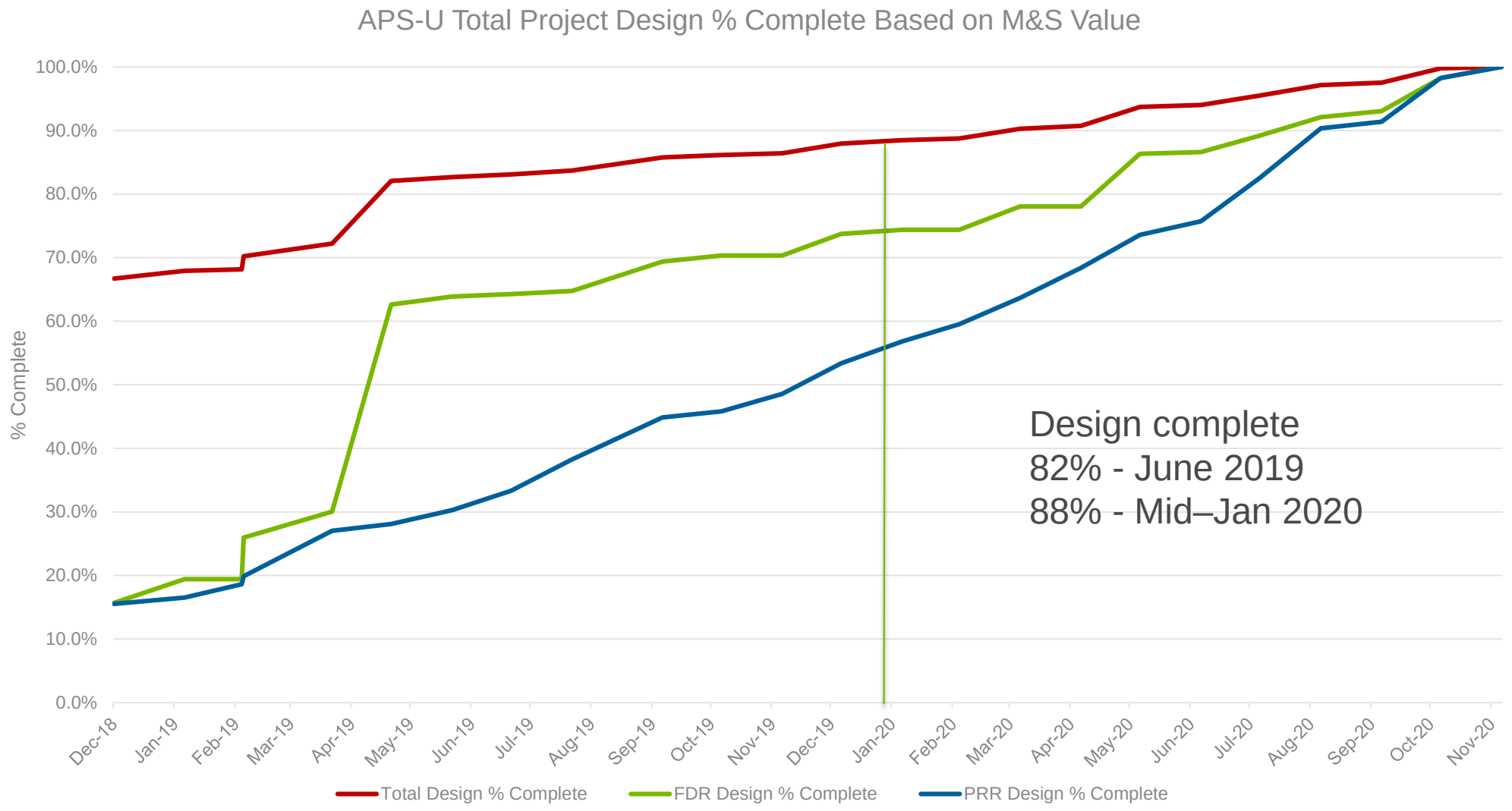
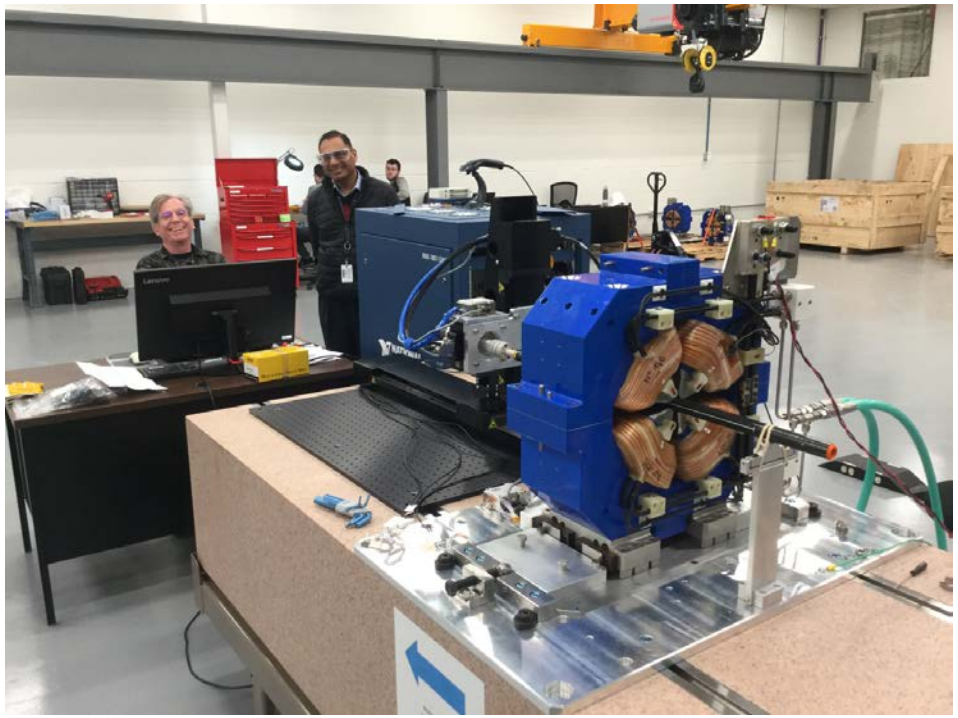
DESIGN-COMPLETE STATUS



MAGNETS AND MEASUREMENT



Magnets undergoing incoming inspection in magnet measurement lab.

154+ magnets in house of 1321 total.

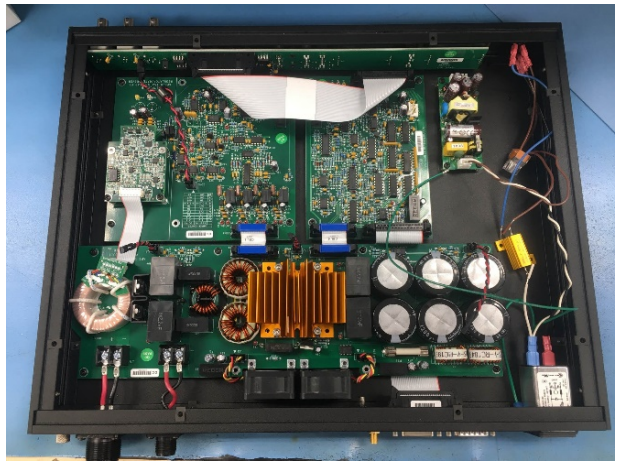
Animesh Jain, Chuck Doose

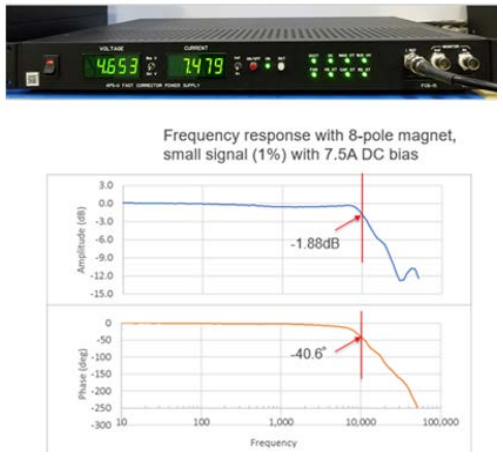
ACCELERATOR COMPONENTS

First article unipolar power supplies from CAEN, Italy

ITech BPM processors

ID vacuum chambers extrusions





Fast corrector and power supply

SC bunch lengthening cavity and cryo-vessel

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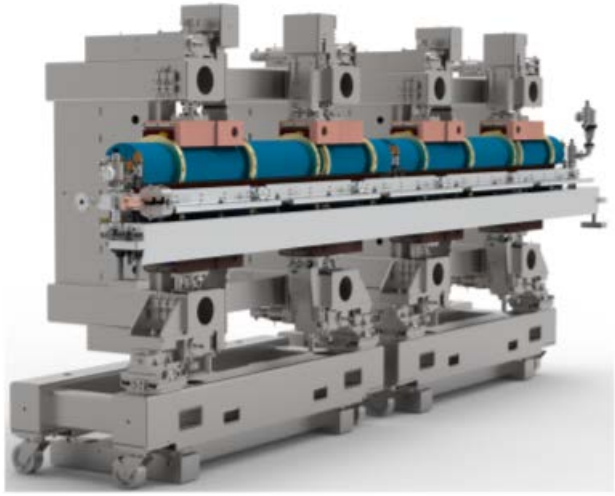
INSERTION DEVICES

Planar HPMU and monokeeper

Superconducting Unduator

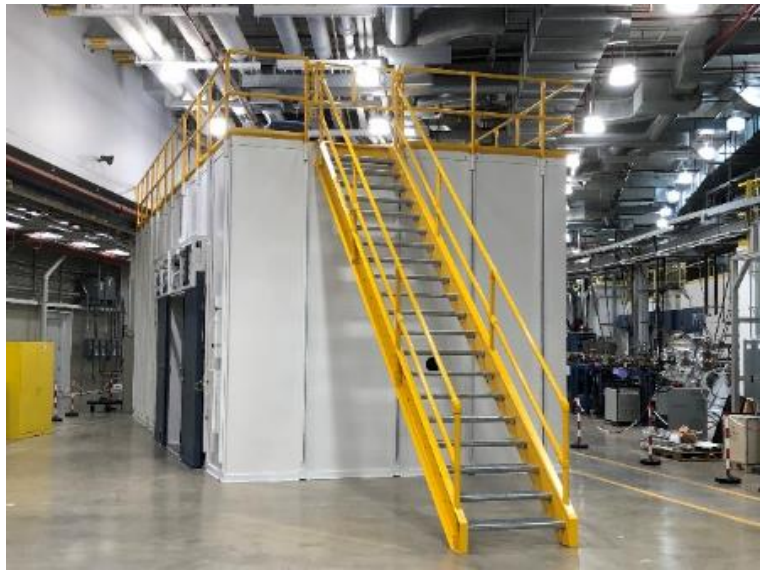
SCU Cryostat delivered to ANL

Copper thermal shield assembly

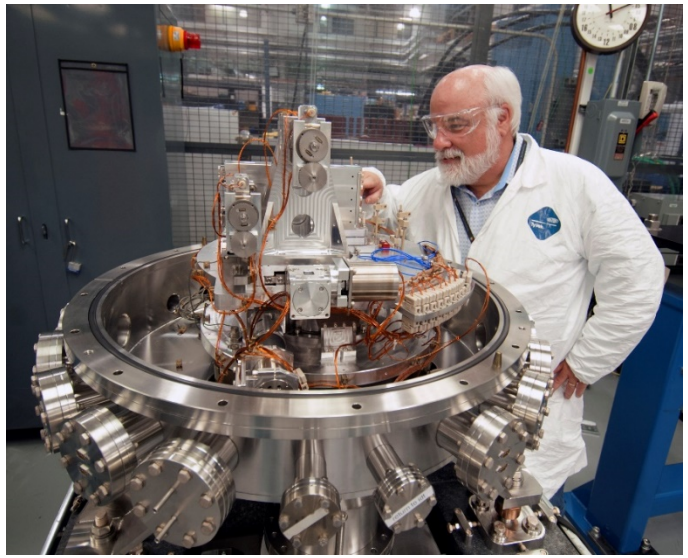


Revolver ID

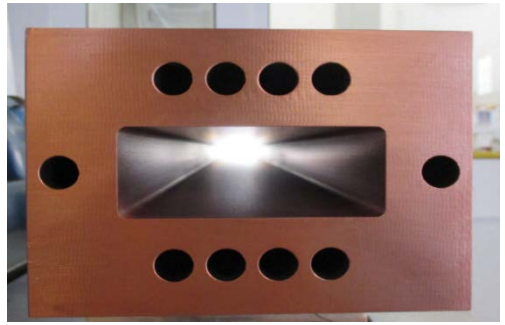
BEAMLINES



28-ID-B Enclosure

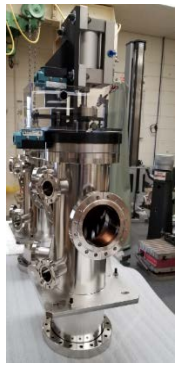


2-ID monochromator after arrival at APS

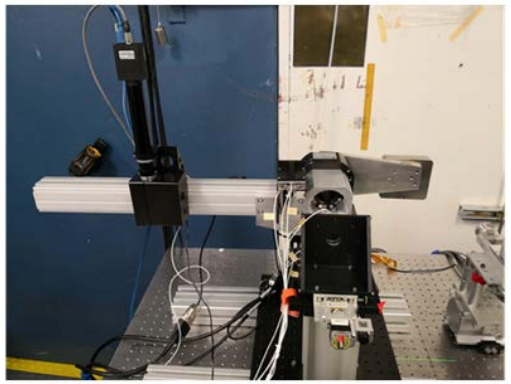


Glidcop bodies for the high heat load front end masks after polishing of the inner surface.

Picture of parts for the bases of the ASL mirrors at vendor, and solid model of what the assembled bases will look like.

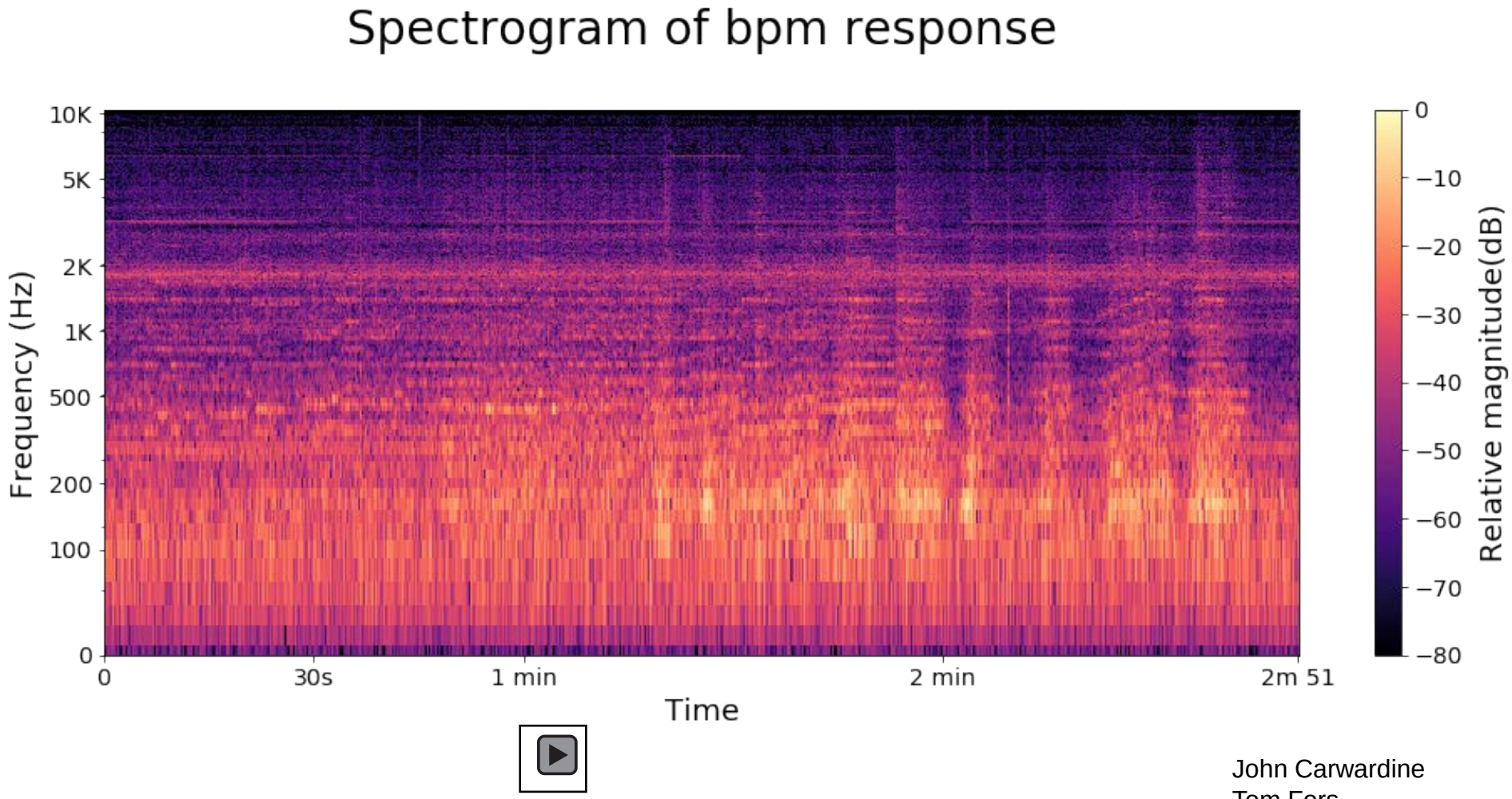


Low power photon shutter parts and assembly



prototype compact wavefront sensor

SOUNDS OF THE BEAM USING THE NEW FAST ORBIT FEEDBACK SYSTEM



John Carwardine
Tom Fors
Sinisa Veseli
et al. July, 2019;
Richard Wagner, 1856

INTERFACING WITH ARGONNE

- Office of the Directorate (Paul Kearns)
  - Leadership
- Financial Management (Sue Rogers, Stacey Adamson, & Michael Shields)
  - Dedicated support (Tazio Kubbs)
  - Assistance with discrepancy tracking, reporting and reconciliation
- Procurement Services (Erik Schimke)
  - Dedicated support (Michael Oprondek & Tiffany Murray)
  - Integrated weekly meetings (incl. Michael Cain)
  - Updated processes to allow more efficient work flow on the project
  - Procurement tracking and reporting
- Experimental Operations and Facilities (Victor Guarino)
  - Engineering and designer support
- PSE / Physics (Mike Kelly)
  - Scientific, engineering and technician support for the Bunch Lengthening System (BLS) and the stripline kickers for Longitudinal Feedback System (LFS)

INTERFACING WITH ARGONNE– CONT.D’

- Infrastructure Services
  - Dedicated Project Controls Resources (Jennifer Fortner)
  - Space planning, procurement and buildout support (Jason Budd & John Busch)
  - Dedicated Project Management resources to help with Long Beamline Building (Mike Finder)
  - Receiving assistance (Doreen Schoening)
  - Fabrication guidance and production from central shops (Bob Swale)
  - Disposal of hazardous waste (Cindy Rock)
  - Off-site security requirements (Nelson Lundy)
- Human Resource Services – Provided through PSC (Tom Padilla)
- Business Information Services
  - Off-site space network requirements (Networking Team)
  - Data access from xink, Paris and AMOS (Dave Skelley)
- Environment, Safety, Health and Quality (Diep McCormick)
  - Dedicated Resources (Jeff McGhee, Tiffany Freedman, Sunil Chitra, & Brian Voelz)

SUMMARY

The APS Upgrade is well on it's way!

- CD-2 and CD-3 achieved last year

Well supported by the Administration, Congress, and Basic Energy Sciences

- Funding in hand to execute

We are climbing up the procurement and fabrication phase

- Targeting $10M / month in business

Initial deliveries are coming in; acceptance tests proceeding well so far

- Vendor Oversight a major task in upcoming years

A critical project for Argonne…and we are getting lots of support from the lab in executing

THANKS!

Back Up

TOP RISKS FROM RISK REGISTER

Risk ID	Title	Description	Status
U2.01-024	Political Conditions	Concerns about the political environment causing prices in foreign countries to rise.	After awarding the plinths and remaining magnet contracts, this will be reduced. Plinths out for bid, remaining magnets coming into procurement
U2.01-023	Severe Occupational Injury	The project experiences a high severity injury that causes delays to the overall schedule.	This is likely to remain one of the top ten for remainder of the project.
U2.03-078	Downtime Electrical Incident	The project may experience a work stoppage if there's an electrical incident during the downtime.	This will remain a high risk for a while and will slowly decrease during the downtime.
U2.01-015	Vendor Relationships	The project may encounter extra costs due to delays if vendor relationships are not managed properly.	Project is pursuing a contractor to help oversee European vendors; multiple trips to vendors as well.

Risks mitigated and dropped from the 'Top Risk' list since last month:

- LBB value engineering risk closed after study completed in Nov 2019

Newly proposed risks since last month:

- Accelerator Integrated Testing w/Beam requirements
- Acceptance testing (in-house and w/vendors)

ISSUES AND ACTIONS

- Vertical vs. horizontal injection

  Work is progressing with production of a risky DC vertical Lambertson septum magnet at FNAL. The study of an alternative horizontal injection scheme continues to advance with promising results. Designs of the transport lines to accommodate the two different schemes is proceeding in parallel. Scheme selection is anticipated by the middle of the CY2020.

- Control system

  Requisitions for additional staff (permanent hires + contractors) are in process. Some APS operation controls staff will be re-assigned to Project-related tasks.

- Insertion Devices

  Magnetic measurement of the first 2.8-cm ID and development of shimming methods that can be carried out by multiple teams is in process.

- Beamline design

  PSC has hired new and deployed in-house engineers for beamline design. Collaboration with NSLS-II beamline science and engineering staff continues for generating procurement specification documents, optics metrology and designs for beamline components.

- Staffing

  Continuing progress is being made on developing the Project/Ops “integrated and optimized” staffing and work plans to ensure all necessary work can be completed before and during the dark time.

- ARR

APS-U FY20 MILESTONE LIST

Milestone	Completion Date	Forecast/Actual Date
1. Off-site Space Lease approved	Nov 2019	Dec 2019
2. Accelerator/FE/ID Vacuum Pumps, Controllers, and Valves FDR/PRR successfully completed	Jan 2020	Jan 2020
3. MS-L2-0061 - Magnets M1-M2 contract awarded	Feb 2020	Feb 2020
4. 100 Power Supplies successfully received and accepted	Mar 2020	Mar 2020
5. MS-L2-5053 - ID Vacuum Chamber Final Design successfully completed	April 2020	Dec 2019
6. Davis-Bacon Determination successfully completed	May 2020	May 2020
7. Final Design successfully completed for Long Beamline Building	June 2020	June 2020
8. ASL Beamline Primary Mirror System successfully received and accepted	July 2020	July 2020
9. First Plinth from Vendor successfully received and accepted	July 2020	July 2020
10. Injection/Extraction System Final Design Review successfully completed	Aug 2020	Aug 2020
11. PtychoProbe and CHEX Beamline Instrument Final Design Reviews successfully completed	Aug 2020	Aug 2020
12. Implementation Plan Matrix for Accelerator Readiness Review successfully released and approved	Aug 2020	Aug 2020
13. MS-L2-0031 - Magnets Q1-Q6 33% successfully received	Sep 2020	Sep 2020
14. Installation of CUFE in 25-ID successfully completed	Sep 2020	Sep 2020
15. First Module Practice Assembly successfully completed	Sep 2020	Sep 2020

INTERFACE PORTFOLIO ADDITIONAL SLIDES

FY19 – FY20 PORTFOLIO

FY19	$	3,610,490
Long Trace Profiler Upgrade	$	256,200
Beamline Single Mode Fiber (D1109 - LOM 435 - LOM 438)	$	461,557
Windows 7 to 10 Upgrade	$	274,439
Business Operations Windows Servers	$	338,250
Linac RF Station #1 (Klystron, Modulator, RF Controls)	$	1,443,260
Replace Valves in the LINAC and PAR	$	36,600
Rigaku Ultrafast Detector for XPCS	$	348,784
Lambda 750k CdTe Detector	$	347,700
Robot Detector Arm for SNOM	$	103,700
FY20	**$**	**4,473,779**
ACIS Upgrade – Phase I	$	440,569
PAR Kicker Magnet Vacuum Chambers	$	333,775
Small Pixel Detector	$	122,000
32-ID Shimadzu HPV-X2 Detector	$	161,650
4-ID Cryopump Replacement	$	152,975
Business Operations Linux Servers	$	195,810
Single Sign-on for All APS web and Oracle Applications	$	61,000
LEA Infrastructure	$	200,000
Germanium Pixel BNL	$	122,000
Storage Ring Relay Rack Gespac Replacement	$	-
Solid State Amplifier, Waveguides and Hardware	$	2,684,000

FY19 – FY22 PORTFOLIO

APS OPERATIONS FY19 - FY22 PORTFOLIO					
FY19	**$**	**3,610,490**	**FY21**	**$**	**3,686,509**
Long Trace Profiler Upgrade	$	256,200	Solid State RF Utilities (AC Power, Water)	$	244,000
Beamline Single Mode Fiber (D1109 - LOM 435 - LOM 438)	$	461,557	ACIS Upgrade - Phase II	$	1,995,432
Windows 7 to 10 Upgrade	$	274,439	Beamline Single Mode Fiber (D1109 - LOM 431 - LOM 434)	$	368,440
Business Operations Windows Servers	$	338,250	Accelerator Single Mode Fiber Infrastructure	$	195,200
Linac RF Station #1 (Klystron, Modulator, RF Controls)	$	1,443,260	Upgrade Acc. Core Tier 1 & Tier 2 Network Switches for Storage Ring	$	646,600
Replace Valves in the LINAC and PAR	$	36,600	Storage Ring Double Sector Interlock Relay Rack Gespac Replacement	$	236,837
Rigaku Ultrafast Detector for XPCS	$	348,784			
Lambda 750k CdTe Detector	$	347,700			
Robot Detector Arm for SNOM	$	103,700			
FY20	**$**	**4,473,779**	**FY22**	**$**	**1,831,220**
ACIS Upgrade – Phase I	$	440,569	Linac RF Station #2 (Klystron, Modulator, RF Controls)	$	1,035,780
PAR Kicker Magnet Vacuum Chambers	$	333,775	Linac RF Guns	$	549,000
Small Pixel Detector	$	122,000	Booster DI Water Valve Replacement	$	26,840
32-ID Shimadzu HPV-X2 Detector	$	161,650	DI Water Resistivity Analyzers	$	61,000
4-ID Cryopump Replacement	$	152,975	Replace DI H2O Control System for Linac/Booster/PAR	$	158,600
Business Operations Linux Servers	$	195,810			
Single Sign-on for All APS web and Oracle Applications	$	61,000			
LEA Infrastructure	$	200,000			
Germanium Pixel BNL	$	122,000			
Storage Ring Relay Rack Gespac Replacement	$	-			
Solid State Amplifier, Waveguides and Hardware	$	2,684,000			
			TOTAL COST (LOADED)		**$ 13,601,998**