NSLS-II Accelerator Systems

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Triennial Operations Peer Review

June 20th 2017

Outline

- Current status
  - Performance metrics
  - Spares program
  - Preventive Maintenance program
  - Development program
- Budget FY15-17
  - Labor and materials
  - Benchmarking
- Evolution of organization since 2015
  - Changes in org structure
  - Efficiency improvements since 2015
  - Response to recommendations
- Future Plans
- Summary

Current status

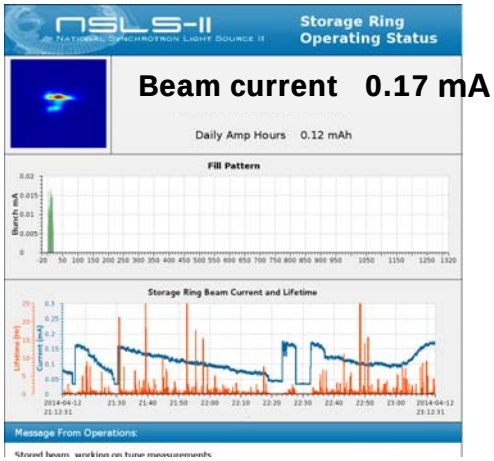
Motivation

Our mission is to deliver reliable, stable, intense beams in support of the user program

Our priorities:

1. Reliability
   - Reached >95% reliability in the 3rd year of operations
2. Stability
   - Stabilized orbit angle / coordinate at the source points to 10% of σ / σ'
   - Stabilized average / peak intensity to 0.5% / 20%
3. Intensity
   - Operating with 300 mA and planning 350 mA this FY
   - Studies at 400 mA and planning 450 mA this FY
4. New Beamlines
   - Installed 10 IDs, 5 3PWs, 15 FEs in FY15-17
   - 19 beamlines now taking beam
   - Increase to 28 beamlines by the end of FY18

April 2014



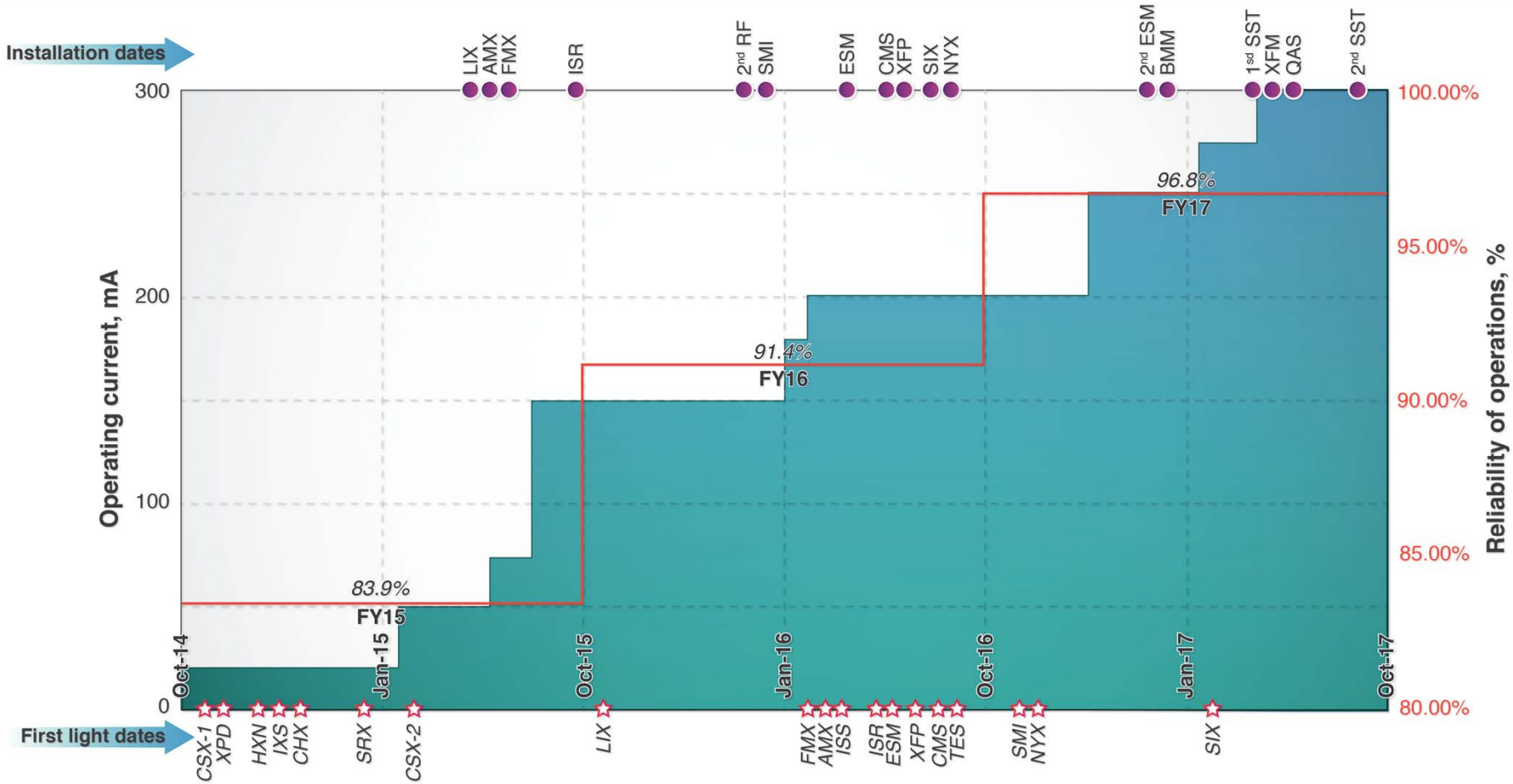
April 2017

Our budget is aligned with these priorities

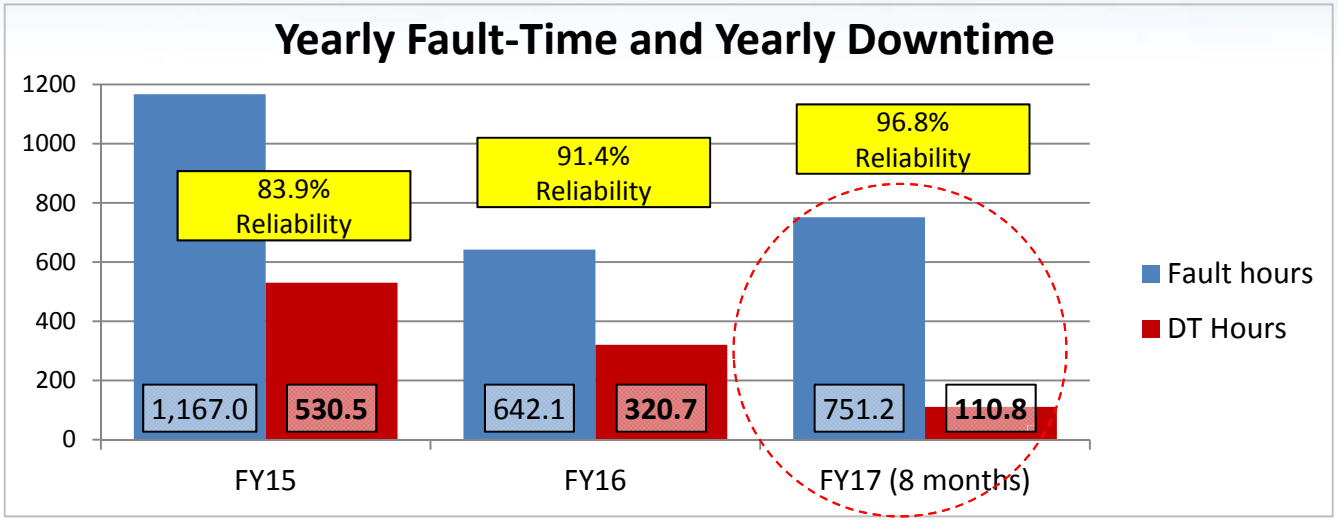
Accelerator Milestones and Accomplishments FY15-17

- Advances in Operations
  - Active Orbit Interlock, Oct 2014
  - Fast Orbit Feedback, June 2015
  - Top-off commissioning, Sept 2015
- RF Development
  - Developed, installed and commissioned 2nd RF cavity, Feb-Mar 2016
  - Started linac klystron and modulator upgrade project, Mar 2016
  - Started 3rd RF Cavity project, June 2016
- ID, FE and BL Development
  - NSLS-II Project: Commissioned 2 EPUs, 4 IVUs, 1 DW FE and BLs, Oct 2014-Mar 2015
  - ABBIX: Installed and commissioned 3 IVUs, FEs and BLs, Nov 2015-Mar 2016
  - NEXT: Installed and commissioned 2 IVUs, 3 EPUs, 1 DW, their FEs and BLs, July 2016-Nov 2016
  - PARTNER: Installed and commissioned 1 IVU, 1 3PW, their FEs and BLs, July 2016 - Nov 2016
  - BDN: Installed and commissioned 1 3PW and 2 BM FEs and BLs, Aug 2016
  - In Process: 1 undulator, 1 EPU, 2 3PWs, 2 ID FEs, and 2 BM FEs (BDN & Partner)
- Power Supply Upgrade
  - Begun booster kicker upgrade project
  - Begun booster QPS upgrades
- Ceramic chamber coating facility is operational
- Beam coupling control demonstrated during studies

Performance Metrics: Reliability and Current



Greatly reduced downtime

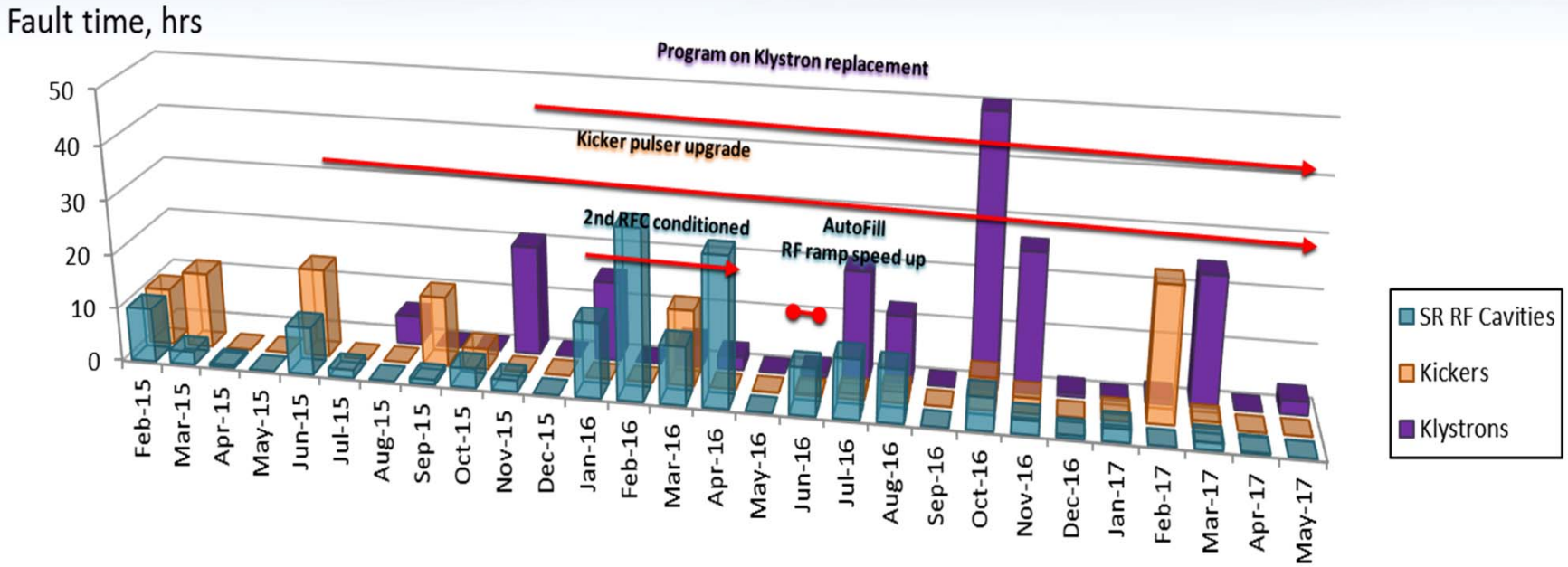


Total hours lost in operations & studies= **Fault time**

Total hours lost in operations only = **Downtime**

- Overcame many challenges
  - 320 hours lost in FY15 due to a single BDPS failure
  - 282 RF-related beam dumps in FY16 vs 80 in FY17 – reduced by factor of 4!
  - 48 hours in FY17 due to a single QPS fault
- While experiencing uptick of Fault time in FY17, managed to keep Downtime low
  - Majority of faults during system start-up and testing
  - Worked out quick recovery from faults during beam operations
- Continue with learning, debugging and improving subsystems

Quest for Reliability: Trends



- Trending hardware faults and working out solutions to fault patterns.
  - Major rework of PPS door switches ✓ done
  - RF conditioning for new RF cavity ✓ done
  - Replacement of linac klystrons ❖ in progress
  - Correction of coupling induced by IDs ❖ in progress
  - Upgrade of kicker power supplies ❖ in progress

Spares: Continuously Improving Process

- Master list of spare parts and consumables developed
  - GL experience and recent faults also factored in
  - A total of 1,717 items have been identified
  - 33.9M$ in total with 7.3M$ not on-hand

- Associated with each item is:
  - Cost
  - Lead time
  - Likelihood of failure (based on lifetime)
  - Impact on performance
    1. Halts Operations
    2. Impedes performance
    3. Can wait until break in operations
  - Quantity on hand and in use
  - Whether it has been approved for purchase

- Calculate priority based on above values
  - (Impact * Likelihood of failure * Lead time) / Cost
  - GL input also used for prioritization

Service building

Pump seals

Preventive Maintenance

- Preventive maintenance strategy
  - Priority given to systems that impact the machine over those that impact individual beamlines
  - Focus driven by recent experience with faults and downtime
  - Preventive maintenance is overseen by ADD and managed by each AD group
  - Fault reporting reviewed weekly at AD Group Leader meetings

- During Operations:
  - Surveillance and diagnostics (ex. daily rounds by groups to monitor their system parameters)
- Maintenance Days:
  - Periodic inspection of components based on time in service (ex. actuation counters and time for FE components)
- Long Shutdowns:
  - Extensive checklists are completed to confirm operation of systems and components

- Ongoing improvements to PM program:
  - Additional checklists and process descriptions being worked on
  - Software tools for trending subsystem parameters are evolving
  - Good progress with PM training of AD staff

Development Program

Following the NSLS-II Strategic Plan we have 3 Categories of development programs:

1. Baseline projects to **fix** known issues, optimize performance or enhance protection of subsystems
   - PPS door switches
   - Booster kicker pulsers
   - Booster Quadrupole Power Supplies

2. Improvements project that significantly **improve** operations performance, increase beam stability and availability, and decrease downtime
   - 3rd RF **cavity**, cryo and transmitter (total of 7.75M$). 1.4M$ is scheduled for FY17.
   - Development of ceramic chamber coating set-up
   - Harmonic cavity to stretch the bunch (total of 1.9 M$) is planned

3. **R&D projects** that are aimed at novel techniques needed for upgrades in the longer-term. Note, these are not funded out of operations.
   - LDRD on NSLS-II lattice upgrade

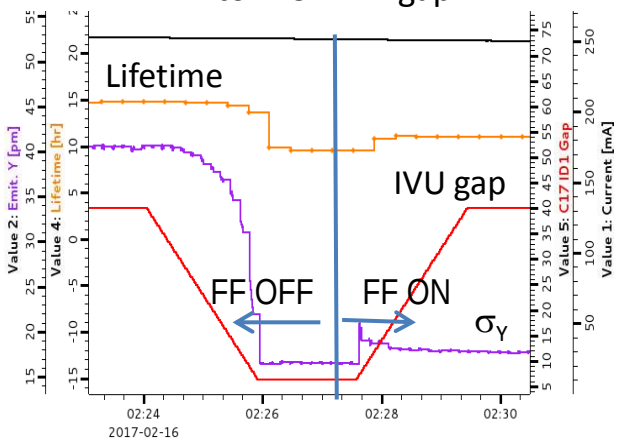
Ceramic chamber coating facility at NSLS-II

Some recent accomplishments

- 170 MeV booster injection
  - ❖ Reduce klystron power to 25 MW
- Fast RF autostart and fast refills
  - ❖ Restarts shortened 45 mins → 20 mins
- Reproducibility program complete
  - ❖ Recovery of orbit / optics after beam dumps
- BM/3PW sources: RF frequency feedback
  - ❖ Reduced drift in dispersive source points
- Feed-forward tables for coupling correction
  - ❖ Minimized changes in σ_Y due to gap variations
- Realignment of IDs with beam
  - ❖ Increased intensity of harmonics by 30-70%

FeedForward coupling correction

Minimized sensitivity of vert. beam size to IVU ID17 gap



Managing Current Challenges

- Focusing on subsystems currently limiting reliability
  - Linac klystrons, SRF and cryoplant
  - Booster kickers and quadrupole power supplies
  - Overheating vacuum chambers

  ❖ Ongoing improvement projects

- Few development projects
  - ❖ Carefully prioritizing and planning developments according to budget
- Optimizing staffing levels as we transition from construction to operations:
  - Involves significant reduction in AD head count
  - Consequent reduction in skills mix available
  - Especially critical in controls, Interlocks, Pulsed magnets, IDs
  - ❖ Cross training to increase depth of skill mix in organization
- Mitigating risk to reliability
  - ❖ Budgeting procurement of spares not in-hand in out-years
- Despite the above challenges we have been making steady progress in FY15…FY17

Budget FY15-17

Summary of FY16 Operations Costs

	FY16 BES-SUF funds			FY16 Other funding source		
	FTEs	Direct ($k)	Burdened ($k)	FTEs	Direct ($k)	Burdened ($k)
Total	**289.5**	**69,858.2**	**98,011.3**	**42.6**	**10,951.0**	**13,805.7**
Facility Management and Business Operations	21.6	11,217.0	15,384.3	4.0	822.1	823.2
Facilties (management and biz services)	21.6	4,035.4	5,726.8	4.0	792.4	793.5
Space and power		7,181.6	9,657.5		29.6	29.6
Accelerator Operations	107.5	20,195.5	31,342.9	1.2	271.2	387.3
Accelerator ops	107.5	20,195.5	31,342.9		-	-
R&D	-	-	-	1.2	271.2	387.3
Beamline Operations	145.5	35,071.1	46,298.3	37.2	9,[illegible]	[illegible]
Experimental Program	91.3	18,626.9	28,434.7	22.9	4,[illegible]	
Beamline Development	54.2	16,444.2	17,863.6	14.3	5,511.2	6,077.3
ESH&QA	14.9	3,374.6	4,985.8	0.2	-	-
ESH	13.1	3,374.6	4,985.8	-	-	-
QA	1.8			0.2		

This presentation

- Full data in **Facility FTE and Cost Summary** (table 1.iii.9) in volume 1
- BES SUF funds: Operations, BDN and NPB work
- Other funding: SPP, LDRD, Proprietary and NIH/BER

Accelerator Operations Cost in FY15-17

k$	FY15	FY16	FY17
Total	**37,136[A]**	**31,343[A]**	**37,821[P]***
Labor	29,975	25,875	25,769
Materials	6,952	5,254	11,886
Travel	209	214	166

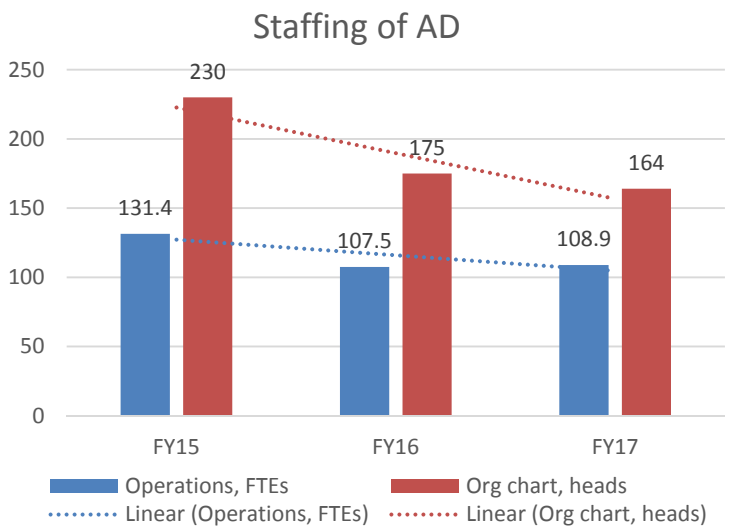
[A,P] FY15 and FY16 data are **A**ctual cost, FY17 data are **P**rojected cost

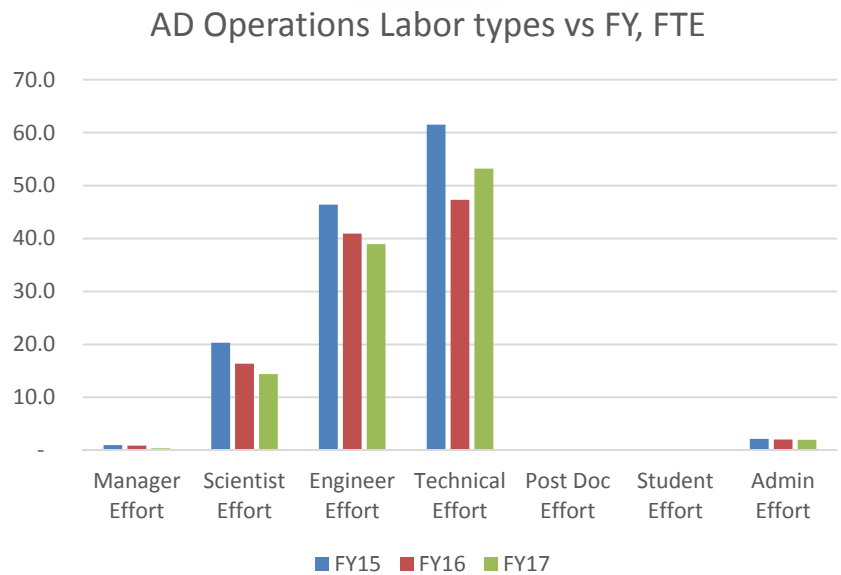
* FY17 funds include commitments of 3.828M$ from FY16 for 3rd RF cavity work, development materials and one-time RF system spares

Other funded projects:

- LDRDs: 3 in FY17, applying for 1 more
- Work for others: APS-U

Evolution of Accelerator Division FY15-FY17





- Scientist, engineer, & tech effort have significantly reduced since FY15
- At the start of FY17 164 heads in support of both operations and construction
- FY17 Accelerator Operating budget supports 108.9 FTEs (rest of heads support beamline operations and construction)

Changes in Org structure

- Injection and Storage Ring Coordination groups merged in early 2015
- Controls group moved to Photon Division
- In FY15, 230 heads in AD (including Controls group, 43 heads)
- In FY17, 164 heads in AD reflecting reduction in staffing requirements in operations and in beam line construction
- Ongoing changes to the AD org chart to increase efficiency further
- Transitioning organization from construction/commissioning to reliability, stability and intensity of operations

Increase in ops efficiency since FY15: staffing

- We are continually working on operating NSLS-II more efficiently

- As compared with FY15 staffing:
  - Accelerator operations of 131.4 FTE in FY15 vs. 107.5 FTE in FY16 – 23.9 FTEs (18%)
  - FY17 projected to be similar to FY16
  - Accelerator Physicists: reduction by 10 heads across all groups

- Cross-training evolving
  - ID techs help Vacuum Group
  - Electrical engineers support safety activities across NSLS-II and lab wide
  - RF group supports cryo operations
  - Accelerator coordination and ID groups support Controls group efforts in software development
  - FLOCOs supporting PPS certification & repairs
  - Ops staff supports installation work during shutdowns

Group	FY15	FY16	Δ
Electrical	19.3	15.4	-3.9
Safety Systems	4.4	3.1	-1.3
Mechanical	10.0	4.9	-5.1
ID	4.7	5.5	0.8
Survey	2.1	1.7	-0.4
Vacuum	8.2	6.9	-1.3
RF	12.4	11.4	-1.0
D&I	10.5	10.1	-0.4
Accel. Controls	13.0	7.0	-6.0
Physics	10.8	6.8	-4.0
Mech. Utilities	7.2	8.3	1.1
Management	5.4	5.4	0.0
Beam Operations	17.5	16.2	-1.3
Coordination	6.0	4.8	-1.2
Total	**131.4**	**107.5**	**-23.9**

18% reduction of staff for accelerator operations

Benchmarking: Comparison with APS

- Compared with sister facility of similar scale

- Received FTE data by WBS from APS
- APS Total FTE count 124
  - Excludes electrical utilities
- APS is mature synchrotron facility
  - Steady-state operations at 100 mA
  - Routinely delivering >98% reliability
  - Redundancy of critical subsystems
  - Complete spare inventory

- NSLS-II is in 3rd year of operations
  - Still improving and developing
  - Yearly increasing current
  - Constantly commissioning new IDs, FEs, BLs
  - Set of spares not yet complete

WBS Description	NSLS-II FY17 FTEs	APS FY16 FTEs
Acc Management	5.5	2.3
Operations Safety	1.1	0.3
Coordination Effort	3.8	-
Acc Physics Ops Support	6.7	4.8
Beam Operations	12.1	22.3
Mechanical Utilities	6.7	7.7
Electrical Utilities	3.5	-
RF	11.3	22.7
Pulsed Magnet Systems	2.4	-
Vacuum	10.2	8.9
Power Supplies	10.2	9.7
Safety Systems	3.6	2.7
Diagnostic Systems	10.3	8.4
Insertion Devices	3.4	15
Controls	8.4	15.5
Mechanical Systems	9.7	3.6
Total	**108.9**	**123.9**

Recommendation 2

Establish clear operational priorities across the NSLS-II organization to ensure excellent machine performance and scientific output… and delivering maximum operating hours, 5,000 hours or more per year, reliably to users by FY2018

We are focused on operations with clearly identified priorities:
1) high reliability (>95%), 2) high stability ($<\sigma/10$) and 3) high intensity (300 mA and beyond)

In support of these goals we have

1) Held Reliability workshops (Feb 2016) and High Brightness Synch. Light Source Workshop (Apr 2017)
2) Established a detailed, systematic tracking of causes of faults
3) Developed, and funded a detailed spares program, including initiating a 3rd RF cavity purchase in FY16
4) Established and optimized improvement and development program

Planning of accelerator operations in FY18

4750 hours of user operations

- Shutdown: 2200 hrs
  - Winter: 840 hrs (FIS-MET, 3rd RFC, repair and mainten., PPS cert. and SR RF conditioning)
  - Spring: 672 hrs (3rd RFC, repair and mainten., PPS cert. and SR RF conditioning)
  - Fall: 720 hrs (3rd RFC, repair and mainten., PPS cert. and SR RF conditioning)
- Studies: 850 hrs
  - Machine Start-up / Shutdown, Lattice Optimization, Injector, Beam Stability, Lifetime, High Beam Current, Instabilities & RF-Related Beam Dynamics, RF Optimization, Diagnostics, Slow and Fast Orbit Feedback
- Beamline Commissioning: 520 hrs
  - XFM (4-BM), QAS (7-BM) – 3PW, FE, BL
  - SST-1, SST-2 (7-ID), EPU60, U42, FE, BL
  - FXI (18-ID) – FE and BL, PDF (28-ID) new beamline to B-hutch,
  - FIS-MET (22-BMV), IR BL, new dipole chamber with mirror
  - beamline improvements and optimization with beam
- Maintenance: 360 hrs
  - Parallel Maintenance Activities, Injector Start-up, RF Conditioning, Injector Study Overnight
- Dedicated Interlock Recertification: 80 hrs
  - All operating beamlines

Total: 8760

Future Plans

FY18 Plans

- Support user program
- Operate the accelerator and deliver 4750 hours for user operations at > 95% reliability
  - Achieve 400 mA by the end of FY18 and
  - Remain on track to achieve 500 mA operations with 5000 hours in FY20
- Deliver 3rd RF cavity, advance procurement of 3rd RF transmitter and cryo system
- Further advance construction of harmonic cavity
- Resolve heating problems
- Investigate DI water quality issues
- Develop mode of operations with low vertical emittance
- Alignment of insertion devices to gain in X-ray brightness
- Further enhance beam orbit stability

Summary

- Carefully managed budget to deliver >95% level of reliability to date in FY17
- Reduced FTEs by 23.9 FTEs while increasing the current to 300 mA

- We are committed to progress with our focus on:
  - Maintain high safety record
  - Sustaining reliability and increasing current
  - Increasing annual operating hours
  - Delivering 3rd RF cavity and 3rd Harmonic RF cavity
  - Overcoming problems with overheating of chambers

- Exciting to see how facility evolved since commissioning in 2014!

- Thanks to the talent and commitment of the NSLS-II staff for the excellent progress we have made