APS Engineering Support (AES) Division
Strategic and Five-Year Development Plan

February 2017

Introduction

The APS accelerator complex is the backbone of the APS scientific program. It includes a 7-GeV, 1.1-km storage ring, operating with a 100-mA electron beam; a full energy booster synchrotron; a 400-MeV particle accumulator ring; a 400-MeV pulsed linear accelerator (LINAC); and an S-band radio frequency (RF) thermionic electron gun.

The APS has the largest installed 352-MHz continuous wave RF power system in the U.S. and the second largest installed pulsed S-band RF power system. APS uses over 1,500 power supplies to power various magnets, supports over 50 insertion devices, and utilizes numerous precision diagnostic devices to maintain beam quality.

Maintaining high reliability of the APS presents significant challenges, as discussed below. The accelerator systems continually undergo improvements directed at meeting new needs of scientific experiments.

In a longer perspective, the APS Upgrade project is developing a technical design for a new storage ring using a multibend achromat (MBA) lattice. Replacing the existing storage ring with a new ring is foreseen early in the next decade and will result in a dramatic, two-to-three order of magnitude increase of x-ray brightness.

The APS Engineering Support Division (AES) provides engineering, maintenance services, and computing infrastructure in direct support of enabling world-class performance of the APS accelerator and beamline complex, while ensuring a safe environment exists for APS users and personnel.

The support provided by the AES division includes the following:

- Leading-edge information technology and computer infrastructure through support of the networks, servers, storage and desktop computers.
- An accelerator controls system that maintains the high reliability of the APS accelerator facilities and plays a leading role in the advancement of accelerator control system technology.
- Mechanical and operations support services for the accelerator facilities that help the APS achieve its goals for high reliability, high availability, and long mean time between failures.
- Engineering design and drafting services in the support of highly reliable accelerator facilities.
- Precision survey and alignment services essential for the positioning and alignment of the accelerator components.
- Responsibility for work on all radiation shielding safety systems.
- Maintaining a reliable safety interlock system for personnel access control and equipment protection of the APS accelerators to ensure a safe working environment.

- Significant coordination with the FMS division for APS conventional construction and facility maintenance projects to provide effective and efficient site services.

AES Strategic and Five-Year Development Plan

The main purpose of this document is to describe the budget needs of the AES division to support APS operations as well as other engineering projects and technology developments grouped by the following categories:

1. Major (non-recurring) purchase of spares and replacement of "end-of-lifetime" equipment.
2. Obsolete hardware and equipment reliability issues.
3. Infrastructure development.
4. R&D projects in support of improvement and upgrades to accelerator hardware.
5. R&D projects in support of new or improved capabilities of the APS accelerators beneficial for APS Upgrade.

The summary tables in the introduction section give budget totals for each AES group, while more detailed information for individual AES groups is provided in the body of the document.

Not all options will be able to be implemented within the expected constraints in the current fiscal year, hence a complementary document, will be developed to list a balanced selection of projects with a globally assigned execution priority. It is intended that this document be used as the basis of a broad consultation across the APS, to help prioritize the suite of developments according to available funding and resource limitations.

This 5-year plan doesn't include activities directly funded by the APS Upgrade, but does make reference to active efforts in the specific group sections.

Beyond projects, this document includes a brief description of group's missions, operational responsibilities and group's staffing. A brief plan for personnel developments in each AES group is also given.

Critical skills matrices have been developed by group, retained and updated by Group Leaders, then combined by the Division Director for a divisional view. These are utilized in discussions and considerations for headcount backfill or hiring, to ensure staffing occurs in areas of skill gaps.

In individual group sections, risk prioritizations of projects are given for each category that are based on risk assessments of consequences of completing or postponing a project (c-column) on the scale from 1 to 4 (with 4 being the highest priority) and probabilities of these consequences to materialize (p-column). Cost estimates do not include an indirect (overhead) burden.

Finally, this plan is a working document and it is updated on an annual basis or as needed. It is used to guide planning and decision making by AES and APS management.

From this document, one should be able to find:
a) What will be accomplished in the next 5 years with more focus on the current year,
b) Additional project requests from each AES group,

c) Staffing needs and personnel development plans for each AES group and
d) Supportive AES efforts targeting LDRD and Work For Others / SPP projects.

Guiding Principles

The overarching Strategic Plan is, first, that of the Department of Energy, listed as Reference 1 in this document. Namely, there are 4 priorities listed that AES directly supports:

Goal 1 (Science and Energy)
Strategic Objective 3 – Deliver the scientific discoveries and major scientific tools that transform our understanding of nature and strengthen the connection between advances in fundamental science and technology innovation.

In the hard x-ray sciences initiative published by the APS, it is noted that the facility is an essential international resource for advancing mankind's science and engineering knowledge across a large number of fields, and is essential to maintaining a leadership in these fields by advancing the forefront of hard x-ray science. The APS is a core capability at Argonne - its capabilities are a critical enabling component of Argonne's broad R&D programs, and serve an extraordinarily diverse user community.

The AES division is a direct enabler in ensuring the accelerator complex design and facility is safe, operable and available at a level that permits users to conduct research to enable major scientific breakthroughs.

Goal 3 (Management and Performance)
Strategic Objective 9 – Manage assets in a sustainable manner that supports the DOE mission
Strategic Objective 10 – Effectively manage projects, financial assistance agreements, contracts and contractor performance.
Strategic Objective 11 – Operate the DOE enterprise safely, securely and efficiently
Strategic Objective 12 – Attract, manage, train and retain the best federal workforce to meet future mission needs

While the DOE Strategic Plan is written from the perspective of how DOE will oversee and manage facilities such as national laboratories and their respective assets, these strategic objectives relate directly to how the AES division should carry out its work in the course of operating the APS. Efficient use and retirement of assets, oversight and diligence in completing projects and managing contractors, ensuring operation of the APS is done safely and within the bounds of governing DOE directives and attracting and retaining a qualified, diverse and inclusive workforce all translate directly to AES division priorities.

More locally, the Photon Sciences Directorate (PSC) maintains a vision of:

"Operate and develop hard X-ray facilities and advance the forefront of X-ray science, transforming exploration of energy, biological and other functional materials, chemistries and systems to create a better world by overcoming global challenges to sustainable energy, health, and national security."

And a PSC strategy, to achieve that vision, of:

- Upgrade APS to maintain world leadership and attain the Basic Energy Sciences Advisory Committee (BESAC) vision of building the world's leading high-brightness hard x-ray storage-ring user facility
- Sustain excellence and improve efficiency in current APS operations
- Continue to improve accelerator and beamline capabilities
- Advance hard X-ray science and technology (S&T) to exploit APS-U energy, brightness, and coherence, to meet grand challenges in science and engineering
- Leverage Argonne leadership computing, mathematics and computer science to meet data science challenges
- Leverage Argonne leadership in hard X-ray science to support programs across Argonne, and draw from expertise in other divisions (CSE, IME, MSD, NST)
- Develop concepts for future sources and accelerator technologies

Vision

The goals for FY2017 and beyond required by the AES mission are:

- Provide world-class engineering, design, maintenance services and computing infrastructure in the most efficient manner to enable outstanding user science.

- Provide modern software and hardware systems to sustain excellence in operations and take full advantage of scientific aspirations.

- Enable the realization of APS Upgrade's state of the art designs and future operation through efficient transfer of resources and oversight of performance with the Project.

- Attract, develop and retain Human Capital to enable the AES mission. Maintain a vibrant, challenging, open, diverse and inclusive work environment where innovation, excellence, and perseverance flourish.

Strategy

To achieve the AES vision, we must concentrate on:

- People: The AES staff is key in providing the expertise in system and component design and maintenance for the accelerator complex, including beamline support. Retention of staff is vital due to the facility complexity, demands of the APS Upgrade project and unique design criteria and requirements, which are difficult to draw a comparison to in most commercial environments, with few exceptions. Knowledge transfer is crucial as earlier career staff are hired to develop system ownership, as late career staff move to retirement. Opportunities have to be provided to employees to pursue next generation designs, as well as R&D efforts, whether on APS Upgrade, LDRD, SPPs or other funding mechanism.

  AES will make full use of Argonne HR best practices including Talent Reviews as well as the performance appraisal process steps to reinforce workforce planning. Critical skills matrices

have been developed for the division to anticipate skill gaps that could form with attrition and plan for training, job rotations or mentoring to fill these gaps before they materialize.

- Processes: The AES division must rely on safe, diligent and thorough processes in the course of daily operations. Convoluted, redundant and wasteful steps should be eliminated, replaced by lean processes that represent a unified APS facility approach, rather than divisional mandates. Policies and procedures should follow suit in order that a documentation standard is maintained.

  AES division is currently undertaking a host of efforts related to APS facility and process improvements. A white paper has been issued proposing enhancements to the design review process as well as number and type of safety committees in practice. A document management system is well underway, based on best practices gleaned from prior working groups and other DOE laboratories. Lastly, enhancements are being made to the shutdown planning process, to bolster the fidelity already in place for preparation ahead of the three annual shutdowns.

- Technology: Many AES groups have an implied mandate to modernize legacy hardware and software systems, due to obsolescence or driven by increased operating requirements, such as those of the APS Upgrade project design. Engineering, design, survey, control, diagnostic and monitoring tools should challenge state-of-the-art principles in support of ongoing operations.

  AES division has already implemented state-of-the-art rendering tools for 3D models, instituting a burgeoning reverse engineering capability that has received tremendous demand once publicized, and has started the supply of 3D printed not only for models but for direct beamline installation, drastically reducing conventional production durations. In R&D, the MED group has current project underway for acoustic levitation on 2- and 3-axis sample holders as well as developing advanced COMSOL multiphysics simulation predictive capability for next generation synchrotron light source compact vacuum chambers.

Implementation

The following summary tables and group-by-group summaries outline how AES division will invest in efforts, projects and people to provide required support to the APS. The group reports outline their staff's mission, operational responsibilities, projects for addressing end of life hardware or software concerns, obsolescence issues, infrastructure development needs, R&D undertakings or direct support of SPPs like the LCLS-II project at SLAC. Anticipated staffing levels by fiscal year are summarized at the conclusion of each group report.

Summary Tables

TABLE 1 Spares and Replacement of End-of-Life Equipment

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
Replace Adobe Flex SDK	4	4	8	0	96	96	0	0

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
Replace Oracle SQR module	4	4	8	0	64	48	0	0
Replace Obsolete Laser Trackers	4	4	8	80	140	140	0	0
DI H2O Control System for SR sect 1&2	3	3	6	0	35	0	0	0
DI H2O Control System for SR sect 39&40	3	3	6	0	0	35	0	0
DI H2O Control Sys Injectors	3	3	6	0	0	0	80	0
Spare PC Gun Water System	3	3	6	0	0	0	0	0
FE Instrumentation Reliability Upgrade	3	3	6	40	40	40	40	40
DG535 Timing Generators	3	2	5	0	30	30	0	0
Custom VME Module Spares	3	2	5	10	10	10	10	10
Insertion Device Control System Spares	3	2	5	0	50	50	0	0
VME Crate Power Supplies	2	2	4	0	22	22	0	0
VM Cluster for control system	2	2	4	0	0	0	40	0
TOTAL				**130**	**487**	**471**	**170**	**50**

TABLE 2 Obsolete Hardware Projects

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
Upgrade Oracle Web Content Servers	4	4	8	80	20	90	20	100
Upgrade Sencha Ext JS JavaScript Framework	4	4	8	10	10	10	10	10
Upgrade Oracle Database and WebLogic Server	4	4	8	0	64	0	80	0
Oracle License Management	4	4	8	50	0	0	0	0
Replace Beamline and Backup Storage	4	4	8	185	150	150	150	150
X-ray Tape Library Hardware	4	4	8	75	75	50	50	50
Eleven Hadoop Nodes	4	4	8	80	80	80	80	80
Business Operations Windows Servers	4	4	8	325	300	300	300	300
Business Operations Linux Servers	4	4	8	94	80	80	80	80
CLO/Conference Wireless Upgrade	4	4	8	128	50	0	0	0
Experiment Floor/LOM Wireless Network	2	4	7	230	50	50	50	50
Upgrade X-ray Blade Chassis Modules	4	3	7	50	50	50	50	50
Accelerator Wireless Network	4	3	7	98	50	0	0	0
Replace obsolete PCMM	4	3	7	70	0	0	0	0
DI Water Resin Replacement	3	4	7	0	40	40	40	0
ACIS Upgrade	3	4	7	100	100	100	350	200
FEEPS Upgrade	3	4	7	0	100	100	100	100
PSS Upgrade	3	4	7	0	75	0	0	0
BLEPS Upgrade	3	4	7	0	0	0	0	0
Analog Frame-grabber Replacement	2	4	6	0	25	0	0	0
Booster DI Water Valves Replacement	3	3	6	0	36	36	0	0
Replace valves in the Linac and PAR	3	3	6	0	25	0	0	0
Replace PLC5 Control Systems	3	3	6	75	75	50	0	0
Replace vacuum equipment – Booster	3	3	6	300	0	0	0	0
Replace vacuum equipment – LINAC	3	3	6	0	200	0	0	0
Replace Voltaire Infiniband Switch	4	4	5	66	60	0	0	0
Re-engineering of obsolete modules	2	2	4	0	20	20	20	20
Beamline Network Core Upgrade	2	2	4	100	100	100	100	100
Beamline Network Switch Upgrades	2	2	4	100	100	100	100	100
Computer Obsolescence	2	1	3	60	60	60	60	60
Printer / Scanner	1	1	2	30	5	5	5	5

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
TOTAL				**2306**	**2000**	**1471**	**1645**	**1455**

TABLE 3 Infrastructure Development

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
APS Integrated Management System (AIMS)	4	4	8	7	7	7	7	7
Document Management System (DMS)	4	4	8	64	48	48	20	80
Web Application Framework	4	4	8	0	64	64	20	20
Booster DI H2O System Modification	3	4	7	24	0	0	0	0
SR Power Supplies Water Isolation Valves	3	4	7	30	30	30	0	0
LINAC Timing System	3	3	6	0	30	70	0	0
Business Intelligence and Data Warehouse	3	3	6	0	90	90	25	25
Integrated Component Management System	3	3	6	0	0	0	0	0
Implementation of Agile and ITIL methodologies	3	3	6	7	5	5	5	5
PCMM	3	3	6	0	70	0	0	0
VME crates with redundant power supplies	2	2	4	15	30	30	0	0
Wet Laboratory Development	1	1	2	50	25	0	0	0
TOTAL				**197**	**399**	**344**	**77**	**137**

TABLE 4 Hardware Improvements and Upgrades

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
VFD Elec Bypass for Injection Pumps	3	3	6	0	40	0	0	0
VFD Elec Bypass for SR Pumps	3	3	6	0	25	0	0	0
VFD Elec Bypass for RF Pumps	3	3	6	51	0	0	0	0
SR Vacuum Chamber Water Skid Control Valves Replacement	3	3	6	30	30	0	0	0
TOTAL				**81**	**95**	**0**	**0**	**0**

TABLE 5 R&D for New and Improved Capabilities

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
Upgrade Building 382	3	4	7	100	300	300	100	100
Replace leak detectors	3	4	7	100	100	100	100	100
Web Services and API	3	3	6	0	96	64	10	10
Reduction of pump and flow induced vibration	3	3	6	0	100	60	0	0
Vacuum Oven	3	3	6	0	600	0	0	0
X-Ray Sample Systems Development	2	3	5	0	50	50	50	25
Acoustic Levitator Sample Chamber	2	3	5	0	50	75	75	50
Single Sign-on	2	2	4	0	0	20	0	0
Additive Manufacturing	1	2	3	0	0	0	0	75
Small Scale Water Jet Cutting	1	1	2	0	10	3	3	3
Large Format FDM Printer	1	1	2	25	5	6	6	6
Scanning Development	1	1	2	75	5	5	5	5
TOTAL				**300**	**1316**	**683**	**349**	**374**

TABLE 6 R&D Projects in Support of a Future Light Source

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
Chamber testing*	4	4	8	200	100	100	0	0
Production of new light source*	4	4	8	0	200	400	400	400
APS-U sector mock up*	3	4	7	200	200	0	0	0
Welding R&D*	3	3	6	200	200	200	100	0
Pumping Systems for new light source	3	3	6	0	0	100	50	50
TOTAL				**600**	**700**	**800**	**550**	**450**

* = Already supported by the APS-Upgrade project

TABLE 7 Staffing Summary

Function that Role Supports	FY17 (FTE)	FY18 (FTE)	FY19 (FTE)	FY20 (FTE)	FY21 (FTE)
Operations, maintenance, obsolescence and infrastructure	96.4	96.4	97.4	95.9	94.9
Operations upgrades and improvements	12.0	14.0	15.0	14.5	14.5
APS-U support	36.5	41.5	49.0	60.0	61.0
R&D support	4.75	6.25	5.75	5.75	5.75
TOTAL	**149.7**	**158.2**	**167.2**	**176.2**	**176.2**

TABLE 8 LDRD Projects

Description	FY17	FY18	FY19	FY20	FY21
Sample Manipulation via Acoustic Levitator					
FTEs	0.2	0.2	0	.0	0
M&S ($k)	0	0	0	0	0
Effort ($k)	21	21	0	0	0
Additive Manufacturing					
FTEs	0	1.2	1.2	1.2	0
M&S ($k)	0	100	150	100	0
Effort ($k)	0	193	193	193	0
Reduction of Thermal and Photon Stimulated Gas Desorption in Compact Accelerator Vacuum Chambers					
FTEs	0.1	0.5	0	0	0
M&S ($k)	20	80	0	0	0
Effort ($k)	16	85	0	0	0
Nanobonding					
FTEs	0.75	1.2	0	0	0
M&S ($k)	35	100	0	0	0
Effort ($k)	170	200	0	0	0
TOTAL ($k)	**262**	**779**	**343**	**293**	**0**

TABLE 9 Strategic Partnership Projects (Work For Others)

Description	FY17	FY18	FY19	FY20	FY21
LCLS II Vacuum Chamber Project (MED)					
FTEs	0.5	0.8	0	0	0
M&S ($k)	0	0	0	0	0
Effort ($k)	62	99	0	0	0
LCLS II Vacuum Chamber Project (MOM)					
FTEs	2.8	2.25	2	2	0
M&S ($k)	100	25	0	0	0
Effort ($k)	200	50	0	0	0
Advanced Integrated Storage Ring Vacuum Design Software SBIR					
FTEs	0.5	0.5	0	0	0
M&S ($k)	0	0	0	0	0
Effort ($k)	42	42	0	0	0
NST User Program and NST using ICMS					
FTEs	0.1	0.1	0.1	0.1	0.1
M&S ($k)*	5% ICMS	5% ICMS	5% ICMS	5% ICMS	5% ICMS
Effort ($k)	0	0	0	0	0
TOTAL ($k)	**404**	**216**	**0**	**0**	**0**

* = 5% cost of ICMS not estimated here as M&S and therefore not reflected in total above

1. AES Controls (CTRLS) Group – Five-Year Development Plan

1.1 Mission

The AES Controls Group mission is to provide remote control and monitoring of the diverse accelerator technical sub-systems to allow them to be operated as a single integrated machine. A large spectrum of technology is utilized to achieve this end, including distributed control system software (EPICS), real-time operating systems, Field Programmable Gate Arrays (FPGAs), industrial single board computers, programmable logic controllers (PLCs), high speed communication links, and numerous software tools and languages.

1.2 Operation Responsibilities

The Controls Group has primary responsibility for the engineering, integration, and lifecycle management of the hardware and software to operate the APS accelerator systems to a high reliability. The group also assists with deployment of non-accelerator control systems when needed. The accelerator controls hardware is distributed around the entire accelerator complex and comprises more than 10,000 replaceable components. The software has more than 950 control applications and approximately 75 FTE years of customized code. The system operates continuously 24/7 monitoring and reporting over 500,000 process variables, each representing a machine parameter. The subsystems controlled or supported by the group include: (RF) radio frequency, timing, feedback, power systems, vacuum, diagnostics, magnetic devices, liquid nitrogen distribution, conventional facility monitoring, and many of the control room accelerator operations tools. A standardized approach to controls is taken by the APS controls/software groups (BCDA, Controls, and Software Support Groups) utilizing common software builds, similar hardware and tool sets across the groups.

1.3 Major (non-recurring) Purchase of Spares and Replacement of "End-of-Lifetime" Equipment

Much of the instrumentation used in the control system is more than 20 years old and numerous items are approaching end-of-life and have become difficult to procure. For items in this section, procuring or fabricating additional spare components is the most effective way to mitigate this risk. Listed below are items of significant cost.

- **VME Crate Power Supplies**

  Rather than replacing the entire VME chassis, we are in the process of swapping out original power supplies in the Tracewell crates with a more recent design that has also demonstrated higher reliability.

- **DG535 Timing Generators**

  There are 34 Stanford Research Systems DG535 Timing Generators installed that provide critical triggers to accelerator equipment. Many of these are at least 20 years old, so increasing our spares count is necessary.

- **Increase spares of custom VME modules**

  Numerous custom VME modules are utilized in the control system and many contain components that are increasingly difficult to procure. This project covers building additional spares of several modules to increase the longevity of our support.

- **VM Cluster Replacement**

  Controls runs hundreds of "soft IOCs" and other software services on linux servers. These servers require updated hardware every 4-5 years to ensure maintainability and security.

- **Insertion Device Control Systems**

  There are over 50 insertion device control IOCs which are critical to user operation. Many of these components are reaching end-of-life. Additional spares must be procured to keep these systems operational until the APS Upgrade design for ID control systems is available.

TABLE 1.1 Spares and Replacement of End-of-Life Equipment

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
VME Crate Power Supplies	2	2	4	0	22	22	0	0
DG535 Timing Generators	3	2	5	0	30	30	0	0
Custom VME Module Spares	3	2	5	10	10	10	10	10
VM Cluster for control system	2	2	4	0	0	0	40	0
Insertion Device Control System Spares	3	2	5	0	50	50	0	0
TOTAL				**10**	**112**	**112**	**50**	**10**

1.4 Obsolete Hardware Replacement

The items in Table 1.2 are identified as hardware which is either technologically obsolete or no longer supported for service or parts by original manufacturers and should be replaced in a timely fashion. There will be labor resources associated with these replacements because the replacement components are unlikely to be "plug-compatible".

- **Analog Frame-grabbers and Video Processors**

  These modules have been unsupported by the manufacturer for many years. Replacing these would require a significant software development effort to fully replace the existing functionality on different hardware. This would require a formal project submission to ensure resources are available. The estimated cost is only for development hardware, not the production hardware (which would be paid for by ASD Diagnostics).

- **Re-engineering obsolete boards and chassis**

At times we are no longer able to procure the components necessary to build additional spare modules and chassis of old designs. This triggers a redesign of the module to provide the same functionality with new components.

TABLE 1.2 Obsolete Hardware Projects

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
Analog Frame-grabber Replacement	2	4	6	0	25	0	0	0
Re-engineering of obsolete modules	2	2	4	0	20	20	20	20
TOTAL				**0**	**45**	**20**	**20**	**20**

1.5 Infrastructure Development Plan

The following items are systems that require upgrades or enhancements to provide facilities necessary to support present and future R&D and maintenance activity.

- **VME Crates with Redundant Power Supplies**

  Critical control systems (e.g. RF, timing, MPS, etc.) would benefit in having VME chassis with redundant power supplies to maintain a high level of availability. These would be selectively upgraded over a period of time.

- **LINAC Timing System**

  The timing system in the LINAC is still the original design that was engineered to fulfill the original requirements. There are frequent requests for more precise triggering (higher resolution, less jitter) for applications that were not originally envisioned (e.g. injector test stand, photocathode guns, LEA, etc.). Replacement of this system with newer technology would benefit several R&D efforts.

TABLE 1.3 Infrastructure Development

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
VME crates with redundant power supplies	2	2	4	15	30	30	0	0
LINAC Timing System	3	3	6	0	30	70	0	0
TOTAL				**15**	**60**	**100**	**0**	**0**

1.6 R&D Projects in Support of Improvement and Upgrades to APS Hardware

There are some R&D initiatives with intent to pursue, but they are not significant cost and will be funded from annual recurring M&S.

1.7 R&D Projects in Support of New or Improved Capabilities of the APS and APS Upgrade

There are some R&D initiatives with intent to pursue, but they are not significant cost and will be funded from annual recurring M&S. Examples include µTCA-based BPM instrumentation platform and improved timing signals to beamlines.

1.8 R&D Projects in Support of a Future Light Source

- **EPICS Collaboration Support**

The Controls Group's contribution to the EPICS Collaboration is an example of an on-going R&D project in support of future light sources. This contribution is entirely labor and it is covered in the recurring annual budget, estimated to be about 0.5 FTE / year.

1.9 Personnel Development Plan

- **Promotion**
  - FY17 – 0
  - FY18 – 1 (to RD3)
  - FY19 – 2 (to RD4, RD5)
  - FY20 – 2 (to RD4)
  - FY21 – 0

- **New hire**
  - FY17 – 2 (RD3/4 and RD1/2 for software development)
  - FY18 – 2 (Additional staff funded by upgrade. May be a contractor)
  - FY19 – 1 (Additional staff funded by upgrade. May be a contractor)
  - FY20 – 0
  - FY21 – 0

- **Education (graduate, co-op or summer students)**
  - FY17 – 1
  - FY18 – 1
  - FY19 – 1
  - FY20 – 1
  - FY21 – 0

1.10 Staffing Summary

Function that Role Supports	FY17	FY18	FY19	FY20	FY21	Comments
Operations, maintenance, obsolescence and infrastructure	10	10	10	10	10	New hire in FY17
Operations upgrades and improvements	1.5	1.5	1.5	0	0	
APS-U support	5	7	8.5	10	10	New hire in FY17 Add contract hires in FY18, FY19
R&D support	0.5	0.5	0	0	0	

Function that Role Supports	FY17	FY18	FY19	FY20	FY21	Comments
TOTAL	**17**	**19**	**20**	**20**	**20**	

LDRD projects

None identified.

Work for Others (Strategic Partnership Projects) projects

None identified.

2. AES Design and Drafting (DD) Group - Five-Year Development Plan

2.1 Mission

The AES Design and Drafting Group supports the ASD, XSD and AES divisions' continued improvement of the accelerator as well as the scientific community's continued development of advanced research at the APS.

2.2 Operation Responsibilities

Assist the engineering and scientific staff in producing documentation to create components to perform leading edge science and to maintain the operational effectiveness of the APS in producing reliable x-rays.

2.3 Major (non-recurring) Purchase of Spares and Replacement of "End-of-Lifetime" Equipment

None identified

2.4 Obsolete Hardware Replacement

- **Computer Obsolescence**

Replace aging computers with new generation of systems, there has finally been a significant gain in performance from the new chipsets being introduced in the HP 840s. The original testing performed on the first generation of HP 840s had shown little to no gain, the new system is a major increase and is worth investing in a new system.

- **Printer / Scanner**

The first generation of printer/scanner combination is reaching end of life, it was purchased 9 years ago and is still on Windows XP since the scanner software cannot be upgraded.

TABLE 2.1 Obsolete Hardware Projects

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
Computer Obsolescence	2	1	3	60	60	60	60	60
Printer / Scanner	1	1	2	30	5	5	5	5
TOTAL				**90**	**65**	**65**	**65**	**65**

2.5 Infrastructure Development Plan

- **Wet Laboratory Development**

Transition an available space to house the rapid prototype production and post processing facility. The area will need to have water, drain and venting. This will centralize a process that

is using space in three different areas currently. The current unused space of the Document Control Center could be utilized for this endeavor if an existing location that already has these amenities cannot be found.

TABLE 2.2 Infrastructure Development

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
Wet Laboratory Development	1	1	2	50	25	0	0	0
TOTAL				**50**	**25**	**0**	**0**	**0**

2.6 R&D Projects in Support of Improvement and Upgrades to APS Hardware

None identified

2.7 R&D Projects in Support of New or Improved Capabilities of the APS and APS Upgrade

- **Small Scale Water Jet Cutting**
  Desktop water jet cutting, adds a capability that can handle small aluminum parts to create mounting plates and brackets quickly. The machine has a capability of 12 x 18 inches, making it ideal for small parts that require a quick turn around with limited details.

- **Large Format FDM Printer**
  FDM improvements and the current demand from the user base for large enclosure type parts has made this a viable solution for some of the non-precision components that we are currently creating. This technology has made strides forward in the last few years making this a cost effective method to create inert gas experimental enclosures and sample holders.

- **Scanning Development**
  Procure and utilize new 3D scanning technology, this will include a second handheld scanner for large objects as well as a borescope type 3D scanner for internal geometry. This technology is advancing forward and can be utilized for quality control and inspection.

TABLE 2.3 R&D for New and Improved Capabilities

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
Small Scale Water Jet Cutting	1	1	2	0	10	3	3	3
Large Format FDM Printer	1	1	2	25	5	6	6	6
Scanning Development	1	1	2	75	5	5	5	5
TOTAL				**100**	**20**	**14**	**14**	**14**

2.8 R&D Projects in Support of a Future Light Source

None identified

2.9 Personnel Development Plan

- **Promotion**
  - FY17 – 1 (PT1), 1 (PT3)
  - FY18 – 2 (PT1)
  - FY19 – 1 (PT1)
  - FY20 – 1 (PT1)
  - FY21 – 1 (PT1)

- **New hire**
  - FY17 – 2 Replacements, 2 Upgrade Support
  - FY18 – 4 Upgrade Support
  - FY19 – 4 Upgrade Support
  - FY20 – 0
  - FY21 – 0

- **Education (graduate, co-op or summer students)**
  - FY17 – 1
  - FY18 – 1
  - FY19 – 1
  - FY20 – 1
  - FY21 – 0

2.10 Staffing Summary

Function that Role Supports	FY17	FY18	FY19	FY20	FY21	Comments
Operations, maintenance, obsolescence and infrastructure	8.5	8.5	8.5	6	6	Decreasing support in FY20 & 21 as projects decrease toward the APS-U downtime.
Operations upgrades and improvements	3	3	3	3	3	
APS-U support	10.5	12.5	16.5	23	23	Increasing support required over the project years.
R&D support	2	2	2	2	2	
TOTAL	24	26	30	34	34	

LDRD projects

None identified

Work for Others (Strategic Partnership Projects) projects

None identified

3. AES Information Solution (IS) Group – Five-Year Development Plan

3.1 Mission

The Information Solution Group is a business software development group within the AES division, committed to developing effective and innovative software that:

- Helps users conduct scientific experiments at APS, from user registration and proposal submission, to publication.
- Empowers APS scientists, engineers, and administrators to work efficiently.
- Manages APS Operations to meet DOE requirements and regulations.

3.2 Operation Responsibilities

The group is responsible for developing and maintaining software applications, web services and computing scripts to support:

- Users conducting experiments on-site and remotely at APS Beamlines
- APS Operation
- APS Upgrade Project
- APS Web Site backend process and data sources
- DOE, ANL and CATs (Collaborative Access Team) Data Services
- Document Management

3.3 Major (non-recurring) Purchase of Spares and Replacement of "End-of-Lifetime" Equipment

- **Replace Adobe Flex 3.0 SDK and components in Beamline Scheduling System**

The Beamline Scheduling System is a critical business application, which provides APS beamline administrators and users the functions to review the APS run schedule, arrange beamline activities, and find user and experiment information.

Adobe Flex 3.0 SDK is used in developing the web calendar interface of the APS Beamline Scheduling System. According to Adobe products and Enterprise Technical Support policy, Adobe Flex 3.0 is ending the extended support now. The need to upgrade Flex 3.0 to its current version Flex 4.6 or replace it with different technology is a near term action.

- **Replace Oracle SQR module**

Oracle SQR module has been widely used in programming the APS Oracle applications and system scripts. It provides comprehensive enterprise reporting capabilities through a graphical report creation environment and a powerful 4GL reporting language (called SQR) for advanced reporting and data processing. The IS Group has been using the SQR module to create formatted reports and using it as CGI to interact with scripting languages.

According to Oracle, SQR will be on end-of-life in two or three years, thus the need to replace Oracle SQR with different business intelligence products is evident.

TABLE 3.1 Spares and Replacement of End-of-Life Software

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
Replace Adobe Flex SDK	4	4	8	0	96	96	0	0
Replace Oracle SQR module	4	4	8	0	64	48	0	0
TOTAL				**0**	**160**	**144**	**0**	**0**

3.4 Obsolete Software Replacement

- **Upgrade APS ICMS to Oracle WebCenter Content 12c**

  APS ICMS is implemented with Oracle WebCenter Content 11g, which serves as one of the most important document repositories for APS business needs. Oracle released a new version of Oracle WebCenter Content 12c in October 2015.

  This new version includes a full list of new features and enhancements, such as new User Interface, Imaging Component, Content Services, HTML Converter Template Editor, Desktop Integration Suite, WebCenter Enterprise Capture.

  APS ICMS should be updated to Oracle WebCenter Content 12c to take advantage of these new features to meet APS document management requirements.

- **Upgrade Sencha Ext JS JavaScript Framework**

  There are a few critical business applications developed with Ext JS 4 JavaScript Framework to build the web user interfaces, implement asynchronous web applications, and generate Work Request Gantt Charts.

  The following applications are using Ext JS 4:
  - APS User Portal
  - APS User Administration
  - Project proposal system
  - Work Request System
  - Network Tracking (IT- ETS)
  - XOP

  Sencha Ext JS 6 is the latest version released in June 2015. With this new release, Ext JS framework provides a single framework for creating applications that run across all types of devices, from phones and tablets to desktops.

  While the Ext JS 6 release is out, the Ext JS 4 Standard Support is ending on Dec 31, 2016. The desire is evident to upgrade Ext JS 4 to Ext JS 6 and adjust applications to run with the Ext JS 6.

- **Upgrade Oracle Database and WebLogic Server**

Most of the IS Group's business software applications and systems are implemented with Oracle database 11g and Oracle Weblogic 11g. The current Oracle database release is 12c and Oracle Weblogic release is 12c. The benefits of Oracle 12c includes plug-in to cloud, automation and optimized data services, maximum availability and database security.

To take advantage of the 12c new features, both Oracle database and Oracle Weblogic server would need to be upgraded to release 12c.

- **Oracle License Management**

  In the APS computing network, there are multiple Oracle database instances installed for supporting different applications. The APS Oracle license agreement was modified while the Oracle products were changed or replaced. Because these changes were made over the past 15 years, there is no up-to-date clear license agreement with Oracle.

  A consultant will be hired to review the Oracle license agreement and the installed Oracle instances in the APS computing network.

TABLE 3.2 Obsolete Software Projects

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
Upgrade Oracle Web Content Servers	4	4	8	80	20	90	20	100
Upgrade Sencha Ext JS JavaScript Framework	4	4	8	10	10	10	10	10
Upgrade Oracle Database and WebLogic Server	4	4	8	0	64	0	80	0
Oracle License Management	4	4	8	50	0	0	0	0
TOTAL				**140**	**94**	**100**	**110**	**110**

3.5 Infrastructure Development Plan

- **APS Integrated Management System (AIMS)**

  The IS Group continues to support and develop new features for the APS Integrated Management System (AIMS) as directed by the APS AIMS Implementation Team and AIMS Committee. The group is also developing solutions to integrate AIMS components in the Argonne ServiceNow cloud platform with the on-premises software systems at APS computing network.

- **Document Management System (DMS)**

  As a subset of the AIMS project, the IS Group continues to develop the DMS software tool in a series of 3 releases, to increase the efficiency of APS document management.

- **Business Intelligence and Data Warehouse**

The IS Group will acquire a modern business intelligence tool to allow users to tailor data-rich reports from a subset of available data and fields. This tool is a modern data warehouse tool to extract, transform, summarize and store temporal data for ease of data analysis and decision-making.

- **Integrated Component Management System**

  The IS Group plans to consolidate the beamlines, machines, and general parts management into one integrated component management system. One approach is to extend the Component Database (CDB) with more functions that are currently implemented in two individual web applications: Beamline Component Database and Machine Component Database. Then, the current obsolete versions of the Beamline Component Database and Machine Component Database can be retired.

- **Web Application Framework**

  In order to rapidly respond to APS business needs with effective and efficient software tools, the IS Group will need to move to modern web application frameworks within the best industry standards. The IS Group will adopt the best practices and develop user-friendly, reliable, secured, and scalable business software with innovative technologies.

- **Implementation of Agile and ITIL methodologies**

  We plan and implement Agile and ITIL methodologies on the ServiceNow platform to improve the efficiency and effectiveness of IS group business software development and business service support.

TABLE 3.3 Infrastructure Development Projects

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
APS Integrated Management System (AIMS)	4	4	8	7	7	7	7	7
Document Management System (DMS)	4	4	8	64	48	48	20	80
Business Intelligence and Data Warehouse	3	3	6	0	90	90	25	25
Integrated Component Management System	3	3	6	0	0	0	0	0
Implementation of Agile and ITIL methodologies	3	3	6	7	5	5	5	5
Web Application Framework	4	4	8	0	64	64	20	20
TOTAL				**78**	**214**	**198**	**77**	**137**

Note: The listed cost for AIMS is only for IS Group's training and seminars in support of the ServiceNow platform, since the AIMS project is an ALD-level project.

3.6 R&D Projects in Support of Improvement and Upgrades to APS Hardware

None identified

3.7 R&D Projects in Support of New or Improved Capabilities of the APS and APS Upgrade

- **Single Sign-on**

  There are three authentication credentials for accessing APS business applications and systems.

  - Oracle web account: Used for accessing APS in-house developed business applications, such as, APS User Portal, Beam Time Request (user proposals), ESAF, Work Request System, etc.
  - APS LDAP server account: Used for accessing APS ICMS document management system, and for APS employees to login to APS in-house developed business applications.
  - Argonne Domain account: Used for accessing Argonne Lab owned applications and systems.

  A Single Sign-on solution means the user only need to sign on just one single time to access multiple applications and services.

  The IS Group plans to implement a single sign-on solution for APS business software systems when Argonne CIS provides an enterprise identity management infrastructure for lab-wide use.

  The single sign-on solution can greatly reduce the number of passwords a user has to remember, provide convenience to users, improve compliance and security capabilities, reduce help desk costs, and boost productivity.

- **Web Services for Beamline Systems**

  In the past decade, APS groups and CATs have developed many applications using various programming languages on various different platforms. These heterogeneous applications need some sort of communication to interact between them. The Web services architecture is designed for highly dynamic program-to-program interactions.

  The IS Group plans to design and implement web services architecture to provide a common platform that supports the integration and communication between IS Group business software systems and XSD beamline data management, CATs owned systems, Argonne publications and DOE publication libraries, as well as other systems.

TABLE 3.5. R&D for New and Improved Capabilities

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
Single Sign-on	2	2	4	0	0	20	0	0
Web Services and API	3	3	6	0	96	64	10	10

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
TOTAL				0	96	84	10	10

3.8 R&D Projects in Support of a Future Light Source

None identified

3.9 Personnel Development Plan

- **Promotion**
  - FY17 – 0
  - FY18 – 1
  - FY19 – 1 (PT6)
  - FY20 – 1 (PT5)
  - FY21 – 1 (PT4, PT5)

- **New hire**
  - FY17 -1 (PT3)
  - FY18 - 0
  - FY19 – 0
  - FY20 – 0
  - FY21 – 0

- **Education (graduate, co-op or summer students)**
  - FY17 – 3 (2 co-op, 1 undergrad summer students)
  - FY18 – 3 (2 co-op, 1 undergrad summer students)
  - FY19 – 3 (2 co-op, 1 undergrad summer students)
  - FY20 – 3 (2 co-op, 1 undergrad summer students)
  - FY21 – 3 (2 co-op, 1 undergrad summer students)

3.10 Staffing Summary

Function that Role Supports	FY17	FY18	FY19	FY20	FY21	Comments
Operations, maintenance, obsolescence and infrastructure	2	2	2	2	2	
Operations upgrades and improvements	3	3	3	3	3	
APS-U support	1.5	1.5	1.5	1.5	1.5	
R&D support	0.5	0.5	0.5	0.5	0.5	
TOTAL	**7**	**7**	**7**	**7**	**7**	Including one new hire in 2017

LDRD projects

None identified

Work for Others (Strategic Partnership Projects) projects

The IS Group continues to support the Nanoscience & Technology (NST) division in the following areas:

- NST user program support

  Support of the NST user registration, user data, institution data, user proposal and ESAF related information.

- NST document repository support

  Support of the NST computer accounts for accessing ICMS, NST staff privileges, and ICMS help requests.

Description	FY17	FY18	FY19	FY20	FY21
NST User Program and NST using ICMS					
FTEs	0.1	0.1	0.1	0.1	0.1
M&S ($k)	5% ICMS	5% ICMS	5% ICMS	5% ICMS	5% ICMS
Effort ($k)	0	0	0	0	0
TOTAL ($k)	12	12	12	12	12

4. AES-Information Technology (IT) Group – Five-Year Development Plan

4.1 Mission

The mission of the Information Technology Group is to support the strategic goals of the APS and to provide APS access to the latest computer and network technology for the purposes of enhancing science, the operation of the APS, and furthering the goals set by the APS management.

4.2 Operation Responsibilities

- Set up, maintain and support the APS computer infrastructure including managing APS Enterprise networks and CAT backbone networks, managing tier 2 firewalls, Internet access tools, computer servers, and printers, server and desktop backups, and supporting all Laboratory cyber security policies.

- Provide technical support to the APS beamlines in the planning, acquisition, and operation of computers and networking equipment. Scientists do not have to deal with computers and networks, cyber security, backups so they can concentrate on science.

- Provide support for the APS staff in the use of software tools and computer technology to be effective and efficient in their work. Provide hardware and software support for all APS beamline, accelerator, and central servers and software support for all Linux, Windows and Macintosh desktop computers.

- Provide software support, including installation of software purchased by and for the performance of Laboratory business.

4.3 Major (non-recurring) Purchase of Spares and Replacement of "End-of-Lifetime" Equipment

None identified since summarized in next section with obsolete replacements and approaching end of life equipment.

4.4 Obsolete Hardware Replacement

- **Replace Beamline and Backup Storage Devices**

IT began the process of replacing aging beamline storage devices in fiscal year 2016 with the purchase of a NetApp FAS8040 storage system. That resource allowed the replacement of Xray dserv servers to virtual machines (VMs), and the migration of much of the storage to the NetApp appliance. The total capacity of the NetApp appliance was approximately half of the total storage space currently used by XSD beamlines. Some of the older storage hardware still in use will reach the end of vendor support at the end of 2017, making it imperative that these devices be replaced this year. Additionally, 2 of these end-of-support storage arrays are in use in the Xray file backup system, and must be replaced as well.

There are two options for adding capacity to the NetApp storage system:

1. Add additional storage shelves to the existing appliance

2. Add a second NetApp FAS8040 appliance

Both options will provide the same total storage space for XSD beamline data. The first option would result in lower overall cost (approximately $75K), while option 2 provides increased reliability as well as additional storage capacity. Adding a second storage appliance would allow us to leverage additional features provided by NetApp clustering technology, including the ability to more easily balance workloads, and perform many maintenance tasks while storage remains online and available to users.

Hardware requested:

- NetApp FAS8040 storage appliance with approximately 150 terabytes of storage ($160K)
- 2 HP D2600 storage arrays ($25K)

Failure to replace the storage devices reaching end-of-support status could result in extended downtime and loss of data in the event of a failure. Replacement disk drives will not be available, and a failure would require replacing the faulty disk array with a new purchase.

- **X-ray Tape Library Hardware Refresh**

In August 2016, the Xray backup tape library, a Sun/Oracle/StorageTek SL500, reached 100% of its capacity. As Xray beamline data continue to grow, the rate at which new tapes need to be added has increased. As the SL500 is past end-of-purchase, we can no longer upgrade tape drives, and the tape capacity is at its maximum.
Additional tape storage capacity and additional tape drives are required to fully replace the capabilities and capacity of the old tape library.

The faster LTO7 tape drives will allow more data to be written to tape in less time, which is crucial to hitting the tight backup windows for XSD beamlines. The expanded storage capacity afforded by more tape slots and larger per-tape capacity of the new LTO7 tape drives is critical to mainlining reliable backups of all beamline data. The old SL500 tape library is nearing 9 years old, and is reaching the end of its useful lifespan. Failure to maintain backup system resources in step with beamline storage needs increases the likelihood of files not being reliably backed up, which can result in the loss of beamline data in the event of a storage system failure that requires restoring files from backup tape to recover.

Hardware requested:
- Three HP MSL4680 tape storage expansion modules ($30K)
- Six LTO7 tape drives ($30K)
- 100 LT07 tapes ($15K)

- **Beamline Network Core Uplink Upgrades**

New top-of-rack network switches are needed in the computer room to offload 10Gig connections from the beamline core switches to provide additional 40Gig ports. Additional

core uplinks and new beamline switch uplinks require 40Gig connections. Some of the new servers also require 40Gig connections.

For upgrading the 2 x 10Gig direct uplink to B240 to 100Gig, two 100Gig optics will have to be purchased.

Beamline network uplinks to the APS core would be limited to 10Gig instead of 40Gig for beamline data transfer if purchases are not made. Data transfer and backup services to ALCF would also be limited to 10Gig for a single stream.

- **Beamline Network Switch Upgrades**

  Beamlines continue to transfer more data and have been adding devices to the beamline that have 10Gig interfaces. To support these, additional 10Gig devices and in order to provide 40Gig uplinks, it is necessary to provide high performance network switches with line rate 10Gig interfaces and 40Gig uplinks.

  Some of the beamlines have limited expansion capabilities to add additional 10Gig ports. The current network switches at the beamline also don't provide 10Gig line rate ports. The high performance sectors that require these additional switches are 1, 2, 8, 12, 32 and 34. This would be a total of 6 additional switches.

  The beamline Data Transfer Node (DTN) server "orthros" also requires a network upgrade to provide additional 10Gig ports at line rate with 40Gig uplinks to the beamline core. This will bring the total to 7 additional switches.

  If this project is not completed, beamline devices may not get full 10Gig connectivity and would impact data transfer performance. Additional beamline devices may not be able to connect at 10Gig because of port availability. Multiple 10Gig devices at the beamline may have to share a single 10Gig uplink.

- **Eleven Hadoop Nodes**

  Sector 8 uses Hadoop for XPCS data analysis. Currently, they have 10 dedicated nodes. Each node has 64GB RAM and two SSD drives, one for the OS and one for the Hadoop data processing. Due to a new detector, computational requirements have increased. Ideally, twenty additional compute nodes are required. This also includes a replacement for the Hadoop head node. It was upgraded three years ago with a second CPU and more memory. This node is over 6 years old and needs to be replaced.

  The compute nodes will be a shared resource. Other Orthros users will have access to them when large Hadoop jobs are not being run.

  The cost for these nodes is largely determined by the CPUs purchased and local Hadoop storage. The requested amount reflects a mid-range CPU, 2.1Ghz with 16 cores, 2 CPUs per node. The local storage in the request is a 960GB SSD. It is recommended a second 960GB drive be added to increase local storage to 4.8TB, leaving ~1.7TB/node for Hadoop processing. The cost of the additional computing nodes is estimated at $80k.

If this project is not completed, users will have inadequate resources to analyze beamline data. This could lead to less than optimal experiment settings and wasted beam time. Due to limited resources, the Hadoop cluster ran out of space in the middle of a run. Adding nodes increases the Hadoop storage. If the head node (hpcs08) fails, the Hadoop environment would be unusable.

- **Replace/Augment Voltaire Infiniband Switch**

  The Voltaire Infiniband switch is no longer supported, as parts are no longer available. A catastrophic failure of the Voltaire switch will cause excessive downtime, greater than 3 days. Replacement parts are not available. A new switch would have to be ordered. Additional ports would be available from the Mellanox switch while continuing to use the Voltaire. The Mellanox switch could also be expanded in the future and receive full support from the vendor.

- **Business Operations Windows Servers**

  The investment in the APS' 3Par storage solution should continue to deliver the performance and services required to maintain our current and future computing needs.

  A 3Par solution should be considered an essential part of our long-term strategy to virtualize our servers and storage environment. Being able to meet the storage requirement of our virtual servers on one storage platform is the purpose of 3Par storage platform.

  The 3Par is a major component in our effort to reduce the number of physical servers and storage devices we need to manage and maintain. The current system experienced high I/O wait and services times for Oracle database transaction logs and the Windchill application. The I/O load that the Windchill application generated was enough to cause a negative impact on the other virtual server's environments.

  The current Linux and Windows blade chassis virtual environment consists of 32 blade servers in two separate blade chassis. The Linux and Windows virtual environment has approximately 110 virtual machines including:

  - RHEL Systems Management (Satellite Server)
  - NetApp Performance Monitor
  - APS Mail Server
  - Print Servers
  - Linux Kickstart Testing
  - NX Terminal Server
  - DNS
  - PII Encrypted Server
  - License Servers
  - LDAP Master Authentication Server
  - LDAP Test Servers
  - Software Development and Build Servers
  - Wiki Server
  - Wiki Test Server
  - Windchill and related Design and Drafting Servers

- HP Intelligent Management Center for APS Network Management
- Netbackup Ops Center
- TFTP Servers
- ICMS Servers
- Zend PHP Servers
- APS Web Farm
- AutoDesk Vault
- SharePoint Databases
- Citrix Servers (including Dayforce)
- Windows patching servers
- Windows application deployment
- Cryptocard authentication (VPN & SSH)
- Radius authentication (authenticated wireless)
- ICMS refineries

The proposal recommended is to add a third HPE blade chassis to the Business Operations environment. The two current chassis are at maximum capacity for blade servers. Any upgrade to software applications provided by the virtual environment will be severely impacted due to insufficient resources.

- **Experiment Hall Floor and LOM Wireless Network Upgrade**

  APS is currently using 2010 technology 802.11n wireless controllers and access points. The wireless access points are becoming unreliable and beginning to fail at an alarming rate. Support for the outdated equipment is requiring administrator intervention on a daily basis. Over half of the access points (155/238) are dual radio 150 Mbps/radio limited.

  Currently, wireless devices are being equipped with 802.11ac gigabit wireless capable network interface hardware. However, these devices must function at 802.11n 150 Mbps on the APS network. The Lab Office Modules supports engineers, scientists, operations staff and administrators and a host of visitors whose aggregated traffic would benefit from increased wireless throughput on each access point radio.

  HPE/Aruba has now announced and end-of-life date for the HP Procurve WLAN equipment APS is currently using: 12/31/2016. Although HPE/Aruba will continue to provide technical support for another 3 years, after 12/31/2016, APS will not be able to purchase additional (compatible) wireless controllers or access points.

  If this project is not completed, the aggregate wireless client network throughput in the LOMs and Experiment Hall floor will be limited to 150 Mbps/AP-radio, even though many clients are gigabit wireless capable. Wireless service will continue to be unreliable and access points will continue to fail at an alarming rate. Users report poor wireless performance in some areas, which APS-IT can only address one at a time using spares.

  The APS has operated an HP Procurve Wireless LAN solution since 2010. HP recently purchased Aruba Networks. HP/Aruba has confirmed that they are selling the Aruba Wireless LAN product line exclusively going forward and are abandoning the HP Procurve Wireless LAN product line. If the APS doesn't upgrade, they risk being in a position of needing support for an obsolete technology.

Once APS WLAN equipment goes EOL on 12/31/2016, APS-IT will no longer be able to provide wireless service in new areas, as we have done in the past, because HPE/Aruba will no longer sell HP Procurve WLAN equipment.

- **Accelerator Wireless Network Upgrade**

  APS is currently using the same 2010 technology 802.11n wireless controllers and access points. The wireless access points are becoming unreliable and beginning to fail at an alarming rate. Support for the outdated equipment is requiring administrator intervention on a daily basis. Over half of the access points (155/238) are dual radio 150 Mbps/radio limited.

  The same rationale applies here for an upgrade to the accelerator wireless network as explained in the preceding Experiment Hall floor and LOM wireless upgrade section.

- **CLO/Conference Center Wireless Network Upgrade**

  APS is currently using the same 2010 technology 802.11n wireless controllers and access points. The wireless access points are becoming unreliable and beginning to fail at an alarming rate. Support for the outdated equipment is requiring administrator intervention on a daily basis. Over half of the access points (155/238) are dual radio 150 Mbps/radio limited.

  The same rationale applies here for an upgrade to the CLO/Conference Center wireless network as explained in the preceding Experiment Hall floor and LOM wireless upgrade section.

- **Upgrade Blade Chassis Network Modules**

  Nearly all X-ray beamline servers have migrated to a virtual machine (VM) environment that is supported by a high-availability pair of HP blade server chassis. The 2 chassis were purchased approximately 2 years apart, with a change in the network interconnect technology between the 2 purchases. The network interconnect devices on the old chassis are no longer sold, and as a result, runs at half the speed of the new chassis, and requires different configuration.

  This results in unequal performance of VMs on one chassis compared to the other, and complicates configuration and management of the virtual server system. This configuration also violates HP's best practices recommendation that both blade chassis have identical hardware configurations.

  If the asymmetric chassis configuration is allowed to remain, it could result in significant downtime of critical beamline servers such as the sector "dserv" servers, as well as web and database servers that are essential to beamline operations. It is possible that such a failure could affect all X-ray beamlines.

- **Business Operations Linux Servers**

With the average hardware life cycle at 5+ years, it is now time to replace our HP Gen 7 blade and standalone servers. Reduced maintenance time and improved performance makes this an ideal time to start a hardware refresh on these servers. The most critical on this list would include Gen 7 blade servers that support many of the business Ops resources utilized by the Controls group for day-to-day operations and IT test/development.

IT will continue to cycle the latest hardware into our most critical environment with the goal to improve the availability, reliability and serviceability our computing infrastructure. IT would like to replace four Gen 7 blade servers with two Gen 9 high performance blade servers that will be used to boost our virtual server capacity in the APS Web Server RHEV Cluster environment. IT also has five Gen 7 standalone servers that need to be replaced under the guidelines of a standard hardware refresh primarily used to troubleshoot network issues and Splunk log collection.

IT has begun to start deploying Red Hat 7.x (physical/virtual) servers into our Business Operations production environments for all new server builds wherever possible. Red Hat's recommended path for moving from Red Hat Linux 6.x to 7.x is a new install so there will be an overlap between Red Hat 6.x and 7.x server services as we transition between operating systems. Upgrading to Red Hat 7.x is a top priority for our Linux team which requires additional server capacity to achieve to initiative.

IT also needs to address our Ops Server backup storage capacity. The HP MSL6480 modular tape library that was implemented in fall of 2015 is current operating at full capacity with limit room for growth. Storage Life Cycle policy current stage backups directly to disk for a time period of one month before de-staging backups to LTO 6 tape backup for two more months of storage before the backup policy expires. IT doesn't currently have enough tapes in our tape storage pool successfully cycle through from disk to tape without interruptions. We need to add enough additional tape capacity to allow us to cycle through tapes during a three-month retention period without interruptions. Adding another tape backup module, two LTO 6 tape drives and 80 more tapes would provide enough additional capacity would accomplish this goal.

The consequences of not completing this project are:

- Gen 7 hardware is 5 -6 years old increase maintenance cost and time
- Concern about Red Hat 7 compatibility with Gen 7 hardware; not all features available
- Not starting this hardware refresh will increase the cost later
- Not enough backup resources to reliable meet the current backup capacity

TABLE 4.1 Obsolete Hardware Projects

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
Replace Beamline and Backup Storage	4	4	8	185	150	150	150	150
X-ray Tape Library Hardware	4	4	8	75	75	50	50	50
Beamline Network Core Upgrade	2	2	4	100	100	100	100	100
Beamline Network Switch Upgrades	2	2	4	100	100	100	100	100

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
Eleven Hadoop Nodes	4	4	8	80	80	80	80	80
Replace Voltaire Infiniband Switch	4	4	5	66	60	0	0	0
Experiment Floor/LOM Wireless Network	2	4	7	230	50	50	50	50
Upgrade X-ray Blade Chassis Modules	4	3	7	50	50	50	50	50
Accelerator Wireless Network	4	3	7	98	50	0	0	0
Business Operations Windows Servers	4	4	8	325	300	300	300	300
Business Operations Linux Servers	4	4	8	94	80	80	80	80
CLO/Conference Wireless Upgrade	4	4	8	128	50	0	0	0
TOTAL				**1,531**	**1,095**	**960**	**960**	**960**

4.5 Infrastructure Development Plan

None identified

4.6 R&D Projects in Support of Improvement and Upgrades to APS Hardware

None identified

4.7 R&D Projects in Support of New or Improved Capabilities of the APS and APS Upgrade

None identified

4.8 R&D Projects in Support of a Future Light Source

None identified

4.9 Personnel Development Plan

- **Promotion**
  - FY17 – 1
  - FY18 – 1
  - FY19 – 1
  - FY20 – 1
  - FY21 – 1

- **New hire**
  - FY17 – 0
  - FY18 – 0
  - FY19 – 0
  - FY20 – 1
  - FY21 – 1

- **Education (graduate, co-op or summer students)**

- FY17 – 2
- FY18 – 2
- FY19 – 2
- FY20 – 2
- FY21 – 2

4.10 Staffing Summary

Function that Role Supports	FY17	FY18	FY19	FY20	FY21	Comments
Operations, maintenance, obsolescence and infrastructure	20	20	20	20	20	
Operations upgrades and improvements	0	0	0	0	0	
APS-U support	1	1	2	3	3	
R&D support	0	0	0	0	0	
TOTAL	**21**	**21**	**22**	**23**	**23**	

LDRD projects

None identified

Work for Others (Strategic Partnership Projects) projects

None identified

5. AES Mechanical Engineering & Design (MED) Group (including Survey & Alignment Section) – Five-Year Development Plan

5.1 Mission

The MED Group provides highly-specialized mechanical engineering, precision metrology, measurement and alignment services, and analysis and design services for experimental and accelerator facilities. MED effort is strongly focused on engineering for the APS Upgrade project for the duration of this five-year plan.

5.2 Operation Responsibilities

- Design engineering and fabrication for beamline and accelerator projects
- Survey, fiducialization, and alignment of beamlines and accelerators
- Engineering support for insertion devices and magnetic measurements
- Vacuum systems design for beamlines and accelerator improvements
- Manufacturing engineering for mechanical engineering projects and operations
- Vibration analysis, measurement, and mitigation for system designs
- Engineering R&D in support of XSD and ASD priorities
- Engineering and fabrication for strategic partnerships
- Pressure safety leadership

5.3 Major (non-recurring) Purchase of Spares and Replacement of "End-of-Lifetime" Equipment

- **Replace Obsolete Laser Trackers**

Laser trackers are essential for precision alignment of accelerator components. We continue to use hardware that is more than 20 years old. It is not as accurate or as easy to operate as currently available hardware and is subject to failure at critical times. APS should embark on a program to replace one laser tracker each year for the next three years.

For the first year a smaller, less expensive, and less capable laser tracker can be acquired. APS-U purchased one tracker in FY 2016. This instrument will be permanently moved to the proposed assembly facility. There is no plan to purchase any additional units but use rentals for all future APS-U needs.

TABLE 5.1 Spares and Replacement of End-of-Life Equipment

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
Replace Obsolete Laser Trackers	4	4	8	80	140	140	0	0
TOTAL				**80**	**140**	**140**	**0**	**0**

5.4 Obsolete Hardware Replacement

- **Replace obsolete PCMM**

  Replace obsolete FaroArm with a new articulating arm portable coordinate measurement machine (PCMM) in FY 2017. Our current PCMM was purchased in 2007. Since that time the accuracy and efficiency of these devices has advanced significantly. In addition to the technical advances, a larger measurement volume device (longer reach) and higher accuracy will improve efficiency in the inspection, measurement and alignment of accelerator and experimental components (Accelerating structures straightening project).

TABLE 5.2 Obsolete Hardware Project

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
Replace obsolete PCMM	4	3	7	70	0	0	0	0
TOTAL				**70**	**0**	**0**	**0**	**0**

5.5 Infrastructure Development Plan

- **Portable Coordinate Measuring Machine (PCMM)**

  An additional PCMM is needed for the EAA cleanroom to expand the capabilities and improve efficiency in QA and fiducialization of accelerator and beamline components. The number of components to fiducialize will be increasing and this equipment will be necessary to be able to keep up.

TABLE 5.3 Infrastructure Development

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
PCMM	3	3	6	0	70	0	0	0
TOTAL				**0**	**70**	**0**	**0**	**0**

5.6 R&D Projects in Support of Improvement and Upgrades to APS Hardware

MED does not currently envision any R&D in support of improvements and upgrades to APS hardware but will contribute to improvements and upgrades promoted by other groups and divisions when mechanical engineering is required.

5.7 R&D Projects in Support of New or Improved Capabilities of the APS and APS Upgrade

- **Additive Manufacturing R&D**
  Continue to develop systems useful to the APS after additive manufacturing LDRD produces useable results.

- **X-Ray Sample Systems Development**

APS management provides beamtime to carefully scrutinized researchers to perform their unique experiments and the users bring samples in many varieties and in different physical forms. APS beamlines that utilize various kinds of samples must maintain a wide range of sample holders and mounts. Currently, these beamlines (such as small angle x-ray scattering) have limited options to mount their samples. Usually, the users have only a few choices from generic sample mounts from the available pool for selection. These sample holders and sample mounts are extremely useful; however, it is time consuming to work with them.

The proposed project will seek requests from beamlines to adapt to their sample holder needs. The project team will design sample-mounts using magnets, magnetic devices, kinematic mounts, and push and pop assembly, often utilizing 3D printing for rapid access and for unique geometries. Moreover, each sample paddle/cassettes/holder can be equipped with sensors such as a photo diode, thermocouple or thermistor, strain gage etc. that can be incorporated with a data acquisition system to check environment conditions, alignment, and send status notes that can be utilized during unattended operation. We propose developing and incorporating such systems for the beamlines at the APS and it will require a small investment in comparison to the benefits in beamline throughput.

- **Acoustic Levitator Sample Chamber**

We are proposing to further develop the capabilities of the acoustic levitation by building a chamber that can surround the levitator to allow the researcher to do experiments at variable pressures. Such a chamber will provide excellent environmental control to do biological or high-temperature research in inert as well as reactive gas environments.
It will benefit a wide variety of users and scientific communities present at the APS from materials science and photochemistry to structural biology. This is well within the mission statement of APS and time-resolved research community, which has a specialized and diverse community to take full advantage of such systems.
Enter summary text here of rationale / reason to perform project and intended benefits.

TABLE 5.5 R&D for New and Improved Capabilities

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
Additive Manufacturing	1	2	3	0	0	0	0	75
X-Ray Sample Systems Development	2	3	5	0	50	50	50	25
Acoustic Levitator Sample Chamber	2	3	5	0	50	75	75	50
TOTAL				**0**	**100**	**125**	**125**	**150**

5.8 R&D Projects in Support of a Future Light Source

None identified

5.9 Personnel Development Plan

- **Promotion**
  - FY17 – 4 (RD5, RD4, RD3, RD2,)

- FY18 – 4 (RD4, RD5, RD3, Promote SA tech to RD1)
- FY19 – 3 (RD2, RD2, RD3)
- FY20 – 3 (RD3, RD3, RD4, RD4)
- FY21 – 4 (RD4, RD3, RD2)

- **New hire**
  - FY17 - 1 (Postdoc (accepted), RD1 Already hired)
  - FY18 - 2 (Postdoc, SA Tech)
  - FY19 – 2 (RD1, SA Tech)
  - FY20 – 2 (RD2, SA Tech)
  - FY21 – 0

- **Education (graduate, co-op or summer students)**
  - FY17 – 4
  - FY18 – 4
  - FY19 – 4
  - FY20 – 4
  - FY21 – 4

5.10 Staffing Summary

Function that Role Supports	FY17	FY18	FY19	FY20	FY21	Comments
Operations, maintenance, obsolescence and infrastructure	13.9	13.9	14.9	15.9	15.9	Increase operations support 0.5 FTE in FY19 Increase SA techs to train in prep for APSU
Operations upgrades and improvements	0.5	1.5	2.5	3.5	3.5	Increasing support for APS-U Operations readiness
APS-U support	14.5	14.5	14.5	14.5	14.5	Assume level APSU support
R&D support	0.75	2.25	2.25	2.25	2.25	Hire postdoc in FY17 and second in FY18
TOTAL	**29.7**	**32.2**	**34.2**	**36.2**	**36.2**	

LDRD projects

1. Sample Manipulation via Acoustic Levitator

MED proposed to develop acoustic levitator based sample manipulation systems that can provide a variety of methods of contamination-free and container-less experimental apparatus. An acoustic levitator can levitate nanoliter to milliliter volume droplets that can be loaded into the multiple nodes of an acoustic standing wave and a single droplet is held stable in a node. Piezo-actuated nozzles are used to generate a variety of droplet sizes and the droplet array can be advanced vertically on demand by phase shifting the acoustic wave. Thus, displacing the position of each node uniformly and maintaining synchronization with the x-ray source. The funding for the proposed work in FY17 was secured through an LDRD that is helping us to achieve a conveyer belt type manipulation of a train of droplets and a continuation in FY18 will be sought.

Description	FY17	FY18	FY19	FY20	FY21
Sample Manipulation via Acoustic Levitator					
FTEs	0.2	0.2	0	0	0
M&S ($k)	0	0	0	0	0
Effort ($k)	21	21	0	0	0
TOTAL ($k)	**21**	**21**	**0**	**0**	**0**

2. Additive Manufacturing R&D

Recent advances in 3D printing technology have opened up many ways of producing complex parts using novel materials that were not possible a decade back. The simplest example is the 3D printed sample holder for Small Angle X-ray Scattering. This designed and printed sample holder using 3D printing technology is not possible to produce using a conventional metal working method. 3D printed sample holders are being used at sector 9 and the biggest challenge the users are facing is that the sample holder is transparent to the X-rays and that makes it difficult to see in radiography mode. The proposed work will utilize photopolymer and nanomaterials to produce an X-ray absorbent 3D printing polymer. The material that is developed will be used to produce 3D printed sample holders that will absorb X-rays. The development of photopolymerized nanocomposite-ink requires the basic understanding of photopolymerization chemistry and nanomaterials. We have a tabletop 3D printer that can print CAD models utilizing UV light. The project will utilize a student's help to produce various nanocomposite ink material and characterize resulting materials.

For biological applications, we are exploring materials and techniques of producing 3D material ink/thermoplastic polymer composites with electrolytes and biomolecules that can provide breeding sites for biological tissue to grow and arrange in a bottom-up manner. The biological samples such as proteins, bacterial cultures, peptides, DNA etc. can be embedded in a 3D-printed petri-dish or sample holder. The printed parts with such biomaterial-composites can be utilized for various purposes and their uses are not only limited to X-ray characterization. There are many possibilities and avenues that X-ray scientific community can benefit, especially where small quantity samples are needed.

Similarly, in 3D metal printing, nanomaterial is under consideration for producing high strength alloy materials. However, not many research publications or commercial products are in the public domain. This technology will be very crucial to producing the lightweight structures that will be useful in producing prosthetic skeleton structures to space exploration parts. ANL has started an initiative in this area, which mostly deals with after-production characterization. There is a wide range of scientific, applied science, and engineering challenges associated with 3D-metal-printing technology. AES can play a large part in material processing, optimization of process, optimization of structure, and providing support to the user community in physical or mechanical characterization 3D-metal-printed parts and specimens.

MED is proposing to start research in the above three areas where APS's user community, department of homeland security, and biological research community can benefit.

Description	FY17	FY18	FY19	FY20	FY21
Additive Manufacturing					
FTEs	0	1.2	1.2	1.2	0
M&S ($k)	0	100	150	100	0
Effort ($k)	0	193	193	193	0
TOTAL ($k)	**0**	**293**	**343**	**343**	**0**

3. Reduction of Thermal and Photon Stimulated Gas Desorption in Compact Accelerator Vacuum Chambers

The proposed research is to precisely measure the thermal and photon-stimulated outgassing from a variety of vacuum chamber materials, many of which will be coated or otherwise treated to reduce outgassing. These measurements will accomplish two things. First, they will determine whether or not new surface treatment technologies recently developed at Argonne can be expected to reduce outgassing behavior of vacuum chamber materials. Second, the measurements will provide more reliable outgassing measurements for use in accelerator vacuum system simulations. A proposal has been made for FY17 and the work will be extended into FY18 in a future proposal.

Description	FY17	FY18	FY19	FY20	FY21
Reduction of Thermal and Photon Stimulated Gas Desorption in Compact Accelerator Vacuum Chambers					
FTEs	0.1	0.5	0	0	0
M&S ($k)	20	80	0	0	0
Effort ($k)	16	85	0	0	0
TOTAL ($k)	**36**	**165**	**0**	**0**	**0**

4. Nanobonding

Metal nanoparticles can melt at significantly lower temperatures than the bulk metal. They are highly reactive due to their high surface-to-volume ratios; therefore, they can be reacted to produce compounds with other bonding materials without extensive chemical processing. For example, Nano-thermite materials such as a mixture of Aluminum and Nickel/Copper oxide nanoparticles can produce a very high temperature and can be reacted in vacuum. These properties of nanomaterials can be utilized for bonding. The resulting bonds will be thermally efficient, structurally sound, and with minimal residual thermal stresses in the bulk material. The assimilated nanoscale materials will assume properties of the bulk material, including its higher melting temperature.

The accelerator physics community requires bonding of dissimilar materials with thermally efficient, structurally sound, and strain-free bonds for many next-generation accelerator systems. Non-metallic materials, such as Quartz, Si, SiC, GaN, Si3N4, AlN, Fe2O3, etc. are often required to be bonded to metals. These ceramic/nonmetallic materials typically have low CTEs while the metallic structures that house them and act as heat sinks typically have high CTEs. Bonding of ceramics to metallic base/housings poses major challenges in the fabrication of many high-power accelerator and front-end components, including high-heat-load windows and absorbers, feedthroughs, and switches.

Description	FY17	FY18	FY19	FY20	FY21
Nanobonding					
FTEs	0.75	1.2	0	0	0
M&S ($k)	35	100	0	0	0
Effort ($k)	170	200	0	0	0
TOTAL ($k)	**205**	**300**	**0**	**0**	**0**

Work for Others (Strategic Partnership Projects) projects

1. LCLS II Vacuum Chamber project

This is a commitment of the APS to DOE to support the LCLS II project. It benefits the APS by maintaining our leading role in the design and fabrication of small gap chambers and developing capability for a future FEL at Argonne

Description	FY17	FY18	FY19	FY20	FY21
LCLS II Vacuum Chamber Project					
FTEs	0.5	0.8	0	0	0
M&S ($k)	0	0	0	0	0
Effort ($k)	62	99	0	0	0
TOTAL ($k)	**62**	**99**	**0**	**0**	**0**

2. Advanced Integrated Storage Ring Vacuum Design Software SBIR

APS participated in the completion of a Phase 1 SPIR. A proposal has been submitted by Radiasoft, which includes AES/MED participation. This project benefits APS by being responsive to the program direction of the DOE SBIR office and by helping to develop the next generation of tools for storage ring vacuum design.

Description	FY17	FY18	FY19	FY20	FY21
Advanced Integrated Storage Ring Vacuum Design Software SBIR					
FTEs	0.5	0.5	0	0	0
M&S ($k)	0	0	0	0	0
Effort ($k)	42	42	0	0	0
TOTAL ($k)	**42**	**42**	**0**	**0**	**0**

6. AES Mechanical Operations & Maintenance (MOM) Group (including Vacuum Section) – Five-Year Development Plan

6.1 Mission

The MOM Group provides support for APS accelerators and beamlines during operations and maintenance periods that help the APS achieve its goals for high reliability, high availability, and long mean time between failures. The Group supports design and installation services for vacuum, water and mechanical systems as it relates to machine improvement, APS-Upgrade, accelerator R&D and APS research goals.

6.2 Operation Responsibilities

- Monitoring the mechanical, vacuum, and water systems, of accelerators, beamlines, and front ends
  Provide 24/7 response to downtime incidents
- Routine maintenance and emergency repairs
- Maintain a spare parts inventory for mechanical, vacuum, and water systems
- Provide engineering and technician support to APS technical groups and beamlines
- Assist in the design and installation of accelerator, front end, and beamline upgrades
- Providing services for UHV vacuum fabrication, cleaning, assembly and commissioning to the APS community
- Supporting accelerator R&D, the APS-Upgrade, and APS research goals
- Work for other - provide services for organizations outside of APS (as time permits)

6.3 Major (non-recurring) Purchase of Spares and Replacement of "End-of-Lifetime" Equipment

- **DI H2O Control System for SR sect 1 & 2**

  Replace obsolete Johnson Controls equipment, wiring, field devices as necessary. Company no longer support the current hardware/software, hence component failure may result in extended machine downtime.

- **DI H2O Control System for SR sect 39 & 40**

  Replace obsolete Johnson Controls equipment, wiring, field devices as necessary. Company no longer support the current hardware/software, hence component failure may result in extended machine downtime.

- **DI H2O Control System for Injectors**

  Replace obsolete Johnson Controls equipment, wiring, field devices as necessary. Company no longer support the current hardware/software, hence component failure may result in extended machine downtime.

- **Spare PC Gun Water System**

One skid available to provide water to either PC gun or ITS room. Build and install separate water system for ITS room. This system may also serve as a spare for the PC Gun.. Failure of existing system may result in extended machine downtime.

- **FE Instrumentation Reliability Upgrade (Project #)**

  Replace existing aging differential pressure transmitters with Yokogawa transmitters, the APS standard component.

TABLE 6.1 Spares and Replacement of End-of-Life Equipment

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
DI H2O Control System for SR sect 1&2	3	3	6	0	35	0	0	0
DI H2O Control System for SR sect 39&40	3	3	6	0	0	35	0	0
DI H2O Control Sys Injectors	3	3	6	0	0	0	80	0
Spare PC Gun Water System	3	3	6	0	0	0	0	0
FE Instrumentation Reliability Upgrade	3	3	6	40	40	40	40	40
TOTAL				**40**	**75**	**75**	**120**	**40**

6.4 Obsolete Hardware Replacement

- **Booster DI Water Valves Replacement**

  Existing 2” valves no longer seal when turned off due to radiation damage to the valve seals. Any repair work to machine components requires draining of entire Booster water system resulting in extended downtime and waste of expensive DI water.

- **Replace valves in the Linac and PAR**

  Existing 2” valves no longer seal when turned off due to radition damage to the valve seals. . Any repair work to machine components requires draining of entire tunnel water system resulting in extended downtime and waste of expensive DI water.

- **DI Water Resin Replacement**

  Maintaining DI water resistivity is crucial for operation of the accelerator and longevity of its components. Current resin will increasingly require more frequent service due to old age. Resulting in increased spending for both effort and M&S to maintain quality of the systems.

- **Replace PLC5 Control Systems**

  Replacement of aging A-B PLC-5 PLC system with A-B Controllogix (or similar) system: The current Allen-Bradley secondary process water temperature controls for both the copper water and the aluminum vacuum chamber water are being done by an aging PLC-5 system. There have been failures of several modules. The cost of replacement modules is increasing

and some modules replacement parts are not available. To increase beam reliability, the PLC-5 systems need to be replaced.

- **Replace Vacuum Equipment – Booster**

  Booster vacuum equipment such as ion pumps, controllers and gauges are over 20 years old. Vacuum gauges are outdated and no longer provide accurate vacuum diagnostics. Replacement of these equipment will improve vacuum quality, enable more accurate vacuum diagnostics and prepare us to meet the APS-U with a more robust vacuum system for the next 20 years.

- **Replace Vacuum Equipment – LINAC**

  LINAC vacuum equipment such as ion pumps, controllers and gauges are over 20 years old. Vacuum gauges are outdated and no longer provide accurate vacuum diagnostics. Replacement of these equipment will improve vacuum quality, enable more accurate vacuum diagnostics and prepare us to meet the APS-U with a more robust vacuum system for the next 20 years.

TABLE 6.2 Obsolete Hardware Project

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
Booster DI Water Valves Replacement	3	3	6	0	36	36	0	0
Replace valves in the Linac and PAR	3	3	6	0	25	0	0	0
DI Water Resin Replacement	3	4	7	0	40	40	40	0
Replace PLC5 Control Systems	3	3	6	75	75	50	0	0
Replace vacuum equipment – Booster	3	3	6	300	0	0	0	0
Replace vacuum equipment – LINAC	3	3	6	0	200	0	0	0
TOTAL				**375**	**376**	**126**	**40**	**0**

6.5 Infrastructure Development Plan

- **Booster DI H2O System Modifications (Project #)**

  2-6” headers from separate pumping ststions supply DI water to the booster. The current headers configuration create unstable pressure conditions which may cause equipment damage. Isolation valves in this configuration no longer closes in the off position due to radiation damage to the valve seals. Work involves replacing valves and installing pipe blank offs.

- **SR Power Supplies Water Isolation Valves (Project #)**

New valves are required because existing valves are in difficult to access locations. In case of a leak it will take a long time to isolate the water leak potentially resulting in major electrical equipment damage and extended downtime (from a few hours to days).

TABLE 6.3 Infrastructure Development

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
Booster DI H2O System Modification	3	4	7	24	0	0	0	0
SR Power Supplies Water Isolation Valves	3	4	7	30	30	30	0	0
TOTAL				**54**	**30**	**30**	**0**	**0**

6.6 R&D Projects in Support of Improvement and Upgrades to APS Hardware

- **VFD Elec Bypass for Injection Pumps**

  Install variable frequency drive electrical bypass for pumps serving the Linac, PAR. New system will significantly reduce downtime in the event of VFD failure.

- **VFD Elec Bypass for SR Pumps**

  Install variable frequency drive electrical bypass for pumps serving SR sectors 1, 2 and EAA. New system will significantly reduce downtime in the event of VFD failure.

- **VFD Elec Bypass for RF Pumps**

  Install variable frequency drive electrical bypass for pumps serving RF water systems. New system will significantly reduce downtime in the event of VFD failure.

- **SR Vacuum Chamber Water Skid Control Valves Replacement**

  The control valves on the SRVC water stations are found to be worn and are likely due to 20 plus years of service. Temperature stability is directly related to beam stability. A small upset in the water temperature causes a change in the vacuum chamber position that can be detected by the beam position monitors. These valves are electronically operated and some failures have occurred affecting machine reliability.

TABLE 6.4 Hardware Improvements and Upgrades

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
VFD Elec Bypass for Injection Pumps	3	3	6	0	40	0	0	0
VFD Elec Bypass for SR Pumps	3	3	6	0	25	0	0	0
VFD Elec Bypass for RF Pumps	3	3	6	51	0	0	0	0

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
SR Vacuum Chamber Water Skid Control Valves Replacement	3	3	6	30	30	0	0	0
TOTAL				**81**	**95**	**0**	**0**	**0**

6.7 R&D Projects in Support of New or Improved Capabilities of the APS and APS Upgrade

Enter a bulleted list of projects with brief descriptions of the effort and benefits below, that are identified as R&D projects that are recommended to enhance and improve the performance and capabilities of the APS in support of the APS Upgrade.

- **Reduction of pump and flow induced vibration**

  APS-U will be many times more sensitive to vibration. Test different pump types and vibration reduction devices.

- **Upgrade building 382**

  To support the APS-U with their 700 new vacuum chambers and to continue support of the current APS aging vacuum equipment, vacuum cleaning and certification equipment in Building 382 needs to be refurbished or replaced.

- **Replace leak detectors**

  Replacement of aging leak detectors and pumping carts.

- **Vacuum Oven**

  Replace or refurbish UHV oven due to aging.

TABLE 6.5 R&D for New and Improved Capabilities

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
Reduction of pump and flow induced vibration	3	3	6	0	100	60	0	0
Upgrade Building 382	3	4	7	100	300	300	100	100
Replace leak detectors	3	4	7	100	100	100	100	100
Vacuum Oven	3	3	6	0	600	0	0	0
TOTAL				**200**	**1100**	**460**	**200**	**200**

6.8 R&D Projects in Support of a Future Light Source

- **Welding R&D for L-Bend vacuum chamber**

A new vacuum chamber for the bending magnets is needed and can be welded on the automated welders in building 382. Development and testing is needed.

- **APS-U Sector Mock Up**

  A full sector mock up is to be created to prove that all components can be manufactured and that vacuum can be maintained under various conditions.

- **Chamber testing**

  New vacuum chambers are needed for the upgrade. New designs need to be vacuum tested and certified.

- **Production of new light source**

  The fabrication of 200 new vacuum chamber and the certification of 700 vacuum chambers in Building 382.

- **Pumping Systems for new light source**

  Modifications to the existing water systems to accommodate future light sources flow requirements.

The majority the projects with the exception of the last item above are supported by the APS Upgrade project, but are listed here for completeness.

TABLE 6.6 R&D Projects in Support of a Future Light Source

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
Welding R&D	3	3	6	200	200	200	100	0
APS-U sector mock up	3	4	7	200	200	0	0	0
Chamber testing	4	4	8	200	100	100	0	0
Production of new light source	4	4	8	0	200	400	400	400
Pumping Systems for new light source	3	3	6	0	0	100	50	50
TOTAL				**600**	**700**	**800**	**550**	**450**

6.9 Personnel Development Plan

- **Promotion**
  - FY17 – 1
  - FY18 – 1
  - FY19 – 1
  - FY20 – 1
  - FY21 – 1

- **New hire**
  - FY17 - 0
  - FY18 - 1
  - FY19 - 1
  - FY20 - 2
  - FY21 - 0

- **Education (graduate, co-op or summer students)**
  - FY17 – 1
  - FY18 – 1
  - FY19 – 1
  - FY20 – 1
  - FY21 – 0

6.10 Staffing Summary

Function that Role Supports	FY17	FY18	FY19	FY20	FY21	Comments
Operations, maintenance, obsolescence and infrastructure	27	27	27	27	26	
Operations upgrades and improvements	1	2	2	2	2	
APS-U support	2	2	3	5	6	
R&D support	1	1	1	1	1	
TOTAL	**31**	**32**	**33**	**35**	**35**	

Work for Others (Strategic Partnership Projects) projects

1. LCLS Vacuum Chambers

LCLS work for others includes fabricating and certification of vacuum chambers. Two Adjunct Technicians were hired in FY16 to support this work.

Description	FY17	FY18	FY19	FY20	FY21
LCLS Vacuum Chambers					
FTEs	2.8	2.25	2	2	0
M&S ($k)	100	25	0	0	0
Effort ($k)	200	50	0	0	0
TOTAL ($k)	**300**	**75**	**0**	**0**	**0**

7. AES Safety Interlocks (SI) Group – Five-Year Development Plan

7.1 Mission

The AES/Safety Interlocks Group is responsible for developing, implementing, and supporting primarily PLC-based interlock systems for personnel access control and equipment protection of the APS accelerators and beamlines, specifically ACIS, PSS, BLEPS and FEEPS. Coordinate and provide oversight for work performed on radiation safety systems, movable and stationary.

7.2 Operation Responsibilities

- Access Control Interlock System (ACIS) for the Accelerator. Perform DOE mandated annual validations and perform maintenance/operational enhancements of 8 subsystems on ~5500 accelerator I/O field points that enable and monitor 43 sets of controlled equipment in a geographically large area.

- Front End Equipment Protection Systems (FEEPS). Maintaining over 5000 field I/O points on 63 systems and verify every ~5 yrs. Upgrade systems when funding is available

- Personnel Safety Systems (PSS) for Beamlines. Perform maintenance, upgrades and DOE mandated annual validations on 57 redundant systems, monitoring ~20,000 field I/O points that enable and monitor controlled equipment.

- Beamline Equipment Protection Systems (BLEPS). Installed and maintain 13 standardized ControlLogix PLC based systems, maintain 7 more but help with many others.

- Radiation Safety System Engineers (RSSE). Coordinate and oversee ALL work on radiation safety devices

7.3 Major (non-recurring) Purchase of Spares and Replacement of "End-of-Lifetime" Equipment

None identified

7.4 Obsolete Hardware Replacement

- **ACIS Upgrade**

The ACIS utilizes 1985 vintage redundant Allen Bradley PLC's for monitoring and control of RSS equipment, and these are now obsolete. A new, modern system following the latest DOE orders and latest industrial standards must be developed to reliably support the new upgraded accelerator.

A prototype has been designed and implemented in the LINAC Extension Area (LEA) for proof of concept in FY16. The next 5 years will be spent designing, procuring, assembling and testing the complete replacement of the ACIS in the LINAC, PAR, Booster and Storage Ring. This upgrade will be installed during the 1-year dark period of the APS Upgrade

project. This system is too complicated and the scheduled shutdowns too short to install one system at a time.

- **FEEPS Upgrade**

  Like the ACIS, FEEPS utilizes 1985 vintage Allen Bradley PLC's for monitoring and control of FE equipment, and these are now obsolete. This request will replace the FEEPSs not being replaced by the APS Upgrade project.

- **PSS Upgrades**

  Like the ACIS and FEEPS, PSS utilizes 1985 vintage Allen Bradley PLC's for monitoring and control of beamline RSS equipment, and these are now obsolete.

  Additionally, the GE remote I/O blocks are obsolete and must be replaced. This request designs the new system for implementation into new beamlines and will be used to replace the existing PSSs.

- **BLEPS Upgrade**

  The BLEPS at beamlines 1-ID, 1-BM, 2-ID, 2-BM, 4-ID, 6-BM, 31-ID utilize 1985 vintage Allen Bradley PLC's for monitoring and control of RSS equipment, and these are now obsolete. A new, modern system following the latest DOE orders and latest industrial standards must be developed to reliably support these beamlines. This upgrade will be requested to be funded by XSD due to its direct support of beamline operation.

TABLE 7.1 Obsolete Hardware Projects

Description	C	P	Risk	FY17 ($k)	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)
ACIS Upgrade	3	4	7	100	100	100	350	200
FEEPS Upgrade	3	4	7	0	100	100	100	100
PSS Upgrade	3	4	7	0	75	0	0	0
BLEPS Upgrade	3	4	7	0	0	0	0	0
TOTAL				**100**	**275**	**200**	**450**	**300**

7.5 Infrastructure Development Plan

None identified

7.6 R&D Projects in Support of Improvement and Upgrades to APS Hardware

None identified

7.7 R&D Projects in Support of New or Improved Capabilities of the APS and APS Upgrade

None identified

7.8 R&D Projects in Support of a Future Light Source

None identified

7.9 Personnel Development Plan

- **Promotion**
  - FY17 – 1 (RD4 to RD5)
  - FY18 – 2 (RD2 to RD3)
  - FY19 – 0
  - FY20 – 0
  - FY21 – 0

- **New hire**
  - FY17 - 2 (Tech replacement for L. Roberts, RD2 replacement for J. Bombard)
  - FY18 - 0
  - FY19 - 0
  - FY20 - 0
  - FY21 – 3-4 (1 Adjunct Engineer and 3 Adjunct Techs for ACIS Upgrade)

- **Education (graduate, co-op or summer students)**
  - FY17 – 0
  - FY18 – 0
  - FY19 – 0
  - FY20 – 0
  - FY21 – 0

7.10 Staffing Summary

Function that Role Supports	FY17	FY18	FY19	FY20	FY21	Comments
Operations, maintenance, obsolescence and infrastructure	15	15	15	15	15	
Operations upgrades and improvements	3	3	3	3	3	

Function that Role Supports	FY17	FY18	FY19	FY20	FY21	Comments
APS-U support	2	3	3	3	3	
R&D support	0	0	0	0	0	
TOTAL	**21**	**22**	**23**	**23**	**23**	

LDRD projects

None identified

Work for Others (Strategic Partnership Projects) projects

None identified

References:

1. DOE/CF-0067, "United States Department of Energy Strategic Plan 2014-2018", available via https://www.energy.gov/sites/prod/files/2014/04/f14/2014_dept_energy_strategic_plan.pdf

2. The Advanced Photon Source Five-Year Facility Plan, March 31, 2015 (next revision pending), available via https://www1.aps.anl.gov/files/download/APS/APS%205-year%20plan%20033115%20FINAL.pdf

3. Accelerator Systems Division Four-Year Development Plan, revised August 18, 2015

4. X-ray Sciences Division Strategic Plan, December 2015