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

April 2018

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 FY2018 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	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
VME Crate Power Supplies	2	2	4	22	22	0	0	0

Description	C	P	Risk	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
DG535 Timing Generators	3	2	5	30	30	0	0	0
Custom VME Module Spares	3	2	5	10	10	10	10	0
VM Cluster for control system	2	2	4	0	0	40	0	0
Database Servers	2	2	4	15	0	0	0	0
Insertion Device Control System Spares	3	2	5	30	50	30	0	0
Replace Adobe Flex SDK	4	4	8	96	96	0	0	0
Replace Oracle SQR module	4	4	8	0	64	48	0	0
Replace Obsolete Laser Trackers	4	4	8	159	159	159	0	0
DI H2O Pump Control System for SR Sectors 1&2	3	3	5	35	0	0	0	0
DI H2O Pump Control System for SR Sectors 39&40	3	3	5	0	35	0	0	0
DI H2O Pump Controls for Injectors (Linac gallery, Linac tunnel, PAR, Booster)	3	3	5	35	35	35	70	0
DI H2O Pump Control Storage Ring RF Systems	3	3	5	0	40	40	0	0
PC Gun Water System	3	3	5	0	25	0	0	0
FE Instrumentation Reliability Upgrade	3	3	5	60	60	65	65	0
TOTAL				**470**	**604**	**427**	**145**	**0**

TABLE 2 Obsolete Hardware Projects

Description	C	P	Risk	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
Extending Lifetime of non-APSU systems	4	4	5	0	50	50	50	50
Computer Obsolescence	2	1	3	60	60	60	60	60
Printer / Scanner	1	1	2	5	5	0	0	0
Upgrade Oracle Web Content Servers	4	4	8	20	90	20	100	0
Upgrade Sencha Ext JS JavaScript Framework	3	3	6	10	10	10	10	0
Upgrade Oracle Database and WebLogic Server	4	4	8	64	0	80	0	0
Oracle License Management	4	4	8	0	75	0	0	0
Increase NetApp Storage System Capacity	4	4	8	130	130	130	130	130
X-ray 3Par Storage and Windows Servers	3	3	8	120	120	120	120	120
Beamline Network Core Switch Upgrade	4	4	4	200	200	200	200	200
Upgrade Orthros DTN Storage System	4	4	4	175	100	100	100	100
Replace DDN Storage System	3	4	8	396	100	100	100	100

Description	C	P	Risk	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
Experiment Floor/LOM Wireless Network	2	4	5	391	0	0	0	0
Upgrade APS Tier 2 Firewall to 40 Gbps	4	4	7	200	100	100	100	100
Accelerator Control NetApp Storage	4	3	7	80	80	80	80	80
Booster DI Water Valves Replacement	3	3	5	36	36	0	0	0
DI Water Resin Replacement	2	2	5	42	44	0	0	0
Replace PLC5 Control Systems	3	3	6	112	56	0	0	0
LINAC Gallery and Klystrons Vacuum Systems Upgrade	2	2	5	214	0	0	0	0
LINAC Cooling Water Skids Upgrade	3	3	5	100	100	100	100	100
DI Water Resistivity Analyzers Replacement	3	3	5	0	25	25	0	0
ACIS Upgrade	3	4	7	40	130	360	100	100
FEEPS Upgrade	3	4	7	90	90	0	0	0
PSS Upgrade	3	4	7	0	0	0	0	0
BLEPS Upgrade (XSD Funded)	3	4	7	0	0	0	0	0
TOTAL				**2485**	**1601**	**1535**	**1250**	**1140**

TABLE 3 Infrastructure Development

Description	C	P	Risk	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
VME crates with redundant power supplies	2	2	4	30	30	0	0	0
LINAC Timing System	3	3	6	0	100	0	0	0
Wet Laboratory Development	1	1	2	35	35	30	0	0
APS Integrated Management System (AIMS)	4	4	8	7	7	7	7	0
Document Management System (DMS)	4	4	8	48	48	20	80	0
Business Intelligence and Data Warehouse	3	3	6	90	90	25	25	0
Integrated Component Management System	3	3	6	0	0	0	0	0
Implementation of Agile and ITIL methodologies	3	3	6	5	25	5	5	0
Web Application Framework	4	4	8	64	64	20	20	0
New Nanomaterials Lab	3	3	6	75	0	0	0	0
PCMM	3	3	6	0	70	0	0	0
SR Power Supplies Water Isolation Valves	3	3	6	30	30	30	0	0
VFD and Controls for DI Water Make-Up Pumps	3	3	6	0	25	0	0	0
TOTAL				**384**	**524**	**137**	**137**	**0**

TABLE 4 Hardware Improvements and Upgrades

Description	C	P	Risk	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
VFD Elec Bypass for Injector Pumps	3	3	5	40	0	0	0	0
VFD Elec Bypass for SR Sectors 1,2 & EAA Pumps	3	3	5	25	0	0	0	0
SR Vacuum Chamber Water Skid Control Valves Replacement	3	3	5	30	0	0	0	0
Sulfur Hexaflouride (SF6) Recovery System	2	2	5	33	0	0	0	0
TOTAL				**128**	**0**	**0**	**0**	**0**

TABLE 5 R&D for New and Improved Capabilities

Description	C	P	Risk	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
Small Scale Water Jet Cutting	1	1	2	10	3	3	3	3
Large Format FDM Printer	1	1	2	15	10	6	6	6
Scanning Development	1	1	2	5	25	8	8	8
Metal FDM System	1	1	2	40	85	10	10	10
Single Sign-on	2	2	4	0	20	0	0	0
Web Services and API	3	3	6	96	64	10	10	0
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
Reduction of pump and flow induced vibration	3	3	6	100	60	0	0	0
Secondary Process Water Systems Reconfiguration and Upgrade - Copper Systems Serving Magnets, Power Supplies Front Ends Absorbers Beamlines	3	3	6	0	0	0	280	280
Vacuum Chamber Cooling Water Skids	3	4	7	0	0	0	300	300
Bake-out Skids	3	3	6	0	0	0	600	600
Upgrade Building 382	3	4	7	300	300	100	100	0
TOTAL				**566**	**667**	**262**	**1442**	**1357**

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

Description	C	P	Risk	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
Welding R&D*	3	3	6	200	200	100	0	0
APS-U sector mock up*	3	4	7	200	0	0	0	0
Chamber testing*	4	4	8	100	100	0	0	0
TOTAL				**500**	**300**	**100**	**0**	**0**

* = Already supported by the APS-Upgrade project

TABLE 7 Staffing Summary

Function that Role Supports	FY18 (FTE)	FY19 (FTE)	FY20 (FTE)	FY21 (FTE)	FY22 (FTE)
Operations, maintenance, obsolescence and infrastructure	87.9	87.4	86.4	84.4	61.4
Operations upgrades and improvements	15.5	17.5	20	26	27
APS-U support	44	50.5	63	91	103
R&D support	5.75	4.75	3.5	3.5	3.5
TOTAL	**153.2**	**160.2**	**172.9**	**204.9**	**194.9**

TABLE 8 LDRD Projects

Description	FY18	FY19	FY20	FY21	FY22
Sample Manipulation via Acoustic Levitator					
FTEs	0.2	0	0	0	0
M&S ($k)	0	0	0	0	0
Effort ($k)	21	0	0	0	0
Additive Manufacturing					
FTEs	0	1.2	1.2	1.2	1.2
M&S ($k)	0	100	150	100	100
Effort ($k)	0	120	120	120	120
Reduction of Thermal and Photon Stimulated Gas Desorption in Compact Accelerator Vacuum Chambers					
FTEs	0	0.5	0.25	0	0
M&S ($k)	0	0	0	0	0
Effort ($k)	0	100	50	0	0
Nanobonding					

Description	FY18	FY19	FY20	FY21	FY22
FTEs	0	1.2	0	0	0
M&S ($k)	0	100	0	0	0
Effort ($k)	0	200	0	0	0
TOTAL ($k)	**21**	**620**	**320**	**100**	**100**

TABLE 9 Strategic Partnership Projects (Work For Others)

Description	FY18	FY19	FY20	FY21	FY22
LCLS II Vacuum Chamber Project (MED)					
FTEs	1.5	0	0	0	0
M&S ($k)	0	0	0	0	0
Effort ($k)	0	0	0	0	0
LCLS II Vacuum Chamber Project (MOM)					
FTEs	2.25	2	2	0	0
M&S ($k)	25	0	0	0	0
Effort ($k)	50	0	0	0	0
Advanced Integrated Storage Ring Vacuum Design Software SBIR					
FTEs	0.6	0.6	0	0	0
M&S ($k)	0	0	0	0	0
Effort ($k)	0	0	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)	**75**	**0**	**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.

Each year, numerous additional components in use at the APS become harder to maintain due to obsolescence or end-of-life designation. As we look toward the APS Upgrade, several technical subsystems will be decommissioned yet other systems will be expected to lengthen their lifetime to another 20-30 years. Since we now have a preliminary idea of the APS-U requirements, the Controls Group will do a fresh and exhaustive analysis (in FY2018) of obsolete and aging components/subsystems and develop a plan to address the most critical ones in the next five years. Some systems can be properly supported with additional spares (Section 1.3) while other systems will require new technology and re-engineering to sustain them through the expected lifetime (Section 1.4).

1.3 Major (non-recurring) Purchase of Spares or Direct 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 – Replace with Comparable Units**

  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. Very similar instruments (DG645s) will be purchased to replace several of the DG535s, thereby increasing our spare count of the old units and improving the performance of certain subsystems with the new units.

- **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.

- **Database Servers**

  Controls runs several database applications and other high-level engineering tools 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	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
VME Crate Power Supplies	2	2	4	22	22	0	0	0
DG535 Timing Generators	3	2	5	30	30	0	0	0
Custom VME Module Spares	3	2	5	10	10	10	10	0
VM Cluster for control system	2	2	4	0	0	40	0	0
Database Servers	2	2	4	15	0	0	0	0
Insertion Device Control System Spares	3	2	5	30	50	30	0	0
TOTAL				**107**	**112**	**80**	**10**	**0**

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. In these cases, acquiring additional spares is not possible or is insufficient, so proper mitigation will require some re-engineering around new technology. There will be labor resources associated with these replacements because the replacement components are unlikely to be "plug-compatible".

- **Extending the Lifetime of non-APSU Systems that must Remain Functional**

This section addresses those systems which cannot be sustained simply by procuring additional spares. In addition to procuring new technology, re-engineering a portion of the system will be necessary. Detailed plans will be completed in FY2018, so the out years in the table below are rough estimates prior to this exercise.

TABLE 1.2 Obsolete Hardware Projects

Description	C	P	Risk	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
Extending Lifetime of non-APSU systems	4	4	5	0	50	50	50	50
TOTAL				**0**	**50**	**50**	**50**	**50**

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	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
VME crates with redundant power supplies	2	2	4	30	30	0	0	0
LINAC Timing System	3	3	6	0	100	0	0	0

Description	C	P	Risk	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
TOTAL				**30**	**130**	**0**	**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**
  - FY18 – 1 (to RD3) - Complete
  - FY19 – 1 (to RD4 or RD5)
  - FY20 – 2 (to RD4)
  - FY21 – 0
  - FY22 – 1 (unknown)

- **New hire**
  - FY18 – 1 (Additional staff funded by upgrade. May be a contractor)
  - FY19 – 1 (Additional staff funded by upgrade. May be a contractor)
  - FY20 – 1 (Additional staff funded by upgrade. May be a contractor)
  - FY21 – 0
  - FY22 – 0

- **Education (graduate, co-op or summer students)**
  - FY18 – 1
  - FY19 – 1
  - FY20 – 1
  - FY21 – 1
  - FY22 – 1

1.10 Staffing Summary

Function that Role Supports	FY18	FY19	FY20	FY21	FY22	Comments
Operations, maintenance, obsolescence and infrastructure	10	8	8	8	5	
Operations upgrades and improvements	1.5	2	2	2	0	
APS-U support	7	8.5	10	10	15	Add contract hires in FY18, FY19, FY20
R&D support	0.5	0.5	0	0	0	
TOTAL	**19**	**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**

The 840 computers purchased in FY17 show a great improvement in performance from the existing 820's. During FY18 and FY19 the remaining computers will be replaced with this generation of machine.

A new generation of laptops, the HP ZBook, has been released providing a workstation class computer in a 12 inch tablet format, the Surface Pro's will be replaced with these machines as funds become available.

- **Printer / Scanner**

The first generation of printer/scanner combination is reaching end of life, it was purchased 10 years ago and is still on Windows XP since the scanner software cannot be upgraded. The system is still functional but needs to be replaced soon.

TABLE 2.1 Obsolete Hardware Projects

Description	C	P	Risk	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
Computer Obsolescence	2	1	3	60	60	60	60	60
Printer / Scanner	1	1	2	5	5	0	0	0
TOTAL				**65**	**65**	**60**	**60**	**60**

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 renovation of existing space has been proposed, and will be phased in over the next 3 years as funding is available.

TABLE 2.2 Infrastructure Development

Description	C	P	Risk	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
Wet Laboratory Development	1	1	2	35	35	30	0	0
TOTAL				**35**	**35**	**30**	**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. The additional build size provided by these inexpensive machines provides an added capability that would be cost prohibitive in the PolyJet style machines.

- **Metal Printer System**

Metal FDM uses the same technique as plastic FDM, by extruding a binder material mixed with a high concentration of metal powder. This technology uses sintering to provide the final product, removing the binder material extruded during the part creation. This technology has begun to shown promise with a significant increase in the material that it can print, which includes Aluminum 6061 and 2024, Copper, Tungsten Heavy Alloy, Stainless Steel 316L, and low expansion material such as Invar and Kovar, all materials used daily at the laboratory level.

- **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. Investigation into using inexpensive medium range scanners for as-built construction layouts during the upgrade installation is underway.

TABLE 2.3 R&D for New and Improved Capabilities

Description	C	P	Risk	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
Small Scale Water Jet Cutting	1	1	2	10	3	3	3	3
Large Format FDM Printer	1	1	2	15	10	6	6	6
Scanning Development	1	1	2	5	25	8	8	8
Metal FDM System	1	1	2	40	85	10	10	10
TOTAL				**70**	**123**	**27**	**27**	**27**

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

None identified

2.9 Personnel Development Plan

- **Promotion**
  - FY18 – 2 (PT1/2)
  - FY19 – 1 (PT2)
  - FY20 – 1 (PT2)
  - FY21 – 1 (PT2)
  - FY22 – 1 (PT2)

- **New hire**
  - FY18 – 2 Upgrade Support
  - FY19 – 4 Upgrade Support
  - FY20 – 2 Upgrade Support
  - FY21 – 0
  - FY22 – 0

- **Education (graduate, co-op or summer students)**
  - FY18 – 1
  - FY19 – 1
  - FY20 – 1
  - FY21 – 0
  - FY22 – 0

2.10 Staffing Summary

Function that Role Supports	FY18	FY19	FY20	FY21	FY22	Comments
Operations, maintenance, obsolescence and infrastructure	8	8	7	6	6	Decreasing support as projects decrease toward the APS-U dark time.
Operations upgrades and improvements	3	3	3	3	3	
APS-U support	13	15	20	23	23	Increasing support required over the project years.
R&D support	2	2	2	2	2	
TOTAL	26	28	32	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.

The IS Group is currently investigating an off-the-shelf system implemented at the ALS by Softtek Systems. Demonstration and feasibility studies were held on March 7, 2018.

- **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	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
Replace Adobe Flex SDK	4	4	8	96	96	0	0	0
Replace Oracle SQR module	4	4	8	0	64	48	0	0
TOTAL				**96**	**160**	**48**	**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	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
Upgrade Oracle Web Content Servers	4	4	8	20	90	20	100	0
Upgrade Sencha Ext JS JavaScript Framework	3	3	6	10	10	10	10	0
Upgrade Oracle Database and WebLogic Server	4	4	8	64	0	80	0	0
Oracle License Management	4	4	8	0	75	0	0	0
TOTAL				**94**	**175**	**110**	**110**	**0**

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.

  The IS group is implementing release and configuration management policies for software development and will use phased environment based deployments and testing.

TABLE 3.3 Infrastructure Development Projects

Description	C	P	Risk	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
APS Integrated Management System (AIMS)	4	4	8	7	7	7	7	0
Document Management System (DMS)	4	4	8	48	48	20	80	0
Business Intelligence and Data Warehouse	3	3	6	90	90	25	25	0
Integrated Component Management System	3	3	6	0	0	0	0	0
Implementation of Agile and ITIL methodologies	3	3	6	5	25	5	5	0
Web Application Framework	4	4	8	64	64	20	20	0
TOTAL				**214**	**234**	**77**	**137**	**0**

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.

  IS Group is moving towards a "One-Account" framework where users will be able to login to applications with their ANL domain accounts.

- **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	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
Single Sign-on	2	2	4	0	20	0	0	0
Web Services and API	3	3	6	96	64	10	10	0
TOTAL				**96**	**84**	**10**	**10**	**0**

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

None identified

3.9 Personnel Development Plan

- **Promotion**
  - FY18 – 1
  - FY19 – 1 (PT6)
  - FY20 – 1 (PT5)
  - FY21 – 1 (PT4, PT5)
  - FY22 – 0

- **New hire**
  - FY18 - 0
  - FY19 – 1 Quality Assurance & Testing
  - FY20 – 0
  - FY21 – 0
  - FY22 – 0

- **Education (graduate, co-op or summer students)**
  - FY18 – 0
  - 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)
  - FY22 – 0

3.10 Staffing Summary

Function that Role Supports	FY18	FY19	FY20	FY21	FY22	Comments
Operations, maintenance, obsolescence and infrastructure	2	2.5	2.5	2.5	2.5	
Operations upgrades and improvements	3	3.5	3.5	3.5	3.5	

Function that Role Supports	FY18	FY19	FY20	FY21	FY22	Comments
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**	**8**	**8**	**8**	**8**	

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	FY18	FY19	FY20	FY21	FY22
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

- **Increase NetApp Storage Capacity**

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 with 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. The migration of data from older storage to the NetApp appliance continued in FY 2017 with the addition of two new NetApp controller nodes and approximately 240 terabytes of additional storage. Once all of the data on the remaining older beamline storage servers is moved, which is targeted for the January, 2018 shutdown, the Xray NetApp system will be greater than 90% full. The IT best practice for storage devices is to consider adding capacity once more than 60% of the space is allocated, to make sure there is sufficient capacity to fill urgent needs. The capacity of the storage system can be increased by adding a pair of disk shelves.

Failure to add additional storage space will result in requests from XSD beamlines for additional storage space for scientific data to be unfulfilled.

The hardware requested are two NetApp DS4246 disk shelves with 8 TB SATA drives for the FAS8040 storage appliance (~ $130k).

- **Xray 3Par Storage and Windows Servers**

  The 3Par is a major component in our effort to reduce the number of physical servers and storage devices the IT group manages and maintains.

  The current Linux blade chassis virtual environment consists of blade servers in two separate blade chassis. The Linux and Windows virtual environment has approximately 110 virtual machines hosting the following applications:

  - Dserv cluster (6 blades):
    - Sector dserv VMs
    - Data management VMs
  - CAT dserv cluster (2 blades):
    - CAT sector dserv VMs
    - CAT data management VMs
  - General purpose cluster (2 blades):
    - XSD web/database servers
    - IOC Console server
    - Authentication servers for Globus tools
    - Beamline scheduling application
    - Email and logging servers
  - BCDA cluster (2 blades):
    - Per-sector workstation VMs for BCDA development and beamline services
  - Xstor Lustre storage system (6 blades):
    - Luster file system metadata and storage blades
    - Globus data transfer nodes (DTNs)
    - Development/management

  We need to continue our investment in our Xray 3Par storage solution to deliver the performance and services required to maintain our current and future computing needs. 3Par solution is 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.

  Without additional storage, performance of the 3Par will degrade to a point where the connected systems and virtual machines will no longer be able to perform at an acceptable level. Available free space may be exhausted. Systems may randomly crash or reboot.

  The hardware requested is:

- 3Par Storage:
    - 6 Large Form Factor disk enclosures
    - 24 Nearline Class Disks
    - Total hardware cost of about $80k
    - 0 hours Tech
    - 24 hours Staff
- Blade Servers:
    - Two Prolia2nt BL460 Gen10,
    - Total hardware cost of about $40k
    - 0 hours Tech

- **Beamline Network Core Switch Upgrade**

  An upgrade of the existing beamline networking core infrastructure switches is needed to provide 40Gig uplinks for the new high-speed switches installed at six of the beamlines. Some of the new servers for the beamlines also require 40Gig connections. These new network core switches provide 1.2 Terabits per slot with very low latency. They also will support 100Gig uplinks to upgrade the connection to ALCF, the lab and the internet. These switches provide more 10Gig ports per slot and will reduce the number of beamline core switches from three to two. This will reduce the number of interswitch connections providing more uplink ports for beamline switches. The existing beamline core switches will be redistributed to the beamlines to provide greater bandwidith and uplink capacity.

  DTNs will be limited to 10Gig connections throttling data transfer offsite. New beamline high-speed switches will only have 10Gig uplinks. These uplinks will become overloaded and network packets will get dropped. New beamline servers that have 40Gig interfaces can only be connected at 10Gig. Existing beamline network core switches cannot support 100Gig uplinks. Data transfer and backup services to ALCF would also be limited to 10Gig for a single stream. New projects such as PRISMA/RAVEN may be affected because bandwidth will be severely limited.

  The hardware requested are:
  Aruba 8400 Core switch and associated modules: $175k
  Aruba 8400 Top-of-Rack switches to offload 10Gig server connections: $25k

- **Replacement/Upgrade of Orthros On-Demand Analysis and Data Transfer Node (DTN) Storage System**

  The Orthros On-Demand analysis and DTN environment has five disk arrays going off warranty in the coming year.. The current storage system is based on commodity hardware connected with Fiber Channel (FC) interfaces and switches. The FC switches have been in use for over five years and are due for replacement. The Lustre storage servers are also due for replacement. In fact, one of them had a CPU failure two years ago. As storage systems grow larger, building out using commodity hardware becomes less cost effective. It’s time to look at a vendor supported complete storage solution.

  As datasets continue to grow, larger and faster storage will be required. Without a place to put their data, in-situ beamline analysis can’t be done. As the hardware gets past five years old, the risk of service interruption due to hardware failure increases.

The hardware requested is comprised of 2 options:

Option 1

- 2 Fiber Channel Switches and 36 Optical Transceivers - $50,000
- 8 Fiber Channel interface cards - $16,000
- 8 New Servers - $64,000
- 3 Disk Arrays - $45,000
- Total of about $175,000

To replace/upgrade just the FC hardware with the latest 32Gb/sec standard would cost approximately $70,000, 2 FC switches and optics plus eight interface cards. Add on to that, new servers ($64,000) and 3 disk arrays ($45,000) and the price approaches $175,000.

Option 2

- 1 – DDN ES7700KE – Controller with embedded GPFS or Lustre - $110,000

The Orthros cluster recently had its Infiniband (IB) switch upgraded. This switch is capable of 56Gb/s port speeds. There are storage systems available that have IB interfaces. By moving the storage to Infiniband, the storage environment can be simplified, only one high-speed network to support. Also, the money saved can be spent on the actual storage and not the supporting infrastructure.

The requested amount would pay for an entry level DDN ES7000K system with active/active controllers, 600TB raw storage (420TB usable), Lustre or GPFS software, installation, configuration services and on-going Lustre/GPFS support.
If Lustre is used, this system will run in parallel with the existing hardware, augmenting the current filesystem. The transition to this storage will have little/no negative affect on the user experience. If GPFS is used, we could leverage GPFS data management features to move data to other GPFS systems.

- **Replace DDN storage system (APSData) in Building 369**

In 2019, the DDN hardware will be end-of-life and support will no longer be available. Due to its critical nature to beamline operations, this must be replaced before the warranty expires. The current DDN storage is approximately 3PB raw and fills four seven foot tall racks. The proposed storage system is comprised of much larger drives (10TB vs 1TB) and will use approximately one half of a rack. All capacities are raw unformatted storage. The usable storage would be approximately 75% of the raw storage, listed in parentheses.

A catastrophic failure of the DDN storage will cause excessive downtime, greater than 3 days. It will be a serious risk of significant data loss. Replacement parts will not be available. A catastrophic failure would require a new storage system be ordered. Since January 2017, the APSData storage system has had two downtime occurrences due to failed hardware or power loss. During that same time, there have been 11 support cases opened to replace either disk drives or faulty hardware.

The hardware requested is comprised of 2 options:

Option 1

- 2 DDN ES7700KE 60-bay controllers running GPFS, 1.2PB (950TB) - $180,000
- 4 DDN SF8460 84-bay expansion enclosures $54,000 each - $216,000
- Total of about $396,000

If we were to replace APSData with entry level DDN hardware, it would cost approximately $396,000. This would provide two ES7700 enclosures with embedded controllers providing 1.2PB of raw storage. Each ES7700 would then connect to two SF8460 84-bay enclosures (840TB each) giving a combined 4.5PB (3.4PB). An ES7700 can support up to four SF8460 enclosures. The two ES7700 systems would support a maximum 7.9PB (5.9PB).

Option 2

- 1 DDN SFA14KE 72-bay Controller with GPFS - $190,000
- 5 DDN SF8460 84-bay enclosures - $54K each - $270,000
- Total of about $460,000
-

The fastest DDN storage is their ES14K storage system. Replacing both ES7700 from option 1 with a single ES14K would bring the total to approximately $460,000. This price would include one ES14K and five SF8460 enclosures yielding 4.9PB (3.6PB). An ES14K can support up to twenty SF8460 enclosures for a maximum of 17.5PB (13PB).

- **Experimental 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.

  In the Lab Office Modules, aggregate wireless client network throughput 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.

On the Experimental Floor, aggregate wireless client network throughput 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.

The hardware requested are:

LOMs
- 1 each Aruba 7205 WLAN Controller
- 45 each AP-335 Aruba Wireless Access Points

Experiment Floor
- 32 each Aruba AP-335 Wireless Access Points
- 22 each External Omni-antennas

- **Upgrade APS Tier 2 Firewall to support 40 Gbps**

Current APS tier 2 firewall only provides 10Gbps interfaces. The existing firewall hardware was end of life in December 2016. The vendor no longer supports the hardware because it is end-of-life and there are no replacements available. Beamlines require additional bandwidth to transfer data. Current firewall hardware was installed in 2010. Additional security features are available on the new firewall to protect the APS from attacks. Beamline data transfer speed would be limited to 10Gbps. This could provide a significant bottle neck for data transfer. The APS tier 2 firewall would not have the latest security features and enhancements to protect the APS. An upgraded firewall will provide 40Gbps uplinks and the latest hardware to process packets faster. The new firewall would be fully supported for both hardware and software so we would not experience any extended outages.

The existing firewall is end-of-life and no longer has vendor support. A hardware failure of either firewall would result in the loss of high-availability and throughput. A second hardware failure results in no network connectivity to Argonne or the internet. The entire APS would be crippled with NO network access. We had two hardware failures in the last year and fortunately was able to recover. In addition, beamline data transfer would be limited to 10Gbps per stream passing through the firewall. Upgrading edge networks to 40Gig or 100Gig will be throttled to 10Gig at the firewall. Current firewall hardware will be eight years old in FY18. As firewall hardware ages more problems will occur resulting in more downtime.

The hardware requested are two Stonesoft 3305 NGFW Appliances each with 6 x 40Gig interfaces for a total of about $165k, as well as Cisco and Aruba 40Gig network optics for a total of about $35k.

- **Accelerator/Controls NetApp Storage Appliance:**

Accelerator/Controls FAS3220 "Phoebus" NetApp storage appliance is End-Of-Life (EOL) platform as of July 2017. Support for this hardware platform moving forward is limited to maintenance releases at OnTap 9.1 operating system (OS). This platform provides file sharing resources for all subnet 8 clients (Linux, Mac, and Windows) with AES Controls group being its primary consumers. Applications and tools that directly support the Accelerator operations are being developed, tested and use in production are being used by AES technical groups (Controls & IT) and ASD operations.

In addition to the file-sharing services this unit also serves as an essential component of our change management system. The Phoebus (FAS3220) has been the platform where we introduce changes first in efforts to ensure we reduce the risks before deploying to Helios (Accelerator) and Sector s#data file shares (Xray). Our standard maintenance schedule for changes happens three times annually starting about 30 days before the start of a shutdown maintenance period. This time allows our technical support groups an opportunity to collaborate with each other to thoroughly test configurations and software changes. This process has been disrupted due to the limits of the FAS3220 hardware and no support of NetApp latest OnTap OS 9.2 features and functionality.

Replacing the FAS3220 now make sense with this product is EOL, limited features and the need to restore of change management process. This will help reduce risk, improve reliability and allow for new features to be tested without disrupting services in our most critical file-sharing environments.

Applications and services being provided by Phoebus (FAS3220) include:
- AES Controls: EPICS, MEDM, iocapps, VxWorks, Home directories,
- Subversion and CVS
- ASD Operations: OAG Tools and applications
- AES IT: McAfee Security Incident Event Monitor (firewall logs and generates reports)
- Subnet 8 file sharing - Home Directories and applications all clients

NetApp's recommended replacement for the FAS3220 is the new FAS8200 two node HA storage appliance. The FAS8200 is the next generation of NetApp's FAS storage appliances with increase SAS bandwidth, increased capacity, reliability, and performance.

This totals about $80k and includes:
- ~60 TB of usable storage
- 2 Terabytes of Controller Flash Cache (read performance
- SnapMirror Software bundle.

TABLE 4.1 Obsolete Hardware Projects

Description	C	P	Risk	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
Increase NetApp Storage System Capacity	4	4	8	130	130	130	130	130
X-ray 3Par Storage and Windows Servers	3	3	8	120	120	120	120	120
Beamline Network Core Switch Upgrade	4	4	4	200	200	200	200	200
Upgrade Orthros DTN Storage System	4	4	4	175	100	100	100	100
Replace DDN Storage System	3	4	8	396	100	100	100	100
Experiment Floor/LOM Wireless Network	2	4	5	391	0	0	0	0
Upgrade APS Tier 2 Firewall to 40 Gbps	4	4	7	200	100	100	100	100
Accelerator Control NetApp Storage	4	3	7	80	80	80	80	80
TOTAL				**1,692**	**830**	**830**	**830**	**830**

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**
  - FY18 – 1
  - FY19 – 1
  - FY20 – 1
  - FY21 – 1
  - FY22 – 0

- **New hire**
  - FY18 – 0
  - FY19 – 0
  - FY20 – 2 for APS-U support
  - FY21 – 0
  - FY22 – 0

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

- FY18 – 2
- FY19 – 2
- FY20 – 2
- FY21 – 2
- FY22 – 0

4.10 Staffing Summary

Function that Role Supports	FY18	FY19	FY20	FY21	FY22	Comments
Operations, maintenance, obsolescence and infrastructure	20	21	21	21	21	
Operations upgrades and improvements	0	0	0	0	0	
APS-U support	1	1	3	3	3	Additional staff added for APS-U support
R&D support	0	0	0	0	0	
TOTAL	**21**	**22**	**24**	**24**	**24**	

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. The manufacturer no longer supports these obsolete systems. APS should embark on a program to replace one laser tracker each year for the next three years.

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 for APS-U but to use rentals for all future APS-U needs.

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

Description	C	P	Risk	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
Replace Obsolete Laser Trackers	4	4	8	159	159	159	0	0
TOTAL				**159**	**159**	**159**	**0**	**0**

5.4 Obsolete Hardware Replacement

None identified

5.5 Infrastructure Development Plan

- **Acquisition and Development of Wet Lab for Engineered Nanomaterials**

The sub-group within MED developing engineered nanomaterials as part of an LDRD requires a dedicated space. This effort has already generated a patent application and more are expected. The group currently borrows space from XFD and CNM. This has led to crowded conditions. The cross-divisional space utilization has led to difficulties with equipment and WCD review and approvals, particularly with CNM which has no investment in the outcome of the experiments. The cost depends largely on whether an existing wet lab can be obtained or whether another space needs to be retrofitted with water, sewer, and hood. If an existing wet lab can be obtained the cost is small and can be covered with group recurring M&S.

- **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 5.2 Infrastructure Development

Description	C	P	Risk	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
New Nanomaterials Lab	3	3	6	75	0	0	0	0
PCMM	3	3	6	0	70	0	0	0
TOTAL				**75**	**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**

MED Group is 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.

TABLE 5.5 R&D for New and Improved Capabilities

Description	C	P	Risk	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($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**
  - FY18 – 5 (RD2, RD3, RD3, RD3, RD3)
  - FY19 – 2 (RD3, Promote SA tech to RD1)

- FY20 – 3 (RD3, RD3, RD4, RD4)
- FY21 – 3 (RD4, RD3, RD2)
- FY22 – 0

- **New hire**
  - FY18 – 4 (RD2, RD4, RD5, SA Tech)
  - FY19 – 3 (RD2, SA Tech, SA Tech)
  - FY20 – 2 (RD2, SA Tech)
  - FY21 – 0
  - FY22 – 0

- **Education (graduate, co-op or summer students)**
  - FY18 – 2
  - FY19 – 4
  - FY20 – 4
  - FY21 – 4
  - FY22 – 4

5.10 Staffing Summary

Function that Role Supports	FY18	FY19	FY20	FY21	FY22	Comments
Operations, maintenance, obsolescence and infrastructure	13.9	14.9	15.9	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	1.5	2.5	3.5	3.5	3.5	Increasing support for APS-U Operations readiness
APS-U support	16.5	18.5	19.5	19.5	19.5	Assume level APSU staff support after increase in FY18 but increasing number of SA techs.
R&D support incl. LDRD and SBIR	2.25	1.25	0	0	0	LDRD postdoc in group ends in FY18. SBIR ends in FY19 No LDRDs in pipeline.
TOTAL	**34.2**	**37.2**	**38.9**	**38.9**	**38.9**	

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	FY18	FY19	FY20	FY21	FY22
Sample Manipulation via Acoustic Levitator					
FTEs	0.2	0	0	0	
M&S ($k)	0	0	0	0	
Effort ($k)	21	0	0	0	
TOTAL ($k)	**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	FY18	FY19	FY20	FY21	FY22
Additive Manufacturing					
FTEs	0	1.2	1.2	1.2	1.2
M&S ($k)	0	100	150	100	100
Effort ($k)	0	120	120	120	120
TOTAL ($k)	**0**	**220**	**270**	**220**	**220**

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.

Description	FY18	FY19	FY20	FY21	FY22
Reduction of Thermal and Photon Stimulated Gas Desorption in Compact Accelerator Vacuum Chambers					
FTEs	0	0.5	0.25	0	0
M&S ($k)	0	0	0	0	0
Effort ($k)	0	100	50	0	0
TOTAL ($k)	**0**	**100**	**50**	**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	FY18	FY19	FY20	FY21	FY22
Nanobonding					
FTEs	0	1.2	0	0	
M&S ($k)	0	100	0	0	
Effort ($k)	0	200	0	0	
TOTAL ($k)	**0**	**300**	**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	FY18	FY19	FY20	FY21	FY22
LCLS II Vacuum Chamber Project					
FTEs	1.5	0	0	0	
M&S ($k)	0	0	0	0	
Effort ($k)	0	0	0	0	
TOTAL ($k)	**0**	**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	FY18	FY19	FY20	FY21	FY22
Advanced Integrated Storage Ring Vacuum Design Software SBIR					

Description	FY18	FY19	FY20	FY21	FY22
FTEs	0.6	0.6	0	0	
M&S ($k)	0	0	0	0	
Effort ($k)	0	0	0	0	
TOTAL ($k)	**0**	**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 Obsolete Equipment

- **DI H2O Pump Controls System for SR sectors 1 & 2 (Proposal #2373)**

  Current pump controls is the Johnson Controls, Base Frame Gen-1 Metasys. Company no longer supports the current hardware and software. It has become more difficult to find hardware for spares on the open market; hence, component failure may result in extended machine downtime. Replace obsolete Johnson Controls equipment, wiring, and field devices as necessary with newer technology.

- **DI H2O Pump Controls System for SR sectors 39 & 40 (Proposal #2374)**

  Current pump controls is the Johnson Controls, Base Frame Gen-1 Metasys. Company no longer supports the current hardware and software. It has become more difficult to find hardware for spares on the open market; hence, component failure may result in extended machine downtime. Replace obsolete Johnson Controls equipment, wiring, and field devices as necessary with newer technology.

- **DI H2O Pump Controls System for Injectors – (LINAC gallery, LINAC tunnel, PAR, Booster east & west) (Proposal #2376)**

Current pump controls are the Johnson Controls, Base Frame Gen-1 Metasys. Company no longer supports the current hardware and software. It has become more difficult to find hardware for spares on the open market; hence, component failure may result in extended machine downtime. Replace obsolete Johnson Controls equipment, wiring, and field devices as necessary with newer technology.

- **DI H20 Pump Controls System for Storage Ring RF Systems (Bldg 420) (Proposal #2375)**

Current pump controls are the Johnson Controls, Base Frame Gen-1 Metasys. Company no longer supports the current hardware and software. It has become more difficult to find hardware for spares on the open market; hence, component failure may result in extended machine downtime. Replace obsolete Johnson Controls equipment, wiring, and field devices as necessary with newer technology.

- **PC Gun Water System (Proposal #3138)**

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 #416)**

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

TABLE 6.1 Spares and Replacement of Obsolete Equipment

Description	C	P	Risk	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
DI H2O Pump Control System for SR sect 1&2	3	3	5	35	0	0	0	0
DI H2O Pump Control System for SR sect 39&40	3	3	5	0	35	0	0	0
DI H2O Pump Controls for Injectors (Linac gallery, Linac tunnel, PAR, Booster)	3	3	5	35	35	35	70	0
DI H2O Pump Control Storage Ring RF Systems	3	3	5	0	40	40	0	0
PC Gun Water System	3	3	5	0	25	0	0	0
FE Instrumentation Reliability Upgrade	3	3	5	60	60	65	65	0
TOTAL				**130**	**195**	**140**	**135**	**0**

6.4 “End of Life” 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.

- **DI Water Resin Replacement (Project #2929)**

  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 (Project #3136)**

  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.

- **LINAC Gallery and Klystrons Vacuum Systems Upgrade**

  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.

- **LINAC Cooling Water Skids Upgrade**

  Upgrade 5 cooling water LINAC skids with new pumps, heat exchangers pressure and temperature transmitters and controls. Replace 20-year old heat exchangers, replace PLC5 controls with ControlLogix, install new temperature and pressure transmitters.

- **DI Water Resistivity Analyzers Replacement**

  Water quality is critical for reliability of machine components with resistivity being one of the principal parameters. Replace failing obsolete resistivity analyzers.

TABLE 6.2 “End of Life” Hardware Projects

Description	C	P	Risk	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
Booster DI Water Valves Replacement	3	3	5	36	36	0	0	0
DI Water Resin Replacement	2	2	5	42	44	0	0	0
Replace PLC5 Control Systems	3	3	6	112	56	0	0	0
LINAC Gallery and Klystrons Vacuum Systems Upgrade	2	2	5	214	0	0	0	0
LINAC Cooling Water Skids Upgrade	3	3	5	100	100	100	100	100

Description	C	P	Risk	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
DI Water Resistivity Analyzers Replacement	3	3	5	0	25	25	0	0
TOTAL				**504**	**261**	**125**	**100**	**100**

6.5 Infrastructure Development Plan

- **Storage Ring Power Supplies Water Isolation Valves**

  Isolation valves in the 2" PVC header are located every five sectors around the ring and are in difficult to reach locations. 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). Additional valves are required, which will allow us to isolate individual sectors allowing us to make repairs in a timely manner and reduce the potential water damage to equipment.

- **Variable Frequency Drive (VFD) and Controls for DI Water Make-up Pumps**

  Variable frequency drives and controls are needed on the DI water make-up pumps in Building 450, to prevent potentially damaging pressure spikes currently observed with each make-up pump operation.

TABLE 6.3 Infrastructure Development

Description	C	P	Risk	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
SR Power Supplies Water Isolation Valves	3	3	6	30	30	30	0	0
VFD and Controls for DI Water Make-Up Pumps	3	3	6	0	25	0	0	0
TOTAL				**30**	**55**	**30**	**0**	**0**

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

- **VFD Elec Bypass for Injector Pumps**

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

- **VFD Elec Bypass for Sectors 1, 2 and EAA 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.

- **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.

- **Sulfur Hexaflouride (SF6) Recovery System**

SF6 is used in the LINAC waveguide system as a dielectric material to reduce high voltage breakdown and arcing. SF6, identified as a greenhouse gas can contribute to the greenhouse effect when released into the atmosphere. Occasionally, the waveguide system has to be vented for repairs and maintenance. The design, testing and installation of a recovery system will reduce cost and support the EPA program to reduce the emission of SF6 into the atmosphere.

TABLE 6.4 Hardware Improvements and Upgrades

Description	C	P	Risk	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
VFD Elec Bypass for Injector Pumps	3	3	5	40	0	0	0	0
VFD Elec Bypass for SR Sectors 1,2 & EAA Pumps	3	3	5	25	0	0	0	0
SR Vacuum Chamber Water Skid Control Valves Replacement	3	3	5	30	0	0	0	0
Sulfur Hexaflouride (SF6) Recovery System	2	2	5	33	0	0	0	0
TOTAL				**128**	**0**	**0**	**0**	**0**

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

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

The MBA storage ring stability requirements are much more stringent than those for the current ring, and will be many times more sensitive to vibration. It has already been proven that the current storage ring vacuum chamber cooling water-pumping system induces unwanted vibration into those chambers that are detected by the stored beam. This program will test different pump types and vibration reduction devices.

- **Secondary Process Water Systems Reconfiguration and Upgrade - Copper Systems Serving Magnets, Power Supplies, Front Ends, Absorbers, Beamlines**

The secondary process water system serving copper components such as magnets, power supplies front ends and photon absorbers must be reconfigured to meet the demands of the MBA storage ring. As of 2017, estimated required flow for APS-U is 350 gpm vs current 450 gpm. This flow is within the existing pumps operating capabilities.

Potential required modifications include:

Install variable frequency drives on pumps to match required load – 20 units = $200k.
Install new control valves to match new operating requirements – 20 units = $160k.
Improve temperature control by installing mixing sections and new RTD/transmitters. – 20 units = $200k.

- **Vacuum Chamber Cooling Water Skids**

Estimated required flow is 4 gpm per skid vs current 50 gpm. Potential required modifications include:

Replace 20 current skids with 5 new ones - $100k per skid = $500k
New piping around storage ring - $100k

- **Bake-out Skids**

Currently need a total of 20 skids (similar to vacuum chamber cooling water skids). Potential required modifications:

Procure 4 portable bake out skids - $100k per skid = $400k
Retrofit existing bake out skids - $30k per skid = $600k
Piping modification to bake out manifolds = $200k

- **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.

TABLE 6.5 R&D for New and Improved Capabilities

Description	C	P	Risk	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
Reduction of pump and flow induced vibration	3	3	6	100	60	0	0	0
Secondary Process Water Systems Reconfiguration and Upgrade - Copper Systems Serving Magnets, Power Supplies Front Ends Absorbers Beamlines	3	3	6	0	0	0	280	280
Vacuum Chamber Cooling Water Skids	3	4	7	0	0	0	300	300
Bake-out Skids	3	3	6	0	0	0	600	600
Upgrade Building 382	3	4	7	300	300	100	100	0
TOTAL				**400**	**360**	**100**	**1280**	**1180**

6.8 R&D Projects in Support of a Future Light Source (APS-U)

- **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 chamber designs are being considered for the MBA storage ring. NEG coated chambers and copper vacuum chambers are unfamiliar to the current APS personnel. New designs need to be vacuum tested and certified.

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	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
Welding R&D	3	3	6	200	200	100	0	0
APS-U sector mock up	3	4	7	200	0	0	0	0
Chamber testing	4	4	8	100	100	0	0	0
TOTAL				**500**	**300**	**100**	**0**	**0**

6.9 Personnel Development Plan

- **Promotion**
  - FY18 – 1
  - FY19 – 1
  - FY20 – 1
  - FY21 – 1
  - FY22 – 1

- **New hire**
  - FY18 – 1
  - FY19 – 2
  - FY20 – 2
  - FY21 – 2
  - FY22 – 0

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

– FY22 – 1

6.10 Staffing Summary

Function that Role Supports	FY18	FY19	FY20	FY21	FY22	Comments
Operations, maintenance, obsolescence and infrastructure	27	27	27	26	8	Expectation is that in FY21 APS-U construction will be winding down and installation will begin.
Operations upgrades and improvements	1.5	1.5	2	7	8	Expectation is that in FY22 APS-U installation is on-going and a skeleton staff of MOM Group supporting operations improvements.
APS-U support	4	4	6	16	18	Expectation is that in FY22 APS-U installation will be on going supported by greater portion of MOM personnel.
R&D support	.5	.5	1	1	1	
TOTAL	**33**	**33**	**36**	**50**	**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	FY18	FY19	FY20	FY21	FY22
LCLS Vacuum Chambers					
FTEs	2.25	2	2	0	0
M&S ($k)	25	0	0	0	0
Effort ($k)	50	0	0	0	0
TOTAL ($k)	**75**	**0**	**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

44 Generation 1 PSS’s will eventually have to be upgraded/replaced with a 4th generation PSS that utilizes safety certified PLC’s. Upgrades will begin with select APS-U beamlines and continue years after the upgrade. Depending on resources, 1-2 beamline can be upgraded per shutdown.

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 is being developed to reliably support the new upgraded accelerator.

A prototype was designed and implemented in the LINAC Extension Area (LEA) for proof of concept in FY16. The next 4 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 sub-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 are also obsolete. This request will replace the Bending Magnet FEEPS's not being replaced by the APS Upgrade project.

The APS-U will require replacement of every ID FEEPS and modifications to the newly installed BM FEEPS. Additionally, the ACIS-U project requires modifications to FEEPS. Additional staff will be required in FY22.

- **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.

Sector 28 will be the first PSS utilizing the new safety certified PLC's and based off the ACIS LEA installation. A huge influx of techs and staff is anticipated to cover the modifications of the beamlines PSS's but these are guesses at this time as we have very very little information from the upgrade office. The staffing summary chart reflects the additional staff requirement starting in FY21.

- **BLEPS Upgrade**

The BLEPS at beamlines 1-ID, 1-BM, 2-ID, 2-BM, 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 has been developed to reliably support these beamlines. Upgrades are being requested by XSD and are being installed as resources permit.

A huge influx of techs and staff is anticipated to cover the modifications of the beamlines EPS's but these are guesses at this time as we have very very little information from the upgrade office. The staffing summary chart reflects the additional staff requirement starting in FY21.

TABLE 7.1 Obsolete Hardware Projects

Description	C	P	Risk	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
ACIS Upgrade	3	4	7	40	130	360	100	100
FEEPS Upgrade	3	4	7	90	90	0	0	0

Description	C	P	Risk	FY18 ($k)	FY19 ($k)	FY20 ($k)	FY21 ($k)	FY22 ($k)
PSS Upgrade	3	4	7	0	0	0	0	0
BLEPS Upgrade (XSD Funded)	3	4	7	0	0	0	0	0
TOTAL				**130**	**220**	**360**	**100**	**100**

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**
  - FY18 – 2 (RD2 to RD3)
  - FY19 – 1 (RD2 to RD3)
  - FY20 – 0
  - FY21 – 1 (RD4 to RD5)
  - FY22 –

- **New hire**
  - FY18 - 0
  - FY19 - 0
  - FY20 – 1
  - FY21 – 16 for APS-U
  - FY22 – 5 for APS-U

- **Education (graduate, co-op or summer students)**
  - FY18 – 1
  - FY19 – 0
  - FY20 – 0
  - FY21 – 0
  - FY22 – 0

7.10 Staffing Summary

Function that Role Supports	FY18	FY19	FY20	FY21	FY22	Comments
Operations, maintenance, obsolescence and infrastructure	7	6	5	5	3	
Operations upgrades and improvements	5	5	6	7	9	
APS-U support	1	2	3	18	23	
R&D support	0	0	0	0	0	
TOTAL	**13**	**13**	**14**	**30**	**35**	

LDRD projects

None identified

Work for Others (Strategic Partnership Projects) projects

None identified