U.S. DEPARTMENT OF ENERGY | Office of Science

Update on SC-24.2, Accelerator R&D, and New Initiatives ASW 2021

October 5, 2021

Eric R. Colby
ARDAP Director

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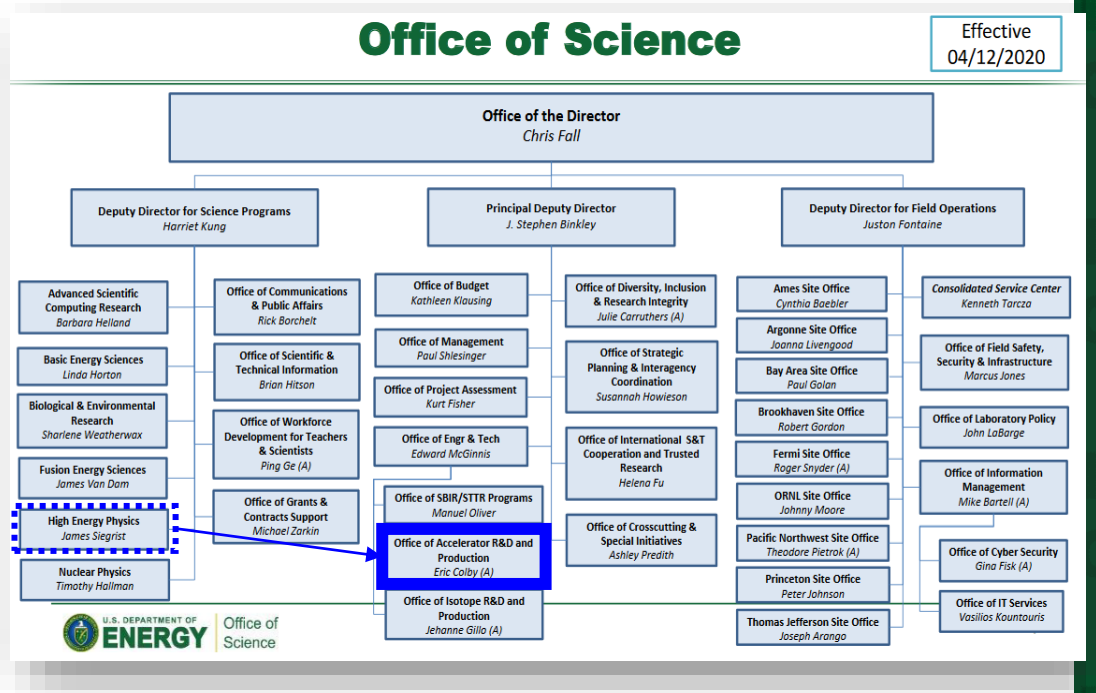
Accelerator R&D and Production (ARDAP) SC-24.2 At-a-glance

Mission: **Ensure a robust pipeline of next-generation Accelerator Science & Technology to support physical sciences research while providing technology advances and industrial strength that position the U.S. to lead the world for decades to come.**

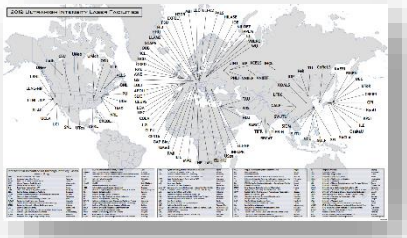
- Established: April 12, 2020
  - in recognition of the central importance of accelerators and related technologies to the current and future scientific capabilities stewarded by SC programs
- Budget in FY 2021: $16.935M
  - Initial budget and activity are the **Accelerator Stewardship program**
  - First appears in SC Authorization and budget in FY2022
- Staff: ~1.5 FTE
  - Director – Eric R. Colby, 100% time
  - Physicist – Marion White (detailee) (home office: SC-35) ~40% time
  - Incoming Physicist – Bruce Carlsten (IPA, start date 10/11/21) ~10% time
- TRL Footprint: TRL-1 to TRL-5
  - Cross-cutting basic R&D and
  - Technology maturation, technology transfer, and (coming soon) public-private-partnerships for production
- Activities are tightly integrated with BES, FES, HEP, and NP



Mission of Accelerator R&D and Production

- **Mission: Ensure a robust pipeline of next-generation Accelerator Science & Technology to support physical sciences research and provide technology advances and industrial strength that position the U.S. to lead the world for decades to come.**

- ARDAP will fulfill this mission by:
  - Maintaining a strategic picture of AS&T* needs and worldwide competition,
  - Facilitating coordination of Programmatic AS&T R&D investments across SC,
  - Investing in selected cross-cutting AS&T areas,
  - Providing a system engineering perspective for SC facility projects,
  - Supporting workforce development, when needed,
  - Maturing key AS&T technology and developing capable U.S. vendors,
  - Transitioning accelerator technology to broader uses.



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*AS&T = Accelerator Science & Technology

More than 47% of SC's nearly 33,500 users* perform research at an accelerator-based facility


Linac Coherent Light Source


Advanced Light Source


Fermilab Accelerator Complex


Advanced Photon Source


National Synchrotron Light Source II

Relativistic Heavy Ion Collider

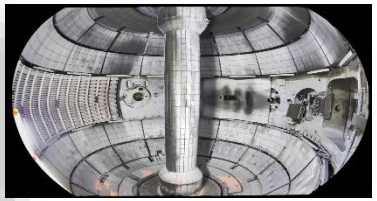

FACET Beam Test Facility

Accelerator Science & Technology (AS&T) advances form the foundation of these world-leading instruments


BNL Accelerator Test Facility


Stanford Synchrotron Radiation Light Source


DIII-D


NSTX-U


Spallation Neutron Source


ATLAS


Continuous Electron Beam Accelerator Facility

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* In FY 2020, COVID reduced the number of users coming to physical facilities significantly.
Pre-COVID numbers (FY 2019): 19,337 users (**54%** of 35,771 total SC users) were at accelerator-based SC facilities.

Continued U.S. Leadership in the Physical Sciences will require transformative new accelerator facilities

Office of Science

OPERATING NOW


Advanced Light Source


Advanced Photon Source


National Synchrotron Light Source II


Stanford Synchrotron Radition Light Source


Linac Coherent Light Source


Spallation Neutron Source


DIII-D


Fermilab Accelerator Complex


FACET Beam Test Facility


BELLA

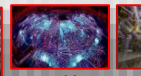

BNL -ATF


ATLAS


Relativistic Heavy Ion Collider


Continuous Electron Beam Accelerator Facility


LANSCE


Z Machine


NIF


DAHRT

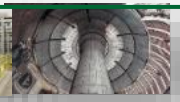

JUPITER


FACET-II

2-5 years


LCLS-II


MPEX


NSTX-U


HL-LHC


BELLA-Staging


FRIB

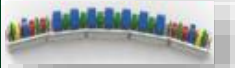

PIP-II

2-5 years

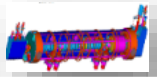

Scorpius

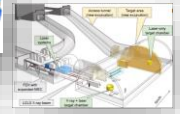
5-10 years


APS-Upgrade

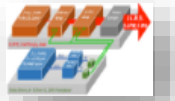

ALS-Upgrade


LCLS-II-HE


SNS-PPU


MEC Upgrade

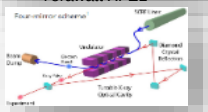

SNS-STS


K-BELLA-Power

5-10 years

>10 years


Terawatt XFEL


XFEL Oscillator


Fusion Prototypic Neutron Source


PIP-III


FCC-ee/FCC-hh

FRIB 400 MeV/u Upgrade

EIC

>10 years

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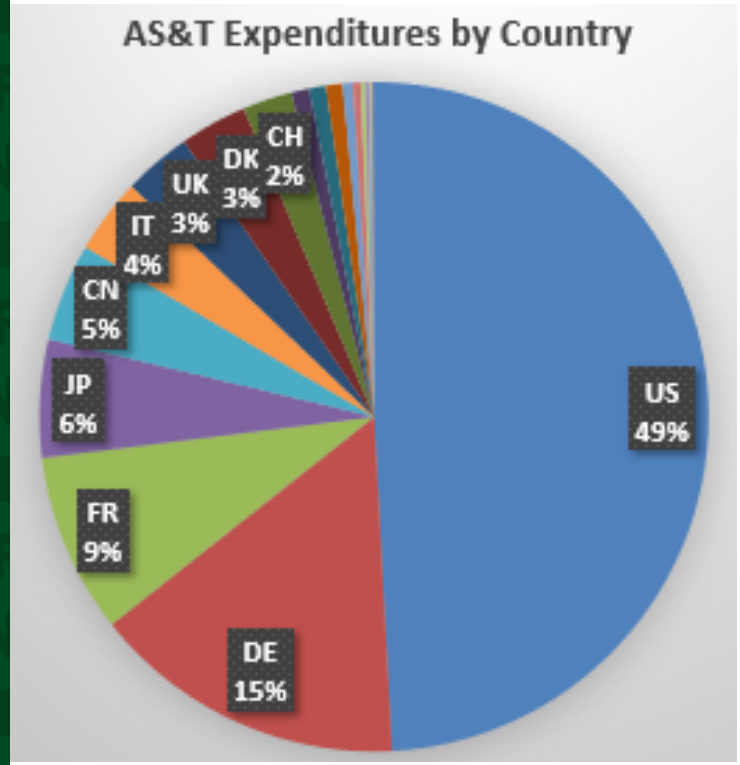
Worldwide Competition in Accelerator-Based Science Facilities is Strong

SC and ARDAP are investing in the scientific capabilities of SC's future facilities

DOE's reliance on off-shore vendors is significant

[AS&T Supplier Data Call, December 2020-January 2021]

Risk – probability that relying on offshore vendors will lead to problems
Impact – impact a vendor problem will have on U.S. accelerator facilities



Source: FY 2021 AS&T Supplier Data Call to DOE labs. Includes all active projects and FY19-20 operations procurements.

Office of Science Supply Chain Vulnerabilities (last updated: February 2020)						FY 2021 Data Call	
Risk #	Technology Area	Areas of Vulnerability	Vendor Issues	Risk	Impact	SC	% Foreign
1	Superconducting Accelerators	Accelerator Cavity Manufacturing	Two EU vendors only: RI (DE), Zanon (IT)	High	High	$149	70%
2	Detectors	Sensors, front-end electronics	Limited US vendors	High	High	$ 18	51%
3	*Workforce Development*	*Systems and Technology Experts*	*Insufficient US supply; Strong draw from EU, AS facilities*	*High*	*High*		
4	RF Power Systems	High power klystrons, gyrotrons, solid state systems	Limited US vendors, multiple EU, AS vendors	Med-High	High	$132	53%
5	Superconducting Magnets	Superconducting cable and wire	One dominant vendor: Bruker (DE)	Med-High	High	$ 49	50%
6	Optics	Specialty mat'ls, coatings, optics	EU and AS vendors lead in quality and dominate market	Medium	High	$ 11	100%
7	Conventional Magnets	Manufacturing, Perm. Magnet Mat'ls	AS dominates low-cost market and the supply of rare-earth permanent magnet materials	Med-High	Med-High	$ 95	61%
8	Laser Systems	Advanced ultrafast laser systems	EU vendors dominate: Amplitude, Thales (FR), EdgeWave, Trumpf (DE)	Low-Med	Med-High	$ 9	37%
9	High Radiation Mat'ls and Design	High radiation targets, beam lines	Limited lab testing capacity in U.S., Japan	Medium	Medium	$ 11	
10	Cryogenic Systems	Large capacity liquid helium cryoplants	Two EU vendors dominate: Linde Kryotechnik (CH), Air Liquide (FR)	Medium	Medium	$108	55%
11	Particle Sources	Cathodes, Ion source expertise	CN is sole source of GaAs cathodes; limited expertise to manufacture sources	Low-Med	Medium	$ 23	15%

Table developed by BES, FES, HEP, and NP, updated February 2020.

$430M spent off-shore for current projects and operations
Most of this accelerator technology was invented (and at one time produced) in the U.S.

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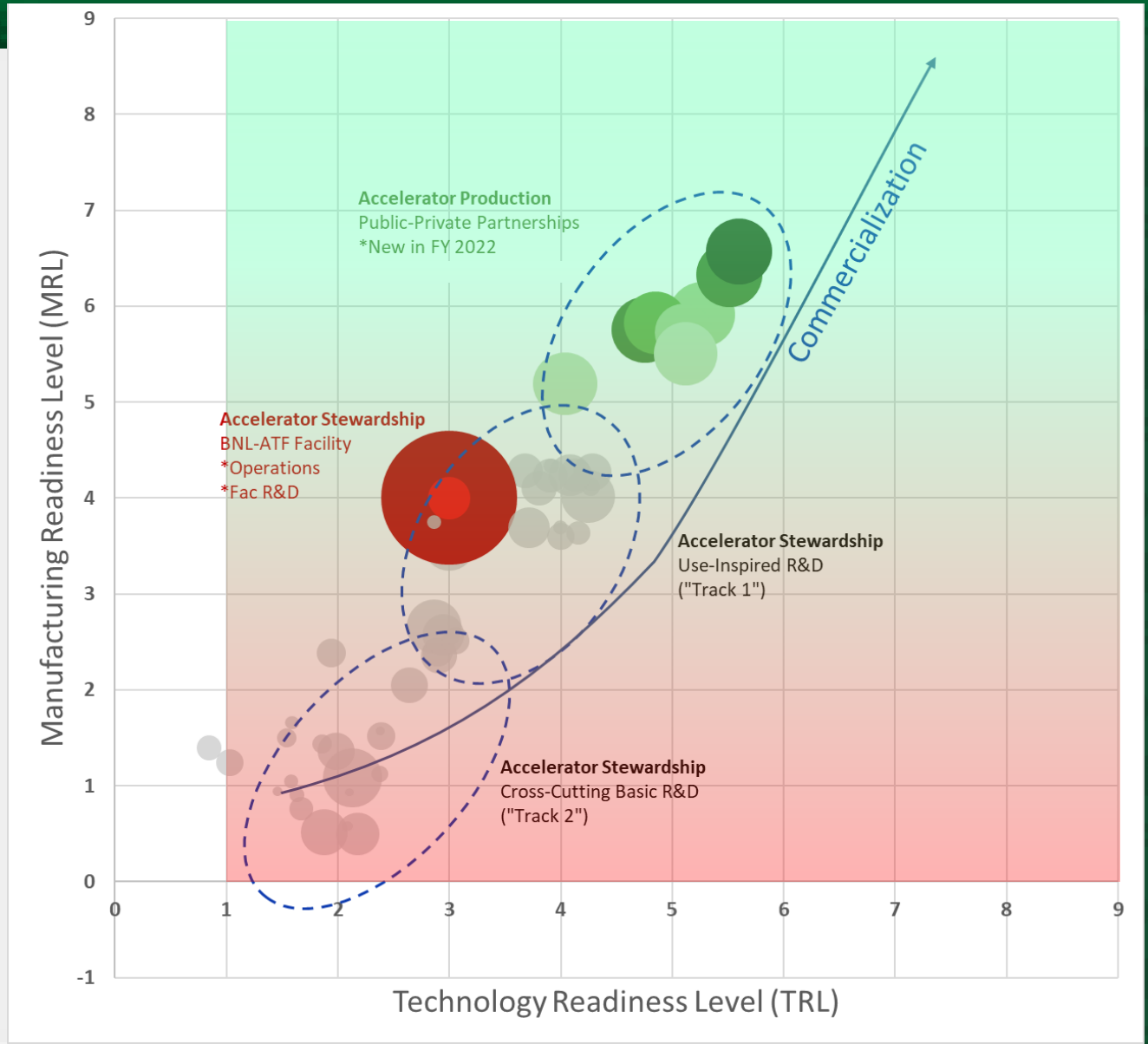
ARDAP: Accelerator Production

- **Focused on supply chain vulnerabilities**
- **Market intelligence**
  - RFIs, data calls, roundtables
- **Technology Transfer**
  - Technology maturation
  - New application development
- **Funding Mechanisms**
  - SBIR/STTR
  - Collaborative R&D with Industry
  - Public-Private Partnerships



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Next generation facilities will continue to need the close collaboration of multiple labs and multiple Office of Science Programs…

This map shows the principal collaborating institutions for LCLS-II

…and will benefit from having a corporate memory of engineering and supplier knowledge

ARDAP Chief Systems Engineer (CSE)

1. Supports SC-24.2's ability to see the totality of SC accelerator work being operated, constructed, and planned
    - Provides project-oriented system-wide knowledge of SC AS&T enterprise
    - Maintain awareness of current schedule of upcoming SC accelerator User Facilities
    - Identifies required technology components and current or anticipated production deficiencies for upcoming SC accelerator needs
    - Identifies cross-cutting basic R&D that has long-term, DOE-wide applicability
    - Identifies current or anticipated accelerator workforce deficiencies
2. Collects, disseminates, and curates database of lessons learned and best practices
3. Curates database of available technologies and vendors
4. Owner of Systems Engineering principles and standards for SC projects
5. Provides ongoing SME support to projects

Complementary OPA and ARDAP CSE roles

OPA's role

- Provide independent advice to SC on construction and operation of SC facilities
  - Conduct peer reviews on technical, cost, schedule, and management
  - Direct/supervise policies/plans/procedures for constructing and operating SC facilities
- Formal role representing SC with oversight bodies on construction and operation of SC facilities

Chief Systems Engineer role

- Provide the project-perspective part of ARDAP's total view of the SC AS&T enterprise
- Support projects as a Systems Engineering SME consultant
  - Develops SC-centric SE implementation guidance (O 413.3B)
  - Provides databases of LL/BP and technologies for projects
- Provides FPD with project SE plan assessment

ARDAP: Accelerator Research & Development

- BES, FES, HEP, and NP formed a task force in May 2018 to document the Accelerator Science & Technology (AS&T) needed to support physical science research for the coming decades. The analysis is refreshed annually and forms the basis for both the Accelerator Science & Technology Initiative and the initial strategy for ARDAP.

- The analysis organized AS&T into 5 themes:

1. **Advances in superconducting accelerator systems—both radiofrequency accelerators and high field magnets**—are a prominent theme shared by all four offices. Advances in superconducting materials, engineering, and cryogenic techniques will expand the capabilities and lower the operating cost of superconducting-based accelerator facilities.
2. **Beam physics and high-fidelity computer modeling**, together with better diagnostics and advanced control systems—are also a prominent theme shared by all four offices. Advances in theory and simulation to accurately model the next generation of particle accelerators need to be matched by **better diagnostics** and more sophisticated (and automated, **AI/ML-based) control systems**. Advances in particle-collider-specific beam physics including **focusing and advanced cooling techniques** are essential for HEP and NP science.
3. **Advances in high intensity electron, proton, and ion sources,** benefit BES, HEP, and NP science by increasing usable data and extending sensitivity. More robust **megawatt-class targets** for secondary beam production similarly will benefit the science.
4. **Higher average power radiofrequency and ultrafast laser sources** are becoming increasingly important to all four offices as time progresses. With improvements in power sources must come **improvements in power handling devices**—waveguide windows and couplers for radiofrequency systems, high power optics and coatings for laser systems, and **high accuracy x-ray optics**.
5. In the future, **high-risk high-reward advances in particle sources, beam dynamics** (e.g., integrable optics, HPC simulations), **acceleration techniques** (e.g., plasma wakefield), **and materials** (e.g., HTS superconductors) will provide the transformative advances needed to keep U.S. facilities at the forefront.

SC's Near-term R&D is focused on technologies which provide U.S. facilities a competitive advantage

- **Superconducting Accelerator Systems**
  - SC Undulators with strong focusing
  - HTS SC magnets for fusion confinement and high energy accelerators
  - SRF capability upgrades in material characterization, cavity processing
- **Beam physics and modeling**
  - AI/ML for control, optimization, and data analysis
  - Beam dynamics and FEL simulations for an XFEL oscillator
- **High intensity particle sources**
  - High brightness electron sources for light sources
  - High intensity ion sources for future ion facilities
- **High average power rf and laser sources, devices**
  - High average power ultrashort lasers for accelerators and HED physics
  - High energy lasers for fusion
  - Advanced x-ray optics
- **High-risk high-reward**
  - New materials for x-ray detectors
  - Plasma wakefield accelerators

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This slide lists the near-term priority areas included in the multi-Office Accelerator Science & Technology Initiative

Parting Thoughts

- Future accelerators will continue to develop new technologies that push the limits of energy, intensity, and power.
- Automation and high-accuracy design modeling will continue to increase in importance and use. Each will have safety impacts.
- Facilities will continue to grow in complexity, incorporating subsystems from multiple sources and vendors. Managers will push project risk and integration costs “out the door”, where possible, by buying increasingly integrated subsystems, complicating safety analysis.
- ARDAP will work to support the R&D and suppliers for SC’s facilities and provide systems engineering expertise to aid projects. The CSE can serve as another champion of safety lessons learned.