



Accelerator R&D and Production

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Director, Office of Accelerator R&D and Production (SC-25)

July 19, 2022



U.S. DEPARTMENT OF
ENERGY

Office of
Science

Bottom Line Up Front

Why

- **U.S. Accelerator Science and Technology (AS&T) capability is essential for keeping the U.S. lead in scientific research**
 - SC accelerator-based user facilities provide a suite of world-leading tools for probing physics, chemistry, material science, and biology
 - Particle accelerators touch nearly \$0.5 trillion of goods and treat more than 5 million cancer patients each year
- **U.S. AS&T competitive position is declining**
 - Long-term AS&T R&D funding has **declined 70%** since 2011
 - SC now purchases **more than half** of all key accelerator technology from **foreign sources**
 - U.S. AS&T publications comprise **less than 1 in 8 downloads**, down from 1 in 4 in 2011; Chinese AS&T publications now exceed 1 in every 3 downloads

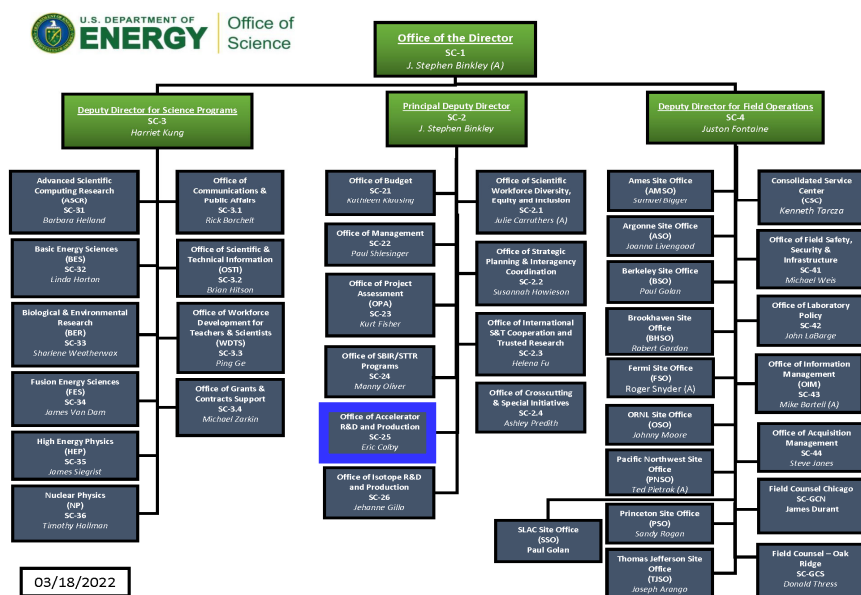
What

- **ARDAP Program Elements**
 - **Research (ongoing)**
 - Transformative advances of use to multiple SC Programs and the broader USG; first-of-kind technology demonstrations to develop new markets
 - DE&I enhancing workforce training and research programs FAIR (FY 2023) and RENEW (FY 2024)
 - **Facilities (ongoing)**
 - Facilitate access to accelerator test capabilities and workforce training
 - **Production (starting in FY 2022)**
 - Supply chain risk reduction through a variety of measures, with a focus on strengthening domestic suppliers
 - **Coordination and Dissemination (starting in FY 2022)**
 - Maintain a USG-wide strategic overview of accelerator technology needs and strong lines of communication

Accelerator R&D and Production (ARDAP) SC-25 At-a-Glance


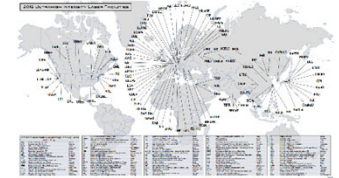
Mission: Ensure a robust pipeline of next-generation Accelerator Science & Technology to support physical sciences research while providing technology advances and industrial strength that position the U.S. to lead the world for decades to come.

- 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 2022: \$17.4M
 - Mostly Accelerator Stewardship program with new Accelerator Development program element
 - ARDAP's first dedicated Appropriation occurred in FY2022
- Staff: ~3.8 FTE plus more coming
 - Director – Eric R. Colby, 100% time
 - Deputy Director – Bruce Carlsten (IPA) ~90% time
 - Physicist – Marion White (detailee) ~40% time
 - Physicist – Roark Marsh (detailee) ~50% time
 - Budget Support – Chandra Hopkins, 100% time
 - Chief Systems Engineer – reposting position soon
 - Program Manager – offer made!
 - A&P Support – Christie Ashton, Carol Atherly (home office: SC-35) ~5% time total



Accelerator R&D and Production Mission

- **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.
- 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.



ARDAP Programs Mature and Commercialize Accelerator Technologies

SC science programs often focus on low-TRL development of mission-specific technologies

• ARDAP Accelerator R&D Program

- TRL 1 through TRL 4: **Accelerator Stewardship** program (red rectangle) is aimed at tech transfer and new applications, creating market pull.

• ARDAP Accelerator Production Program

- MRL 1 through MRL 7: **Accelerator Technology Production** sub-program (yellow rectangle) is aimed at strengthening domestic suppliers of AS&T.
- (Future) TRL 5 through TRL 7: **Accelerator Technology Maturation** sub-program (green rectangle) will be aimed at pushing critical AS&T across the 'valley of death'.

ACCELERATOR RESEARCH & DEVELOPMENT		ACCELERATOR TECHNOLOGY PRODUCTION	
TRL 1	Basic principles observed and reported	MRL 1	Manufacturing feasibility assessed
TRL 2	Technology concept and/or application formulated	MRL 2	Manufacturing concepts defined
TRL 3	Analytical and experimental critical function and/or characteristic proof of concept	MRL 3	Manufacturing concepts developed
TRL 4	Component and/or breadboard validation in a laboratory environment	MRL 4	Capability to produce the technology in a laboratory environment
ACCELERATOR TECHNOLOGY MATURATION			
TRL 5	Component or breadboard validation in a relevant environment	MRL 5	Capability to produce prototype components in a production relevant environment
TRL 6	System/subsystem model or prototype demonstration in a relevant environment	MRL 6	Capability to produce prototype system or subsystem in a production relevant environment
TRL 7	System prototype demonstration in an operational environment	MRL 7	Capability to produce systems, subsystems or components in a production relevant environment
TRL 8	Actual system completed and qualified through test and demonstrated	MRL 8	Pilot line capability demonstrated; Ready to begin Low Rate Initial Production
TRL 9	Actual system proven through successful mission operations	MRL 9	Low rate production demonstrated; Capability in place to begin Full Rate Production

From Technology Readiness Assessment Deskbook, July 2009,
http://www.skatelescope.org/public/2011-11-18_WBS-SOW_Development_Reference_Documents/DoD_TRA_July_2009_Read_Version.pdf

ARDAP Programs Mature and Commercialize Accelerator Technologies

\$10.2M

• Accelerator Stewardship

- Identifies and invests in cross-cutting and use-inspired R&D technology areas that enable new accelerator applications in industry, medical treatment, and national security
- Accelerator Stewardship Test Facility Program
- Long-term program, in current FOA
- Operation of the Brookhaven ATF as a National User Facility

\$5.5M

\$1.7M

• Accelerator Technology Production

- Identifies AS&T accelerator science and technology areas which are high-risk, or have the potential to be high-risk, supply-chain vulnerabilities, and to make targeted investments to build up the domestic vendor capability in those areas
- Business plan development funded in FY2021 FOA
- FY2022 FOA included funding for the first private-public partnerships

\$0M

• Accelerator Technology Maturation (Future)

- *Will identify accelerator science and technology areas which are high-risk, or have the potential to be high-risk, supply-chain vulnerabilities and which are struggling to cross the “TRL valley of death,” and to make targeted investments to ensure these areas are sufficiently technically mature to be commercialized by domestic accelerator technology vendors*
- *Awaits funding increases in future FY*

\$17.4M total in FY 2022

ARDAP Coordinates Closely with the SC Program Offices, the Interagency, and the Accelerator Community

- **ARDAP program priorities are coordinated with the SC Accelerator Joint Oversight Group (AJOG)**
 - Prioritization and coordination of specifics of the technical work also with NNSA, DOD, DHS, NIH, and NSF* ensure broader USG synergy as well
- **Community Input Efforts**
 - Inventory of R&D Needs for DOE Facilities
 - Completed in 2018, refreshed in 2020 – what accelerator R&D is needed and when for future accelerator facilities
 - Accelerator S&T Supplier Survey
 - December 2020 – where are current projects and accelerator facilities purchasing accelerator technology components?
 - Request for Information on Creating a Robust Accelerator S&T Ecosystem
 - January 2021 – how can we make the domestic ecosystem better?
 - Office of Science Roundtable on Supply Chain Risk Mitigation for Scientific Facilities and Tools
 - Led by SC-3 (Talia Melcer)
 - November 2021 – covered all technologies used for physical science R&D



*an MOU between SC and NSF is in development which could lead to closer coordination

Accelerator Science & Technology Initiative

The Accelerator Initiative has grown out of a 2018 Inventory of AS&T Needs and an analysis of supply chain vulnerabilities that was completed by BES, FES, HEP, and NP.

Five primary technology areas are strategically important for SC facilities

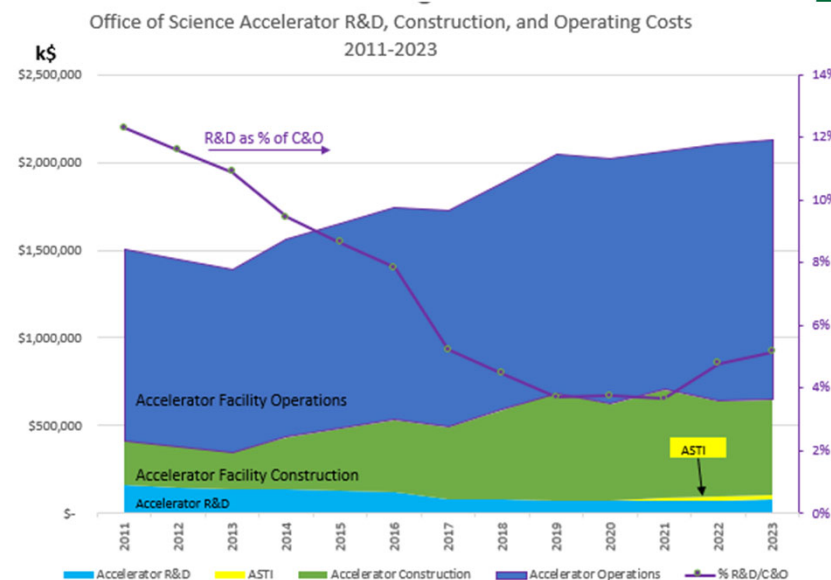
1. Advances in **superconducting accelerator systems**, including SRF, SC magnets, and cryogenic engineering.
2. **Beam physics** and **high-fidelity computer modeling & control**, including better diagnostics, (AI/ML-based) control systems, advanced focusing, and beam cooling techniques.
3. Advances in high intensity **electron, proton, and ion sources**, also including **megawatt-class targets** for secondary particle sources.
4. Higher average power **radiofrequency** and **ultrafast laser sources**, including **power handling devices**, and **high accuracy x-ray optics**.
5. **High-risk high-reward R&D** in advanced materials, particle sources, beam dynamics, acceleration techniques, and other advanced topics.



SC Accelerator R&D funding has declined sharply during the last decade

Between 2011 and 2022, SC AS&T* R&D funding has declined **55% in absolute terms**, and **70% relative to the total cost of R&D, Operations, and Construction**

- The U.S. has
 - Lost leading accelerator scientists
 - U.S. now has half the impact in AS&T relative to 2011, measured by paper downloads (Web of Science)
 - Lost leading vendors
- The U.S. now
 - Buys more than half of all AS&T technology offshore
 - Competes internationally for workforce
- The U.S. will
 - Fall behind in research facilities
 - Lose the lead in physical sciences



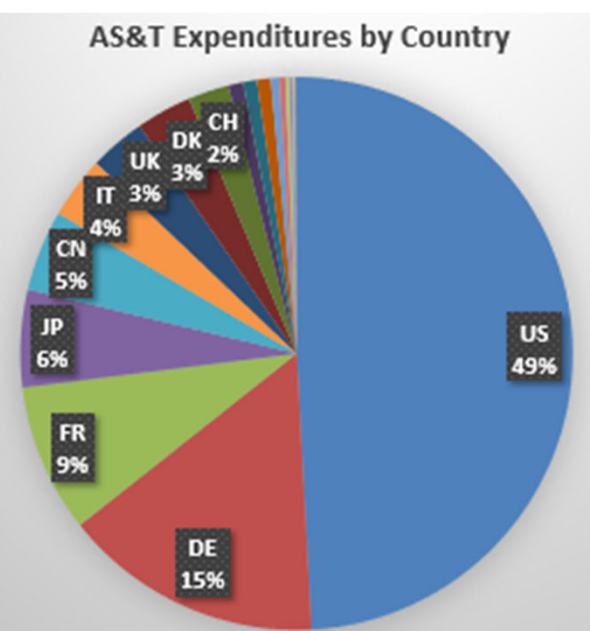
The Accelerator Science and Technology Initiative is beginning to address this



*AS&T = Accelerator Science & Technology

DOE's Reliance on Off-Shore Vendors is a Supply-Chain Risk

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



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

Technology	Specific Areas	Value [M\$]	% Foreign
Optics (incl. x-ray optics)	Specialty mat'ls, coatings, optics	\$ 11	100%
Superconducting Accelerators	Accelerator Cavity Manufacturing	\$ 149	70%
Laser Systems	Advanced ultrafast laser systems	\$ 16	67%
HV/UHV Systems	Pumps, chambers	\$ 40	66%
Conventional Magnets	Manufacturing, Perm. Magnet Mat'ls	\$ 117	61%
Cryogenic Systems	Large capacity liquid helium cryoplants	\$ 110	56%
RF Power Systems	High power klystrons, gyrotrons, solid state systems	\$ 156	51%
Superconducting Magnets	Superconducting cable and wire	\$ 49	50%
Power supplies	DC, high current, high voltage, pulsed	\$ 62	20%
Precision Mounts	Precision movers, ultrastable bases, alignment equipment	\$ 15	17%
Advanced Mfr Techniques and equipmeent	UHV furnaces, Add Mfr tools, advanced CMMs/CNC tools	\$ 38	15%
Particle Sources	Cathodes, Ion source expertise	\$ 28	15%
Specialized dielectrics	HV insulators	\$ 2	8%

\$430M spent off-shore for current projects and operations

Much of this accelerator technology was invented (and at one time produced) in the U.S.



How do ARDAP and GARD differ?

	ARDAP	GARD
Customer	Office of Science, other Federal Agencies, US industry	HEP
Program Aim	<ul style="list-style-type: none"> • Acc. Stewardship expands market pull and funds cross-cutting basic R&D • Acc. Development strengthens suppliers 	<ul style="list-style-type: none"> • Develops transformative new AS&T for HEP • Strengthens key suppliers needed for HEP facilities
Activities Funded	<ul style="list-style-type: none"> • Broadly applicable AS&T R&D • Tech transfer and new application development • Industrialization and supplier development for all SC Programs 	<ul style="list-style-type: none"> • AS&T R&D primarily for HEP • Tech transfer • Industrialization and supplier development for HEP construction projects
Advisory Mechanisms	SC Accelerator Joint Oversight Group, other Federal Agencies, data calls, RFIs, and BRN Workshops	HEPAP, Snowmass+P5 process, and Research Roadmap Workshops
Metrics of Success	<ul style="list-style-type: none"> • Technologies put to new uses • Suppliers strengthened, new capabilities developed • Standard academic measures of R&D productivity 	<ul style="list-style-type: none"> • HEP science that technology enables • Reduction of technical risk to science mission • Standard academic measures of R&D productivity
Follow-On Investment	Through SC facility projects, applied programs, and from industry	HEP-funded directed R&D projects to prepare for facility construction

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