U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND – ARMY RESEARCH LABORATORY

Army Research Office (ARO) - Overview

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ARMY MODERNIZATION

To have the best Army in the world,
we must have the best Science.

ARO is always looking for answers to the question:

How will we ensure success in the future?

Current Abilities

Technology Development (Science ≠ Technology)

Acquisition Requirements

Near Future ~5 years

Scientific Discovery

Cross-Cutting Competencies

Informing Future Warfighting Concepts

Far Future >20 years

ARO's work with basic scientific research drives toward the Army's *far* future capabilities 20, 30, 40 years from now.

MISSION

ARO's Mission

A component of DEVCOM ARL, the Army Research Office contributes to Army modernization by focusing on **basic scientific research.**

1. **Build the Future**
   Create and direct scientific discoveries for revolutionary new Army capabilities

2. **Solve Existing Problems**
   Drive science to develop solutions to existing Army technology needs

3. **Accelerate**
   Accelerate transition of basic research

4. **Educate**
   Educate and train future Army Scientists & Engineers workforce

5. **Prepare**
   Create technological superiority for U.S. Forces, and prevent adversary technological surprises

ARL's Mission:
Operationalizing Science for **Transformational Overmatch**

Disruptive Foundational Research Leading to U.S. Army modernization

Possess, create, and apply leading niche and cross-cutting competencies

Cultivate and optimize diverse talent in new areas for the modernized Army team

Army's primary collaborative link to the World-Wide Scientific Community

Shape Future Concepts and inform the future operating environment

RECENT ACCOMPLISHMENTS

3 NOV

Harnessing microbes for carbon-neutral biofuels

Professor Arpita Bose at Washington University in St. Louis utilized synthetic biology to engineer microbes that can synthesize a biofuel using only renewable energy sources. Certain microbial species can exchange electrons with external energy sources to drive metabolic mechanisms essential for their survival, in a process known as extracellular electron transport (EET). Researchers used synthetic biology to adapt EET in one of these species, *R. palustris*, enabling the organism to produce a biofuel using only three renewable and naturally abundant source ingredients: light, carbon dioxide, and electricity generated by solar panels. The resulting biofuel, n-butanol, is a carbon-neutral fuel alternative that could be adapted for use in blends with diesel or gasoline.

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Novel 2D materials may enable advances in electronic material properties

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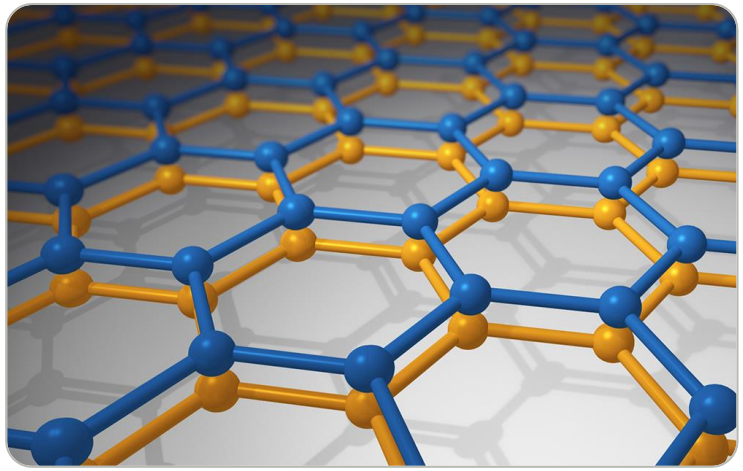
2 NOV

Responsive metamaterial may prevent vibrational damage in future rotorcraft systems

Professor Vincenzo Vitelli at the University of Chicago and Professor Guoliang Huang at the University of Missouri developed an active material that responds to environmental stimuli and could one day lead to new mechanical energy dissipation systems. The research team was able to build a physical system with so-called “odd elasticity.” Odd elasticity occurs when a material responds differently based on the direction of a mechanical wave, such as if a structure allows vibration to transmit in one direction but blocks vibration coming in the opposite direction. This testbed could lead to further advances in odd elastic materials that could enable platforms that are far less susceptible to vibrational damage, such as rotorcraft systems, given that loads from certain directions and frequencies could be manipulated and diverted to shield sensitive locations.



Bilayer graphene, a two-atom thin layer of carbon atoms arranged in two honeycomb lattices stacked together.

9 NOV

Reduction of bias in sensing systems for robust autonomous systems

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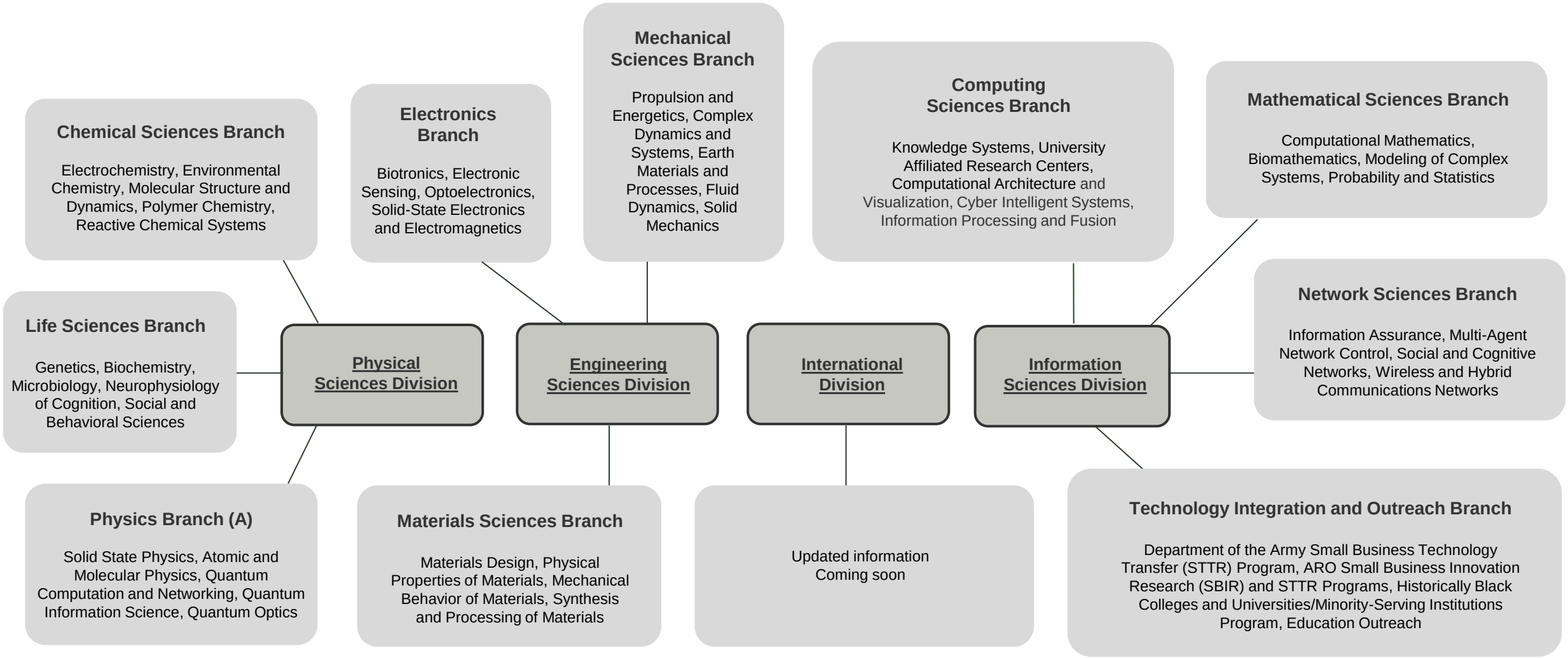
2 NOV

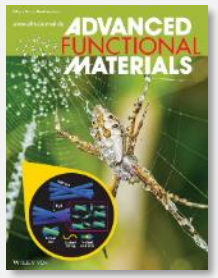
New understanding and control of electronic properties achieved in bilayer graphene

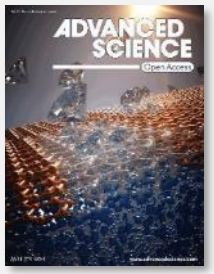
Professor Fan Zhang at the University of Texas at Dallas and colleagues were able to observe and control the quantum anomalous Hall effect, an unusual electronic property, in bilayer graphene, two single-atom thick layers of carbon stacked on top of each other. The Hall effect is a phenomenon in physics whereby the electrons in a current are driven in predictable directions when exposed to an external magnetic field. The quantum anomalous Hall effect occurs when a material not exposed to an external magnetic field experiences the Hall effect and the current increases in a quantized, step-wise manner. Additionally, the team was able to control the presence of the quantum anomalous Hall effect and other electrical properties of the material. This discovery offers the potential to enable new quantum information devices.

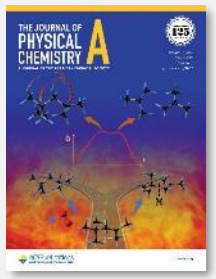
ARO RESEARCH AREAS

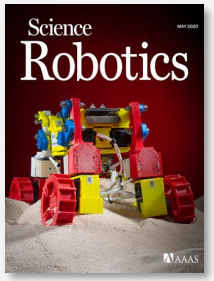


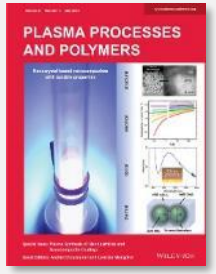
ARO ACADEMIC PARTNERNSHIP METRICS

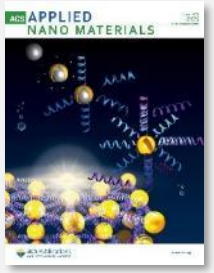


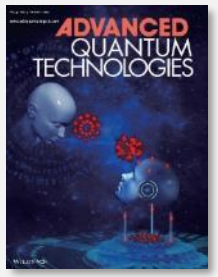












>7000
peer-review journal articles (2018 – 2020)

125
Patents (2020)

31
Tenure Promotions (2020)

ARL Competencies and ARO Basic Research Portfolios Reviewed by NAS TAB

In the press

12
ARL-ARO news releases featured on Army.mil in 2020

242
University news releases named ARL-ARO in 2020

73
University 2020 news releases quoted ARL-ARO program managers

166
funded NAE/NAS Members (2019 – 2020)

5
VBFF Awardees (of 8 total) (2021)

>110
Paper/Poster Awards (2019 – 2020)

13
PECASE and ECASE Awardees (2017-2019)

>3500
Average Graduate Students and Post-Doctoral Scholars supported per year (2018 – 2020)

7
ARO S&Es are Society Fellows (2020)

34
High School Apprenticeships (2021)

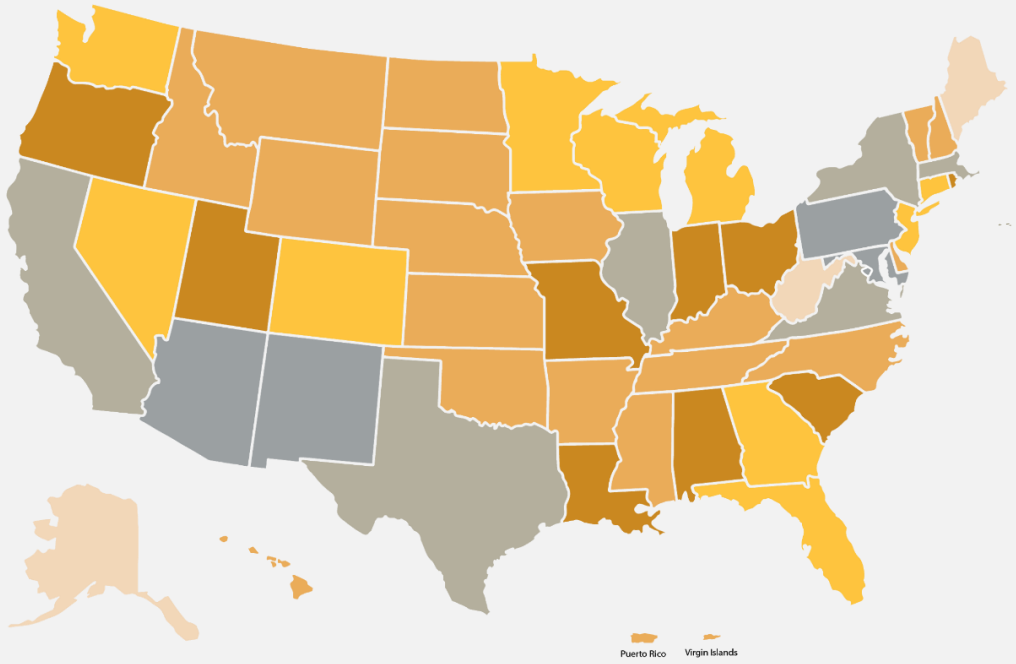
73
Undergrad Apprenticeships (2021)

FUNDING SCIENCE AROUND THE WORLD

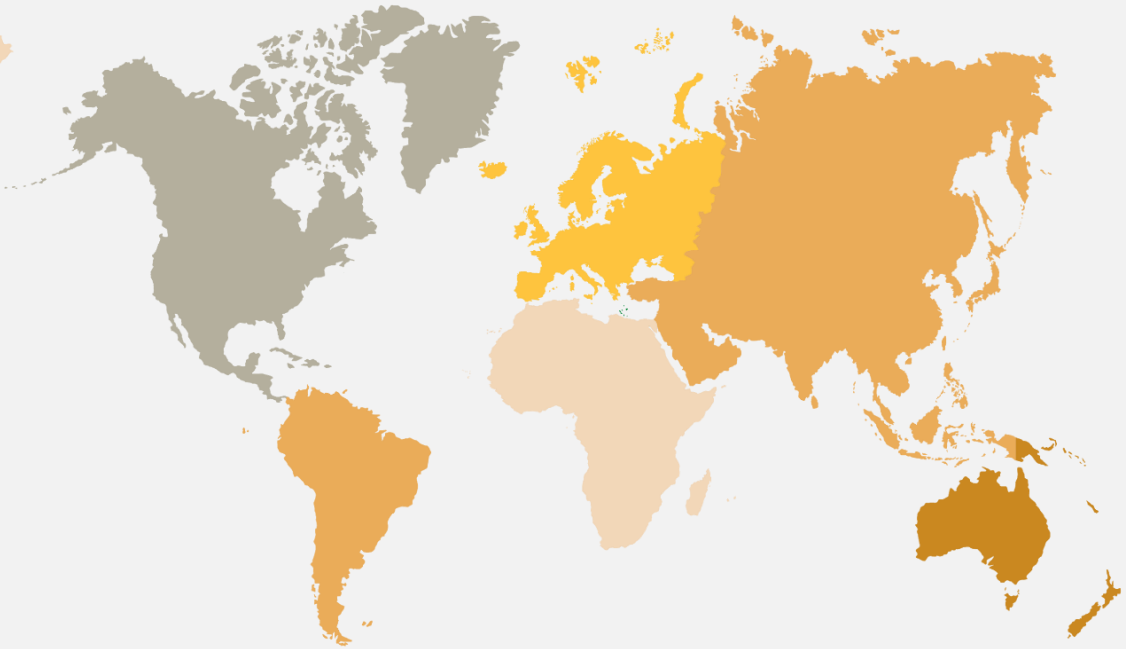
Total/cumulative award amounts for ARO-managed agreements active in FY21

- 0-$1M
- 0-$10M
- $10M-$25M
- $25-$50M
- $50M-$100M
- >$100M

Total/Cumulative Funding for FY21 Active Agreements by State



Total/Cumulative Funding for FY21 Active Agreements by Continent



ARO Research Activities

575
Institutes of Higher Learning
(CONUS and OCONUS)

1961
Individual Investigators

50
States

28
Countries

as of 15 JULY 2021

FY21 ARO-ADMINISTERED MISSION INSTRUMENTS

$100.8M

SI Single Investigator Program

Grants with one or two faculty and graduate students and/or postdocs.

- ~$141K/year average for 3-5 year periods
- 575 Universities

$64.7M

URI University Research Initiative

MURI Multidisciplinary University Research Initiative Program supports university teams whose research efforts intersect more than one traditional science and engineering discipline ~$1.25M per year, 3-5 year period, 7-8 new initiatives annually

DURIP Defense University Research Instrumentation Program improves capabilities for basic research in defense S&T areas and promotes education and training of future STEM pros

PECASE Presidential Early Career Awards for Scientists and Engineers enhance career development of early career investigators. $200K per year for a five-year research grant

$>19.8M*

SBIR & STTR Small Business Innovation Research and Small Business Technology Transfer

Established to provide small businesses and research institutions with opportunities to participate in gov't.-sponsored research and development.

* FY21 SBIR/STTR funds typically received in summer; also includes FY20 funds received and executed in FY21

$15.0M

UARCs University Affiliated Research Centers

Large centers associated with the U.S. Army, ARO manages the Institutes for Collaborative Biotechnologies (ICB), Soldier Nanotechnologies (ISN), Creative Technologies (ICT)

- 5 year efforts
- ~$5 – 10M per year

$1.6M

HBCU/MI Historically Black Colleges & Universities/Minority Serving Institutions ARO Core Grants

Matching funds support primarily single investigator research expanding and diversifying the Army research base via the HBCU/MI Community

- Topics from ARO BAA and consistent with SI funding

$30.4M

REP DOD Research & Educational Program for HBCU/MIs

ARO has administered REP on behalf of OSD since 1992. REP aims to enhance research capabilities of HBCUs and MIs and to strengthen their education programs in STEM disciplines that are relevant to the defense mission.

Under this program, qualifying institutions were able to submit proposals to compete for basic research equipment and instrumentation grants. In FY19, 59 grants totaling $23.3 million were made to 18 HBCUs, 26 MIs, and 1 Tribal College or University (TCU).

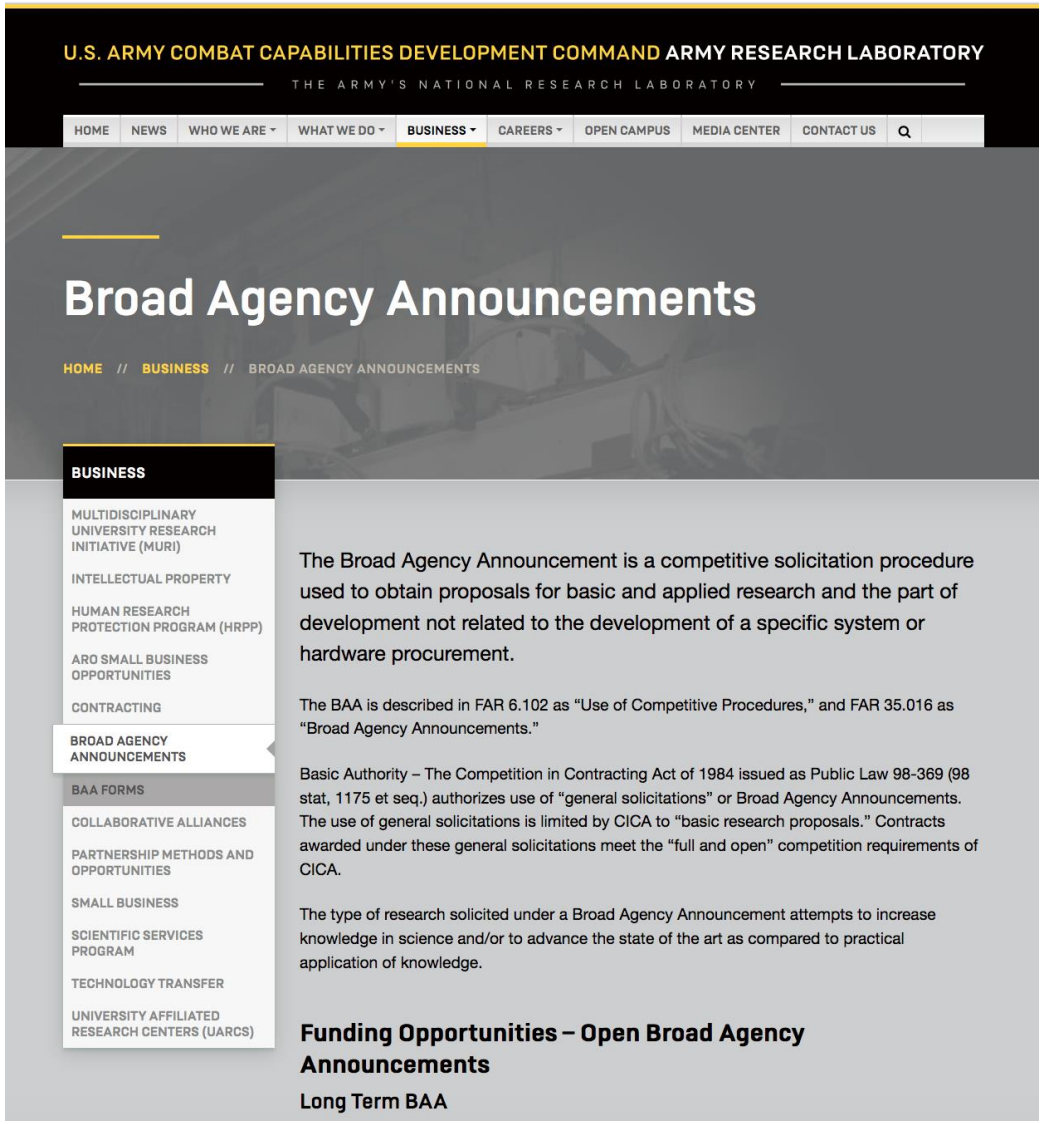
APPROVED FOR PUBLIC RELEASE

ARO AND OTHER BROAD AGENCY ANNOUNCEMENTS

Award Type	Target	Funding
Single Investigator (SI)	Single-laboratory projects	~$141K/year for ~3.4 years avg*
Short Term Innovative Research (STIR)	Very high-risk pilot projects	$60K for 9 mo.
Early Career Awards (formerly Young Investigator Program)	Early-career PIs	$120K/year for 3 years
Conferences / Workshops / Symposia	Academic State of Science	$10K–$30K
Presidential Early Career Award for Scientists and Engineers (PECASE)	Promising future leaders	$200K/year for 5 years
Defense University Research Instrumentation Program (DURIP)	Instrumentation	$240K (avg) per award*
Multidisciplinary University Research Initiative (MURI)	Large multidisciplinary programs	~$1.25M/year up to 5 years
Historically Black College/University and Minority Institution (HBCU/MI)	Minority serving institutions	~$140K/year for 3 years
Small Business Technology Transfer (STTR)	Multi-phase awards bridging academia & industry	$150K (6 mo.) to $1M (24 mo.)
Small Business Innovative Research (SBIR)	Multi-phase research for industry transition	$150K (6 mo.) to $1M (24 mo.)

*FY21 averages; funding level and duration in this award category vary based on scope of project, proposal, evaluations, and PM recommendation.

CONNECTING WITH DEVCOM ARL - ARO



ARL/ARO BAA

www.arl.army.mil/business/broad-agency-announcements

ARO Areas of Interest

Physical Sciences

Chemical Sciences
Life Sciences
Physics

Engineering Sciences

Electronics
Materials Science
Mechanical Sciences

Information Sciences

Computing Sciences
Mathematical Sciences
Network Sciences

Technical POC: Name, Email, Phone

How Prospective PIs Can Engage with ARO

CRITICAL QUESTIONS TO CONSIDER WHEN PITCHING IDEAS

Is it basic research?

- What's the scientific question?
- What foundational knowledge is not currently available about the workings of the universe?
- Proposals focused on specific devices/components/technologies are beyond the scope of ARO's mission.

Is it hard?

- If an "old" question, why haven't we found an answer yet?
- If a "new" question, where's the sticky part?

Why you? Why now?

- What's been done before? Why wasn't it successful?
- What's novel about your skills/abilities/ approach that makes you think there's a shot at an answer?
- What new advance provides opportunity to make new progress?

So what? Who cares?

- What impact will the research make on the scientific community?
- What papers will be written because of your efforts? What papers will stop being written?
- What are the potential implications for the future of technology?

Where's the risk?

- How confident are you that you're asking the right question?
- How will you know when you have an answer? If you find a different answer, will you still learn something?

What will it take?

- What resources (time, money, infrastructure, personnel, partnerships) are required to pursue the research?

ARO PROGRAMS: HOW TO ENGAGE

Your 'menu' of ideas

- Suggested initial ideas to share with PM: 3-4 ideas, 1-2 Paragraphs each, 2 pages max
- 2 ideas aligned with the program (see the BAA)
- 1 idea outside the program
- 1 idea characterized as half-baked, super high-risk, possibly "crazy"
- Submit directly to PM any time via email. Feedback is relatively fast.
- Do not ask "what research does ARO want me to do"

Whitepaper

- 5 pages max
- Provides a well-written scientific question and proposes a novel approach
- Describes the level of risk associated with the effort.
- Identifies the resources required to pursue the research (rough order of magnitude).
- Provides a short bibliography positioning the research in the body of knowledge.
- Submit any time via email.

Proposal

- Consult the ARO Core BAA for full details on requirements.
- Expands on the discussion in the whitepaper to adequately describe the proposed effort.
- Provides a reasonably self-contained description; expert reviewers should not have to heavily consult the literature or supplementary material to understand the question and the approach.
- Submit via grants.gov. Preferred receipt in _____ and majority of decision points are in ____.

PROPOSAL PROCESS: FROM IDEA TO POST-AWARD

Idea Curation

- Research Menus
- Whitepapers
- Discussions

Proposal Submission

- Detailed description of question(s), approach and potential impact
- Reviewed by external evaluators and Army/DoD SMEs

Proposal Selection

PM analyzes:

- Program fit
- Evaluator feedback
- Funds availability
- Potential for discovery
- Potential for transition

Proposal Award

- PM regularly engaged with research
- Site visits
- Conference attendance
- Relationship management
- Formal reporting

RECENT ACCOMPLISHMENTS

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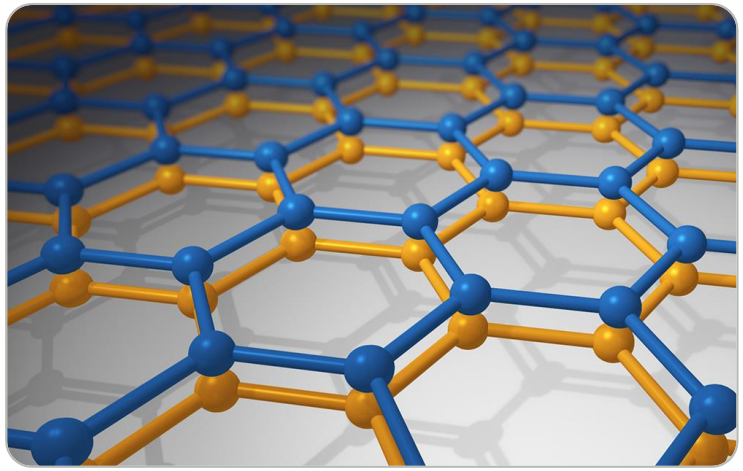

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ARL Outreach Programs

IMPORTANCE AND VALUE OF ACADEMIC RESEARCH TO THE ARMY

The scientific process is the foundation for **generating knowledge** of what is possible.

A **diversity of approaches** is key to discovery.

The Army's capacity for discovery and disruptive technology advances is expanded by **building a network**, not a pipeline.

Fundamental scientific knowledge opens new doors

- Army-Academic partnerships encourage use-inspired research otherwise unexplored.
- If I could tell you a new truth about the world, would it change the way you fight?
- If I had new understanding of how the world works, could I make it work in a new way?

Talent Development

- Students and research scientists become available to the Army.
- Annually, over 3,000 graduate students supported via CCDC partnerships. Over 45 Educational Partnerships Agreement are currently in place.

Expanded Research Capacity for the Army

- New advances emerge from building collaborative relationships with partners.
- The process of discovery and disruption is highly non-linear, iterative, and relational.
- In FY20, the Army was partnered with 256+ distinct academic partners to advance scientific knowledge via a diverse set of mechanisms.

DEVCOM-ARL PORTFOLIO OF OUTREACH PROGRAMS

ARL Programs

K-12 Local Outreach Program

Summer Researcher Program
Student Orientation; Summer Student Professional Development Series; Summer Student Week; Summer Student Symposium

ARL/USMA Technical Symposium

ROTC Summer Program

USMA AIAD Summer Program

ORAU Research Associateship Program (RAP)

National Research Council (NRC)

Educational Partnership Agreements (EPAs)

Army Educational Outreach Program

Undergraduate Apprenticeship Program

Undergraduate Research Apprenticeship Program

Graduate-Postdoctoral Fellowship

High School Apprenticeship Program

Gains in the Education of Mathematics & Science (GEMS)

Junior Sciences and Humanities Symposium (JSHS)

eCYBERMISSION

Army/Customer Programs

National Defense Science and Engineering Graduate (NDSEG) Fellowship

Science, Mathematics and Research for Transformation (SMART)

Pathways Internship Program

Pathways Recent Graduate Program

STEM Student Employment Program

**Managed by ARO*

Army Civilian Training, Education and Development Systems (ACTEDS)

HBCU/MI Design Competition

DoD Summer Internship Program

Centers of Excellence

Spelman AI/ML Initiative

DTRA Faculty Fellow Research Team Program

**Managed by ARL*

2021 ARL SUMMER PROGRAM OFFERINGS

High School Apprentice Program

Matches practicing DoD scientists with talented high school students creating a direct mentor-student relationship that provides students with training that is unparalleled at most high schools. The program fosters desire in its participants to pursue further training and careers in STEM. This program is open to students meeting all the following requirements:

- Enrolled in the 10th, 11th, or 12th grade
- 16 years old at time of apprenticeship
- U.S. Citizens or Permanent legal resident

Duration: The program is primarily designed for summer experiences; however work study and year round experiences are also available.

Resources: Students receive an educational stipend.

Application: https://www.usaeop.com

Application Deadline: February 28th

Summer Student Experience Program

Provides opportunities for select scientists, engineers and students (Bachelor degree through pre-PhD level) to engage in their choice of research problems that are compatible with or contribute to ARL research efforts. SSE is open to students meeting all the following requirements:

- Enrolled student or non-PhD recent graduates in Science, Technology, Engineering, or Mathematics (STEM) majors
- U.S. Citizens, Permanent Resident, and Foreign Nationals

Duration: May 10–Sept 24, 2021

Resources: ARL can offer a stipend, health insurance stipend supplement, relocation allowance and travel allowance.

Application: https://orau.org/arlfellowship/applicants/how-to-apply-summer-student-experience.htm

Application Deadline: February 28th

Army/Customer Programs

The ROTC Program is a summer enrichment program for ROTC college students in STEM related disciplines.

The Internship programs are leader development initiatives and a catalyst to help develop, retain, and ultimately commission quality ROTC Cadets as Second Lieutenants. All Cadets participating in these programs are volunteers and should be treated as junior staff officers.

Duration: Program runs 28 days during July through August. Students work 40 hours a week.

Resources: ROTC students are eligible to receive cadet pay based on academic and military rank. Transportation and housing resources are provided by cadet command.

Interested cadets should apply through their Brigade.

Application Deadline: December 1st

2021 ARL SUMMER PROGRAM OFFERINGS

Undergraduate Apprenticeship Program

Matches practicing DoD scientists with talented undergraduate students creating a direct mentor-student relationship, providing participants with training that is unparalleled at most colleges. This program is open to students meeting all the following requirements:

- Enrolled undergraduate students or recent graduates (within past six months)
- Science, Technology, Engineering, or Mathematics (STEM) majors
- U.S. Citizens or Permanent Residents

Duration: The program is primarily designed for greater than six month work study-internships and are available year round.

Resources: Students receive an educational stipend.

Application: https://www.usaeop.com

Application Deadline: February 28th

Post-College/Faculty/Senior Programs

ARL Fellowship Program

Provides opportunities for select scientists, engineers and students (Bachelor degree through pre-PhD level) to engage in their choice of research problems that are compatible with or contribute to ARL research efforts.

ARL Fellowships are managed through two cooperative agreements:

ORAU: www.orau.org/arlfellowship

NRC: sites.nationalacademies.org/pga/rap

Duration: The program operates year round to provide the Directorates maximum flexibility and ranges from a number of weeks to a year. Renewal option is available for most Fellows up to a maximum of three years.

Resources: Depending on the type of Fellowship and the needs of a specific Fellow, ARL can offer a stipend, health insurange stipend supplement, relocation allowance and travel allowance.

Oakridge Associate Universities (ORAU)

Postdoctoral: less that 5 years post-PhD

Senior Fellow: More than 5 years post-PhD

Short Term Fellow: A Postdoc or Senior Fellow at ARL for up to 20 weeks

Journeyman Fellow: A non-PhD (BA/BS or working on graduate degree)

Summer Student Experience: A summer student or non-PhD post-graduate

National Research Council (NRC)

Postdoctoral Fellow: less that 5 years post-PhD

Senior Fellow: More than 5 years post-PhD

Short Term Fellow: A Postdoc or Senior Fellow at ARL for up to 20 weeks

Davies Fellow: Teaches at USMA and conducts research at ARL

ARL Distringuished Fellow: Currently being established

- Three year program managed by ARL Fellows
- Awardee selected by ARL Fellows
- Awardee will select their technical research problem