>> 2022 ANNUAL REPORT

APPLIED RESEARCH LABORATORY FOR
INTELLIGENCE
AND SECURITY

ARLIS VISION: **Support Defense Intelligence and Security Enterprise goals with an organization that maintains world-class Science and Technology (S&T) Core Competencies, establishes trustworthy Research & Engineering and Testing & Evaluation capabilities, and performs education and outreach while maintaining excellence in its operating environment, management, resourcing, and facilities.**

CONTENTS

DELIVERING VALUE TO THE INTELLIGENCE ENTERPRISE

Two years almost to the day after insurrectionists entered the U.S. Capitol, thousands of protesters stormed Brazil's Congress, Supreme Court and presidential palace refusing to accept recent election results for the new president. Like the United States, Brazil now faces a period of introspection.

The events in Brazil are another proof point threats to democracy continue in 2023. Russia's on-going war against Ukraine; the lingering effects of COVID-19; and migrations in Latin America and South Asia all indicate continued regional destabilization that will impact U.S. national security. They place a finer point on the fact that there is a need to understand the human and social conditions creating these circumstances.

They also emphasize the continued need for improved collaboration across the intelligence community and security enterprise, and for a stronger connection of these communities to a science and technology community that can produce new understanding and capabilities.

The National Academies of Sciences, Engineering and Medicine's *Improving the Intelligence Community's Leveraging of the Full Science and Technology Ecosystem (2022)* recommends elevating the priority of science and technology, outlining specific areas for attention. ARLIS is contributing to many of the recommendations already and, over the last year, we have demonstrated our role in strengthening this ecosystem. We are connecting communities in ways that serve both short- and long-term interests; and are filling a void in scientific research.

ARLIS has definitively moved from "start-up" to an operational posture that delivers value to meet growing demand. This is pushing our four-year-old ARLIS endeavor to rapidly scale and mature. We closed out 2022 on a sharp growth projection as sponsors continue coming to us with more programs and we account for higher percentages of the University of Maryland's overall research expenditures.

It is with deep gratitude to the ARLIS Team (our "ARLISans") for their amazing efforts over the past 12 months that we provide you with this annual report for 2022. There are literally too many people to thank and acknowledge—this document is a testament to the collective output of our faculty and staff. I would also like to thank the steadfast support of the University of Maryland Division of Research, the Office of the President of the University of Maryland, and our many affiliate faculty and campus stakeholders, principal investigators, and ad hoc committee members. Standing up this major applied research laboratory for the intelligence and security enterprise has truly been an all-of-institution undertaking.

In the following pages there are examples of our latest successes and how we continue to demonstrate results. We look forward to continuing as a trusted government agent for applied research in the human domain.

>> **Dr. William Regli**
EXECUTIVE DIRECTOR

WHO WE ARE

Located in College Park, Md., the Applied Research Laboratory for Intelligence and Security (ARLIS) is part of the University of Maryland and has a unique relationship with the Department of Defense. It was established under the sponsorship of the Office of the Undersecretary of Defense for Intelligence and Security (OUSD I&S) to serve as a long-term strategic asset, one of 14 designated DOD university-affiliated research centers (UARC) in the country. Situated in UMD's Discovery District—a research park home to 60 private and governmental organizations—ARLIS connects the UMD, government agencies, and other higher education institutions to deliver strategic, multidisciplinary applied research.

ARLIS is the only DOD UARC focused on the human domain—the space where people, technology and information intersect and adversaries exercise influence for strategic advantage. Some of humanity's grand challenges reside in the human domain and our work supports the university's strategic plan to take on those challenges and advance the public good.

ARLIS conducts classified and unclassified research and serves the government as an independent, objective trusted agent. ARLIS provides rigorously obtained scientific insights and sociotechnical solutions to hard security and intelligence challenges, helping defense and intelligence mission owners respond to their needs effectively.

ARLIS CORE MISSION: Enable national security information advantage and decision superiority by developing scientific foundations and engineering sociotechnical capabilities in the Human Domain.

Trusted Agent

ARLIS is an objective, trusted partner for government sponsors. A key UARC tenet is to act in the public interest as a strategic partner with government sponsors rather than, for example, in the interest of corporate shareholders. ARLIS conducts business in a manner appropriate for this special relationship with DOD, combining technical excellence with independence and objectivity.

This strategic relationship allows unique access to our sponsors' operational contexts and information, resulting in deeper knowledge of their needs to provide greater impact.

Part of a World-Class University

The University of Maryland, College Park is the state's flagship university and one of the nation's preeminent public research universities. A global leader in research, entrepreneurship and innovation, the university is home to more than 40,700 students, 14,000 faculty and staff, and nearly 400,000 alumni, all dedicated to the pursuit of Fearless Ideas. Located just outside Washington, D.C., we discover and share new knowledge every day through our renowned research enterprise and programs in academics, the arts and athletics. And we are committed to social entrepreneurship as the nation's first "Do Good" campus.

Inspired by its land-grant mission legacy, the University of Maryland honors its commitment to develop research, educational, and technological strengths to positively impact the quality of life, not just locally but worldwide. The benefits of UMD's land-grant tradition have given ARLIS a clear mission to not only create purpose-driven research to address some of our country's most difficult challenges but also to nurture a pipeline of future scientists and build academic partnerships with higher learning institutions nationwide.

UMD's state-of-the art research capabilities and facilities, coupled with its prime location and status as the largest university in the Washington Metropolitan Area, have facilitated extensive strategic research partnerships with U.S. federal agencies, positioning UMD as the nation's research university. In the immediate neighborhood are numerous government agencies devoted to scientific

research, including the Army Research Laboratory, the U.S. Army's primary facility for scientific research; NASA Goddard Space Flight Center; the National Institute of Standards and Technology; the Food and Drug Administration; National Oceanic and Atmospheric Administration; and the National Security Agency. These strategic research partnerships with the federal government offer unique opportunities for students and intelligence community professionals to work alongside ARLIS researchers to create new academies and foster internship programs.

Our People

Researchers are at the core of ARLIS. Multidisciplinary and interdisciplinary teams are technically and academically grounded and use robust scientific practices to deliver their analyses.

The ARLIS research team draws from a wide range of expertise and disciplines representing 40 different degrees in the areas of social and behavioral sciences, political and economic sciences, languages and linguistics, systems engineering, and computer science. With more

CORE VALUES

HUMANS FIRST

ARLIS is building a research and experimentation (R&E) capability to help tackle complex national security problems, which are invariably human problems. We use technology to better understand and augment humans and sociotechnical systems for the benefit of the nation. We create better solutions by keeping human diversity at the center of our research and our operations. We embrace teamwork as key to our success: we value—and celebrate—those who put the team first.

MISSION ALWAYS

Being an applied research lab means we ensure our work is useful. It creates urgency in what we do: enabling those who serve us to better preserve and defend our democracy. We focus on mission impact by developing a deep familiarity with our sponsors and their challenges, ensuring that our work makes a lasting and positive contribution to the nation. We also think long-term as we build our R&E capability, never forgetting that we are planting trees today whose shade may only be enjoyed by those who come after us.

TRUSTWORTHY TOGETHER

We understand our mission puts us in a position demanding trust—from our sponsors, our partners, our country, and each other. We hold ourselves accountable to the highest research and ethical standards, and we keep the confidence of those whose mission depends on us. We treat ourselves and each other with respect, acknowledging everyone's inherent right to dignity, and we earn our trust every day through what we do.

than 100 employees, the ARLIS team continues to grow in the areas of human and social systems; intelligent human-machine systems; data science, advanced computation and emerging technologies; and software and systems engineering.

These technical experts work with ARLIS's many former and current defense security and intelligence operators and policymakers to solve difficult national security problems, resulting in quality research that is relevant both to academia and our operational partners.

Facility and Research Infrastructure

ARLIS's 128,000 square-foot secure workspace allows work at all levels of classification and provides our government partners with secure access to our core capabilities and breakthrough scientific research. The infrastructure, coupled with our location, provide a useful venue for hosting conferences and wargaming exercises year-round.

The facility includes a 180-person auditorium and an 80-person conference room, both with secure video teleconferencing, supporting multi-participant meetings at the classified level. The facility is ideal for wargaming exercises as well, with multi-room, real-time and adaptive gameplay infrastructure. As a result, ARLIS continues to support a series of high-visibility cyber-resilience exercises for the government.

Research infrastructure of course encompasses more than physical space. ARLIS is building a diverse and scalable multi-domain, multi-tenant computational infrastructure to better integrate research projects and capabilities from both academia and government. Existing projects like the Cognitive Security Proving Ground and the digital-twin model for supply chain security require particularly robust IT infrastructure and the ability to interface with the systems of DOD and intelligence community sponsors. ARLIS infrastructure (especially our NIST SP 800-171 compliant environment for controlled unclassified information) serves as a critical enabler for INSURE consortium members and other partners. Many partners do not have the ability to handle CUI in-house, which greatly limits the type of unclassified trusted work they could contribute to without ARLIS partnership.

RESEARCH IN THE HUMAN DOMAIN: WHERE PEOPLE, TECHNOLOGY AND INFORMATION INTERSECT.

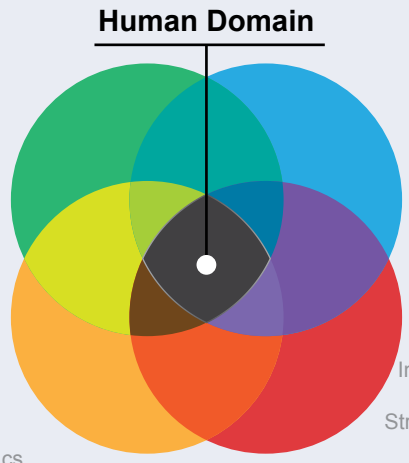
More than 40 different degrees and disciplines are represented within ARLIS.

Social Science

Cognitive Security
Behavioral Science
Cognitive Psychology
Sociolinguistics
NLP
Foreign Language
Culture
Anthropology
Neuroscience
Collective Intelligence
Behavioral Modeling

Computer Science

Machine Learning
Artificial Intelligence
Autonomous Systems
Computational Linguistics
High Performance Computing



Engineering

Manufacturing Systems
Systems Engr
Digital Manufacturing
Digital Engr
Software Design Engr
Mechanical Engr
Industrial Engr

Government/ Operational

Insider Risk
Supply Chain Risk
Counterintelligence
Info. Environ. Operations
National Security Policy
Strategic Communications
National Intelligence
Intelligence & Security Policy
International Affairs

CONNECTING COMMUNITIES TO MORE EFFECTIVELY SOLVE CHALLENGES IN THE HUMAN DOMAIN

While ARLIS supports the government as a trusted agent, it also brings value to the government as the nexus between government agencies, academic institutions and a future pipeline of skilled employees. ARLIS connects these communities to improve communication and collaboration and increase bench strength to more effectively solve challenges in the human domain.

Across UMD

ARLIS collaborations with and for campus researchers serve as force multipliers for both groups. Campus affiliates contribute directly to ARLIS-led research and programs, offer technical perspectives to program development and bolster ARLIS's strategic scientific vision by providing guidance on and access to cutting-edge research developments worldwide.

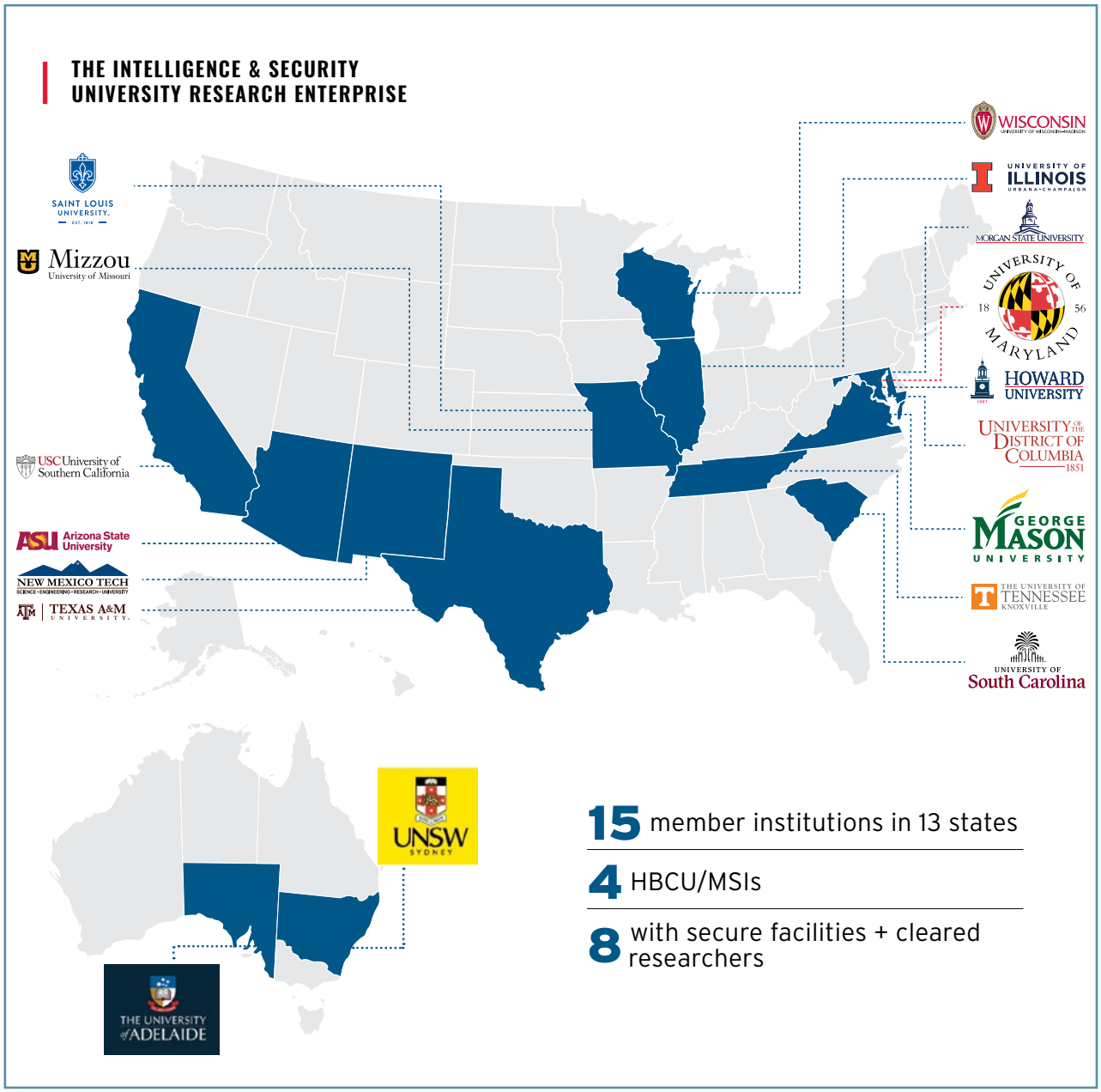
In turn, researchers at ARLIS contribute to UMD success broadly through participating in campus-led initiatives (such as the $68 million Army Research Laboratory collaborative agreement known as AI and Autonomy for Multi-Agent Systems (ArtIAMAS)), holding joint appointments with academic units, teaching classes, and mentoring and advising students.

In 2022, 21 ARLIS and UMD researcher—about half each—supported work at ARLIS or UMD projects across six colleges and 15 departments or research units.

Strengthening the Intelligence and Security University Research Enterprise (INSURE)

As the only UARC principally established to support the intelligence and security communities, it is critical ARLIS pull together the right team of experts for any challenge those communities bring. UMD provides one source of scientific strength, however through the ARLIS-led university consortium, the Intelligence and Security University Research Enterprise (INSURE), UMD leads in filling capability gaps and growing the pool of institutions able to do critical national security research. Established in 2020, the consortium coordinates applied and use-inspired research activities for intelligence and security at member institutions, aligning projects with specific DOD and intelligence community program managers and activities. This alliance improves the translation of products into operational use and enhances the pipeline of students and faculty to work directly on technology problems for the national security community.

INSURE members include notable Carnegie-R1 research institutions alongside top-quality institutions too often left out of applied defense research such as Historically Black Colleges and Universities (HBCUs) and other minority-serving institutions (MSIs). All bring institutional strengths in ARLIS priority areas; a track-record of conducting applied, quick-turn, mission-relevant research and development; existing relevant security partnerships to integrate into INSURE stakeholder community; and institutional leadership buy-in, to ensure sustained partnership not reliant on individual researchers or projects. INSURE projects are within scope of ARLIS core competencies and of UARC character. They include an ARLIS lead to track progress, connect



relevant stakeholders, and integrate the effort into the corresponding ARLIS portfolio. There are multiple pathways to funding, including a member engaging a potential sponsor directly about work and develop programming, members conducting joint program development, leveraging inter-institutional strengths, or a U.S. government agency requests research and development effort needing ARLIS partners' strengths.

By the end of 2022, INSURE had 15 member universities including four MSIs, plus its first two international affiliates: the University of Adelaide and the University of New South Wales, both in Australia. New members in 2022 were the University of Southern California, University of Tennessee in Knoxville, and New Mexico Tech.

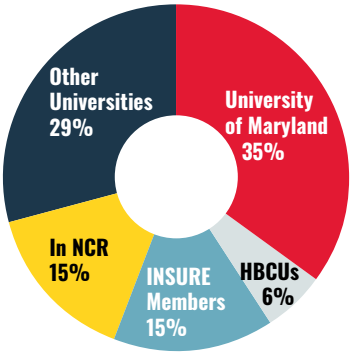
Research for Intelligence & Security Challenges (RISC)

One of the biggest challenges facing the defense and intelligence communities is the competition for talent. The demand for employees who hold security clearances continues to outpace the supply of available workers, particularly in STEM fields (Science, Technology, Engineering, and Mathematics) and with rigorous academic training. In 2020, ARLIS launched the Research for Intelligence & Security Challenges (RISC) initiative to help fill the pipeline of employees needed to address today's security issues.

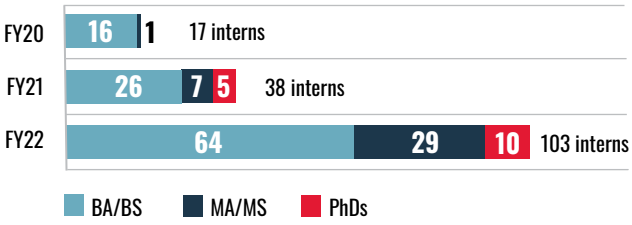
Over a 10-week internship, top undergraduate and graduate students from UMD and other universities work on real-world problems within ARLIS's focus areas as a UARC. In the process, RISCers learn about sponsor missions and career opportunities in the defense and intelligence security enterprise. RISC targets students from various disciplines including science, technology, engineering, mathematics and social science fields.

The interns work in teams of two-to-four students under guidance from faculty and government mentors. They use realistic data sets to work on real-world problems.

UNIVERSITIES ENGAGED



PROGRAM GROWTH BY NUMBER OF INTERNS



77 cleared by program's end (90 today)

The program is structured to facilitate interaction within teams, between teams and with government sponsors.

Beyond the training experience and mission exposure, team deliverables vary greatly by project. Some generate a shareable code base, while others generate and brief policy recommendations. ARLIS also helps RISC interns obtain clearances, adding value to the interns' summer efforts and setting students up for national security work in the future.

Ultimately, the RISC program aims to attract new talent to the DOD, intelligence community, and larger security and intelligence enterprise by exposing top students to interesting work in support of a compelling mission. Though the program remains young, early data indicate a clear return on investment: of the 38 interns who participated in the summer 2021 program, 14 were employed by the government, the defense industry or ARLIS as of October 2022.

RISC has grown exponentially since its inception, from 17 students the first year to 103 in 2022. More than 35 continued working on projects into the fall, and the majority of the interns have expressed a desire to pursue careers in intelligence and security. As of November 2022, 91 interns from RISC 2022 had been successfully adjudicated for security clearances which will further facilitate those career paths.

The Phoenix Challenge

Finally, another important way ARLIS connects communities is across intelligence and security agencies themselves. Under the patronage of the Office of the Undersecretary of Defense for Intelligence and Security and in partnership with the nonprofit Information Professionals Association, ARLIS organizes a series of events known as the Phoenix Challenge. Through the Phoenix Challenge, ARLIS demonstrates itself to be a thought leader, convening stakeholders and focusing them to collaboratively address challenges to operations in the information environment.

ARLIS uses broad authority to serve the needs of the intelligence and security community to facilitate workshops with wide attendance including senior-level defense and intelligence leaders. ARLIS sets the vision and strategic direction for leaders to discuss and develop actionable plans to address challenges to operations in the information environment. These events uniquely bring together military, intelligence, interagency, allied, academic, and industry participants across broad domains of expertise.

The main Phoenix Challenge events take place on a quarterly basis with additional workshops held in between. ARLIS subject matter experts capture and synthesize the outcomes from the events, connect agencies to actions and track progress. Ultimately, the goal is to accelerate success for Operations in the Information Environment and the National Defense Strategy.

The overarching theme of the 2022 workshops was improving the Defense Department's ability to gain and maintain information advantage—including the challenges of misinformation and disinformation—using current and future capabilities and technologies. The workshops sought to achieve three goals:

- Inform and coalesce departmental efforts supporting information advantage and cognitive security.
- Support the Information Operations Posture Review, as required by Section 1631 of the National Defense Authorization Act for FY 2020.
- Support revision of the 2016 Strategy for Operations in the Information Environment.

In 2022, ARLIS articulated known gaps and challenges to operations in the information environment; informed key department leaders about the needs in each area; and began establishing the relationships that will allow us to collectively make progress in realizing the potential of Operations in the Information Environment.

Phoenix Challenge has become the nucleus of engagement and outcome-based collaboration for the broader information enterprise. The ongoing series of events will ensure that community members hold each other accountable for filling the gaps and ensuring ARLIS follows through on commitments.

SPANNING THE HUMAN-MACHINE SPECTRUM

All actions in the global competition for national security come down to influencing the humans responsible for national security in their respective countries. These humans rely ever more on machines to express and amplify their influence, as exemplified by the internet. This reliance on machines, combined with advances in artificial intelligence (AI) and other technologies, point toward a future where the human and machine domains merge into a single, integrated human-machine domain. We see this happening in cyber space, where actions not only engage the software and hardware in the machines, but the human developers and users. Conducting influence actions in the context of national security is a complex human-machine (or socio-technical) undertaking requiring many disciplines working together.

In recognition of the trend toward an integrated human-machine domain for national security, ARLIS has organized itself accordingly, with multi-disciplinary core competencies spanning the human-machine spectrum, and mission areas focused on human-machine applications important to national security.

We have three core competencies, one human-centered (Human and Social Systems), the second machine-centered (Advanced Computing and Emerging Technologies), and the third bridging the first two (Intelligent Human-Machine Systems). As a UARC, ARLIS provides expertise in such human-centered disciplines as psychology, cognitive science, sociology, computational social sciences, neuroscience, language and computational linguistics, organizational science, political science, anthropology, criminology, economics, education, philosophy, and law.

Machine-centered fields at ARLIS include engineering, mathematics, operations research, integrated systems, advanced computing hardware, software-defined networks and edge computing, quantum information sciences, neuromorphic and alternative computing; biocomputing, and advanced electronics.

Disciplines at ARLIS important to intelligent human-machine systems comprise machine learning, adversarial methods, autonomy, human-computer interaction, human-machine teaming, natural language processing, data science, virtual reality/augmented reality, and the systems engineering, integration, and verification and validation approaches to enable the transition and application of these technologies into operational deployment.

Four mission areas cut across the three core competencies to form a matrix organization dedicated to overcoming important challenges to the Department of Defense and Intelligence communities in their mission of national security:

Cognitive Security
- Capabilities for online and offline influence, and protecting against influence

Insider Threat, Trust and Risk
- Capabilities for vetting personnel, countering malign influence

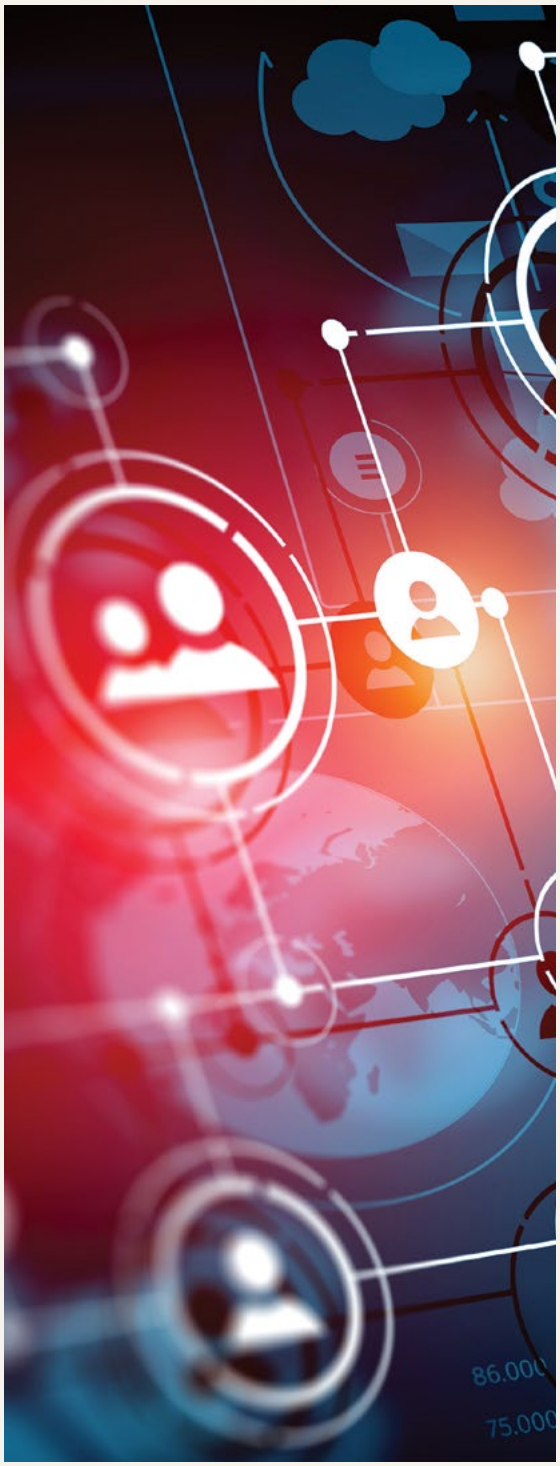
Acquisition and Industrial Security
- Capabilities for creating high assurance supply chains, and protecting U.S. technologies

Autonomy, Augmentation and AI
- Capabilities for the operationalization of human-AI teams, such as crowdsourced forecasting

The ARLIS multi-disciplinary/multi-mission matrix started out strong in 2022 and is poised to help solve the complex problems of human-machine influence actions critical to national security.

>> Dr. Brian Pierce
CHIEF SCIENTIST

CORE COMPETENCIES



>> HUMAN AND SOCIAL SYSTEMS

ARLIS's origins as a UARC focused on comprehensive language preparedness for DOD and the intelligence community, particularly in the aftermath of the September 11, 2001 terrorist attacks. Then known as the Center for Advanced Study of Language (CASL), the organization assembled language, culture, and human performance researchers capable of responding to operational requirements while pursuing the strategic research needs of the government.

ARLIS builds upon CASL's unique capability to collect, curate, annotate, and analyze unstructured and multilingual textual data, particularly from social media and other Internet sources. It requires area studies experts to identify data sources; computer scientists to acquire, clean, and archive them; linguists to design search terms and sampling techniques, interface with native annotators, and build or implement machine learning models; and social scientists to interpret and visualize data for government, academic, and public audiences. Researchers have honed this capability on a variety of test and evaluation (T&E) teams for funding agencies, including DARPA and IARPA.

Since the end of the U.S. military presence in Afghanistan in 2021, ARLIS has focused on building in-house capacity in five stronghold languages critical for national security: Arabic, Chinese, Farsi, Korean, and Russian. However, our researchers represent a uniquely diverse collection of languages and cultures from around the world. When additional expertise is needed—for example, for native-level evaluations of highly contextual social media data—researchers can quickly leverage ARLIS's INSURE consortium, international partnerships, and the University of Maryland community.

ARLIS equally builds upon CASL's track record of research for the government in support of judgment and decision-making and workforce development; this has required researchers to develop specialized expertise to meet both government and academic compliance standards for experimental design and human subjects research.

The Human and Social Systems Core Competency Area has emerged as a critical enabler for our Cognitive Security and Insider Risk mission areas. This includes developing a better understanding of the role of emotions in communication, how emotions may be expressed differently in different languages and cultures, and the role that emotions play in online social media-sharing behaviors. ARLIS also serves as the T&E partner on a program that works to detect influence campaigns. In this capacity, ARLIS develops scenarios, evaluation metrics, and annotated datasets to inform the program's understanding of the role of agendas, concerns, and emotions in influence campaigns.

Given the growing volume of unstructured, non-English textual data available to the government the lab's behavioral, cognitive, and social scientists have the potential to contribute to all of the ARLIS's mission areas.

The Human and Social Systems core competency area recruits, maintains, and develops expertise in:

- Foreign languages and dialects;
- Linguistics;
- Disciplines relevant to the acquisition and practice of analysis and critical thinking (e.g., psychology, cognitive science, neuroscience, computer science, organizational science, political science, anthropology, criminology, economics, education, philosophy, and second language acquisition); and
- Disciplines relevant to the manipulation, use and sharing of information of varying quantities and diverse forms (e.g., artificial intelligence, knowledge acquisition, knowledge representation and reasoning, knowledge discovery and data mining, knowledge management, organizational learning, organizational behavior, machine learning, human-computer interaction, natural language processing, information studies, data science, computer science, and virtual reality/augmented reality).

Battling an "Infodemic"

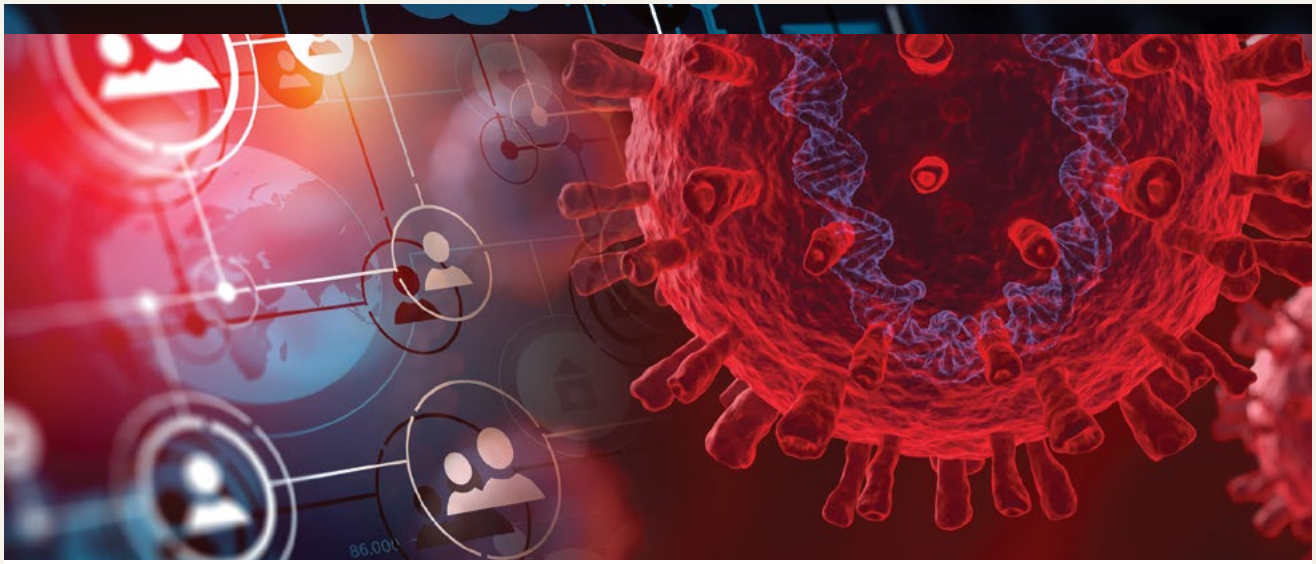
While countries battled the COVID-19 pandemic, they also found themselves battling a parallel "infodemic"—the spread of misinformation that caused dramatic shifts in national reputation, communication strategies, and research priorities. A better understanding of these dynamics could improve U.S. and allied nations' cognitive security, public health response, and operations in the information environment.

ARLIS used language and social media analysis to track and characterize COVID disinformation narratives in the United States. The project grew into a larger portfolio of U.S. government-funded projects around pandemic-related changes to the international information environment.

One research area analyzed how adversaries sought to re-shape perceptions of the U.S. pandemic response. Russia, which focused criticism on the United States, tended to represent many diverse and contradictory narratives, targeting varied interest groups within the United States. Chinese narratives balanced praise and criticism. However, ARLIS also discovered China leveraged the pandemic to incite fear and division about biological weapons within target populations, while trying to deflect responsibility for the virus to the United States and position itself as trustworthy on epidemiological issues.

This positioning parallels China's accelerated pace in biotechnology and neuroscience research production, an observation supported through bibliometric tracking in another ARLIS study. ARLIS identified trends in brain-computer interfaces, human performance, health, and related technological capabilities pointing to focused attention by China. ARLIS also identified top Chinese funding organizations supporting these thrusts.

ARLIS researchers were also interested in social media narratives about U.S. pandemic response among allies >>



BATTLING AN "INFODEMIC" CONT.

including Canada, Australia and France. Researchers identified and tracked geolinguistic distribution of topics, sentiments, and attitudes toward the United States and found variation across countries and languages. Negative discussions of U.S. response were particularly prevalent in English-language French tweets, where the most common topic in the model involved conspiracy theories. Canadian English had the least content relating to misinformation or conspiracy theories.

Within the United States, narratives spread differently in English- and Spanish-language communities. Both communities discussed vaccination information, COVID origin theories and conspiracies, and case counts. However, English-language discussion was more likely to include personal reports about vaccination experiences, and anger at anti-vaxers/anti-maskers as well as about COVID-19 more generally. Spanish-language discussion included greater focus on debunking conspiracies, and on U.S. vaccine donations to other countries. However, both datasets included discussion of how U.S. policy compared with and affected other countries, highlighting the importance of integrating study of the information environment across national borders.

Further exploring international spread, ARLIS carried out open-source information tracking of Russian propaganda about Western vaccines. The Russian state-owned media outlet Russia Today (RT) leveraged drug-manufacturer Pfizer's own vaccine side-effect data to create false narratives about the vaccine, including exaggerated claims about its risks and claims that the company was stalling release of the side-effect data itself. ARLIS detected the use of RT language and framing in fringe and far-right U.S. media outlets, demonstrating how foreign influence campaigns move across borders and find traction within communities.

Finally, researchers examined strategies for mitigating disinformation, testing messages and imagery among unvaccinated populations in Australia and Canada. We tested summarized pro-vaccination messages focused on key points, in comparison to verbatim vaccine efficacy information. We also tested the use of different emotional content and imagery. Fear-based messages and imagery produced strong resistance in unvaccinated groups. Based on these results, we offered guidance on improved messaging to avoid backlash and address reasons for resistance among long-term unvaccinated groups.

The results highlight the value of open-source message tracking, and the importance of examining information flows across international boundaries in order to create richer sensemaking of local information environments. The methods used here can be applied not only within the COVID pandemic, but to a wide range of crises with the potential to dramatically alter the international information environment.

Enhancing Linguistic Learning

Proficiency in strategic languages is key to the success of the DOD's intelligence linguist workforce and, therefore, to national security. While the DOD invests considerable resources and time in language training, learning outcomes regularly fall short. ARLIS pursued a novel approach to this problem grounded in neuroscience: transcutaneous vagus nerve stimulation (taVNS).

TaVNS is a safe, comfortable, and effective technique for stimulating the vagus nerve and related brain areas associated with learning and attention. It consists of a small electrical current administered to the surface of the skin in the outer ear canal through an earbud which propagates, via the vagus, to key areas in the brain.

Through an award to the University of Maryland, ARLIS researchers led a performer team for the Defense Advanced Research Projects Agency's (DARPA) Targeted Neuroplasticity Training (TNT) program. The goal of the UMD team's effort was to develop an intervention based in taVNS to significantly accelerate learning rate and skill performance in foreign language training, with an emphasis on speech perception, vocabulary, and grammar training.

Through this work, ARLIS sought to determine the optimal taVNS parameters for inducing short- and long-term neural plasticity in cortical-level brain regions involved in auditory decoding, cognitive control, and memory encoding, all of which support language learning, while minimizing negative physical and cognitive side effects. Validation studies were conducted in humans and animal (ferret) models, using behavioral and psychophysiological methods. In human studies, taVNS was the primary focus but additional nerve targets (cervical vagus and trigeminal) were also examined in laboratory experiments, and in field studies.

Beginning in April 2017, the initial team included UMD as prime, Arizona State University as a subcontractor, and the UMD Institute for Systems Research. During the two-year base phase, DARPA increased UMD funding by $1 million to support additional experiments with cervical tVNS and trigeminal stimulation. In the option phase, DARPA gave the UMD team additional support for a joint effort with the U.S. Air Force Research Laboratory and the Institute for Human and Machine Cognition (IHMC, subcontractor to Parallax Advanced Research Corporation) to conduct field studies with the U.S. Air Force 517th Training Group in Monterey, California. This effort ended in August 2022.

The overall findings of the double-blind treatment studies indicate taVNS can enhance certain aspects of language learning. In speech perception experiments, results showed that administering taVNS prior to, and during, the study phase led to better performance in the testing phase for Mandarin tone discrimination and vocabulary learning when words were distinguished by tone only, as well as psychophysiological indicators of enhancements to arousal and attention and linguistic processing. The results of other experiments showed stimulation during the testing phase can impair vocabulary recall performance, suggesting the shifts in arousal and attention interfere with retrieval and retrieval-based practice. These results are important for understanding the limitations of taVNS and, therefore, optimal administration.

The results also showed taVNS can be effective in more realistic learning environments. There was evidence for a positive effect of taVNS on grammar learning using the commercially available Duolingo language learning platform. In the field study, cervical taVNS boosted performance on a vocabulary learning task.

Taken together these findings validate the hypothesis that vagus nerve stimulation can accelerate language learning, provide actionable insights for DOD language learners and establish this line of inquiry as a fruitful and important area for future research.

>> ADVANCED COMPUTING & EMERGING TECHNOLOGY

Advanced technologies play a critical role in defense and intelligence. As technology rapidly evolves, so do opportunities to improve how they support mission success. While there are benefits to incorporating new technologies, there can also be risks. Technology built specifically for the commercial market may not meet the demands of national security missions. It could also present threats to national security missions and workforce. Understanding how new emerging technologies impact issues such as anonymity, cover, counterintelligence, and operational security can only be determined through research, testing, and analysis.

ARLIS provides research and insights into how advanced computing and emerging technologies can reap the rewards of these advanced technologies while mitigating the threats they bring. ARLIS recently conducted research and development of a novel cloud enclave to support a research environment with multiple parties who required collaboration under strict information-sharing requirements. ARLIS also tested and evaluated novel graph-processing hardware designed to accelerate key data analysis.

ARLIS's efforts in advanced computing and emerging technologies are wholly supportive of the human-focused mission of the intelligence community. These technologies are research, developed, and tested with use-cases focused on the human domain.

The Advanced Computing and Emerging Technology core competency area recruits, maintains, and develops expertise in:

- Computational and data infrastructures
- Application and Mission Testbeds
- Emerging technologies for acquiring, disseminating, processing, or communicating information
- Relevant disciplines such as engineering, mathematics, operations research, integrated systems, advanced computing hardware and application-specific hardware, software-defined networks and edge computing, quantum information sciences, neuromorphic and alternative computing; biocomputing, and advanced electronics.

Creating a "Pop-Up" Cloud-Computing Infrastructure

Sharing information is one of the most challenging problems facing companies performing research that combines proprietary technology with new research with academia. Collaboration is needed in a way that the research can be advanced while protecting the intellectual property and trade secrets of all parties.

Such was the challenge facing ARLIS with the DARPA Automatic Implementation of Secure Silicon (AISS) program that aims to ease the burden of developing secure chips. AISS seeks to create a novel, automated chip design flow that will allow security mechanisms to scale consistently with the goals of a chip design.

A complete application-specific environment was needed (semiconductor chip design) with all the security provisions to protect valuable software and intellectual property over the course of the program's life.

ARLIS subject matter experts developed a solution that had the structure and the look-and-feel of an on-premises computing environment of a large semiconductor company. ARLIS was able to build and deploy a scalable cloud environment in about three months. The environment's complexity has grown as new capabilities have been added and the program has progressed to different phases. The "pop-up" domain-specific cloud environment has lowered anticipated costs through eliminating duplicated efforts performed by contractors and improved efficiency by allowing researchers to securely collaborate in real time.

Today, all 14 companies are using the AISS cloud environment with more than 125 users. The AISS cloud has become a blueprint for how to "pop up" application-specific cloud environments that are both secure and useful at a minimal cost. Several users said executing the program would have been difficult, if not impossible, without the common AISS cloud environment. ARLIS expects the program to expand in complexity and capability in the future.

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>> INTELLIGENT HUMAN-MACHINE SYSTEMS

Using technology to complement and expand human performance, making tasks easier, more efficient, faster, or even achievable, has increased in ways unimaginable a century ago. Specifically, artificial intelligence, autonomy, and augmentation technologies free humans from the mundane and help them achieve what was once impossible. The key to successfully integrating these technologies into operational workflows depends on a deep understanding of the strengths and limitations of the technologies, as well as the human operators.

ARLIS conducts research in support of Intelligent Human Machine Systems (IHMS) for Department of Defense and Intelligence Community missions. Broadly scoped with a cross-disciplinary approach, the research brings together experts in computer science, psychology, engineering, and other areas. Researchers apply technology to improve human performance in critical missions, as well as objectively assessing the operational impact of such technologies.

Research includes developing and prototyping tools and methodologies that leverage technology to automate and augment intelligence and security workflows, optimally supporting the humans that are ultimately responsible. An important component of this work is focused on user research, human factors, and human-machine teaming.

A complementary line of research involves developing tools and methodologies to evaluate the effectiveness of technology in terms of its operational impact on missions. This research forms the foundation for ARLIS support to the government in our critical role as a trusted agent providing test and evaluation services. Our assessments help the government build trust by developing a clear picture of the operational utility of a technology under consideration.

Finally, another line of research within IHMS focuses on assessments and learning. Researchers assess human aptitude for learning technologies and tailoring training to improve successful technology adoption. They also examine the best methods for helping humans learn new skills.

Evaluating AI-Driven Technologies

Project Maven, also known as the Algorithmic Warfare Cross-Functional Team, is aimed at speeding the adoption of best-in-class AI technologies into the DOD community to support their ability to transform data into timely, actionable intelligence. One effort within Project Maven is Collected Exploitable Materials (CEM). CEM seeks to apply AI to the processing of the vast and diverse data acquired during military operations.

Test and evaluation (T&E) is an integral part of this effort; evaluating AI-driven technologies is non-trivial. Comprehensive T&E will both enable the DOD to make informed decisions regarding the development, selection, and deployment of technologies in operational environments. T&E also provides the performers with critical feedback to speed technological growth, improve reliability, and enhance end-user mission effectiveness.

During 2022, ARLIS supported the government team as a trusted agent in the T&E of AI for CEM. To date, ARLIS has provided objective findings from its evaluations to the DOD supporting the program's ability to make critical decisions. As 2022 closed, ARLIS is continued its CEM T&E activities and supported the transition of this effort to the Chief Digital and Artificial Intelligence Office.

As the technologies grow and evolve, ARLIS will commensurately expand its evaluations. Ultimately, ARLIS envisions its findings will offer critical truth to support the DOD's mission including the acceleration of technological development and end user adoption.

Crowdsourcing for Improved Intelligence

There is growing evidence U.S. government policy decision-making processes can benefit from including more diverse, outside perspectives using mechanisms like aggregative crowdsourced forecasting. This ability to leverage the "wisdom of the crowd" as one piece of a larger effort toward building "Collective Intelligence" can emerge from combining many humans and machines, demonstrating the ability to help support more rigorous analysis before policies are developed. It can also facilitate the evaluation of policies once adopted and explore what future policies might be better.

The notion Collective Intelligence could provide democracies with an asymmetric decision-advantage was the starting point for the INtegrated Forecasting and Estimates of Risk (INFER) platform's inaugural year. The platform is run by ARLIS in partnership with Cultivate Labs, and seed funding through an Open Philanthropy grant.

INFER seeks to ultimately create an ecosystem of platforms, including a public platform (infer-pub.com), a government-only platform (infer-gov), and eventually a classified platform (infer-ts). This structure will generate valuable signals and early warning about future critical science and technology trends and high-risk geopolitical events for U.S. government policy makers. By enabling individual forecasters to provide their best and most up-to-date estimates of future events (including rationales behind them), INFER can empower scientists, researchers, analysts, and hobbyists from inside and outside the U.S. government to directly impact policy and decision-making. The public portion of INFER, INFER-Public, launched in 2022 and is the first of multiple forecasting sites to operate.

To begin, INFER receives requests from policymakers on topics. Using a process we call "issue decomposition," the INFER team identifies the key factors and signals indicating one possible scenario playing out over another, ultimately resulting in falsifiable questions we can pose on our forecasting site(s).

From there, we ask forecasters to estimate the probability of the answer to these questions *and* to provide a rationale for why their estimate is accurate, and why they may be wrong. Unlike a survey, INFER is designed to generate real-time crowd forecasts, so participants are encouraged to log in regularly to update their forecasts based on new information or perspective they have acquired.

Ultimately, individual forecasts are aggregated into a "crowdsourced" forecast, which is reliably more accurate than those of a single subject matter expert or small group predictions. This forecast, along with other outputs like the aggregate forecast trend over time, rationale summaries, identification of consensus and disagreement among individuals and cohorts, and weak signal alerts are provided to analysts and policymakers. Recipients have already used this information to challenge conventional wisdom, understand if there has been status quo departure, and improve forecast assumptions in machine learning models.

We have only begun to tap the potential for crowdsourced forecasting, and Collective Intelligence generally, to improve decision-making.

2022 HIGHLIGHTS

33,000+ Forecasts

150+ live forecast questions

2,500 Users

25 Countries Represented

Achievements in 2022 included identifying a government sponsor for launching a CUI-compatible site (infer-gov) for government employees by Summer 2023; operationalizing our issue decomposition process; soliciting forecast questions and providing outputs to multiple government partners; launching a syndicated reporting and alert service for curated outputs; and attracting and engaging with new subject matter experts to serve as forecasters.

The INFER team in the next year plans to launch a major forecasting tournament with an industry partner, roll out a business model for working with government partners (to include allied partners including Australia, the United Kingdom and Canada), and increase the size and scope of our forecasting community and topic areas.

FINANCIAL OVERVIEW

ARLIS is one of the fastest-growing units at UMD. Over the last five years, ARLIS has increased overall campus expenditures from 0.58 percent to more than 7 percent in 2022. Increasing expenditures are a key measurement for how well funded campus research is.

ARLIS ended 2022 with a 36 percent increase in expenditures over its 2021 expenditures.

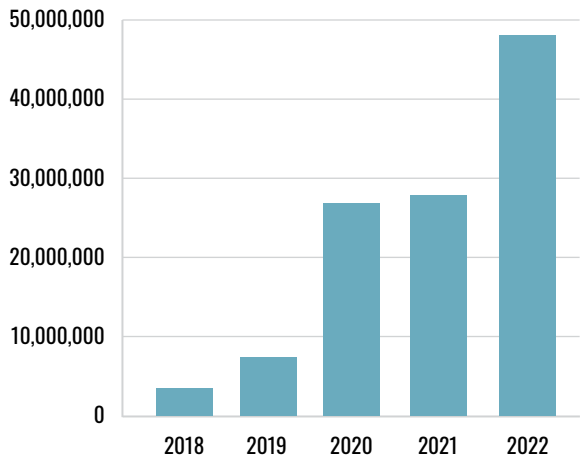
Revenue has grown since ARLIS transitioned from a UARC focused on comprehensive language preparedness for DOD and the intelligence community. Awards leveled off during the pandemic and then soared again between fiscal years 2021 and 2022. Evolving disciplinary focus and portfolio of capabilities has driven demand for research in the human domain.

ARLIS's role as an objective, trusted partner has continued to resonate with government sponsors interested in working with a neutral party focused in the public interest. While OUSD (I&S) and the Defense Advanced Research Projects Agency (DARPA) remain our biggest sponsors, more military, philanthropic organizations, non-defense agencies and university collaborations are coming to ARLIS. We expect to see more diversity as the lab's reputation and credibility build.

"Higher education institutions in the United States serve as a key component to the U.S. R&D system, helping drive innovation, as well as scientific and technological breakthroughs. R&D activity and funding can demonstrate the United States' investment in expanding knowledge and economic growth."

–NATIONAL CENTER FOR SCIENCE AND ENGINEERING STATISTICS, WHICH CONDUCTS THE ANNUAL HIGHER EDUCATION RESEARCH AND DEVELOPMENT SURVEY TO MEASURE RESEARCH AND DEVELOPMENT AT COLLEGES AND UNIVERSITIES IN THE UNITED STATES.

ARLIS REVENUE



ARLIS SPONSORS

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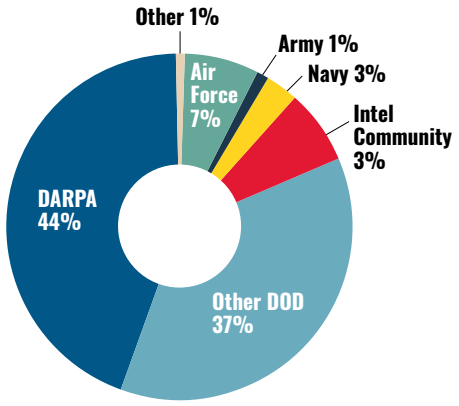
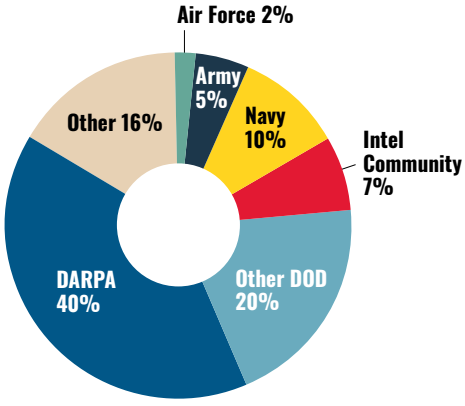


2022



ARLIS EXTERNAL ADVISORY BOARD

Prof. David Bader (UMD Ph.D. 1996) is Distinguished Professor in the Department of Computer Science and Director of the Institute for Data Science at New Jersey Institute of Technology.

Dr. Steve Cambone is Associate Vice Chancellor for Cybersecurity Initiatives for the Texas A&M University System and previously served as the first Under Secretary of Defense for Intelligence, a post created in March 2003.

LTG (Ret.) Edward Cardon is a Professor of the Practice at UMD and formerly served in roles including Commanding General, U.S. Army Cyber Command, and Director, Office of Business Transformation, leading the Task Force that helped create Army Futures Command. [ex-officio]

Lt. Gen. (Ret.) James Clapper is a retired lieutenant general in the United States Air Force and is the former Director of National Intelligence and former Under Secretary of Defense for Intelligence, among other roles.

Prof. Rita Colwell is Distinguished University Professor at UMD, a member of the National Academy of Sciences, and a former director of the National Science Foundation.

Dr. Steve Fetter is Associate Provost and Dean of the Graduate School, University of Maryland and former leadership within the White House Office of Science and Technology Policy.

Dr. Gary Flake (UMD Ph.D. 1994) is a technology advisor, investor, and inventor, with past technical leadership roles at Salesforce and Microsoft and as the founder of Yahoo! Research Labs.

Vice Admiral (Ret.) Paul Golden Gaffney II was the seventh president of Monmouth University in West Long Branch, New Jersey, from 2003 to 2013, becoming president emeritus August 1, 2013. Gaffney graduated from the United States Naval Academy in 1968. He is the former Chief of Naval Research.

Honorable Zachary J. Lemnios is the vice president of government programs for IBM Research.

Dr. Mark Lewis is executive for the National Defense Industrial Association's Emerging Technologies Institute.

Dr. Robert Kahn is the founder and CEO of the Corporation for National Research Initiatives (CNRI). Among other technical achievements, Dr. Kahn was responsible for the system design of the Arpanet and originated DARPA's Internet Program.

Mr. Gilman Louie is a partner at Alsop Louie Partners and is the founder and former CEO of In-Q-Tel, an independent, non-profit venture capital firm established with the backing of the Central Intelligence Agency. Mr. Louie is also a commissioner to the National Security Commission on Artificial Intelligence and Chairman of the Federation of American Scientists.

Mr. Jason Matheny is president and CEO of RAND Corporation.

Dr. Victor R. McCrary Jr. is vice president of research and graduate programs at the University of the District of Columbia.

Adm. (Ret.) William Moran is the former Vice Chief of Naval Operations, with previous roles as the Chief of Naval Personnel and Deputy Chief of Naval Operations for Manpower, Personnel, Training, and Education.

Honorable Dr. Samantha Ravich is the chair of the Foundation for Defense of Democracies Center on Cyber and Technology Innovation.

Dr. Alton Romig is the Executive Officer of the National Academy of Engineering and former VP & GM of the Lockheed Martin Aeronautics Company Advanced Development Programs (i.e. Skunk Works) and Deputy Lab Director of Sandia National Laboratories.

Maj. Gen. (Ret.) Annette Sobel is Associate Professor in Medical Education and Biomedical Sciences at Texas Tech University and an expert in human factors research. Past roles include senior advisor for biological defense for the Defense Threat Reduction Agency and Office of the Secretary of Defense.

Adm (Ret) William Studeman is a retired admiral of the United States Navy and former deputy director of the Central Intelligence Agency—with two extended periods as acting Director of Central Intelligence—and former director of the National Security Agency.

Dr. Michael Vickers is a former Under Secretary of Defense for Intelligence. He previously served as Assistant Secretary of Defense for Special Operations, Low-Intensity Conflict, and Interdependent Capabilities, as a CIA Operations Officer, and as an Army Special Forces Officer.

Mr. Austin Wang is vice president of intelligence at MITRE.

Prof. Ellen Williams is Distinguished University Professor and Director of the Earth System Science Interdisciplinary Center at UMD and Chair of the JASONs. Her past experience includes serving as Director of the Advanced Research Projects Agency for Energy (ARPA-E).

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