DISCOVER DSO

June 2019

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Time Flies...

It's hard to believe that I am already well into my second year of service as director of DARPA's Defense Sciences Office. It certainly has been a busy and productive time! Speaking of time, it really has flown by and I'd like, on the occasion of our annual Discover DSO Newsletter, to share some thoughts on a few of many recent DSO accomplishments and how we are having an impact on national security.

DSO has been busy with various outreach events and activities. It was great to see many of you at the D60 Symposium last September where DSO was well represented between our Weapons of Mass Destruction/Weapons of Mass Terror (WMD/WMT) plenary session, multiple breakout sessions and our DSO booths. Earlier this year, several DSO programs and PMs were also featured at the DARPA AI Colloquium. We continue to seek out opportunities to share our DSO 101 and Doing Business with DARPA tutorials, so please let us know if there is a community that we need to meet!

DARPA Director Dr. Steven Walker often talks about the Agency success being built around people, programs and partnerships. As I look back on the last 12 months, I see much to be proud of in terms of DSO accomplishments in each of these areas.

In terms of people, DSO has successfully recruited six new program managers since last summer with expertise in AI, material science, radiation science, and cognitive science. We were sad when we had to say goodbye to DSO Assistant Director, Program Management (ADPM) Kristen Fuller last fall, but we get to see her from time to time and know she is doing well. We were lucky to have Scott Wenzel take over as ADPM and he has become a much valued asset to the Office. We also had to say goodbye to DSO Deputy Director Mark Rosker who assumed the role of MTO office director in April 2019. It was really great to be able to work with Mark for a year and we know MTO is in good hands.

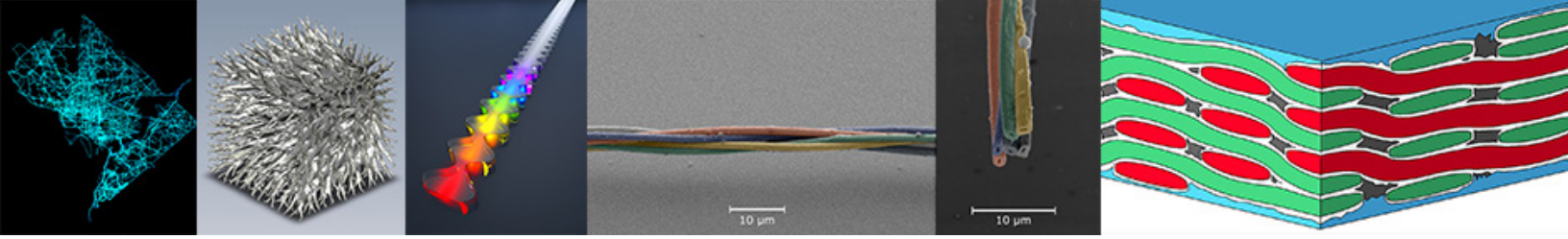
With respect to programs, DSO PMs have been working hard to get their new start programs approved. Over the past year, DSO has initiated seven new major programs that will help the U.S. win important technology races in hypersonics, AI, space, quantum, and WMD/WMT deterrence. In addition we've initiated multiple Disruptioneering and AI Exploration efforts. These rapid R&D acquisition efforts are helping to accelerate DSO innovation by significantly expanding our performer network and enabling program managers to more quickly determine feasibility for very high-risk, high-reward topics.

DSO continues to build and foster partnerships that help guide our programs and identify opportunities for transition. For example, relationships with the DoD components, DHS, and other federal, state, local and U.S. allied partners have facilitated the transition, commercialization and operational deployment of our SIGMA system, a city-scale sensor network for detecting radiological and nuclear threats. Another exemplar partnership is the "Machine Learning for Pharmaceutical Discovery and Synthesis Consortium" that was established by the MIT Make-It research team. The consortium already has 13 members from companies such as Merck, Pfizer, Bayer, and GlaxoSmithKline that are using the MIT Make-It software tools, that guide synthesis of new molecules, and providing feedback to MIT to improve performance.

People often ask me if I am enjoying my time at DARPA and I always answer "Every morning I wake up, open my calendar and ask myself--what do I get to do today?" It truly is a great time to be part of the DARPA team and I am grateful for the opportunity to work with so many passionate and dedicated individuals. In closing, I'd like to wish the entire community of DSO friends and colleagues all the best, and to express my hope that you enjoy our latest Discover DSO newsletter.

Respectfully yours,

Valerie Browning
Director, DARPA DSO
June 2019



DSO's Program Managers

Dr. Bill Carter

Bill is interested in new materials for extreme environments, including hypersonics, space, arctic and deep ocean. He has additional interests in advancing our ability to field new materials, understanding and preventing material failure, and enhancing human learning.

Dr. Tatjana Curcic

Tatjana is interested in advancing quantum science and technologies for solving national security problems. Topics of interest include exploration of the utility of Noisy Intermediate-Scale Quantum (NISQ) devices, quantum-enhanced machine learning methods, and novel quantum sensing and metrology approaches.

Dr. Michael Fiddy

Mike is interested in electromagnetic propagation/scattering in complex media and inverse scattering methods for imaging/material design. Specific topics include linear/nonlinear metamaterials and signaling/imaging through strongly scattering media/biosystems.

Dr. Anne Fischer

Anne is interested in pursuing creative applications of molecular approaches, methods, and tools to advance a wide range of technologies.

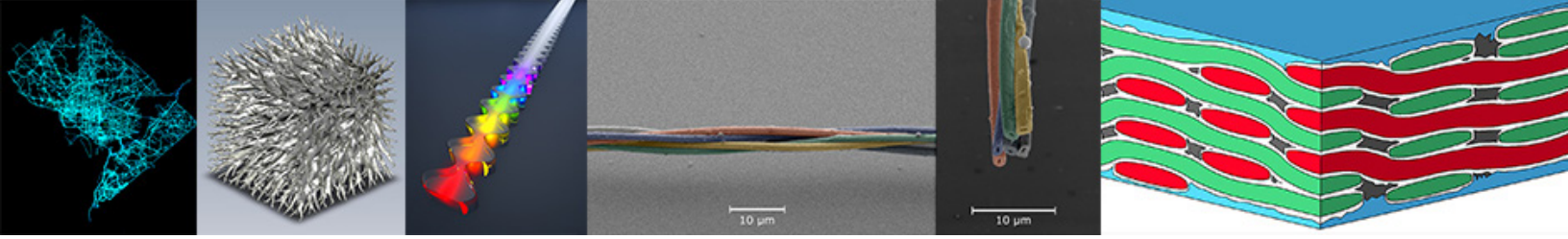
The Defense Sciences Office (DSO) identifies and pursues high-risk, high-payoff research initiatives across a broad spectrum of science and engineering disciplines — sometimes reshaping existing fields or creating entirely new disciplines — and transforms these initiatives into radically new, game-changing technologies for U.S. national security.

Major C. David Lewis

Maj. Lewis is interested in applying the forefront of fundamental physics in unique ways to DoD challenges using the disciplines of quantum mechanics, space and plasmas, and gravitational physics.

Dr. Rosa Alejandra Lukaszew

Ale's interests include understanding and developing new materials, structures, and devices incorporating strongly correlated electrons — particularly exploiting topological correlations to create pathways to a new paradigm of electronics for applications in memory, logic, energy conversion devices, and sensors. The emergent understanding of topological phenomena, along with discoveries of topological materials, offers great opportunities to extend the storage/logic device roadmap beyond current state of the art.



DSO's Program Managers

Dr. John Main

John's interests focus on mining emerging science and technology for the purpose of defending the United States.

Dr. John Paschkewitz

John is interested in new paradigms, abstractions, and mathematics for the design of agile, system-of-systems architectures. He is currently focused in the hybrid human-machine dimension of these systems and on improving collective capability in rapidly changing, uncertain environments such as firefighting or urban ground combat.

Dr. Adam Russell

Adam is interested in new tools and platforms to experimentally test and validate fundamental measures in social and behavioral sciences and to go from big data (observation and correlation) to big validation (causation and prediction) in human social behavior and performance.

Dr. Bartlett Russell

Bart is a Cognitive Neuroscientist whose work focuses on understanding the variability of human cognitive and social behavior to enable the decision-maker, improve analytics, and generate autonomous and AI systems that enable human adaptability.

Mr. Ted Senator

Ted is interested in fundamentals, principles, applications, and methods of AI, including new science needed for classes of problems not yet attempted, applications of existing technologies to new domains, and the system engineering methods needed for developing, integrating, scaling, and sustaining these applications.

Dr. Vincent Tang

Vincent is developing and deploying technologies for transforming our defenses against weapons of mass destruction.

Dr. Jan Vandenbrande

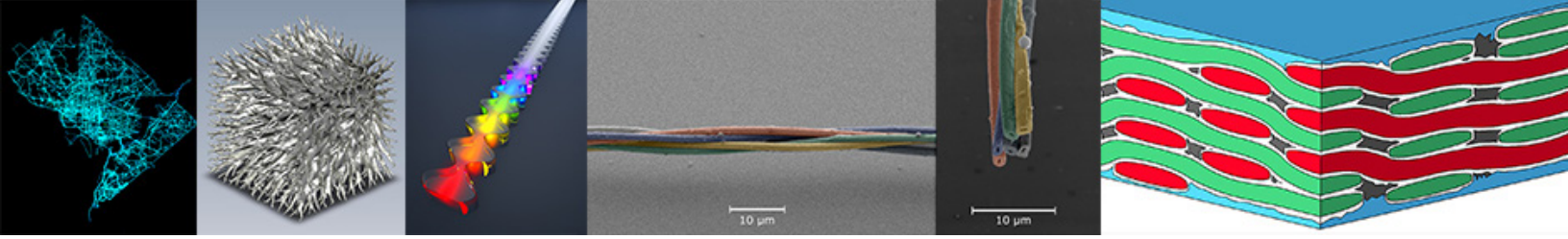
Jan is interested in the mathematics and computational technology required to make computers a true partner in mechanical design to fully leverage advanced materials and manufacturing techniques.

Dr. Mark Wrobel

Mark's interests include advanced sensing modalities for chemical, biological, radiological and nuclear and explosive threats and their precursors, and advanced analytics for both sensor and transactional data.

Dr. Jiangying Zhou

Jiangying is interested in understanding the foundations of machine intelligence, novel concepts of unconventional computing, human machine teaming.



DSO's Leadership

Dr. Valerie Browning

DSO Director

Dr. Valerie Browning was named director of DARPA's Defense Sciences Office (DSO) in December 2017.

Dr. Browning has more than 30 years of experience in managing and executing defense-related research and development. Prior to her most recent DARPA appointment, Dr. Browning worked as an independent consultant providing subject matter expertise and strategic planning support to the Department of Defense, Department of Energy, and other government clients in the areas of advanced materials and alternative energy. She also served as chief technology officer for HELM System Solutions, Inc., a woman-owned small research and development (R&D) business.

Dr. Browning was a program manager in DSO from 2000-2007, where she initiated and managed a diverse R&D portfolio in areas that included metamaterials, bio-magnetics, unmanned underwater vehicle energy storage, portable power, thermoelectric materials, and others. Dr. Browning also worked as a research physicist at the Naval Research Laboratory from 1984-2000 where her primary areas of research included thermoelectric materials, superconductors, magnetics, and magnetic oxide materials.

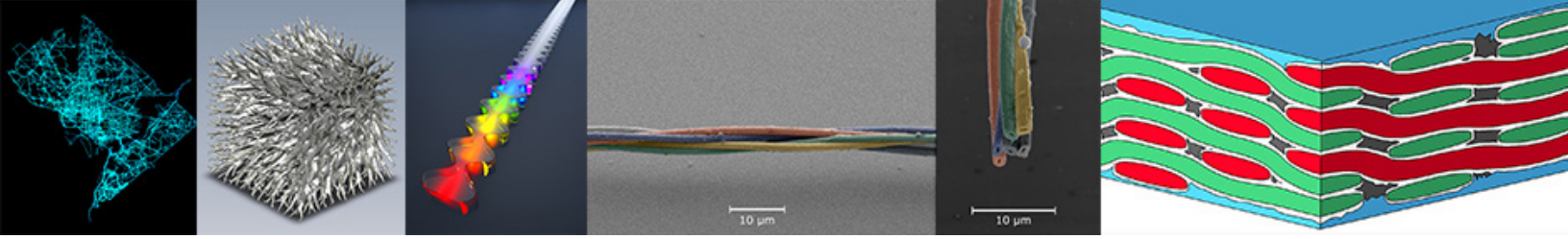
LTC Philip Root

DSO Deputy Director

Lt. Col. Philip Root was named deputy director of the Defense Sciences Office (DSO) in June 2019. He will continue to manage the Squad X portfolio and the Urban Reconnaissance through Supervised Autonomy (URSA) programs in DARPA's Tactical Technology Office (TTO) where he explores the intersection of autonomy and military operations. His former TTO programs include the ALIAS aircrew autonomy program, the Mobile Force Protection counter-UAS program, the Underminer Tactical Tunneling program, and the DSO Fast Lightweight Autonomy (FLA) program.

Before coming to DARPA, Root was the director of the Center for Innovation and Engineering at the United States Military Academy at West Point where he oversaw cadet and faculty research in support of Army operations. As a research and development officer, Root has deployed to Afghanistan developing and implementing the hardware and software needed to support cloud-based military intelligence analytics. He served two years as an Astronaut Office support engineer at the Johnson Space Center where he had oversight responsibilities for the booster and launch abort system of the Constellation program intended to return Americans to the Moon. Root spent the nearly the first decade of his career as an Apache helicopter pilot in Germany and Korea. He is a graduate of the United States Military Academy, and he received his Master of Science and doctorate from MIT at the Laboratory for Information and Decision Systems (LIDS).

Consider submitting your idea as an executive summary to DSO's Office-wide BAA. Executive summaries are reviewed by all DSO PMs. PMs who find an idea interesting will provide feedback requesting an abstract or full proposal.



Mr. Scott Wenzel

DSO Assistant Director, Program Management (ADPM)

Scott became DSO's ADPM, in September 2018. In this role, Mr. Wenzel is responsible for managing DSO's business processes. He has 5 years of experience at DARPA managing budgets, finance, contracts, acquisition, and policy for multiple technical offices, and 4 years of Army Acquisition Workforce experience as a civilian supporting the Program Manager for DoD Biometrics under Program Executive Office for Enterprise Information Systems. Scott is especially interested in streamlining processes to ensure compliance with regulations without impacting technical execution. He is also actively engaged in managing relationships between DARPA and those military and civilian agencies who do work on its behalf.

Ms. Karen McMullen

DSO Program Analyst

Karen joined DSO in April 2014 as program analyst. Karen brings 31 years of experience supporting various DARPA technical offices to her duties overseeing day-to-day office operations and supporting DSO's ADPM in financial formulation, budget formulation and program management support. A key responsibility is acting as contracting officer's representative for DSO's SETA support contracts. In this role, she ensures DSO program managers get the support they need to create and manage successful programs.

What makes a great idea?

For every idea that leads to a DSO program, there are a dozen that do not. What makes a great idea? And how do we know a great idea when we hear one? We wrestle with this every day at DARPA. Here are some things we learned in the process:

- *Great ideas often have a degree of the fantastic or impossible. A previous DARPA director was fond of saying "I know it's gonna be a great DSO program if my first reaction is to laugh." If you are so sure that you can solve the problem, then there is no risk. But if the question feels just out of reach, and if the implications are profound regardless of the hypothesis being shown true or false, then it feels like we are onto something. If false, then we have closed off an area of possible technical surprise. If true, then we crack open the door to new possibilities!*
- *Great ideas often have an independent, auteur quality. A technical workshop may help DARPA understand the community consensus and the current scientific pulse. But, almost by definition, a truly disruptive idea will not be something that emerges from consensus. The DARPA program manager often has the role of the auteur, asking the questions not asked or showing a new direction.*
- *Great ideas are aligned with the national security mission of the Department of Defense. There are many excellent ideas for which the connection to the DoD mission is tenuous or non-existent. Great DARPA ideas, even those of fundamental discovery in the basic sciences, are always pointing toward the insights needed to help our nation's service personnel in the near and long term.*

We can't possibly think of every possible great idea on our own—we need your help. If you think you have a great idea, send us an email, and talk with a program manager.

AI NEXT CAMPAIGN

AI Exploration

DARPA investments in research that lead to prototype development resulting in new, game-changing AI technologies for U.S. national Security. Researchers will work to establish the feasibility of new AI concepts within 18 months of award.

Ongoing AI Programs

Larger and longer term DARPA technology efforts in A.I. that range from basic research to advanced technology development and are aimed at creating powerful new capabilities for the DoD

AI Colloquium

DARPA hosted event in March 2019 bringing together the DoD research community and stakeholders to learn more about DARPA's current and emerging AI programs, and discover how the technologies in development could apply to diverse missions.

DARPA's Artificial Intelligence Exploration (AIE) program

DARPA announced in September 2018 a multi-year investment of more than $2 billion in new and existing programs called the "AI Next" campaign. Key areas of the campaign include automating critical DoD business processes, such as security clearance vetting or accrediting software systems for operational deployment; improving the robustness and reliability of AI systems; enhancing the security and resiliency of machine learning and AI technologies; reducing power, data, and performance inefficiencies; and pioneering the next generation of AI algorithms and applications, such as "explainability" and common sense reasoning.

The Artificial Intelligence Exploration (AIE) program, which was first announced in July 2018, constitutes a series of high-risk, high payoff projects where researchers will work to establish the feasibility of new AI concepts within 18 months of award. Leveraging streamlined contracting procedures and funding mechanisms enables these efforts to move from proposal to project kick-off within three months of an opportunity announcement.

Forthcoming AIE Opportunities will be published on the FedBizOpps website. Below are DSO's AIE efforts.

Artificial Intelligence Research Associate (AIRA)

PM: Dr. Jiangying Zhou

AIRA is part of a broad DAPRA initiative to develop and apply "Third Wave" AI technologies that are robust to sparse data and adversarial spoofing, and that incorporate domain-relevant knowledge through generative contextual and explanatory models.

The vision of the AIRA program is to elevate AI to the role of an insightful and trusted collaborator in the scientific process. A key challenge today is the lack of generalizability of statistical AI methodologies beyond the narrow set of questions they are initially trained on and their poor ability to interpret beyond training. Overcoming the challenges outlined above will require new ideas to generate "deep insights" based on physics-, math-, and context-aware learned representations that succinctly capture relevant dynamics and behaviors of the complex systems under study and can generalize across domains.

To facilitate use of AI in the scientific process, AIRA will challenge the research community to address two main objectives: 1) explore and develop new AI architectures and approaches to facilitate the discovery of physical laws and models governing complex physical phenomena; 2) explore new approaches to assess where data are too sparse, noisy, or are otherwise inadequate to build predictive models; to generate testable hypotheses; to identify high-value experiments that could alleviate the problems of data shortfalls; and to quantify the confidence of predictions outside of the training space.

Physics of Artificial Intelligence (PAI)

PM: Mr. Ted Senator

The Physics of Artificial Intelligence (PAI) program is part of a broad DAPRA initiative to develop and apply "Third Wave" AI technologies to sparse data and adversarial spoofing, and that incorporate domain-relevant knowledge through generative contextual and explanatory models.

It is anticipated that AI will play an ever larger role in future Department of Defense (DoD) activities, ranging from scientific discovery, to real-time sensor processing, to control and coordination of composable systems. However, despite rapid progress of AI in the commercial sector – particularly in the subfield of machine learning – AI's successful integration into numerous DoD applications has proven challenging. Key challenges include the development of causal, predictive models and dealing with incomplete, sparse, and noisy data.

To facilitate better incorporation of AI into DoD systems, the PAI program is exploring novel AI architectures, algorithms, and approaches that "bake in" physics, mathematics, and prior knowledge relevant to DoD application domains. PAI aims to show that embedding physics and prior knowledge into AI will help to overcome the challenges of sparse data and will facilitate the development of generative models that are causal and explanative.

Serial Interactions in Imperfect Information Games Applied to Complex Military Decision Making (SI3-CMD)

PM: Mr. Ted Senator

Serial Interactions in Imperfect Information Games Applied to Complex Military Decision Making (SI3-CMD) builds on recent developments in artificial intelligence and game theory to enable more effective decisions in adversarial domains. SI3-CMD will explore several military decision making applications at strategic, tactical, and operational levels and develop AI/game theory techniques appropriate for their problem characteristics. These applications will extend current AI/game theory techniques to be effective when there are multiple interacting agents, extremely large search spaces, sequential revelation of information, use of deception, continuous resource quantities, stochastic outcomes, and the ability to learn from past iterations. The program will produce new techniques and assessments of their effectiveness for military uses.

Teaching AI to Leverage Overlooked Residuals (TAILOR)

PM: Dr. Adam Russell

Military and civilian organizations have deep interest in human performance optimization (HPO). A key challenge for optimizing human performance, however, is the "tyranny of averages:" a common experimental approach that uses between-subject outcomes and group averages (means) to make conclusions about the efficacy of a given intervention. This approach frequently (mis)characterizes individual variance as statistical "noise," "residuals," or "error." The resulting interventions (e.g., diet, physical training regimen, brain stimulation) are, at best, suboptimal and, at worst, deleterious for each person. Current AI capabilities for identifying, characterizing, and modeling human performance interventions are limited for similar reasons as most approaches likewise treat individual differences as residual error, particularly because accounting for individuals can significantly increase dimensionality of the datasets.

To address this challenge, the TAILOR program is exploring whether and, if so, to what extent AI methods can enhance prediction about which HPO intervention(s) will be most effective for different individuals and teams. In particular, TAILOR seeks to test third wave AI tools and approaches that can use contextual reasoning to make counterfactual predictions about HPO interventions and better leverage individual variability (i.e., if person X had been given intervention Y, then they would have had outcome Z). By incorporating biological, psychological, and social factors that give rise to individual differences, TAILOR hypothesizes that successful approaches will be able to reason over multiple factors in order to better "tailor" individualized HPO outcomes, adapt if those factors change, and continue to help the DoD leverage diversity as a strength.

μBRAIN

PM: Dr. Michael Fiddy

The past decade has seen explosive growth in development and training of artificial intelligence (AI) systems. However, as AI has taken on progressively more complex problems, the amount of computation required to train the largest AI systems has been increasing ten-fold annually. While AI advances are beginning to have a deep impact in digital computing processes, trade-offs between computational capability, resources and size, weight, and power consumption (SWaP) will become increasingly critical in the near future.

Current neuromorphic/neural architectures rely on the digital computing architectures that attempt to mimic the way nature computes, but not the way it functions. Actual physical interactions and mechanisms that could enable improved engineered function as observed in bio-systems, such as miniature insects, remain to be fully described.

μBRAIN will explore innovative basic research concepts aimed at understanding highly integrated sensory and nervous systems in miniature insects and developing prototype computational models that could be mapped onto suitable hardware to emulate their impressive function. Nature has forced on these small insects drastic miniaturization and energy efficiency, some having only a few hundred neurons in a compact form-factor, while maintaining basic functionality. This research could lead to capability of inference, prediction, generalization, and abstraction of problems in systematic or entirely news ways in order to find solutions to compelling problems.

The primary goal is to understand the computational principles, architecture, and neuronal details of small bio-systems driven by extreme SWaP needs in nature. By doing so, DARPA aims to identify new computing paradigms that would enable improved AI with considerably reduced training times and power consumption.

Virtual Intelligence Processing (VIP)

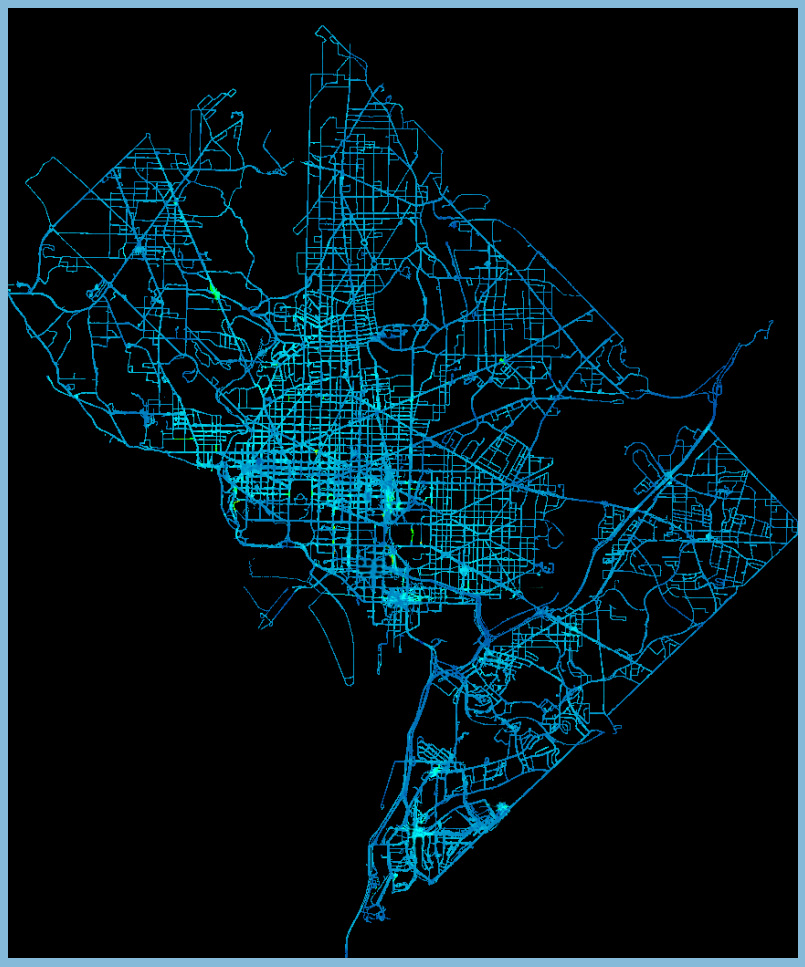
PM: Dr. Rosa Alejandra "Ale" Lukaszew

Successful integration of next generation AI into DoD applications must be able to deal with incomplete, sparse and noisy data as well as unexpected circumstances that might arise while solving real world problems. Thus, there is a need for new computing models that are efficient and robust, can learn new concepts with very few examples, and can guide the development of adequate novel hardware to support them. The Virtual Intelligence Processing (VIP) will explore novel and heretofore under-explored mathematical and computational "brain-inspired" massively-scalable approaches that have the potential to support solutions to real-world DoD problems.

DARPA transitions city-scale radiological and nuclear threat monitoring capabilities to federal, state and local, and US ally partners

By Dr. Vincent Tang

SIGMA



DARPA's SIGMA program, which began in 2014, has demonstrated a city-scale capability for detecting radiological and nuclear threats that is now being operationally transitioned and deployed. SIGMA successfully developed low cost, high capability sensors that are networked through a real-time IT backbone. The network supports the ingest and analysis of full spectrum sensor data, scalable from 10s to 10,000 sensors, allowing for practical wide-area coverage. The program successfully produced more than ten thousand fully automated, personal and mobile sensors with performance and cost up to an order of magnitude better than prior state-of-the art, and field tested the network system with multiple partners in varied areas. These tests included deployment of continuous, real-time networks of wearable, vehicle-mounted, and statically deployed detectors in multiple regions, such as New York City and Washington D.C. as well as areas outside of the United States. An example of an extended field trial includes the network of vehicle mounted detectors in the D.C. ambulance fleet, enabled by a partnership between DARPA and D.C. Fire and Emergency Medical Services (EMS). With the successful completion of field trials in 2018, the SIGMA system is operational and in full transition to federal, state and local operational partners, facilitated by the full commercialization of the system and availability on the GSA schedule. These partners include DHS Countering Weapons of Mass Destruction (CWMD) Office and components of the Department of Defense as well as U.S. allied partners utside the United States, forming the next generation of global detection capability.

DARPA is building on this work with the SIGMA+ initiative. Over the next five years, SIGMA+ will build on SIGMA's successful strategy of distributed, networked, and scalable mobile sensing to develop and demonstrate a real-time, persistent early detection system for the full spectrum of chemical, biological, radiological, nuclear, and explosive threats.

Reimagining Your Power to Shape the Future

By Michael Becker

Gamifying the Search for Scientific Surprise (GS3) Program

After 50 years of work across a crazy-quilt of jobs, it turns out that my last two pre-retirement years (ages 68 & 69) of working were to help build a new internet platform called Polyplexus (www.polyplexus.com). Surprisingly, that has been the most empowering work I've ever been a part of. This isn't because I was involved, but because this new scientific forum allows everyone, including non-scientists and even the retired, to become part of an ongoing global community whose innovations will change all our lives.

It's my 70th birthday this Spring, and as I begrudgingly transition into the ranks of the retired, I searched for an opportunity to reinvent myself. Surprisingly, as I stepped back from work, the reinvention opportunity was right under my nose. Over the last few months, I've watched scientists, researchers, and creative thinkers employ Polyplexus to develop radical new ideas that led to DSO seedling awards, including: using social media to reinvent weather prediction, instilling human values in next-generation robots, advancing quantum computing, shielding future interplanetary travelers from radiation, and developing new ways for us to read computer displays. These ideas didn't just spring from brilliant minds. These insights evolved through a new imagining process that the Defense Advanced Research Projects Agency (DARPA) has created to accelerate our nation's research.

If you don't use a keyboard or mouse on the internet, Polyplexus probably won't be for you. However, if you venture online, polyplexus.com is just a click away. Once signed in, Polyplexus offers all of us the ability to connect with a worldwide community of people who care about the ideas that will shape the future. You'll be exposed to the newest and smartest thinking by researchers and experts, and be able to find and read thousands of exciting new papers in nearly a hundred fields of science as they're added by contributors, including you. This platform also offers the opportunity for generalists in social sciences, communications, the arts, and creative thinkers of all kinds to explore issues important to humanity by applying your decades of acquired knowledge and experience. Since this no-cost platform is just starting, you will also be quickly known.

What's emerging in Polyplexus is a rapidly growing idea collider where thousands of pieces of evidence and conjectures form the building blocks of new ideas and innovations. Accessing these, you can graze for knowledge, use social media tools to connect with experts, grow your online expertise and reputation, or collect idea chunks and shape them into outlines and ultimately research papers. For the most ambitious, sponsors are offering research grants in multiple fields, as the first five awards summarized above show, with dozens more coming each year. Or perhaps you'll be enriched by simply helping support ideas and experiencing the joy that gives.

Polyplexus is just starting and will continue to be enhanced and expanded in the years to come. Beyond DARPA, who is funding multiple awards each year based on innovative abstracts and proposals, many commercial sponsors are eager to become involved. Currently the first users are mostly scientists and researchers, but ideas and connection of the thoughts of diverse disciplines are something everyone can contribute to. Remember that those with the most life experience offer the most because they've glimpsed roads not yet traveled.

So far on Polyplexus I've consumed thousands of articles in fields of science I never thought I'd explore, and mused on hundreds of conjectures about how divergent disciplines could be combined to create new areas to explore. I've developed friendships with very smart people across the scientific spectrum, and I've even ventured to add my own ideas in areas where I could contribute. It's also a heck of a lot more fun that reading news and listening to posturing pundits, because what I'm reading about is the future.

DSO's Most Recent Programs

New Programs since June 2018:

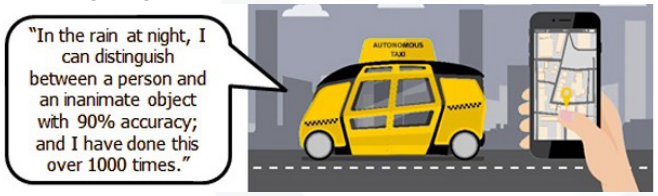
Accelerated Molecular Discovery (AMD)

Dr. Anne Fischer

This program is developing new, systematic approaches that increase the pace of discovery and optimization of high-performance molecules. Specifically, performers are developing closed-loop systems that exploit, build and integrate tools for: 1) extracting existing data from databases and text; 2) executing autonomous experimental measurement and optimization; and 3) incorporating computational approaches to develop physics-based representations and predictive tools. AMD systems will provide a comprehensive computational and experimental means to design, discover, validate and optimize new molecules, iteratively and actively learning to more efficiently and effectively discover molecules that enhance performance in applications relevant to national security.

Competency-Aware Machine Learning (CAML)

Dr. Jiangying Zhou



The program addresses this challenge by enabling learning systems to be aware of their own competency. Systems will have knowledge of their learned abilities, the conditions under which those abilities were learned, knowledge of their resultant task strategies, and the situations for which those strategies are applicable.

CAML contributes to improved human-machine teaming and realization of the task synergies expected of autonomous systems. By creating a fundamentally new machine learning approach, CAML will facilitate mission planning by giving human operators insight into available machine assets based on task requirements, determining the level of autonomy to be granted, and controlling behaviors to adapt for operating conditions.

Space Environment Exploitation (SEE)

Major C. David Lewis

The program seeks to develop new models and sensing modalities to predict and observe the dynamics of the near-earth space environment. The SEE program explores how to go beyond magnetohydrodynamic descriptions of the magnetosphere, ionosphere, thermosphere coupled system to include wave/wave, wave/particle, and particle/particle interactions while using the latest advances in high performance computing such as GPUs and TPUs. Furthermore, SEE is exploring how to unify current space environmental sensing networks to produce a common operating space environment picture and how to develop low cost, non-traditional, exploitive, and expeditionary means to observe near-earth plasma dynamics. Another big component of SEE is understanding the viability of how Artificial Intelligence and Machine Learning can be used to help assimilate environmental data into models and virtually produce synthetic data.

The expected outcomes of SEE will give future commanders and operators the necessary and precise space environment situational awareness to make relevant space operational/tactical decisions and differentiate between human-made and natural dynamic perturbations of the environment.

Materials Architectures and Characterization for Hypersonics (MACH)

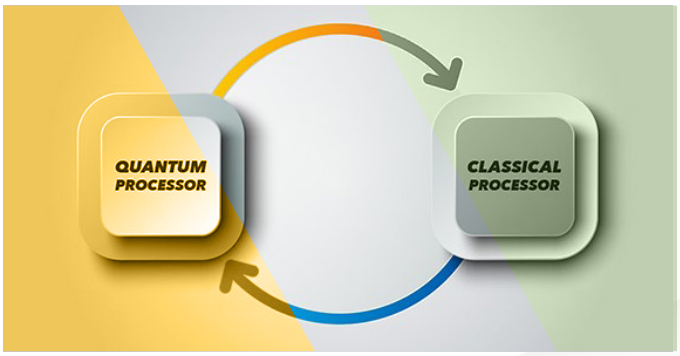
Dr. William Carter

The Materials Architectures and Characterization for Hypersonics (MACH) program aims to develop and demonstrate new materials architectures for sharp, shape-stable, cooled leading edges for hypersonic vehicles. The program will investigate innovative approaches that enable revolutionary advances in the materials, design and implementation of shape-stable, high heat flux capable leading edge systems.

MACH comprises two technical areas. The first area aims to develop and mature fully integrated passive thermal management system to cool leading edges based on scalable net-shape manufacturing and advanced thermal design. The second technical area will focus on next-generation hypersonic materials research, applying modern high-fidelity computation capabilities to develop new passive and active thermal management concepts, coatings and materials for future cooled hypersonic leading edge applications.

Optimization with Noisy Intermediate-Scale Quantum devices (ONISQ)

Dr. Tatjana Curcic



The program aims to exploit quantum information processing before fully fault-tolerant quantum computers exist. This effort will pursue a hybrid concept that combines intermediate-sized quantum devices with classical systems to solve a particularly challenging set of problems known as combinatorial optimization. ONISQ seeks to demonstrate the quantitative advantage of quantum information processing by leapfrogging the performance of classical-only systems in solving optimization challenges.

ONISQ researchers will be tasked with developing quantum systems that are scalable to hundreds or thousands of qubits with longer coherence times and improved noise control. Researchers will also be required to efficiently implement a quantum optimization algorithm on noisy intermediate-scale quantum devices, optimizing allocation of quantum and classical resources. Benchmarking will also be part of the program, with researchers making a quantitative comparison of classical and quantum approaches. In addition, the program will identify classes of problems in combinatorial optimization where quantum information processing is likely to have the biggest impact.

Science of Artificial Intelligence and Learning for Open-world Novelty (SAIL-ON)

Mr. Ted Senator

The program intends to research and develop the underlying scientific principles, general engineering techniques, and algorithms needed to create AI systems that act appropriately and effectively in novel situations that occur in open worlds. The program's goals are to develop scientific principles to quantify and characterize novelty in open-world domains, create AI systems that react to novelty in those domains, and demonstrate and evaluate these systems in a selected DoD domain.

SIGMA+

Dr. Vincent Tang

The SIGMA+ program aims to expand SIGMA's advance capability to detect illicit radioactive and nuclear materials by developing new sensors and networks that would alert authorities to chemical, biological, and explosives threats as well.

SIGMA+ calls for the development of highly sensitive detectors and advanced intelligence analytics to detect minute traces of various substances related to weapons of mass destruction (WMD) threats. SIGMA+ will use a common network infrastructure and mobile sensing strategy, a concept that was proven effective in the SIGMA program. The SIGMA+ chemical, biological, radiological, nuclear and high-yield explosive (CBRNE) detection network would be scalable to cover a major metropolitan city and its surrounding region.

Planned execution of SIGMA+ will occur in two phases. Phase 1 will focus on developing novel sensors for chemicals, explosives, and biological agents while Phase 2 will focus on network development, analytics and integration.

Gamma Ray Inspection Technology (GRIT)

Dr. Mark Wrobel

The Gamma Ray Inspection Technology (GRIT) program seeks transformational approaches to achieving high-intensity, tunable, and narrow-bandwidth gamma ray production, but in a compact form factor suitable for transporting the source to where the capability is needed. Such sources have the potential to help discover smuggled nuclear materials in cargo, provide new non-destructive inspection techniques at various scales, and enable new medical diagnostics and therapies.

Recent News

(July 2018 – June 2019)

DARPA Tests Advanced Chemical Sensors

DARPA's SIGMA program, which began in 2014, has demonstrated a city-scale capability for detecting radiological and nuclear threats that is now being operationally deployed. DARPA is building on this work with the SIGMA+ initiative that is focused on providing city- to region-scale detection capabilities across the full chemical, biological, radiological, nuclear, and explosive threat space.

DARPA Launches Social Media Platform to Accelerate R&D

DARPA aims to apply the power of social networks to research and development via a novel social media platform purpose-built to quicken the pace of U.S. technology development. Polyplexus, which was recently launched as a public platform, is designed to increase access to scientific evidence and accelerate hypothesis development, research proposal generation, and research sponsor engagement. The platform's real-time interactions and functionality are designed to dramatically shorten the time between the emergence of concepts and the submission of worthy proposals.

Faster, Lighter, Smarter: DARPA Gives Small Autonomous Systems a Tech Boost

DARPA's Fast Lightweight Autonomy (FLA) program recently completed Phase 2 flight tests, demonstrating advanced algorithms designed to turn small air and ground systems into team members that could autonomously perform tasks dangerous for humans – such as pre-mission reconnaissance in a hostile urban setting or searching damaged structures for survivors following an earthquake.

Where Are They Now?

Cindy Daniell *DSO PM: 2006-2012*

During the seven years since my DARPA PM days, I have seen a DARPA theme repeated in different venues a number of times. I've seen that to effect the wide-ranging technology engagement required for R&D to thrive, organizations are well-served to incorporate many parts of the DARPA model. I have been lucky enough to be part of that transfer in a couple of different ways.

Shortly after leaving DARPA, I joined SRI where one of my roles was to work with several international partnerships and help instantiate DARPA-like institutions in Japan, Singapore, and Poland. Bringing ideas such as the Heilmeier criteria, seedlings, double helix transition model, and Grand Challenges into completely different cultures was a bit of transfer learning on its own. All of these nations resonated well with the concepts and began their own surrogate institutions. The concepts resonated particularly well in Poland as it has a large start-up culture that embraces the DARPA mindset. Poland is currently planning their own Grand Challenge.

After a few years in the private sector, I am now back in government as Director of Research at the National Geospacial-Intelligence Agency (NGA). Even though the NGA mission is quite different than DARPA's mission, there is still benefit to bringing many of the DARPA practices into play in this large and somewhat operational organization. While some of the technical tenets (e.g., Heilmeier) were already on board at NGA, some of the business practices, contracting techniques, and transition guides will provide benefit to NGA and effect the wide-ranging technology engagement required for NGA Research to thrive. I am proud to be a part of this march of the DARPA way to promote R&D into practical applications.

Finally, having just attended DARPA's AI Colloquium, I am reminded of how much this field has rapidly permeated so many diverse technology areas. Programs in physical domains that DSO excels in would have never thought of using AI just 10 years ago, yet they now have it embedded. Such DSO-esque programs now benefit from AI. In my new role at NGA, where much of our work is algorithmic and analytic, I clearly see the benefit of AI throughout our portfolio. I am glad to see DSO working at the forefront of the basic research in AI to help NGA deliver new capabilities for national security.

Serving as Program Manager

DARPA program managers are each given a unique opportunity to pursue science and engineering in service of national security. Each is on a limited tour, typically 2-to-4 years, during which time they each make considerable personal and professional sacrifices in service to the country. DARPA program managers have gone to conflict zones in Iraq and Afghanistan; others have successfully challenged key tenets of their scientific disciplines; still others have created projects that require we rethink long-held national security approaches. Being a program manager takes a unique kind of courage to question deeply held assumptions while envisioning new capabilities for our warfighters and nation. If you are feeling drawn to federal service and have a disruptive technology idea, please reach out to us for a conversation.

Emerging Results

Automated synthesis of multiple molecules in a single day without user intervention:

Typical small molecule synthesis is done manually in batch, with automated production limited to processes designed for and dedicated to a single product. Recently, two sets of DARPA Make-It performers at MIT and SRI were able to demonstrate the ability to produce a variety of small molecules on a single, automated device. One set of performers produced three molecules, including ribavirin, an important defense-relevant drug, during a continuous 13-hour run using a custom-built software suite that exploits machine learning and automated, computer-controlled synthesis hardware. Another set of performers demonstrated a similar capability with their robotic synthesis device, producing the arthritis drug Celebrex and three similar molecules during a continuous 28-hour run. The ability to produce pharmaceutical ingredients and libraries of drug candidates on a single, automated device could accelerate drug discovery and revolutionize the medical supply chain.

Efficient, error-free data encoding in bacterial DNA:

DARPA Molecular Informatics performers at University of Illionois-Urbana Champaign developed a technique to encode the 1s and 0s of digital data as the presence or absence of small breaks, or "nicks", in bacterial DNA by using an enzyme that is uniquely well-suited for creating these breaks. This technique allows each enzyme to make ~50 alterations at user-specified positions in the strand, greatly increasing writing efficiency and data density. The group has demonstrated a complementary technique to read the nicks (converting back to 1s and 0s) with no conversion errors. Eventually this approach could combine the density (petabytes/gram) and longevity (millennia without energy) advantages of DNA-based storage with higher speed and 200x lower cost than current synthetic approaches.

Low-cost, chemically resistant pumps that may provide on-demand access to expensive chemical reagents:

DARPA-funded researchers at VCU have demonstrated a novel chemical pump developed as part of a system to demonstrate a generalizable, accessible method for producing chemicals. Analogous to a Keurig coffee machine, the chemical "pods" can be used to produce a variety of desired chemicals. The pump design provides chemical resistance and robustness for ~$50, comparable lab scale pumps that cost $3000 or more and suffer from degradation upon exposure to certain chemicals. This pod-based approach could potentially be used in areas such as research, health and manufacturing. Its simplistic design and lack of mechanical parts also makes it amenable to ruggedization for field operation.

Machine agents capable of abstracting and improving design strategies produced by humans:

Under DARPA's Agile Human-Machine Teams (A-Teams) program, AI agents were able to learn design strategies and concepts from images of the step-by-step designs of human teams and ultimately use these concepts to produce designs with a three times higher factor of safety than those from which they were derived. However, they were less efficient by a factor of 1.5 in material use than the goal-oriented human agents. This result, which will be evaluated in future tests, seems to indicate the value of teaming human and machine agents with complementary skills in order to optimize the designs.

Nuclear radiation detection system now available on GSA:

As part of a comprehensive effort to transition persistent, scalable, real time nuclear radiation detection capabilities developed under the DARPA SIGMA program, the system including the network/communications, software and maintenance is now available on the GSA schedule. This will allow Government entities at both the federal and state level to easily order and deploy the SIGMA system at a scale that matches their requirements.

Approach for adaptable, robust flight control algorithms demonstrated:

Performers under DARPA's Fundamental Design program demonstrated the benefits of transfer learning to create adaptive control algorithms for unmanned aerial vehicles. The research team found that a control algorithm to maintain stable hover in tri-copters could be realized by starting with a control algorithm for quad-copters, even though their control dynamics are inherently different due to the balance of opposite rotors. When the reinforcement learning method to control tri-copters was started from scratch, it did not converge, likely due to the inherent stability of the tri-copter rotor configurations. Transfer learning can therefore accelerate development of control algorithms for new configurations. If this learning could be done in seconds rather than minutes (current requirement using a laptop computer) it would lead to adaptable assets that are robust to damage or other unpredicted changes.

New approach to automatically learn cultural models from text data:

Performers in DARPA's Understanding Group Biases (UGB) program have developed AI-enabled methods to infer culturally distinct subgroups within a population based on nuances in language used in social media. The methods incorporate aspects of cultural theory that afford a level of understanding that is not typically present in data-driven models. Once matured, these techniques could potentially be used by decision makers to understand and predict how subgroups may interpret various topics, and how those interpretations may evolve over time.

Ultra-broadband, self-calibrated RF electric-field measurement system:

A DARPA SBIR performer has constructed a high-bandwidth, high dynamic range, electric field probe station based on Rydberg atoms (atoms with very high quantum numbers). One of these units is capable of detecting an unprecedented frequency range spanning 10 MHz - 500 GHz and field strengths of 0.1 V/m to 10 kV/m, enabling metrology applications such as the calibration of radar antennas with up to 4x more accuracy than current state of the art approaches.

Ultrafast waveguide for optical-to-optical switches:

A DARPA SBIR performer, Triton Systems, with Vanderbilt University created an embedded-vanadium dioxide (VO2) silicon waveguide modulator that makes use of VO2's nonlinear optic (NLO) property. The group measured VO2 to have an ultrafast (50 fs) optically induced phase transition at telecom wavelengths - the fastest ever reported for a waveguide NLO device. This has the potential to impact a number of applications requiring high-speed, low-power optical-to-optical switches or modulators including increasing the speed of distributed computing systems and improving energy efficiency in communication networks.

Where Are They Now?

Darryll J. Pines *DSO PM: 2003-2006*

My name is Darryll J. Pines, and I am currently the Dean and Nariman Farvardin Professor of Engineering in the A. James Clark School of Engineering at the University of Maryland. I became interested in becoming a DARPA program manager in January of 2003 after speaking to a colleague named Preston Carter who happened to be a program manager in DARPA's Tactical Technology Office. Preston and I were former engineering staff members at Lawrence Livermore National Laboratory, and he gave me a call and encouraged me to interview for a PM position with the TTO Director, Dr. Arthur Morrish. Thus, my journey to serve as a PM was initiated in March of 2003 when I cornered Dr. Morrish at a TTO Industry Information Day. I asked Dr. Morrish if I could schedule a meeting with him to discuss becoming a TTO PM. Dr. Morrish gave me his assistant's email and said make an appointment. So, I made the appointment for the very same day, and when I showed up to speak with Dr. Morrish at 2pm, he was quite startled to see me and stated you must really want this job. I stated "Yes sir, I really do." This ultimately led to an interview with Dr. Tony Tether a few weeks later. My meeting with Dr. Tether went extremely well and he appeared to like the ideas that I wanted to bring to DARPA to support the warfighter. At the end of my interview, he told me to schedule a meeting with human resources to learn about the process for becoming a program manager. After completing the necessary paperwork, I would start officially as a PM in TTO in October of 2003.

Upon arriving in TTO, Dr. Morrish asked me to be one of the office's aerospace experts and assigned me two Army Future Combat Systems programs. The first was entitled the Affordable Weapon Systems Program (AWS) jointly funded by NAVSEA, but commonly referred to as Long Gun, and the second was a remote sensor emplacement program entitled SensorDart. Both programs involved the development of unmanned aerial systems, which was perfectly suited for me to manage. The first original DARPA program that I pitched to Dr. Tether for financial support in TTO was called the X-ray Navigation and Autonomous Vehicle-XNAV program. This idea originated out of fundamental academic research related to the use of milli-second pulsars as inertially referenced clocks for the navigation of spacecraft. A pulsar is a celestial object, thought to be a rapidly rotating neutron star that emits regular pulses of energy across the broad electromagnetic spectrum at rates of up to one thousand pulses per second. I made a case that if we could build a database of acceptable pulsars and develop nano-second high signal-to-noise detectors, that an integrate sensor system could be used to serve as a backup to the GPS constellation in case of a breach in the ground stations, or space segment. The DARPA XNAV proved that x-ray navigation was possible, and lead to several follow on programs including the DARPA XTIM program, and the NASA SEXTANT and NICER programs respectively.

After 18 months in TTO, I sent up a program pitch about a materials technology that could be hidden in plain sight to the Director's Office, and the very next day I was asked to move to DSO as a program manager. I was surprised by this decision, but also grateful to join the talented team of DSO program managers working on cutting edge science and technology. I continued to manage my TTO portfolio of programs, while seeking to launch new programs in DSO. I was fortunate in March of 2015 that DSO Director Steve Wax supported my program pitch to develop a program that I named the Nano Air Vehicle (NAV). NAV was a program inspired by nature to develop biologically inspired flapping air vehicle system that weighed approximately 10 grams and could navigate inside buildings and provide situational awareness to the warfighter. I was fortunate to downselect four performers for the Phase I of this program. However, my term would end in October of 2006. Nevertheless, this program would continue and yield an autonomous "hummingbird" vehicle that weighed approximately 20 grams and was featured in a box office movie entitled "Eagle Eye" in 2008.

After my three-year tour at DARPA, I returned to the University of Maryland to serve as the department chair of aerospace engineering and now as the Dean of the A. James Clark School of Engineering for the past ten years. I truly enjoyed my time in TTO and DSO at DARPA, and it was a privilege to serve my country as a PM attempting to help solve problems faced by our service men and women. DARPA TTO and DSO provided an incredible environment to work with some of the brightest minds in our nation and to develop revolutionary technology to achieve DARPA's ultimate goal of preventing technological surprise. It was indeed one of the best experiences of my career and life.

Doing Business With DSO

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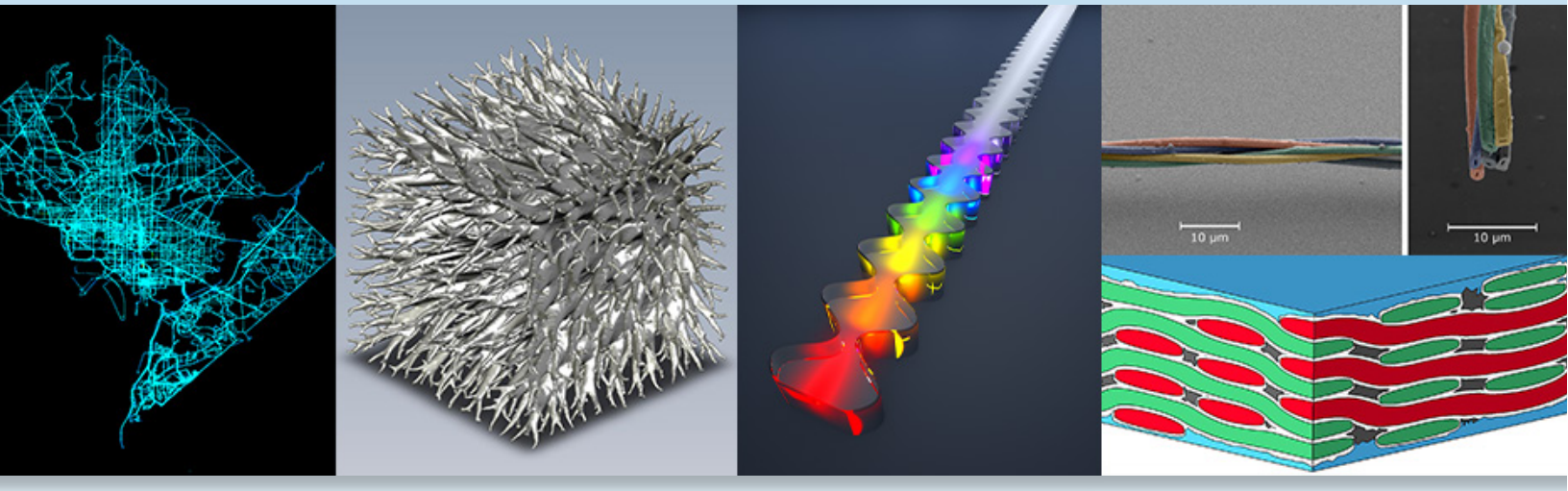

DARPA's Defense Sciences Office (DSO) identifies and pursues high-risk, high-payoff research initiatives across a broad spectrum of science and engineering disciplines, and transforms them into important, new game-changing technologies for U.S. national security. Current DSO themes include Frontiers in Math, Computation & Design, Limits of Sensing & Sensors, Complex Social Systems and Anticipating Surprise.

DSO relies on the greater scientific research community to help identify and explore ideas that could potentially revolutionize the state-of-the-art. There are five ways to make DSO aware of your research ideas:

1. Talk to a Program Manager

Program Managers recommend which proposals should receive DSO funding. You may communicate directly with one or more of them (see DSO's website, http://www.darpa.mil/about-us/offices/dso). E-mails, phone calls, or face-to-face meetings allow you to explore concepts and ideas and translate them into a substantive proposal.

2. Submit a proposal to DSO's Office-wide Broad Agency Announcement (BAA), HR001119S0071

The Office-wide BAA is primarily used to fund small, short-duration exploratory projects. These small projects help DSO determine whether "disbelief" in an idea's plausibility can turn into "mere doubt" – and "mere doubt" is often enough to encourage DSO to make a larger investment to determine if a scientific or technology innovation may be possible. These efforts are typically 3-9 month projects that answer a specific question and involve a very limited number of personnel. Knowledge gleaned from these small projects often lead to the next generation of program ideas. See section entitled "DSO's Office-wide Broad Agency Announcement."

3. Submit a proposal to a program-specific BAA

Exploratory investments that bear fruit and become programs will appear as individual program BAAs throughout the year. You can search for them on FedBizOpps.gov, grants.gov, the DSO website, or the DARPA website under "Solicitations."

4. Submit a proposal to DSO's Disruptioneering Program Announcement, DARPA-PA-19-02

See section entitled "DSO's Disruptioneering."

5. Engage in conversations with DARPA Program Managers and research communities on the Polyplexus platform, which may culminate in a submission to HR001118S0058

See section entitled "Polyplexus."

DARPA's mission is to make the pivotal early technology investments that create or prevent technological surprise for U.S. national security

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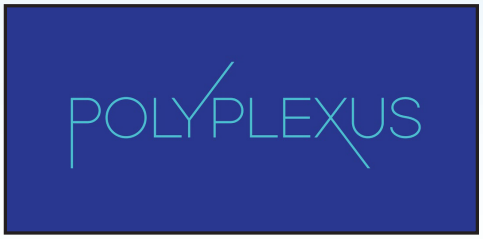
DSO's Disruptioneering

The pace of discovery in both science and technology is accelerating worldwide, resulting in new fields of study and the identification of scientific areas ripe for disruption. In order to capitalize on these new opportunities, DARPA's approach to investing must include faster responses with smaller, targeted investments. DSO has successfully addressed this concern through use of its Disruptioneering acquisition technique to make awards in fewer than 90 days after solicitation.

Targeted special notices called Disruption Opportunities (DOs) are issued under the Program Announcement, DARPA-PA-19-02, for each Disruption effort. These DOs focus on small, high risk programs within technical domains important to DSO's mission. Research topics of interest to DSO may be found at http://www.darpa.mil/about-us/offices/dso.

Polyplexus



To take advantage of platform connectivity and collaborative technologies, DSO has developed Polyplexus (polyplexus.com). Polyplexus is a tool designed to enable cross-disciplinary technical conversations between the research community and DARPA Program Managers. The goal is to fundamentally reshape and accelerate the research and development (R&D) process by significantly reducing the time between concept emergence and proposal submission. The platform employs an evidence-based process to rigorously explore the trends and possible applications of emerging science and technology. The evidence and potential applications can be posted in a specific technical area (Incubator) defined and managed by a participating Program Manager. The resulting online discussion may culminate in an opportunity to submit an abstract and proposal describing proposed research projects to HR001118S0058. Submission of an abstract or a proposal is not a requirement to participate on Polyplexus. We encourage you to join the community.

DSO's Office-wide Broad Agency Announcement

The current DSO Office-wide BAA covers the entire scope of DSO's technical interests for this year and is open for new ideas through June 11, 2020.

Please note that the Office-wide BAA does not supersede program-specific BAAs. Rather it is intended to fund completely new ideas not connected with programs that are already underway or currently soliciting proposals.

The Office-wide BAA offers three different ways to submit ideas: (i) executive summaries (typically no more than two pages in length), (ii) abstracts (not to exceed five pages), and (iii) full proposals (Read the BAA instructions regarding the structure and content of full proposals).

We recommend you start by submitting an executive summary (ES), preferably after discussing your ideas with a Program Manager. Your ES will be circulated among all the Program Managers in DSO, and you will receive feedback letting you know if there is any interest.

If you are not getting a timely response from a Program Manager or have other questions, please contact DSO's BAA Administrator directly at HR001119S0071@darpa.mil.

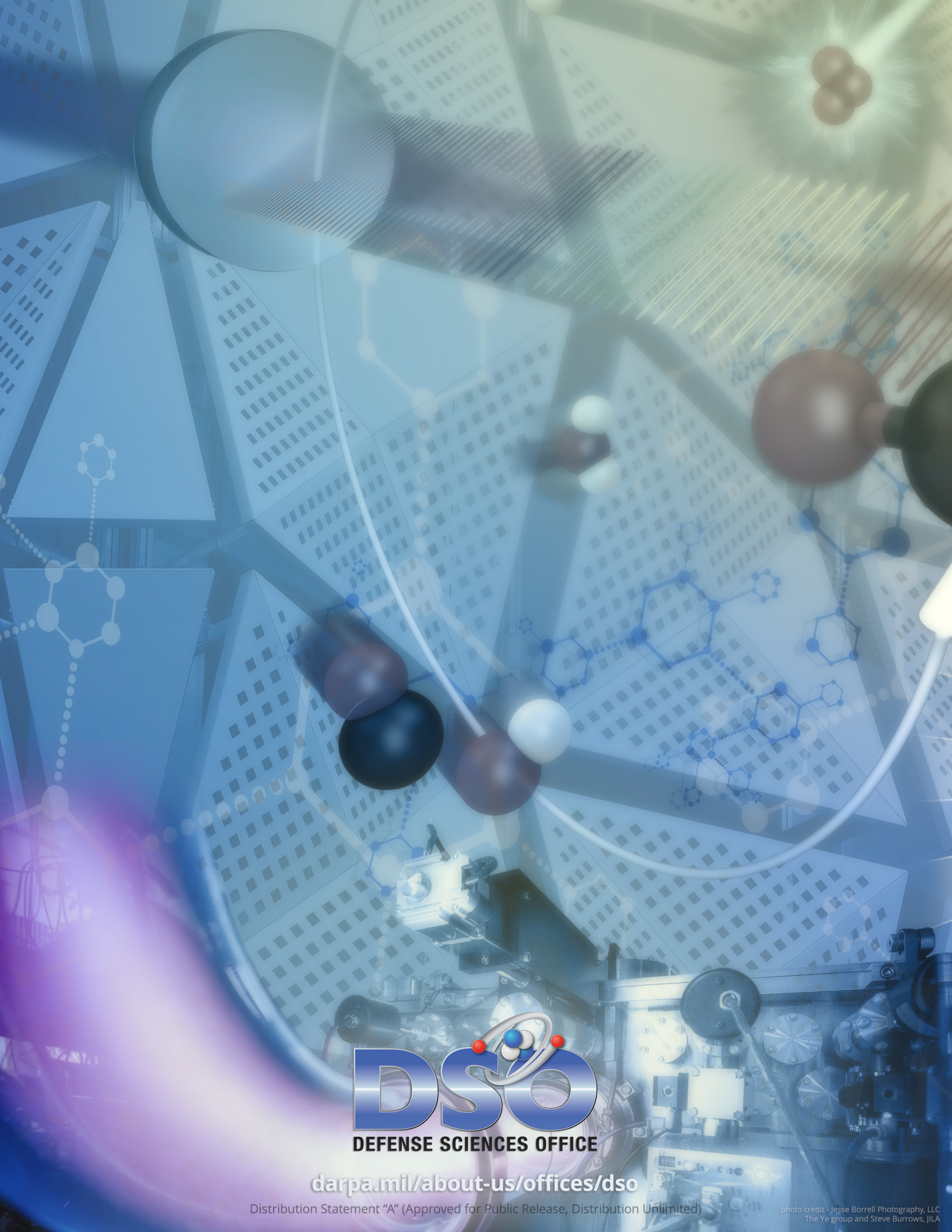
General Advice for Submitting New Ideas to DSO

The "*Heilmeier Catechism*" is helpful for organizing your thoughts. Developed by Dr. George Heilmeier, Director of DARPA from 1975-1977, DARPA has lived by this catechism for decades. It poses the questions we ask ourselves about every new DSO program:

1. What are you trying to do?
2. How is it done today and who does it? What are the limitations of the present approaches?
3. What is new about our approach, and why do we think it will succeed?
4. If we succeed, what difference will it make?
5. How long do we think it will take?
6. What are our mid-term and final exams?
7. How much will it cost?

Initially, we recommend you focus on the first four to help define and scope your proposed research. In addition, we will ask you, "Why DARPA? Why DSO? Why now?" These questions of relevance come up every day in conversations at DARPA.

Above all, please read the BAA. If you have questions about the BAA, contact the Office-wide BAA Administrator at HR001119S0071@darpa.mil.



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