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# 7th Annual Postdoc and Early Career Research Day: DEVCOM Army Research Laboratory's Postdoctoral Symposium

by Ana Alvarez, Catherine Dillier, Andreu Glasmann, Joshua Hill, Haval Kareem, LeighAnn Larkin, Anna Madison, Korosh Mahmoodi, Franklin Nouketcha, Italo'Ivo Lima Dias Pinto, Justine Caylor Rawal, Harold Hohyun Sun, and Elliot Wainwright

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# **7th Annual Postdoc and Early Career Research Day: DEVCOM Army Research Laboratory's Postdoctoral Symposium**

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The DEVCOM Army Research Laboratory (ARL) Postdoc Association (PDA) organized its 7th Annual Postdoc and Early Career Research Day on March 30, 2023, to showcase research outcomes, achievements, and contributions from postdocs and early career researchers across the enterprise. The event included presentation sessions, an invited talk from MAJ Matthew Nulk, and a Q&A panel with successful early career researchers. This special report contains a summary outlining the event and post-symposium survey results, as well as a snapshot of ARL's postdoctoral and early career research communities in FY22-23. The abstracts presented at the event, as well as survey questions and an article published on ARLInside, are included in the appendices.					
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## **Contents**

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<b>List of Figures</b>	<b>iv</b>
<b>List of Tables</b>	<b>iv</b>
<b>Acknowledgments</b>	<b>v</b>
<b>1. Introduction</b>	<b>1</b>
<b>2. The Symposium</b>	<b>1</b>
<b>3. Presenters and Audience Members</b>	<b>2</b>
<b>4. Overview of Decisions and Discussion</b>	<b>4</b>
<b>5. Survey Results: Post-Symposium and Avenues of Improvement</b>	<b>5</b>
<b>6. Lessons Learned from 7PECRD</b>	<b>8</b>
<b>Appendix A. Contributed Abstracts Presented at the 7th Postdoc and Early Career Research Day</b>	<b>9</b>
<b>Appendix B. Survey Questions</b>	<b>18</b>
<b>Appendix C. Article Published on ARLInside</b>	<b>20</b>
<b>List of Symbols, Abbreviations, and Acronyms</b>	<b>24</b>
<b>Distribution List</b>	<b>25</b>

## List of Figures

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Fig. 1	Total number of postdocs at ARL for each fiscal year from 2018 to 2022. This data was compiled using records obtained from the Civilian Human Resources (civilian) and the Educational Outreach (contractor) Offices at ARL.....	4
Fig. 2	Survey results for how participants heard about the symposium .....	6
Fig. 3	Survey results for preferred symposium format .....	7

## List of Tables

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Table 1	7 <sup>th</sup> Annual Postdoc and Early Career Research Day itinerary .....	2
Table 2	List of postdoc and early career researchers who presented at the 7 <sup>th</sup> Annual Research Symposium .....	3

## **Acknowledgments**

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The organizing committee of the 7<sup>th</sup> Annual Postdoc and Early Career Research Day was composed of the 2022–2023 Postdoctoral Association (PDA) cochairs, Drs LeighAnn Larkin and Catherine Dillier. The PDA would like to acknowledge those who assisted with planning, coordinating, and volunteering at the symposium. First, the committee acknowledges the invited speakers at our event: MAJ Matthew Nulk, Dr Steven Dean, Dr Mary Beth Galanko, and Dr Antonio Llopis-Jepsen. We also want to acknowledge the judges for the oral presentation component of the symposium: Dr Rose Pesce-Rodriguez, Dr Chi-Chin Wu, Dr Frank De Lucia, Dr Brenden Hanrahan, Dr Yelena Sliozberg, Dr Richard Becker, Dr Faheem Muhammad, Dr Wendy Sarney, Dr Meagan Small, Dr Greg Lieberman, and Dr Nik Ter-Gabrielyan. Additionally, we want to thank Austin Leonard and Renee Bitner from ARL’s Civilian Human Resource Office, and Joseph Gamson from ARL’s Outreach Office, for providing the reports on the number of postdocs at ARL over the past years. Lastly and most importantly, the PDA wants to acknowledge the presenters and thank the attendees of the symposium.

## **1. Introduction**

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The US Army Combat Capabilities Development Command (DEVCOM) Army Research Laboratory's (ARL) Postdoctoral Association (PDA) is an organization that was established by and composed of ARL postdocs. The PDA was formed with the mission of improving the postdoctoral experience by facilitating an organization-wide culture of inclusive connection amongst the cohort of early researchers. The PDA executes this goal by organizing both professional growth and social events at ARL, including in-person lunches and seminars with organizations at ARL such as the Technical Publishing Office. The PDA's flagship event, however, is the Annual Postdoc and Early Career Research Day at which postdocs and early career researchers are given the opportunity to showcase their work.

The Annual Postdoc and Early Career Research Day is a day-long symposium designed to highlight the impact of our postdocs and early career workforce on the ARL mission. It provides an opportunity for them to not only present their research, but also network with fellow researchers and promote collaborations where suited. Professional growth is also encouraged through a presentation competition and seminars given by invited speakers. Most importantly, the Annual Postdoc and Early Career Research Day provides a venue to celebrate and promote the postdoctoral and early career experience at ARL.

This special report summarizes the day's events and participation, followed by commentary on organizing the event and feedback received. Presentation abstracts are included in Appendix A, survey questions in Appendix B, and an internal article on the event in Appendix C.

## **2. The Symposium**

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The 7<sup>th</sup> Annual Postdoc and Early Career Research Day (7PECRD) was held virtually on the ARL Café on March 30, 2023. Historically, the event had been held on-site either at ARL's Aberdeen Proving Ground (APG) or Adelphi Laboratory Center (ALC) location. Starting in 2020, the COVID-19 pandemic led to the symposium being transitioned to a virtual event held on ARL Café. Because the virtual format allowed for greater participation across the lab, including extended sites, it was decided to run the event virtually again this year.

Due to the smaller number of participants in this year's symposium, the same virtual meeting room was used for all events. The presentations were broken into three main sessions as seen in Table 1. Each presenter was given 15 min (10-min

presentation, 5-min Q&A) and the sessions were organized by research topic. For the presentation competition portion, 11 judges chose a winner for each session.

**Table 1 7<sup>th</sup> Annual Postdoc and Early Career Research Day itinerary**

<b>Time (EST)</b>	<b>Event</b>
1000–1015	Opening remarks by Mr Joseph Alexander, Deputy Director of the Army Research Directorate
1015–1115	Presentation Session 1: Drs LeighAnn Larkin, Franklin Nouketcha, Joshua Hill, and Korosh Mahmoodi
1115–1130	Break
1130–1230	Presentation Session 2: Drs Ana Alvarez, Harold Hohyun Sun, Andreu Glasmann, and Haval Kareem
1230–1330	Sack-lunch presentation, “How ARL Fits into the Army”: MAJ Matthew Nulk
1330–1345	Break
1345–1500	Presentation Session 3: Drs Italo’Ivo Lima Dias Pinto, Justine Caylor Rawal, Anna Madison, Elliot Wainwright, and Catherine Dillier
1500–1600	Q&A panel, “Success at the Bench”: Drs Steven Dean, Mary Beth Galanko, and Antonio Llopis-Jepsen
1600–1630	Awards and closing remarks

In addition to the research presentation portion of the 7PECRD, the PDA organized two other seminars to occur throughout the day. The first, entitled “How ARL Fits into the Army,” featured MAJ Matthew Nulk, who provided an overview of how research generated within ARL ties into the Army Modernization Enterprise and is ultimately fielded into our warfighters’ hands. The second seminar, a Q&A panel entitled “Success at the Bench,” featured three early career researchers, Drs Steven Dean, Mary Beth Galanko, and Antonio Llopis-Jepsen, who discussed their career trajectories at ARL and provided advice on different career paths, building a career at ARL, and adjusting your research to meet the Army’s needs.

### **3. Presenters and Audience Members**

The names, competencies, and physical location of the presenters can be found in Table 2. Thirteen postdoc and early career researchers participated in the technical symposium portion of the day. A select number of the abstracts can be found in Appendix A. In previous years, the PDA has highlighted the presenter’s directorate affiliation within ARL to quantify the engagement across the laboratory. Since the previous iteration of the technical symposium, ARL has been reorganized into key research competencies aligned with the Army’s mission. Each researcher belongs to one of ARL’s 11 competencies, also shown in Table 2.

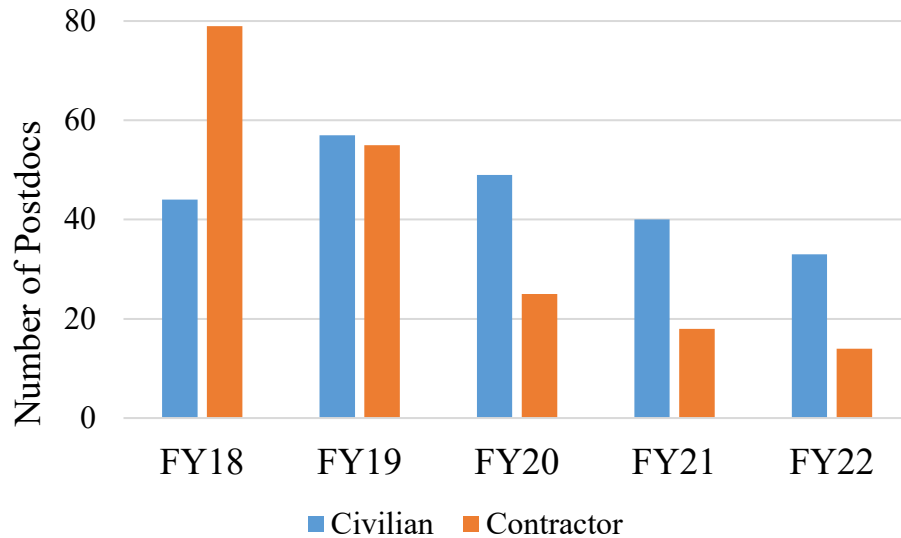
**Table 2 List of postdoc and early career researchers who presented at the 7<sup>th</sup> Annual Research Symposium**

<b>Presenter</b>	<b>Competency</b>	<b>Location</b>
Alvarez, Ana	Energy Sciences (ES)	ALC
Dillier, Catherine	Weapons Sciences (WS)	APG
Glasmann, Andreu	Photonics, Electronics & Quantum Sciences (PEQS)	ALC
Hill, Joshua <sup>a</sup>	Photonics, Electronics & Quantum Sciences (PEQS)	ALC
Kareem, Haval	Energy Sciences (ES)	ALC
Larkin, LeighAnn	Electromagnetic Spectrum Sciences (EMSS)	ALC
Madison, Anna <sup>a</sup>	Humans in Complex Systems (HCxS)	U.S. Air Force Academy
Mahmoodi, Korosh	Humans in Complex Systems (HCxS)	APG
Nouketcha, Franklin	Electromagnetic Spectrum Sciences (EMSS)	ALC
Pinto, Italo Ivo Lima Dias	Humans in Complex Systems (HCxS)	APG
Rawal, Justine Caylor	Military Information Systems (MIS)	APG
Sun, Harold Hohyun <sup>a</sup>	Energy Sciences (ES)	ALC
Wainwright, Elliot	Weapons Sciences (WS)	APG

<sup>a</sup> Denotes session winner

This year, the PDA noted a significant decrease in participation compared to the previous two years (i.e., 13 this year compared to 26 and 31 presenters at the 6<sup>th</sup> and 5<sup>th</sup> Annual Symposium, respectively). The PDA posits that this decrease is primarily due to a reduction in the overall number of postdocs at ARL. Over the past 5 years, except for FY19, there has been a steady decline in both postdocs hired as civilians and contractors. As shown in Fig. 1, while there were over 120 postdocs in FY18, there were less than 50 in FY22. Accordingly, as the number of postdocs at ARL decreases, so does the participation in the Postdoc Symposium. It should be noted though that the percentage of the total number of postdocs participating in this event decreased from 45% at last year’s symposium to 28% at this year’s symposium.

In an effort to increase participation in next year’s symposium, the PDA issued a post-symposium survey (found in Appendix B) this year to acquire feedback from the presenters regarding the content and structure of this year’s symposium. The survey also addresses the possibility of ineffective advertising by asking the participants how they heard about this year’s symposium. Further details on the survey and subsequent results are provided in Section 5.



**Fig. 1 Total number of postdocs at ARL for each fiscal year from 2018 to 2022. This data was compiled using records obtained from the Civilian Human Resources (civilian) and the Educational Outreach (contractor) Offices at ARL.**

The entire ARL workforce was invited to the symposium through a special dispatch that went organization-wide one month before and again, two days before the event. During the opening remarks and technical session 1, we averaged an attendance of 60–78 participants. During technical session 2 and the special lunch session, the attendance ranged from 50 to 59. Over the course of the afternoon sessions (including technical session 3 and the Q&A panel), the attendance ranged from 42 to 48 participants.

#### **4. Overview of Decisions and Discussion**

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Over the last several symposiums, the PDA has provided a series of lessons learned for best practices in hosting future events. Best practices from last year’s events, including (1) having the full itinerary available on ARL Café with links to abstracts ahead of time, (2) advertising via several special dispatches, and (3) hosting the symposium Tuesday–Thursday, were incorporated into this event.

In addition, we chose the special sessions to reflect repeating themes and discussions that arose at the 6<sup>th</sup> Annual Postdoc and Early Career Research Day (6PECRD) amongst the participants. At the 6PECRD, a notable theme of understanding the warfighter and how research projects fit into the Army’s mission emerged from questions and discussion. This year, we elected to host MAJ Matthew Nulk to directly address these topics in his invited talk “How ARL Fits into the Army.” The Q&A portion of this session addressed broad questions. Some

notable topics included the interplay and relationship between academia, industry, and ARL for conducting 6.1 research and building the applications, and how new employees can familiarize themselves with the warfighter.

The other special session, the Q&A panel, was a reiteration of a similar event at the 6PECRD. The Q&A panel at 6PECRD featured three successful and prominent ARL researchers who had more than 10 years' experience at ARL. The panel was received positively and yielded a fruitful discussion. However, there was some discussion amongst the participants related to specific concerns of the postdoc community that could not be adequately addressed by the panel. As such, the PDA decided to host this event again, but chose to invite scientists that are still considered early career (at ARL for less than 10 years) and were originally hired as postdocs at ARL before transitioning to full-term employees. This provided a space where the postdoc community was able to speak candidly about long-term career goals inside and outside of ARL.

Outside of the special seminars, the primary focus of the day was the technical sessions. The day contained three technical sessions in which participants were broadly organized based on research fields. Each presenter was given 15 min for presentation and discussion, and advised to present at a technical level like that of a technical conference. The PDA also chose to transition to an oral presentation over the poster format. In the virtual format, we believed that a traditional oral presentation would encourage more discussion. Also, we believed that screen-sharing posters (rather than slides) during the 6PECRD hindered the presenters' ability to communicate the broader picture of their research (due to having to zoom in to specific sections).

## **5. Survey Results: Post-Symposium and Avenues of Improvement**

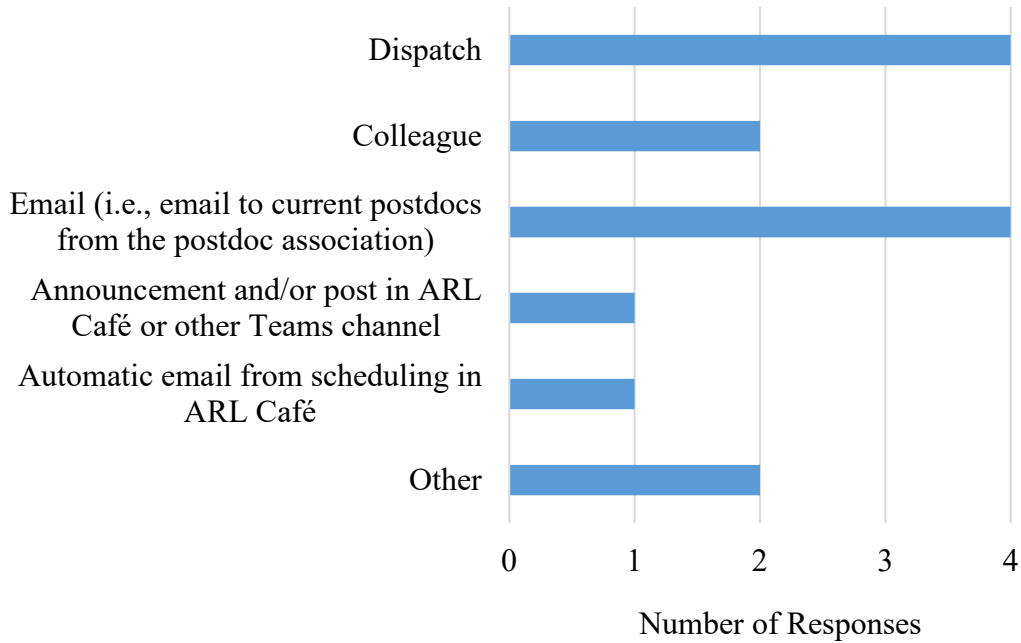
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In previous years, the PDA relied on word-of-mouth to receive feedback on the event. This year, a short survey was directly sent out via email to presenters and judges. The questions in the survey can be found in Appendix B. The survey participants were informed that all responses would be anonymous, all questions were optional, and the responses would be read by the PDA to improve future events. We received 10 responses to the survey, which was a response rate of 45%. The first two questions were multiple choice, while the remainder were open-ended text-based responses.

In Fig. 2, we show the response to the multiple-choice question, "How did you hear about the symposium?" This question was asked because a top goal of the PDA with respect to the symposium is to increase participation in the event. To

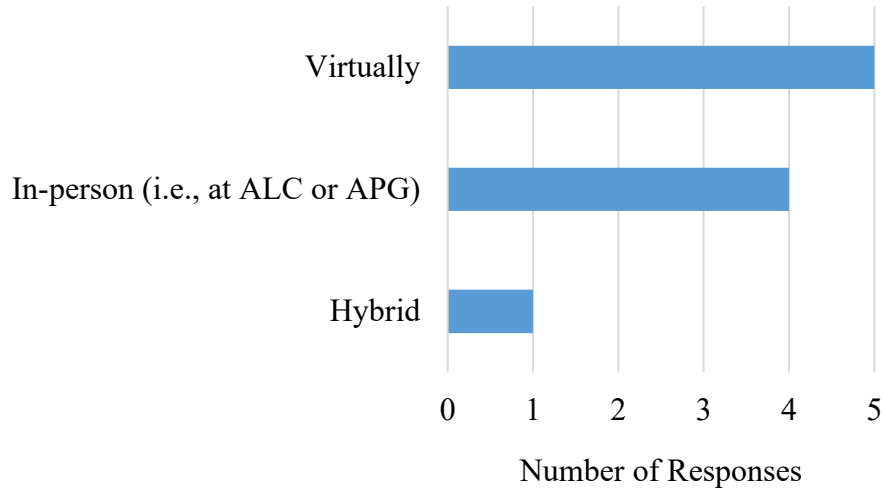
accomplish this goal, our advertisement of the event must be effective in reaching the target audiences. Most of the respondents heard of the symposium through the special dispatches or in the emails sent directly to the postdoc community. This indicates that it remains crucial for the PDA to maintain list and contact information of the postdocs.



**Fig. 2 Survey results for how participants heard about the symposium**

In Fig. 3, we show the multiple-choice responses to the question, “How would you prefer this conference to occur?” Prior to the COVID-19 virus, this symposium was always held on-site at either APG or ALC, alternating locations each year. We decided to continue to have the conference virtually since many ARL events are still occurring on ARL Café. The broader ARL workforce, especially our invited speakers and judges, can attend more freely when the event is hosted virtually. As evidenced by Fig. 3, both virtually and on-site are preferred, with a virtual conference holding one point more. It is, however, unclear if participants are just as willing to attend on-site if the event is not hosted at their physical location (i.e., will they be as likely to attend the symposium at APG if they are stationed at ALC?). In the future, we will likely continue to host the symposium virtually.

The remainder of the survey questions asked were open-ended. Participants could write-in responses to provide feedback. All these questions were chosen to gauge participants’ opinions on the day’s content (the special seminars, the organization, the technical events, etc.). We will qualitatively assess these responses and provide feedback for future symposiums.



**Fig. 3 Survey results for preferred symposium format**

The results indicated that the participants overwhelmingly listed the technical sessions as their favorite portion of the day. The participants felt that the event is useful for networking, making connections internally, and getting feedback from ARL researchers. However, with respect to the content of the technical symposium, there were some comments alluding to the presentations being too technical and to be aimed at a more general, broader audience. Some comments suggested that it may be beneficial for the participants to focus more on how their research fits into the mission and impacts the Army.

After reviewing these comments, the PDA feels that the goal of the symposium should be explicitly stated to all those who participate. As such, there are two primary avenues the symposium could take. The goals are to (1) provide technical feedback to the researchers and encourage research collaboration or (2) introduce and engage with the postdoc community and network with the ARL research community. If the PDA elects to align the symposium with the former, then more judges should be chosen, and with care to align their research expertise with the presenters. If the latter is chosen, the presenters should be advised to focus on how their research fits into the Army and be accessible to the broader community. We should note that the symposium is currently limited to content that is distribution A (i.e., approved for public release). Any focus on the Army mission could increase the distribution level of the symposium and possibly limit participation.

Either way, the PDA recommends that in future conferences, the presenters should be given specific guidance for what to include in their presentations and the level of technical detail. This recommendation also ties into another common thread among the comments provided by the responses: the time allotted for the

presentations. Some comments suggested there was not enough time for discussion with the judges. As one respondent stated, “Engagement and discussion create a research community, and that would promote broader thinking and higher quality research.” With clear guidance to the presenters, timing could fall in line easier. A practice session prior to the actual symposium and before submission to Form 1 could also aid with this. In addition, the PDA recommends that specific guidance should be provided to the judges on what they should be looking for within the presentations. A “rubric” or general document with guiding questions could be distributed to the judges beforehand so that they can address specific goals of the presentations. These documents could then be later distributed to the presenters for real-time feedback.

## **6. Lessons Learned from 7PECRD**

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The PDA board would like to conclude this special report with a summary of lessons learned and best practices for future research symposia. Key practices adopted include the following:

- Continue to host the symposium on days that allowed for the greatest participation of invited guests (Tuesday, Wednesday, or Thursday).
- While there are some who prefer attending the symposium in-person, hosting the event virtually on the ARL Café channel is still the best option as it makes the event widely accessible to the entire workforce.
- Advertising in several special dispatches to the full ARL workforce and emailing the postdocs directly are effective ways to publicize the event.
- Clearly state the goal of the symposium. Either define the symposium as an opportunity for the presenters to receive technical feedback on their research or advertise the event as a more general networking event for the wider ARL community to meet and interact with the postdoc and early-career workforce.
- Provide more guidance in terms of presentation content based on the goal of the symposium.
- Provide the judges with a rubric or general document containing guiding questions so the judging criteria align with the goals of the symposium.
- Distribute a post-symposium survey to all of the participants. This feedback was key for determining areas of improvement.

**Appendix A. Contributed Abstracts Presented at the 7th Postdoc  
and Early Career Research Day\***

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\* The contents of this appendix appear in original form, without editorial change.

## TiO<sub>2</sub> Channel Material for Lithium-Ion-Gated Neuromorphic Transistors

Alvarez, Ana I.<sup>1\*</sup>, Boltersdorf, J.<sup>1</sup>, Grew, K. N.<sup>2</sup>, Schroeder, M. A.<sup>2</sup>, Hoerauf, J.<sup>2</sup>, and Theodoru, S.<sup>2</sup>

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Ubiquitous Internet of Things (IoT) platforms have exponentially increased the relay of an abundance of data between memory and processor in current computing architectures, ultimately limiting throughput and advancing towards the von Neumann bottleneck. Brain-inspired computing using neuromorphic devices presents an encouraging alternative framework capable of power-efficient real-time inference, self-learning, and decision-making. This work focuses specifically on ion-gated, three-terminal transistors that rely on electrochemically driven ion intercalation between an electronically insulating electrolyte and a conducting channel. While other nonvolatile memories (NVMs) can be used in neuromorphic devices, electrochemical random-access memory (ECRAM) advantageously enables the programming of multi-states and their retention in the absence of applied power. This talk will present our recent work on anatase TiO<sub>2</sub> as a channel material in a lithium-ion-gated, three-terminal transistor. Based on the literature, anatase TiO<sub>2</sub> covers a wide channel conductance range and exhibits a linear response, allowing for numerous well-defined synaptic weights [1]. We explore a range of channel conductance values using both potentiostatic and galvanostatic pulsing and correlate material properties to electrical measurements. These results provide a benchmark and roadmap for lithium-ion-based neuromorphic transistors capable of multi-states.

[1] Y. Li, E.J. Fuller, S. Asapu, S. Agarwal, T. Kurita, J.J. Yang, and A.A. Talin, *ACS Appl. Mater. Interfaces* 11, 38982 (2019).

## Microscale Electrostatic Discharge (ESD) Sensitivity Characterization of Energetic Materials

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Prior to formulating and large-scale testing, all novel energetics must undergo a variety of safety testing, including characterizing the electrostatic discharge (ESD) sensitivity, where the material is exposed to a spark discharge-generated shockwave at varying energy levels to determine the ignition threshold. The current standards for these sensitivity tests include a variety of technique implementations and subjective and operator-dependent go/no-go criteria. As a result, the values reported for the same material vary across different laboratories. Furthermore, these tests typically require grams of material to complete, which is generally unavailable during the initial development process when only milligrams are synthesized at a time. Waiting to test until after developing scale-up procedures is nonideal since it is often too late to modify the synthesis procedure without significant additional cost and labor; if the material does not pass, it is often abandoned. Therefore, an objective microscale method to pre-screen the ESD sensitivity of novel energetic materials was developed in our laboratory. The amount of material required is reduced by an order of magnitude (less than ten milligrams of material per test) and objective go/no-go criteria are incorporated, including time-resolved integrated emission measurements, emission spectroscopy, and high-speed imaging. This presentation details our unique microscale ESD sensitivity procedure and provides example characterizations of commercial aluminum powders.

## Physics-based Compact Device Model for Ferroelectric Field Effect Transistors for Neuromorphic Computing

*Glasmann, Andreu L.<sup>1\*</sup>, Pearson, S.<sup>2</sup>, Sarney, W.<sup>2</sup>, Chin, M.<sup>3</sup>, and Najmaei, S.<sup>3</sup>*

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Next generation military edge systems require a dramatic change computing paradigms which utilize new electronic devices and circuit architectures to address increasing power demand and to enable cognitive sensing and autonomy in varied environments. In this work, we present a physics-based compact model for three-terminal ferroelectric field effect transistors to facilitate the design and integration of this emerging class of electronic devices into these systems. Non-volatile memory devices based on ferroelectric hafnia are a promising device platform for future neuromorphic computing systems for several reasons. First, hafnium oxide has a long legacy for use as a high-k gate dielectric for submicron transistor technologies; therefore, there is a low barrier for integration of ferroelectric hafnia into existing CMOS foundries. Second, the ferroelectric property of doped hafnia has been demonstrated to be scalable to films below 10 nm in thickness, making this material suitable for integration into advanced submicron technology nodes. Last, non-volatile memory devices based on ferroelectric hafnia have been demonstrated to have fast (~ns), low power read and write cycles with high endurance. Nevertheless, to continue to assess the viability of ferroelectric-based devices for future neuromorphic systems there is a need for continued development of reliable device models that span device- and circuit-scales to inform system-level impact.

In this work, we present a physics-based compact device model for three-terminal ferroelectric field effect transistors. The model has been designed with explicit support for transient analysis to capture time-dependent polarization switching dynamics down to nanosecond scale with multiple types of ferroelectric domains. In the presentation, we will discuss the model's calibration against experimental data and use in optimizing the design of a ferroelectric-metal field effect transistor (FeMFET). Finally, we conclude with future direction of the work, including how the model has been used in a Monte Carlo analysis to set the stage for future incorporation into neural network accelerator simulations.

## Wideband Simultaneous Microwave Demodulation with a Quantum Receiver

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Receiving and demodulating signals encoded with radio frequency (rf) electromagnetic fields spanning 30MHz to 300GHz is a key component of many modern technologies. A single traditional antenna coupled to electronics has well-known performance bounds with respect to its size and the frequency band of interest. Electric field sensors based on highly excited Rydberg atoms have attracted recent interest for their sensitivity to receiving (not transmitting) fields with frequencies from zero to terahertz in a single device with measurements traceable to SI-defined fundamental constants. Here, I will discuss our recently published work using Rydberg atoms to demonstrate reception and demodulation of rf fields spanning nearly two decades in frequency. Specifically, we perform rf heterodyne and measure the baseband beat frequencies between five pairs of simultaneously applied signal and local oscillator fields with carriers of 1.72, 12.11, 27.42, 65.11, and 115.75 GHz. From these, we recover the amplitude and phase of the corresponding signals. In addition, we perform on-off-keyed communication reception using four of the tones and quantify the resulting bit error ratios. While future work is necessary to increase the sensitivity of Rydberg-atom receivers, these demonstrations expand the design space to a regime that would be challenging to implement with traditional technologies.

# Advanced Nanomaterial for Low Operation Temperature Solid Oxide Fuel Cell

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Lowering the operation temperature of SOFC (500 °C -600 °C) allows the use of more durable, cheaper, more available, faster startup and cool down period which is important to fit the requirement for Army application. Unfortunately, at lower temperatures, the conventional Ytria-stabilized Zirconia-based electrolyte/electrode has too low conductivity to achieve desired power density and experiences performance degradation due to the harsh redox environment and sluggish oxygen reduction reaction (ORR) at the cathode. Mixed ionic and electronic cobaltite-based perovskite materials (ABO<sub>3</sub>) including Sm<sub>1-x</sub>Sr<sub>x</sub>CoO<sub>3-δ</sub> (SSC) are highly desirable and considered a promising option for cathode for low operation temperature (500 °C -600 °C). However, long-term cell degradation due to the surface migration of metal cations which in turn affects the oxygen surface exchange kinetics at the cathode still a challenge. Surface modification with an electroactive catalyst plays a key role in tuning the perovskite into a fascinating electrocatalytic property. Modification of the perovskite structure with metal nanoparticles enhances catalytic activity through fast chemical diffusion (oxygen self-diffusion), and surface exchange, which in turn lower the chemical impedance of the cell and enhances ORR kinetics. The developed materials are expected to lower the operation temperature of SOFC with high power density.

## Thermal Conductivity of Nanometer Scale Compositionally Inhomogeneous AlGa<sub>N</sub> UV-Emitters

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The presence of random and ordered phases of semiconductor alloys has previously been established to have a strong impact on the thermal transport properties, especially regarding tuning the thermal conductivity of semiconducting binary alloys with some degree of long-range ordering [1,2]. AlGa<sub>N</sub> with nanoscale compositional inhomogeneities (NCI) has been shown to have high room temperature (RT) radiative efficiency in the ultraviolet (UV) [3,4] without the need for commonly employed multiple quantum well (MQW) active regions that suffer with low thermal conductance [5]. In this work, we investigate the relationship between radiative efficiency and thermal conductivity of high-Al content NCI-AlGa<sub>N</sub> and explore pathways to thermally efficient UV-emitters. AlGa<sub>N</sub> samples with Al content of 66 -79% grown by plasma-assisted molecular beam epitaxy on AlN/sapphire templates exhibit strong RT photoluminescence (PL) redshifted by ~ 300 to 750 meV, depending on the growth temperature, due to NCI. This strong PL is characterized by an internal quantum efficiency (IQE) as high as 40% obtained by comparison of low and RT PL. The thermal conductivity of thin (~50-250 nm) AlGa<sub>N</sub> films with NCI measured by ultrafast time domain thermal reflectance was found to be around 12 W/mK, only slightly lower than the thermal conductivity of bulk compositionally homogeneous AlGa<sub>N</sub> films of similar Al content [6], while the thermal conductivity of a MQW sample was measured at 3 W/mK. This result suggests that NCI-AlGa<sub>N</sub> offers the possibility of more thermally conductive, efficient UV-emitters relative to MQWs. In addition, optimization of growth conditions for both high radiative efficiency and high thermal conductivity will be discussed.

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## Co-recording of Eye and Head Tracking with EEG to Understand Unconstrained Vision

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Future Soldier technology will fundamentally change how missions are executed by combining human and non-human agents (or artificial intelligence; AI) to accomplish mission objectives. Effectiveness of these human-agent teams depends on efficient ways of communicating, adapting, and executing missions as a cohesive group. A critical aspect of these human-agent teams is the bidirectional flow of information, where the AI has a model of the human (state) and the human teammate has a mental model of the AI's behavior. Our research focuses on investigating complementary ocular, head, behavioral, and neural signals to track Soldier attention and changes in cognitive state in effort of developing multi-modal human input to facilitate communication and AI adaptation. This multi-modal sensor approach combined with VR overcomes conventional vision research limitations by increasing ecological validity relevant to current Army technologies while maintaining experimental control to provide robust signals for developing and training models used in intelligent systems. Since the selection of visual information in a 3D space occurs through the coordination eye and head movements, performing this task in VR preserves sensory realism and produces naturalistic visual behaviors that cannot be accomplished using a standard computer setup. Furthermore, studies using electroencephalography (EEG), a temporally sensitive measure of neural activity, traditionally have limited these naturally occurring visual behaviors to minimize artifacts in the data recording. Experiments with co-recording of eye tracking and EEG are becoming more prevalent due to advances in signal processing to minimize artifacts and modeling approaches that overcome overlapping neural activity and nonlinear covariates. Time locking EEG to fixation onsets results in fixation-related potentials (FRPS) providing a neural snapshot of visual processing in a more naturalistic context. But, the impact of head movements on FRPs are still poorly understood limiting the use of this approach in a more unconstrained context. The present work aimed to extend the co-recording approach by allowing participants to move their heads while completing a simple search task in an immersive virtual environment. Participants reported the orientation of Gabor patches (0.5 cycles/degree or 4.9 cycles/degree) appearing at eight radial spatial positions varying in eccentricity (10 – 50 DVA) while we co-recorded eye and head movements with EEG. There were two types of trials to produce different head movement profiles: a pursuit condition where a disk moved at a constant speed of 20 degree/sec and turned into a Gabor patch at its final spatial position, and an instantaneous condition where the same light gray disk disappeared and a Gabor patch re-appeared at its final spatial position. We used deconvolution modeling to estimate potentials time-locked to head movement onsets, fixation onsets, and Gabor onsets. The modeling disentangled a prominent FRP component called the lambda response in addition to early (P1) and late (P300) ERP components while minimizing artifacts introduced from eye and head movements. Our approach demonstrates the co-recording approach can be used to better understand vision in unconstrained contexts and is a step towards integration of these multi-modal signals into future human-agent systems.

## Complexity Synchronization

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Since the turn of the century Network Science and Complexity Theory have been growing dramatically and their nexus has led to profoundly different ways of thinking about physiology, health, disease, and medicine in general from the modeling based on the Newtonian paradigm. The observational ubiquity of inverse power law spectra (IPL) in complex phenomena entails theory for dynamic fractal phenomena capturing their fractal dimension, dynamics, and statistics<sup>1</sup>. These and other properties are consequences of the complexity resulting from nonlinear dynamic networks collectively summarized for biomedical phenomena as the Network Effect (NE) or focused more narrowly as Network Physiology. The NE is often described by homogeneous scaling variables with power law scaling having index  $\delta$  determined by the fractal dimension of the time series being a direct measure of the network's complexity. Herein we address the measurable consequences of the NE on time series generated by different parts of the brain, heart, and lung organ networks, which are directly related to their inter-network and intra-network interactions. Moreover, these same physiologic organ networks have been shown to generate crucial event (CE) time series, and herein are shown, using modified diffusion entropy analysis (MDEA), to have scaling indices with quasiperiodic changes in complexity, as measured by scaling indices, over time. Such time series are generated by different parts of the brain, heart, and lung organ networks, and the results do not depend on the underlying coherence properties of the associated time series but demonstrate a generalized synchronization of complexity. This high-order synchrony among the scaling indices of EEG (brain), ECG (heart), and respiratory time series is governed by the quantitative interdependence of the multifractal behavior of the various physiological organs' network dynamics. This consequence of the NE opens the door for an entirely general characterization of the dynamics of complex networks in terms of complexity synchronization (CS) independently of the scientific, engineering, or technological context. CS is truly a transdisciplinary effect. CS may be a foundational principle underlying how information is transmitted within and among complex systems from complex human neurophysiological networks to complex networks of humans and technology systems (human-human and human-agent teaming). Please add this abstract and poster in a special report on postdoc research day.

## Comparative Performance Study of Wide- and Ultrawide-Bandgap Semiconductors for Power- and Opto-Electronics

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The large bandgap of semiconductors allows them to sustain high internal electric fields, enabling the development of electrical platforms with boosted speed, power density, and efficiency. Wide-bandgap (WBG) and ultrawide-bandgap (UWBG) materials are, thus, suited for armored electric vehicles and autonomous aircraft. They are also used for solar-blind ultraviolet photodetectors for non-line-of-sight communication. WBG (SiC and GaN) and UWBG (Diamond, Ga<sub>2</sub>O<sub>3</sub>, Al-rich AlGa<sub>N</sub>) materials lack the maturity of silicon; it is essential to perform a detailed study of those materials so that their performance can be predicted from the fundamental postulates of device physics.

This work discusses a model for the temperature dependence of impact ionization coefficients for semiconductors. The parameters of the model are correlated to the physical quantities governing carriers' transport (mean free path, ionization energy, phonon energy, and thermal factor); an

approach is proposed to calibrate the parameters of the model with measured multiplications, measured breakdown voltages, and impact ionization coefficients reported in the literature where available. The calibrated coefficients are used to evaluate the performance of selected semiconductors. The trade-off between the on-resistance versus breakdown voltage, the Baliga figure-of-merit (BFOMs), is carefully examined using calibrated impact ionization coefficients and solving the ionization integral to find the breakdown voltage. In addition, the study of incomplete ionization enables a more accurate evaluation of the on-resistance. The study of impact ionization coefficients and incomplete ionization also allows a more precise assessment of the losses in power switches.

Efforts of this work allow the recovery of the critical field, which depends on the doping concentration and the thickness of the drift layer. A developed simulation tool from this work enables the design of devices for targeted operational voltages. The simulator has given insights into the best materials for army electronics and has helped design test structures for several ongoing research programs within the army (FREEDOM ERP and APEX ARAP).

## **Brain Flexibility as a Marker of Mutual Adaptation of Humans and Machines.**

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Technology is rapidly developing more intelligent capabilities, displaying flexible and adaptive behaviors more so than ever before. For the future operating environment (FOE), seamlessly mutually adaptive technologies must be developed for optimal, flexible, and adaptive Soldier-systems. Such systems require that not only humans adapt, learning to use these new technologies, but the intelligent technology itself must be capable of adapting, augmenting its behavior to better suit system goals - a synthetic metacognition of sorts. A step forward to this mutual adaptation of humans and machines is the use of physiological data to assess human states and build predictive models of behavior to inform machines of the appropriate level of interference for a continually evolving context. In this work, we analyze electroencephalography (EEG) recordings of brain activity using network neuroscience techniques to predict individual adaptability to an intelligent system. Network neuroscience provides a variety of tools to understand the complex coordination of neural elements underlying cognition and has previously proven successful in characterizing a variety of behaviors. For example, the rate at which networks within the brain rapidly reconfigure to support cognition has been highly predictive of various cognitive processes. This so-called brain flexibility has been used to describe the rate of motor learning, associated with multi-tasking, pattern recognition, and adaptations to new stimuli or stress. Here, we investigate how brain flexibility, derived whilst subjects are awake and not engaged in any task, can predict how well an individual can adapt to an intelligent exoskeleton boot (ExoBoot) designed to reduce the metabolic cost of walking. We compared neural flexibility at rest to metrics derived from electromyography (EMG) and motion tracking while subjects used the ExoBoot. Results suggest that “trait-based” neural flexibility relates to the extent of adaptation an individual displays while walking with the ExoBoot. This strong predictive association, if extended across tasks, has the potential to accelerate the learning and usability of mutually adaptive Soldier-systems of the future.

## **Dynamic Multi-Criteria Decision-Making for Artificial Reasoning**

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Decision-making is present in everyday life and can have significant impact in environments that are complex and dynamic. Information is a major driver in the decision process—influencing alternatives and criteria for judgement. In addition, there are many different techniques for aiding decision making. One is Multi-criteria Decision-Making (MCDM), which is popular in operations research and can aid in the decision-making process by providing suitable algorithms that can help evaluate and prioritize the criteria and alternatives of a particular problem.

My research in MCDM began with my dissertation. I graduated May 2022 and the title of my work was “Dynamic Multi-Criteria Decision-Making in Complex Environments”. The goals of this research were to improve decision-making in complex and dynamic environments and investigate whether augmenting traditional MCDM methods with dynamic-case handling and Multi-Variable Logic to create a novel approach improves decisive performance. The expected outcomes of this research were not to necessarily develop the “one solution”, but to set up a common architecture for decision-making in complex and dynamic environments. Several MCDM augmentations were evaluated using various datasets and case studies related to the COVID-19 pandemic. Results highlighted that the more augmented MCDM method, FAHP-TOPSIS with dynamic-case handling shows promise for providing the most realistic and improved decision for a problem in a complex and dynamic scenario.

I am now expanding on this research within the Artificial Reasoning team at ARL. As previously stated, decision-making is a very complex task that considers a wide range of information, particularly for Command and Control (C2). While information is necessary for informed decisions, it can present a multitude of challenges. One of the critical challenges is that information comes different levels of uncertainty. This motivated the research on Uncertainty of Information (UoI). One aspect of the UoI research involved creating Army relevant scenarios to uncover prioritization of UoI in relationship to decisions. Utilizing these scenarios an experimental user study was conducted. Then dynamic MCDM methodology was applied to the UoI data from the user study. Results from this analysis will be presented.

The path forward will consist of continuing the evaluation of the preliminary framework that has been established and explore existing state of the art approaches to identify computational models that automate decision making leveraging dynamic MCDM and UoI research.

## **Degradation of High Nickel Li-ion Cathode Materials Induced by Exposure to Fully-Charge State and Its Mitigation**

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Ni-rich layered oxides are strong candidates for next generation high energy batteries. However, unlike batteries in typical laboratory settings, batteries in practical applications are generally not discharged immediately upon reaching a fully charged state, but instead remain there for varying periods of time before usage. Such a state places immense electrochemical stress on the cathode as many of the degradation processes of the Ni-rich layered oxide occur at the highly charged state. Differentiating between lab and practical use cases, we show for Li[Ni<sub>0.90</sub>Co<sub>0.05</sub>Mn<sub>0.05</sub>]O<sub>2</sub> that even the introduction of a short dwell period at the highly charged state leads to substantial differences in cycling performance (capacity retention of 89.4% versus 37.5% at the 100th cycle with or without dwelling, respectively). To overcome the rapid deterioration at high voltage, antimony (Sb) was used as a dopant to reduce the lattice instability of the high Ni layer structure, especially at the grain boundaries regions, where degradation concentrates at the cathode-electrolyte interfaces. The resulting Li[Ni<sub>0.895</sub>Co<sub>0.05</sub>Mn<sub>0.05</sub>Sb<sub>0.05</sub>]O<sub>2</sub> cathode material not only maintains stability during extended dwelling periods at the charged state, but also facilitates superior fast-charge capabilities. As the batteries are becoming a major power source in many Army applications, it is important to provide the warfighter with durable batteries that will be ready in a charged state for extended periods of time.

## **Automation of High-throughput Laser-induced Shock and Acoustic Measurements for Machine Learning Dataset Generation**

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Materials subjected to high-energy nanosecond laser pulses release energy on microsecond timescales which can be measured and used to discriminate between samples based on the material's shock velocity and acoustic response. These measurements, often coupled with a suite of complementary optical characterization techniques, can be completed rapidly and generate large quantities of data; they are therefore well-suited for big-data analysis approaches including machine learning (ML). However, until recently the potential sample throughput has been limited by various bottlenecks during data collection, saving, analysis, etc. and each step requires its own unique solution to facilitate increased throughput. Here, we will discuss recent efforts to automate and optimize data acquisition and processing for shock and acoustic data generated from pulsed laser ablation. Finally, we outline our vision of ML dataset generation at the click of a button.

## **Appendix B. Survey Questions**

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- Q1. How did you hear about the symposium? Please select all that apply.
- Q2. How would you prefer this conference to occur?
- Q3. Which sessions did you find useful and/or enjoy?
- Q4. Which sessions did you dislike and/or think need improving?
- Q5. What kind of information would you have liked seen shared with the postdoc and early career community at an event like this?
- Q6. Do you think this event is beneficial to the postdoc and early career community? Please elaborate on your answer, if possible.
- Q7. What kind of events would you like to see the ARL Postdoc Association host (such as social events, professional development, career panels, informational sessions, etc.)?

## **Appendix C. Article Published on ARLInside\***

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\* The contents of this appendix appear in original form, without editorial change.

Postdoctoral Association hosts 7<sup>th</sup> Annual Postdoc & Early Career Research Symposium for new ARL teammates

ADELPHI, Md. (April 10, 2023) – The U.S. Army Combat Capabilities Development Command, known as DEVCOM, Army Research Laboratory recognized the research of civilian and contractor postdocs who recently joined the DEVCOM ARL workforce at a virtual symposium, March 30.

During three sessions, 13 participants delivered 10-minute presentations to a panel of in-house judges on Army-relevant research ranging from ultrawide-bandgap materials to brain flexibility.

The event, hosted by the ARL Postdoctoral Association, provided opportunities for new hires to not only showcase their work, but also receive early career advice from more experienced researchers at the laboratory.

“The symposium has changed shape a lot over the past few years because of the COVID-19 pandemic,” said Dr. LeighAnn Larkin, research physicist at the Electromagnetic Materials and Devices Branch. “It has traditionally been held either at Aberdeen Proving Ground or the Adelphi Laboratory Center, but it has transitioned into a fully virtual event since 2020. We’ve been receiving a lot of positive feedback from that decision.”

Larkin, a civilian postdoc, leads the Postdoctoral Association as a co-chair alongside fellow co-chair Dr. Catherine Dillier, a postdoc contracted through the Oak Ridge Associated Universities program.

Formed in 2013 and celebrating its 10th anniversary this year, the ARL Postdoctoral Association serves as a community where postdocs can connect with their peers, find answers to questions about the laboratory and locate resources that may help them better navigate the logistics of their career.

“A lot of times, the transition between grad school and your next position—especially at ARL or any kind of Department of Defense laboratory—presents unique challenges,” said Dillier, mechanical engineer at the Detonation Sciences and Modeling Branch. “One of our goals is to provide transitional support to help manage those challenges.”

The Seventh Annual Postdoc & Early Career Research Symposium, which invited postdocs and early careers professionals across the entire laboratory, represents one of many endeavors by the Postdoctoral Association to address the feeling of isolation that newcomers may have encountered following the pandemic.

“The organization took a big hit because of COVID,” Larkin said. “People are not onsite oftentimes, and new employees may feel disconnected from the laboratory. In the past year, we have really tried to organize more low-stakes events to have the postdocs get to know one another, especially those outside of their own branch or even their own division.”

In line with this goal, the symposium opened with remarks from Joseph Alexander, deputy director of the Army Research Directorate, who stressed to listeners the importance of people and relationships in the laboratory.

“Relationships matter, particularly in the world we’re in,” Alexander said. “This community is very small, so you’ll find yourselves running into the same people over and over again. The relationships you make with these people will help build the Army’s greatest transformation in the next 40 years.”

The event also featured a presentation from keynote speaker Maj. Matthew Nulk, an Army Acquisitions officer assigned to the Advancing Concepts Office, who discussed the important role that DEVCOM ARL plays within the Army Modernization Enterprise.

“ARL is very much at the front-end of the acquisitions process,” Nulk said. “We wargame and collaborate across Army Futures Command to determine what we need capability-wise to deter, offset or overmatch the threat. If you think of it as a funnel, we’re funneling down to providing actual capability to units that are executing tasks.”

After the presentations, the attendees had the chance to engage with a Q&A panel with three former DEVCOM ARL postdocs who have since risen the ranks of leadership in the laboratory.

The panelist members—Dr. Steven Dean, Dr. Mary Beth Galanko and Dr. Antonio Llopis-Jepsen—answered questions about their transition in the laboratory and shared advice on how postdocs can find their path at DEVCOM ARL.

“Look for ways that you can make a difference on high impact projects, such as opportunities to brief your work and show that you can connect it to Army relevance,” Galanko said. “I know that’s important for my branch chief and my leaders, as well as understanding and, to the best of your ability, working toward the Army impact of your work.”

During the discussion, Llopis-Jepsen also described their ongoing detail at the Office of the Director where they shadow the activities of ARL Director Dr. Patrick Baker.

“There are a lot of detail opportunities that provide you a chance to see how the organization runs,” Llopis-Jepsen said. “You should keep in mind that there’s a lot of ways you can progress your career at ARL.”

At the end of the event, after careful deliberation, the judges announced the three winners for best presentation:

- Dr. Josh Hill, Quantum Science & Technology Branch: “Wideband Simultaneous Microwave Demodulation with a Quantum Receiver”
- Dr. H. Hohyun Sun, Battery Science Branch: "Degradation of High Nickel Li-ion Cathode Materials Induced by Exposure to Fully-charged State and its Mitigation"
- Dr. Anna Madison, Cyber and Networked Systems Branch: "Co-recording of Eye and Head Tracking with EEG to Understand Unconstrained Vision"

According to the co-chairs, the Postdoctoral Association will release a special report about the virtual symposium. The report will include a series of reflections and quantifications on the success of the event as well as an appendix of all the abstracts submitted for the event.

“Anyone who is interested in the Postdoctoral Association can reach out to either of the current co-chairs to join,” Larkin said. “We’re happy with any level of involvement that people are comfortable with committing.”

## **List of Symbols, Abbreviations, and Acronyms**

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6PECRD	6 <sup>th</sup> Annual Postdoc and Early Career Research Day
7PECRD	7 <sup>th</sup> Annual Postdoc and Early Career Research Day
ALC	Adelphi Laboratory Center
APG	Aberdeen Proving Ground
ARL	Army Research Laboratory
DEVCOM	US Army Combat Capabilities Development Command
FY	fiscal year
PDA	Postdoctoral Association
Q&A	question and answer

1 DEFENSE TECHNICAL  
(PDF) INFORMATION CTR  
DTIC OCA

1 DEVCOM ARL  
(PDF) FCDD RLB CI  
TECH LIB

13 DEVCOM ARL  
(PDF) FCDD RLS RP  
A WILSON  
FCDD RLC IB  
P SHARMA  
FCDD RLA IC  
J RAWAL  
FCDD RLA FE  
A MADISON  
FCDD RLA GC  
H KAREEM  
A ALVAREZ  
FCDD RLA GD  
H SUN  
FCDD RLA PD  
J HILL  
FCDD RLA PE  
A GLASMANN  
FCDD RLA LE  
L LARKIN  
F NOUKETCHA  
FCDD RLA WA  
C DILLIER  
E WAINWRIGHT