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Chairwoman Sherrill, Chairman Beyer, Ranking Members Bice and Babin, and Members of the Subcommittees, I am Dr. Stephen Volz, the Assistant Administrator of NOAA's National Environmental Satellite, Data, and Information Service (NESDIS). Thank you for the opportunity to participate in today's hearing. I am pleased to join the other witnesses, John Gagosian, Director of NASA's Joint Agency Satellite Division and Fred Meny, Assistant Inspector General of the Department of Commerce Office of the Inspector General to discuss NOAA's next generation of environmental satellites and the importance of these assets for the Nation.

NOAA has a unique mission to understand, predict, and support the health of our oceans and atmosphere. From daily weather forecasts and severe storm warnings to fisheries management, coastal restoration, and data to enhance marine commerce, NOAA's products and services promote economic vitality, affecting more than one-third of America's gross domestic product. We work to save lives, protect property, and enhance the American economy through the timely delivery of trusted weather, water, and climate forecasts, analyses, and information.

For decades, NOAA has been at the forefront of the world's weather and climate enterprise. We are a global leader in measuring, observing, modeling, archiving, and delivering data and information on the Earth's changing environment with state-of-the-art coastal, marine, terrestrial, aerial, and space-based observing platforms. These measurements form the basis of NOAA's weather and climate products and services, which afford vital industries–shipping, fishing, agriculture, construction, energy and water resources, and more–the ability to predict and plan for the future. As an authoritative source for weather and water data, we provide critical predictions and decision support tools

Satellite data sets are essential for NOAA predictions and monitoring across all scales and times, and account for around 90 percent of all data that is used by NOAA's operational forecast models. NOAA has the distinct and important role of planning for, managing builds of, and operating the Nation's operational environmental satellites. Our satellites are relied upon 24 hours a day, seven days a week for weather, ocean, climate, and space weather data by NOAA, as well as individuals, businesses, and all levels of government to protect lives and property within the U.S. and around the world.

NOAA accomplishes this environmental satellite and data mission through strategic partnerships and operational cooperation with a number of Federal, private, and international space organizations. Our longest standing and closest strategic partner in earth observations from space is the National Aeronautics and Space Administration (NASA). NOAA's Mission[1] is "science, service, and stewardship to understand and predict changes in climate, weather, ocean and coasts; to share that knowledge and information with others; and to conserve and manage coastal and marine ecosystems and resources." NASA seeks[2] "new knowledge and understanding of our planet Earth, our Sun and solar system," and "to understand how biological and physical systems work at a fundamental level," with the intent to understand "how and why Earth's climate and environment (are) changing." These complementary missions enable NOAA to address the observation and information needs to meet the operational service delivery demands of the Nation, including among other services, environmental and climate predictions and analysis, and weather and water forecasts, warnings, and information.

NOAA also has strategic partnerships with the Department of Defense, the U.S. aerospace industry, and the international space earth observations community. NOAA benefits from and leverages our partnerships with Cooperative Institutes and Minority Serving Institute Cooperative Science Centers for R2O2R (research to operations to research) and algorithm development to increase the use of NOAA's satellite data to address societal challenges. NOAA has provided integral environmental satellite data since the 1960s and we plan to do so into the future, as our next generation of satellite architecture will extend well into the 2050s and beyond, serving as the national backbone for environmental satellite information. NOAA has benefited from the longstanding support of the U.S. Congress to provide oversight and appropriations for our satellite programs. I am pleased to provide an update on our next-generation satellite architecture plans and discuss the importance of our future environmental data for our Nation.

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[1] If the hyperlink is insufficient, here is the weblink: https://www.noaa.gov/our-mission-and-vision

[2] https://science.nasa.gov/about-us/smd-vision

NOAA's User Needs

At NESDIS, our satellite data and information has prominently supported NOAA's weather forecasting mission to provide forecasts, watches, and warnings for the protection of life and property.

Our improvements to satellite data and information are focused on meeting the evolving needs for end-use products and services that are provided reliably. Over the past five years, even through the Covid-19 pandemic, NOAA has had meaningful interactions with numerous stakeholders to ensure that we understand the requirements of our primary users. We have also met with the customers of our users to ensure that we understand the downstream needs of our products and services and address future needs.

Every day, we see communities grappling with environmental challenges due to unusual or extreme events that affect their health, security, and economic well being. Below are some examples of regions, populations, and severe events that benefit from observations from NOAA satellites.

Coastal Populations. In 2020, the marine economy accounted for $361.4 billion, or 1.7 percent of current-dollar U.S. gross domestic product.[3] The concentration of people and economic activity at the coasts places pressures on ecologically sensitive coastal ecosystems and leaves residents and visitors vulnerable to coastal hazards such as hurricanes, erosion, sea level rise, and harmful algal blooms.

Underserved Communities. The most severe harm from climate change falls disproportionately upon underserved communities who are least able to prepare for, and recover from, heat waves, poor air quality, flooding, coastal erosion, and other impacts. For example, African American individuals are more likely to live in areas with the highest projected increases in childhood asthma diagnoses and extreme temperature related deaths.[4]

Farmers. Key production regions for food grains in central California and the central U.S. are experiencing severe drought this year. According to the U.S. Department of Agriculture, as of August 2, 2022, drought affected at least 45 percent of the production acreage for barley, cotton, rice, sorghum, winter wheat, and hay.[5]

Arctic. The Arctic is warming two to three times as fast as the global average and warming is projected to continue. Older, thicker sea ice that once covered the central Arctic ocean is now

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[3] Marine Economy Satellite Account, 2014-2020. Bureau of Economic Analysis. 2022

[4] Climate Change and Social Vulnerability in the United States: A Focus on Six Impact Sectors. Environmental Protection Agency.

[5] USDA summary of agricultural products affected by drought. USDA. August 2022.

almost entirely gone.[6] Extreme events and increasing variability throughout the Arctic impact the safety and well-being of communities within and far away from the Arctic, and carry implications for U.S. national security interests.[7]

Wildfires. Drought and persistent heat set the stage for extraordinary wildfire seasons from 2020 to 2022 across many western states.[8] Such rapid increase of wildfires has become a major threat to lives, property, public health, electricity supply, water resource quality, and local and regional economies in the western U.S. and beyond.

Floods. Floods are the most common and widespread of all weather-related natural disasters.[9] In June through August 2022, major flooding or flash floods occurred in six states, as well as Death Valley National Park and Yellowstone National Park.

Heat. Heat is the leading cause of all weather-related deaths in the United States.[10] In summer of 2022, more than 150 million people were placed under heat warnings and advisories.

Harmful Algal Blooms. Harmful algal blooms (HABs) occur when algae grow out of control. These HABs may produce toxic or harmful effects on people, infrastructure, fish, shellfish, marine mammals, and birds. HABs have been reported in every U.S. coastal state, and their occurrence are on the rise, affecting the health of people and marine ecosystems.

NOAA is working to meet these challenges through the provision of trusted and validated data and information as well as user-ready products and services. NOAA must be innovative- leveraging new technological solutions, developing broader business models and partnerships with public and private sectors, and demonstrating organizational agility to adjust to changing needs, opportunities, and risks. We must do this all while meeting our critical mission of delivering environmental observations without interruption.

Solely maintaining current satellite performance and capabilities will not provide the necessary observations to monitor future global climate change and its impacts throughout the Earth system, and will not allow for the monitoring of our important ocean ecosystems. Our communities need better information which is scaled and designed to meet their local and specific needs to address the challenges of increased extreme weather events and environmental changes. New technologies, which are developed by the commercial sector and often demonstrated by NASA research satellites, must be integrated into NOAA's next-generation

[6] Arctic Report Card: Update for 2021. NOAA. 2021.
[7] Department of Defense Arctic Strategy. DOD. 2019.
[8] Wildfire Climate Connection. Noaa.gov. August 2022.
[9] Severe Weather 101. NOAA National Severe Storms Laboratory.
[10] Weather Related Fatality and Injury Statistics. National Weather Service.

satellite architecture to enable us to more completely deliver to users the most impactful observations and data in support of the NOAA mission.

NOAA's Next-Generation Satellite Architecture

NOAA NESDIS' next-generation satellite programs will provide enhanced observations through the 2050s to meet increasing and evolving needs, contributing both continuous and innovative environmental information to diverse end users. NESDIS will also modernize our information systems architecture by including seamless integration of NESDIS and partner satellite data and in situ, ship, plane, and drone observations. Developing these next-generation satellite architecture and re-engineered information systems takes a decade or longer from concept to launch and full deployment. Scoping of the next generation satellite programs is underway and definitive life cycle costs (LCC) have not been finalized. Arriving at approved program scopes and final LCCs, along with the relevant technological review assessments, will be developed in close coordination and consultation with NASA and the Department of Commerce's Office of Acquisition Management.

NESDIS conducted the NOAA Satellite Observing System Architecture study from 2014 to 2017 to evaluate alternative architectures for its next-generation missions. The study indicated a few key takeaways for consideration in NOAA's next-generation satellite constellation plans, including an integrated system of observations from NOAA and international and commercial partners. NESDIS used this comprehensive assessment to guide the design and development framework for the future architecture, and continues to develop NOAA's next-generation plans based on new information and resource constraints.

Our next-generation plans are also informed by our space engineering experience over past decades, such as the successes of the Geostationary Operational Environmental Satellite (GOES)-R Series and Joint Polar Satellite System (JPSS) programs, the experiences of our domestic and international partners, and the U.S. commercial space sector. For example, the GOES-R program has demonstrated the cost and risk reduction benefits of "bulk buys" of essential program elements such as instruments and space craft; the JPSS program demonstrated the value of selective use of firm fixed price procurements. These lessons learned and coordination activities are focused on delivering reliable and continuous data and information for users.

Further, NOAA relies on the US aerospace industry for support throughout the lifecycle of the satellite acquisition-from instrument and spacecraft bus development, to launch vehicle and services, to development and deployment of the antennas and ground system. NOAA is increasingly assessing the ability of commercially provided data to fill specific mission requirements. Through the Commercial Weather Data Pilot and the Commercial Data Program, NOAA has purchased radio occultation data that are currently being ingested into its weather forecast models. As the commercial sector demonstrates the ability to deliver data that meets its mission requirements, NOAA will continue to engage and acquire these commercially-based data as part of its overall next generation satellite architecture plans.

To best facilitate user needs across orbits and observations, we are looking at NOAA's future space architecture in three portfolios: geostationary observations, low earth orbit, and space weather observations (see Figure 1). The next-generation enterprise architecture also includes an evolved support system to operate the satellites and use the data. This includes supporting our satellite operators while integrating more and varied observing system elements. It also involves evolving the ground infrastructure into a system that supports all satellites and ensuring the data are reliable and shareable. We will leverage science to transform the "bits and bytes" received from around the world into timely, actionable, and reliable environmental information and to create new data products and services. NOAA's future architecture will also ensure the quality, accuracy, and preservation of the Nation's historical environmental data archives while augmenting this vast repository with new data sets, merged products, and integrated observations from NOAA, U.S., and global observing systems.

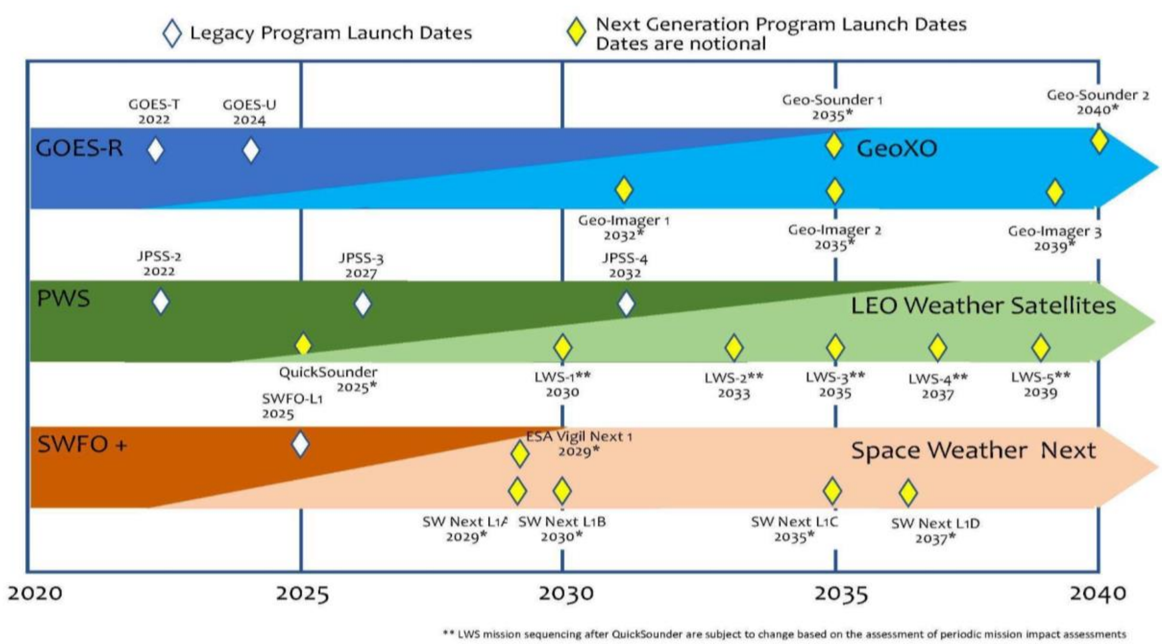

Figure 1: Notional Floyout of NOAA's Next-Generation Satellites

Geostationary Observations. NOAA's Geostationary Earth orbiting (GEO) satellites provide the only continuous observations of weather and hazardous environmental conditions over the Western Hemisphere, from the eastern Atlantic to the western Pacific. Information generated from our GOES system helps protect the lives and property of the one billion people who live and work in the Americas with continuous, near-real-time observations and warnings. NOAA's Geostationary Extended Observations (GeoXO) program is the next generation of GEO capabilities that will support terrestrial weather prediction and warning, climate adaptation and mitigation, healthy oceans, and resilient coastal communities and economies. As the follow-on program to the current GOES-R Series, GeoXO will provide continuity of critical geostationary data with its first launch in 2032 and planned observations through 2055. Due to the significant capabilities proposed, GeoXO is our largest investment through the 2030s, and due to the criticality of providing continuous observations, GeoXO has an aggressive 11-year development schedule.

The GeoXO pre-formulation phase included extensive, direct user outreach to thousands of end users in many dozens of organizations as well as observation value assessments. It also included Observational System Simulation Experiments (OSSEs) analyses, an analysis of observations relative to the NOAA mission service areas, and consultation with the NOAA Observing System Council to define future observational needs and select the recommended payload instruments for GeoXO. End users require continuity of existing observations for short-term forecasting, severe weather watches and warnings, and monitoring a range of hazardous environmental conditions, such as tropical storms, lightning and winds, flooding, snow, wildfires, volcanic ash, and others. Current and future instruments in NESDIS' geostationary observing system on GOES-R and GeoXO, respectively, support NOAA's weather mission with essential information to inform and protect people and property across the country. These observations, together with the 50 year record of GOES observations, provide an essential climatological data record supporting NOAA and national climate analyses and a range of climate products and services.

Users also seek new observations and NOAA is conducting industry studies to evaluate the technology readiness and costs of potential new instruments. A hyperspectral infrared sounder promises to improve localized forecasts and nowcasting—critical as extreme weather events including storms, tornados, and hurricanes become more frequent and more severe—by enhancing weather forecasting models. An atmospheric composition instrument could provide a new platform to monitor air quality, track dispersion of hazardous emissions (volcanic, smoke, chemical, and radioactive), and monitor greenhouse gasses. A geostationary ocean color instrument could complement instruments in low Earth orbit to expand NOAA's ocean observing system to support the blue economy, increase coastal resilience, and help enable NOAA's oceans, coastal, and fisheries services. This information is also valuable to other non-federal users to better assess ocean productivity and health, ecosystem change, aquaculture and fisheries management, coastal and inland water quality, seafood safety, and hazards such as harmful algal blooms.

Due to the international partnership of GEO satellites, GEO data will be leveraged in innovative global inputs that supplement Low Earth Orbiting (LEO) observations. NOAA observations will be matched with similar satellite missions deployed in the same period by EUMETSAT over Europe and by the Japanese Meteorological Agency and Korean Meteorological Agency over the western Pacific and Asia, to create a GEO ring of observations. These combined observations will provide global data sets for use by NOAA and our international partners to meet global modeling system and mission service needs. NOAA has previously benefited from acquisition efficiencies as other partners have utilized U.S. instrument vendors to meet their own mission needs.

Low Earth Orbit. LEO satellites from NOAA, NASA, and international partners provide a half century of unbroken climate data records and are the backbone of global weather forecasting models. These satellites detect and monitor hazards such as fires, droughts, floods, poor air quality, coral bleaching events, unhealthy coastal waters, and others. NESDIS collects about half of the LEO data we use every day to meet our ongoing mission needs, with the balance provided by our interagency and international partners. Satellites in the LEO Weather Satellite Program will supplement, and eventually replace, the current JPSS satellites.

The next generation of NOAA LEO satellites will leverage commercial space capabilities for increased flexibility. Together with NOAA's fleet and aircraft observations, NESDIS LEO satellite data will support the missions of all NOAA services, including weather forecasting, fisheries management, ocean and coastal monitoring, and the research that supports these activities. As an example, a distributed constellation of satellites will provide greater diversity in data needed by the weather forecast models to cover all facets of the event under investigation, a resilient system less susceptible to individual satellite failures, and a higher refresh rate for measurements, which enables higher-accuracy weather forecasts and improvements in other key applications.

For accurate forecasts, weather models integrate measurements from microwave (MW), infrared (IR), and radio occultation (RO) sounders on polar satellites. These observations are especially important in polar regions where other observational data are sparse. For example, JPSS provides critical data for nearly all weather forecasting in Alaska, and this is critical for aviation and the maritime industry. Ozone measurements also track the health of the ozone layer.

Improved MW, IR, and RO soundings with more frequent observations and better spatial and vertical resolution have the potential to improve modeling and allow for higher-resolution short- and long-term weather forecasts. NOAA's next-generation LEO satellites would also provide vital data for wind speed, sea surface temperature, and ocean color. Hyperspectral ocean color imagery at improved spatial resolution would improve our understanding of harmful algal blooms and phytoplankton dynamics to give managers tools to mitigate economic impacts. Enhanced atmospheric chemistry sensors for methane, sulfur dioxide, ozone, and others would enable more timely and accurate forecasts of air quality hazards, and would allow us to assess climate change both granularly and holistically. It is important to note that this increased amount and diversity of data going into forecast models may require the models to adapt and increase their computing power.

NESDIS has determined, through the NSOSA study and user engagement, that the LEO program could serve users by collecting and delivering the following global observations: MW soundings and imagery, hyperspectral IR soundings, RO soundings, visible-IR imaging including day-night band imagery, measurements of atmospheric chemistry including ozone, ocean surface winds, ocean color, radio detection and ranging imagery, 3D winds, and ocean surface height. NESDIS will continue to evaluate and prioritize these data demands as we scope the program.

Space Weather Observations. Space weather observations aid in safeguarding fundamental power grid infrastructure, civil aviation, and on-orbit assets and astronauts. According to the National Research Council, disabled electric power grids and collateral impacts from geomagnetic storms could result in economic and societal costs of up to $2 trillion per large storm, and it could take four to ten years for full recovery.[11] Building on the Space Weather Follow-On (SWFO) program, the Space Weather Next (SW Next) program will reliably provide critical space weather products and services to observe and identify this hazard and support the needs of diverse users across the U.S. and internationally. These users will include the electric power and airline industries, utility and telecommunications companies, commercial and government satellite operators, U.S. and foreign governments, and the space weather research and academic communities.

Observations and measurements from NESDIS' SW Next program will be combined with complementary data collected by federal and international partners and processed through NESDIS' Office of Satellite Ground Services to provide the necessary information flow for space weather forecasts. This data and information flow will enable NOAA's Space Weather Prediction Center (SWPC), the Office of Space Commerce, and other operational users to deliver actionable information that protects critical power grid infrastructure and civil aviation, and provides essential space situational awareness.

SW Next will maintain and extend space weather observations from a range of different observing points, selected to most efficiently provide the comprehensive knowledge of the sun and the near-earth space environment. These observation points could include LEO, GEO, highly elliptical orbit, Lagrange Point 1 (L1) and, with the European Space Agency, Lagrange Point 5 (L5) orbits. These observations will provide near-real-time coronal mass ejection imagery, solar wind, solar imaging, coronal imagery, solar wind parameters, magnetospheric particles, and ionosphere parameters, and other relevant observations required to support space weather

[11] National Research Council 2009. Severe Space Weather Events Understanding Societal and Economic Impacts: A Workshop Report: Extended Summary. Washington, DC: The National Academies Press. https://doi.org/10.17226/12643.

forecasts provided by SWPC. The program supports space weather forecasts as authorized by the Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow (PROSWIFT) Act (P.L. 116-181) and as driven by the National Space Weather Strategy and Action Plan (March 2019). Several complementary projects within SW Next will provide continuity and resiliency of space weather observations from multiple orbits, with launches in the 2020s, early 2030s, and onward. Just as with our LEO portfolio, it is important to note that this increase in the amount and diversity of the data must be accompanied by improvements in our space environment and weather models, requiring the models to adapt and increase their resolution and available computing power.

Space weather observations are needed from a multitude of orbit views, requiring multiple program capabilities to fulfill the necessary architecture. SW Next is therefore pursuing partnerships to augment the SW Next architecture. In addition, SW Next is developing a methodology to understand the impacts of observational capabilities on user needs such as alerts, watches, and warnings. We are engaging with users to better understand how our products and services support end-user decision-making. This process will aid in prioritizing NOAA program requirements and in assessing potential economic and societal benefits. The SW Next program is evaluating its alternatives to determine the most cost-effective architecture to meet user needs and will continue to leverage user engagement to identify and prioritize user needs across the enterprise.

Conclusion

In conclusion, today's investments in NOAA's next-generation satellite architecture will allow us to make the environmental space-based observations needed to make critical weather forecasts and meet the growing needs of the Nation in a changing environment. Our integrated next-generation observing system will leverage new technologies and partnerships at all levels, and combine data from various sources, allowing us to deliver significantly improved products and services to our users. The urgency of our changing environment requires action now to better deliver on the NOAA mission to protect lives, property, critical infrastructure, and our economy.

Stephen Volz

Assistant Administrator for Satellite and Information Services

Dr. Volz has more than 30 years of professional experience in aerospace. As the head of NESDIS, he sets the strategic vision and implementation objectives for the Nation's civilian operational earth observing satellite fleet. Within NOAA he serves as the Co-Chair of the NOAA Observing Systems Council and is a member of the NOAA Executive Council. He is a leader in the international Earth observation community, serving as the NOAA Principal to the Committee on Earth Observation Satellites (CEOS) and to the Coordination Group for Meteorological Satellites (CGMS). He has also served as the NOAA and US Principal to the Executive Committee (ExCom) of the international Group on Earth Observations (GEO). In each of these roles Dr. Volz leads efforts to coordinate global satellite-based observations among international space agency partners and interested users of remote sensing earth observation data to further the development of a Global Earth Observation System of Systems, and to meet the global weather and environmental monitoring and forecasting efforts..

Prior to coming to NOAA, Dr. Volz served as the Associate Director for Flight Programs in the Earth Science Division of NASA's Science Mission Directorate where he managed all of NASA's Earth Science flight missions in operation, development, and conception, and the ground and data systems to support them. Prior to serving as the Flight Program Director, Dr. Volz was the Earth Science program executive for a series of Earth Science missions, including EO-3 GIFTS, CloudSat, CALIPSO, and ICESat, and he led the Senior Review for the Earth Science operating missions. Dr. Volz worked in industry at Ball Aerospace and Technologies Corporation from 1997–2002, where he was the Project Manager for the Space Infrared Telescope Facility superfluid helium cryostat and other flight projects. From 1986–1997 Dr. Volz worked for NASA's Goddard Space Flight Center as an instrument manager, an IT Manager, a systems engineer, and a cryogenic systems engineer on missions and instruments including the Cosmic Background Explorer (COBE), among others.

Dr. Volz is a member of numerous professional societies, including the American Physical Society (M'82), the American Astronomical Society (M'87), the American Geophysical Union (M'02), and the American Meteorological Society (M'08). He is a senior member of the Institute of Electrical and Electronics Engineers (IEEE), an active member of and participant in the Geoscience and Remote Sensing Society (GRSS), and served as a member of the GRSS Administration Committee (AdCom) for the period of 2013–2015.

Dr. Volz has a doctorate in Experimental Condensed Matter Physics from the University of Illinois at Urbana-Champaign (1986), a master's in Physics from Illinois (1981), and a bachelor's in Physics from the University of Virginia (1980). He has more than 20 publications in peer-reviewed journals.