2021

Emerging Technologies Workshop

Summary Report

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DEFINITIONS

AA - Assistant Administrator

AI - Artificial Intelligence

AOML - Atlantic Oceanographic and Meteorological Laboratory

AUV - Autonomous Underwater Vehicle

BGC - Biogeochemical

BLM - The Bureau of Land Management

CO2 - Carbon dioxide

COP26 - 2021 United Nations Climate Change Conference

CRADAs - Cooperative Research and Development Agreements

CSTAR - Collaborative Science, Technology, and Applied Research

DIAL - Differential Absorption Lidar

DNA - Deoxyribonucleic Acid

DOD – Department of Defense

DOE - Department of Energy

EDMC - Environmental Data Management Committee

ESTO - Earth Science Technology Office (NASA)

FAA - Federal Aviation Administration

FIREX-AQ - Fire Influence on Regional to Global Environments and Air Quality

eDNA - Environmental Deoxyribonucleic acid

EHS -Enhanced Surveillance

EOS - Earth Observing System

ETW - Emerging Technologies Workshop

GHG - Greenhouse gas

GL - Great Lakes

GLERL - Great Lakes Environmental Research Laboratory

HAB - Harmful Algae Bloom

HALO - High-Altitude Lidar Observatory

HQ - Headquarters

HRRR Smoke - High-Resolution Rapid Refresh of Smoke - Over a 48-hour period, a 3D visualization of a prediction of smoke movement across the USA, simulating the impact of weather on smoke movement, and how visibility, temperature, and wind are affected by the smoke.

DEFINITIONS

HSRL - High Spectral Resolution Lidar

IMCO - Interagency Meteorological Coordination Office

IOOS - Integrated Ocean Observing System (NOAA)

IT - Information Technology

JPL - (NASA) Jet Propulsion Laboratory

JPSS - Joint Polar Satellite System

LaRC - (NASA) Langley Research Center

LL - Lincoln Laboratory (Massachusetts Institute of Technology)

LO - Line Office

MIT - Massachusetts Institute of Technology

MPD - Micro-pulse DIAL

MSA - Mission Service Area

NASA - The National Aeronautics and Space Administration

NCAR - National Center for Atmospheric Research

NESDIS - National Environmental Satellite, Data, and Information Service

NMFS - National Marine Fisheries Service

NOAA - National Oceanic and Atmospheric Administration

NOC-C - NOAA Oceans and Coasts Council

NOS - National Ocean Service

NOSC - NOAA Observing Systems Council

NRDD - NOAA Research & Development Database

NSF - National Science Foundation

NUI - Nereid Under Ice

NWP - Numerical Weather Prediction

NWS - National Weather Service

OAR - Office of Oceanic and Atmospheric Research

OMAO - Office of Marine and Aviation Operations

ORTA - Office of Research, Transition, and Application

OSAAP - Office of System Architecture and Advanced Planning

OSC - Observing System Committee

DEFINITIONS

PAIR - Polarimetric Atmospheric Imaging Radar

PMEL - Pacific Marine Environmental Laboratory

PNNL - Pacific Northwest National Laboratory

QOSAP - Quantitative Observing System Assessment Program

R&D - Research and Development

R2O - Research to Operations

R2X - Research to Applications

SASe - Subsurface Automated Samplers for eDNA

SBIR - Small Business Innovation Research

SJSU - San José State University

SPR - Surface Plasmon Resonance

STI - (Office of) Science and Technology Integration

SWE - Snow Water Equivalent

TPIO - Technology, Planning, and Integration for Observation

TPO - NOAA Technology Program Office

UAV - Underwater Autonomous vehicle

US - United States

USDA - The United States Department of Agriculture

USGEO - United States Group on Earth Observations

USGS - United States Geological Survey

USM - University of Southern Mississippi

WETO - Wind Energy Technologies Office

WHOI - Woods Hole Oceanographic Institution

WPO - Weather Program Office

EXECUTIVE Summary

The Emerging Technologies Workshop (ETW), sponsored by the NOAA Observing Systems Council (NOSC) and the NOAA Science Council, was a multi-day event designed to showcase innovations for collecting, analyzing, and assimilating environmental data that support Agency and Administration priorities. The 2021 ETW served as a forum for strengthening relationships with partner federal agencies by focusing on shared needs and opportunities for collaboration. Building on the success of previous workshops, this year's event aimed to improve the impact of emerging technologies through the end-to-end processes of:

1. **D**iscovery - of new and emerging technologies,
2. **D**evelopment - of new technologies through interactions with end-users,
3. **D**eployment - pathways to operations, research, commercial, and beyond.

The workshop brought together over 600 registrants from NOAA, our partners and beyond to discuss challenges and solutions to meeting Administration priorities using observing technologies. For this year's workshop, the emerging technologies of interest focused on observing and monitoring the areas of **Fire Weather, Extreme Weather, Great Lakes and Oceans, and Climate**. Through these areas, it was discussed how best to identify, develop, and transition these promising technological developments for the final end-user.

Highlights from this workshop were centered around five topics, of which improvements in all would have a significant impact on driving the creation, production, and implementation of emerging technologies in the environmental sciences. These topics included Transitions, Tech Transfer, and Commercialization; Partnerships; Uncrewed Systems; Data Management; and Equity and Inclusion.

The ETW continues to provide a safe collaborative space to discuss emerging environmental technologies across the federal government. The next ETW is slated for calendar year 2023.

Navigate to Conclusions, Outcomes, and Recommendations with this hyperlink.

KEYNOTE Summary

Dr. Richard Spinrad

There have been extraordinary developments in technology in the last 20 years, for example, with uncrewed systems, eDNA, and Omics. The question is, where will we be in the next 20 years? The application of new technologies is critical to how we will meet new mission objectives. To start, there are three top priorities. One, to establish NOAA as the primary authoritative source for climate products and services. Two, the act of balancing economic development and environmental stewardship. And three, to integrate equity into everything NOAA does. With Dr. Spinrad at the helm, NOAA will have a tolerance for high risk which will lead to increased payoffs. In turn, this should influence in what NOAA invests and develops.

Dr. Louis Uccelini

In response to Extreme weather events, NOAA's implementation of impact-based decision support services has saved lives and property and has increased trust by local decision-makers. The National Weather Service (NWS) has mapped the budget structure to the forecast process to form six budget portfolios that accurately represent the value the NWS brings to the nation. We are living in an Earth System Science environment with respect to how we approach problems. There are enormous gaps in observing the environment across this spectrum, but enormous opportunities as well.

Craig McLean

The Great Lakes (GL) are often overlooked. But the GL are an environmentally complex place and every line office in NOAA is involved in GL mission objectives. As NOAA sets work goals, the importance of the GL must stay on everyone's radar. This is the time where NOAA needs to address climate concerns and focus on conducting quality science. Environmental data and technology delivery are NOAA's representation in the New Blue Economy. The uncrewed systems that NOAA uses and develops for use in the GL and oceans are highly needed. NOAA should do more to accelerate the transition of these uncrewed systems to sustain and support their expanded use.

Ko Barrett

The COP26 meeting in Glasgow set ambitious goals and will be critical to climate change mitigation. The work being done and discussed at ETW 2021 will directly influence NOAA's ability to meet COP26 goals. The technologies presented at the Climate Day of the ETW cover the breadth of the current observing needs. And this workshop should act as a steppingstone to influence emerging technologies and foster innovation.

FIRE WEATHER Summary

Session Moderator Summary

NOAA has a long-term goal to ensure society is prepared for and responds to weather-related events. Ensuring the U.S. is a Weather Ready Nation entails the improvement of fire weather forecasting abilities. This session outlines several new technologies which will improve satellite detection and monitoring of fires. These improved capabilities are the result of advances in satellite technology, physical science, data science and user engagement.

Discovery Technologies

1. **NESDIS Fire Detections** - Michael Pavolonis (NOAA/NESDIS)

The NOAA NESDIS fire product portfolio is evolving to address capability gaps in fire detection and monitoring. Advances in sensor technologies, algorithms and user engagement have enabled the development of new fire detection and monitoring products. These new products will help support a fire ignition alerting dashboard which in turn supports NOAA's Fire Weather mission service area (MSA). Such products are beneficial to NOAA as they disseminate information that was previously difficult to access. This is bolstered by collaborations between the NWS, Office of Atmospheric Research (OAR), and National Environmental Satellite, Data, and Information Service (NESDIS).

2. **FireGuard** - Peter Vidmar (State of Colorado)

The newly created FireGuard is an interagency effort between the National Interagency Fire Center and National Guard units to provide near real-time fire detection and monitoring using multiple sources. This fills an identified capability gap by providing uninterrupted coverage during periods of wildfire activity. Such knowledge directly fulfills NOAA's fire weather mission service area and the broader goal of a weather ready nation. FireGuard is useful to additional agencies because of its support for existing incident awareness and assessment tools. The National Guard and the state of Colorado support this tool's development and application.

3. **OAR smoke** - Georg Grell (NOAA/OAR)

Using NOAA's regional and Global models, OAR discussed the successful implementation of smoke modules for existing numerical weather forecast models. Incorporating smoke into forecast models provides new data which provides increased awareness of smoke conditions. Such information serves to advance NOAA's Weather Ready Nation goal. Implementation of these models serves as a foundation for which additional models can incorporate smoke data into numerical forecast simulations. The advances presented here were achieved through collaboration with the Joint Polar Satellite System (JPSS) Proving Ground and Risk Reduction program and the Fire Influence on Regional to Global Environments and Air Quality (FIREX-AQ) teams.

FIRE WEATHER Summary

Key Takeaways/Actions

Discovery

- The NESDIS Fire product portfolio is evolving to address capability gaps along with advances in sensor technology and user engagement.
- Fire weather has become a national concern, especially during the Covid-19 pandemic, of which FireGuard has contributed to fire detection and monitoring.
- Fire weather detection work is supporting international endeavors; HRRR-Smoke may be the first time that interactive aerosols are successfully included in international operational forecast models.

Development

- Fire weather products/tools on mobile devices are widely utilized and useful in decision support, especially to firefighters on-site who may not have access to computers.
- A challenge within development is managing and supporting system/product applications (IT) with small teams while continuing to be involved with the latest research.
- System or product complexity often makes transitions to operational entities extremely difficult. In-house knowledge and techniques make this even harder. The transition of quasi-operational systems is not unique to NOAA.

Deployment

- The challenge of commercialization is related to business. Patents and licensing enable partnerships with business entities that envision investment opportunities.
- NASA developed forms and applications that consumers and users could complete. NASA then increased patent licensing 10X.
    - Start-ups formed with NASA
    - Accepted the realities of some start-up failures along with the successes
    - NASA formed over 100 start-up companies in 5+ years
    - High risk equals high reward
- The Government can be proactive in marketing available Technology Transfer opportunities. This can be critical for developing a culture of engagement that can more effectively address issues of equity and inclusion.

Special Topic - NOAA's Service Delivery Framework: Connecting User Engagement with Products and Services

- NOAA's users struggle to find the right entry points and/or timely solutions that meet their information needs with the best available science for their decisions. The program level is the primary relationship with an end-user. A critical step is moving from those that know the user to those that also understand the development process.
- The NOAA service delivery framework is designed to incorporate user feedback into the development of products and services and is made up of clear assessment phase elements each with a checklist that includes elements for success. NOAA AAs have already reviewed and adopted this framework.

Examples:

- Hawaii Anchialine Pools - Sea level rise impact viewer developed with users of the app.
- Monthly Climate Services Webinars - Real-Time Regional Climate Support.
- The North Central US Climate and Drought Summary and Outlook delivering actionable climate information including energy sector partnerships.

Special Topic - Partnerships and Commercialization: Introduction to the NOAA Technology Partnerships Office

- The Technology Program Office is made up of two congressional mandated programs under the umbrella of commercialization: The technology Transfer Program and SBIR. TPO serves all of NOAA, but they are housed within OAR.
- SBIR stimulates the US economy and business growth through investment in mission-relevant technologies, encouraging entrepreneurship by women and socially/economically disadvantaged individuals.
- The Technology Transfer Program promotes the increased use of NOAA's technology and determines potential pathways early to ensure IP is protected. Cooperative Research and Development Agreements (CRADAs) establish public-private partnerships to work collaboratively towards solutions.

Link to Appendix I: Abstracts and Presentations

EXTREME WEATHER Summary

Session Moderator Summary

NOAA has a long-term goal to create a Weather Ready Nation where society is prepared for and responds to weather-related events. Accomplishing this requires the ability to predict the occurrence of extreme weather events. This session outlines advances in observational technology that can improve the ability to prepare for extreme events. It touched upon radar systems, precipitation measurements, and in-situ weather balloon measurements.

Discovery Technologies

1. **Micropulse DIAL** (Differential Absorption Lidar) – Kevin Repasky (Montana State), Scott Spuler (NCAR)

Micro-pulse DIAL (MPD) instruments can provide continuous measurements of atmospheric water vapor, temperature, and quantitative aerosol properties. New instruments will address NOAA's Severe Weather MSA by measuring temporal and spatial variability of thermodynamic profiles in the lower atmosphere. By creating this new instrument, agencies such as the NSF, NOAA, Department of Energy (DOE), and NCAR can gain new data to improve forecasting abilities. This product is formed via collaboration between NCAR and Montana State University.

2. **Polarimetric Atmospheric Imaging Radar (PAIR) and HORUS Phased Array Radars -** Robert Palmer, Tian Yu (University of Oklahoma)

New radar systems HORUS and Polarimetric Atmospheric Imaging Radar (PAIR) are being created to develop the next generation of weather radar systems. These systems are designed to increase the temporal resolution and vertical coverage of weather radar systems. Such advances support multiple mission service areas within NOAA's goals for a Weather Ready Nation. These projects are designed to be used by both the border scientific community and the National Weather Service. Development was sustained by a collaboration between Oklahoma University and the NSF.

3. **Hotplate precipitation sensors** - Tim Garrett (University of Utah)

The University of Utah has developed new instrumentation for accurate measurement of precipitation. By providing ultra-high-resolution time-series for Snow Water Equivalent (SWE), rain rate, snow depth, precipitation visibility reductions, and avalanche risk this product addresses multiple mission service areas of NOAA's Weather Ready Nation goal. These factors are important in addressing the forecasting and severe weather needs of the National Weather Service. This technology was created via a collaboration between the University of Utah, Particle Flux Analytics, the NSF, and the DOE.

4. **Evaluating Impact of In-situ Observations from Dynamically Targeted Long-Range Long-Duration Balloons** - Andrey Sushko (Windborne Systems, Inc.)

WindBorne Systems has developed an actively controlled long-endurance sounding balloon for collecting in situ meteorological measurements. These sounding balloons will improve the data collection used to inform Routine Weather Forecast, Severe Weather, and multiple other MSAs within NOAA's Weather Ready Nation goal. This information is already being used by NOAA, the Office of Naval Research, and the U.S. Air Force (USAF) to improve data collection. This technology was created in collaboration with these same offices.

5. **Development and Demonstration of a Low-Cost, Standalone Mode S EHS Aircraft Derived Atmospheric Observation System for Enhanced Weather Forecasting** - Michael McPartland (Lincoln Laboratory, MIT LL)

A collaborative effort has demonstrated the feasibility of Low-Cost Standalone Aircraft Derived Atmospheric observations. By incorporating additional low-cost data collection this technology fills gaps in data collection which arise due to the limited number of monitoring aircraft available. These new data improve NOAA's ability to forecast weather as a part of its goal for a Weather Ready Nation. Additional data benefit data needs for NOAA, the Federal Aviation Administration (FAA), Department of Defense (DOD), and DOE. The collaborating groups who developed this technology were the MIT Lincoln Laboratory, and NOAA.

6. **Anonymization, Bias Correction, and Assimilation of Smartphone Pressure Observations for Use in Numerical Weather Prediction in NOAA** - Clifford Mass (University of Washington)

The University of Washington has developed a new technology to anonymize, correct bias and assimilate smartphone pressure observations for use in NOAA numerical weather prediction. New data increases data resolution improving the fidelity of hurricane, severe, and routine weather forecasts benefiting Hurricane, Severe Weather, and Routine Weather Forecast MSAs. Since multiple federal agencies utilize pressure data, any federal agency with weather models will be able to incorporate the higher resolution data. This development was due to a collaboration between research scientists at the University of Washington Department of Atmospheric Sciences.

Key Takeaways/Actions

Discovery

- Current data sources are limited and have data gaps. For example, the bulk of the Earth's atmosphere is under sampled. New emerging technology research and tools are working to fill those data gaps.
- Research in progress continues to advance understanding of the atmosphere and weather phenomena for extreme weather. Partners and users span NOAA and the weather enterprise.

- Increasing the availability of data, both temporally and spatially, and ingesting that data into models will continue to improve Numerical Weather Prediction (NWP), and weather forecasts and protect lives.

Development

- NSF has different tiers of funding opportunities for extreme weather research from individual proposals ($100k) to major multi-user research facility support ($100M+)
- NOAA presented several funding opportunities for extreme weather development. From WPO Observations funding opportunities ($10M for 2yrs) or smaller funding opportunities through CSTAR ($800k) to bridge NOAA and academic research.
- NOAA recommends transition plans for R2O (and other R2X). A transition plan is not a binding contract and doesn't guarantee transitions. It is a tool to outline the path to make/help the transitions happen.

Deployment

- Commercializing technology may be necessary to realize the full impact of a given technology. The government may conduct critical research while the private sector invests to deploy the technology.
- Commercialization can take a long time and the Earth doesn't have the time. Increased gap detection, resources and manpower are the limiting factors.
- A full team of experts, including those in licensing and patents, contributing to the R2X process can streamline technology transfer thus challenging the commercialization process.

Special Topic - Accelerating Transition

- The Office of Research, Transition, and Application (ORTA) is a new office within NOAA formed to accelerate the transition to R2X to serve NOAA's mission and the American people.
- ORTA is meeting the objective to accelerate transitions by demystifying transition plans. Currently, ORTA has developed (with the help of a cross LO tiger team) transition plan templates, fully signed transition plan examples and transition plan guidance. These materials can be found on orta.research.noaa.gov.
- ORTA is working towards a transition management tool to create a one-stop-shop to organize and manage transition plans.

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Session Moderator Summary

NOAA has a long-term goal of Healthy Oceans through the management of fisheries, habitats, and biodiversity within productive ecosystems. Healthy oceans refer to the Great Lakes as well. To foster healthy oceans, there is a need for improved sampling technologies. This session describes several new sampling techniques which are poised to transition from development to operational use. These include automated sampling of environmental DNA (eDNA), uncrewed sampling of harmful algal blooms and under-ice habitats, as well as open-source approaches to developing new technologies.

Discovery Technologies

1. **Real-time sequencing on autonomous platform -** Peter Thielen (Johns Hopkins University, Applied Physics Laboratory)

Researchers at Johns Hopkins University have completed a proof of concept enabling the incorporation of environmental genetic analysis into autonomous sampling platforms. Increased knowledge of eDNA fosters improved Protected Species Monitoring, Ecosystem Monitoring, and Fisheries Monitoring MSAs within NOAA. Such information would benefit the National Marine Fisheries Service (NMFS) with the regulation of commercial fishing grounds. This technology was created through a collaboration between Johns Hopkins University and the Monterey Bay Aquarium Research Institute.

2. **SPR chip for real-time HAB monitoring** - Bill Ussler (Monterey Bay Aquarium Research Institute)

The incorporation of reusable toxin specific Surface Plasmon Resonance (SPR) chip technology allows for real-time monitoring of harmful algal blooms (HABs). This technology can help meet NOAA's Habitat Monitoring and Assessment MSAs. This technology is useful for multiple agencies which have fisheries or ecosystem habitat concerns. This technology was created through collaboration between NOAA's NMFS and the Monterey Bay Aquarium Research Institute, the University of Washington, Queen's University Belfast, and Wayne State University.

3. **Under-ice AUV Demonstration Projects -** Steve Ruberg (NOAA/OAR/GLERL) and Brett Hobson (Monterey Bay Aquarium Research Institute)

Advances in under-ice ecosystem observation have led to the development of an under-ice docking station. The ability to monitor ecosystems underneath ice increases data collection capacity and supports NOAA's Ecosystem and Habitat Monitoring MSAs. Autonomous under-ice observation technology improves the ability of NOAA's offices, such as NMFS, to improve forecasting and monitoring. This technology was created collaboratively with the Great Lakes Environmental Research Lab and the Monterey Bay Aquarium Research Institute.

4. **NUI - Woods Hole/NASA/JPL** - Mike Jakuba (Woods Hole Oceanographic Institution)

The creation of a hybrid Remotely Operated Vehicle (ROV) with acoustic controls has led to improved under-ice data collection. This technology supports NOAA's MSAs of Habitat and Ecosystem Monitoring, Assessment and Forecasting. Hybrid ROV technology will aid agencies such as the GLERL, and NOAA's NMFS which work in ice-covered environments. Collaboration between NOAA, NASA, the NSF, and the Avatar Alliance Foundation has enabled the creation of this technology.

5. **SASe sampler (inexpensive, open access, 3-D printing)** - Nathan Formel (NOAA/OAR)

NOAA's Atlantic Oceanographic and Meteorological Lab (AOML) has created a makerspace for leveraging new technologies to create novel sampling systems, including an eDNA sampler. New sampling product development, such as subsurface automated samplers for eDNA, will support NOAA's Healthy Oceans goals by increasing knowledge relevant to Ecosystem, Habitat and Protected Species Monitoring MSAs. Such advances would serve AOML, NMFS and other NOAA offices concerned with fisheries research. This development is due to collaboration between various NOAA offices as well as researchers and universities in and outside of the US.

Key Takeaways/Actions

Discovery

- To use DNA as a data source its sequence is converted from chemical to digital. Biological sensing is using this DNA data, aka eDNA, to monitor the health of our lakes and oceans.
- eDNA sequencing from samples collected underwater/under-ice is an emerging products category for NESDIS providing a new data sink of satellite observations for NESDIS to ingest and analyze.
- With the many innovative products being developed to monitor Great Lakes and Oceans, NESDIS is taking an agile approach to processing new types of data.

Development

- Two autonomous innovative technologies collect organism data in the oceans: Mesobot (zooplankton) and UAV (cetacean). Autonomous vehicles can lower risks to data quality and eliminate risks of humans diving all while lowering the costs of sampling.
- Mesobot has been successful with using autonomous vehicles to collect samples using tools and algorithms to process the raw data. Autonomous sampling still has its challenges. The cost, durability and data analysis are obstacles that require "end to end innovation."
- The main obstacle with Great Lakes research is that the government and private grant support for this research is smaller than the Great Lakes themselves. More cross collaborative government research is needed to garner the support necessary to continue to innovate automation in data collection and analysis.

Deployment

- NOAA heavily invests in BGC Argo to expand ocean heat measurements to ecosystems to represent overall ocean health.

- Managing massive amounts of data received from emerging technologies, such as uncrewed systems, is a challenge. This challenge must be addressed to ensure large amounts of data are useful and available to end-users.
- Data solutions should be coupled with education to ensure communities and decision-makers understand what these new data mean and how they can be applied to policy and prevention.

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CLIMATE Summary

Session Moderator Summary

NOAA has a long-term goal of Climate Adaptation and Mitigation which focuses on creating an informed society capable of anticipating and responding to climate change and its impacts. It is necessary to collaborate with partners across the federal, academic, and private industries to better inform society of the potential impacts of climate change. New technologies include the use of satellites and high-altitude balloons for measurements of atmospheric and plankton communities, as well as buoys to aid in the development of offshore renewable energy sources.

Discovery Technologies

1. **NASA's Differential Absorption Lidar for water vapor and aerosol profiling from Airborne and Space-Based platforms** - Ahmin Nehrir (NASA/LaRC)

NASA Langley Research Center has developed the High-Altitude Lidar Observatory (HALO), a Differential Absorption Lidar (DIAL) and High Spectral Resolution Lidar (HSRL) system to address the observational needs of weather, climate, carbon cycle, and atmospheric composition communities. This system characterizes the complex three-dimensional thermodynamic structure of the troposphere from a global perspective. This supports NOAA's Climate Science MSA. DIAL and HSRL techniques are beneficial for federal partners involved in climate change research such as NOAA's Office of Atmospheric Research (OAR) as well as additional NOAA and NASA airborne programs. This technology was formed through the collaboration between the NASA Langley Research Center, NASA Earth Science Technology Office (ESTO), NASA SBIR and NASA Langley Research Center Internal Research and Development Program.

2. **NOAA's High-altitude Operational Returning Unmanned System** - Bianca Baier (NOAA/OAR)

Driven by the need to both expand potential balloon-borne sampling locations and improve the feasibility of payload recovery, an uncrewed platform to return atmospheric instrumentation from the stratosphere has been created. NOAA's Climate Assessment and Projection MSAs are supported by the expanded potential profiling locations to climate-relevant regions, increased satellite evaluation efforts in remote regions, and improved weather and climate forecast model predictive capabilities. This technology supports NOAA's Global Monitoring Laboratory, and OMAO, as well as the Uncrewed Systems Research Transition Office. This technology was created by collaborations between NOAA's Global Monitoring Laboratory, OMAO, and the University of Colorado-Boulder.

3. **Optical Plankton Imaging and Analysis System** - Hassan Moustahfid (NOAA/NOS) and Deana Crouser (NOAA/NMFS)

Combining imaging technology with artificial intelligence (AI), researchers have been able to improve the speed and accuracy of zooplankton sampling. The advanced imaging systems and development of AI algorithms to identify zooplankton may be used to address NOAA's MSAs of Advancing Climate-Ready Fisheries Management and Ecosystem-Based Fisheries Management. This would serve the NOAA National Marine Fisheries Service (NMFS). This technology was created through collaborations between scientists working with the NOAA Integrated Ocean Observing System (IOOS).

4. **Buoy-based Observations to Support Offshore Wind Development** - Alicia Mahon (Pacific Northwest National Laboratory)

Deployment of new buoys with enhanced sensors measuring wind speed and direction at multiple heights is relevant to offshore wind energy production. A collection of offshore U.S. hub-height observations fills a data gap inhibiting the characterization of wind resources supporting NOAA's Climate Mitigation and Adaptation Strategies MSA. The DOE uses this technology in the development of offshore wind energy resources. This technology was the product of the Pacific Northwest National Laboratory (PNNL) and the U.S. Department of Energy's Wind Energy Technologies Office (WETO).

Key Takeaways/Actions

Discovery

- Partnerships are essential to approach and overcome challenges such as funding limitations, working in extreme environments, and navigating existing regulations.
- New technologies can collect more frequent data at a lower cost helping to track shorter timescale effects of climate change, which are often missed.
- With the advent of new environmental technologies, the infrastructure needed for timely data processing, data sharing and knowledge transfer must be prioritized.

Development

- Public and private partnership collaborations are critical for emerging environmental observations. The US government may implement a funding structure to reward private industry and grant nonprofits for investing in earth observational improvements. Financing is still an issue for environmentally innovative technologies.
- Satellite and in-situ resources must work together to address gaps in observational coverage.

Deployment

- SBIRs are critical for helping overcome targeted technological hurdles, which can speed up the technology development process.
- Supporting effective partnerships requires communication throughout the technology transfer process.

Link to Appendix I: Abstracts and Presentations

Conclusions

1. **Transitions, Tech Transfer, and Commercialization**
   - Quasi-operational system transition challenges are not unique to NOAA. System or product complexity and in-house knowledge often make transitions to operational entities more difficult.
   - Cooperative Research and Development Agreements (CRADAs) can be useful tools to develop partnerships and commercial transitions.
   - Commercializing technology is often necessary to realize the full impact of a technology. The government may continue to do critical research while the private sector may take on the investment needed to broadly deploy the technology.
   - Engaging with technology transfer groups early in the technology development process is critical to ensure partnerships and commercialization opportunities are identified while technologies are still maturing.
   - NOAA/ORTA is working towards a transition management tool to create a one-stop shop to organize and manage transition plans.

2. **Partnerships**
   - Partnerships are essential to approach and overcome challenges such as funding limitations, working in extreme environments, and navigating existing regulations.
   - Federal agencies should work together to solve these challenges to ensure emerging technologies are successful.
   - SBIRs are critical to helping knock down targeted technological hurdles and speed up the technology development process.
   - Public and private partnerships are critical for emerging environmental observations; they need to work together because no one entity can solve the problem.

3. **Uncrewed Systems**
   - Uncrewed systems are increasingly used to meet mission requirements.
   - Uncrewed platforms are critical to the future of Great Lakes and Ocean research, but there are still challenges to operational deployment.
   - The uncrewed systems that NOAA uses and develops are often at high readiness. More needs to be done to accelerate the transition of these systems and to sustain and support their expanded use.
   - There are a lot of opportunities to innovate for longer UAS missions.
   - Innovation in UMS can cut operation costs and make UMS more viable for operation.

4. **Data Management**
   - Managing the massive amounts of data coming from these emerging technologies and uncrewed systems is a big challenge and one that needs to be addressed going forward to ensure that all this data is useful and available.
   - There is a need to couple data solutions with education to ensure all communities and decision-makers understand what these new data mean.
   - New technologies can collect more data more frequently, and sometimes at a lower cost to help track the shorter timescale effects of climate change, which are often missed.
   - Data collection by new technologies is important, but the focus should be on the infrastructure needed for timely data processing as well as data sharing and knowledge transfer.

5. **Equity and Inclusion**
   - Federal agencies should be proactive in marketing what Technology Transfer opportunities are available. To develop an engagement culture, it is critical to address issues of equity and inclusion.
   - Commercializing technology is often necessary to realize the full impact of the technology and can help emerging technologies reach communities that would otherwise not have access.

Workshop Outcomes

The workshop structure, participants, and topics were designed to best support the needs of NOAA and other federal agencies to improve mission outcomes. In Table 1, workshop outcomes have been aligned with workshop objectives identified in the planning process.

Table 1. Objectives and Outcomes

Workshop Objectives	2021 Workshop Outcomes
Clearly understand observing needs/requirements & gaps	Subject matter experts in the fields of Fire Weather, Extreme Weather, Great Lakes and Oceans, and Climate identified priority observing needs and gap-filling technologies to highlight at the workshop.
Strengthen the observing portfolio through identification and uptake of gap-filling innovations.	Thirty-four technologies were presented throughout the workshop with panel discussions focused on technology development and deployment. Follow-on activities will be identified to move the technologies into appropriate portfolios.
Address Climate observing needs	One full day of the workshop was dedicated to Climate observing needs and systems. Thirteen different presentations were given including panel discussions on climate technology development and deployment.
Increase collaboration with partner agencies.	Eight federal agencies assisted NOAA with planning the ETW. Technologies that had a cross-agency component, or that benefitted from cross-agency collaboration were highlighted, facilitating connections, and enabling discussions.
Better understand opportunities and procedures for transitioning technologies	Two technology transfer and commercialization sessions included presentations and discussions with the Federal Labs Consortium, NASA, USGS, and the Naval Research Laboratory highlighting best practices and recommendations to improve transitions and areas of improvement.

Workshop Objectives	2021 Workshop Outcomes
Increase compliance with NAO 216-105b: Policy on R&D Transitions	The workshop prioritized the End-to-End process of technology discovery, development, and deployment with a focus on technology transition from research to operations, commercialization, and other applications. Each session included panel discussions on technology development and deployment increasing the awareness of Technology Transfer and commercialization. Special topic sessions highlighted ongoing efforts and advances in transitions and transition support within NOAA that have and will improve compliance with NAO 216-105b: Policy on R&D Transitions.
Increase use of the NOAA Research & Development Database (NRDD) and Earth Observing Systems (EOS) database to identify technologies already in development to leverage existing opportunities and avoid duplicating efforts.	Use of the NRDD and EOS to identify and track technology development remains a challenge for NOAA. The NRDD has become a vital tool for understanding NOAA's R&D portfolio, however, linking emerging technologies with NRDD projects using existing features of the database is an ongoing effort.

Recommendations

1. Develop an Action Plan based on the workshop conclusions and outcomes to support continued advancement in areas such as: strengthening the observing portfolio, R2X Transitions, and increasing collaboration with partner agencies.

2. Establish a sustainable way to engage with the private sector on emerging technologies that increases technology adoption, builds partnerships, and encourages mutually beneficial outcomes.

3. Continue engagement between the NOAA Observing Systems Committee, the NOAA Line Office Transition Managers Committee, and the NOAA Office of Research Transition and Application (ORTA) to ensure the continued advancement of observing system transition best practices.

4. Collaborate with other federal agencies to solve some of the big challenges of discovery, development and deployment of emerging technologies to ensure success and equitable access to technology.

5. Identify and market Technology Transfer opportunities.

6. Engage with Technology Transfer teams early in the technology development process to ensure partnership and commercialization opportunities are identified while technologies are still maturing.

7. Address the data management challenges, requirements and opportunities presented by emerging technologies to ensure that all this data is useful and available.

CONCLUSIONS, Recommendations, and Next Steps

8. Identify the appropriate path forward for the NOAA Emerging Technologies Workshop including the key relationship with the NOAA Science and Technology Focus Areas and the Science and Technology Synergy Committee under the NOAA Science Council.

APPENDIX I – Abstracts and Presentations

The link will take you to a NOAA Google Folder containing select abstracts and presentations. If you are a NOAA employee and/or you were registered for the 2021 ETW, you will have access to these folders. Some presenters declined to participate in the file sharing.

Speaker Abstract and Presentation Folder Link

APPENDIX II – Full Agenda

Day 1 – October 25: Fire Weather

12:00 - 12:05 Welcome and Opening Remarks

Observing System Committee (OSC) Co-Chair Tom Cuff (NOAA/NWS)

- Agenda overview, ground rules, and logistics

12:05 - 12:30 Keynote Address: Dr. Richard Spinrad (NOAA/HQ)

12:30 - 13:50 Session 1: Discovery

Introduction - Robyn Heffernan (NOAA/NWS)

- NESDIS Fire Detections - Michael Pavolonis (NOAA/NESDIS)
- FireFly - Peter Vidmar (State of Colorado)
- OAR smoke - Georg Grell (NOAA/OAR)

Q&A

13:50 - 14:20 Break

13:55 - 14:15 ***SPECIAL TOPIC BREAKOUT***: NOAA's Service Delivery Framework: Connecting User Engagement with Products and Services - Ellen Mecray (NOAA/NESDIS)

14:20 - 15:20 Session 2: Development

Introduction - Nicholas Nauslar (BLM)

- WindNinja - Natalie Wagenbrenner (USDA)
- Coupled modelling - Adam Kochanski (SJSU)
- Fire Danger - Matt Jolly (USDA)

Q&A

15:20 - 15:50 ***Break***

15:25 - 15:45 ***SPECIAL TOPIC BREAKOUT***: Partnerships and Commercialization: Introduction to the NOAA Technology Partnerships Office - Kelly Wright (NOAA/OAR)

15:50 - 16:50 Session 3: Deployment - Commercialization Part 1: Federal Partner Presentations and Fire Tech Transition

Introduction - Wayne Mackenzie (NOAA/OAR)

- Paul Zielinski (Executive Director, Federal Labs Consortium)
- Dan Lockney (Technology Transfer Manager HQ, NASA)
- James Mitchell (Patent and Licensing Manager, USGS)

Q&A

16:50 - 17:00 ***Wrap up*** **-** co-chair Tom Cuff (NOAA/NWS)

Day 2 – October 26: Extreme Weather

12:00 - 12:05 Welcome and Opening Remarks

Observing System Committee (OSC) Co-Chair Tom Cuff (NOAA/NWS)

- Agenda overview, ground rules, and logistics

APPENDIX II – Full Agenda

12:05 - 12:30 Keynote Address: Dr. Louis Uccellini (NOAA/NWS)

12:30 - 14:10 Session 1: Discovery

Introduction - Nick Anderson, NSF

- Micropulse DIAL – Kevin Repasky (Montana St), Scott Spuler (NCAR)
- Polarimetric Atmospheric Imaging Radar (PAIR) and HORUS Phased Array Radars - Robert Palmer, Tian Yu (Univ of Oklahoma)
- Hotplate precipitation sensors - Tim Garrett (Univ of Utah)
- Evaluating Impact of In-situ Observations from Dynamically Targeted Long-Range Long-Duration Balloons - Andrey Sushko (Windborne Systems, Inc)
- Development and Demonstration of a Low-Cost, Standalone Mode S EHS Aircraft Derived Atmospheric Observation System for Enhanced Weather Forecasting - Michael McPartland (Lincoln Laboratory, MIT LL)
- Anonymization, Bias Correction, and Assimilation of Smartphone Pressure Observations for Use in Numerical Weather Prediction in NOAA - Clifford Mass (Univ of Washington)

14:10 - 14:20 *Break*

14:20 - 15:20 Session 2: Development - Resources and Opportunities for Weather Observation Development

Introduction - Renee Richardson (NOAA/OAR)

- National Science Foundation: Instrumentation and Facilities Programs - Nick Anderson (NSF)
- NOAA's Weather Program Office: Observations Program - Sandra LaCorte (NOAA/OAR/WPO)
- Collaborative Science Technology and Applied Research (CSTAR) - Chris Hedge (NOAA/NWS/CSTAR)
- Facilitating R2O Transitions in NWS Using Transition Plans - Tabitha Huntemann (NOAA/NWS/STI)

15:20 - 15:50 *Break*

15:25 - 15:45 ***SPECIAL TOPIC BREAKOUT:*** Accelerating Transitions: How Do We Speed Up the Transition Process - Fiona Horsfall (NOAA/OAR/ORTA)

15:50 - 16:50 Session 3: Deployment - Commercialization Part 2: NOAA Commercialization and Discussion with Federal Partners

Introduction - Wayne Mackenzie (NOAA/OAR)

Panel Discussion and Q&A

- Amanda Horansky-McKinney (Naval Research Lab)
- James Mitchell (Patent and Licensing Manager, USGS)
- Christian Meinig (NOAA/OAR/PMEL)
- Joe Cione (NOAA/OAR/AOML)

16:50 - 17:00 *Wrap up* - co-chair Tom Cuff (NOAA/NWS)

Day 3 – October 27: Great Lakes and Oceans

12:00 - 12:05 Welcome and Opening Remarks

Observing System Committee (OSC) Co-Chair Rich Edwing (NOAA/NWS)

- Agenda overview, ground rules, and logistics

12:05 - 12:25 Keynote Address: Craig McLean NOAA/OAR)

12:25 - 13:50 Session 1: Discovery

Introduction - Kelly Goodwin (NOAA/OAR)

- Real-time sequencing on autonomous platform - Peter Thielen (Johns Hopkins U, Applied Physics Laboratory)
- SPR chip for real-time HAB monitoring - Bill Ussler (Monterey Bay Aquarium Research Institute)
- Under-ice AUV Demonstration Projects - Steve Ruberg (NOAA/OAR/GLERL) and Brett Hobson (Monterey Bay Aquarium Research Institute)
- NUI - Woods Hole/NASA/JPL - Mike Jakuba (Woods Hole Oceanographic Institution)
- SASe sampler (inexpensive, open access, 3-D printing) - Nathan Formel (NOAA/OAR)

Panel Discussion

- Steve Ruberg (NOAA/OAR)
- Brett Hobson (Monterey Bay Aquarium Research Institute)
- Mike Weise (Office of Naval Research)
- Genevieve Lind (NOAA/OAR)
- Wayne Mackenzie (NOAA/OAR)

13:50 - 14:20 *Break*

13:55 - 14:15 ***SPECIAL TOPIC BREAKOUT***: Lake Erie as a Test Bed: Emerging Technology to Address Multiple Ecosystem Stressors - Steve Ruberg (NOAA/OAR)

14:20 - 15:20 Session 2: Development

Introduction - Chris Beaverson (NOAA/HQ)

- eDNA collection technology, mesobot - Dana R Yoerger (WHOI)
- ScanEagle and other long-range platforms - Robyn Angliss (NOAA/NMFS)

Panel Discussion

- Robyn Angliss (NOAA/NMFS)
- Peter Esselman (USGS)
- Kim Parsons (NOAA/NMFS)
- Annette Hollingshead (NOAA/OAR)

15:20 - 15:50 *Break*

15:25 - 15:45 ***SPECIAL TOPIC BREAKOUT:*** Uncrewed Systems Transitions - Bryan Cole (NOAA/OAR)

15:50 - 16:50 Session 3: Deployment

Introduction - Philip Hoffman (NOAA/OAR)

- BGC Argo - Emily Smith (NOAA/OAR)
- Scenario Testing of the Ocean Aero Triton Hybrid AUV - Jason McKenna (USM)

Panel Discussion

- Emily Smith (NOAA/OAR)
- Jason McKenna (USM)
- Gabrielle Canonico (NOAA/NOS)
- Reagan Errera (NOAA/OAR)
- Mike Weise (Navy)

16:50 - 17:00 *Wrap up* - co-chair Rich Edwing (NOAA/NOS)

Day 4 – October 28: Climate

12:00 - 12:05 Welcome and Opening Remarks

Observing System Committee (OSC) Co-Chair Rich Edwing (NOAA/NOS)

- Agenda overview, ground rules, and logistics

12:05 - 12:20 Keynote Address: Ko Barrett (NOAA/OAR)

12:20 - 13:50 Session 1: Discovery

Introduction - Diane Stanitski (NOAA/OAR), Barry Lefer (NASA)

- NASA's Differential Absorption Lidar for water vapor and aerosol profiling from Airborne and Space-Based Platforms - Amin Nehrir (NASA/LaRC)
- NOAA's High-altitude Operational Returning Unmanned System - Bianca Baier (NOAA/OAR)
- Optical Plankton Imaging and Analysis System - Hassan Moustahfid (NOAA/NOS) and Deana Crouser (NOAA/NMFS)
- Buoy-based Observations to Support Offshore Wind Development - Alicia Mahon (Pacific Northwest National Laboratory)

Panel Q&A

13:50 - 14:05 *Break*

14:05 - 15:05 Session 2: <u>Development</u>

Introduction - Amber Emory (NASA)

- Mapping methane and CO2 point sources - Riley Duren (Carbon Mapper)
- Constraining the GHG emissions using commercial aircraft - Colm Sweeney (NOAA/OAR)
- Autonomous Profiling FLoat Powered by Ocean Temperature Difference - Yi Chao (SeaTrec)
- DopplerScatt, a Ka-band Doppler scatterometer for simultaneous wide-swath measurements of ocean surface vector winds and currents and spaceborne mission prototype - Dr. Dragana Perkovic-Martin (NASA/JPL)

Panel Q&A

15:05 - 15:20 *Break*

APPENDIX II – Full Agenda

15:20 - 16:40 Session 3: Deployment

Introduction - Chris Meinig (NOAA/OAR)

- Mid- and Long-Wave Infrared Digital Focal Plane Arrays for SmallSat Applications - Sarath Gunapala (NASA/JPL)
- Water vapor MicroPulse Differential Absorption Lidar - Scott Spuler (NCAR)
- The NightFOX remote sensing payload for wildfire applications - Troy Thornberry (NOAA/OAR)
- Seagliders - under ice measurements in changing Arctic - Luc Rainville (Univ of WA)

Panel Q&A

16:40 - 17:00 ***Closing Discussion on Outcomes and Next Steps*** - co-chair Rich Edwing (NOAA/NOS)

APPENDIX III – Important ETW Links

Landing Page/Webpage

Dashboard

Previous ETW Reports

2016 report

2017 report

2019 report

APPENDIX IV – Acknowledgments

The 2021 NOAA Emerging Technologies Workshop was made possible through the efforts of the following people. We would like to express our sincere gratitude to all those who assisted in making it possible.

Workshop Co-Chairs

- **Rich Edwing**, NOAA/NOS, OSC Co-Chair
- **Tom Cuff**, NOAA/NWS, OSC Co-Chair

Keynote Speakers

- **Rick Spinrad**, NOAA/HQ, Under Secretary of Commerce for Oceans & Atmosphere, NOAA Administrator
- **Louis Uccellini,** NOAA/NWS, Assistant Administrator for Weather Services, NWS Director
- **Craig McLean,** NOAA/OAR, Acting Chief Scientist, Assistant Administrator for Oceanic & Atmospheric Research
- **Ko Barrett**, NOAA/OAR, Senior Advisor for Climate

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- **Sandra LaCorte**, NOAA/OAR, Program Planning
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- **Martin Yapur**, NOAA/NESDIS
- **Thanh Vo Dinh**, NOAA/NESDIS
- Fire Weather:
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    - **Nicholas Nauslar,** BLM
    - **Matt Jolly,** USDA
    - **Sean Triplett,** USDA
- Weather & Water Extremes:
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    - **Joe Cione,** NOAA/OAR
    - **Sandra LaCorte,** NOAA/OAR
    - **Nick Anderson,** NSF
- Oceans & Great Lakes:
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    - **Reagan Errera,** NOAA/OAR
    - **Philip Hoffman,** NOAA/OAR
    - **Chris Beaverson,** NOAA/OAR
    - **Patrick Hogan,** NOAA/NESDIS
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    - **Barry Lefer,** NASA
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NOSC Website

APPENDIX VI

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