National Oceanic and
Atmospheric Administration

U.S. Deprtment of Commerce

NOAA Emerging Technologies Workshop for Observations

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Prepared by Technology, Planning and Integration for Observation

Preface

On Wednesday, July 27, 2016, the NOAA Observing System Council (NOSC) hosted a workshop on Emerging Technologies for Observing systems, with an attendance of more than 200 NOAA government employees and contractors at the NOAA Auditorium and Science Center in Silver Spring, Maryland. The workshop brought together NOAA senior leaders, researchers, analysts, and practitioners of systems - both traditional and nontraditional; remote sensing or in situ, with expertise in observations across the Atmosphere, Terrestrial, Ocean, and Space domains. The workshop focused on showcasing sensors and platforms that could replace or improve current capabilities, lower costs, or fill gaps within the next three to five years. In a series of 23 ten-minute presentations and 28 posters, the workshop highlighted key research, collaborations, projects, and efforts within the NOAA community to develop and use emerging technologies. The outcomes of the workshop centered on gaining a better understanding of emerging technologies and capabilities, discussing how these technologies might meet NOAA observation requirements and impact NOAA programs, and promoting collaboration between NOAA Strategy Councils and line offices.

The workshop hosts were the Observing Systems Committee (OSC) co-chairs, Mr. Joseph Pica (National Weather Service) and Dr. Richard Edwing (National Ocean Service). This report contains summaries of the keynote speeches and main presentations, followed by a summary of the executive session discussion. The agenda of the workshop, a list of posters and their authors, and the post-workshop survey results can be found in the appendices.

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The web link below points to all of the abstracts, presentations and posters that were presented at the workshop.

https://nosc.noaa.gov/2016_NOAA_ETW/

Opening Remarks

VADM Manson Brown, NOSC Chair

The NOAA Observing System Council (NOSC) was created in 2003 as one of three NOAA Strategic Councils. The NOSC Terms of Reference specify three tasks: a) coordinating Earth observing and environmental data management activities across NOAA, b) providing policies and guidance in the development of the NOAA Integrated Earth Observation and Environmental Data Management System Architecture, and c) providing recommendations to the NOAA Executive Council (NEC) on Earth observation and environmental data management system requirements, architectures, emerging technologies, and investments.

The NOSC has established a vision to achieve an efficient observing system portfolio management capability that will allow NOAA to develop and sustain a mission effective, integrated, adaptable and affordable global observation and information system enterprise. Evaluation of promising science and technology will be the first of many steps in a process that drives new technology into NOAA's observing systems portfolio, and integrates them into the broader observing system architecture. NOAA operates in a fixed budget environment, with competing requirements that need continuous, open dialogue and cross-line coordination. A high priority of the NOSC is therefore to closely analyze NOAA's end-to-end requirements generation, validation, and prioritization process, and refine it towards greater precision while building in efficiencies that create budget space for new technologies.

The workshop allows us to take the first step towards evaluating new technologies. By raising awareness of the technological possibilities and fostering collaboration between labs, NOAA will be on the path to achieving the vision of an efficient observing system portfolio.

Keynote Address

Dr. Kathryn D. Sullivan, Under Secretary of Commerce for Oceans and Atmosphere & NOAA Administrator

There is a critical importance of our observing system portfolio in every line of work from research, to regulation, to management, to operations. We all know without data we are nothing. NOAA takes the pulse of the planet, and without data there is no way to produce the sort of increase in knowledge of how the earth works or have insights of actual environment intelligence that we produce to serve the country. We must improve the value, impact, and benefit of what we do and use our time and talent to better use the resources that the taxpayers give us. Many NOAA people have dedicated sizeable portions of their careers to the development of the observing enterprise or particular systems, and architectures.

Our goal is to use real time, near real time, and archival data to increase our environmental intelligence of how the earth works. NOAA spends about 20 percent of its annual appropriation just to sustain and maintain our existing observing assets. The challenge is how well we are doing with that 20 percent. Even a 1 percent savings is significant. NOAA has strong leadership at the lab level and this is where the requirements process needs to be initiated. When we engage in dialogue we must keep in mind what is best across the agency and ultimately the American public. Building a better model is not always the answer; we need to stay focused on what is needed to accomplish our mission.
Dr. Sullivan challenged the workshop attendees with three questions:

1. ***What from outside your domain strikes you as the most powerful idea you encountered here today to advance NOAA's mission?***

2. ***What ideas did you hear today that could be incorporated and be most impactful to the way you do business?***

3. ***What kinds of strategies or government structures would be most helpful for NOAA to adopt to optimize our innovation and nimbleness going forward?***

Workshop Sessions

The goal of the workshop was to promote broader awareness of emerging observing technologies that could instill agility and infuse new technologies in the NOAA observing system portfolio. The presentations were divided into four sessions by observing domain (Space, Atmosphere, Terrestrial, and Ocean) in order to best capture the breadth of NOAA observation capabilities. Common themes ran through the sessions, tying the session domains together.

The transition from research to operations, and partnerships between NOAA and other agencies and the private sector, were two themes that ran through the presentations. NOAA's Research to Applications, Operations and Services (R2X) program was lauded as NOAA's biggest recent success towards transitioning from Research to Operations. The R2X program identifies a research project's development level and highlights the path forward to completion. NOAA leadership should consider adding more weight to regional feedback and inputs, as appropriate, to the R2X program, and focus on true Research to Operations (R2O).

Partnerships will be crucial to large-scale or national- scale implementation of these types of technologies due to the cost of measuring widely dispersed terrestrial phenomena. To be successful in transitioning emerging technologies to operations, program budgets and affordability are key elements. Researchers were asked to consider the total cost continuum to include initial costs, maintenance costs, and what it will cost to take it to the field operationally. Speakers emphasized that as NOAA examines the cost of these emerging technologies, researchers should not place emphasis solely on cost but also on the amount of data being generated at that particular cost, a form of data per minute metric. Workshop participants discussed the need to keep in mind that technology is advancing so rapidly that the miniaturization of electronics will drive the original costs down.

Atmosphere Session

Operating environments of observing systems that are located in the atmosphere; specifically, from 10 meters to 100 kilometers above sea level.

Summary

The Atmosphere session focused on filling critical observation gaps in the atmosphere, such as boundary layer observations, aerosols observations, sensing harmful algal blooms (HAB), and collecting gravity data measurements. Representatives from several Line Offices presented a variety of projects utilizing Unmanned Aircraft Systems (UAS). As one speaker mentioned, new technologies are advancing so quickly that these emerging systems could potentially fill the atmosphere with swarms of lightweight sensors like flying, steerable, circuit boards, some possibly evening drifting with the wind.

Participants emphasized leveraging research and advancements (within NOAA and with other government agencies) to further NOAA's mission and collaborating with other organizations. A good example of this is testbeds that explore spatial resolution requirements, evaluate the optimality of different kinds of remote sensing systems, and work jointly with UASs and conventional radiosonde and dropsonde systems. A point was made to not only share the sensed data but also maximize its usefulness to the fullest extent possible. This can be done more easily with more scientific group interactions leading to unrealized and improved synergies.

The Atmosphere-based technologies presented at the workshop include:

1. **The Coyote Unmanned Aircraft System: Advancing the Technology Readiness of Low Altitude Expendable UAS Observations in Hurricanes to Address Critical Data Gaps, Improve Understanding and Enhance Future Forecasts of Intensity Change – Dr. Joe Cione, Oceanic and Atmospheric Research/Air Resources Laboratory**

   The Coyote Unmanned Aircraft System (UAS) is equipped with sensors similar to a dropwindsonde that capture vertical atmospheric profiles in the boundary layer of tropical cyclones, allowing increased sampling time and data collection (hours versus minutes). These profiles are of critical importance to measurement of hurricane intensification with a strong sensitivity to moisture conditions, which has been difficult to sense. Temperature, moisture, and wind observations below 500 meters within and surrounding the hurricane inner core are limited. This deficient data coverage is the primary reason why hurricane boundary layer structures remain poorly represented in operational models (Zhang et al. 2012), leading to errors in initialization and data assimilation and

resulting in impacts to forecast accuracy. Improved understanding of boundary layer processes through targeted, enhanced observation is essential for accurately predicting hurricane structure and intensity. The cost is expected to be lower than dropwindsonde costs (using data/min metrics), while simultaneously providing enhanced data coverage and capabilities.

2. **Low Altitude Rotary- and Fixed-Wing UAS Observations of Severe Storms to Fill Critical Data Gaps – Dr. Steven Koch, Oceanic and Atmospheric Research/National Severe Storms Laboratory**

   A major issue for ground-based remote sensing systems is obtaining high vertical resolution profiles (temperature, moisture, and winds within the atmospheric boundary layer) over sufficient depth of the troposphere within acceptable costs. Specifically, "satellite observations of the storm environment lack the needed vertical resolution in the boundary layer and are primarily limited to cloud-free conditions, whereas ground-based remote sensing instruments provide profiles at essentially one location, are unevenly distributed, and degrade in vertical resolution rapidly with height." Fixed-Wing UAS will provide a mobile observing system or multiple observing systems for monitoring rapidly evolving high-impact severe weather conditions not observed with current operational systems. The technology is also uniquely capable of collecting targeted observations with superb vertical resolutions in pre-tornadic storms. It is critical that the routine application of UAS for surveilling the pre-tornadic storm environment is "predicated on a demonstrable improvement in the accuracy and lead time of tornado warnings enabled through incorporation of these data into the warning decision process."

3. **Applications of Small Rotary Wing UAS for Protected Species Research – Mr. Wayne Perryman, National Marine Fisheries Service/Southwest Fisheries Science Center**

   Aerial photographs from manned platforms used to collect images of protected species are very expensive to operate and are unavailable in some remote locations. The APH-22 Hexacopter is a small (back-pack size), multi-rotor, portable UAS, carrying a high end mirrorless digital camera that has demonstrated its ability to collect high resolution images necessary for monitoring protected species. The technology has been safely and effectively operated by scientists in the field and has the potential to a) provide better data with almost no disturbance to the species being sampled and b) assess the impacts of fisheries, weather, and climate at a significantly reduced cost. The aircraft can take off and land vertically and can be launched from ships, boats, or from shore, allowing a wide range of research and monitoring applications, as long as the winds are less than 25 knots.

4. **The Printed Optical Particle Spectrometer (POPS) and Miniature Scanning Aerosol Sun Photometer (miniSASP) Instruments – Mr. Ru-Shan Gao, Oceanic and Atmospheric Research/Earth Systems Research Laboratory**

Frequent vertical profile measurements of aerosol number, size distribution, and optical depth are highly desired for air quality, climate, and satellite validation research. The Printed Optical Particle Spectrometer (POPS) and Miniature Scanning Aerosol Sun Photometer (miniSASP) are low-cost, light-weight, and low power consumption instruments that are capable of numerous applications including wide-scale sampling and citizen science activities. These miniaturized instruments were constructed using 3D printing technology representing approximately one order of magnitude decrease in size, weight, and cost over existing commercial products, allowing them to be deployed on small UASs and weather balloons. Both instruments were developed and commercialized with a total cost of approximately $1500. These measurements have the capability to fill critical aerosol monitoring data gaps for climate models, climate analysis and prediction; understanding of climate mitigation; prediction of volcanic ash plume evolution for aviation safety; satellite aerosol data retrieval; and aerosol distribution and hygroscopic growth factors including aerosol radiative effect. Both instruments are small, light, and inexpensive enough to be widely deployable to provide unprecedented temporal and spatial coverage.

5. **Integrated Hyperspectral Detection of HABS with Airborne and Handheld Sensors – Mr. Steven Ruberg, Oceanic and Atmospheric Research/Great Lakes Environmental Research Laboratory (GLERL)**

Prevalent harmful algal blooms (HABs) require routine monitoring in order to warn drinking water processing managers and charter fisherman. Currently, satellites only provide approximately 60-70 cloud free images a year for the Great Lakes. NOAA/GLERL began routine flyovers of water intake systems in FY15 with a hyperspectral camera that flies under the clouds, allowing more frequent HAB monitoring updates (weekly timescales) to drive the hydrodynamic models. The hyperspectral data will improve the HAB tracker model and provide more information on community dynamics throughout the bloom period by pulling out different functional groups of phytoplankton, which is important for ecosystem model development. Emerging technology efforts are currently in development to place the airborne hyperspectral sensor on an unmanned aerial system (UAS) to increase the frequency of flyovers.

6. **Unmanned Aircraft for Airborne Gravity Measurements – Dr. Vicki Childers, National Ocean Service/National Geodetic Survey**

Developing the capability for measuring gravity from an unmanned aircraft was proposed and awarded under the Small Business Innovation Research program. The technology provides quality gravity data for improved height measurements relative to where water will flow to protect life and property based on floodplain mapping, coastal resilience planning, storm surge modeling, precision

agriculture, and transportation development. The Centaur is an Aurora-modified Diamond aircraft with a modification that enables interchangeable flight operations in manned, unmanned, and augmented "hands-off" safety pilot modes. The platform and sensor (gravimeter) satisfies requirements as defined by the NOAA National Geodetic Survey's Gravity for the Re-definition of the American Vertical Datum project (GRAV-D). This new technology will likely reduce the cost of operations, human risk in operations, fuel consumption, carbon emissions, and transit times due to longer endurance and on-station times. The expected societal benefits of GRAV-D include an estimated $522 million in economic benefits annually and approximately $240 million saved from improved floodplain mapping alone.

Terrestrial Session

Operating environments of terrestrial observing systems that are located on or near the land; specifically, on dry land from 2 meters below the soil to 10 meters above the ground level, bounded from the ocean by the mean low water level of the coasts.

Summary

The Terrestrial session showcased a diverse range of new technologies with the potential to fill gaps in NOAA's ability to satisfy observing requirements and better address societal needs. These technologies include measurement of atmospheric mercury, stream discharge, snow level measurement, boundary layer profiles, and local weather conditions derived from traffic-camera analytics.

Mercury monitoring in national and global networks is critically important to assess impacts on human health. Improved calibration is needed to address documented, sporadic measurement biases/errors. NOAA is proposing to partner with the agencies responsible for these networks to improve the quality of data from the existing network via improved calibration techniques.

Partnering with other agencies is leading to the development of safer and more cost-effective ways to measure stream discharge. There are gaps in the United States Geological Survey stream-gage network, especially in headwaters and watersheds with burn scars. New technologies employing Light Detection and Ranging (LIDAR), RADAR, and ultrasonic ranging do not require direct contact with stream flows making measurement less hazardous and lowering the cost of annual calibration and maintenance.

Snow level measurement, the altitude at which precipitation changes from solid to liquid, has applications in hydrometeorology, transportation, recreation, and other applications. NOAA has partnered with the California Department of Water Resources to install snow-level radars to improve local forecasts, including determining whether a precipitation event will be snow or rain. This experience has shown reduced forecast bias in certain storm conditions and elevations.

NOAA needs higher spatial and temporal resolution of measurement of temperature, moisture, and winds in the boundary layer when forecasting severe weather, aviation, and air quality and for renewable energy forecasting and regional climate modeling. NOAA labs are partnering with the Department of Energy (DoE), universities and the private sector to investigate new technologies to measure these parameters. Large-scale implementation would be expensive and the National Severe Storm Lab is proposing an expanded network of sensors to better answer questions about the impact of the different techniques.

Commercial vendors have demonstrated the ability to use machine learning techniques to exploit the large installed base of traffic cameras in the US (at least 30,000) to ground-truth weather forecasts to supplement the Automated Surface Observing System network. When partnering with the commercial sector, it is important to ensure data transparency and practice iterative engagement with forecasters.

The Terrestrial-based technologies presented at the workshop include:

1. **Novel Calibration Systems for Mercury Measurement Research – Dr. Winston Luke, Oceanic and Atmospheric Research/Air Resources Laboratory**

   Air Resources Laboratory (ARL) has developed two low-cost capabilities for calibrating mercury measurement networks: (1) Mercury Inlet Calibrator and (2) a Gaseous Oxidized Mercury Source. The ARL calibration capabilities will increase the accuracy and utility of all commercial instruments widely deployed in monitoring networks. Cost-benefit Research & Development considerations have delayed commercial development of these devices, but NOAA Research has been and is developing these capabilities to further understanding of the mercury cycle. These new calibration systems cost $1000-2000 per system and need to be deployed to calibrate in-situ mercury monitoring equipment across areas of responsibility, both nationally and globally.

2. **Remote Sensing of Stream Discharge Estimation – Mr. Jonathan Gourley, Oceanic and Atmospheric Research/National Severe Storms Laboratory**

   National Severe Storms Laboratory, in cooperation with United States Geologic Survey has developed a non-contact stream discharge solution offering less chance of getting lost and no need for road access: a compact instrument package consisting of three instruments; a Doppler radar to measure velocity, a radar or ultrasonic sensor to measure stream height, and a scanning Light Detection and Ranging (LIDAR) that scans across the stream profile to penetrate and measure depth to the stream bottom. It is powered by a marine battery and solar panel. Data communications are enabled via 3G cell signal or Iridium. Year 1 cost is higher than the conventional stream gage, but subsequent maintenance should be much lower.

3. **A New Ground-Based Snow-Level Radar – Mr. Allen White, Oceanic and Atmospheric Research/Earth System Research Laboratory**

   Engineers at Earth System Research Laboratory have designed and built a frequency modulated, continuous- wave profiling radar. This instrument provides vertical profiles of radar reflectivity and Doppler vertical velocity from which the snow level (i.e., the level in the atmosphere where snow changes into rain) is retrieved during precipitation. A key innovation of this capability is that it provides continuous measurement of the snow-level during precipitation events. Snow-level radar

can also be used to detect the depth of the convective boundary layer during the warm season. This technology is useful for Aviation Weather. This is also useful for river forecast centers to determine and forecast runoff amounts and to improve warnings for winter weather hazards. Existing forecasts of snow level have significant errors compared with observations.

4. **Ground-based Network of Boundary Layer Profilers – Dr. Dave Turner, Oceanic and Atmospheric Research/National Severe Storms Laboratory**

The Ground-based Network of Boundary Layer Profilers network has provided continuous observations that characterize the vertical and temporal evolution of temperature, water vapor, aerosol backscatter, and winds in the boundary layer. The impacts of this technology could result in improved Numerical Weather Prediction models (after assimilation), real-time now-casting impact, better forecasting of severe weather due to the ability to monitor the evolving boundary layer, dispersion modeling, air quality modeling due to better characterization of the vertical structure of the boundary layer, and improved winter weather forecasts, especially the evolution of the freezing level. Better mesoscale analysis results in better numerical weather prediction forecasts which, in turn, results in improved forecasting for severe weather, aviation, hydrology, and renewable energy. These systems are small and can all be accommodated on a single 16-foot trailer and moved as needed.

5. **Traffic Camera Analytics in the National Mesonet Program – Dr. Curtis Marshall, National Weather Service/Office of Observations**

The National Mesonet Program is the largest National Weather Service (NWS) data-buy program, purchasing from both the private sector and from states. There are about 36 networks from which data are purchased. These thousands of ubiquitous traffic cameras can be used to supplement existing observing systems to determine fine-scale weather in the roadway environment. The private sector is developing the analytics using neural networks and fuzzy logic, and then generating probabilistic estimates of binary condition. Anticipated impacts for this technology include: integrating a "Weather Intelligence" capability to support NWS Weather Ready Nation, decision support services activities, leveraging a ready-made capability, improved NWS warning and forecasts for short-term, high-impact events that impact the roadway environment, as well as to the economic and emergency management communities. The Helios package is already developed. Rich data- source traffic cameras are now ubiquitous, even in rural areas. There are several weather forecast offices in Eastern Regions which are using this, and the first results are expected in early Fall. Program budget of National Mesonet Program is about $16M; traffic cams will be just a small part of that.

Ocean Session

Operating environment of observing systems that are located in the ocean; specifically, from the ocean surface to the ocean floor; bounded from the land by the mean low water level of the coasts.

Summary

The Ocean session featured emerging technologies focused on improving environmental measurements, lowering operational costs, and increasing operational efficiencies. Some technologies focused on increasing geographic coverage and reducing operational costs through partnerships, advanced unmanned systems, reducing system payloads, or automating biological sampling for genomics using autonomous underwater vehicles. Other technologies focused on improving or enhancing measurements of specific environmental parameters, including tsunami waves, sea floor mapping requirements, and measuring phytoplankton for harmful algal bloom forecasting.

Speakers highlighted the importance of non-federal partners, such as companies and academic research institutions, in supporting advancement of emerging technologies. Partnerships have helped NOAA scientists in a variety of ways, including filling technical gaps, addressing data management challenges, and expanding geographic coverage of observations. In one example, university partners assisted NOAA scientists with data acquisition, processing, and formatting challenges. In the case of Integrated Ocean Observing System underwater gliders, partnerships are used for both sustaining observation networks and technology development. Given that some technologies are spreading globally, it will be particularly important to utilize international partnerships to both standardize and consolidate operations and collaborate on data exchanges. While external partnerships provide a variety of opportunities, one speaker noted that money lost in overhead is sometimes a caveat of partnerships.

Workshop participants discussed the challenges associated with using and standardizing data sets. Speakers noted data latency issues due to off-ship data processing and the challenge of big data, particularly with regard to using bioinformatic capabilities to assess the genome sequencing process. Session participants also discussed the ability to adopt new sensors, specifically boundary layer sensors, noting that some technologies can take on new sensors either through auxiliary payloads or retrofitting new sensors.

The Ocean-based technologies presented at the workshop include:

1. **Self-Contained Ocean Observing Payload (SCOOP) – Mr. Lex LeBlanc, National Weather Service/National Data Buoy Center**

The National Data Buoy Center (NDBC) has developed a new Self-Contained Ocean Observing Payload (SCOOP) that improves upon and can be placed within the original buoy network. Improvements include a reduced latency to every 10 minutes, smaller battery developed with industry partner LithiumStart, smart modules that are quicker to put together at sea, and improvement on environmental measurements with modern sensors. The SCOOP was tested adjacent to 3m weather buoys to compare data collection and demonstrate the convertibility from the 3M buoy to the SCOOP while at sea. The SCOOP system is more cost-effective with the use of smaller vessels to transport to assembly sites for a less amount of time and can be installed on smaller platforms and buoys than the 3M buoy.

2. **U.S. IOOS National Underwater Gliders – Mr. Derrick Snowden, National Ocean Service/Integrated Ocean Observation System**

The Integrated Ocean Observation System (IOOS) Underwater Gliders network is a combination of a flexible platform for observations and a network for coordination. IOOS Underwater Gliders may be deployed and recovered from a wide range of platforms and cover a large geographic range. Gliders have the capability to measure numerous physical, chemical, and biological environmental parameters and thus support multiple mission service areas. The gliders have completed more than 45,000 glider days since 2008 and have supported long-term ecosystem monitoring efforts. A wide network of partners also enabled quick response observations for measuring oil presence in the water column after the Deepwater Horizon oil spill.

3. **3G ESP/LRAUV Mobile 'Omics Platform – Dr. Kelly Goodwin, Oceanic and Atmospheric Research/Atlantic Oceanographic & Meteorological Laboratory**

The 3rd Generation Environmental Sample Processor, Long Range Autonomous Underwater Vehicle (3GESP/LRAUV) is a mobile technology that conducts in-situ wet sampling, preservation, and analysis. The ESP, which fits in the payload section of a LRAUV, serves as an in-situ molecular biology lab and conducts adaptive sampling triggered by temperature, chlorophyll, or oxygen signals. The 3GESP/LRAUV can be deployed by small boats and contains 60 cartridges in each vehicle. Sampling occurs in cartridges, each outfitted with the necessary reagents for sample preservation or analysis of genomic information. The 3GESP/LRAUV was developed by the Monterey Bay Aquarium Research Institute and involves many partners.

4. **Unmanned Systems for Hydrographic Surveys – Mr. Rob Downs, National Ocean Service/Office of Coast Survey**

NOAA's Office of Coast Survey (OCS) has been working with four different types of unmanned vehicles for the past ten years to test their usefulness in hydrographic surveys. Both small AUVs and USVs have been used to meet the OCS's requirement to collect quality data while being rapidly deployable, low cost, very shallow water deployability, and collect some biological data like sea turtle assessments. The large AUVs have the ability to improve the deep water mapping by providing high resolution results. The large USVs are long endurance vehicles that have the potential to improve survey efficiency for the hydrographic survey missions. All these unmanned surveying vehicles will help the Coast Survey collect better and more data while increasing efficiency during the hydrographic surveys.

5. **DART-4G: Near and Far Field Tsunami Monitoring and Reporting – Mr. Chris Meinig, Oceanic and Atmospheric Research/Pacific Marine Environmental Laboratory**

The fourth Generation of the Deep-ocean Assessment and Reporting Tsunamis has improvements to the previous generation, has been deployed in different test sites that include the Oregon coast, Chile, and Alaska and include 39 US buoys and 60 International buoys. The buoy measures change in bottom pressure with a high resolution of ¼ mm change in water height, and sends the data from seafloor to desktop in 2 minutes. Although the system has not been able to capture a near field tsunami, the system measured a small earthquake on November 11, 2015 that produced a small tsunami, recorded by tide gauges, and the system was able to filter between the two signals successfully. The impacts of this new generation include greater reliability, flexibility by allowing new array configurations, and improve tsunami warnings to the near field citizens.

6. **Saildrone Development for Science Operations: From the Arctic to the Tropics – Mr. Chris Meinig, Oceanic and Atmospheric Research/Pacific Marine Environmental Laboratory**

Saildrone is a multidisciplinary platform that is solar and wind power oceanic unmanned surface vessel (USV). The Saildrone can carry 200 lbs. with 15 different environmental sensors, ranging from physical to oceanographic to meteorological, and can be used alongside echosounders used for fish stock assessments. With these different sensors the Saildrone has been able to contribute to the NOAA core missions. To test durability the Saildrone was sent out into the Bering Sea and completed 97 days at sea. To test the distance capability the Saildrone was sent on a transect from San Francisco to Hawaii, although with both of these tests the limit of endurance and the operational boundaries are still to be determined. The Saildrone can be used to address to service gaps for different Line Offices, increase operational efficiency, and reduce operational risk.

7. **Imaging FlowCytoBot (IFCB) – Mr. Marc Suddleson, National Ocean Service/National Centers for**

Coastal Ocean Science

The Imaging FlowCytoBot (ICFB) is an automated underwater microscope and flow cytometer that can count and identify phytoplankton. Invented at the Woods Hole Oceanographic Institute (WHOI), the IFCB is capable of generating up to 30,000 high resolution images per hour. The ICFB is a proven technology for Harmful Algal Bloom (HAB) detection and has the potential to improve HAB forecasts, inform fisheries surveys, and support water quality monitoring.

Space Session

Operating environment of observing systems that are located in space; specifically, bounded by the Earth's atmosphere, at least 100 kilometers above the Earth's surface and beyond.

Summary

In the Space session, NOAA satellite engineers discussed emerging technologies focused on filling future critical observation gaps efficiently, and the development of new innovative technologies. Currently, a central theme within Low Earth Orbiting satellites is the use and development of CubeSats. Not only are they small, making them cheaper to launch into orbit, but their parts are readily available and easily interchangeable, bringing down cost. CubeSats are an outstanding platform for testing new technologies. Three such technologies were presented: Earth Observing Nanosatellite-Microwave (EON-MW), Earth Observing Nanosatellite-Infrared (EON-IR), and Cyclone Global Navigation Satellite System (CYGNSS), representing great potential to enhance the NOAA mission. Innovative technologies such as the Compact Coronagraph and Satellite Radar Altimetry continue to support the NOAA mission by providing more efficient systems that deliver superior results.

NOAA currently has solar observing capabilities on GOES and DSCOVR. Geosynchronous satellites and those found at the Lagrangian Point are good platforms for the compact coronagraph. CubeSats are intended for gap mitigation with no current plans (next 20 years) to turn them into replacement systems. Transitioning CubeSats to the commercial sector and then making commercial data buys is possible, but NOAA would need to be sure of what it's buying and how the data was processed; it might require buying the raw data. Surface-based observations are important for validating space-based measurements, and observations from space- based systems can be combined with other systems for enhanced products. NWS requirements and other NOAA missions can influence satellite requirements if users state their requirements, but many do not for fear of having to contribute to the cost.

The Space-based technologies presented at the workshop include:

1. **Earth Observing Nanosatellite - Microwave (EON-MW) – Mr. Dan Mamula, National Environmental Satellite, Data, and Information Service/Office of Projects, Planning and Analysis/Research to Operation and Project Planning**

   EON-MW is a three-unit CubeSat being developed by the Space Systems Laboratory to integrate an MIT Lincoln Laboratory microwave radiometer payload with a three-axis stabilized CubeSat bus. The payload is a multispectral passive microwave radiometer that collects observations in the 118 GHz range, complementing existing on-orbit radiometer capabilities delivered by larger systems that

operate in other spectral bands. MicroMAS will provide unprecedented observations of the dynamics of hurricane and other large storm systems with significantly improved revisit times and comparable resolution to large polar-orbiting satellites.

2. **Earth Observing Nanosatellite - Infrared (EON-IR) – Mr. David Furlong, National Environmental Satellite, Data, and Information Service/Office of Projects, Planning and Analysis**

   EON-IR is a proposed constellation of low-cost CubeSats with compact infrared sounder instruments measuring atmospheric temperature and moisture profiles that could will allow for a more robust architecture that is more resistant to failures, and also allow for more frequent worldwide revisit times, lower latency, and better tracking of developing weather conditions. The constellation would have a global 30-minute revisit frequency in tropical latitudes to track hurricane development. The CubeSat advantages include standardization of parts and a large number of rideshare opportunities that can reduce the costs of space missions by an order of magnitude and potential for significant diversity in architectural implementations (e.g. inclination, revisit times, robustness). NOAA is working with the Jet Propulsion Laboratory (JPL) to study the possibility of achieving middle - wavelength infrared Cross-track Infrared Sounder performance specifications from a CubeSat Platform.

3. **Compact Coronagraph – Mr. Larry Zanetti, National Environmental Satellite, Data, and Information Service/Office of Projects, Planning and Analysis**

   NOAA is collaborating with the U.S. Naval Research Laboratory on the design of an operational Compact Coronagraph (CCOR). CCOR will provide solar coronagraph data continuity by replacing the aging SOHO/LASCA coronagraph capability. Data obtained from the CCOR will provide long lead-time forecasts of solar storms. The CCOR compact design reduces the sensor optical train by two thirds and the mass by one half when compared to current coronagraphs.

4. **Cyclone Global Navigation Satellite System (CYGNSS) – Dr. Paul Chang, National Environmental Satellite, Data, and Information Service/Center for Satellite Applications (STAR)/Satellite Oceanography and Climatology**

   The NASA CYGNSS mission will use a constellation of eight micro-satellites to measure wind speeds over Earth's oceans, increasing the ability of scientists to understand and predict hurricanes. Each satellite will take advantage of the fact that GPS satellites continuously broadcast highly defined radio signals towards the Earth. CYGNSS will measure the specular reflection of the GPS signal off the ocean surface in tropical latitudes. Smooth water in areas of low-wind stress produces a small reflective spot with a higher peak energy; as wind speed increases, the surface gets rougher and the

reflective spot gets broader and weaker. Having eight satellites in the constellation will dramatically reduce the temporal gaps with current ocean surface wind measurements. NOAA should be prepared to take advantage of this opportunity to obtain ocean surface wind speed measurements with higher temporal frequency.

5. **Satellite Radar Altimetry in Transition – Dr. Walter H.F. Smith, National Environmental Satellite, Data, and Information Service/Center for Satellite Applications and Research (STAR)/Satellite Oceanography and Climatology**

Satellite altimeters are nadir-looking active radars that measure the height, roughness, and backscatter of the patch of the Earth's surface beneath them. Over oceans, these measurements are used to derive sea level, wave height, and wind speed data that are used operationally by NOAA, Navy & Coast Guard. Over sea ice, land ice, and inland waters the data are used both operationally and in research. Advances in signal processing for CryoSat-2 and Sentinel-3 and currently planned for Sentinel-6/Jason-CS enables Doppler/Synthetic Aperture Radar (SAR) measurements to effectively reduce the measurement patch and increase the spatial definition of measurements from several kilometers to about 300 meters. NOAA STAR has developed "fully focused SAR altimetry," taking the SAR calculation all the way to 0.5 m along-track resolution. SAR altimetry may be able to furnish detailed swaths of altimeter data useful for high-resolution ocean circulation modeling.

Senior Executive Panel Discussion

Panel Members: VADM Manson Brown, Dr. Russell Callender, Mr. Craig McLean, Dr. Richard Merrick, RADM David Score, Dr. Stephen Volz

The workshop concluded with a panel comprised of senior NOAA leaders. The panel members provided their reactions to the workshop and the emerging technologies presented during the sessions. They agreed that the workshop was a great success and thanked the presenters, participants, and organizers. The workshop provided participants with a valuable opportunity to work across boundaries, establish connections, and identify areas for collaboration. By working together, collaborators can leverage the new technologies and optimize their capabilities to meet data gaps, improve affordability and support an integrated approach to managing observing systems.

Workshop Reflections

In their opening statements, panelists made observations and comments on the day's discussions, including:

- Trades are important when considering what systems to build in the future. There is a need to build not just a better system, but build the right system that complements NOAA's existing capabilities.
- Lack of system integration contributes to inefficiencies and potential underutilization of promising technologies.
- Trade spaces such as life cycle cost, end-to-end development, and data integration should be carefully evaluated when considering which new technologies should be expanded to a regional or global scale.
- Handling large data sets and supporting infrastructure around both new and existing observing systems is a challenge. In the context of fisheries, identifying relevant information within the data is often a challenge.
- Limited or static funding can make developing new technologies and transferring them to operations or service delivery difficult.
- When applying for funding the research community could have more success in NOAA and in Congress by explaining the ultimate goal of the research and its relevance to the mission.
- NOAA should embrace and understand what it means to be an innovative agency with a specific mission purpose outcome.

Question and Answer Session

During an open question and answer period, panelists engaged with audience members to discuss a series of challenges pertaining to effectively managing NOAA's observing systems portfolio. Discussion topics included long-term sustainment of the enterprise, observing systems portfolio management, the NOAA fleet, and NOAA's workforce management. Summaries are given below.

The end of the administration is approaching and the new NOAA leadership will be tasked with continuing the very consequential work that NOAA does for America. The panel explained that the best way to ensure the long term sustainment of the NOAA enterprise is to provide directives and processes that clearly articulate what NOAA is trying to achieve and a path for attaining that goal. Career employees can play an important role in maintaining the momentum that's already been achieved as new leadership is brought in.

The panel described how a rigorous and integrated user requirements process is important for the management of NOAA's observing systems. NOAA faces difficult decisions when working within a fixed budget. Reviewing and strengthening requirements generation, validation, and prioritization processes can help NOAA better support trade-space decisions. A strong user requirement process can also open up opportunities to expand the user base, identify new observing system applications, enable choosing between competing weather models, support arguments for a larger budget, and help communicate the value of NOAA's investment in observing systems to the public. Trades are made within the portfolio to increase performance and take advantage of extra resources and capabilities. Managing observing systems through an integrated, cross-line office approach will improve the health of the entire portfolio, provide a data set that is richer and more expansive, and make room to support research and development.

The panel also discussed challenges associated with NOAA's aging fleet. The NOAA Office of Marine and Aviation Operations (OMAO) is working with an independent review team to develop a high level recapitalization plan for the NOAA fleet. NOAA is engaging in ongoing conversations with the Hill and the Administration on how to sequence the recapitalization, and move the effort forward. Through international agreements for ship time, NOAA may be able to leverage the fleets of other countries.

Finally, senior leadership acknowledged the challenges associated with NOAA's workforce. NOAA has a very talented and dedicated workforce, but the workforce is stretched. The new hiring director has come up with a rebuilding plan, but it will take time to fill NOAA's 1,800 vacancies and more creatively use the workforce as it is intended to be used. NOAA has also put a diversity and inclusion campaign in place to create a safe, welcoming, and professionally challenging work environment for everybody.

Recommendations for Next Steps

The Emerging Technologies workshop provided a forum for individuals across NOAA to gather, to share, and to communicate new technology development and research. The workshop featured a diversity of exciting capabilities that could increase innovation, improve efficiency, and address gaps in meeting mission requirements. NOAA leadership provided key takeaways and recommendations for future work including:

- Improving integration of all its observing systems will help NOAA fulfill requirements and address gaps in environmental observations.
- Greater communication and collaboration across NOAA and its partners will be beneficial for integrating management of observing systems.
- Solid requirements processes and sound prioritization methods will help address mission efficiency, integration, adaptability, and affordability goals.
- Smaller, more targeted, and nimble technologies could improve the time needed for acquisition and development, while keeping costs down and maintaining pace with rapid technology advances.
- Considering emerging technologies during technical refresh cycles could help NOAA make more effective, efficient, and affordable investments with a better return of data per unit effort.
- Development of technologies that improve both data management and data accessibility will allow NOAA to more readily share its data with a broad range of users, including citizen scientists.
- Accepting both failures and successes will ensure that innovation within NOAA is not stifled.

NOAA has committed to institutionalizing the workshop as a NOSC-sponsored activity and as a tool for NOAA's decision making on observing systems management. The workshop will continue to showcase emerging technologies with potential value to meeting NOAA's mission and be expanded to include additional topics and themes, including managing new, incoming data streams. The participant list will also be expanded to maximize engagement with external partners such as other federal agencies, the private sector, and cooperative institutes.

Appendix 1: Agenda

08:30 - Welcome by Observing System Committee Co-Chairs: Richard Edwing and Joseph Pica

08:35 - Opening Remarks by VADM Manson Brown

08:40 - Keynote Address by Dr. Kathryn Sullivan

08:50 - Agenda overview, ground rules, and logistics by OSC Co-Chairs

09:00 - 10:30 Session I - Atmosphere

09:00 - 09:05 Intro - Charles Alexander (OMAO/PPMD)

09:05 - 09:15 The Coyote Unmanned Aircraft System: Advancing the Technology Readiness of Low Altitude Expendable UAS Observations in Hurricanes to Address Critical Data Gaps, Improve Understanding and Enhance Future Forecasts of Intensity - Change *Joe Cione (OAR/AOML)*

09:15 - 09:25 Low Altitude Rotary- and Fixed-Wing UAS Observations of Severe Storms to Fill Critical Data Gaps - *Steven Koch (OAR/NSSL) Bruce Baker (OAR/ARL)*

09:25 - 09:35 Applications of Small Rotary Wing UAS for Protected Species Research - *Wayne Perryman (NMFS/SWFSC)*

09:35 - 09:45 The Printed Optical Particle Spectrometer (POPS) and Miniature Scanning Aerosol Sun Photometer (miniSASP) Instruments - *Ru Shan Gao (OAR/ESRL/CSD) Troy Thornberry (OAR/ESRL/CSD), Contributor*

09:45 - 09:55 Integrative Hyperspectral Detection of HABS with Airborne and Handheld Sensors - *Steven Ruberg (OAR/GLERL) Andrea VanderWoude (OAR/GLERL), Contributor*

09:55 - 10:05 Unmanned Aircraft for Airborne Gravity Measurements - *Vicki Childers (NOS/NGS) Monica Youngman (NOS/NGS), Contributor*

10:05 - 10:30 Panel Q&A

10:30 - 11:00 Break & Posters

11:00 - 12:20 Session II - Terrestrial

11:00 - 11:05 Introduction - Kevin Schrab (NWS/OBS)

11:05 - 11:15 Novel Calibration Systems for Mercury Measurement Research - *Winston Luke (OAR/ARL)*

11:15 - 11:25 Remote Sensing of Streams for Discharge Estimation - *Jonathan Gourley (OAR/NSSL)*

11:25 - 11:35 A New Ground-based Snow-level Radar - *Allen White (OAR/ESRL)*

11:35 - 11:45 A Ground-based Network of Boundary Layer Profilers - *Dave Turner (OAR /NSSL)*

11:45 - 11:55 Traffic Camera Analytics in the National Mesonet Program - *Curtis Marshall (NWS/OBS)*

11:55 - 12:20 Panel Q&A

12:20 - 13:20 Lunch & Posters

13:20 - 15:00 Session III - Oceans

13:20 - 13:25 Intro - Alan Leonardi (OAR/OER)

13:25 - 13:35 Self Contained Ocean Observing Payload (SCOOP) - *Lex LeBlanc (NWS/NDBC) Michaela Elliott and James Elliott (NWS/NDBC), Contributors*

13:35 - 13:45 U.S. IOOS National Underwater Gliders - *Derrick Snowden (NOS/IOOS), Becky Baltes (NOS/IOOS) Gustavo Goni (OAR/AOML/PhOD), Contributors*

13:45 - 13:55 3G ESP/LRAUV Mobile 'Omics Platform - *Kelly Goodwin (OAR/AOML), Gregory Doucette (NOS/NCCOS) Timothy Davis (OAR/GLERL), Contributors*

13:55 - 14:05 Unmanned Systems for Hydrographic Surveys - *Rob Downs (NOS/OCS) LT Matthew Forrest (OMAO), Contributor*

14:05 - 14:15 Advancements in Tsunami Observing: DART-4G and Operations Improvements - *Chris Meinig (OAR/PMEL) Craig Kohler (NWS/NDBC), Contributor*

14:15 - 14:25 Saildrone Development for Science and Operations: From the Arctic to the Tropics - *Chris Meinig (OAR/PMEL) Jessica Cross (OAR/CPO), Contributor*

14:25 - 14:35 Imaging FlowCytoBot (IFCB) - *Marc Suddleson (NOS/NCCOS)*

14:35 - 15:00 Panel Q&A

15:00 - 15:30 Break & Posters

15:30 - 17:00 Session IV - Space

15:30 - 15:35 Intro - John Pereira (NESDIS/OPPA)

15:35 - 15:45 Earth Observing Nanosatellite - Microwave - *Dan Mamula (NESDIS/OPPA)*

15:45 - 15:55 Earth Observing Nanosatellite – Infrared - *David Furlong (NESDIS/OPPA)*

15:55 - 16:05 Compact Coronagraph - *Larry Zanetti (NESDIS/OPPA)*

16:05 - 16:15 Cyclone Global Navigation Satellite System - *Paul Chang (NESDIS/STAR)*

16:15 - 16:25 Satellite Radar Altimetry In Transition - *Walter H.F. Smith (NESDIS/STAR)*

16:25 - 16:50 Panel Q&A

16:50 - Leadership Panel - Senior Perspective, Information Gaps, Service Imperatives by VADM Manson Brown, Dr. Stephen Volz, RADM David Score, Dr. Russell Callender, Dr. Richard Merrick, and Mr. Craig McLean

17:20 - Closing Remarks by VADM Manson Brown

17:30 - Workshop Conclusion

Link to Workshop Dashboard: https://nosc.noaa.gov/OSC/noaa-etw-2016/index.php

Appendix 2: Poster Exhibits

Atmosphere:

- Topobathy (Topographic/Bathymetric) Lidar to support NOAA's Charting and Integrated Ocean and Coastal Mapping Activities – Mike Aslaksen, Stephen White, Gretchen Imahori, Jamie Kum, and Rodolfo Troche
- Improvements to the NOAA WP-3D Tail Doppler Radar to Improve Resolution and Sensitivity - David Jorgensen, Alan S. Goldstein
- POPS and miniSASP: Miniaturized instruments for aerosol particle sizing and aerosol optical depth measurements – Troy Thornberry, Ru-Shan Gao, and Daniel Murphy
- Aph-22 Hexacopter Application to Assessments of Protected Species: Better Data; Less Cost; No Disturbance - Wayne Perryman
- Integrated Hyperspectral Detection of HABS with Airborne and Handheld Sensors – Steve Ruberg , Andrea VanderWoude, Dack Stuart, Thomas Johengen, Brandi McCarty, Jim Churnside, Danna Palladino, Ashley Burtner
- A High Resolution Balloon-borne Microphysics Probe for use in Severe Weather - Sean Waugh, David Jorgensen
- Using the Global Hawk Unmanned Aircraft for Weather Monitoring and Forecasting – Gary Wick
- Unmanned Aircraft for Airborne Gravity Measurements – Monica A. Youngman, Vicki Childers

Terrestrial:

- Multi-Radar/Multi-Sensor Tools for Aviation – C. Bruce Entwistle, Heather D. Reeves
- Remote Sensing of Streams for Discharge Estimation – Jonathan J. Gourley, Daniel Wasielewski
- Innovative River Stage Gage - Crane Johnson
- Novel Calibration Systems for Mercury Measurement Research – Paul Kelly, Xinrong Ren, Winston Luke
- A Ground-based Network of Boundary Layer Profilers – David D. Turner, Steven E. Koch
- A New Ground-based Snow–level Radar, Allen White
- Improving WSR-88D (NEXRAD) Base Data Quality – Mike Istok

Oceans:

- NOAA/AOML – CARICOOS Hurricane Underwater Glider Operations – Gustavo Jorge Goni, Francis Bringas, Ricardo Domingues, Jili Dong, Grant Rawson, Julio Morell, George Halliwell, Sang-Ki Lee, Hyun-Sook Kim, Luis Pomales, Becky Baltes, Richard Bouchard, Yamil Rodriguez
- 3G ESP/LRAUV Mobile 'Omics and Toxin Detection Platform (building on success of 2G technology) – Kelly Goodwin, Gregory Doucette, Timothy Davis, Stephanie Moore, Linda Rhodes
- Real-Time Coastal Ocean Observing System to Support Safe Navigation and Enhance Environmental Intelligence along U.S. Arctic Coasts - Robert Heitsenrether, Winston Hensley, Eric Breuer, Warren Krug
- Deep Argo - Gregory C. Johnson, Dean Roemmich, Stephen Riser
- The PRAWLER, A Vertical Ocean Profiler Powered by Wave Energy - Christian Meinig, Jim Osse, Scott Stalin
- Saildrone Development for Science and Operations from the Arctic to the Tropics – Chris Meinig, Noah Lawrence-Slavas, Calvin Mordy, Jessica Cross, Heather Tabisola, Ned Cokelet, Meghan Cronin
- National Data Buoy Center Wave System Refresh - Rodney Riley
- Ecosystem Observations Technology Development - Steven Ruberg, Doran M. Manson, Ron Muzzi, Tom Johengen
- Remotely Obtaining Data from Ocean-Bottom Moored Instruments
  Adaptable Bottom Instrument Information Shuttle System (ABIISS) – Ulises Rivero, Pedro Pena, Grant Rawson, Andrew Stefanick, Thomas Sevilla, Christopher Meinen

Space

- Operational Algorithms for the Retrieval of Water Quality Parameters in the Great Lakes from Satellite Data - George Leshkevich, Robert Shuchman, Son Nghiem
- Argos Data Collection and Location System - Scott Rogerson

Technology, Planning, and Integration for Observation

- NOAA Observing System Integrated Analysis (NOSIA-II) Calibration using Sensitivity Studies – Aaron Pratt, David Helms, Sid Boukabara, Kevin Garrett
- NOAA Observing System Integrated Analysis (NOSIA) Integration with the Federal Earth Observation Assessment (EOA) Efforts – David Helms, Mark LaJoie, Robert Reining

Appendix 3: Post-workshop Survey

Upon conclusion of the workshop, the attendees were asked to respond to a number of questions including Dr. Sullivan's three challenge questions. Below is a summary and compilation of the answers that we received.

1. What, from outside your domain, strikes you as the most powerful idea for advancing NOAA's mission that you encountered at the workshop?

Mission

- Bring diverse experts together to discuss the topics and advancements across the four science domains and find collaborations in how they relate to the enhancement of NOAA's mission.

Requirements

- Ensure clear processes are in place for the generation and prioritization of requirements. Research efforts should be linked to actionable environmental intelligence needs or requirements.

Technologies

- NOAA should look at what needs to be observed, and explore the best technology to eliminate gaps.
- Unmanned vehicles show great potential for hosting needed sensors and instruments. Discussions across line offices could help to optimize funds/efforts to develop these systems and better meet mission requirements. Synergies between ground-based remote sensors and unmanned systems should be explored.
- Miniaturization of sensors to reduce size and weight can decrease cost and increase the ease of use. This technology allows for the potential use of Small Business Innovation Research (SBIR) which could allow for advanced technology to be applied in a broader range of situations.

Data

- NOAA needs innovations in the use of the ever increasing volume (and types) of data that will be made available to the agency and to the public for use on other projects.

2. From what you learned at the workshop, which ideas could have the greatest impact on the way you do business?

Technologies

- Utilize requirements to help in ship design and to find new ways to deploy platforms.
- The greatest impact to our mission will be the use of unmanned systems.
- Great attention should be dedicated to engineering customization to maximize cost reduction and data exactness.
- Being innovative is the only way we can move forward and advance capabilities given the

budget constraints and the increasing demands on the observing enterprise.

Communication

- NOAA needs to integrate observational data across all of the line offices, and a more efficient communication strategy within and outside NOAA to enhance our mission and better serve the American Public. NOAA must be able to communicate what it does and why it matters.
- Take advangement of more intra-agency and inter-agency involvement.

Data

- Commit more thought and resources to the collection, storage, and distribution of the increasing volumes of data.
- Search for integration of observations that would have the largest impact on improved NWP.
- Explore the idea of data driving the requirements.

3. What kinds of strategies or government structures would be most helpful for NOAA to adopt going forward in order to optimize our innovation and nimbleness?

Policy

- Establish a NOAA wide oversight and policy to guide the individual NOAA line offices in making selections of innovative approaches.
- NOAA should streamline processes by eliminating redundancy, simplifying procurement, and eliminating barriers. With appropriate oversight, policies, and guidelines in place, line offices can then meet their basic missions, and select innovative technologies more effectively.
- NOAA needs to review and define what its data sharing policies will be in the future. This greatly impacts the business model for all commercial companies that will potentially provide services to NOAA.
- Increased tolerance for failure and using science rather than budget to make decisions will improve the quality of NOAA's observing systems.

Technologies

- Increased benefits could be derived from an "instrument pool" that was supported by funding outside the labs (something like the NCAR Earth Observing Lab (EOL) instrument pool, or the Local Applications Database (LAD) for sharing AWIPS applications). This would provide a mechanism to acquire a number of instruments that could be deployed in field experiments or demonstration networks, but it would also be a resource that is open to use (perhaps via proposal) to all NOAA labs.
- Cost estimates and business cases need to be explored early on in the development process so that the utility of the new technology can be assessed against budget realities.

Communication

- There must be better cross line office communication, interaction and collaboration. Making the Emerging Technology Workshop an annual event, allowing greater attendance at other annual conferences and scientific workshops, and rotational assignments across programs and line

offices could help to improve methods development and research of new and existing observing systems.

- Improved interaction with organizations outside of NOAA, such as academia and the commercial sector, could minimize duplication of effort, enhance development of products and services, and optimize NOAA's innovation and nimbleness. Agreements with outside organizations to test/assess developing technologies within the context of NOAA's mission could help increase research and access to these technologies, while giving them greater visibility to NOAA's requirements.

NOAA Observing System Council (NOSC)

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Vice Chair (NWS)	Dr. Louis Uccellini	*Alternate:* Laura Furgione
Vice Chair (OMAO)	RADM David Score	*Alternate:* RADM Anita Lopez

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NOAA Chief Information Officer	Zack Goldstein	Doug Perry
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NMFS	David Detlor	Rebecca Shuford
NOS	Richard Edwing	Colleen Roche
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	Rob Mairs (TPIO)
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