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Transitioning NOAA Moored Buoy Systems From Research to Operations

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Abstract- **After the devastating Indian Ocean tsunami of December 2004 the eyes of the world searched for the tools to reduce the risk of such hazards in the future. Initiated under the National Tsunami Hazard Mitigation Program (NTHMP), the symbol of this effort has been the NOAA Deep-ocean and Assessment and Reporting of Tsunami (DART) station. With support from the President, over the next 18 months NOAA will expand deployment of the DART station network across the Pacific, Atlantic, Caribbean and Indian Oceans. But what more does this buoy represent? It represents operationalized science that will deliver data, change international policies, and forge new partnerships that serve multiple purposes. It has the promise of infusing research results into a 24-7 operational real-time warning system with fewer false alarms and set the stage for a tsunami forecast system that will help communities become more resilient to tsunami and related coastal hazards. This is of course a challenge with the high expectation that buoys must be part of a durable and sustainable network of observations, communications, and understanding. To deploy and maintain such a network is a test of technical, capacity, and fiscal commitment. To create and leverage partnerships and to harmonize the expertise of experts is required to achieve the desired benefits. But what else does it represent beyond budget constraints and personal challenges. It represents an opportunity for Government agencies to work with Academia and Industry to recognize a new focus on buoys to deliver the benefits of saving lives, property, economy and livelihoods across the globe. NOAA has protected and made available DART technology by working with all stakeholders, offering functional specifications and designing network capabilities. In recent weeks, commercial and industrial vendors have captured these lessons and begun delivering equipment and knowhow into the hands of individuals, organizations, and countries. NOAA considers this a success story but also only the beginning of what is the promise of the Integrated Ocean Observing System (IOOS) and the Global Earth Observing System of Systems. This somewhat simple buoy project within the Tsunami Program is a catalyst for real time information and knowledge, government-industry partnerships, and research to applications. In coming years we anticipate buoy stations becoming more multipurpose and multiuse, serving ecosystem, climate, weather, ocean, and commerce goals. At the same time, buoy-related IOOS and GEOSS projects will be vehicles for breaking down political and policy barriers by promoting data sharing and technology transfer. NOAA welcomes all buoy stakeholders to work with us and with new partners on research, operational, and commercial opportunities as we strive to deliver on the benefits of a truly global earth observing system of systems.**

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I. Introduction

NOAA's Tsunami Program is part of an international cooperative effort to save lives and protect property through hazard assessment, warning guidance, mitigation, research capabilities, and coordination. Warning guidance is accomplished by tsunami warning centers that acquire observational data from seismic, sea level, and deep-ocean bottom-pressure monitoring networks, process the data to assess the tsunami threat, and disseminate using a variety of communication systems to issue timely and accurate warnings and information bulletins to emergency management agencies and the public.

Strengthening the Tsunami Warning and Mitigation System

In the late 1990's, the National Tsunami Hazard Mitigation Program (NTHMP), a Federal-State partnership program led by NOAA, launched the research and development project that resulted in Deep-ocean Assessment and Reporting of Tsunami (DART) technology and associated forecast system science. Developed by NOAA's Pacific Marine Environmental Laboratory (PMEL) and operated by NOAA's National Data Buoy Center (NDBC), DART stations are deployed in regions where the historical record and hazard assessments suggest high exposure and vulnerability to tsunamis.

At the time of the devastating Indian-Ocean tsunami in December 2004, the U.S. was operating an array of 6 DART-I stations. These stations, of the first generation design, were only deployed in the waters of the Pacific. The data was intended to provide early warning for tsunami threats to the

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most exposed coastal communities of Alaska, Washington, Oregon, California, and Hawaii. Starting in 2005, the US Administration provided supplemental resources to strengthen and expand the tsunami early warning and mitigation system for all US assets. As a result, NOAA accelerated the transition from research to operations of a second-generation station, DART II, which is more robust and includes 2-way communication capabilities. Funding was also provided to continue research and development of multipurpose and easier to deploy technologies and advance the research to operations transition of the associated site-specific inundation forecast system. The final operational configuration of the strengthened DART II array will comprise 32 stations around the Pacific Ocean basin and 7 stations in the vicinity of the Atlantic, Caribbean and Gulf of Mexico.

Combined with parallel efforts to strengthen the network of real-time sea level (tide) gauges, broad-band seismic stations, data management and communications, NOAA is establishing a durable and integrated tsunami observing system. The new data streams provide input to NOAA's evolving forecast capability, using real-time observations with bathymetric and historical event data, for predicting the propagation and inundation of destructive tsunamis. The National Tsunami Hazard Mitigation Program and TsunamiReady education and outreach initiatives contribute to the desired outcome of developing resilient communities within a multi-hazard approach. NOAA's Tsunami Program achieves this goal by working closely with the United Nations Educational, Scientific, and Cultural Organization's Intergovernmental Oceanographic Commission (UNESCO-IOC), the World Meteorological Organization (WMO), and the Joint Commission on Ocean and Marine Meteorology (JCOMM) to ensure an interoperable and sustainable contribution to the Global Earth Observing System of Systems (GEOSS).

II. Operations

A. Operational and Research Requirements

NOAA's tsunami program requires maintaining a DART Network in a high state of performance, i.e. a network with percentage of data availability meeting the evolving needs of NOAA's two 24x7 operational Tsunami Warning Centers to fulfill their responsibility for hazard warning, forecasting and mitigation. The program requires ongoing acquisition of repair parts, consumables and spares. In support, NOAA requires service visits, which implies ships and crews for deployment and maintenance cruises. To maintain this capability requires a robust research and development activity and partnerships for ongoing improvement.

DART-II systems with bi-directional data communications hardware and service, via Iridium, provide network operators and researchers the opportunity to monitor status, conduct diagnostics and make corrective changes to the system. The key is the acquisition, processing, display, and utilization of DART data and integration with related data and information products. Examples in the tsunami application include testing and implementation of de-tiding algorithms for DART data. As is the standard for operational systems, NOAA monitors station performance statistics, and archives raw data. Operators must also maintain component and systems documentation appropriate for small scale production, change management, contracting, research and development. This includes functional and test specifications.

B. DART Station Overview

Deep-ocean Assessment and Reporting of Tsunami (DART) stations are moderately sophisticated. They are based on an anchored seafloor bottom pressure recorder (BPR) and moored surface unit for real-time communications. An acoustic link transmits data from the BPR to the surface buoy. The data are then relayed via satellite link to ground stations, which demodulate the signals for immediate dissemination to the NOAA's Tsunami Warning Centers. DART technology is capable of detecting tsunami amplitudes as small as 0.5 cm and reporting these data to a warning center within minutes of the warning center request for data.

The bottom unit is designed and built for recovery, refurbishment, and reuse. Theses place design constraints on the system for deployment and operation. The acoustics and electronics system includes a buoyancy system. The mooring must also operate in hazardous seas. The DART system uses a commercially available pressure sensor device along with custom designed and built hardware and software.

C. NOAA's Technical Capability

The technical staffs at NOAA's research and operational centers have a wide-ranging research and engineering background. Their experience includes long-term ocean deployment, mechanical, electrical and acoustic system design, sensor and power system packaging, concept development, prototyping, analysis, testing, proof-of-concept modeling, low quantity manufacturing, and transition to production. They develop and integrate active and passive ocean sensing and communication arrays, battery power sources, and have experience in free floating and moored buoys in harsh environments. NOAA's technical experience also includes oversight and acquisitions related to components and full service contracts for system integration, test, operation, and maintenance.

D. Transitioning Research to Operations

The transition of operational responsibility for the second generation DART II network from NOAA's PMEL to NDBC began prior to December 2004, but was greatly accelerated in the Spring of 2005. During this period, a team of NDBC personnel and contractors visited the research group a number of times, to exchange information and establish a time line and milestones to complete the transition. During subsequent visits, operational personnel and contract integrators became increasingly familiar with the DART-II system and the differences from the first generation. NDBC began purchasing of capital, expendable and test equipment necessary to ensure reliable integration and maintenance of the DART II network. Both groups worked together to develop operational documents, assemble and test components, and further characterize the prototype systems. During the

transition periods, operational staff and contractors completed assembly and testing of the new design, including the bottom pressure recorder sensors and cables, batteries, electronics, and other system upgrades. My March, the operational team was confident in their ability and hardware system declared transitioned. By early April the software and documentation were also considered transitioned with NDBC accepting logistical responsibility for the network. PMEL shipped spare parts and provided a buoy to help meet the aggressive timeline of deployment.

E. Opportunities and Partnerships

Soon after the devastating tsunami of December 2004, nations of the world looked to the U.S., and in particular to NOAA, for leadership in marine technology for tsunami hazard mitigation. However, DART technology was not commercially available and the research to operations capacity of NOAA or U.S. industry was not immediately in a position to respond. Moreover, it was not obvious whether there was a suitable market and business model to validate research to commercialization.

After such an event is clearly not the time to begin looking at transitioning technology. The keen interest in DART technology has made many in U.S. government, industry and academia to re-examine the portfolio of marine research and technology as well as the pipeline from research to commercialization and roles of public-private partnerships. It is the priority of technical agencies in the government to provide comprehensive, sustainable and affordable operational services to the nation. Applied and developmental research is focused on addressing mandates and identifying the results of research that may fill gaps in operational capacity and capability. DART technology was the result of such a push and pull. But taking a closer look at the challenge may reveal opportunities for partnerships.

To ensure the technology would be made widely available and consistent with national and intergovernmental policy for free and open exchange of relevant data for hazard risk reduction NOAA filed a patent. Researchers and operators also published functional specifications and held workshops on the nature and potential contribution of the technology.

Meanwhile other researchers, countries and business groups began to either integrate systems of their own or investigate the possibility of adding bottom pressure sensing capabilities to their existing buoys. To date no operational data from these other systems is available. The US is prepared to work with all those willing to share and exchange data. The US is also interested in expanding and accelerating science and technology partnerships to develop enhancements, new practices, and sustainable solutions.

DART-like technology will be operated by a limited number of other suppliers, domestically or internationally. This means that there are great benefits to be gained from pooling research, development and production activities where possible and appropriate. In some cases the technologies involved will be sourced from the private sector.

NOAA is exploring the feasibility of combining DART and traditional operational buoy requirements on a single platform. Next generation easier to deploy technology is also being prototyped by NOAA research. Miscellaneous improvements and development in sensors, electronic and power components, packaging, materials, design and software are also required.

NOAA encourages DART partnerships for cooperation on the research, development, production, deployment, operation and maintenance of DART instruments, buoys and moorings. The aim of such partnerships is to support operational tsunami detection and warning systems, including the Pacific Ocean, Atlantic/Caribbean/Gulf and Indian Ocean Tsunami Warning and Mitigation Systems.

Such partners should be committed to sharing pre-competitive information about research, development, production, operation and maintenance to the maximum extent possible.

The purposes of the Partnership are to:

- Set common DART standards, including with regard to a testing and calibration protocol that seeks to ensure that DART data are consistent, comparable and available to the maximum extent possible
- Establish, coordinate and support international DART research and development efforts, including joint activities
- Maximize the sharing of DART technology among partners to facilitate the production of DARTs worldwide
- Cooperate where appropriate on the testing and calibration of DART instruments, buoys and moorings
- Maximize opportunities for coordination and cooperation among Partners with regards to the siting, deployment, operation, maintenance and support of DART instruments, buoys and moorings

Partners should recognize that there are important benefits to be gained from producing and assembling DARTs in a collaborative manner, including in terms of standardization, agility, efficiency, effectiveness, and redundancy.

III. CONCLUSIONS

Government, industry, and academia have opportunities to look at new business models appropriate for involvement in transitioning marine technologies. The DART market is small so it is expected to be of limited interest to small suppliers. Nevertheless it is an example of the type of application of components and services that bring attention to the quality, reliability and capability of U.S. products and services.

DART technology may not lend itself to a strong business case for the private sector but it has raised awareness to transition marine research to operations and government technology solutions to commercialization. The lessons to be observed include making more available science and technology partnerships to stimulate economic growth in marine technology. This has both domestic and international implications and challenges the current policy and practices.