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Tsunamis: Monitoring, Detection, and Early Warning Systems

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Summary

Congress is concerned about the possible vulnerability of U.S. coastal areas to tsunamis and the adequacy of early warning for coastal areas. This stems from a December 26, 2004 tsunami that devastated many coastal areas around the northern Indian Ocean, where few tsunami early warning systems currently operate. Caused by a strong underwater earthquake off the coast of Sumatra, Indonesia, the tsunami claimed an estimated 220,000 lives. In December 2005, President Bush's plan for expanding U.S. tsunami detection and early warning coverage was released. Nations affected by the Indian Ocean tsunami, assisted by other counties, are pursuing multilateral efforts to develop a regional tsunami detection and warning network for coastal populations around the Indian Ocean (IOTWS). The U.N. Intergovernmental Oceanographic Commission (IOC) of UNESCO is leading that international effort. To leverage costs of the IOTWS, IOC members suggested "piggy backing" on existing distributive ocean observation and monitoring networks, data collection systems, marine buoys and tide gage networks, and global telecommunications systems, which may pose technical challenges in standardizing communications protocols and ensuring interoperability of systems. The Bush Administration and congressional supporters consider a fully deployed U.S. network an important component of a future *global* tsunami warning capability.

Expansion of the U.S. tsunami early warning network was expected to cost millions of dollars to include building the infrastructure and maintaining operations over the long-term. Some have argued that the benefits far outweigh the costs; others question whether the risks of tsunamis outside the Pacific Basin justify the investment. President Bush pledged nearly $40 million to expand the U.S. tsunami early warning network from six deepwater tsunami detection (DART) buoys, to the 20 now operating, to a planned total of 39 sited in the Pacific and Atlantic Oceans, Gulf of Mexico, and Caribbean Sea. Emergency appropriations for FY2005 funded initial procurement and deployment of a comprehensive detection and warning network. The President has requested funding to complete the task. Also, the 109th Congress has approved legislation to fund long-term needs of the U.S. network, such as maintenance, and address social issues, such as education and risk adaptation.

Some developed countries bordering on the Indian Ocean currently operate tsunami warnings systems, but guarding their Pacific shores. Disaster management experts contend that a global tsunami early warning system capability is most useful in countries that have expansive regionally/locally based emergency management capabilities. Yet, in some areas of these and neighboring countries a communications infrastructure to receive and disseminate tsunami warnings is wanting. Thus local officials may be incapable of rapidly alerting populations to evacuate or to take appropriate safety precautions. Emergency experts also assert that disaster planning is not only about issuing tsunami warnings, but also educating indigenous people and visitors about the potential dangers in the area; being able to clearly communicate evacuation options; adapting to potential risks through construction of public shelters; conducting periodic evacuation drills; and producing tsunami inundation maps for guidance for future land-use planning. This report will not be updated.

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Introduction

On December 26, 2004, a tsunami disaster was triggered by an underwater earthquake off the west coast of northern Sumatra in Indonesia. Based on physical evidence of displacement of the sea floor, U.S. seismologists determined the earthquake to have been a M_w 9.2.[1] The ensuing tsunami devastated many coastal areas around the northern Indian Ocean; the earthquake caused economic upheaval in many areas. International disaster agencies estimated that more than 220,000 people may have lost their lives as a direct result of the tsunami.[2] The disaster prompted some Members of the 109th Congress to raise questions about (1) the possibility of tsunamis occurring in U.S. coastal areas; (2) the extent to which these areas are currently monitored; (3) how tsunamis can be detected; and (4) whether there is a national capacity to issue evacuation warnings for tsunamis.[3]

On January 5, 2005, the House Science Committee House Coastal Caucus and House Oceans Caucus co-sponsored a briefing organized by the U.S. Geological Survey (USGS) of the Department of the Interior whose purpose was to consider possible implications of the type of the tsunami disaster that occurred in the Indian Ocean for the United States. Experts from USGS and the National Oceanic and Atmospheric Administration (NOAA) of the Department of Commerce delivered presentations at the briefing about the scientific circumstances surrounding the Indian Ocean tsunami and discussed global capabilities for tsunami monitoring, detection, and early warning.[4]

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[1] M_w, the moment of magnitude, is a way to measure the force of an earthquake's total seismic energy released as a function of rock rigidity in the fault, the total area of contact where friction occurs, and the amount of slippage (or displacement). It is used for earthquakes greater than M8.2 on the Richter scale.

[2] U.N. World Health Organization, Department of Health Measurement and Information Systems, "Asian Tsunami: Death-Toll Addiction and its Downside," by Michel Thieren, available at [http://www.who.int/bulletin/volumes/83/2/82.pdf], accessed Oct. 11, 2006.

[3] A tsunami is a seismic sea wave (or a series of waves) usually generated by an underwater earthquake or landslide, but occasionally is caused by volcanic eruption or major landslide *into* the ocean. Tsunami is translated from Japanese as "harbor wave."

[4] Presenters at that briefing included, David Applegate, Science Advisor for Earthquake and Geological Hazards at the USGS; General David Johnson, Assistant Director of NOAA's National Weather Service; Gregg Withee, Assistant Director for NOAA Satellite and Information Services; and, Eddie Bernard, Associate Director of NOAA's Pacific Marine Environmental Laboratory (teleconferencing from Seattle, WA).

Scientists and emergency experts assessing the damage in the wake of the tsunami disaster found that there were few, if any, systems for monitoring tsunamis in the Indian Ocean on December 26, 2004, and little, if any, capability to warn populations locally. Some nations affected by the tsunami that were also bounded by the Pacific Ocean, including Australia and Indonesia, had tsunami early warning systems monitoring their Pacific shores where they perceived the greatest threat however.[5] Due to geographic proximity of many human settlements to where the tsunami was generated, and without ability to receive tsunami warnings rapidly, some post-disaster assessments indicate that for Indonesia's Indian Ocean coastal populations, emergency communications would have been useless in many cases. Other findings show that (1) many indigenous people and tourists were not educated about the dangers of tsunamis; (2) they were not aware of the physical warning signs of an onset of a tsunami; and (3) no procedures were included in local or regional emergency plans for issuing evacuation alerts in the event important "lifelines" such as electric utilities and telecommunications were disrupted.[6]

On January 29, 2005, the House Committee on Science, and on February 2, 2005, the Senate Committee on Commerce, Science, and Transportation held hearings about the need for expanding tsunami early warning protection for the United States and its possessions. Also discussed were long-term goals for guarding non-U.S. coastal regions. Legislation introduced in the 109th Congress prior to these hearings by Senator Lieberman of Connecticut (S. 34) and Senator Inouye of Hawaii (S. 50), among others, called for a rapid U.S. response to upgrade existing U.S. capacity for tsunami warning in the Pacific, and to expand operations to include the Atlantic Ocean, the Gulf of Mexico, and the Caribbean Sea. Senator Inouye's bill was closely aligned with President Bush's initial proposal for U.S. tsunami protection released on January 14, 2005.[7] In contrast, S. 50 also addressed related social issues such as tsunami disaster education, local emergency preparedness, adaptation, and mitigation. (See "Tsunami-Related Legislation.")

Although most deadly tsunamis have occurred historically in the western Pacific Ocean, there are examples of recorded events in the eastern Pacific and North Atlantic Oceans going back centuries. In 1692, a tsunami generated by massive landslides in the Atlantic Puerto Rican Trench reached Jamaica's coast, causing an estimated 2,000 deaths. In 1775, a tsunami struck in the eastern Atlantic Ocean on the coast of Portugal, killing an estimated 60,000 people. More recently, in 1929, a

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[5] General David L. Johnson, "NOAA Tsunami and Natural Disaster Information," Jan. 5, 2005 House briefing.

[6] Lifelines are emergency response services, hospitals, other care facilities, energy and water delivery systems, telecommunications, and electronic commerce. See U.S. Congress, Senate, Committee on Commerce Science and Transportation, *Earthquake Hazards Reduction Act*, report to accompany S. 910, 105th Cong., 1st sess., S.Rept. 105-59 (Washington: GPO, 1997), p. 3.

[7] U.S. Office of Science and Technology Policy, "U.S. Announces Plan for Improved Tsunami Detection and Warning System," press release, *OSTP News*, Jan. 14, 2005, available at [http://www.ostp.gov/html/Tsunamiplanrelease.pdf], accessed Dec. 1, 2006. See also Eli Kintisch, "South Asia Tsunami: U.S. Clamor Grows for Global Network of Sensors," *Science*, vol. 307, Jan. 14, 2005, p. 191.

tsunami generated in the Grand Banks region of Canada hit Newfoundland, killing 51 people. It was the third lethal tsunami for Canada's Atlantic Coast within 150 years.[8]

A Global Tsunami Early Warning System?

Many international scientific agencies foresaw considerable challenges to be overcome before an extensive tsunami early warning network for the Indian Ocean and other earthquake-prone areas such as the Black Sea could be established. In some ways, developed nations that had the resources and capability to establish their own regional emergency management networks for disaster warning and who had executed comprehensive disaster plans were able to avoid some of these challenges.

Challenges

Development of "truly global" tsunami early warning system with a capability for issuing regional and local warnings has required involvement of many nations with widely varying technological capabilities and financial resources. Reports indicate that international political leaders expected that most of the responsibility for paying for such a system would fall on the wealthiest nations. Procurement of state-of-the-art monitoring and detection technology; operations and maintenance of scientific instruments, platforms, and communications networks; and sustaining international cost sharing appear to be the most critical challenges for long-term, collaborative international effort for tsunami detection and early warning.

After the Indian Ocean tsunami disaster, international science agencies called for an inventory of existing capacity for tsunami monitoring, detection, and warning systems to be conducted under the auspices of the United Nations. That inventory would represent a baseline from which outstanding requirements for a global network would be determined. Government policy analysts also raised technological and national security issues as further challenges to building and sharing a truly "global" tsunami early warning network. Technological issues included standardizing international tsunami warning instrumentation, data collection, communications protocols for systems relaying and receiving data and issuing warnings. National security issues involved proposed open access and possible sabotage of international telecommunication networks. U.S. intelligence experts were concerned that certain data collected could be considered sensitive and revealing collection methodologies could compromise nations' intelligence-gathering operations.

At a January 2005 House briefing, Assistant Director of NOAA for Satellite and Information Services, Gregg Withee, raised yet another challenge when he testified that some nations, including India, maintained proprietary rights to all of their real-time satellite data. Some of these data, he asserted, could be critical for detecting and

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[8] Statistics on deaths resulting from tsunamis were compiled by CRS from online sources, including data from the Tsunami Laboratory of Novosibirsk, NOAA's National Geophysical Data Center, the University of Southern California, Tsunami Research Group, and others. See [http://geology.about.com/library/bl/bltsunamideathtable.htm], visited Jan. 11, 2005.

tracking tsunamis in the Indian Ocean, and for assessing post-disaster damage, leaving many tsunami monitoring institutions having to pay for them.[9]

International Proposals

On January 6, 2005, the United Nations proposed an international effort to develop a tsunami early warning capacity for potentially vulnerable populations located on Indian Ocean coasts. That endeavor is being spearheaded by the U.N. Educational, Scientific, and Cultural Organization (UNESCO)'s Intergovernmental Oceanographic Commission (IOC) for which the United States is a member. Australia, Japan, Thailand, and India also have individual initiatives that would expand existing monitoring capacity for Indian Ocean coastlines.[10] Thailand held a ministerial meeting in Phuket, January 28-29, 2005, on tsunami early warning protection for the Indian Ocean and Southeast Asia. The United States was represented by President Bush's Science Advisor and Director of the Office of Science and Technology Policy, John Marburger III.[11]

On a related matter, on February 15, 2005, in Brussels, Belgium, IOC members finalized plans for an international global ocean observing system (IGOOS). IGOOS, they noted, might serve as the physical network for a regional tsunami early warning system for the Indian Ocean (IOTWS). A month later, in March 2005, experts from Indian Ocean countries affected by the December 26, 2004 tsunami along with other countries convened a U.N. IOC summit in Paris, France. The Director of the UN International Strategy for Disaster Reduction (ISDR) chaired the event.[12] IOC officials stated the purpose of the session was to firm up plans for an internationally coordinated tsunami early warning system for the Indian Ocean and solicit members' financial pledges.

Communication of Tsunami Warnings. The Director of NOAA's National Weather Service (NWS), Brig. Gen. David L. Johnson, USAF, (Ret.), who

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[9] Gregg Withee, January 5, 2005 House briefing. Stefan Maus of NOAA's National Geophysical Data Center (NGDC) of the NOAA Environmental Satellite program (NESDIS) visited India Oct. 22, 2005 to Nov. 20, 2005 to enhance the exchange of geomagnetic data for space weather, main field, and crustal field modeling. See [http://www.ngdc.noaa.gov/products/news_archive_2005.html], accessed Feb. 15, 2006.

[10] British Broadcasting Corporation, "Indian Ocean Tsunami Warning System, *BBC News*, Dec. 23, 2005, available at [http://news.bbc.co.uk/2/hi/science/nature/4524642.stm], visited Dec. 1, 2006. "Thailand, India and Indonesia are forging ahead with their own systems and Australia, Malaysia and Singapore are planning to develop warning capacities."

[11] U.S. Executive Office of the President, Office of Science and Technology Policy, "OSTP Director John Marburger to Head U.S. Delegation at Thai-Sponsored Meeting to Develop Tsunami Early Warning System for Indian Ocean and Southeast Asia," press release, Jan. 27, 2005.

[12] UN ISDR, "Meeting in Paris to Plan Tsunami Early-Warning System," Press Release: IHA/1019 (Geneva, Mar. 1, 2005). See also, ISDR, *Proposed Strategy for Building Resilience to Tsunamis in the Indian Ocean 2006-2008*, Jan. 27, 2006, available at [http://www.unisdr.org/asiapacific/ap-iotsunami/proposed-TEWS-strategy-2006-2008.pdf], accessed Oct. 5, 2006.

also testified in January 2005 congressional hearings, emphasized that in addition to operating a capacity to monitor and detect possible tsunamis, an emergency communications infrastructure for further disseminating tsunami warnings regionally or locally is critical for safeguarding Indian, western Atlantic, and far Pacific Oceans coastal populations. He noted that NOAA's responsibility for tsunami warnings terminate after communications are relayed to international emergency management officials.[13] He added that in the United States forecasts and warnings of severe weather issued by local or regional NWS weather forecast offices are picked up and distributed by local emergency managers and the broadcast media. The NWS directly broadcasts warnings to individuals and institutions possessing NOAA Weather Radio receivers. He noted that in terms of global adequacy, observers of international disasters have cited varying capabilities for relaying public emergency warnings and that some regions are at risk for tsunamis, a local disaster management capacity may be inadequate or non-existent.

NOAA's Administrator, VADM Conrad C. Lautenbacher (Ret. Navy) who is spokesperson for developing and implementing an international, collaborative Global Earth Observing System of Systems (GEOSS), an initiative supported by President Bush, also has addressed international tsunami detection and warning capabilities. Billed as "an excellent example of science serving society," and noted, the GEOSS infrastructure will be built from extant data collection platforms, telecommunications capabilities, and environmental observation systems and communication networks operating around the world.[14] One of the international networks proposed to be part of GEOSS is an International Global Ocean Observing System (IGOOS). Another is a network of thousands of ARGO floats that are monitoring global climate in the equatorial Pacific, known collectively as the ARGO Array. (See "Tsunami Detection Operations.") Through the interoperability of GEOSS and IGOOS, the United States would assist other IOC members in developing an Indian Ocean tsunami early warning capacity and eventually a global network.[15]

On February 16, 2005, the United States Group on Earth Observation (US GEO) along with international science ministers met in Brussels, Belgium, to adopt a 10-

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[13] U.S. Congress, Senate Committee on Science, Commerce and Transportation United States, *Tsunami Preparedness*, hearing, Feb. 2, 2005. Oral testimony of Brig. Gen. Jack Kelly, Jr., former NWS Director, and present Deputy Administrator for NOAA on behalf of Vice Admiral Conrad Lautenbacher, Jr. (U.S. Navy, Ret.) Undersecretary of Commerce for Oceans and Atmosphere and NOAA Administrator, National Oceanic and Atmospheric Administration, Department of Commerce.

[14] U.S. Dept. of Commerce, NOAA, Office of the Federal Coordinator for Meteorology, "World Weather Program: The Global Observing System: Its Impacts and Future," by BGEN John J. Kelly Jr., (USAF, Ret.), *The Federal Plan for Meteorological Services and Supporting Research: Fiscal Year 2006*, Report FCM P1-2005, Appendix B: 237-243 (Washington, DC: October 2005). Other examples of international communications networks are included.

[15] Gen. David Johnson, Jan. 5, 2005 House briefing. For more information on ocean observing systems, see U.S. Congress, House Resources Subcommittee on Fisheries, Conservation, and Wildlife, *Status of Ocean Observing Systems in the United States*, Oversight Hearing, serial no. 108-102, July 13, 2004 (Washington, DC: GPO, 2005).

year implementation plan for GEOSS. The European Union hosted the event that was attended by representatives of 61 countries. Since then, U.S. funding commitments and its role in global tsunami warning efforts is unfolding as GEOSS is being implemented.[16] Most international science agencies and non-governmental organizations representing Indian Ocean nations generally support GEOSS as the primary infrastructure for a global tsunami early warning network. Many also praised President Bush's January 2005 proposal and his July 2005 "action plan" for the U.S. tsunami warning system as "a good start" for a global system.

During discussions on developing new generation state-of-the-art deep water tsunami detection instruments and deploying other ocean and coastal observing systems, Congress has urged that whatever technology is adopted to upgrade the U.S. tsunami warning network, it serves multiple purposes so as to support other environmental observations systems, such as the GEOSS and IGOOS.

U.S. DART Buoys for the Indian Ocean. At a May 2006 meeting in Melbourne, Australia, the United States laid out plans for lending two of its state-of-the-art DART II buoys for "operational detection of tsunami and verification of non-events in the Indian Ocean." This, and similar contributions from other developed countries such as Germany, is helping to establish a prototypical IOTWS."[17] The NWS selected two sites outside the limits of any single nation's Exclusive Enterprise Zone (EEZ): (1) near the Andaman Islands off Sumatra, Indonesia (0°N) and (2) between Colombo, Sri Lanka and Phuket, Thailand (9°N). The first U.S. DART II is to be deployed in December 2006. The second deployment is scheduled for May 2007. Although the United States (NOAA) would not service these buoys in the Indian Ocean, NOAA officials say that they would provide technical assistance and funding for O&M through whatever entity would manage the IOTWS-at-large. The ICG/IOTWS is established as the governing body of the IOC for Indian Ocean states. Strategies to fund a "tsunami watch capacity," including long-term O&M of the IOTWS, are being discussed. Members discussed the inherent interoperability of technologies, such as DART buoys, ARGO floats, and tide gauges in environmental observation. They noted that development and operation of the IOTWS provided opportunities for hosting other environmental sensors. Moreover, they noted joint use of international fleets would assist deployment and maintenance of the buoys.[18]

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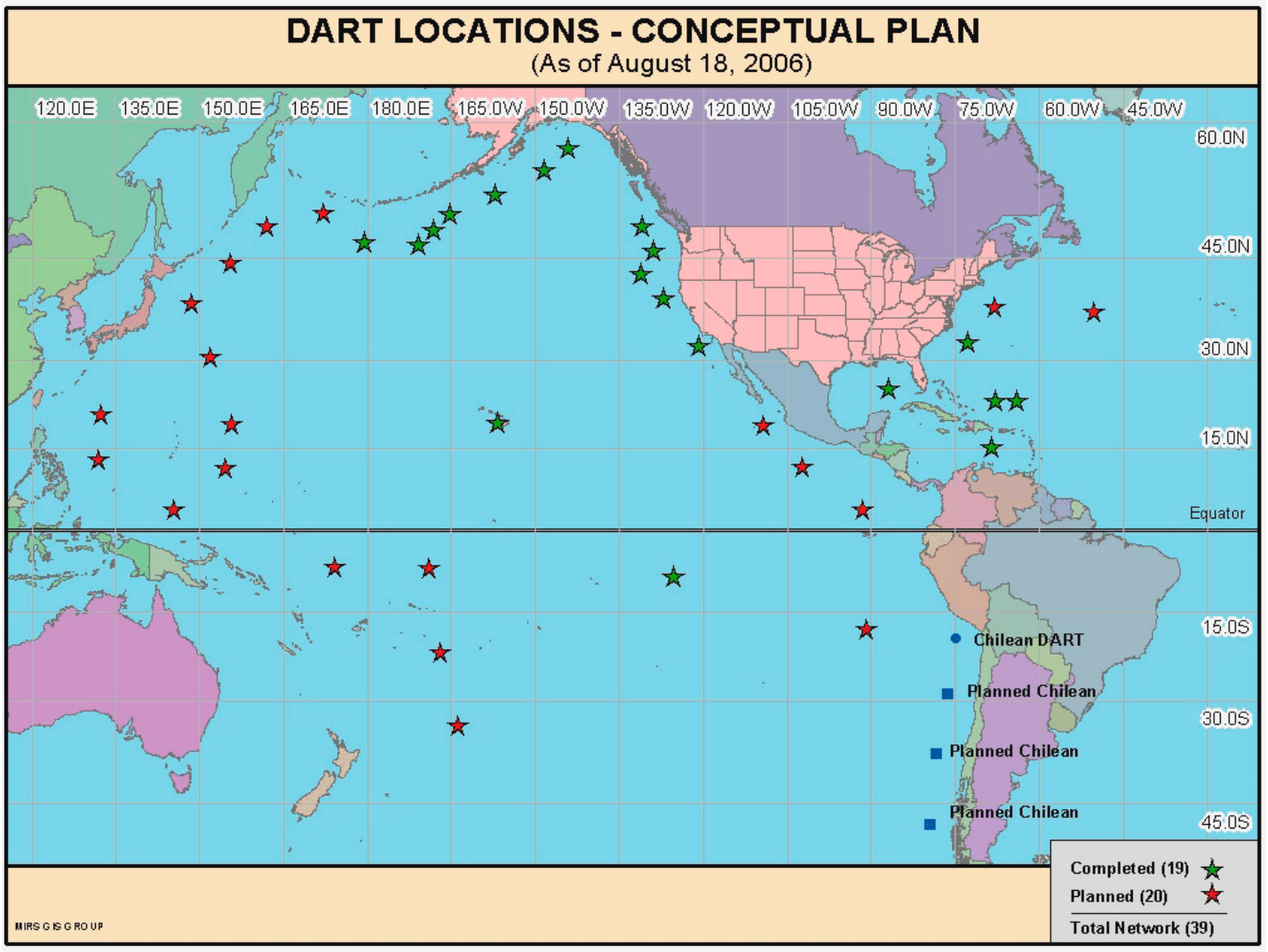
[16] Written testimony of Hon. John Marburger III, Director of the Office of Science and Technology Policy, Feb. 2, 2005.

[17] ICG/IOTWS Working Group 2 on Sea Level Data Collection and Exchange, Including Deep Ocean Tsunami Detection Instruments, *Draft Minutes: Annex IV, Proposal by U.S. for Contribution of two DART buoys to the IOTWS*, in Inter-sessional Meeting, 1-2, May 2006, Melbourne, Australia, pp. 16-25, [41 p.], available at [http://ioc3.unesco.org/indotsunami/documents/wgfiles/WG2%20Intersessional%20meeting%20report%20Melbourne.pdf], accessed Oct. 5, 2006.

[18] IGO/PTWS Coordination Group, Article 4.9, p. 8.

Figure 1. Proposed U.S. Dart Buoy Network



Source: National Oceanic and Atmospheric Administration. "NOAA Adds Four New DART Buoys to the U.S. Tsunami Warning System," *NOAA News*, August 21, 2006. Available at [http://www.noaanews.noaa.gov/stories2006/s2685.htm], accessed Oct. 5, 2006.

Tsunami Protection for the United States

Although some Members of Congress were on record as supporting an international effort to build a regional tsunami detection and warning system for the Indian Ocean after the December 2004 disaster, Representative Pallone of New Jersey was the first to call for establishing a tsunami detection and warning network for the U.S. Atlantic coast, Gulf of Mexico, and Caribbean Sea.[19] However, other lawmakers questioned whether the risk of a tsunami for the U.S. western Atlantic coasts justified such expenditures. To assure that the risks were real, in January 2005 congressional briefings, NOAA scientists emphasized the potential dangers related to the Puerto Rican Trench — the deepest point in the western Atlantic Ocean.[20] They cited massive landslides and sloughing that are occurring historically along the face of North American continental shelf and advised of strong underwater earthquakes that have occurred off the coast of Puerto Rico, and in some cases have generated tsunamis that caused major loss of life and property damage.[21]

One U.S. Atlantic coast state, New Hampshire, has a contingency plan for tsunamis emergencies and it also manages a clearinghouse of information about historical tsunami disasters that have affected the northeast United States.[22] In 2005, two U.S. communities in the western Atlantic basin received notoriety for having become the first NWS *TsunamiReady* communities outside the Pacific Basin. One of these was in Florida on the Gulf of Mexico and the other was Norfolk, VA, on the mid-Atlantic Coast.[23] Since then, five east coast states and Puerto Rico have been declared *TsunamiReady* by NWS. In contrast, some potential areas for tsunamis in the U.S. Pacific coast states, including Alaska and Hawaii have had tsunami emergency evacuation plans in place for 40-60 years.

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[19] Statement of Representative Frank Pallone, *Congressional Record*, Jan. 4, 2005: H40. "There has been a lot of discussion and I think there is a need to expand the tsunami early warning system that exists in the Pacific not only to the Indian Ocean but also possibly to the Atlantic Ocean and throughout the world."

[20] USGS, Woods Hole Science Center, "Caribbean Tsunami and Earthquake Hazards Studies Program," available at [http://woodshole.er.usgs.gov/projects/project_get.php?proj=29210EQ&style=html], accessed Feb. 15, 2006.

[21] See "The Puerto Rico Trench: Implications for Plate Tectonics: Earthquake and Tsunami Hazards" at [http://oceanexplorer.noaa.gov/explorations/03trench/trench/trench.html] and also, University of Puerto Rico at Mayaguez, The Puerto Rico Warning and Mitigation Program at [http://poseidon.uprm.edu], both accessed Oct. 11, 2006.

[22] State of New Hampshire, "Disaster Plan 409," Sect. II, Geological Hazards, Seismic Hazards, at [http://www.nhoem.state.nh.us/mitigation/state_of_new_hampshire.asp], accessed Jan. 11, 2005. See also NOAA, National Weather Service *TsunamiReady* Program, "Is your Community Ready for the Next Tsunami?," at [http://tsunami.gov], accessed Jan. 11, 2005.

[23] NOAA, National Weather Service, "*TsunamiReady* Communities," available at [http://www.tsunamiready.noaa.gov/ts-communities.htm],accessed Nov. 30, 2006.

Bush Administration Actions

On January 14, 2005, the White House Office of Science and Technology Policy (OSTP) announced a proposal for an improved tsunami warning and detection system for the United States.[24] With input from NOAA, the President's plan stated that 32 dedicated tsunami warning and detection "DART" buoys would be procured and deployed by mid-2007. The President's stated goal was to improve tsunami detection for the far Pacific and Atlantic Oceans, Gulf of Mexico, and Caribbean Sea. (See **Figure 1**, above.)

President Bush's Tsunami Action Plan. In December of 2005, President Bush released *Tsunami Risk Reduction for the United States: A Framework for Action* (dated July 2005).[25] This plan of action outlined steps to be taken to reduce tsunami risk on the U.S. mainland, Hawaii, and U.S. territories in the far Pacific Ocean and Carribean Sea.[26] To finish implementing the recommendations of his plan, for FY2007, President Bush has proposed $20.4 million for the NWS. He also requested $3.95 million for USGS's Global Seismic Network (GSN) upgrades, about $35,000 more than FY2006 enacted funding, that would go toward converting the 20% of 127 seismic sensing platforms around the globe that are not capable of real-time telemetry.

To complement the President's plan, concerned social scientists argued for "institutionalizing" a public education component in whatever legislation might be used to implement U.S. protection from tsunamis.[27] The public education initiative they envisioned has included training local authorities to be the resident developers and deliverers of disaster education, as well as developers of local emergency planning for tsunamis. They also encourage federal, state, and local interagency resource sharing and establishing a visible federal agency-presence within the community.[28] Finally, they recommend adaptation as an alternative means of disaster

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[24] U.S. EOP, OSTP, Press release, Jan. 14, 2005.

[25] Executive Office of the President, National Science and Technology Council, *Tsunami Risk Reduction For the United States: A Framework for Action*, A Joint Report of the Subcommittee on Disaster Reduction and the United States Group on Earth Observations, July 2005. (Released Dec. 2005.)

[26] EOP, *Tsunami Risk Reduction For the United States: A Framework for Action*, Ch. 4, "International Cooperation."

[27] Eileen Shea, Project Coordinator, East West Center, Honolulu, HI, "Testimony," Senate Commerce Tsunami Preparedness hearing, Feb. 2, 2005, available at [http://commerce.senate.gov/hearings/testimony.cfm?id=1361&wit_id=3955], accessed Feb. 3, 2005.

[28] See Government Accountability Office (GAO), "State and Local Tsunami Hazard Mitigation Activities Are Under Way although Implementation Varies Considerably among Locations," in *U.S. Tsunami Preparedness: Federal and State Partners Collaborate to Help Communities Reduce Potential Impacts, but Significant Challenges Remain*, GAO Report GAO-06-519, June 2006, p. 29. Prepared for congressional committees and Senator Diane Feinstein.

management, using low-tech, high-impact solutions for disseminating public evacuation orders.[29] (See "S. 50" in the "109th Congress" section.)

Funding for the U.S. Tsunami Warning Program. NOAA officials released estimates for implementing the President's January 2005 plan. Although more modest originally calling for mounting tsunami detection instruments on existing Atlantic Ocean platforms, such as weather buoys, it was decided that a number of dedicated DART platforms would be deployed instead. NOAA had indicated that the costs could vary depending upon the scale of the project — for example, the number of DART buoys, and supporting instruments to be deployed and costs of operation and maintenance (O&M) in the out-years.[30] Other related federal expenditures included funding scientific research on tsunamis, tsunami mitigation programs, public outreach and education, and the *TsunamiReady* program. It was later determined that telecommunication upgrades were needed for tsunami detection-dependent USGS Global Seismic Network (GSN). (See "Related and Contributing U.S. Programs.")

Table 1 shows funding for U.S. tsunami-related programs since FY2001. Prior to FY2004, all of tsunami-related activities were funded by NOAA's Office of Oceanic and Atmospheric Research (OAR) and obligated out of NOAA's Operations, Research, and Facilities (ORF) account. In FY2004, administration of these activities became the responsibility of NOAA's National Weather Service (NWS), at which funds were then obligated out of the NWS ORF and Procurement, Acquisition, and Construction (PAC) accounts. Congress provides funding for U.S. tsunami monitoring and detection operations, early warning, research, outreach and education, and mitigation. These appropriations are found under Title II, Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service, in the annual Science, Space, Justice, and Commerce Appropriations Act.

Thus far, President Bush has committed almost $40 million for FY2005-FY2007 to implement his action plan. (See "President Bush's Tsunami Action Plan.") The Director of OSTP, John Marburger, noted that the U.S. system would "ultimately include the Indian Ocean," in terms of tsunami warning benefits.[31] The United States is now contributing to international tsunami warning efforts, including the IOTWS, through development of the Global Earth Observing System of Systems

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[29] See Eileen Shea, Project Coordinator, East West Center, Honolulu, HI, "Testimony," Senate Commerce Tsunami Preparedness hearing, Feb. 2, 2005, available at [http://commerce.senate.gov/hearings/testimony.cfm?id=1361&wit_id=3955], accessed Feb. 3, 2005.

[30] U.S. Congress, House Committee on Science, "Tsunamis: Is the U.S. Prepared?," hearing, Jan. 26, 2005,p.41, [Serial No. 109-1], prepared statement of Rep. Sheila Jackson Lee. See [http://commdocs.house.gov/committees/science/hsy98395.000/hsy98395_0.htm], accessed Feb. 15, 2006. "DART stations cost about $250,000 to purchase and around $125,000 per year to maintain. Stations are now located off the coasts of Alaska, the Pacific Northwest, and Chile, but we need to consider how this system can be expanded to other parts of the world. Reliability of the DART system needs to be understood as we consider its deployment worldwide."

[31] John H. Marburger, "Testimony," Hearing, Feb. 2, 2005.

(GEOSS) managed by the "US GEO" team.[32] Two second generation deep-water tsunami detection buoys will be on loan for tsunami warning in the Indian Ocean.

Table 1. NOAA Funding for U.S. Tsunami Programs

($millions)

U.S. Tsunami Warning Program[a]		NTHMP[b]	TWEAK[c]	DART Buoy Acq.[d]	Strengthen Tsunami Warnings[e]	Annual Total
FY2007	Approp.[f]	—	—	—	—	**—**
	Req.	0.0	0.0	1.0	11.4	**$12.4**
FY2006	Approp.	2.3	2.0	6.0	3.8	**$14.1**
	Req.	2.3	0.0	6.0	3.5	**$11.8**
FY2005 Suppl.[g]		7.1	0.0	10.2	—	**$17.3**
FY2005	Approp.	4.2	2.0	0.0	—	**$6.2**
	Req.	0.0	0.0	0.0	—	**$0.0**
FY2004	Approp.	4.3	2.0	0.6	—	**$6.9**
	Req.	0.0	0.0	0.0	—	**$0.0**
FY2003	Approp.	4.3	—	—	—	**$4.3**
	Req.	0.0	—	—	—	**$0.0**
FY2002	Approp.	3.3	—	—	—	**$3.3**
	Req.	2.3	—	—	—	**$2.3**
FY2001	Approp.	3.3	—	—	—	**$3.3**
	Req.	0.0	—	—	—	**$0.0**

Source: Funding data compiled by CRS from annual Commerce, Justice, State, Judiciary and Related Agency annual appropriations reports, and NOAA's *FY2007 Budget Summary*, February 6, 2006.

Notes:

a. Funding for NOAA tsunami programs is not authorized by legislation. The last official NOAA authorization to fund NWS/NOAA Research programs occurred on October 29, 1992 in the 102nd Congress (P.L. 102-567).

b. The Tsunami Hazard Mitigation Program is operated out of the Pacific Tsunami Warning Center, HI, and has been funded since FY2004 by NWS. A major portion of the funding for the NTHMP is divided among each of five Pacific states (AK, HI, WA, OR, and CA). The NTHMP administers the NOAA's *Tsunami Ready* program and provides assistance for developing local warning capacity, emergency plans, and tsunami inundation maps.

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[32] The United States Group on Earth Observations (US GEO), Interagency Working Group on Earth Observations is a standing subcommittee under the Committee on Environment and Natural Resources, the United States Group on Earth Observations (US GEO)." See [http://www.sdr.gov/Tsunami%20Risk%20Reduction%20for%20the%20US%20-%20A%20Framework%20for%20Action%202005-12-22.pdf], accessed Feb. 15, 2006.

c. Prior to FY2004, the Tsunami Warning and Environmental (Observation Center) AK conducts experimental tsunami warning system programs, but had no budget line. In FY2004, TWEAK was transferred to NWS, along with all other U.S. tsunami-related programs. Although funding has not been requested by the Administration since, Congress has appropriated $2.0 million annually.

d. Includes funding proposed by the President and authorized by Congress in P.L. 109-13. Funding allocated as FY2006 regular appropriations.

e. For NWS systems acquisition, funded by the PAC account to upgrade tsunami warning communications network capabilities, and global telecommunications infrastructure. (A separate request of $8.1 million in P.L. 109-13 for USGS's Global Seismic Network (GSN) to upgrade GSN telecommunications and an increase the number of seismic monitoring staff at the USGS National Earthquake information Center.)

f. Although for FY2007 the House has indicated support for ongoing tsunami warning activities, no specific appropriation amount is given (H.Rept. 109-520). The Senate Appropriations Committee recommended $33 million for tsunami-related programs for FY2007, including $9.9 million for development of IOOS. No further appropriations action occurred in the 109th Congress.

g. Emergency Supplemental Appropriations Act, 2005 (P.L. 109-13). After the December 24, 2004 tsunami disaster in the Indian Ocean, Congress provided funding to the NWS Procurement, Acquisition and Construction (PAC) account from FY2005 emergency supplemental appropriations (P.L. 109-13). This funding was used to procure a greater number of DART buoys (three out of six were operating at the time of the tsunami disaster) and to fund expansion of the U.S. tsunami warning network in the far Pacific and Atlantic Oceans, the Gulf of Mexico, and the Caribbean Sea.

P.L. 109-13, Emergency Supplemental Appropriations for FY2005. The first round of funding for the President's proposal to upgrade and expand U.S. tsunami detection and warning capabilities was requested as part of emergency supplemental appropriations for FY2005 (P.L. 109-13).[33] The conference report on H.R. 1268 (H.Rept. 109-72, Div. A) — *Emergency Supplemental Appropriations Act for Defense, the Global War on Terror, and Tsunami Relief, 2005* — indicated that NOAA's National Tsunami Warning Program in NWS would receive $25.4 million. Conferees on H.R. 1268 had augmented the President's request by $7.1 million to provide for coastal inundation mapping and outreach and preparedness programs for U.S. communities-at-risk, all part of the *TsunamiReady* Program.

Congress directed that a portion of total NWS tsunami-related funding in P.L. 109-13 be provided to the West Coast/Alaska Tsunami Warning Center (WC/AKTWC) to upgrade services and establish an international regional warning center for the Pacific, in Hawaii. The NWS was authorized to hire an additional 43 full-time equivalents at U.S. tsunami warning centers to monitor USGS seismic alerts and tsunami detection instruments around the clock, for issuing real-time tsunami warnings and reporting false alarms.

Conferees approved $10.2 million for NOAA's PAC account to acquire new generation, DART II buoys for deployment in the Far Pacific and Atlantic Oceans, the Gulf of Mexico, and the Caribbean Sea. They noted that several new data points would be added for observations of ocean conditions at depth. (See "National

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[33] U.S. Congress, House Committee on Appropriations, "Communication for the President of the United States Transmitting a Request for Supplemental Appropriations ... Including Tsunami Relief and Reconstruction," H.Doc. 109-9, Feb. 15, 2005 (Washington, DC, GPO: 2005).

Weather Service Tsunami Programs.") With respect to the U.S. GEOSS initiative, conferees also encouraged NOAA "to develop buoys with capabilities beyond the single purpose of tsunami reporting."[34]

Finally, conferrees approved $8.1 million for the USGS National Earthquake Information Center (NEIC) in Golden, CO, to upgrade the Global Seismic Network (GSN) by increasing the number of GSN instruments capable of relaying real-time seismic data, and to provide additional staff the NEIC to interpret those data around the clock. At the time, only 80% of the 127 instruments in the network had real-time telemetry capability. GSN seismic data are critical for NWS tsunami warning centers to make a determination whether there is a potential for a tsunami to be generated (*tsunamigenesis*) after an underwater earthquake or other geological disturbance. The WC/AKTWS has responsibility for modeling the tracking and potential intensity of tsunamis. In turn, both U.S. TWCs warn national and international emergency management officials. P.L. 109-13 was signed into law on May 11, 2005.

National Weather Service Tsunami Programs

NOAA's NWS manages the U.S. operational program for tsunami warnings in U.S. Pacific coastal areas and has played a role in international tsunami protection. The *National Tsunami Warning Program (NTWP)* consists of two U.S. tsunami warning centers in the Pacific Ocean that monitor, detect, and warn for possible tsunamis. An associated program under the NTWP concentrates on reducing rate of false tsunami alarms issued for the Pacific Ocean. The *National Tsunami Hazards Mitigation Program (NTHMP)* assists states in emergency planning and in developing maps of potential coastal innundation for a tsunami of a given intensity. The NTHMP operates tsunami disaster outreach and education programs through NOAA's *TsunamiReady* program.

Tsunami Warning Centers. NWS operates the Pacific Tsunami Warning Center (PTWC) at Ewa Beach, HI, and the West Coast/Alaska Tsunami Warning Center (WC/AKTWC) at Palmer, AK. The PTWC monitors for tsunamis and issues warnings for the Hawaiian Islands, the U.S. Pacific territories, and other U.S. and international interests in the Pacific Basin. This center was established in 1949 after a strong earthquake and massive landslides off the coast of southwest Alaska caused a disastrous tsunami for the Hawaiian Islands hours later. The WC/AKTWC was established in 1967, following a devastating earthquake of M_w9.2 that struck Anchorage in 1964, causing major localized tsunami damages.[35] The WC/AKTWC is responsible for issuing tsunami warnings to emergency management officials in Alaska, British Columbia (Canada) Washington State, Oregon, and California. The WC/AKTWC now also serves as the warning center for U.S. populations located in the western Atlantic Ocean and is linked telemetrically with seven deep ocean DART

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[34] U.S. Congress, Senate Committee on Appropriations, *Departments of Commerce and Justice, Science, and Related Agencies Appropriations Bill, 2006* (S.Rept. 109-88 on H.R. 2682), p. 78, "Tsunami Preparedness, Warnings, and Forecasts," June 23, 2005.

[35] See NOAA, NWS, "How *TsunamiReady* Helps Communities and Counties at Risk available at [http://www.stormready.noaa.gov/tsunamiready/], accessed Feb. 14, 2006.

buoys now deployed off the U.S. Atlantic, Caribbean, and Gulf of Mexico shores. (See **Figure 1**.)

National Tsunami Hazard Mitigation Program. In 1992, NOAA launched the NTHMP to address the credibility of Pacific tsunami warnings. At that time, there had been a 75% false alarm rate for tsunamis. Local officials were concerned about the significant social upheaval and economic disruption caused by false alarms, and were concerned about whether the public would heed tsunami warnings in the future. Through technological progress and iterative improvements, the error rate has improved significantly since then. Another NTHMP research effort studies the potential for a sizable earthquake in the Pacific Northwest Cascadia Region, which USGS scientists believe would generate tsunamis that could severely damage several U.S. Pacific coastal regions.[36] In addition, the NTHMP has worked with five Pacific states, Alaska, California, Hawaii, Oregon, and Washington and now five Atlantic states and Puerto Rico in developing local tsunami emergency preparedness plans for "communities-at-risk" as part of the *TsunamiReady* program.[37] The NTHMP has also developed tsunami-related disaster models that can project the trajectory and intensity of ensuing waves. The NTHMP also produces maps of potential inundation for coastal communities at the behest of member states.

Tsunami Detection Operations. NOAA is currently operating an expansive network of 20 dedicated tsunami detection and relay stations as part of the NWS Deep-Ocean Assessment and Reporting of Tsunamis (DART) program.[38] (See **Figure 1** for DART buoy locations, and **Figure 2** for the technical components.) Although they have the capacity for early warning of tsunamis, NOAA officials caution these are only effective if there are emergency managers to receive their communications and, in turn, they are able to alert the public to take the necessary precautions or evacuate. In April 2006, seven DART buoys were deployed in the Atlantic Ocean, Caribbean Sea, and Gulf of Mexico.[39] There will eventually be 32 DART buoys operating in the Pacific Ocean, including three previously deployed in the Pacific Ocean, three off the Alaskan Peninsula, and one off the coast of Chile.

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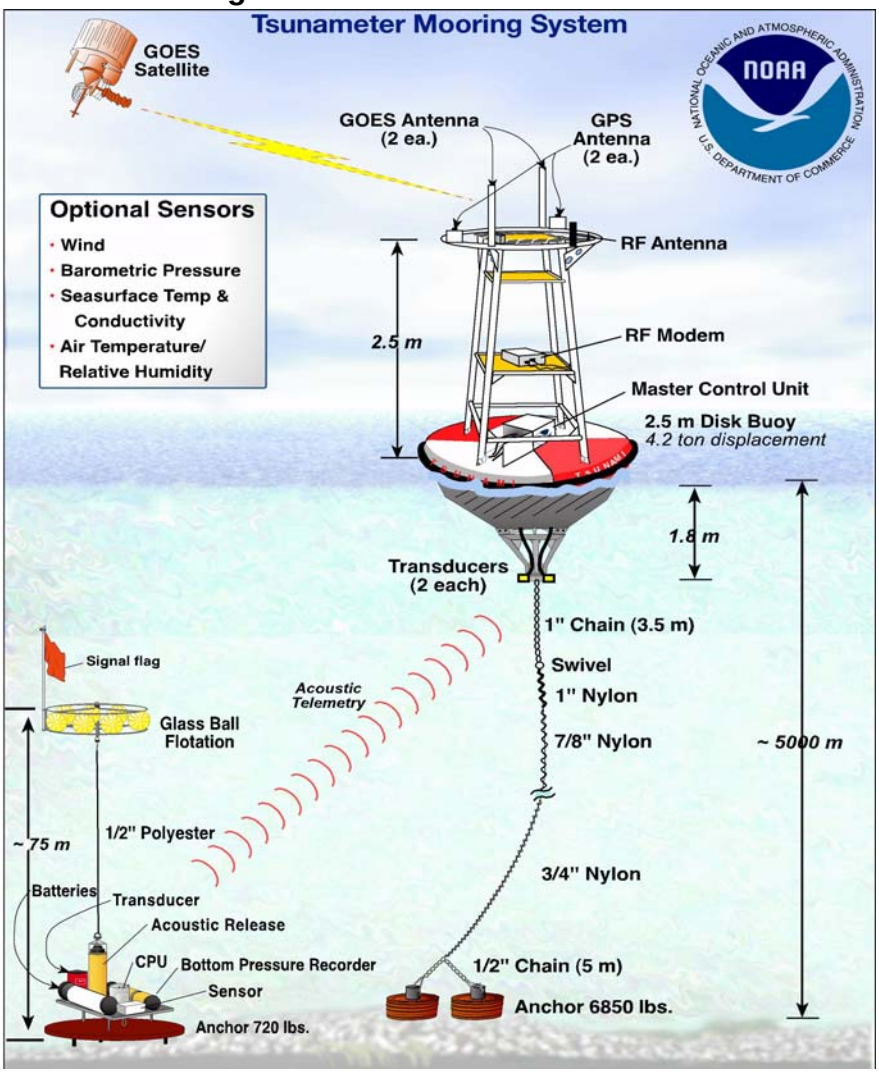
[36] USGS, Local Tsunami Hazards in the Pacific Northwest from Cascadia Subduction Zone Earthquakes by Eric L. Geist, at [http://pubs.usgs.gov/pp/pp1661b/pp1661-b.pdf], accessed Feb. 14, 2006.

[37] NOAA, National Weather Service, "TsunamiReady," available at [http://www.stormready.noaa.gov/ tsunamiready/ts-communities.htm], accessed Dec. 12, 2006.

[38] Hugh B. Milburn et al., "Real-Time Tsunami Reporting from the Deep Ocean," NOAA Pacific Marine Environmental Laboratory (1996), at [http://www.ndbc.noaa.gov/Dart/ milburn_1996.shtml], visited Jan. 4, 2005. A seventh DART buoy owned and operated by the Chilean government is deployed off Chile's coast in South America.

[39] NOAA FY07 Budget Briefing, National Press Club, Washington, DC, Feb. 9, 2006. See also **Figure 1**.

Figure 2. NOAA DART Platform



Source: National Oceanic and Atmospheric Administration, from "U.S. Announces Plans for an Improved Tsunami Warning and Detection System." See [http://www.noaanews.noaa.gov/stories2005/s2369.htm], accessed January 18, 2005.

Other Supporting Technologies. In addition to DART buoys, the NWS has hundreds of marine weather buoys, and NOAA's National Ocean Service (NOS) operates tide-gages off *all* coasts of the United States and in the Great Lakes. These supplemental instrumented platforms figured into the overall plans for an expanded U.S. tsunami warning network. There are also analogs of NOS sea-level monitoring operations in other countries around the globe. NWS weather buoys record meteorological data, such as temperature, wind speed and direction, and atmospheric pressure, while marine "drifting" data buoys also measure speed of ocean currents and changes in salinity (or density) of the ocean. Sea surface height (or sea level) is also measured by the satellite-based GPS (global positioning system) linked with NOS tidal-monitoring networks and NOAA environmental satellites. The tide-gage networks can detect surges or other disturbances which may be indicative of a

possible tsunami. Generally, such buoys are equipped to relay data and other communications that support commercial and recreational navigation.[40]

In addition to weather and marine navigational buoys, there are about 1,000 (of an planned array of 3,000) Argo floats that are used for short-term climate change observations. These operate in the equatorial Pacific Ocean and are primarily situated there to detect variable ocean conditions associated with El Niños and La Niñas, which are periodic climate adjustments that affect global weather. NOAA officials have advocated the use of Argo floats as alternative platforms for situating tsunami detection instrumentation as well as other Earth observation systems.[41] They consider the ARGO Array the "the next step in global observations." As early as the 108th Congress, legislation was introduced calling for several auxiliary technologies to contribute to enhanced U.S. tsunami detection and warning network.[42]

For the eastern United States, other possible platforms for contributing to tsunami monitoring and detection in the Atlantic Ocean have included coastal and ocean observation networks that are either currently operating or being developed along the eastern seaboard of Canada and the United States and in the Great Lakes. On the Gulf of Mexico, Caribbean, and Atlantic coasts of the Greater Antilles, there is an operating tsunami warning system and communications network that was developed by the University of Puerto Rico at Mayaguez. Legislation, S. 361 and H.R. 1584 in the 109th Congress, has called for similar synergistic approaches. (See "Tsunami-Related Legislation.")

Related and Contributing U.S. Programs

The U.S. Geological Survey (USGS) is improving the earthquake monitoring and warning capabilities of the Global Seismic Network (GSN) by upgrading stations that have not had real-time data communication ability. USGS has also increased coverage of seismic alerts at the National Earthquake Information Center (NEIC) in Golden, CO. Other alternatives for broadcasting tsunami warnings may include radios, cellular phone networks, and the Internet to reach local officials or rural populations. International telecommunications networks, such as the GTS, with

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[40] Eddie Bernard, House briefing, Jan. 5, 2005.

[41] NOAA/Woods Hole Oceanographic Institute, *Observing the Ocean in Real-Time: Argo, a Global Array of Profiling Floats to Understand and Forecast Climate,* ed. Stan Wilson (1996). Funded in part by private academic institutions.

[42] On Jan. 5, 2005, Representative Curt Weldon circulated a "Dear Colleague" letter advocating the reintroduction of H.R. 5001 (108th Congress), the Ocean and Coastal Observation System Act, in the 109th Congress. This legislation promoted development of an "Integrated Ocean Observation System," to protect U.S. citizens in coastal communities from tsunamis. For further information on U.S. ocean observation systems, see U.S. House Resources Subcommittee on Fisheries, Conservation, and Oceans, *Status of Ocean Observing Systems in the United States*, Oversight Hearing, serial no. 108-102, July 13, 2004 (Washington, DC: GPO 2005).

common data transmission protocols provide a capability for emergency communications among worldwide government institutions (i.e, weather bureaus).[43]

The U.S. Geological Survey (USGS). USGS contributes directly to the U.S. National Tsunami Warning Program. Its Global Seismic Network (GSN) has been critical in identifying the potential for and issuing early warning of tsunamis. The USGS operates a network of 127 global seismic monitoring stations, including some in the Indian Ocean. The GSN is managed by the Incorporated Research Institutions for Seismology (IRIS), a consortium of academic institutions that are involved with earthquake monitoring, detection, and modeling.[44] Although USGS does not monitor directly for *tsunamigenesis*, the GSN measures land-based and submarine earthquakes around the globe in real-time. Depending on where they occur and their magnitude, the USGS makes determinations whether to alert NOAA (NWS) of the possible onset of a tsunami.

At the time of the tsunami disaster in the Indian Ocean, USGS officials indicated that only about 80% of GSN instruments had capability for real-time data telemetry.[45] P.L. 109-13 funded President Bush's request to begin upgrading the entire GSN network. The 109th Congress appropriated $8.1 million in emergency supplemental appropriations for FY2005 for that purpose. Of the $8.1 million in funding provided, some would be used to increase the number of seismic monitoring stations around the globe.[46] Also, some would be used to increase the staff at the National Earthquake Information Center (NEIC) in Golden, CO. Conferees on the emergency funding bill noted that the resources recommended for communication improvements might enable USGS and NWS to exchange data and information for tsunami modeling exercises more rapidly.

USGS researchers at the NEIC collect and analyze data on crustal deformation and ocean floor displacement from earthquakes and determine which events may be precursors to the generation of tsunamis. USGS topographical mapping data has been used in developing tsunami inundation maps that are spatially accurate for communities-at-risk. These maps assist emergency managers in developing tsunami evacuation plans and guiding local government planners and private developers over the long-term. USGS primarily monitors for seismic activity on land, but its geologists have asserted that land-based operations can be as important for tsunami

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[43] Kenneth B. Allen, Director of the Partnership for Public Warning, "Letter to President Bush," Jan. 3, 2005, at [http://www.partnershipforpublicwarning.org/ppw/], accessed Jan. 21, 2005. See also, Joab Jackson, "Cisco, IBM Propose Internet-Based Disaster Alert System," *Government Computer News*, Feb. 11, 2005, at [http://www.gcn.com], accessed Feb. 15, 2005.

[44] Incorporated Research Institutions for Seismology (IRIS), "Global Seismic Network (GSN) at [http://www.iris.edu/about/GSN/], accessed Feb. 15, 2006.

[45] Dr. Charles Groat, Director of the USGS, presentation on the USGS FY2006 budget held at the Dept. of the Interior, Washington, DC, Feb. 7, 2005. Congress appropriated $8.1 million in emergency supplemental appropriations for FY2005 in P.L. 109-13.

[46] Dr. Charles Groat, Director of the USGS, presentation on USGS FY2007 budget held at the Dept. of the Interior, Washington, DC, Feb. 6, 2006.

detection and warning as deep ocean buoys.[47] In coastal areas of the United States, and especially along the Pacific coast, earthquakes have historically generated landslides. Some of these have resulted in mass wasting of land entering the ocean abruptly and displacing large volumes of water locally. Large landslides also occur beneath the ocean and off the continental shelf occasionally generating tsunamis. USGS has also researched the potential for the Atlantic coast of the United States to be subjected to a"super" tsunami caused by the collapse of a volcano in the Canary Islands off the Coast of west Africa.[48]

World Weather Watch. NOAA and other international weather agencies issue warnings of severe meteorological conditions that may affect commercial air traffic and marine navigation. Past weather-related disasters have put human lives in danger and have caused significant economic disruption over large geographic regions. The U.N. World Weather Watch (WWW) is a cooperative program that is organized and administered by the U.N. World Meteorological Organization (WMO). The mission of the WWW is to ensure that people no matter where they are around the globe are adequately warned to the possibility of severe weather or dangerous ocean-related conditions.[49] NOAA's National Weather Service disseminates meteorological forecasts and warnings of sever weather globally on behalf of the United States as part of the WWW mission.

NOAA also has a leadership role in the WWW with respect to weather data collection, management, and archival. Also, the Department of State negotiates on behalf of the United States to achieve and maintain international agreements that sustain WWW operations globally. WWW members, including the United States and its trust territories in the Far Pacific, communicate through established international telecommunications protocol (GTS) receiving and disseminating weather data, forecasts, and warnings.[50] The NOAA Satellite and Environmental

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[47] These include the USGS Advanced National Seismic System (ANSS), the Global Seismic Network (GSN), National Strong-motion Program, and other U.S. regional networks and cooperators. See [http://earthquake.usgs.gov/research/index.php?areaID=12], accessed Feb. 15, 2006.

[48] Rossella Lorenzi, "Top World Tsunami Hotspots Detailed," *Discovery News (online)*, Jan. 11, 2005, at [http://dsc.discovery.com/news/briefs/20050110/tsunamidanger.html], accessed Feb. 17, 2005. "According to Simon Day, Benfield Greig Hazard Research Center at University College London, U.K., geological evidence suggests that during a future eruption, Cumbre Vieja Volcano on the island of La Palma in the Canary Islands, off West Africa, could experience a catastrophic failure of the western flank."

[49] U.S. Dept. of Commerce, NOAA, Office of the Federal Coordinator for Meteorology, "World Weather Program," *The Federal Plan for Meteorological Services and Supporting Research: Fiscal Year 2005*, Report FCM P1-2004, Appendix B: 223-228 (Washington, DC: Oct. 2004). Examples of international communications networks are included.

[50] NOAA, National Environmental Satellite Data and Information Service (NESDIS), "About the World Data Center System." NESDIS operates two U.S. WWP data centers and performs analysis on and archives weather satellite data for international use. This resource has since provided valuable information about the Indian Ocean tsunami. See the NESDIS website at [http://www.ngdc.noaa.gov/wdc/wdcmain.html] accessed Feb. 15, 2006. See also

(continued...)

Data and Information Service (NESDIS) houses two of three WMO World Weather program (WWP) data centers, that archive weather data and analysis for global access. The WWP centers are telecommunication enabled portals for exchanging historical meteorological data and scientific research findings around the globe.[51] NOAA officials regard the global reach of WWW networks and those of the data centers as an important tool for communicating tsunami warnings among international governments and scientific institutions.

National All Hazards Weather Radio (NAHWR). National emergency management communications for the United States became the responsibility of the Department of Homeland Security (DHS), when FEMA was transferred to the newly created agency in March 2003. The National Weather Service (NWS) operates NOAA Weather Radio (NWR), which is used to warn individuals in their homes and at other public institutions such as schools and hospitals of the potential of severe weather and issues warnings to take appropriate action. DHS initiated discussions with NWS to collaborate in modifying NWR to enable public warnings for all disasters, natural or otherwise. Out of this came the DHS National *All Hazards* Weather Radio Network (NAHWR) that would broad information over the existing NWR communications spectrum, and the Public Alert network.[52]

Over time, Congress has funded the expansion of NOAA NWR and its reach by constructing more NWR transmission towers. Repeaters that can be mounted on structures were also added in some localities to extend the range of NWR emergency transmissions. The NOAA Weather Radio receiver, which is the critical component for receiving emergency warnings, has been made available to the public at a modest cost for individuals and at no cost to some schools applying for grant assistance. The NWR program especially targets rural areas so as many U.S. citizens as possible have an opportunity to receive severe weather-related warnings and other emergency communications from their nearest NWS weather forecast office. As a result of significant advances in weather forecast technologies, the lead time for emergency warnings in most cases has increased. DHS envisions NAHWR, an network for warnings in the event of earthquakes, tsunamis, volcanoes, floods and other natural disasters, and terrorist or industrial-related disasters.

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[50] (...continued)
"NOAA Scientists Able to Measure Tsunami Height from Space," at [http://www.noaanews.noaa.gov/stories2005/s2365.htm], accessed Feb. 15, 2006.

[51] NESDIS's NGDC maintains the NOAA and International Oceanographic Committee (IOC) long-term archive for global tsunami event, inundation, and damage data. NOAA official stress that "The exchange and sharing of data on a worldwide basis is a critical part of developing descriptions and the understanding of our global environment." NOAA notes that "The GEO Workplan for 2006 identifies the WDCs as one of the archives for data collected over coastal regions subject to tsunami risk." See [http://www.ngdc.noaa.gov/products/news_archive_2005.html], accessed Feb. 15, 2006.

[52] See NOAA All Hazards Weather Radio (NWR) at [http://www.nws.noaa.gov/nwr/], accessed Feb. 14, 2006.

The President's budget request included around $10 million for the NAHWR network in FY2006, and $5 million in FY2005.[53] Some observers have noted that about $150 million would be required to develop a broadband network capable of integrating multiple federal agency emergency communications.

However, the NWR network still stands on its own, and access to NWR may help to safeguard some people living in coastal areas of the United States by providing early warning of an approaching tsunami, potential coastal flooding from storm surges, or other hazardous marine conditions. Also, NWR can expediently notify coastal populations of tsunami false alarms, which might alleviate some panic and economic disruption caused by false warnings. It is likely that an expansive NAHWR network would materialize in the future if federal resources were available. However, standardization of telecommunications (communication protocol) and warning system interoperability remain an issue for the various U.S. agencies responsible for disasters.

Cooperative Protection for the Pacific Basin. NOAA's Director of the NWS also leads the UNESCO International Coordinating Group (ICG) for the International Tsunami Warning System in the Pacific (ITSU). ITSU was created in 1968 and has operated out of the PTWC until recently when a separate international warning center for the Pacific was dedicated. In October 2005, ICG/ITSU was renamed ICG/Pacific Tsunami Warning and Mitigation System (ICG/PTWMS). This change was made to align the new center with tsunami warning and mitigation programs established by UNESCO's Intergovernmental Oceanographic Commission (IOC), to distinguish it from the U.S. PTWC. The PTWMS currently serves 28 member nations vulnerable to tsunamis generated around the Pacific Basin. Three member states — Australia, Thailand, and Indonesia (in part) — are unique in that they are also threatened by tsunamis generated in the Indian Ocean.[54] (For more information on U.S. participation in international efforts to develop regional tsunami protection, see "International Proposals.")

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[53] Of note, the Senate approved $156 million for the "National Alert and Tsunami Warning Program Act, 2005," which is §3010 of S. 1932, the Senate amended version of the "Deficit Reduction Act of FY2005." (See H.Rept. 109-362, p. 204). That funding would "provide for an *all hazards* alert system to [issue] alerts in response to natural disasters, man-made accidents, and terror incidents." Plans are to fund the program with the proceeds from a Federal Communications Commission (FCC) spectrum auction. Proceedings of that sale is authorized to be provided to the National Telecommunications and Information Agency (NTIA). The amended measure containing the tsunami warning provisions passed Congress on Feb. 6, 2006 (H.Rept. 109-366). S. 1393 was signed by the President on Feb. 8, 2006. The budget resolution has no force in law however.

[54] See "International Tsunami Information Center: ITSU Master Plan," the International Coordination Group for the Tsunami Warming System in the Pacific (IGC/ITSU), UNESCO/IG, at [http://www.tsunamiwave.info/], visited Feb. 15, 2006.

Tsunami-Related Legislation

In the 108th Congress, before the Indian Ocean tsunami disaster, legislation had been introduced to expand tsunami early warnings networks globally.[55] No fewer than 14 bills were introduced in the 109th Congress, beginning in January 2005. Most of this legislation sought to expedite tsunami protection for the United States and its trust territories. Some of those called for a more globally oriented approach for tsunami protection for populations outside of the United States, however. Those bills supporting U.S. involvement in international efforts encouraged U.S. representation at any negotiations that might define national roles and responsibilities in operating and maintaining a global tsunami early warning network. These also recommended that negotiations be conducted through established international diplomatic channels, citing the U.N. UNESCO IOC, ISDR, and WMO.

Many of the provisions of lawmakers' U.S. and global tsunami protection legislation were enacted indirectly being authorized in emergency appropriation bills, and later in regular appropriation bills for NOAA and the National Weather Service, instead of in stand alone bills. Further, some of these provisions required the United States to incorporate tsunami preparedness and response, public education and awareness, and risk adaptation in domestic disaster planning and in its advisory in efforts abroad.

As with the Administration's January 2005 proposal and its July 2005 *Action Plan*, most congressional legislation had called for domestic needs to be met before international commitments were made.

109th Congress

At the close of the 109th Congress, S. 50 and H.R. 1674 stood as the primary legislative vehicles used to address social needs in post-tsunami disaster planning and other actions needed safeguard communities-at-risk in U.S. waters and areas affected by the Indian Ocean disaster. These bills guided domestic action to protect the United States and its trust territories from future tsunami disasters. Congress has authorized funding for U.S. tsunami protection for FY2005-FY2006 in P.L. 109-13 with a portion of that funding scored as regular NOAA appropriations for FY2006.

As of August 2006, 20 out of a total 39 DART-II buoys were deployed and operate in U.S. waters. In December 2006, the United State deployed its first of two U.S. DART buoys that will be on loan in international waters in the Indian Ocean to protect indigenous populations.

In the first session of the 109th Congress, on April 18, 2005, Representative Boehlert, chair of the House Science Committee introduced H.R. 1674, *The U.S. Tsunami Warning and Education Act of 2005*, also known as the "Boehlert-Inslee Bill." Major provisions of the act included strengthening the National Weather

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[55] Eddie Bernard, House briefing, Jan. 5, 2005. Representative Curt Weldon sponsored an original bill, H.R. 5001, in the 108th Congress. H.R. 1584 is a reintroduction of that measure.

Services's National Tsunami Hazards Mitigation Program by enhancing U.S. tsunami detection and warning capabilities and incorporating tsunami awareness and preparedness in disaster plans. Also, the act confers on Congress the responsibility to oversee development and operations of the U.S. network. The National Academy of Sciences is directed to report on U.S. capacity for tsunami protection and recommend changes if needed. The Government Accountability Office is directed to report on U.S. operations of the program by 2010. H.R. 1674 (amended) is identical to S. 50 (Inouye) and authorizes funding of $40 million for FY2008-FY2012. (For more information on this act, see below.) Nevertheless, congressional authorization to fund long-term, sustained operations and maintenance of the U.S. network; U.S. involvement in international efforts to establish the IOTWS; and eventually build a "global" tsunami warning network may be issues that 110th Congress consider in oversight hearings as is required by H.R. 1674.

Congressional sources have indicated that U.S. lawmakers would have provided appropriations for FY2007 as requested by President Bush to procure and deploy the remaining DART buoys needed to complete the U.S. tsunami network. However, final funding decisions are now left up to the 110th Congress.

S. 50 (Inouye). *The Tsunami Preparedness Act of 2005,* was introduced on January 24, 2005, and referred to the Senate Committee on Commerce, Science, and Transportation. As introduced, it directly supported the Bush Administration's strategy for an expanded U.S. tsunami early warning system. Similarly, it proposes that the United States assist other nations in an international endeavor to build a global detection and warning capacity. In Contrast to the President's proposal, S. 50 would have required that the United States to disseminate U.S. tsunami-related information and scientific research findings internationally, as well as facilitate technology transfer to assist in global tsunami hazard mitigation efforts. To that end, S. 50 would have established a U.S. multi-agency task force that included NOAA, the Federal Emergency Management Agency (FEMA), the USGS, and the National Science Foundation (NSF). NOAA would lead U.S. global tsunami warning efforts through deployment of an international earth observation system [GEOSS]. Section 8 of S. 50 would have authorize $35 million for "each of fiscal years 2006 through 2012, to carry out the Act."

On February 2, 2005, the Senate Commerce Subcommittee on Disaster Preparedness held hearings on S. 50. At that hearing, Senator Inouye noted that "the new subcommittee could be effective in educating populations at risk," referring to potential tsunami disasters. The Senator also stated that S.50 considers sociological needs in addition to detection and warning, which would require NSF's contribution. He also noted that the legislation would authorize NOAA to receive reimbursement of cash or services "in-kind" from international agencies that it assists in developing a global tsunami early warning network.

On March 10, 2005, the Commerce, Science, and Transportation Committee marked up S. 50. S.Amdt.1101 to S. 50, the Tsunami Preparedness Act, was sponsored on July 1, 2005, by Senator Stevens. The amended bill would have authorized specific funding for the Administrator of NOAA to strengthen its tsunami detection, forecast, warning, and mitigation program. S. 50 (amended) also would have authorized establishment of an International Tsunami Warning Center for the

Pacific for monitoring tsunamis and issuing warnings for U.S. trust territories in the far Pacific, and establish a clearinghouse for tsunami-related information accessible to ITSU members' states. The committee amendment was adopted in the nature of a substitute bill. During mark up of S. 50 (amended), Senator Stevens stated that NOAA would have to notify Congress if a DART buoy were to stop functioning so that arrangement for a replacement could be made and deployed expeditiously. Further, the committee amendment would have authorized $5 million annually for an "integrated coastal vulnerability and adaption program." S. 50 (amended) was reported favorably to the full Senate on March 10, 2005. The written report of the committee (S.Rept. 109-59) was issued on April 19, 2005. No further legislative action occurred.

H.R. 1674 (Boehlert). H.R. 1674, *the United States Tsunami Warning Education Act of 2005*, was closely related to S. 50. The House bill directed the National Weather Service to strengthen tsunami detection, forecasts and warnings, and increase support for related disaster mitigation activities. Its primary provision was to upgrade and expand the U.S. warning network for the Pacific, to include U.S. territories, the Atlantic Ocean, the Gulf of Mexico, and the Caribbean Sea. Introduced on April 18, 2004, H.R. 1674 was referred to the House Committee on Science Subcommittee on Environment, Technology, and Standards, which marked up the bill on April, 20, 2005. A full Science Committee markup was held on May 4, 2005. The bill was reported by the House Science Committee on September 28, 2006 (H.Rept. 109-698). The bill passed the House (amended) on December 6, 2006, by voice vote, and then the Senate on December 9, 2006, by unanimous consent. The President is expected to sign the bill into law.

H.R. 1674 encourages cooperation between NOAA, the USGS, and the NSF, in establishing an international (tsunami) research program. It sought to (1) improve coordination for tsunami and other coastal hazards warnings at federal, state, and international government levels; (2) educate for public preparedness; and (3) aid in establishing a multinational regional tsunami warning network for countries bounded on the Indian Ocean. Further, the bill would have encouraged the mutual sharing of related data among countries that are members of a "Global Tsunami and Warning Mitigation Network." It also provided for developing educational and outreach activities for U.S. populations-at-risk, and would have authorized $30 million for each of FY2006-FY2008 to carry out the act. In addition, H.R. 1674 would have allocated 70% of spending to upgrade operations and management of the U.S. network; 20% for mitigation programs; and 10% for an international tsunami research program. In the 110th Congress, lawmakers may initiate oversight hearings to assess the National Weather Service progress in implementing various provisions of the act.

Conclusion

Decisions about whether and how to proceed with establishing an international tsunami early warning system for the Indian Ocean (and elsewhere) have been considered complicated for number of reasons. One reason is the number of different international users that would be collecting and analyzing data and receiving or

disseminating tsunami warnings. A second reason is the financial resources needed to establish and maintain regional tsunami warning systems over the long-term. A third reason is that some nations in the Indian Ocean charge for real-time access to critical satellite data that could help to detect and track tsunamis or in executing post-disaster assessments. Although some Members of Congress contend that the costs of acquiring those data could be well worth it in terms of lives saved, others assert that the licensing requirements and costs of acquiring real-time proprietary data could be prohibitive. Still others are of the opinion that access to global environmental data should be open and free of charge, especially when countries like the United States have provided involved nations disaster relief, or are underwriting tsunami detection and warning activities in the Indian Ocean.[56]

International science and engineering institutions, including NOAA and NASA, have alluded to the challenges of standardizing tsunami detection instrumentation and related technologies for remote sensing and data telemetry. Others have noted the long-term operations and maintenance requirements of a global tsunami warning network. Still others cite national security issues and compromise of intelligence-gathering operations, especially if there is "open" multinational access to established telecommunications networks.

Some U.S. lawmakers still question the risk of a tsunami hitting the U.S. Atlantic coast.[57] They have argued that because the probability is low, the risk factor should guide the scale of development and investment in a cooperative early tsunami warning system for the U.S. eastern seaboard. NOAA scientists argue that the risk exists. There are historical records of tsunamis occurring on the Atlantic coast and in the Caribbean Seas as well as empirical evidence.

Many international scientific and engineering experts have considered the Bush Administration action plan for a U.S. tsunami early warning network as a viable model for different regions of the globe. Countries who currently rely on the U.S. program for their tsunami warnings unquestionably have supported plans to expand and upgrade U.S. tsunami detection and warning capabilities. Many Members of Congress who have backed the President's plan had or have since introduced legislation to implement actions necessary for protection of U.S. coastlines and those of the trust territories.

Funding has been forthcoming. The President's initial appeal for upgrading U.S. tsunami early warning capabilities was nearly $30 million for FY2005-FY2006. The 109th Congress initially approved $25.4 million, which was appropriated in H.R. 1268, the FY2005 Emergency Supplemental Appropriations Act (P.L. 109-13). It also adopted a Senate amendment to S. 50, which provided an additional $2.7 million to fund international "in country" sociological needs, such as public education and adaptation strategies to complement the technological ones. That funding was obligated in lieu of appropriations for FY2006.

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[56] Gregg Withee, January 5, 2005 House briefing.

[57] USGS, Earthquake Hazards Program, "Off W Coast of Northern Sumatra, Can It Happen in the United States?" at [http://earthquake.usgs.gov/eqinthenews/2004/usslav/canit.html], visited Feb. 17, 2005.

For FY2007, the President requested $12.5 million to complete expansion and upgrades of the U.S. network by mid-2007. If Congress approves that request, the federal government will have committed almost $40 million to improve early tsunami warnings for the U.S. mainland, Hawaii, and territorial waters.

Since February 2005, the United States has taken great strides to define its role and responsibilities for tsunami protection in the global context. It has supported international efforts through the U.S. Intergovernmental Oceanographic Committee (IOC) with financial resources and technological advice, and has participated in international planning and development for a global tsunami warning network. Development of an international warning system for the Indian Ocean has proceeded along similar time frames as the U.S. effort. Also, the United States is loaning two second generation DART buoys to contribute to a growing IOTWS network in the northeastern Indian Ocean, expanding involvement in tsunami protection for non-U.S. nations outside the Pacific Basin.

IOC members are also anxious for launch of the Global Earth Observation System of Systems (GEOSS), an initiative led by NOAA. Some countries propose to "piggy back" on GEOSS in order to develop their own tsunami early warning capabilities. Short of financial support, some countries may contribute in their own capacity through exchange of data and information or with *in kind* services. Suggestions have included requesting national fleet assets to deploy and decommission tsunami monitoring and detection equipment. They also encourage nations with fewer resources to contribute manpower to a "corps" responsible for maintenance-related assistance necessary to sustain a long-term multinational effort for tsunami protection. This model is not exclusive to global tsunami detection and warning, but would also be beneficial for building, operating, and maintaining any ocean observation network of global scope. NOAA officials and other international scientific and engineering agencies are concerned that without deployment of GEOSS, a "truly global" tsunami warning system may never be realized.

With the recent passage of H.R. 1674, the U.S. Tsunami Warning and Education Act, Congress has authorized an average of $27 million per year over the next five years. (See "109th Congress," above.) If funded at those levels, NOAA officials believe that there may be sufficient resources to (1) finish deployment of DART buoys in U.S. waters; strengthen the National Tsunami Warning and the National Tsunami Mitigation programs; and foster expanded partnerships between the National Weather Service and U.S. states through the *TsunamiReady* program. Other are more optimistic and believe the funding might go a long way in supporting long-term maintenance of the U.S. tsunami early warning network; be sufficient to cover U.S. costs and advice in building an international infrastructure for tsunami warnings around the Indian Ocean. However, U.S. efforts alone cannot not ensure longevity of global operations.