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Good morning Chair Murkowski, Ranking Member Cantwell and members of the committee. Thank you for the opportunity to testify about the FY 2017 budget and ongoing efforts of the U.S. Geological Survey (USGS). I'm John Vidale, a Professor at the University of Washington. As director of the Pacific Northwest Seismic Network and the Washington State seismologist, I'm privileged to work closely with the USGS to protect the public from earthquake and volcano hazards.

The USGS performs yeoman service assessing and mitigating hazards from earthquakes, landslides and volcanic activity. The combination of universities and the USGS working together, exemplified by the seismic networks covering much of the country, which blend bleeding-edge research, operations, and deep outreach, have been supremely successful. For another example, in my home state of Washington, scientists use airborne laser mapping (also known as LiDAR) to find the locations of previously unknown active faults, slopes prone to destructive landslides, and downstream deposits of past eruptions of Cascade volcanoes. LiDAR mapping is critical to our understanding of natural hazards in the Pacific Northwest and across the Nation.

I'll focus here on new methods to reduce the risk from large earthquakes. A recent article in *The New Yorker* captured public attention with a nightmare scenario of an impending magnitude-9 earthquake on the Pacific Northwest coast, which has worried people across the entire Nation. This M9 in the Pacific Northwest might not come for centuries or it might come tomorrow. It last struck in the year 1700, and the Cascadia fault is now locked and loaded again. When it comes, the strongly shaken region will extend from northern California up the coast to Canada, including the entire coastlines of Oregon and Washington. Coastal Alaska faces a similar threat.

We know what earthquakes of this size can do. In 2011, the M9 Tohoku earthquake in Japan shook communities for four minutes and triggered a devastating tsunami. Damage from the quake and tsunami have cost Japan more than $300 billion, and claimed over 15,000 lives. Through this example, we have seen the level of

destruction that could happen along our Pacific Northwest coast. Fortunately, we can act to protect lives and property now.

I will highlight two opportunities at the USGS that can reduce devastation from quakes of all sizes - earthquake early warning and seafloor monitoring, and discuss why subduction zone earthquakes – the gravest type – need a special focus.

The newest advance in USGS earthquake risk mitigation is the development of ShakeAlert Earthquake Early Warning. We use seismometers and GPS monitors to recognize an earthquake within seconds of its occurrence, and then broadcast a warning to vulnerable communities telling people how strong shaking will be and when it will come.

Early Warning reduces earthquake risks and public fears in several ways. In terms of life safety, ShakeAlert can stop trains, call off airplane take-offs and landings, halt surgeries, clear bridges, stop elevators, open critical doors, and allow for faster tsunami warnings. Simply giving people, such as school children, a few extra seconds to drop, cover, and hold on has great benefit.

Early warnings can kick-start actions that reduce damage for a range of industries. In the private sector, companies can reduce losses by battening down factories, bracing computer operations, and shutting off pipelines. Emergency responders can jump-start emergency operations while communications still work.

ShakeAlert is a powerful tool, built to protect public safety during future earthquakes, and operated in collaboration with universities, state agencies and private companies. USGS-coordinated open collaboration means our methods are transparent. This is necessary because providing serious help in devastating earthquakes may only be needed once every few years and has to work the first time. Open also means that the early warning system is flexible and can be adapted to other earthquake-vulnerable regions across the US. Presently, we are beta testing this system on the West Coast, but the system can be deployed across the US to monitor and give warning to Alaska, Hawaii, Utah, Oklahoma, and Tennessee. In fact, although the system is designed in the US, elements have already been published, discussed and tested in many places across the globe. For example, ElarmS, an essential element in the system, has been tested on four continents, facing a variety of challenging cases.

Several earthquake early warning situations arise from the diverse geology across the United States. The long faults such as the San Andreas in California and the Cascadia and Aleutian subduction faults in the Pacific Northwest and Alaska can allow up to minutes of warning. In contrast, for the faults running through our cities, sometimes only a few seconds of warning are physically possible. So it's imperative that we have a system that can instantly recognize and characterize an earthquake and notify communities about the impending shaking.

The implementation plan for Earthquake Early Warning for Washington, Oregon, and California costs 16 million dollars per year for equipment and operations. This state-of-the-art system is entering the public testing phase. But fully turning on the system for the West Coast requires complete funding to employ the workers needed to deploy the full network of sensors and provide speedy and reliable data transmission.

We are halfway there. The USGS funding level for earthquake early warning from Congress was $8 million in FY 2016 and the Administration has requested the same in the FY 2017 budget, thanks to strong public and private support for four universities — Berkeley, Caltech, the University of Oregon and the University of Washington, coordination from the USGS, and major commitments from the Moore Foundation and corporations, as well as strong support from Congress. We are very grateful for leadership in supporting ShakeAlert from West Coast Congressional delegations. Extension to other states simply requires careful study followed by judicious expansion of ShakeAlert operations.

The second opportunity I'll discuss is the placement of earthquake-sensing equipment on the seafloor, exactly as Japan has already done to protect their coastal communities. There, seafloor sensors sit directly on top of the faults that host great earthquakes. This instrumentation is especially critical for places like the Pacific Northwest, where the Cascadia Subduction Zone runs just offshore and underwater. Just a couple of spots now have realtime instruments, but vast tectonically-active and dangerous areas will be uncovered for the foreseeable future. Seafloor sensors would yield information that provides communities with more accurate warnings that arrive sooner, providing more crucial time for people to take life-protecting action.

Even more critically, offshore instruments would watch for subtle tectonic unrest, which preceded several recent great subduction zone earthquakes, and would accelerate scientific understanding of the associated risks. There is a high level of interest in exploring subduction zone science, both within the academic community and USGS, which goes beyond offshore instrumentation. This type of scientific undertaking is essential to the health and balance of the USGS hazards research aimed at getting to the heart of these dangerous problems.

Earthquake early warning is driven by the need to provide advanced warning of shaking, which dominates the $5 billion per year FEMA estimate of long-term earthquake losses in the US. For example, one of our corporate partners, Intel, has determined it will cost the company $15 million for each hour they are off-line. Furthermore, losses from tsunamis have also been horrific in the past decade, and Earthquake Early Warning, particularly in concert with near-shore seafloor sensors, can speed up tsunami warnings by seconds to minutes and refine the accuracy of inundation forecasts.

In summary, the great earthquakes in the last decade in Japan and Sumatra, which cost hundreds of thousands of lives and hundreds of billions of dollars, are forerunners of the inevitable devastating earthquakes in the US. To prepare, we should complete both an earthquake early warning system and emplace seafloor monitoring. The ShakeAlert warning system is well on its way to help protect lives and property, and I urge it be completed quickly and fully for Washington, Oregon, and California, and evaluated for other vulnerable regions.

Thank you again for allowing me to testify and I look forward to your questions.