POLICY AND GLOBAL AFFAIRS

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

Introduction to briefing on Advances in Nuclear-test Monitoring and Verification

September 24, 2012

Hart Senate Office Building

SH-902

Convened by AAAS

The Study Committee

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Caveats and Limitations

- Technical issues only, not policy
- Current as of early 2011 (limited updating)
- Public version
- Finding and recommendations are in **bold**

The Issues

- Can the U.S. maintain the stockpile without nuclear-explosion testing?
- Can the U.S. detect, locate, and identify nuclear explosions?
- What does the U.S. need to do to sustain the stockpile and the U.S. and international monitoring systems?
- What about evasive testing?

Overview: Maintaining the Stockpile

Conclusion

Provided that sufficient resources and a national commitment to stockpile stewardship are in place, the committee judges that the United States has the technical capabilities to maintain a safe, secure and reliable stockpile of nuclear weapons into the foreseeable future without nuclear-explosion testing.

Overview: Maintaining the Stockpile II

At the time of the *2002 Report*, the Stockpile Stewardship Program (SSP) was in its early stages, and there was uncertainty about maintaining the stockpile in the absence of nuclear-explosion testing.

The technical capabilities for maintaining the U.S. stockpile absent nuclear-explosion testing are better now than anticipated by the *2002 Report*.

Future assessments of aging effects and other issues will require quantities and types of data that have not been provided by the surveillance program in recent years.

The committee judges that Life-Extension Programs (LEPs) have been, and continue to be, satisfactorily carried out to extend the lifetime of existing warheads without the need for nuclear-explosion tests. In addition to the original LEP approach of *refurbishment*, sufficient technical progress has been made since the *2002 Report* that *re-use* or *replacement* of nuclear components can be considered as options for improving safety and security of the warheads.

Overview: U.S. Nuclear-Explosion Testing?

Conclusions

As long as the U.S. sustains its technical competency, and actively engages its nuclear scientists and other expert analyst in monitoring, assessing, and projecting possible adversarial activities, it will retain effective protection against technical surprises. This conclusion holds whether or not the United States accepts the formal constraints of the CTBT.

A technical need for a return to nuclear-explosion testing would be most plausible if the U.S. determined that adversaries' nuclear activities required development of weapon types not previously tested. In such a situation, the U.S. could invoke the supreme national interest clause and withdrawal from the CTBT.

Overview: Monitoring

The United States has technical capabilities to monitor nuclear explosions in four environments:

* Underground
* Underwater
* Atmosphere
* Space

Conclusion

Technical capabilities have improved significantly in the past decade, although some operational capabilities are at risk. Seismology now provides much more sensitive detection, identification, and location of explosions.

90 percent confidence levels for IMS seismic detection are well below 1 (kt) worldwide for fully coupled explosions.

Factoring in regional monitoring and improved understanding of the backgrounds, an evasive tester in Asia, Europe, North Africa, or North America would need to restrict device yield to levels below 1 kt (even if the explosion were fully decoupled) to ensure no more than a 10 percent probability of detection by the IMS.

Seismic Monitoring

- Seismology is the most effective technology for monitoring underground nuclear-explosion testing. Seismic monitoring for nuclear explosions is complicated by the great variety of geologic media and the variety and number of earthquakes, chemical explosions, and other non-nuclear phenomena generating seismic signals every day.

- **Technical capabilities for seismic monitoring have improved substantially in the past decade, allowing much more sensitive detection, identification, and location of nuclear events. More work is needed to better quantify regional monitoring identification thresholds, particularly in regions where seismic waves are strongly attenuated.**

On-Site Inspection

- **A CTBTO on-site inspection (OSI) would have a high likelihood of detecting evidence of a nuclear explosion with yield greater than about 0.1 kilotons, provided that the event could be located with sufficient precision in advance and that the OSI was conducted without hindrance.**

Sustaining U.S. Technical Capabilities

- Sustaining two technical programs are essential
  - U.S. nuclear weapons program
  - U.S. monitoring and verification program
  - Primarily an issue of resources. Concerns:
  - **High quality workforce**
  - Science, engineering, and technology
  - Weapons production complex
  - Weapons surveillance
  - Radionuclide collection
  - Satellite detection
  - Monitoring research and development
  - Also concerned with NNSA management of labs

CTBT Safeguards

- Six CTBT safeguards were proposed in 1995. We did not attempt a revision but have two recommendations.
- **Without agile production capabilities, it is not possible to promptly correct deficiencies revealed by surveillance or to remanufacture components or weapons when required.**
  - **The U.S. CTBT safeguards should include the maintenance of adequate production and non-nuclear-explosion testing facilities.**
  - **There is currently no mechanism that would enable Congress to assess whether the U.S. CTBT safeguards were being fulfilled after entry into force.**
  - **Under the CTBT, the Administration should prepare an annual evaluation of the ongoing effectiveness of safeguards and formally transmit it to Congress.**

Evasive Nuclear-Explosion Testing I

- **An evader determined to avoid detection would test at levels the evader believes would have a low probability of detection.**
- **Mine masking is a less credible evasion scenario than it was at the time of the *2002 Report* because of improvements in monitoring capabilities.**
- **With the inclusion of regional monitoring, improved understanding of backgrounds, and proper calibration of stations, an evasive tester in Asia, Europe, North Africa, or North America would need to restrict device yield to levels below 1 kiloton (even if the explosion were fully decoupled) to ensure no more than a 10 percent probability of detection for IMS and open monitoring networks.**

Evasive Nuclear-Explosion Testing II

- **For IMS and open monitoring networks, methods of evasion based on decoupling and mine masking are credible only for device yields below a few kilotons worldwide and at most a few hundred tons at well-monitored locations.**

- **The States most capable of carrying out evasive nuclear-explosion testing successfully are Russia and China. Countries with less nuclear-explosion testing experience would face serious costs, practical difficulties in implementation, and uncertainties in how effectively a test could be concealed. In any case, such testing is unlikely to require the United States to return to nuclear-explosion testing.**

Hydronuclear Testing

- **Hydronuclear tests would be of limited value in maintaining the United States nuclear weapon stockpile in comparison with the advanced tools of the Stockpile Stewardship Program.**

- **Based on Russia's extensive history of hydronuclear testing, such tests could be of some benefit to Russia in maintaining or modernizing its nuclear stockpile. However, it is unlikely that hydronuclear tests would enable Russia to develop new strategic capabilities outside of its nuclear-explosion test experience.**

- **Given China's apparent lack of experience with hydronuclear testing, it is not clear how China might utilize such testing in its strategic modernization.**

Technical Advances

- **Russia and China are unlikely to be able to deploy new types of strategic nuclear weapons that fall outside of the design range of their nuclear-explosion test experience without several multi-kiloton tests to build confidence in their performance. Such multi-kiloton tests would likely be detectable (even with evasion measures) by appropriately resourced U.S. national technical means and a completed IMS network.**

- **Other States intent on acquiring and deploying modern, two-stage thermonuclear weapons would not be able to have confidence in their performance without multi-kiloton testing. Such tests would likely be detectable (even with evasion measures) by appropriately resourced U.S. national technical means and a completed IMS network.**

Final Thought

- **Threats could arise by clandestine nuclear weapons activity. For instance, a country with no testing experience and a modest industrial base could confidently build and deploy a single-stage, un-boosted nuclear weapon without any testing, if it had access to sufficient quantities of fissile material. These advances could be made whether or not the CTBT were in force. However, it is highly likely that the United States could counter these threats without returning to nuclear-explosion testing and thus could respond equally well whether or not the CTBT were in force.**

My Personal Choices on Continuing Advances in Monitoring (1)

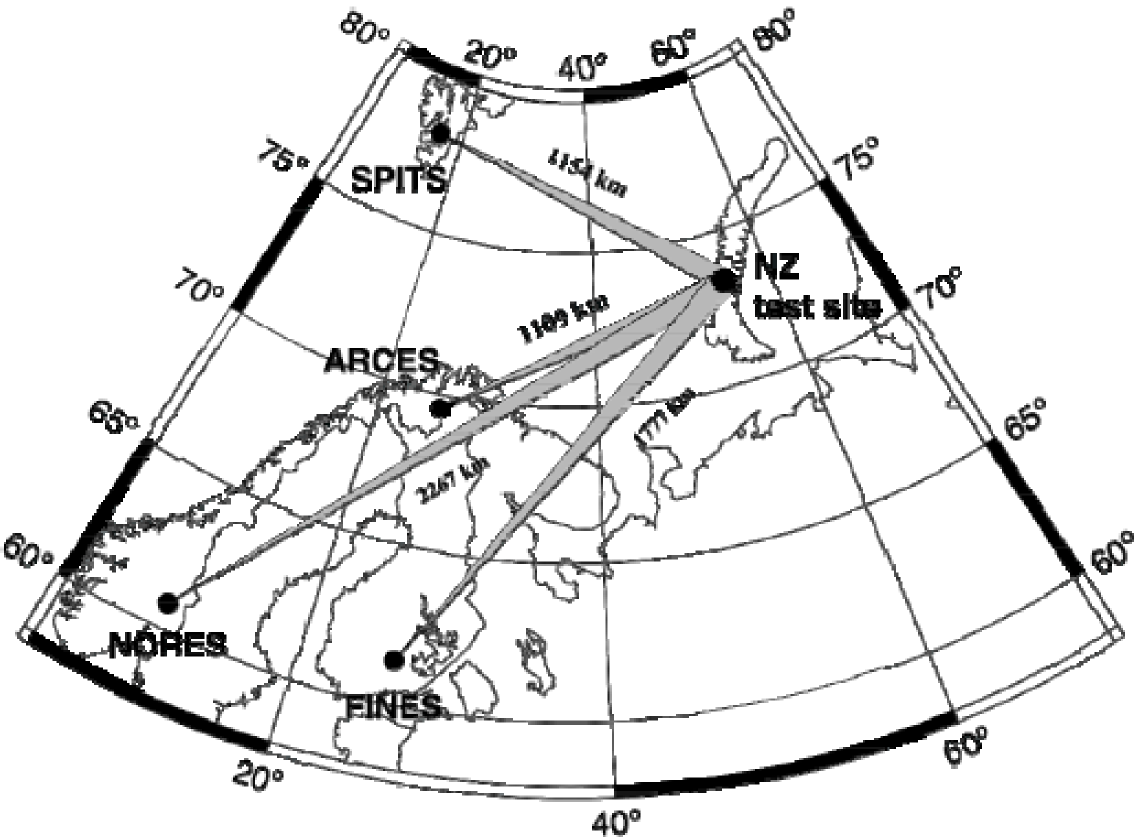


FIGURE D-3: Map of Novaya Zemlya and locations of four seismic arrays in Norway, Finland and Spitsbergen. SOURCE: Kværna et al., 2002

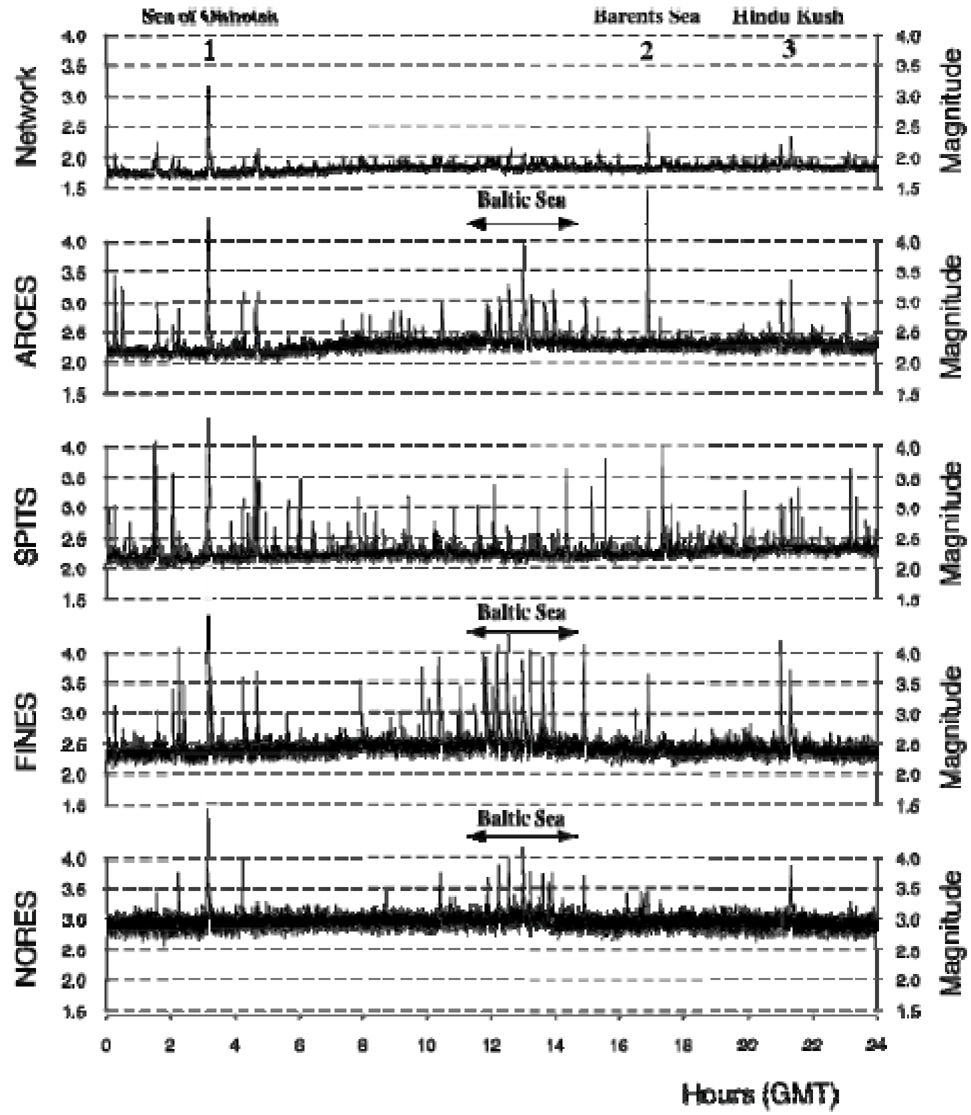
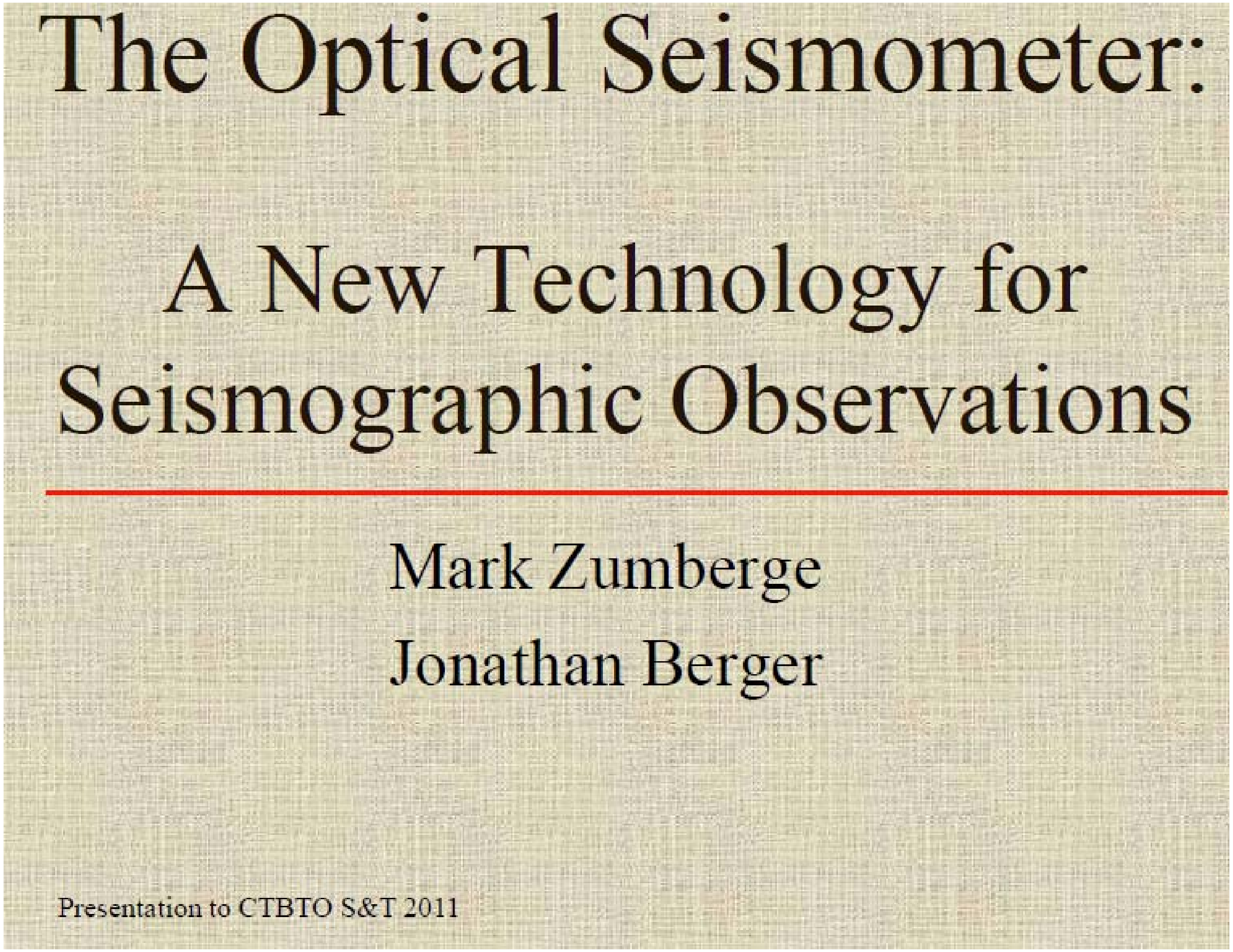


FIGURE D-4: Example of site-specific threshold (“smart network”) monitoring for seismic events from Novaya Zemlya for 24 hours on February 9, 1998. SOURCE: Kværna et al., 2002

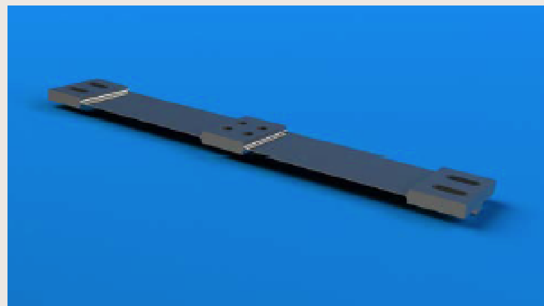
My Personal Choices on Continuing Advances in Monitoring (2)

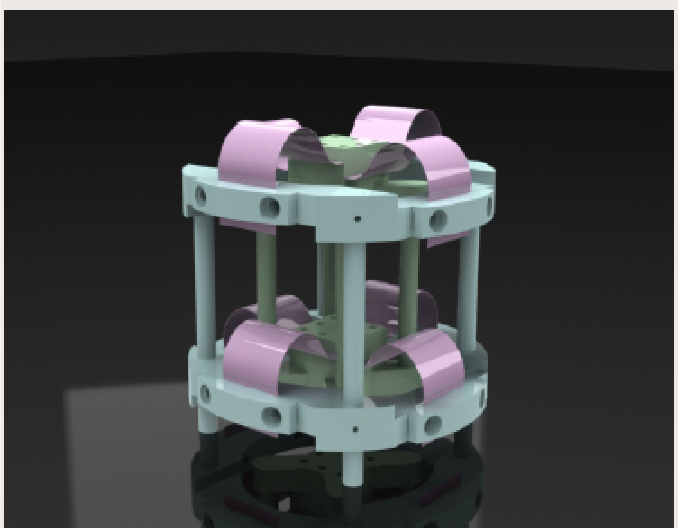


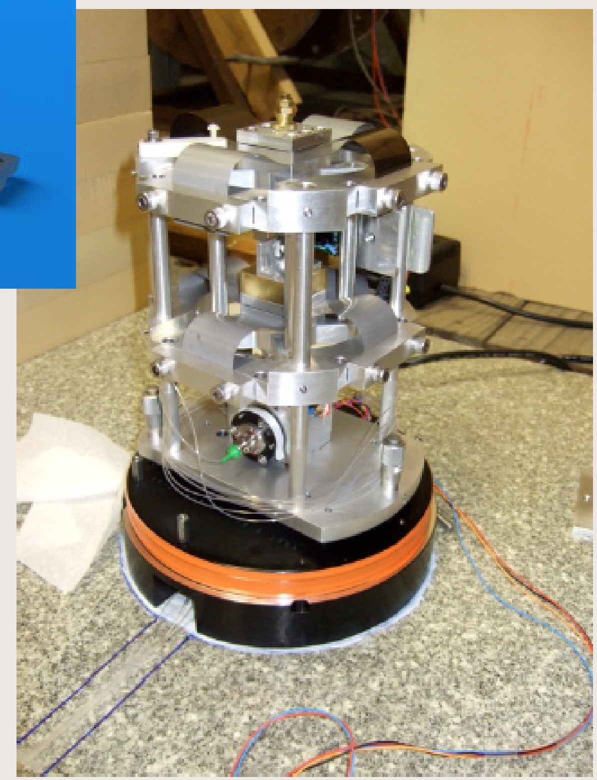
Optical Seismometer (2)

New Design
In-line Vertical Component

Monolithic, electrical discharge machined (EDM) suspension springs







Opportunity for Further Advances of a Remarkable System

- University and government scientists can work with CTBTO to benchmark and substitute improved techniques and analysis
- Seismic detection will benefit from further work on waveform analysis and cross correlation
- Routine incorporation of non-IMS seismometer data can greatly enhance detection and discrimination
- Backtracking of airmass motion for radionuclide detection has come a long way but is still in its infancy
- Research and competition to lower investment and operating cost can pay off in hydroacoustic, infrasound, and seismic fields