Comprehensive Nuclear-Test-Ban Treaty

Seismic Monitoring:

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Short Course on Nuclear Weapons Issues in the 21st Century
APS, Forum on Physics and Society, November 2013
subtitle:

2012 NAS Report and Recent Explosions, Earthquakes, Meteorites
Comprehensive Test Ban Treaty (CTBT)
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negotiations started in 1958

Eisenhower
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....

Eisenhower

Kennedy
Comprehensive Test Ban Treaty (CTBT)

negotiations started in 1958

Eisenhower
Kennedy
Johnson
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negotiations started in 1958

Eisenhower
Kennedy
Johnson
Nixon
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Eisenhower
Kennedy
Johnson
Nixon
Ford
Comprehensive Test Ban Treaty (CTBT)

negotiations started in 1958

Eisenhower
Kennedy
Johnson
Nixon
Ford
Carter
Comprehensive Test Ban Treaty (CTBT)

negotiations started in 1958

... 

... 

Eisenhower
Kennedy
Johnson
Nixon
Ford
Carter
Reagan
Comprehensive Test Ban Treaty (CTBT)

negotiations started in 1958

....

....

(testing moratorium)

Eisenhower
Kennedy
Johnson
Nixon
Ford
Carter
Reagan
Bush, G.H.W.
Comprehensive Test Ban Treaty (CTBT)

negotiations started in 1958

....

....

(testing moratorium)

negotiations ended in 1996

Eisenhower

Kennedy

Johnson

Nixon

Ford

Carter

Reagan

Bush, G.H.W.

Clinton
<table>
<thead>
<tr>
<th>President</th>
<th>Event Details</th>
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<tbody>
<tr>
<td>Eisenhower</td>
<td>negotiations started in 1958</td>
</tr>
<tr>
<td>Kennedy</td>
<td></td>
</tr>
<tr>
<td>Johnson</td>
<td></td>
</tr>
<tr>
<td>Nixon</td>
<td></td>
</tr>
<tr>
<td>Ford</td>
<td></td>
</tr>
<tr>
<td>Carter</td>
<td></td>
</tr>
<tr>
<td>Reagan</td>
<td>(testing moratorium)</td>
</tr>
<tr>
<td></td>
<td>negotiations ended in 1996</td>
</tr>
<tr>
<td></td>
<td>(moratorium continued; UN votes)</td>
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<tr>
<td>Clinton</td>
<td></td>
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<tr>
<td>Bush, G.H.W.</td>
<td></td>
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<td>Bush, G.W.</td>
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</table>
Comprehensive Test Ban Treaty (CTBT)

negotiations started in 1958

....

....

(testing moratorium)

negotiations ended in 1996

(moratorium continued; UN votes)

(moratorium continued; UN votes)
from the text of the Comprehensive Nuclear-Test-Ban Treaty:

ARTICLE I

BASIC OBLIGATIONS

1. Each State Party undertakes not to carry out any nuclear weapon test explosion or any other nuclear explosion, and to prohibit and prevent any such nuclear explosion at any place under its jurisdiction or control.

2. Each State Party undertakes, furthermore, to refrain from causing, encouraging, or in any way participating in the carrying out of any nuclear weapon test explosion or any other nuclear explosion.
Total States (out of 193)

as of October 30, 2013:
183 signed
161 ratified (recently, Iraq)

(36 of Annex 2, ratified; missing China, DPRK, Egypt, India, Iran, Israel, Pakistan, USA)

Total of the Required States having some nuclear capability (out of 44)
Crater Formation As A Function Of Depth Of Burial

Ground Surface Before Explosion

Ground Surface After Explosion

Retarc

Cavity

Chimney

Crater
THE EFFECTS OF HIGH ALTITUDE EXPLOSIONS*

by

Wilmot N. Hess

Goddard Space Flight Center

INTRODUCTION

Seven artificial radiation belts have been made by the explosion of high altitude nuclear bombs since 1958. These artificial belts result from the release of energetic charged particles, mostly electrons, from the nuclear explosions. These seven explosions are:

<table>
<thead>
<tr>
<th>Explosion</th>
<th>Locale</th>
<th>Time</th>
<th>Yield</th>
<th>Altitude</th>
</tr>
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<tbody>
<tr>
<td>Argus I</td>
<td>South Atlantic</td>
<td>1958</td>
<td>1 kt</td>
<td>300 miles</td>
</tr>
<tr>
<td>Argus II</td>
<td>South Atlantic</td>
<td>1958</td>
<td>1 kt</td>
<td>300 miles</td>
</tr>
<tr>
<td>Argus III</td>
<td>South Atlantic</td>
<td>1958</td>
<td>1 kt</td>
<td>300 miles</td>
</tr>
<tr>
<td>Starfish</td>
<td>Johnson Island, Pacific Ocean</td>
<td>July 9, 1962</td>
<td>1.4 Mt</td>
<td>400 km</td>
</tr>
<tr>
<td>USSR†</td>
<td>Siberia</td>
<td>Oct. 22, 1962</td>
<td>Several hundred kt</td>
<td>?</td>
</tr>
<tr>
<td>USSR</td>
<td>Siberia</td>
<td>Nov. 1, 1962</td>
<td>?</td>
<td>?</td>
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</table>

The Argus explosions of 1958 were carried out to study the trapping of energetic particles by the earth's magnetic field. Nicholas Christofolis, a physicist at the Lawrence Radiation Laboratory, had for some time before Argus worked on Project Sherwood—the attempt to make controlled thermonuclear reactions in laboratory containers. To contain the intensely hot material used in the Sherwood experiments, no walls can be used; they would melt. Magnetic fields, shaped into "magnetic bottles" to contain the particles, are used. Such a bottle as that used in Figure 1 has been used successfully to contain hot electrons and protons for short times. The particles eventually leak out of the magnetic bottle, mostly through the ends, but they are contained for a time.

*To be published as a chapter in "Space Physics," edited by Donald P. LeGalley and Alan Rosen (publisher, John Wiley & Sons, Inc.).
†The U. S. explosions Teak and Orange in the Pacific (below 8 km) in 1958 may have injected some particles, but the effects here were small and short-lived. Another reported USSR high altitude explosion of 1961 may have produced some effects, but this is uncertain.
Contributions of key technologies to CTBT monitoring of different test environments

<table>
<thead>
<tr>
<th>Key Technologies of test</th>
<th>Environment of test</th>
<th>Underground</th>
<th>Underwater</th>
<th>Atmosphere</th>
<th>Near Space</th>
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</thead>
<tbody>
<tr>
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<tr>
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<td>secondary</td>
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<tr>
<td>Infrasound*</td>
<td>secondary</td>
<td>secondary</td>
<td>major</td>
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<tr>
<td>Electromagnetic</td>
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<td>secondary</td>
<td>major</td>
<td>major</td>
<td></td>
</tr>
<tr>
<td>Satellite Imagery</td>
<td>major</td>
<td>major</td>
<td>secondary</td>
<td>secondary</td>
<td></td>
</tr>
</tbody>
</table>

* technologies used by the International Monitoring System (Vienna)
Six different steps in nuclear explosion monitoring:

**Detection**  
(did a particular station detect a useful signal?)

**Association**  
(can we gather all the different signals from the same “event”?)

**Location**  
(where was it?)

**Identification**  
(was it an earthquake, a mining blast, a nuclear weapon test?)

**Attribution**  
(if it was a nuclear test, what country carried it out?)

**Yield estimation**  
(how big was it?)
The Study Committee

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MARVIN L. ADAMS, Texas A&M University
LINTON BROOKS, Independent Consultant
THEODORE W. BOWYER, Pacific Northwest National Laboratory
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WILLIAM R. WALTER, Lawrence Livermore National Laboratory
http://www.ctbto.org

and in particular

http://www.ctbto.org/verification-regime/
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 withdraw from the CTBT.

Overview: Monitoring

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

* Underground
* Atmosphere
* Underwater
* 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.
The CTBT will in practice be monitored by:

- the international CTBT Organization in Vienna, Austria;
- National Technical Means, which for the United States includes the Atomic Energy Detection System (AEDS) operated by the Air Force Technical Applications Center (AFTAC); and
- the loosely organized efforts of numerous institutions, acquiring and processing data originally recorded for purposes other than treaty monitoring

Hundreds of institutions continuously operate thousands of seismometers. Seismically active regions of North America, Europe, Asia, North and South Africa, and the Middle East are now routinely monitored down to low magnitudes in order to evaluate earthquake hazards.