Sid Drell: Beyond the Blackboard

Physics of Nuclear Weapons

Raymond Jeanloz
University of California, Berkeley
Advisor to Presidents
... and more
The government needs independent experts, and we are fortunate that Sid is both...

Panofsky (1998)
Physics-Based Policy for Nuclear Weapons

1) Stockpile stewardship and nuclear-explosion ban

2) World without nuclear weapons “joint enterprise”

3) Nuclear-weapons safety & security
JASON

• Founding member – Townes call 1960

I personally think the biggest impact has been creating a generation of scientists… who have had an impact through their direct involvement, either because of the studies they did which then caused defense scientists or parts of the Defense Department to see things better, or because we've entered the public debate...

Drell (1986)
Objective: Provide technical basis for US adopting Comprehensive Nuclear Test Ban Treaty (CTBT)
CTBT: Article I

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.
Status of Stockpile Stewardship

Successful annual assessments of stockpile
Successful life-extension programs
Re-establishment of pit production technology
Retention of core capabilities
  – Advances in understanding weapon performance
  – Advances in understanding materials
  – Developments at experimental facilities
Study starts 2000
Publication: 2002

Study starts 2009
Publication: 2012

Available at National Academies Press
nap.edu
Summary of National Academy of Sciences Studies

Objectives

1) Assess maintaining US nuclear weapons capabilities
2) Assess nuclear-explosion monitoring
3) Assess constraints on nuclear proliferation

Conclusions of studies

2000: Adequate plan
2009: Proven capabilities better than planned
Treaty Monitoring

International Monitoring System (IMS)

50 primary stations
120 auxiliary stations

90% probability recorded at 3/41 IMS stations

40 ton  100 ton

Kvaerna & Ringdal (2013)
North Korea

- 10/09/2006 ~ 0.5 kt
- 05/25/2009 ~ 2
- 02/12/2013 ~ 10
- 01/06/2016 ~ 5
- 09/09/2016 ~ 12
- 09/03/2017 ~ 250

DigitalGlobe – Commercial Satellite Imagery
10/09/2006 ~ 0.5 kt
05/25/2009 ~ 2
02/12/2013 ~ 10
01/06/2016 ~ 5
09/09/2016 ~ 12
09/03/2017 ~ 250

05/2010 event < 0.0005 kt

Test

China Earthquake Administration

~ 1000 stations

Dreger (2016)

Ford & Walter (2015)

Richards, 2017
2) World without nuclear weapons
   “joint enterprise”
“Gang of Four”
“Gang of Four”
“Joint Enterprise”

- Reassertion of the vision of a world free of nuclear weapons and practical measures toward achieving that goal… a bold initiative consistent with America's moral heritage.
- Without the bold vision, the actions will not be perceived as fair or urgent. Without the actions, the vision will not be perceived as realistic or possible.
- We endorse setting the goal of a world free of nuclear weapons and working energetically on the actions required to achieve that goal, beginning with the measures outlined above.

Shultz, Perry, Kissinger & Nunn (2007)
Steps would include...

- Changing the Cold War posture of deployed nuclear weapons to increase warning time and thereby reduce the danger of an accidental or unauthorized use of a nuclear weapon.
- Continuing to reduce substantially the size of nuclear forces in all states that possess them.
- Eliminating short-range nuclear weapons designed to be forward-deployed.
- Initiating a bipartisan process with the Senate, including understandings to increase confidence and provide for periodic review, to achieve ratification of the Comprehensive Test Ban Treaty, taking advantage of recent technical advances, and working to secure ratification by other key states.
- Providing the highest possible standards of security for all stocks of weapons, weapons-usable plutonium, and highly enriched uranium everywhere in the world.
- Getting control of the uranium enrichment process, combined with the guarantee that uranium for nuclear power reactors could be obtained at a reasonable price, first from the Nuclear Suppliers Group and then from the International Atomic Energy Agency (IAEA) or other controlled international reserves. It will also be necessary to deal with proliferation issues presented by spent fuel from reactors producing electricity.
- Halting the production of fissile material for weapons globally; phasing out the use of highly enriched uranium in civil commerce and removing weapons-usable uranium from research facilities around the world and rendering the materials safe.
- Redoubling our efforts to resolve regional confrontations and conflicts that give rise to new nuclear powers.

Shultz, Perry, Kissinger & Nunn (2007)
Bundy, Crowe & Drell (1993)

Drell & Goodby (2007)

Drell & Goodby (2003)
SEPTEMBER 20, 2017

Dozens of states sign nuclear weapons ban treaty at United Nations

Reuters

The Nobel Peace Prize 2017
International Campaign to Abolish Nuclear Weapons (ICAN)
3) Nuclear-weapons safety & security
Safety related technologies need to be robust – Goldsboro, NC Accident

Every safety mechanism had failed, except one: the ready/safe switch in the cockpit. The switch was in the SAFE position when the bomb dropped. Had the switch been set to GROUND or AIR, the X-unit would’ve charged, the detonators would’ve triggered, and a thermonuclear weapon would have exploded in a field near Faro, North Carolina. When Air Force personnel found the Mark 39 later that morning, the bomb was harmlessly stuck in the ground, nose first, its parachute draped in the branches of a tree.

“It would have been bad news—in spades,” Parker F. Jones, a safety engineer at Sandia, wrote in a memo about the accident. “One simple, dynamo-technology, low-voltage switch stood between the United States and a major catastrophe!”

Eric Schlosser, Command and Control (2013)
Table 1A.1  Summary of Accidents Involving U.S. Nuclear Weapons*  

<table>
<thead>
<tr>
<th>Accident Number</th>
<th>Date</th>
<th>Location</th>
<th>Assembled Weapons</th>
<th>Unassembled Weapons</th>
<th>Type of Accident</th>
<th>Nuclear Weapon Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>02/13/50</td>
<td>Puget Sound, WA</td>
<td>X</td>
<td>X</td>
<td>Jettison, 8000'</td>
<td>HE Burn</td>
</tr>
<tr>
<td>2</td>
<td>04/11/50</td>
<td>Manzano Base, NM</td>
<td>X</td>
<td>X</td>
<td>Aircraft lost</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>3</td>
<td>07/13/50</td>
<td>Lebanon, OH</td>
<td>X</td>
<td>X</td>
<td>Crash into mountain</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>4</td>
<td>11/10/50</td>
<td>Over water, outside U.S.</td>
<td>X</td>
<td>X</td>
<td>Crash in dive</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>5</td>
<td>08/05/50</td>
<td>Fairfield-Suisan AFB, CA</td>
<td>X</td>
<td>X</td>
<td>Emergency landing, fire</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>6</td>
<td>03/10/56</td>
<td>At sea (Mediterranean)</td>
<td>X</td>
<td>X</td>
<td>Jettison</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>7</td>
<td>07/27/56</td>
<td>SAC Base</td>
<td>X</td>
<td>X</td>
<td>Jettisons, 4500' &amp; 2500'</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>8</td>
<td>05/22/57</td>
<td>Kirtland AFB, NM</td>
<td>X</td>
<td>X</td>
<td>Aircraft lost</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>9</td>
<td>07/28/57</td>
<td>At sea (Atlantic)</td>
<td>X</td>
<td>X</td>
<td>Crash on takeoff, fire</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>10</td>
<td>10/11/57</td>
<td>Homestead AFB, FL</td>
<td>X</td>
<td>X</td>
<td>Taxi exercise, fire</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>11</td>
<td>01/31/58</td>
<td>SAC base overseas</td>
<td>X</td>
<td>X</td>
<td>Mid-air collision, jettison</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>12</td>
<td>02/05/58</td>
<td>Savannah, GA</td>
<td>X</td>
<td>X</td>
<td>Accidental jettison</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>13</td>
<td>03/11/58</td>
<td>Florence, SC</td>
<td>X</td>
<td>X</td>
<td>Crash on takeoff, fire</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>14</td>
<td>11/06/58</td>
<td>Dyess AFB, TX</td>
<td>X</td>
<td>X</td>
<td>Fire on ground</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>15</td>
<td>11/26/58</td>
<td>Chenault AFB, LA</td>
<td>X</td>
<td>X</td>
<td>Ground alert, fuel tanks on fire</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>16</td>
<td>01/08/59</td>
<td>U.S. base, Pacific</td>
<td>X</td>
<td>X</td>
<td>Crash on takeoff, fire</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>17</td>
<td>07/06/59</td>
<td>Barksdale, AFB, LA</td>
<td>X</td>
<td>X</td>
<td>Grass fire</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>18</td>
<td>09/25/59</td>
<td>Off Whidbey Is., WA</td>
<td>X</td>
<td>X</td>
<td>Navy aircraft ditched</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>19</td>
<td>10/15/59</td>
<td>Hardinsburg, KY</td>
<td>X</td>
<td>X</td>
<td>Mid-air collision, impact</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>20</td>
<td>06/07/60</td>
<td>McGuire AFB, NJ</td>
<td>X</td>
<td>X</td>
<td>Missile fire</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>21</td>
<td>01/24/61</td>
<td>Goldsboro, NC</td>
<td>X</td>
<td>X</td>
<td>Mid-air breakup</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>22</td>
<td>03/14/61</td>
<td>Yuba City, CA</td>
<td>X</td>
<td>X</td>
<td>Crash after abandonment</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>23</td>
<td>11/13/63</td>
<td>Medina Base, TX</td>
<td>X</td>
<td>X</td>
<td>Storage igloo at AEC plant</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>24</td>
<td>01/11/64</td>
<td>Cumberland, MD</td>
<td>X</td>
<td>X</td>
<td>Mid-air breakup, crash</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>25</td>
<td>12/05/64</td>
<td>Ellsworth AFB, SD</td>
<td>X</td>
<td>X</td>
<td>Missile reentry vehicle fell</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>26</td>
<td>12/08/64</td>
<td>Bunker Hill AFB, IN</td>
<td>X</td>
<td>X</td>
<td>Taxi crash, fire</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>27</td>
<td>10/11/65</td>
<td>Wright-Patterson AFB, OH</td>
<td>X</td>
<td>X</td>
<td>Transport aircraft fire on ground</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>28</td>
<td>12/05/65</td>
<td>At sea, Pacific</td>
<td>X</td>
<td>X</td>
<td>Aircraft rolled off elevator</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>29</td>
<td>01/17/66</td>
<td>Palomares, Spain</td>
<td>X</td>
<td>X</td>
<td>Mid-air collision, crash</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>30</td>
<td>01/21/68</td>
<td>Thule, Greenland</td>
<td>X</td>
<td>X</td>
<td>Crash after abandonment</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>31</td>
<td>09/19/80</td>
<td>Damascus, AK</td>
<td>X</td>
<td>X</td>
<td>Lost weapons</td>
<td>HE Detonate</td>
</tr>
<tr>
<td>32</td>
<td>169/31</td>
<td>Spring '68</td>
<td>X</td>
<td>X</td>
<td>Missile fuel explosion</td>
<td>HE Detonate</td>
</tr>
</tbody>
</table>


b The term “assembled weapon” refers to either the separable nuclear capsule that was installed but was not in the bomb's pit or a sealed-pit type of weapon with the nuclear material integral with the HE subsystem. “Unassembled weapons” means that the separable nuclear capsule was not installed in the weapon or that only weapon components were involved. (The USAF press release for accidents 1–13 used the term “assembled weapon” for the above plus where a capsule was on the aircraft).

c Contamination from all accidents except 29 and 30 was low in radioactivity and highly localized in areas affected.

d In the parentheses, the first number indicates the number of weapons that had the named response, and the second number gives the total involved in the accident.
NUCLEAR WEAPONS SAFETY

REPORT

OF THE

PANEL ON NUCLEAR WEAPONS SAFETY

OF THE

COMMITTEE ON ARMED SERVICES

HOUSE OF REPRESENTATIVES

ONE HUNDRED FIRST CONGRESS

SECOND SESSION

DECEMBER 1990

REPORT

OF

THE PANEL ON NUCLEAR WEAPONS SAFETY

OF

The House Armed Services Committee

SIDNEY D. DRELL, Chairman

JOHN S. FOSTER, JR.

CHARLES H. TOWNES

DECEMBER 1990

(III)
1990 Drell, Foster, Townes Safety Panel findings reinforced previous studies of safety needs

Concerns about the safety of several of the nuclear weapons systems in the U.S. arsenal have led the government to take immediate steps to reduce the risk of unintended, accidental detonations that could result in dispersing plutonium into the environment in potentially dangerous amounts or even generate a nuclear yield. These steps include temporarily removing the short-range air-to-ground attack missiles, SRAM-A, from the alert bombers of the Strategic Air Command and modifying some of the artillery-fired atomic projectiles (AFAPs) deployed with U.S. Forces.

Modernization and improvement programs gave priority to military requirements... Safety in general was not viewed with the same urgency.

Specifically, safety, security and use control should be treated together because of their critical importance and their interdependence.

Surety: Safety & Security

A major consequence of these results is a realization that unintended nuclear detonations present a greater risk than previously estimated (and believed) for some of the warheads in the stockpile.
Nuclear Weapon Design Safety

The following are safety criteria design requirements for all U.S. nuclear weapons:

• **Normal environment**—Prior to receipt of the enabling input signals and the arming signal, the probability of a premature nuclear detonation must not exceed one in a billion per nuclear weapon lifetime. $1:10^9$

• **Abnormal environment**—Prior to receipt of the enabling input signals, the probability of a premature nuclear detonation must not exceed one in a million per credible nuclear weapon accident or exposure to abnormal environments. $1:10^6$

• **One-point safety**—The probability of achieving a nuclear yield greater than four pounds of TNT equivalent, in the event of a one-point initiation of the weapon’s high explosive, must not exceed one in a million. $1:10^6$
Public disclosures helped to focus government attention on addressing concerns.
TECHNICAL ISSUES OF A NUCLEAR TEST BAN

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KEY WORDS: testing, safety, reliability

Always/Never  (5 hour history)
https://nsarchive2.gwu.edu/nukevault/ebb498/
enhanced nuclear detonation safety
ENDS

UQS = unique signal

stronglink

weaklink
Nuclear Weapons Surety
(Safety & Security)

1) Path to a catastrophic event

2) Potential for nuclear crisis

3) Difficult to discuss