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# Advanced Diagnostics at U1A

D. B. Holtkamp, Physics Division

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# Outline

- The stockpile and stewardship
- Subcritical experiments
- Three examples
  - Gemini (2012)
  - Ortega (2010)
  - Nightshade (2016)

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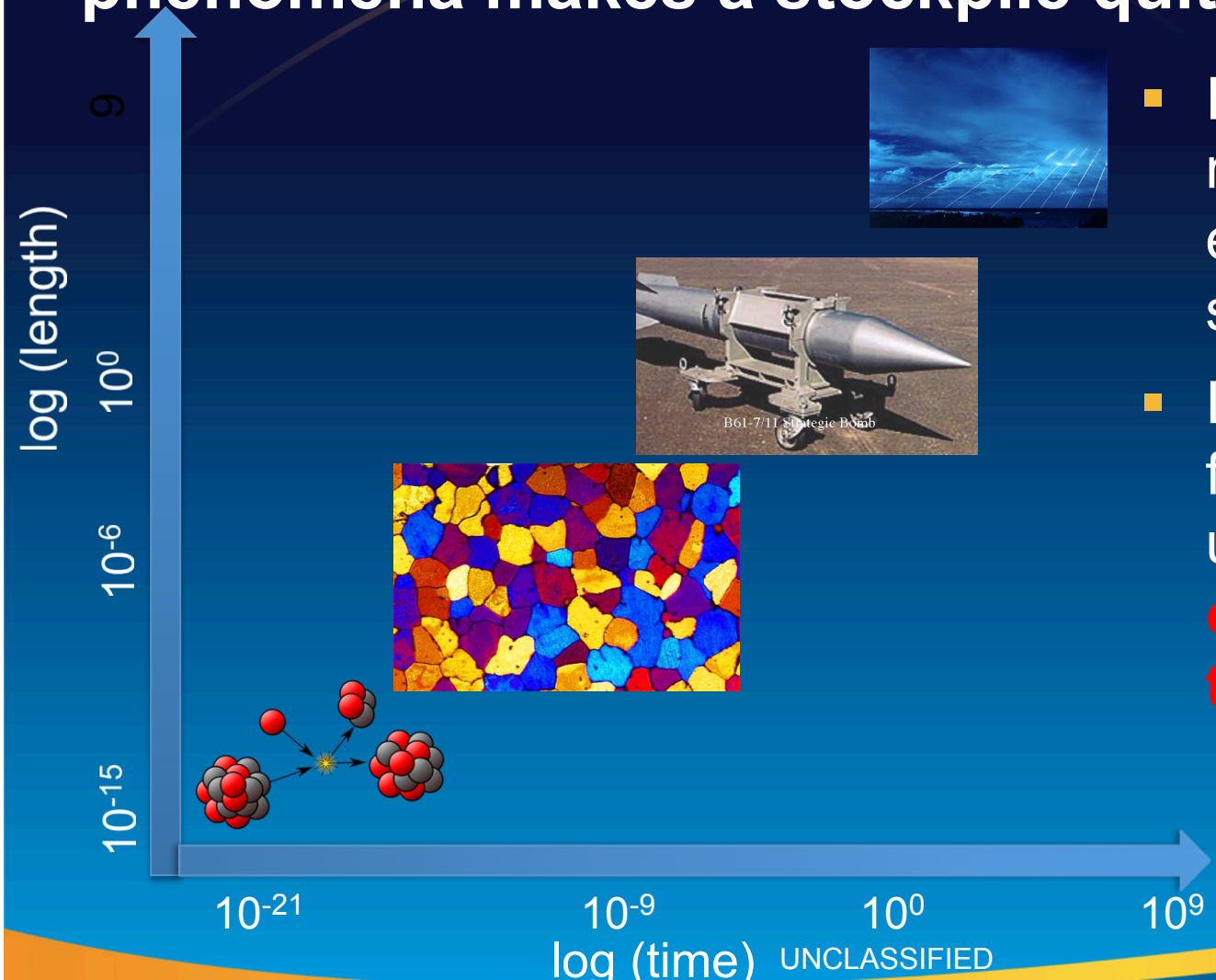
# The vast range of physical scales and phenomena makes a stockpile quite complex




- During the Cold War new weapons entered the stockpile regularly
- Lack of complete fundamental understanding: **confidence through testing**

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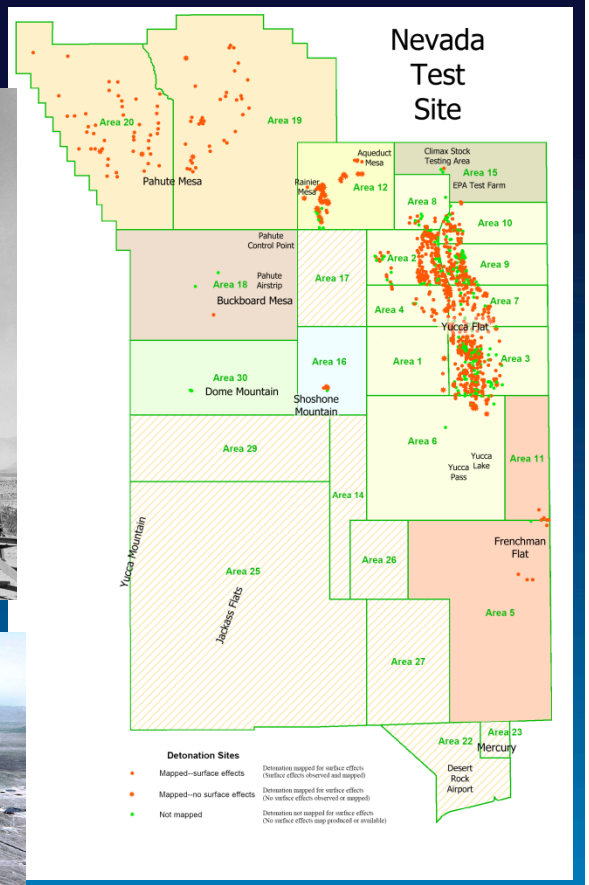
# We used nuclear testing to achieve confidence in the stockpile

- ~1000 tests
- Testing for
  - Weapons physics studies
  - Development
  - Reliability tests
  - Safety tests
  - Effects tests
  - Verification tests
  - Plowshare – peaceful uses of nuclear explosions
- From 1945-1992, LANL/ LLNL developed ~90 weapons for the stockpile to meet changing military needs



# The aging stockpile adds its own challenges

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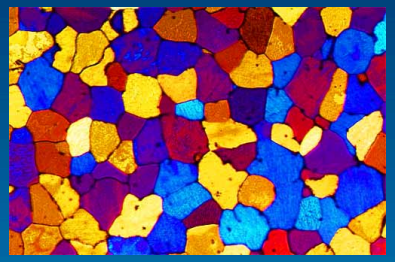

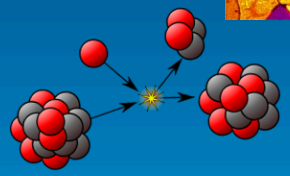

log (length)

$10^{9}$

$10^{0}$

$10^{-6}$

$10^{-15}$

$10^{-19}$ $10^{-9}$ $10^{0}$ $10^{9}$

log (time)

Younger than the stockpile …


Aging stockpile: Reuse Re-manufacture

In the absence of testing, we are driven to **confidence through understanding**

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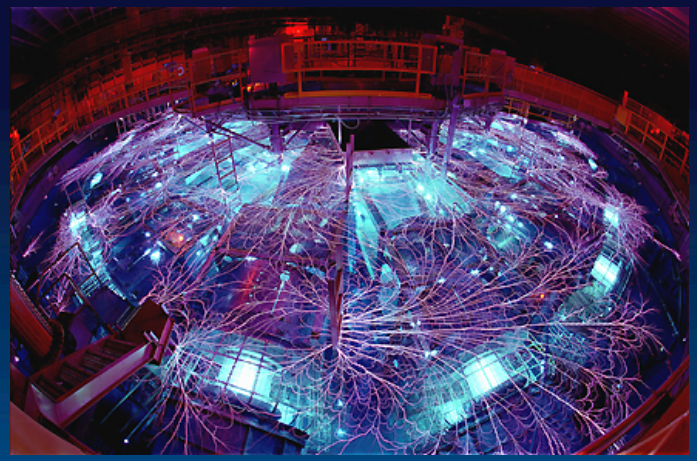
# To address these challenges, we maintain an experimental program studying plutonium

- Fundamental tests in diamond anvil cells, tensile tests, etc.
- Dynamic experiments at Z, JASPER, and TA-55
- Subcritical tests, typically at U1a
  - Plutonium driven by high explosives (HE)
  - K < 1



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# Both weapons laboratories have conducted subcritical tests

- 1997: Rebound, Holog
- 1998: Stagecoach, Bagpipe, Cimarron
- 1999: Clarinet, Oboe 1 through 6, Thoroughbred
- 2001: Oboe 7 and 8
- 2002: Vito, Oboe 9, Mario, Rocco, Piano
- 2004: Armando
- 2006: Krakatau, Unicorn
- 2007: Thermos 1 through 15 (radiological, 13-15 at LANL's pRad facility)
- 2010: Bacchus, Barolo A
- 2011: Barolo B
- 2012: Pollux (Gemini)

LANL
LLNL
LANL/AWE

# Subcritical tests have probed a range of physical phenomena in plutonium

- Dynamic properties of plutonium:
  - Equations-of-state
  - Cavity formation and strength
  - Spall and damage
  - Ejecta
  - Material properties of aged versus new plutonium
  - Material properties of cast versus wrought plutonium
  - Metallurgy and its effects on other dynamic properties
- Certification
- These tests also exercise the skills and equipment needed for test readiness

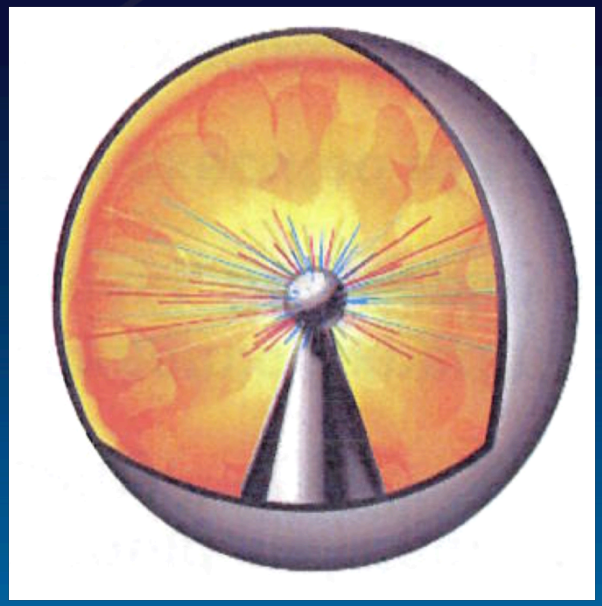
# Three experiments demonstrate the range of science and complexity in subcritical tests

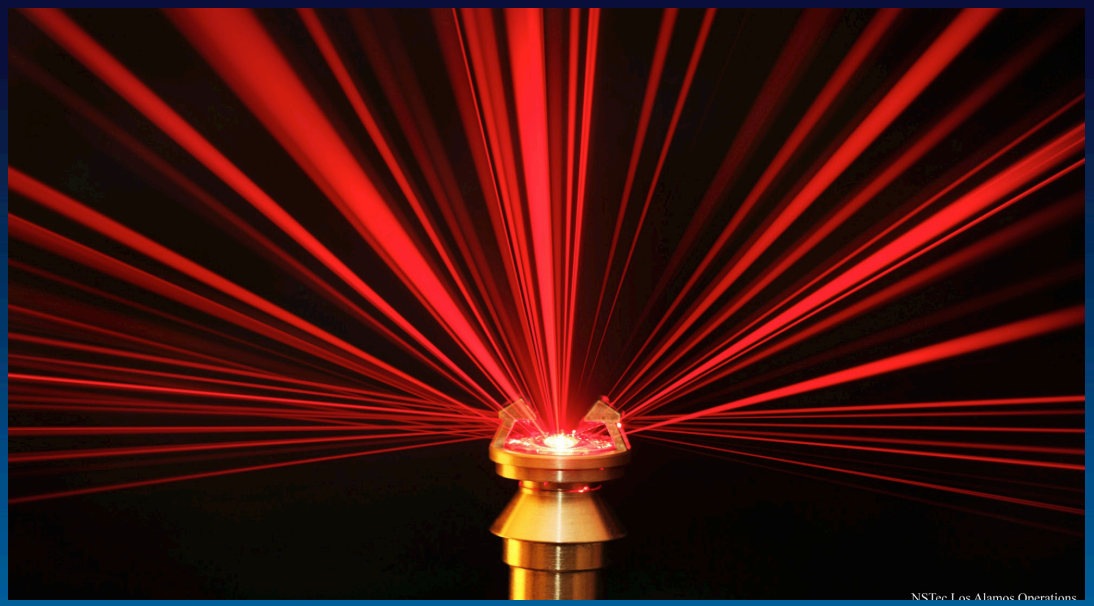
- Gemini (2012)
  - Integral experiment (studying complex system)
  - Primary diagnostic: Velocimetry
  - Driven by challenge from NNSA HQ
- Barolo/Bacchus - Ortega (2010)
  - Focused experiment (studying several physical effects at once)
  - Primary diagnostic: Radiography
  - Driven by changes in the complex
- Nightshade (2016)
  - Fundamental experiment (isolating one bit of physics)
  - Primary diagnostics: Ejecta mass measurements
  - Driven by need for increased understanding

# Gemini was driven by an NNSA challenge.


- We were required to design, build, and field an experiment in ~18 months
- Involved ~800 people, four sites, and ~$100M (~$25M under budget)
- Included three full experiments (one with Pu), novel engineering and fabrication techniques, and several breakthroughs in diagnostics and analysis

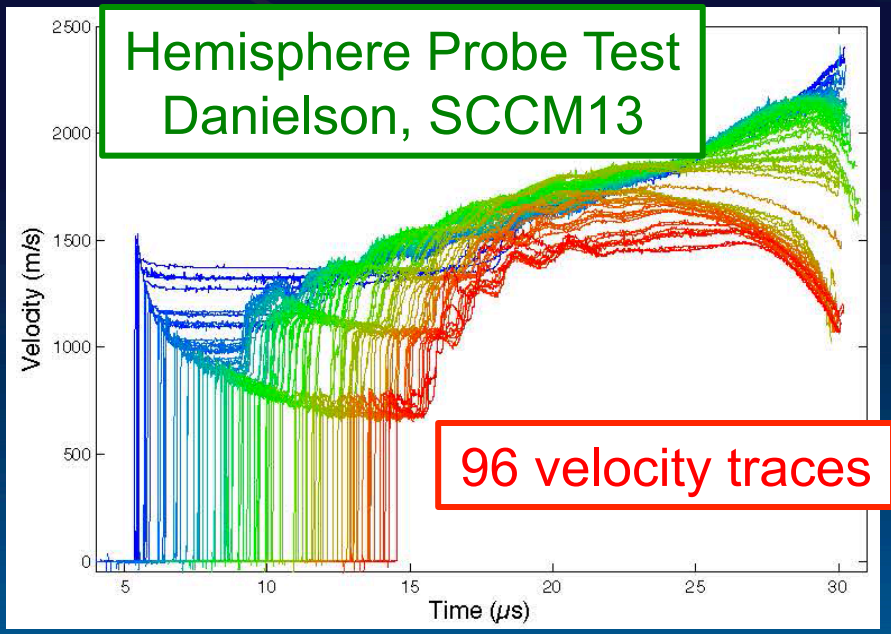
# We invented a new optical probe to track surface motion





- Old technology measured ~500 arrival times
- New technology measures ~3 million velocities
  - Velocity closer to material physics than position

# A new recording technique overcame a fielding bottleneck




- Allowed us to match the number of lines-of-sight used in pin shots
- Large channel count allowed us to do *in situ* measurements of accuracy and reproducibility

O. T. Strand *et al. Rev. Sci. Instrum.* **77** 083108 2006

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# The developments pioneered by Gemini have changed how the complex does early-time hydrodynamic experiments

YouTube: Pollux NNSA

- Surrogate experiments at LANL and LLNL are using this technique
- Future subcritical experiments will explore new surrogate materials (Leda) and new high explosive drives (Lyra)

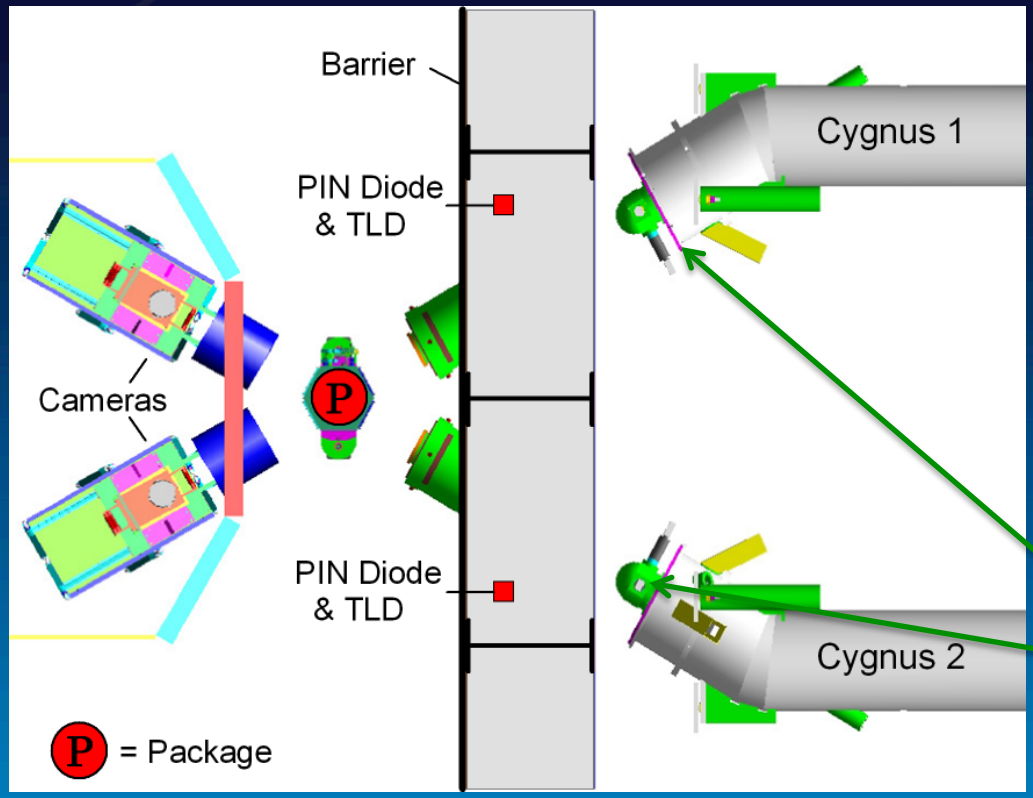
# Ortega was one experiment in the Barolo/Bacchus series

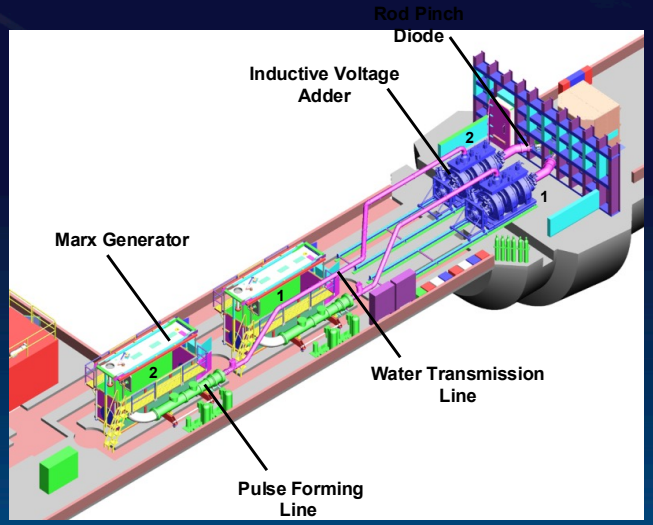


Bacchus Pu sample

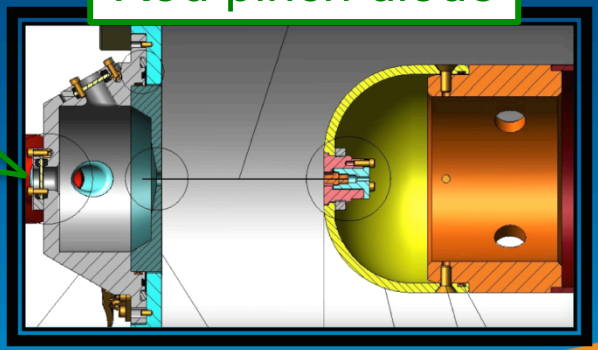
- The Barolo series was a study of the effects of material properties on the strength and damage properties of plutonium
- Ortega and Bacchus were joint experiments between LANL and the U.K. Atomic Weapons Establishment under the 1958 Mutual Defence Agreement

# Cygnus flash x-radiography was the primary diagnostic

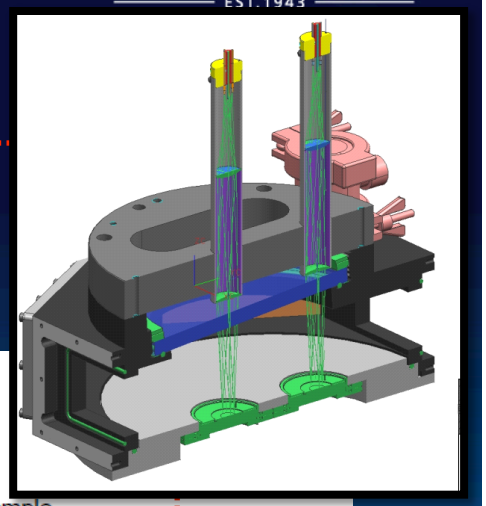


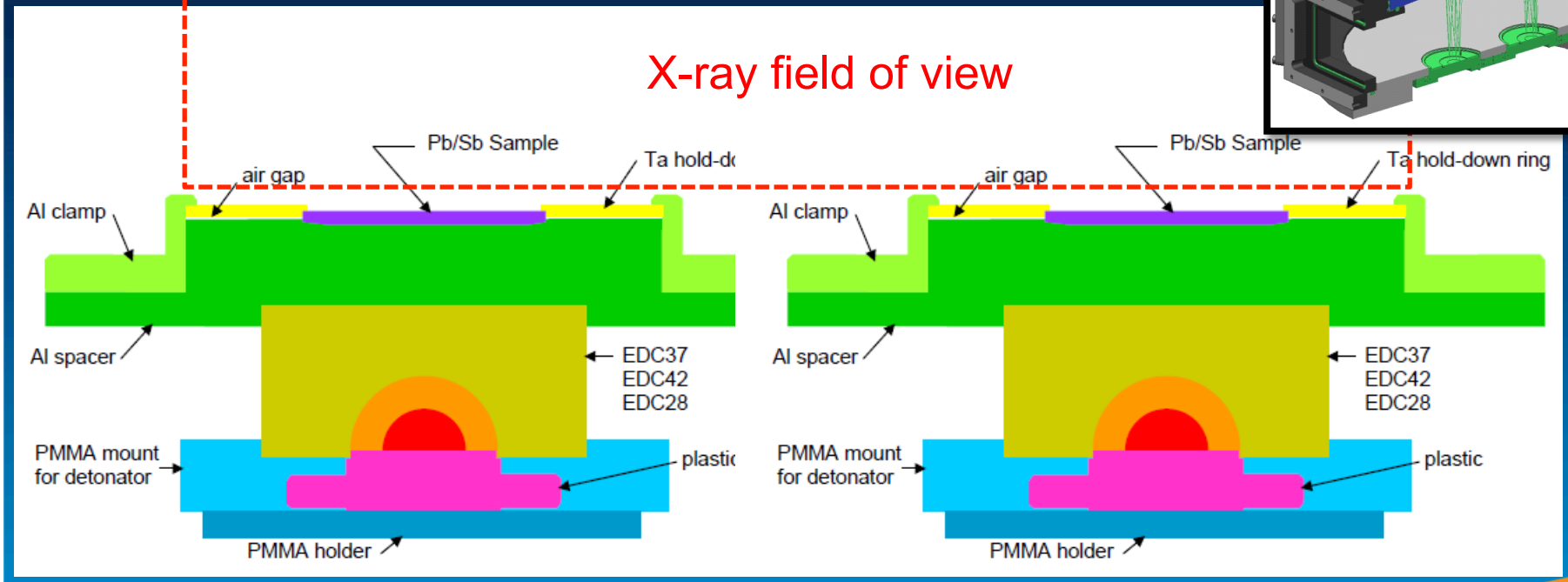




Rod pinch diode

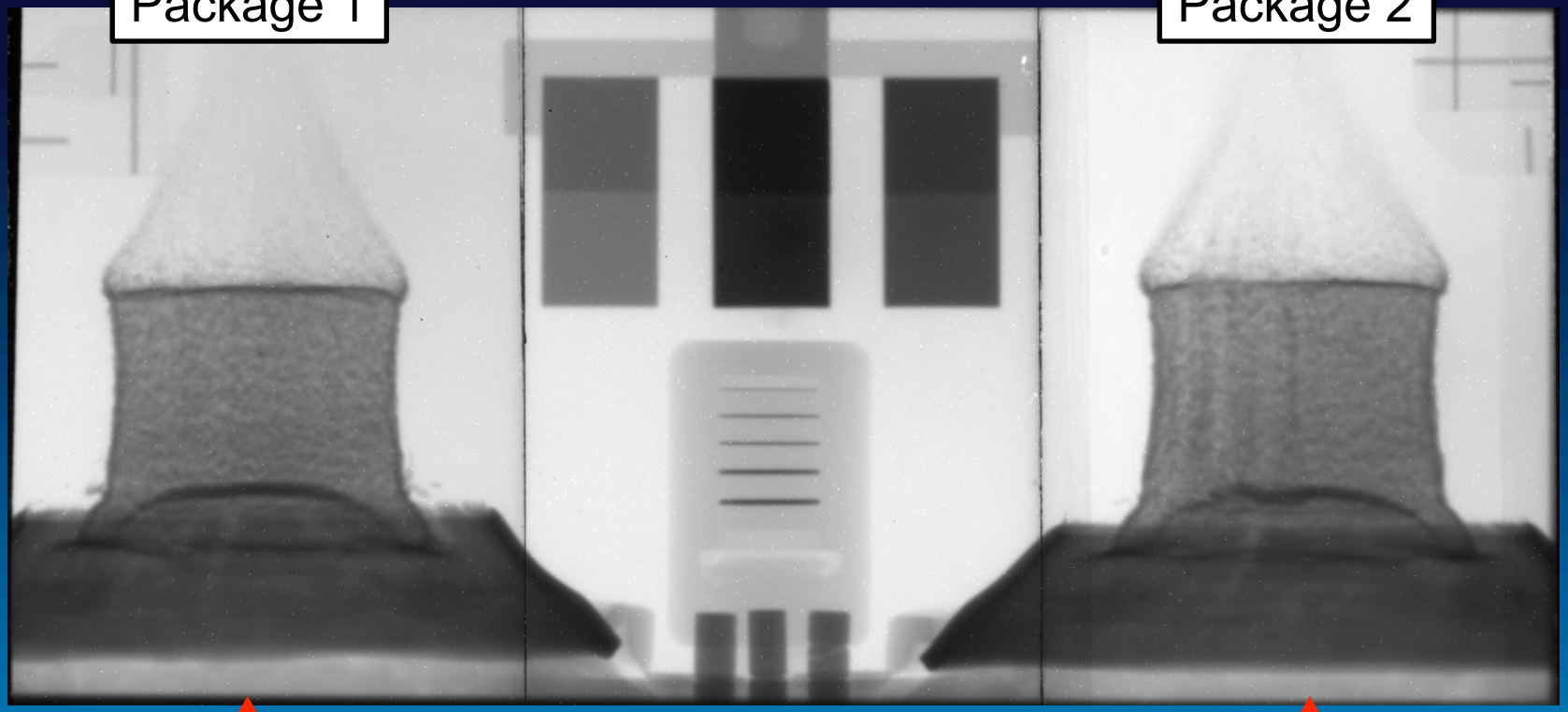


# Ortega was designed to measure the reproducibility of HE-shock-induced damage





# The radiographic data from Pb/Sb test showed 2D reproducibility




Magnification corrected to image plane

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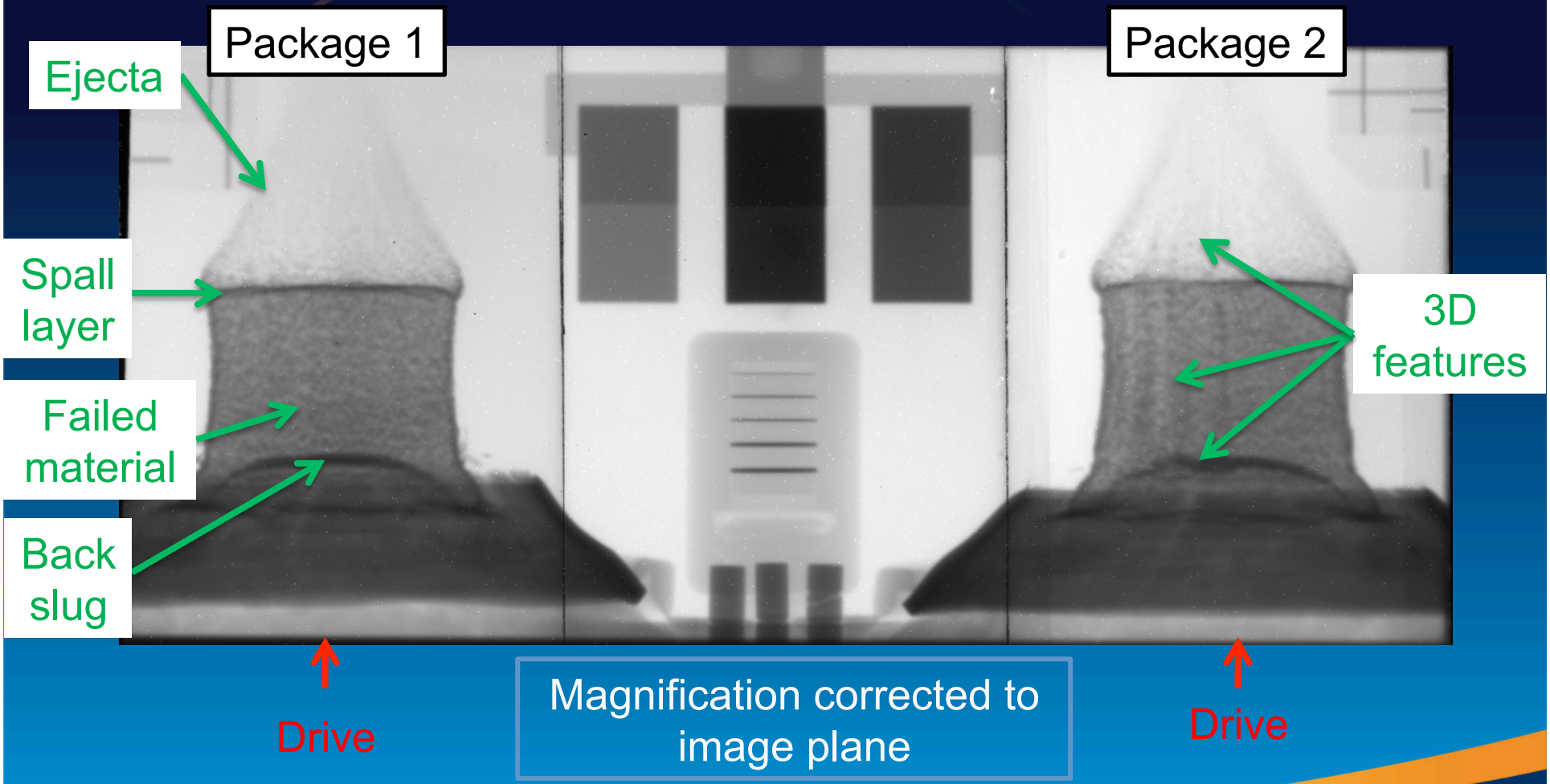
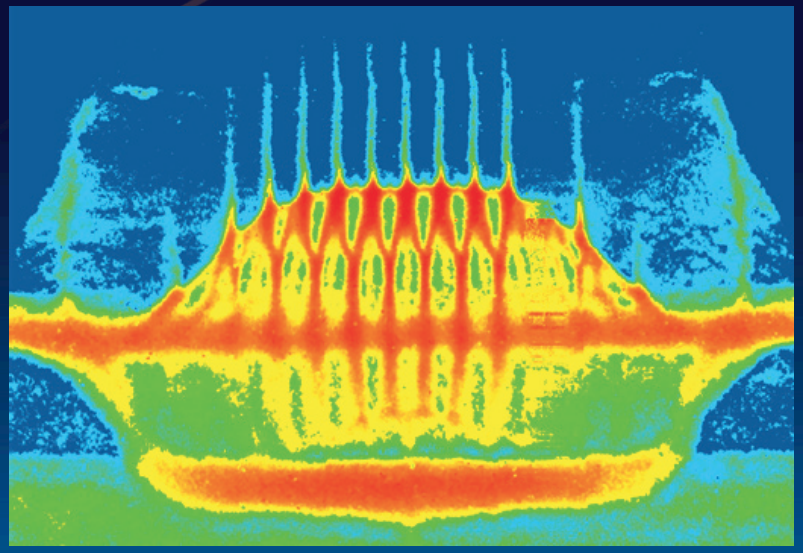
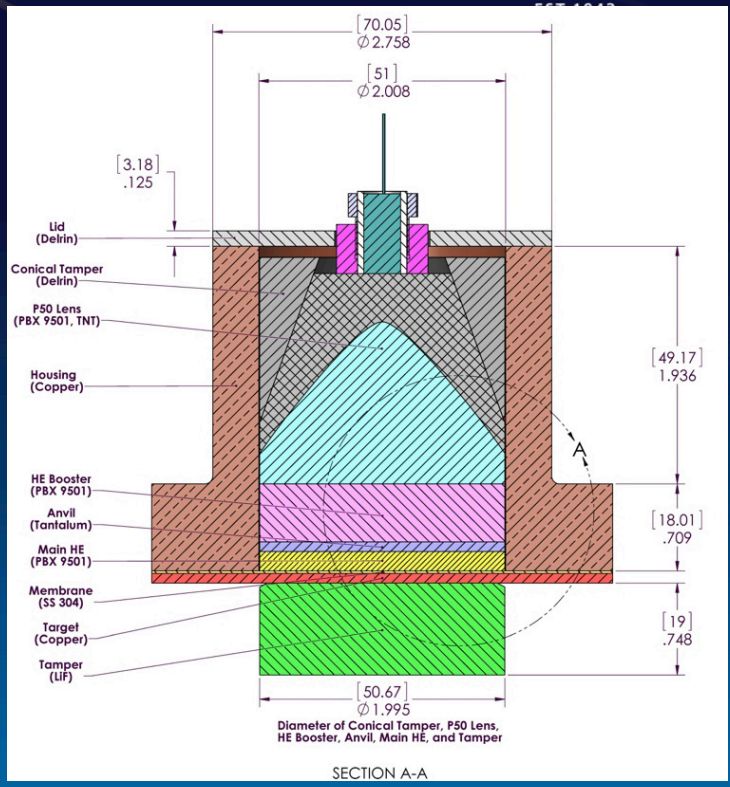


# Nightshade will be the first fundamental experiment since Thermos



Richtmyer-Meshkov ejecta production at pRad (Buttler)




- Detailed study of multiple-shock ejecta in a controlled geometry (in which we can vary parameters of interest)

W. T. Buttler *et al. J. Fluid Mech.* **703** 60-84 2012

# Future subcritical experiments will involve novel probes


- Advanced radiographic facility at U1a
- Neutron experiments to diagnose reactivity directly
- Novel diagnostics (dynamic temperature, light scattering, phase transitions, optical ranging, others?)
- Increased high explosive load

# Conclusions

- Subcritical experiments will remain part of stockpile stewardship for the foreseeable future
- Recently there has been a revitalization in the program at both weapons laboratories
- Subcritical experiments are fairly unique and reminiscent of underground testing, including both open-literature basic science and national security applications