



# Flagging Dual-Purpose Research in the Physical Sciences

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Taken at the MDM Observatory  
in Arizona, Summer 2019

# Physicists should be more aware of the consequences of their work (Pupin Hall Case)



## FOOTBALL SQUAD ON ATOMIC TASK

Physicists Disclose Columbia  
Athletes' Laborious Role  
in 1939-41 Project

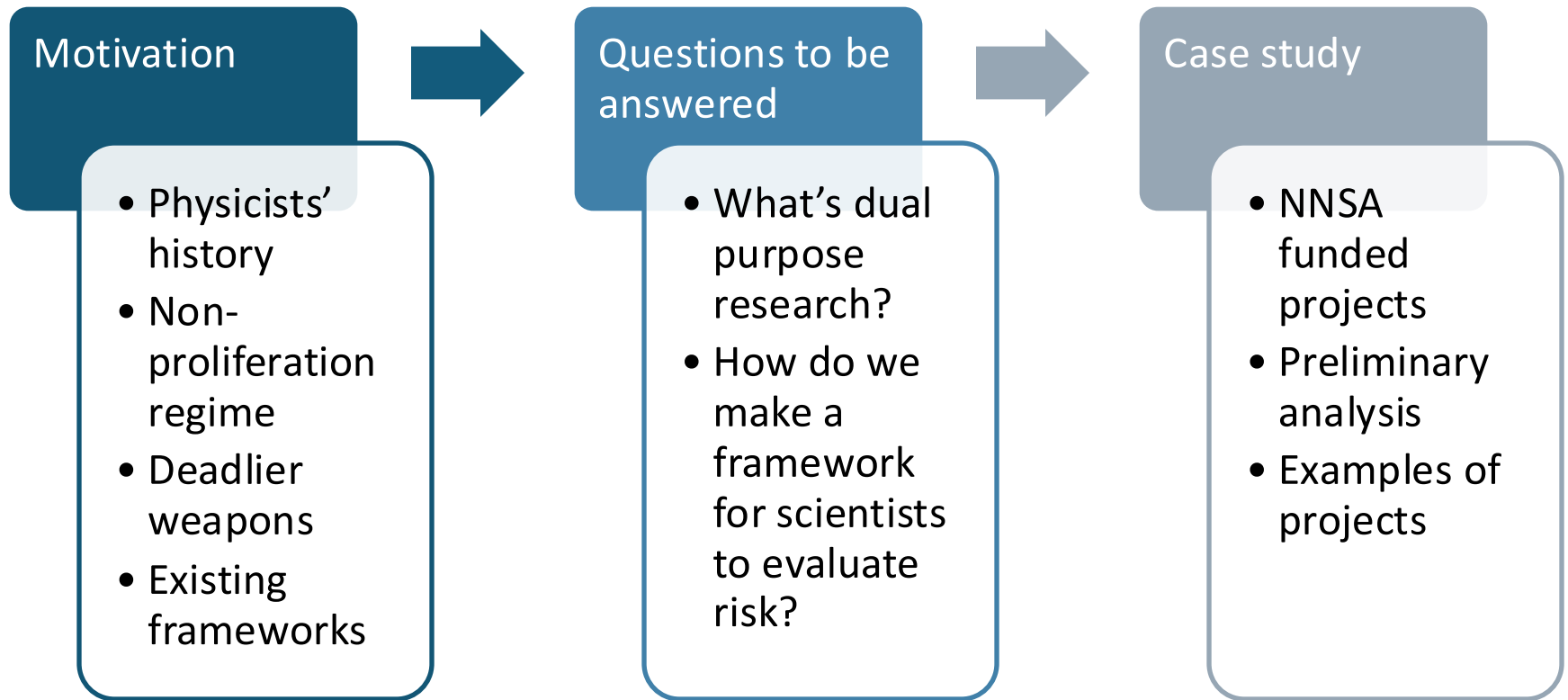
By WILLIAM L. LAURENCE

Page 4 COLUMBIA SUMMER SPECTATOR June 16, 1993  
**The Manhattan Project: Columbia scientists**

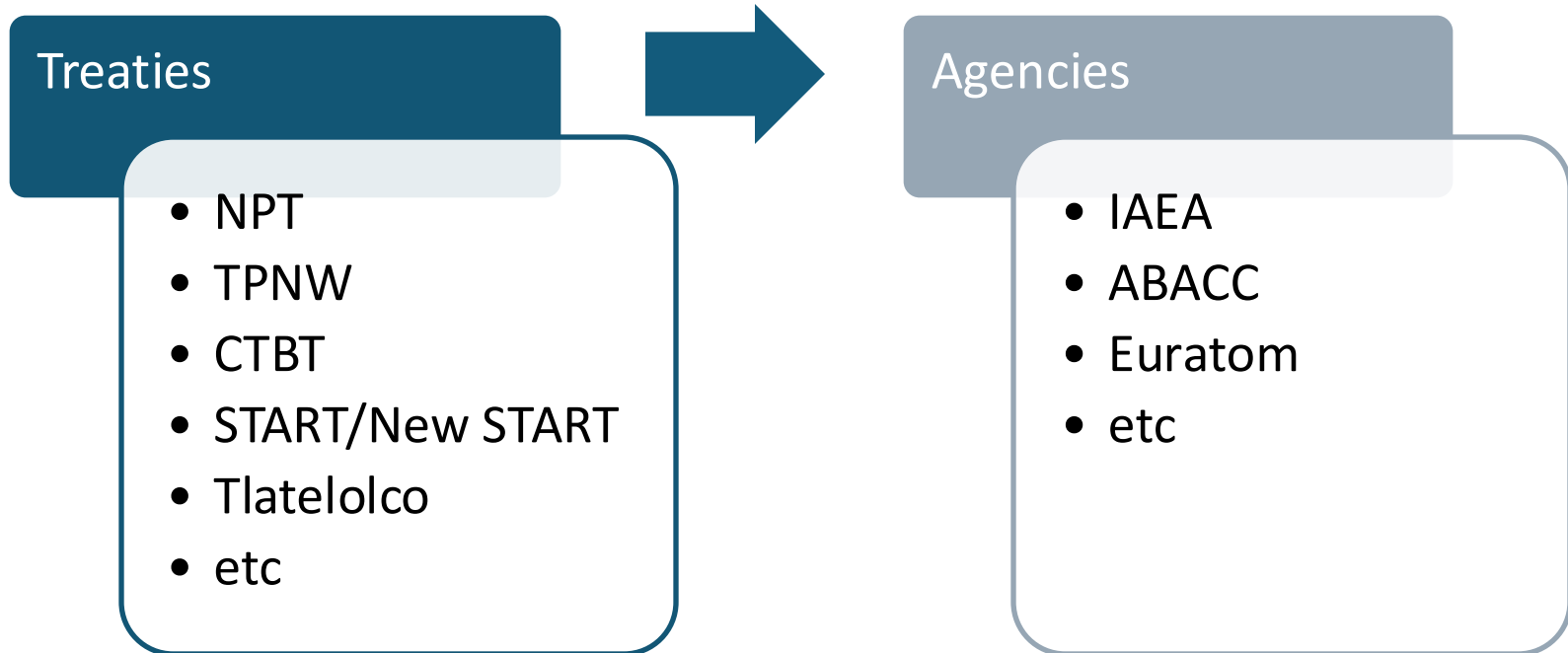
June 16, 1993 COLUMBIA SUMMER SPECTATOR Page 5  
**build the most destructive bomb in the world**

"I asked Fermi once—how do you feel? And he said, 'I was put on this earth in order to make certain discoveries. What people or politicians do with them is something I don't care and I don't worry about,'" Salvadori said.

# Outline



# Motivation: the non-proliferation regime needs a framework to examine contemporary research



Scientists and funding agencies not willing to engage with nuclear weapons should also know the risk of their projects

# Motivation: modern bombs are already very deadly

Modern bombs are not only several times deadlier; they are also more precise and faster.

Modern Weapons  
100+ kt  
580k+ fatalities if  
dropped in NYC

Hiroshima	Nagasaki
15 kt	20 kt
110-210k fatalities combined	



Sources: The Bulletin of the Atomic Scientists, ICAN  
<https://thebulletin.org/2020/08/counting-the-dead-at-hiroshima-and-nagasaki/>  
[https://www.icanw.org/how\\_destructive\\_are\\_today\\_s\\_nuclear\\_weapons](https://www.icanw.org/how_destructive_are_today_s_nuclear_weapons)

# Motivation: modern bombs are already very deadly

Modern bombs are not only

Modern Weapons

100+ kt

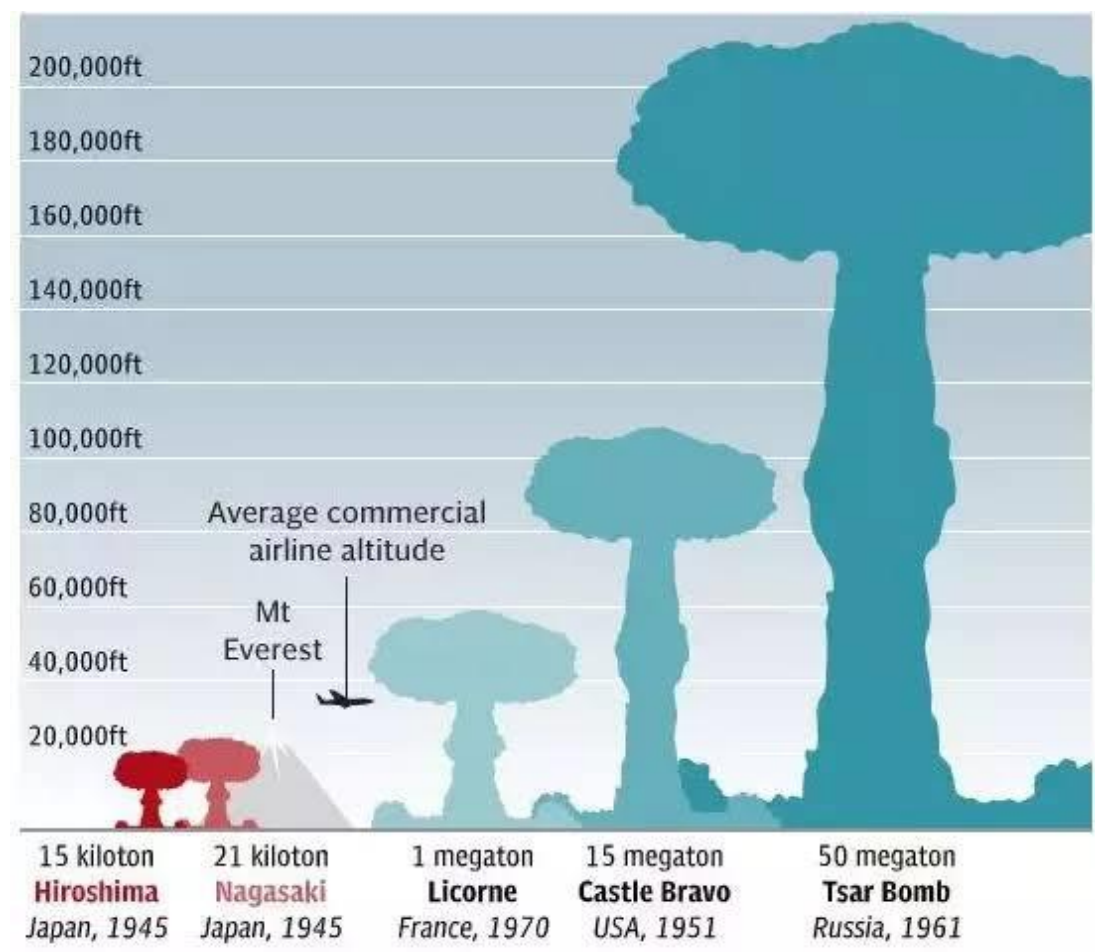
500+ casualties if



The screenshot shows the top portion of a news article from The Washington Post. The masthead includes the newspaper's name and the tagline 'Democracy Dies in Darkness'. The article is categorized under 'ENERGY'. The main headline is 'Fusion Research Shouldn't Be a Nuclear Weapons Side Hustle'. Below the headline, it states 'Analysis by F.D. Flam | Bloomberg' and 'August 26, 2023 at 8:29 a.m. EDT'. The article is framed by a thin black border.

Sources: The Bulletin of the Atomic Scientists, ICAN  
<https://thebulletin.org/2020/08/counting-the-dead-at-hiroshima-and-nagasaki/>  
[https://www.icanw.org/how\\_destructive\\_are\\_today\\_s\\_nuclear\\_weapons](https://www.icanw.org/how_destructive_are_today_s_nuclear_weapons)

# Motivation: modern bombs are already very deadly



# Motivation: developing new bombs is not necessarily needed for deterrence

Bulletin of the Atomic Scientists | Domsday Clock | Nuclear Risk | Climate Change | Disruptive Technologies | Biosecurity | Support Our Work

## Rebuttal: Current nuclear weapons policy not safe or sane

By Stewart Prager, Alan Kaptanoglu | May 24, 2022

Bulletin of the Atomic Scientists | Domsday Clock | Nuclear Risk | Climate Change | Disruptive Technologies | Biosecurity | Support Our Work

## US defense to its workforce: Nuclear war can be won

By Alan Kaptanoglu, Stewart Prager | February 2, 2022

Bulletin of the Atomic Scientists | Domsday Clock | Nuclear Risk | Climate Change | Disruptive Technologies | Biosecurity | Support Our Work

## Dealing with a debacle: A better plan for US plutonium pit production

By Curtis T. Asplund, Frank von Hippel | April 27, 2023

The New York Times Account

### *A Poisonous Cold War Legacy That Defies a Solution*

A \$528 billion plan to clean up 54 million gallons of radioactive bomb-making waste may never be achieved. Government negotiators are looking for a compromise.

**By Ralph Vartabedian**  
Reporting from Richland, Wash.

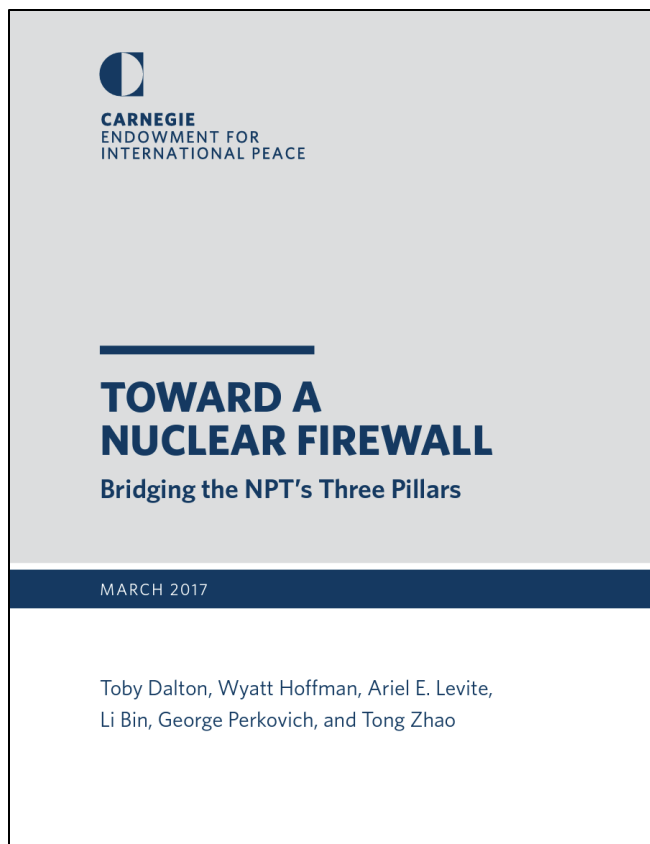
May 31, 2023

# ICAN's Schools of Mass Destruction



- ICAN report from 2019
- 49 universities
- Projects funded by NNSA:
  - 2/3 of funding directed to nuclear-weapon research
- Academic roles in:
  - Direct management
  - Institutional Partnerships
  - Research Programs
  - Workforce Development

# Carnegie Endowment Report: “Towards a Nuclear Firewall”



- Definition in broad terms how political and scientific activities can be warning signs of an imminent nuclear weapons program. Examples:
  - reactor operations
  - control of the fuel-cycle
  - delivery systems
  - military structures
- Need to extend this analysis to even earlier stages of research and funding
- Can we have a more technical framework for RECENT developments?

# What is dual-purpose research in my projects?

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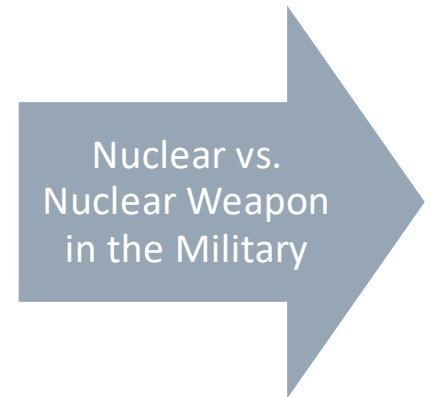


"How can you suggest that this university's research facilities have been co-opted by the military?!"

**Weaponizable** = can be used to produce new bombs or enhance already existing ones or delivery vehicles

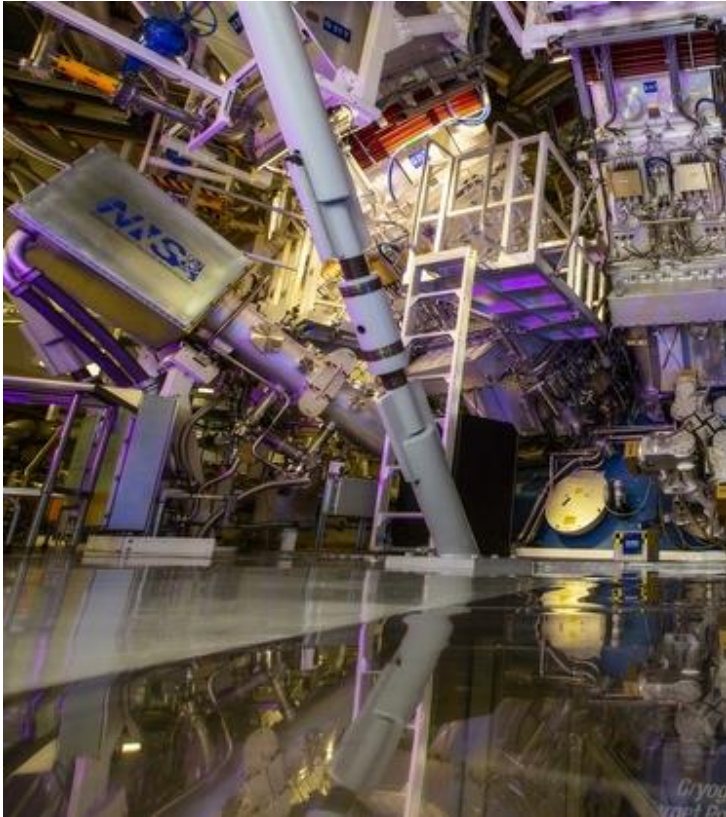


Civilian research used for (nuclear) non-peaceful purposes on purpose or inadvertently



Non-nuclear weapon nuclear research in the military that pose a proliferation risk

# Former postdoctoral projects

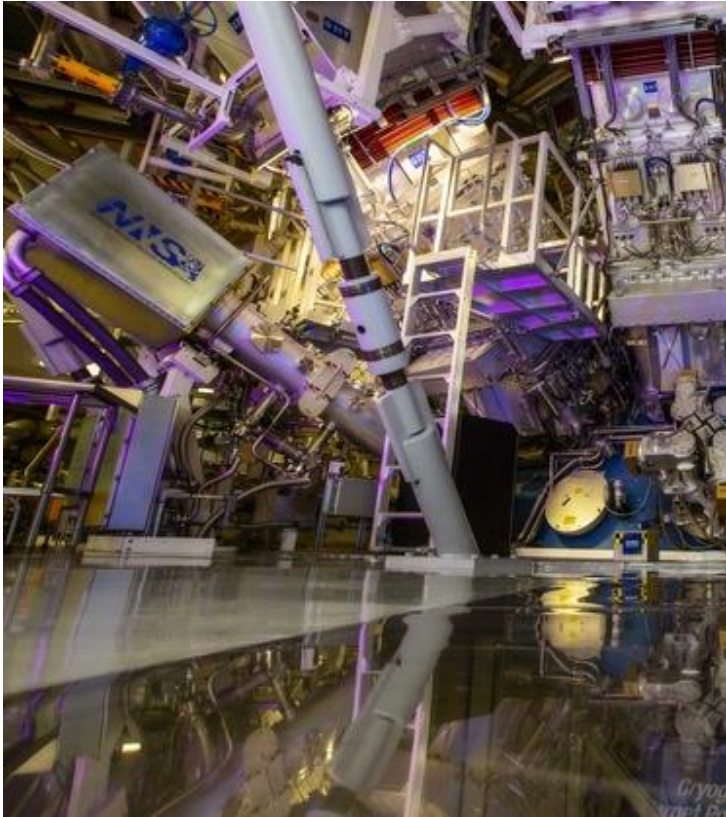


**NNSA Funded Projects**



**Brazilian Nuclear-Powered Submarine**

# Former postdoctoral projects



**NNSA Funded Projects**



**Brazilian Nuclear-Powered Submarine**

# Case Study: What the NNSA currently funds

## Stewardship Science Academic Alliances



National Nuclear Security Administration » NNSA awards \$21 million for research grants for science and technology

**WASHINGTON** – In February 2022, the U.S. Department of Energy’s National Nuclear Security Administration (DOE/NNSA) awarded 36 grants totaling \$21 million to support research activities in areas of physical sciences and engineering as part of the Stewardship Science Academic Alliances (SSAA) Program. The SSAA is one of five academic programs under DOE/NNSA along with the Minority Serving Institution Partnership Program (MSIPP) that includes the Tribal Education Partnership Program (TEPP), the Joint Program in High Energy Density Laboratory Plasmas (JPHEdLP), the Computational Science Graduate Fellowship (CSGF), and the Predictive Science Academic Alliance Program (PSAAP).

- 36 projects awarded in 2022 in academic institutions
- Several (if not most) of them can have **direct applications to nuclear-weapon development**, making it a good place to look for what **contemporary physics research projects** are currently disguised as civilian research but aiding the nuclear weapons complex

## What this project intends to show at this stage

- Make a framework that scientists can use to evaluate the risk of their own research so THEY can make informed decisions
- Enable funders who DO NOT want to be involved in nuclear-weapons development to better understand what they are funding
- Enable the non-proliferation regime to spot budding nuclear-weapons development research disguised as civilian projects

## What this project intends to show at this stage

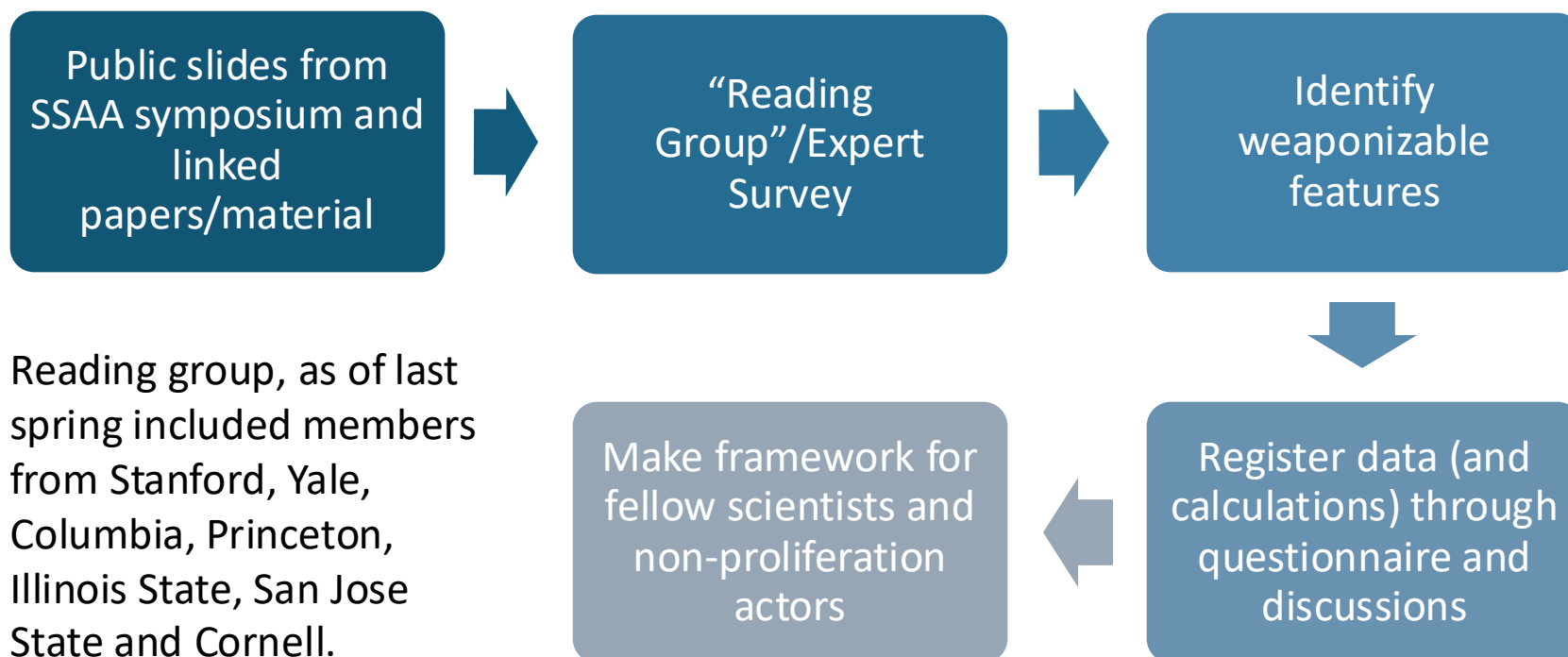
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## What this project does NOT intend to do at the moment

- Make judgement calls on what should be funded by the NNSA, the military, governments across the globe, etc
- Determine what research projects should not be pursued
- Determine what is and is not ethical to research
- Make an all-encompassing framework of everything that will be weaponizable

# Project evaluation

What projects are weaponizable and how do you identify that so we can write a **framework to analyze NEW research?**



# Examples of materials

## Goal

- Optimize mechanical performance during dynamic loading by predicting and controlling solidification and solid-state microstructure development in metals and alloys made by AM processes of interest to the U.S. DOE/NSNSA Weapons Complex
  - Experimentally and computationally link processing conditions (thermal gradient,  $G_s$ , and solid-liquid interface velocities,  $V_s$ ) experienced during laser powder bed fusion (LPBF) and directed energy deposition (DED) processes of Ti-5553 and 316L stainless steels to microstructure development (e.g., columnar to equiaxed transition)
  - Extend constitutional supercooling and inoculation concepts (e.g., for Al alloys) to DED processing of Ti-Nb and/or Ta alloys to achieve grain refinement
  - Gain insights into how microstructural condition (fine grained versus coarse grained) produced by AM dictates quasi-static to dynamic mechanical performance, including under shock loading at the 800 MeV Proton Radiography (pRad) Facility at LANL
- Train and educate the next-generation DOE NNSA workfor **Clarke et al.**

**THE UNIVERSITY OF ARIZONA**

### Imaging and Perturbation Generation

**Particle Image Velocimetry**

Seeding:

- Glycerin droplets
- 2  $\mu\text{m}$  average diameter

Laser: Nd:YLF laser, 70W

- Low resolution: double-pulsed @1.5 kHz, 100 $\mu\text{s}$  dt
- High resolution sequential 7.5 kHz, 133 $\mu\text{s}$  dt

Cameras:

- Low resolution 4 high-speed CMOS @1024 x 1024
- Hi resolution 1 high-speed @2048 x 1920

PIV vector resolution

- Low resolution 874 x 231 vectors 0.37 mm vector spacing
- High resolution 490 x 387 0.26 mm vector spacing

**Jacobs et al.**

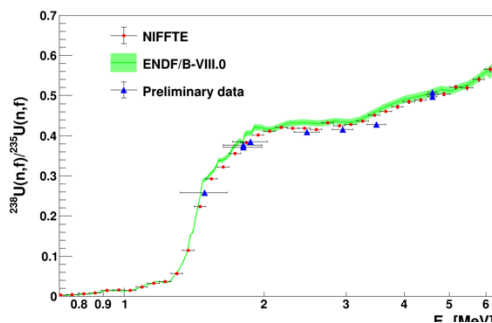
## Preliminary results

$E_p = 4.6$  MeV chosen as "anchor point" since there is agreement between NIFFTE and ENDF/B-VIII

- Present data has excellent agreement ( $<1\sigma$ ) with both NIFFTE and ENDF/B-VIII
- 1.3% precision

Data collected and analysis underway at  $E_p = 1.5 - 3.6$  MeV

Source	Uncertainty
Mass ratio	1.0%
Statistical	$<1.0\%$
Geometric factors	0.5%
Total	$<1.5\%$



**Finch et al.**

## List of publications (2022 - Phase III and IV)

- Zeng L, Jacobsen S.B., Hyung E., Levi A., Nava C., Kirk J., Plaulet C., Lacedelli G., Sasselov D.D., Petaev M.I., Stewart S.T., Alam M.K., López-Morales M., Damasso M., and Latham D.W. (2022) New Perspectives on the Exoplanet Radius Gap from a Mathematica Tool and Visualized Water Equation of State, *The Astrophysical Journal*, 923:247 (30pp). <http://doi.org/10.3847/1538-4357/ac3137>
- Zeng L, Jacobsen S.B., Sasselov D.D., Petaev M.I. (2022) EOS Manual. arXiv preprint arXiv:2211.06518 <https://arxiv.org/pdf/2211.06518.pdf>
- Zeng L, Jacobsen S.B. (2022) Cosmic Hydrogen and Ice Loss Lines, arXiv preprint arXiv:2211.06010 <https://arxiv.org/pdf/2211.06010.pdf>
- Ku Y., Petaev M.I., Jacobsen S.B. (2022) The Timing of Potential Last Nucleosynthetic Injections into the Protosolar Molecular Cloud Inferred from 41Ca–26Al Systematics of Bulk CAIs, *The Astrophysical Journal Letters* 931 (1), L13. <https://doi.org/10.3847/2041-8213/ac666a>
- Chidester B., Millot M., Badro J., Caracas R., Davies E., Fratanduono D., Megan Harwell, Margaret Huff, Stein Jacobsen, Kalita P., Seth Root, Spaulding D., Townsend J., Stewart S. (2022) Experimental temperature measurements of Fe-bearing silicate minerals and glasses to 1.6 TPa. *Bulletin of the American Physical Society* 67. <https://meetings.aps.org/Meeting/SHOCK22/Session/Q04.3>
- Stewart S., Davies E., Chidester B., Kraus R., Kalita P., Root S., Bliss D., Spaulding D., Badro J., Stein Jacobsen S.B. (2022) The Z to Planets Project: Exploring giant impacts and rocky exoplanet interiors at the Sandia Z Machine, *Bulletin of the American Physical Society* 67. <https://meetings.aps.org/Meeting/SHOCK22/Session/G00.54>
- Caracas R. and Stewart S.T. (2023) No magma ocean surface after giant impacts between rocky planets EPSL, in press.
- Stewart S.T., Chidester B.A., Caracas R., Badro J., Harwell M.L., Huff H., Jacobsen S.T. Hydrocode EOS for Pyrolytic Mantles and Magma Oceans, *LPI Contributions* 2678, 1 <https://www.hsu.usra.edu/meetings/lpsc2022/pdf/1535.pdf>

**Jacobsen et al.**

## (Very) preliminary findings

- Still in the process of evaluating these projects, at least 2 people at a time to prevent biases in assumptions for calculations and potential future simulations.
- Out of 36 projects:
  - 17 in physics departments
    - 2 in astrophysics, 4 in condensed matter and 1 in plasma physics
  - All others in closely related fields, some PIs with training in physics
  - 13 projects in schools not on ICAN's list
  - At first glance: ~23 projects with potential weaponization risks, but only 1 mentions weapons in their materials

## Microstructure Control of Additively Manufactured Metals of Interest to the NNSA Weapons Complex

Amy Clarke<sup>1</sup>, Kester Clarke<sup>1</sup>, Jonah Klemm-Toole<sup>1</sup>, Alec Saville<sup>1</sup>, Finn Bamrud<sup>1</sup>,  
Chris Jasien<sup>1</sup>, Tara Mitra<sup>1</sup>, Robin Pacheco<sup>2</sup>, Michael Brand<sup>2</sup>, Colt Montgomery<sup>2</sup>,  
Ryan Mier<sup>2</sup>, Kevin Le<sup>2</sup>, S. Vogel<sup>2</sup>, Andrew Kustas<sup>3</sup>, Don Susan<sup>3</sup>

Article • Mat. Res. 26 • 2023 • <https://doi.org/10.1590/1980-5373-MR-2023-0015>

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# Microstructural Characterization of a 1200 MPa Complex-Phase Steel

AUTHORSHIP

SCIMAGO INSTITUTIONS RANKINGS



» Abstract

» Text

1. Introduction
2. Material
3. Dilatometry
4. Microstructural Charact...
5. Mechanical Properties
6. Results
7. Discussion
8. Conclusions
- » Supplementary material
- » 9. Acknowledgements
- » References
- » Publication Dates

### Abstract

The demand for new advanced high strength steels (AHSS) has been increasing in the last few decades. A large part of this demand comes from automotive companies. We have produced a new complex-phase (CP) steel with 1200 MPa of mechanical resistance and 8% of elongation, called CP1200. In this paper the dilatometric and microstructural characterization of a newly produced CP1200 steel is presented. The new steel was produced by making changes to the heat treatment of the already industrially available CP1100. The microstructure was quantified using light optical microscopy (LOM) and electron backscatter diffraction (EBSD). The microstructure of both steels was compared to identify the origin of the mechanical properties improvement. A new microstructure distribution, with higher amount of bainite and smaller concentration of ferrite and martensite was identified.

#### Keyword:

AHSS; Complex-Phase steel; Phase Transformation

# Example of not-so-obvious dual-purpose research

## Summary of the project progress

- **Science:** Investigate novel states, properties and chemistry of low Z planetary mixtures under extreme conditions:

- EOS of symmetric ice-X
- Superionic phases in H<sub>2</sub>O and He-H<sub>2</sub>O at high PT
- Dynamic compression behavior of H<sub>2</sub>O in dynamic-DAC

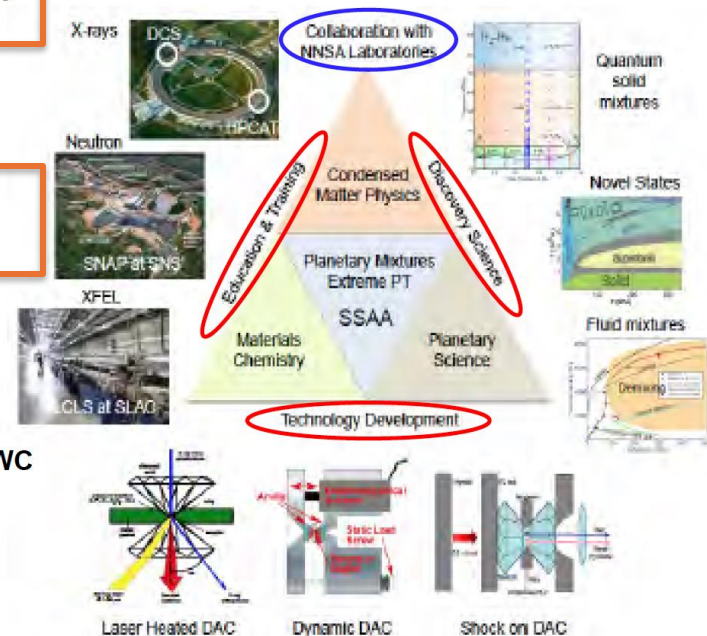
- **Technology:** Develop/apply enabling high PT and in-situ real-time probing technologies;

- KHz TR-XRD for ramp-LH DAC at the APS
- MHz TR-XRD for dynamic-DAC at the Eu-XFEL

- **Education:** Train students with cutting-edge high-PT tools on fundamental research important for NNSA-SS program
  - Brittany Thiessen, PhD in Chemistry, WSU, 2023, now at NSWC

- **Collaborate with NNSA Labs:**

- N<sub>2</sub> d-DAC at EuXFEL (#5640, 3/28-4/2/2024) with D. Sneed, E. O'Bannon, Z. Jenei, W. Evans at LLNL
- NIF-DS on XCHEM: Phase transitions of ramp compressed NaCl with A. Krygier, A. Jenei, J. Eggert, D. Swift, S. Hamel at LLNL

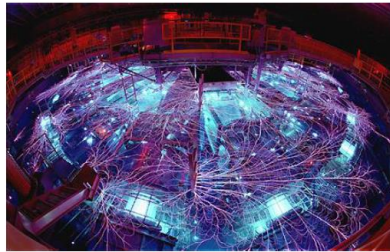


This project emphasizes use of large scientific user facilities such as APS, XFEL, NIF, etc.

Yoo et al.

# Example of not-so-obvious dual-purpose research

## I. PROJECT OBJECTIVES



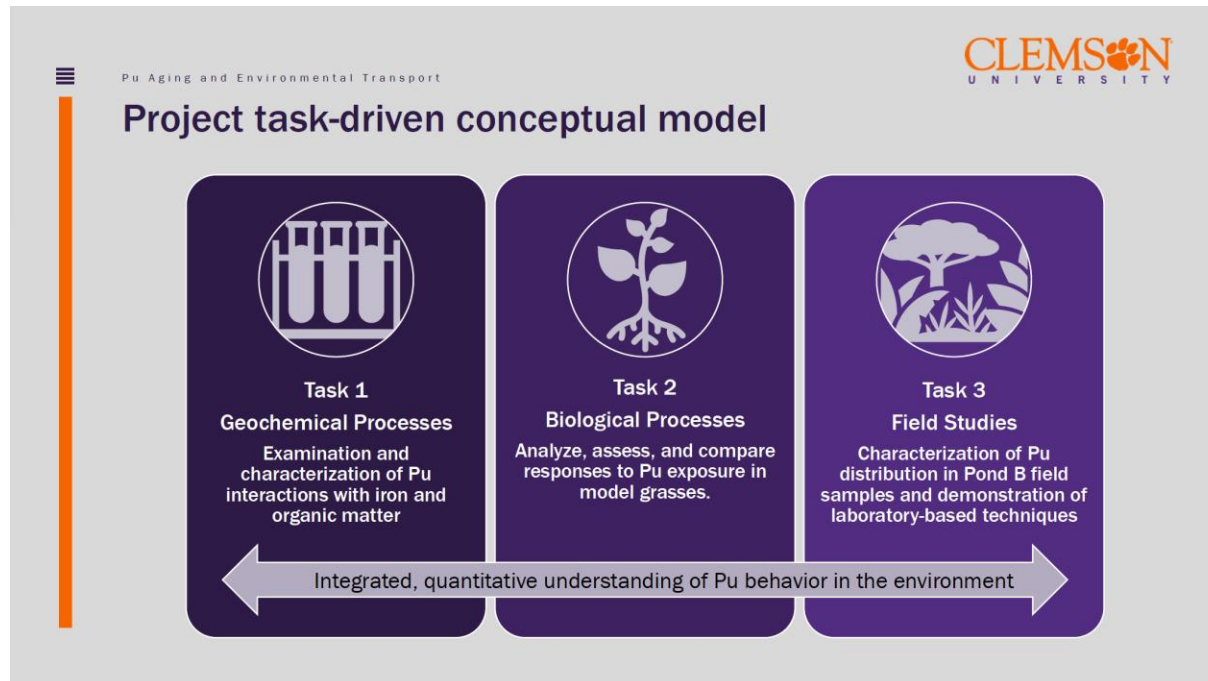
- (1) determining material properties of Earth-like worlds and Water-worlds up to about 1 Tera Pascal (TPa) using the **Z machine**,
  - (2) understanding the internal structure of exoplanets and possibility of life on them, and
  - (3) understanding the planet formation/accretion process and how it may lead to the diversity of observed planets.
- (i) giant impacts, including Moon-forming events,
  - (ii) early silicate vapor atmospheres,
  - (iii) interiors of Earth-like and Super-Earth planets,
  - (iv) planetary thermal evolution, differentiation, and core formation, and
  - (v) why the most common sizes of exoplanets are  $\sim 1.5$  and  $2.3$  Earth radii.

**Objectives:** Measure the physical properties of the major building blocks of Earth-like and Water World planets in order to develop better models of:

Jacobsen et al.

# Project also allows us to identify research that needs to be pursued more broadly

Examples: Pu aging and impact on local communities (immediate need), detection of neutrinos to aid in inspection performance (can have an impact 2-3 decades from now)



Powell et al.

## Possible future directions

- Completing the framework in the form of a public report
- Starting to make considerations about ethical implications of different research projects
- What kind of safeguards and regulation can be applicable to these kinds of technologies?
- Can we expand this project to flagging dual-purpose projects funded by other agencies (DoE, DoD, NASA, NSF, etc) or countries? Maybe through cross-referencing of identified categories?
- Can we automate the process of finding these technologies within the context of published papers using, for example, AI/machine learning to aid in non-proliferation?

# Physicists' Coalition for Nuclear Threat Reduction



The Coalition is not a part of this work but mentored me to start thinking about nuclear security issues from a scientific and policy perspective.

This is my endorsement of them and not their endorsement or participation on this presentation.