SAND2018-1453PE

National Nuclear Security Administration

# Israel Atomic Energy Commission and National Nuclear Security Administration

# Science and Technology Working Group Update Topic area 3 & 4

Under the April 2016 NNSA-IAEC Memorandum of Understanding for Cooperation in the Fields of Science, Nuclear Security and Safeguards, and Nuclear Emergency Management

**February 13, 2018**

Input: Dawn Flicker, SNL
John Sarrao, LANL, Robert Maxwell, LLNL

# Science Cooperation: Recent Progress

## The MOU covers scientific cooperation in areas of mutual interest. These include:

I. Nuclear measurements
II. Science of nuclear forensics
III. High Energy Density Physics (HEDP)
IV. Materials science
V. Basic science of waste management & subsurface science


## On the General Framework

- NNSA and IAEC labs have been working over the past year to develop ideas in: enhancing cooperation and partnership, facility access, site visits, technical and scientific cooperation, and personnel exchanges.
- The efforts include drawing in associated universities and governmental research organizations where it makes sense.
- Work has started in many of the areas and there is visible progress which we will summarize today.
- Two NNSA-IAEC 5-lab, full-portfolio, technical reviews have been held, the most recent in May 2017.

# Science Cooperation: Status Report

**Today we report to the Joint Steering Committee on**

- The current status of the NNSA-IAEC scientific collaboration
- Recommendations about proposals appropriate for launching actual Lab work
- Specific issues which require resolution and guidance

**Over-all Assessment:**

# Topic Area III: High Energy Density Physics

## Major directions in HEDP

- Non-Local-Thermal-Equilibrium (Non-LTE) atomic physics

  Mark Foord, Marilyn Schneider, Yechiel Frank, Moshe Fraenkel, Mark Herrmann, Dawn Flicker and many other participants

- Extensions of STA method for LTE & Non-LTE atomic physics models

  Yair Kurzweil, Giora Hazak, Paul Grabowski, Brian Wilson, Carlos Iglesias

- Experimental verification of the opacity "microscopic equivalence" principle

  Yair Kurzweil, Giora Hazak, Jim Bailey, Stephanie Hansen, Taisuke Nagayama

- Hydrodynamic instabilities time evolution studies in HEDP plasmas

  Eric Harding, Guy Malamud

**Lab POCs:**

- **Dawn Flicker (SNL)**
- **Mark Herrmann (LLNL)**
- **Moshe Fraenkel (SNRC)**
- **Guy Malamud (NRCN)**

# Topic Area III. Recent Activities

- Participation at Z Fundamental Science Workshop in Albuquerque July 31 to August 3, 2016
- Sandia hosted tours of Z and the Dynamic Integrated Compression Experimental (DICE) , August 2016
- Joint NNSA/IAEC/Academic workshop in Atomic and Plasma Physics, LLNL Dec 2016
  - Jointly defined research objectives that can make significant contributions to the understanding of atomic and radiative processes and related topics and their role in HEDP and ICF
- Workshop at LLNL February 8-10, 2017 led by B. Remington (LLNL) and G. Malamud (NRCN)
  - Building on previous collaborations in the NIF Discovery Science program
- Workshop and tours provide basis for competitive proposals in the 2017 ZFSP call, issued in June 2017
- Z Fundamental Science Allocation Awards to be announced imminently

# Topic Area III. Ongoing Projects

## 1. Non-LTE atomic physics experiments and theory

- Development of "clean" non-integrated experiments where the conditions of the plasma are nearly uniform and vary slowly in time, providing the potential for exploring new areas in atomic physics and radiative processes in high temperature non-LTE plasma.

## 2. Development of improved LTE & non-LTE atomic physics models based on the STA/PRCRSTA methods

- Development of flexible LTE and non-LTE models with controlled resolution between full detailed spectral line accounting and more approximate statistical methods.

## 3. Experimental validation of "microscopic equivalence" concept for solar interior opacity

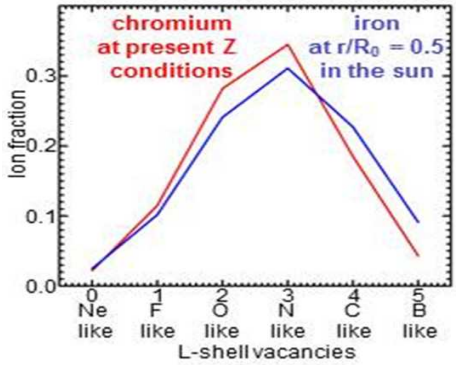
- Development of a method for experimental validation of the STA/CRSTA/PRCRSTA model for opacity in solar interior using the concept of "microscopic equivalence" between two different atom and plasma systems.

# Topic Area III. Collaborations on Z

- **The Z Fundamental Science Program enables collaborations with other institutions on Z**
  - Typically 15-18 days/year
  - Hosted 9 teams in 2016/2017 (**13 days ZAPP/ 20 Materials )**
  - Proposal process with an external panel to review scientific merit
  - 13 proposals received for 84 days in 2018/2019
- **Two 2018/2019 proposals included IAEC participants; notifications will be sent soon**

**Micro-equivalence of solar opacities (Y. Kuzweil, G. Hazak, J. Bailey, T. Nagayama)**

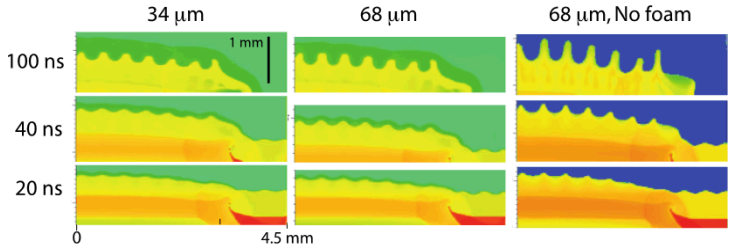
- Proposal to test models for iron opacity deep in the sun integrated into the 6-8 days/year ZAPP team collaboration




**Cr a surrogate for Fe deep in sun?**

**Hydrodynamic Instabilities in HED Plasmas (G. Malamud/ E. Harding)**

- 16 days to study Non-linear Richtmyer-Meshkov instability and transition to turbulence in Rayleigh-Taylor (RT) instability.



# Topic Area IV. Material Science

## Major directions being proposed

- **Process dependent microstructure and mechanical properties characterization**

  Eitan Tiferet; Aviva Melchior, LANL: Don Brown, Rusty Gray; SNL: Paul Specht, Mike Valley; LLNL: Morris Wang

- **Modeling and characterization of radiation damage**

  Arnon Yosef-Hai, Benny Glam, Noaz Nissim, Max Platkov, R. Smith, TBD: LANL,

- **Influence of microstructure, inclusions and pores on dynamic mechanical properties of materials**

  NRCN: Vitali Paris; SNRC: Noaz Nissim, Max Platkov, Avi Ravid; LLNL: R. Smith LANL: Don Brown, Rusty Gray; SNL: Paul Specht, Bradley Jared;

- **Kinetics of Phase Transitions at high pressures and/or temperatures**

  NRCN: Eyal Yahel, Arnon Yosef-Chi; SNRC: Benny Glam; SNL: Seth Root; LLNL: TBD; LANL: Rusty Gray

- **Characterization and tailoring the properties of additively manufactured metallic objects**

  Morris Wang and Ibo Matthews (LLNL), Bradley Jared (SNL)

**Lab POCs:**

- **Eyal Yahel (NRCN)**
- **Eli Sarid (SNRC)**
- **John Sarrao (LANL)**
- **Glenn Fox/ R.Maxwell (LLNL)**
- **Dawn Flicker (SNL)**

# Topic Area IV. Recent Activities

- Bi-Lateral meeting, Tel Aviv – February 2016:
  - Initial technical discussions
- Ongoing IAEC work at LANL's Lujan Center; extended IAEC team – November 2016
- Expansion of technical portfolio– May 2017 in Soreq
- Request for approval of additional Task – July 2017
- Meeting of PIs in July 2017 in St. Louis at APS conference on Shock Compression of Condensed Matter (SCCM)
- Exchange of detailed proposals in the major directions

# Topic Area IV. Recent Activities

- Sept 2017: Sven Vogel visits Rotem and Sarov for 3 days of workshop and research planning.
- Beamtime during 2017/18 Lujan Center Run Cycle.
  - Oct 2017: Tiferet Eitan, Yaron Ganor, Asaf Pesach, and Gennadi Rafailov visit the Lujan center.
    - ~8 days of beamtime on SMARTS to study deformation of AM Ti6Al4V samples heat treated to different temperatures.
      - 7 samples deformed in-situ. Data analysis completed by Bjorn Clausen and Maria Strantza (LANL) and sent to Yaron Ganor (poster in preparation).
    - 2 days of beamtime on HIPPO to determine textures and phase fractions ($\alpha/\beta$) in AM Ti64.

Tiferet, Yaron, and Maria Strantza on SMARTS, Oct 2017.

- 2017/18 Talks at multiple conferences (TMS, ICOTOM etc) highlight research done as part of NNSA/IAEC MOU.
- Submitted combined proposals to CHESS and APS for beamtime to examine residual stresses in AM Ti64 components.
- Proposal to CHESS for in-situ heat treating of Ti64.
- Israel group provided material for in-situ heat treating studies.
- Jan 2018 Gennadi Rafailov hires on to LANL for 1+ year visit as a student.

# Topic Area IV. Continued Collaboration

- March 2018: In-Situ heat treating of AM Ti64 scheduled for beamtime at F2 beamline at CHESS.
  - Material made with 3 distinct AM "flavors", SLM, LENS, and EBM will be heat treated to 4 different temperatures while diffraction data is collected to monitor phase, texture, and dislocation density.
  - Maria Strantza is PI, Gennadi Rafailov will attend and participate in experiments and subsequent analysis.
  - Israel group provide EBM material.

Elad Caspi, Asaf Pesach, Ori Yeheskel with Sven Vogel at White Rock overlook.

- May 2018: Expect, but not yet awarded time at A2 beamline at CHESS for AM Ti64 component residual stress studies.
- May 2018: Planned visit of Elad Caspi to LANL.
- Analyze and report on recent data collected as well as plan future collaboration.
- Proposed long term sabbatical at LANL.
- Submit proposals to SMARTS/HIPPO for beam time to continue collaboration.
- LANL SME's mentoring Gennadi Rafailov on successful proposal writing.

# Discussions to identify areas of mutual interest have been very fruitful

- **Several new or expanded efforts proposed**
  - Process dependent microstructure characterization
  - Modeling and characterization of radiation damage
  - Dynamic and static AM experiments in high pressures and/or temperatures
  - Characterization and tailoring the properties of additively manufactured metallic objects
  - Kinetics of Phase Transitions at high pressures and/or temperatures
  - Studying Equation of state of materials at off-Hugoniot conditions using high intensity lasers and pre-compression DAC
- **Two to five laboratory interest in each**
- **Some convergence on materials, most notably**
  - AM: Ti64 & Al10SiMg
  - Dynamic Phase Transitions: CaF2
- **Propose a workshop to coordinate work on materials and topics of mutual interest**

# Topic Area IV. Next Steps

## 4. (NEW) Characterization and tailoring the properties of additively manufactured metallic objects

- Exploring the role feedstocks may have tailoring the properties of additively manufactured metallic objects.

### Scale of commitment:

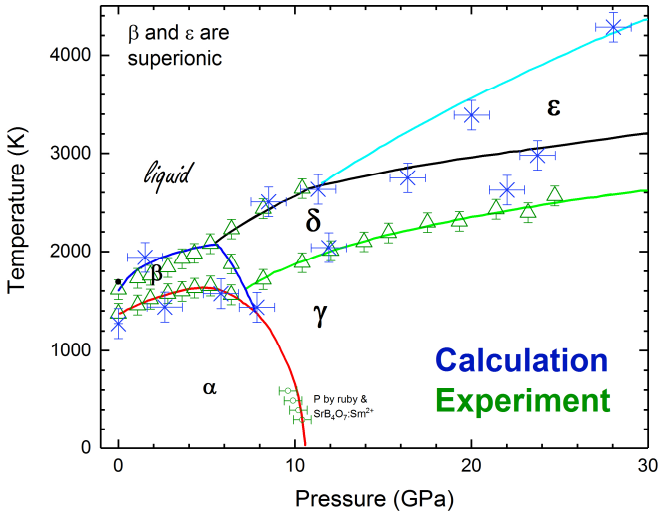
- Printing test objects via powderbed (laser and EB) with mutually sourced Ti64 feedstocks
- Characterization and data exchange
- Modeling of residual stress in EB parts

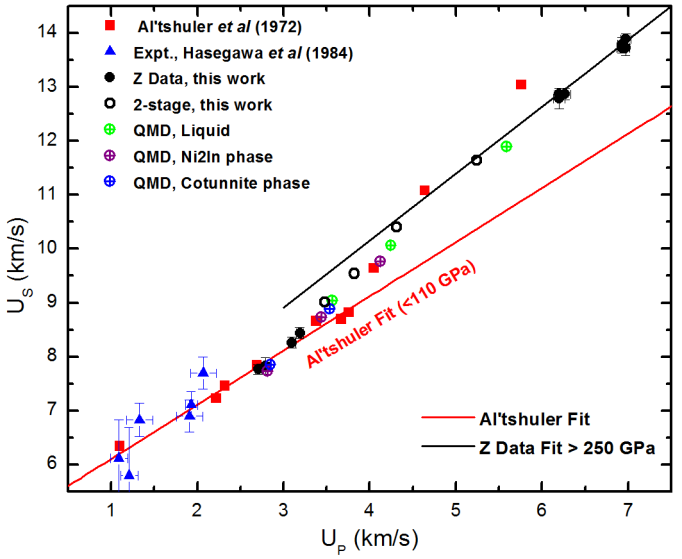
### Timeline: for 201(7?)

- WebEX meetings held to exchange details of approaches and discuss mutually agreeable deliverables for 2018 and 2019
- Proposal drafted

# Dynamic Phase Transitions

- CaF2 has several phase transitions, but the extended phase diagram is undetermined
- Prior dynamic experiments suggest two phase transitions along the Hugoniot
- Proposal initially focuses on the $\alpha$–$\gamma$ phase transition in the 5-20 GPa region
  - IAEC performs shock experiments using their gun platform
  - SNL performs shockless experiments using the THOR platform
  - Higher pressures using 2-stage and Z
  - Orientation dependencies
- Further studies include examining temperature and loading rate effects on elastic-plastic behavior and spall



# Topic Area IV. New Proposal

## 2. Influence of microstructure on dynamic mechanical properties of AM materials (Vitaly Paris (NRCN), Avi Ravid (SNRCN), Paul Specht (SNL))

- Exploring the influence of microstructure, inclusions and bubbles on mechanical properties of materials in dynamic experiments at wide ranges of loading conditions and stress rates
  - First material: $Al_{10}SiMg$ (Samples produced by NCRN)
    - Implanted "pores" with HIP & heat treatments to control pore size & pressure and Si inclusions
  - Main tools will be plate impact experiments and shockless compression (VISAR or PDV) to investigate the influence of the pores/inclusions on elastic yield strength and spall strength.
  - Experiments will be analyzed using hydrodynamic simulation coupled to strength and spall models and post mortem microstructure characterization.

### Scale of commitment:

- Studying strength and failure phenomena by guns, SHB and lasers, including pre and post mortem metallographic characterization and in-situ imaging.
- 2018 Workshop to refine experimental/analysis plans

### Timeline: 2018-2021

# Topic Area IV. New Proposal

## Kinetics of phase transitions in solids

- Study phase diagrams and EOS of selected physical systems at extended pressure, temperature and stress rate ranges.
- Interest in $CaF_2$ – Need to work the details

## Scale of commitment:

- Study of the behavior under different pressure and temperature ranges utilizing gun/laser shock drivers and pulsed power ramp drivers by various diagnostic techniques, including X-ray diagnostics coupled to dynamic loading systems.
- Study pre-compressed targets in DAC using lasers as shock drivers; Suggested use of a modified DAC, based on partially perforated cell developed at SNRC

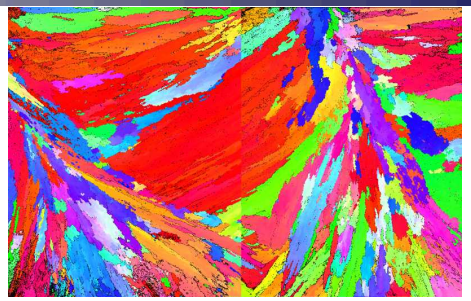
## Timeline: 3 years (anticipated); expect request for approval early 2018

- Abstract exchanged, technical discussions underway
- Technical planning meeting @ APS SCCM meeting July 2017
- **Request from the JSC to delegate chief scientists to review and potentially approve the proposal expected in early 2018**
- 2018 Workshop to refine experimental/analysis plans

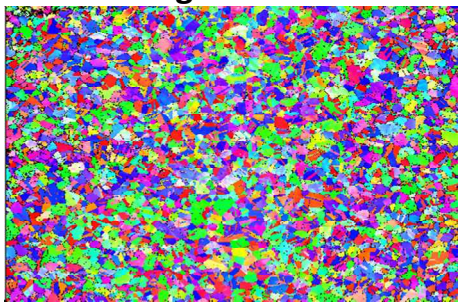
# Microstructure Effects on Dynamic Behavior of Al10SiMg

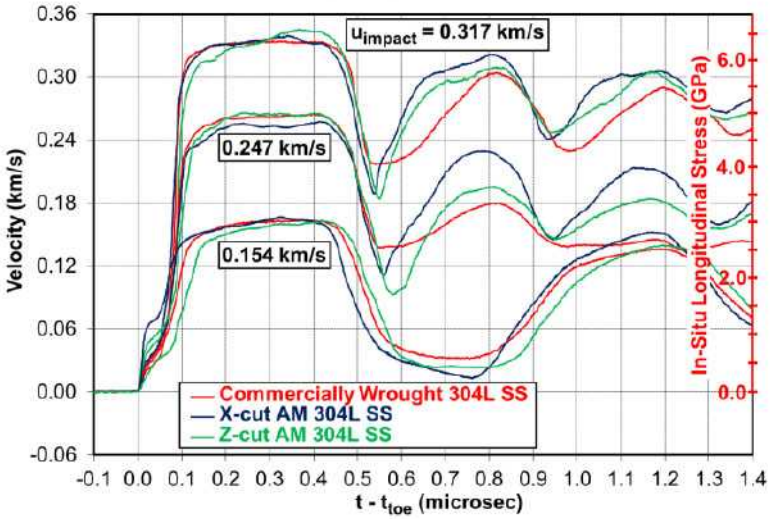
- AM enables creation of complex structures with prescribed pore/void distributions
- Microstructure: Grains, Pores/Void distributions, etc, affect elastic behavior, strength, spall
- NRCN produces samples using the SLM method with powder bed
- Full characterization: texture, porosity, etc
- Shock and Shockless Compression experiments to study AM Al10SiMg with designed microstructure
- Recover experiments for post-mortem analysis

LENS® 304L SS (3.8 kW)



Wrought 304L SS





# Topic Area IV. AM characterization

## Characterization of additively manufactured conventional and tailored heat input builds

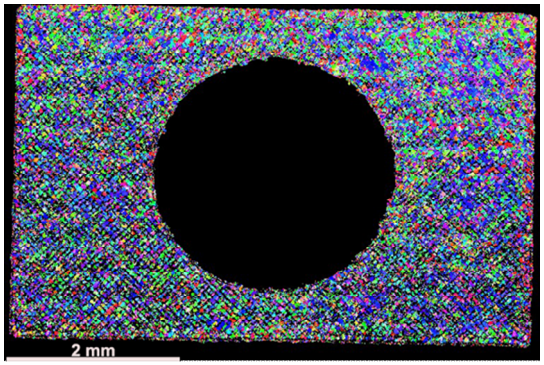
- Characterize same size and shape builds of gamma Ti using conventional powder bed AM and tailored heat input AM from same lot of starting feed powders.

## Scale of commitment:

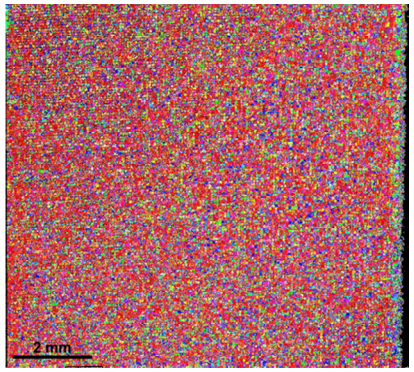
- Exchange samples
- Physical & microstructural characterization
- Static and dynamic testing
- Linking physical and microstructural characterization

## Timeline: 2018-2020

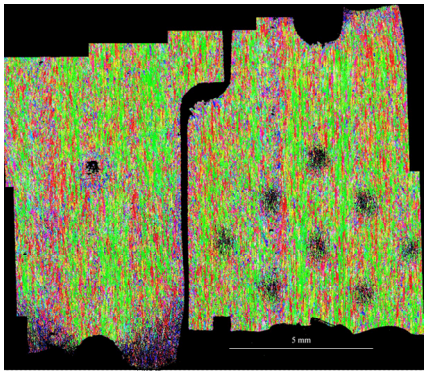
- Workshop to integrate with existing projects



Large area EBSD map of powder bed AM



Large area EBSD map of powder bed AM


Large area EBSD map of tested powder bed AM part.