A Summary of the 2nd NISP Workshop, Mar 8-9, 2016

1. Agenda

Tuesday, March 8, 2016, B481, room 2005

8:00	Gathering and refreshments	
Session 1: Overview of the NISP effort		
8:30	NISP function, goals and FY16 deliverables	J. Frenje/S. Regan
8:45	Review/Summary of the 1st NISP workshop	J. Frenje/S. Regan
Session 2: Model of the stagnated fuel and ablator/liner		
9:00	Consolidated picture of the stagnated fuel (direct drive)	P. Radha
9:20	Consolidated picture of the stagnated fuel/ablator (indirect drive)	B. Spears
9:40	Consolidated picture of the stagnated fuel/liner (magnetic drive)	K. Peterson
10:00	Break	
Session 3: Fuel-bulk flows		
10:15	Update on the nTOF workshop and peer-review analysis of nTOF measurements at OMEGA/NIF	J. Knauer
10:45	Tion variations in OMEGA cryo implosions	J. Knauer
11:30	NIF nTOF diagnostic analysis update	G. Grim
12:15	Lunch	
13:15	Modeling update on non-radial flows at the NIF	B. Spears
14:00	Update on nTOF workshop – An SNL perspective	B. Jones
14:45	Break	
15:00	nTOF measurements at Z: Assessing impacts of flows, spatial variations and Magnetic Fields	P. Knapp
15:45	Developing simple physical descriptions of stagnation in the presence of non-radial flows	E. Yu
16:15	Day 1 wrap-up discussions	All

Wednesday, March 9, 2016, B481, room 2005

8:00	Gathering and refreshments	
Session 4: X-ray emission analysis/ Hot-spot shape vs Ti		
8:30	X-ray emission size/shape analysis at LLE	F. Marshall
9:15	Shape vs Ti in perturbed gas-filled CH implosions	M. Gatu Johnson
10:00	Break	
10:15	3D modeling (ASTER code) of image shapes and Ti variation	P. Radha
11:00	X-ray emission size/shape analysis at SNL	E. Harding
12:00	Lunch	
13:00	X-ray emission size/shape analysis at LLNL	S. Khan/R. Benedetti
13:45	X-ray shape vs Ti	N. Izumi
14:30	Break	
14:45	Workshop wrap-up discussions	All
16:00	Report out	All

Attendees:
Participants: R. Mancini, P. Springer, B. Applebe, B. Sims (NNSA), S. Velikovich, M. Gatu Johnson, D. Schneider, G. Grim, E. Yu, K. Peterson, E. Hartouni, L. Benedetti, D. Casey, B. Spears, A. Schmitt, J. Kilkenny, D. Bradley, P. Knapp, S. Hansen, T. Murphy, P. Patel, S. Regan, J. Frenje, C. Cerjan, F. Marshall, K. Hahn (SNL), S. Batha, D. Fittinghoff, B. Jones, N. Izumi, D. Sayre, F. Marshall, J. Knauer
Web conference participant: P. Radha

2. NISP FY16 Deliverables, Function, Path Forward and End Goal

The NISP FY16 deliverables involve the submission of a document to NNSA by Sep. 30 (1st draft should be ready in June for "peer-review"). This document should include the following points:

1. For each approach, describe a "peer-reviewed", distilled physical picture of the stagnated fuel and ablator/liner that's consistent with most data.
2. For each approach, define a list of "peer-reviewed" hypotheses for explaining the observations or discrepancies between observations and models.
3. For each approach, define a list of new "peer-reviewed" diagnostics, experiments, and analyses methods needed to distinguish/refute the different hypotheses.

The function of NISP is to "peer-review" the updates made to this document, which will be done through workshops that focus on either deliverable 1, 2 or 3. It will be a living document that illustrates the progress each approach has made. The near-term plan is to:

- Leads for each approach will generate a 1st draft of the NNSA document by the end of April (2016) for "peer-review". (Leads: P. Patel for Indirect-drive ICF, P. B. Radha for Direct-drive ICF, K. Peterson for MagLIF)
- Hold a web-conference in the end of May where the NISP steering committee will provide detailed feedback on the 1st draft.
- Have a more complete draft ready for review in conjunction with the larger-scope workshop in Santa Fe the week of June 20 (2016). The 3rd NISP meeting will coincide with the Santa Fe workshop.

The ultimate goal of the multi-year NISP effort in the FY20 time frame is to understand and chart the physics-scaling to multi-MJ yields for the three approaches.

3. Summary of the 2nd NISP Workshop

The 2nd NISP workshop was initiated by a series of presentations of a consolidated physical picture of the stagnated fuel and ablator/liner for each of the three approaches. The first part was followed by a discussion that focused on the top-two actions items identified at the 1st NISP workshop. These actions, which constitute a sub-set of issues that will be discussed in the above-mentioned document, are:

1. Study the Residual Kinetic Energy (RKE) remaining at "stagnation" and its effects on the spectral shape of the primary-neutron spectrum.
2. Study the shape and spectrum of the core-emitted x-rays and their correlation to "T_i" non-uniformities.

3.1 Direct-Drive Approach – A consolidated picture of the stagnated fuel

3.1.1 Experimental observations:

- Absolute pressure decreases with increasing calculated convergence ratio (CR) (or decreasing adiabat).
- Hot-spot radius is larger than simulated for high-CR (or low-adiabat) implosions
- Significant "T_i" variations diagnosed along various lines of sight (LOS) are observed in the DT cryo implosions. These variations do not correlate with measured target offsets.
- "T_i" variations increase with increasing CR (little variation is seen in NIF implosions).
- "T_i" variations are not seen in CR=12 warm CH implosions driven with a 25% P2 drive, while asymmetry in the core x-ray emission, correlated with the drive, is clearly observed.
- Close-to-zero offset is required to achieve symmetry in Ti
- Target offset and laser-power imbalance dictate the level of RKE.
- Measured burn-history is truncated relative to simulation for <u>all</u> implosions.

3.1.2 Hypotheses for the observations or discrepancies between observations and models:

- Laser-beam imbalance causes long-wavelength asymmetries observed in <u>all</u> implosions.
- For <u>DT cryo</u> implosions, short-scale mix due to imprint/jets, relaxation of inner boundary due to secondary shocks, and EOS errors can potentially generate too much mass in the hot spot prior to deceleration.
- Incoming shell-density is too low (imprint growth at ablation front?).

3.1.3 New diagnostics, experiments and new/improved analyses methods:

- A high-time resolution gamma-based burn history diagnostic with a pulse-dilation PMT (Δt ~10ps), insensitive to RKE in the form of fuel-bulk flows, would provide more accurate bang-time (BT) and burn-history data than a neutron-based NTD system.
- Implement a suite of precision paddle-type nTOFs for simultaneous measurements of the DD and DT-neutron spectrum to accurately diagnose RKE in the form of fuel-bulk flows.
- Use x-ray spectroscopy for validation of the hot-spot density.
- Add SLOS for a 2nd and 3rd gated, x-ray imaging diagnostic LOS.
- Add x-ray spectroscopy to diagnose hot-spot mix and to diagnose the spatially-averaged Te of the hot spot using x-ray continuum slope using the 5 to 10 keV photon energy range (in progress).
- Implement a hot-spot Te measurement (PXTD is being implemented for a core Te(t) measurement).
- Make a systematic comparison of the absolute neutron BT and x-ray BT.
- Consider using GCD2 in addition to P11-NTD to assess effect of fuel-bulk flows on BT and burn history. Current GCD3 provide a Δt of ~80ps.
- Quantify higher moments in the x-ray images of the core. What do they tell us about stagnation?
- Investigate correlation between x-ray core shape and "Ti" asymmetries.
- Look at offsets (magnitude/direction) vs "Ti" asymmetry.
- Contrast the effect of offset on warm and DT cryo implosions.

3.1.4 Questions and comments:

- Does the normalized x-ray-emission analysis have a systematic error? What if the assumption for the high-adiabat emission (measured = simulation) is not valid? Measure the absolute x-ray emission.
- Is the compressed shell optically thin to 4-8 keV x-rays?
- What is the absolute level of hot-spot x-ray emission?
- Is a movie of KB images required? This requires a spatial mechanical fiducial in each framed image.
- Is the adjustment of the measured timing of the NTD data within the experimental uncertainty (±25 ps) relative to 1D simulations correct?
- A higher 'Ti" towards 12m-nTOF is observed. Does this mean an offset towards this detector?
- Given that we do not know the thermal Ti, how do we know that yield vs Ti follows the Bosch and Hale reactivity?
- What is the effect of offset on "Ti" and x-ray measurements?
- Does the inferred hot-spot radius vs. time make sense physically?
- How do we validate 100 Gbar? NLTE effects in x-ray imaging maybe important.
- Consecutive gated x-ray images in time are recorded on different strips with probably different gains. XRFC strip coupling affects timing and gain. How the gain is calibrated to flat field XRFC and infer time history of the hot-spot brightness?
- FC strip coupling affects timing and gain.
- Cold fuel around hot spot should be at 59 Gbar.

3.2 Indirect-Drive Approach – A consolidated picture of the stagnated fuel and ablator

3.2.1 Experimental observations:

- The shape of the core exhibits time-varying P1, P2 and P4 asymmetries.
- RKE remains at "stagnation", indicating significant 3D behavior and incomplete stagnation.
- Areal density is low relative to simulations.
- Significant low-mode areal-density asymmetries exist at "stagnation".
- "Ti" is significantly higher than simulated.
- DT-weighted "Ti" is significantly higher than the DD-weighted "Ti", a discrepancy that cannot be explained by reactivity differences and profile effects.
- Analysis of higher moments in the primary DT neutron spectrum suggests presence of significant skew (correlation of temperature and velocity) and kurtosis (shows hot spot cooling and flow effects).
- PRELIMINARY: Skew of DD-neutron spectrum seems to track skew of DT-neutron spectrum, while kurtosis appears to increase more for DT than DD.

3.2.2 Hypotheses for the observations or discrepancies between observations and models:

- Time-varying hohlraum drive asymmetry (P1, P2 and P4) is likely due to CBET or wall-induced spot motion.
- Perturbations from the support tent and fill tube lead to areal-density variation in the confining cold fuel and damage to the hot-spot shape.

- Holes/burn-through, incomplete stagnation and reduction in internal energy due to RKE in the form of bulk flows (CR = 30 – 35) is caused by hohlraum drive asymmetry and support-tent/fill-tube.

3.2.3 New diagnostics, experiments and new/improved analyses methods:

- Implement DIXI and CNXI to better probe P1, P2 and P4 hohlraum drive asymmetries. Implement hohlraum improvements, optimized Cone Fraction (CF), Case-to-Capsule Ratio (CCR) and pulse length/splitting to correct these asymmetries.
- Implement precision neutron-Time-Of-Flight (nTOF) detectors and new fluence Neutron Activation Detectors (fNADS) to better probe 3D effects. Optimize CCR and optimized pulse length to correct these asymmetries.
- Implement modified capsule suspension, optimized adiabat and CR to remove the effects of support tent by implementing modified capsule suspension, optimized adiabat and CR.
- Implement precision nTOFs, improved analysis of Te, and improved shape analysis of the primary-neutron spectrum to more accurately probe thermal Ti.
- Implement new fNADS, Compton radiography to better probe cold shell asymmetries. Optimize CF, CCR and pulse length to correct these asymmetries.
- Implement new spectroscopy to better probe “holes" in the cold shell. Optimize shell thickness, adiabat, CR and dopant to remove these “holes”.
- Implement new spectroscopy and modified fill tubes to better probe and correct for the deleterious effect of the current fill-tube design.
- Implement an NTD for a neutron-weighted burn-history measurement to probe when the implosion starts deviating from 1D behavior.
- Implement a Gamma-based system, insensitive to fuel-bulk flows, for a burn-history measurement to probe when the implosion starts deviating from 1D behavior.
- Implement an MRSt for time-resolved measurement of the neutron spectrum to probe the time-evolution and relative timing of the fuel assembly, formation of hot spot and alpha-particle heating and when these parameters start deviating from 1D behavior.
- Implement exact registration of gated images needed to infer hot-sport motion.
- Implement a Te measurement along different LOS.

3.2.4 Questions, comments and action items:

- At what CR does an implosion start deviating from 1D?
- Does the fill tube break asymmetry?
- Tent scar may confound the P2/P4 asymmetry diagnosis. Trying to fix a P2 asymmetry using a different drive may therefore not be adequate.
- Understanding shell asymmetries is difficult because they are not “under the lamppost”.

3.3 Magnetic-Drive Approach – A consolidated picture of the stagnated fuel and liner

3.3.1 Experimental observations:

- The average emission diameter of the “stagnated” column is ~110 μm (CR could be as high as 45).

- “Stagnated” column is highly magnetized (BR ~ 0.4 MG-cm) with 25-55% magnetic flux conservation.
- Diameter of the x-ray emission increases with increasing neutron yield.
- Axial-diameter variation of the x-ray emission is large compared to the average.
- The x-ray emission varies spatially by more than 50% of the average emission value.
- Local pinching exists, which increases Te and ne. Large variations in ne(z) are observed.
- Significant axial variation in neutron emission and liner areal density is observed.
- DD-neutron yield scales with measured Ti and appears to be of thermonuclear origin.
- Bright Fe emission is observed from the lower-density regions.
- Stagnation appears isobaric - based on what?.

3.3.2 Hypotheses for the observations or discrepancies between observations and models:

- RKE seems unlikely to be a significant contributor to the shape of the primary-neuron spectrum.
- RKE may still be a significant contributor to energy balance.
- Elevated fraction of Fe mix may explain the observed Fe emission.
- The large observed variation in ne(z) may be caused by compression non-uniformities.
- The fact that the observed Te > Ti could be due to sampling of energetic x-rays occurs at peak of profile while neutrons are sampled at larger radii where Te is lower.

3.3.3 New diagnostics, experiments and new/improved analyses methods:

- Failure analysis and diagnostic return (more diagnostic measurements – list them) must be improved, especially for poor performing shots.
- Magnetic field measurement is promising and exciting, but needs improved S/N.
- Space resolving nTOF could be an extremely valuable complement to x-ray diagnostics.
- Need to understand scattering environment and nTOF-IRFs to utilize the Be down-scatter measurement (could it be that current Be down-scatter model is wrong?),
- An NTD for a neutron-weighted burn-history measurement would be useful to diagnose when an implosion starts deviating from 1D behavior.

3.3.4 Questions, comments and action items:

- What’s causing the large spatial variations in the x-ray emission?
- What are the initial shape and thickness of the pressurized LEH window?
- What is the level and effect of LPI (preheat)?
- What is the amount of laser induced mix/contaminants?
- What is the source location of laser-induced mix?
- What is the impact of fuel vorticity on temperature and radiative cooling?
- Is the variation in the liner opacity might be correlated with Te and ne
- Is the x-ray emission structure caused by non-uniform mix?