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NIF Target Assembly Metrology and Results

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19th Target Fabrication Meeting
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NIF Target Assembly Metrology and Results

Ethan Alger
Target Production Engineer

19th Target Fabrication Conference
Orlando, FL

February 21-26, 2010

GENERAL ATOMICS

Participants and Acknowledgements

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- Many others at LLNL and GA

Introduction

- **Recently completed Energetics campaign**
  - 34 shots
  - 51 targets
  - 5 types (Hvac, Hcryo, 0.9HSym, 1.07HSym, ConvAb)
  - >12500 measured and calculated values recorded for target components and assembly

- **Each target type required a custom set of measurements at assembly**
  - On average, 400 measurements and 70 reportables per target

Metrology required at each step in the production process

General Atomics and Vendors

Component Fabrication
- Capsule Production
- TMP Aluminum Components
- LEH Insert
- LEH Washers
- Hohlraum Production
- Target Base Components
- **Metrology**

Subassemblies
- Capsule/Fill Tube Assembly
- TMP Subassembly
- LEH Window
- Target Base Subassemblies
- **Metrology**

LLNL and General Atomics On-site Support

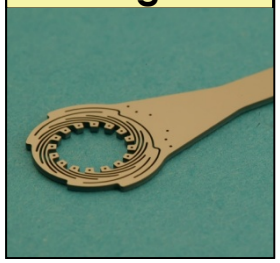
Component Production
- Si Cooling Arms
- Tents
- Wiring Harnesses
- **Metrology**

Assembly
- Target Base Assembly
- Hohlraum Insertion and Tenting
- Final Assembly
- Bonding
- Proofing
- **Metrology**

Component Metrology Approach

- **Component and subassembly metrology methods include:**
  - Contact radiography
  - xRadia
  - Measuring microscope
  - Laser micrometer
  - Atomic Force Microscope
  - Phase Shifting Diffraction Interferometer
- **Some components measured on a sample basis vs. 100% inspection**

Cooling Arm



Hohlraum

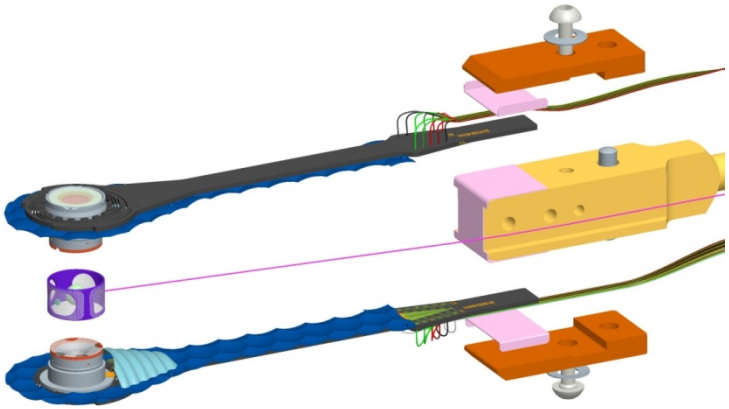
TMP Subassembly

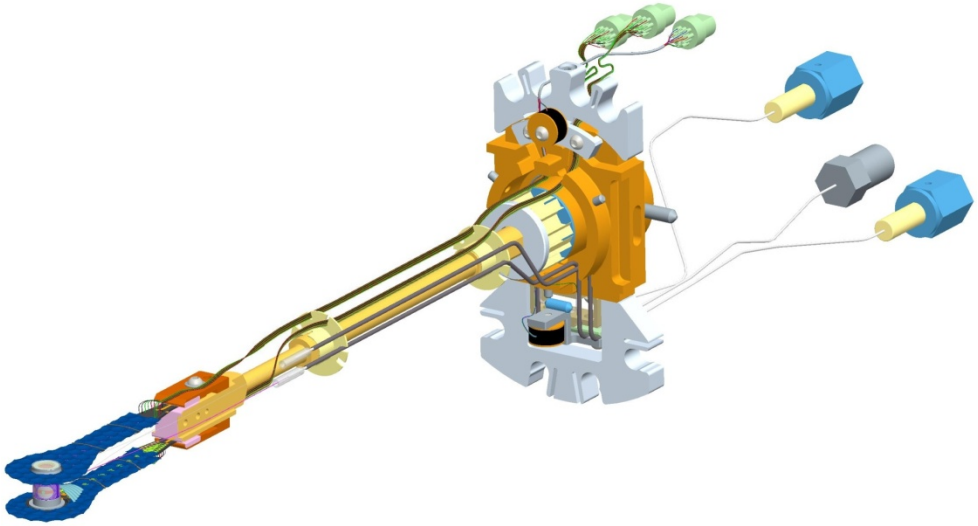
Diagnostic Band

Assembly Metrology Approach

- **Assembly metrology is completed using several precision non-contact methods.**
  - Optical Coordinate Measuring Machines (OCMM)
    - Different probes for different purposes

- **100% of targets in assembly metrologized**





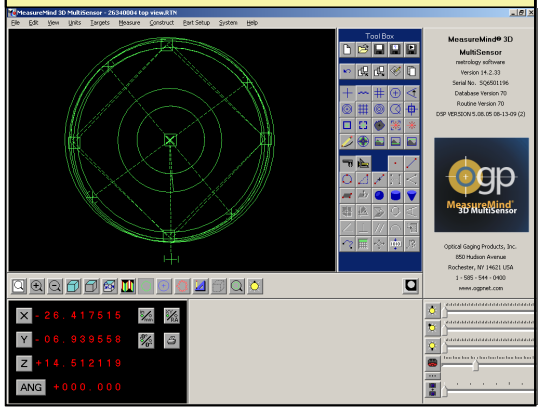
The Primary Tool Used for Assembly Metrology is the Optical Coordinate Measuring Machine (OCMM)

- **Optical Gaging Products OCMM**
  - X/Y accuracy = 1.5 µm
  - Z accuracy
    - Rainbow Probe (RP)
      1.5 µm
    - Through the Lens Laser (TTL)
      2-5 µm (lens dependent)

Quest 650 OCMM and FAM

- **Measuremind software allows for automated 3D measurements of complex assemblies**

Measuremind 3D SW



Metrology Challenges

- **Pushing the limits of dimensional metrology capability**
  - Many tolerances in the 5-20 μm range
  - Many measurements in the 2-5 μm range
- **Complex set of measurements require standardized methods and programmed routines**
  - Variations include target types, machine models, and number of operators
- **Flexible capabilities required to react to real time feedback and design changes**
- **Need for high throughput**

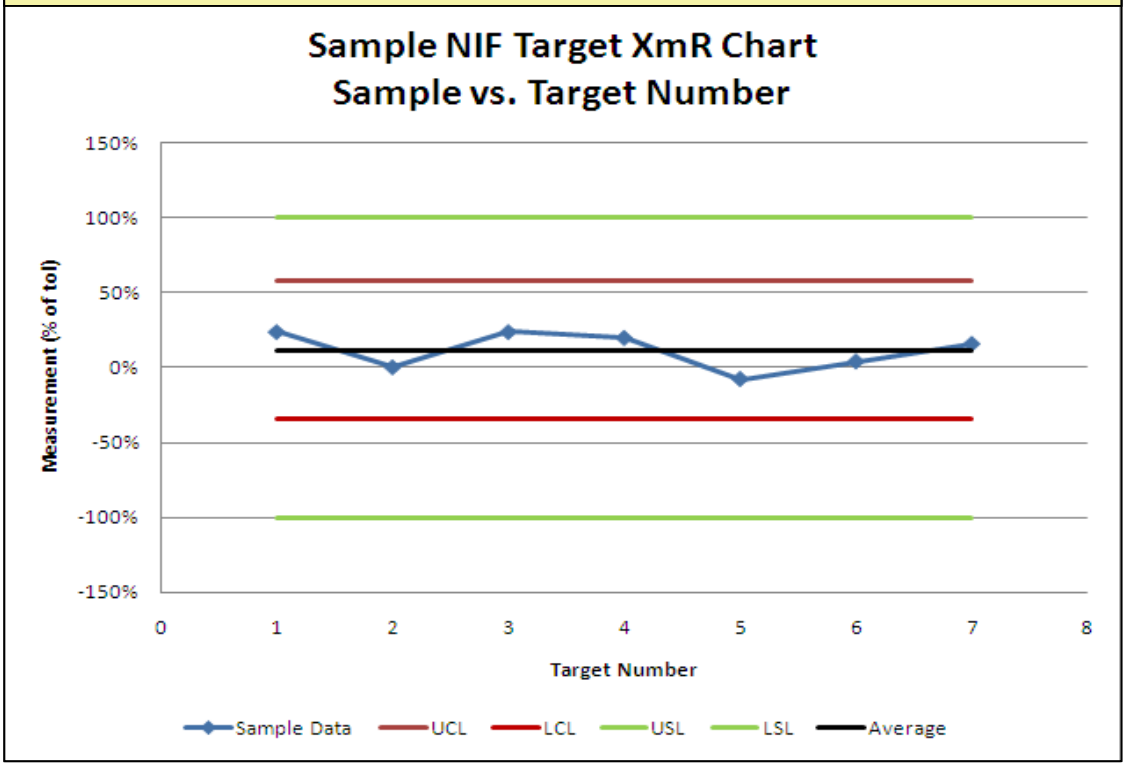
What information is gained from assembly metrology?

- **Assembly Metrology used for:**
  - Target alignment during shot set-up
  - As built dimensions as input for physics models

- **Process Improvement**
  - Assembly deviations provide feedback to process engineering
  - Guidance for future improvements
    - What is acceptable now may not meet future requirements
    - Yield predictions

Results from the Energetics campaign: Which processes worked or needed improvement?

Moving Range Based Process Control Chart



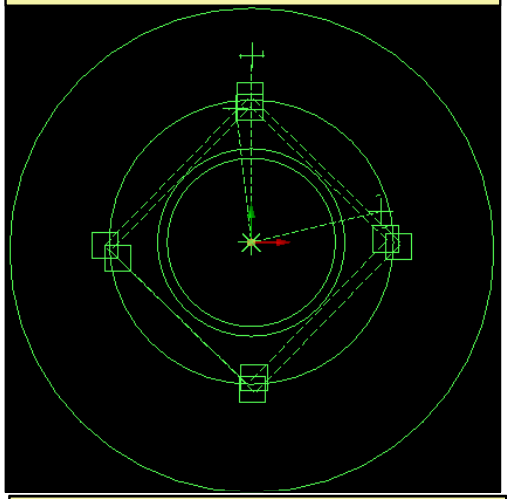
= Data
= Data Average
= Specification Limits
= Control Limits = x_{ave} +/- 3 * MR_{ave}

- **Process Control Charts Provide Information to:**
  - Monitor process variations and react in time to prevent problems
  - To predict future yield based on requirement variations
  - Guide where process improvement effort should be focused

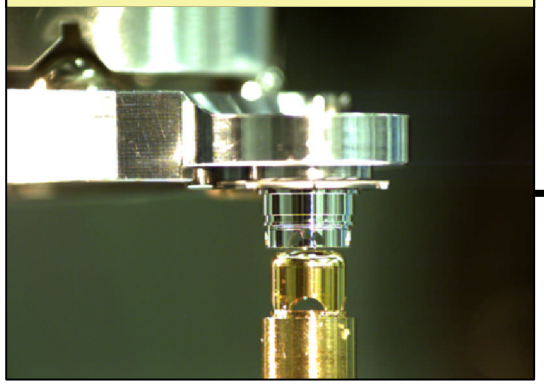
Hohlraum to TMP Shell Clocking Assembly Data Led to Process Improvement

- **Requirement:**
  - 7 +/- 1 degree
- **Method:**
  - OCMM
  - Measurement Precision / Tolerance (P/T) < 0.1
  - Measure the angle between the hohlraum diagnostic port and the TMP can alignment notch

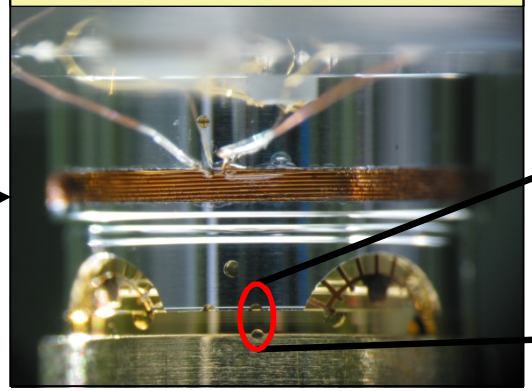
Constructed View of Features



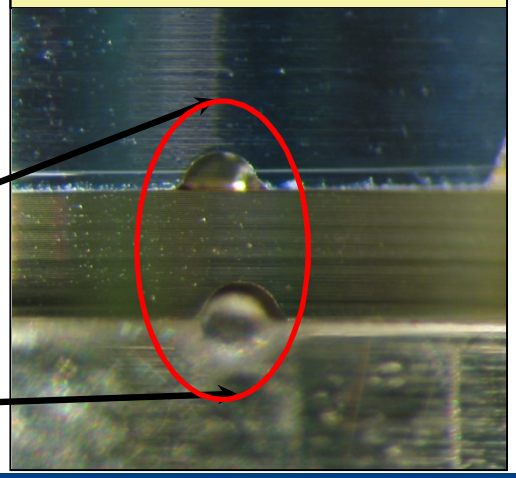
Hohlraum Insertion Tooling



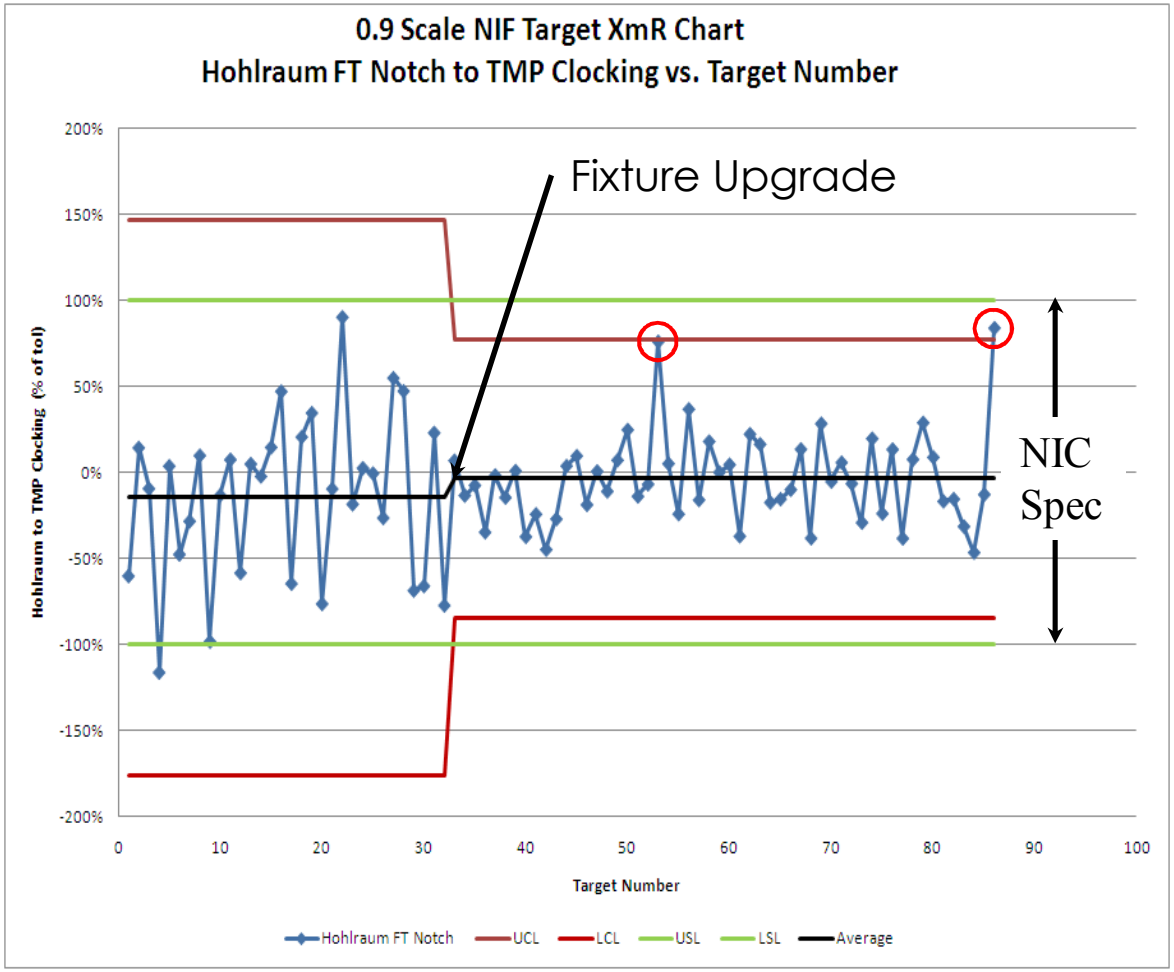
Hohlraum Insertion



Shell to Hohlraum Alignment



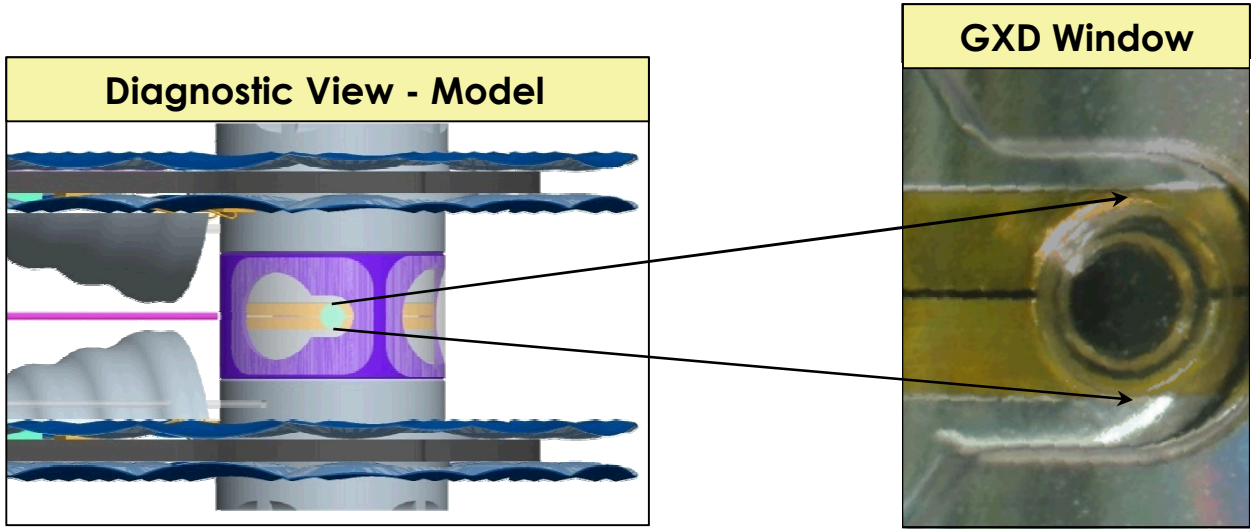
Fixture and Microscope Upgrade Improved Operator View of Alignment Features



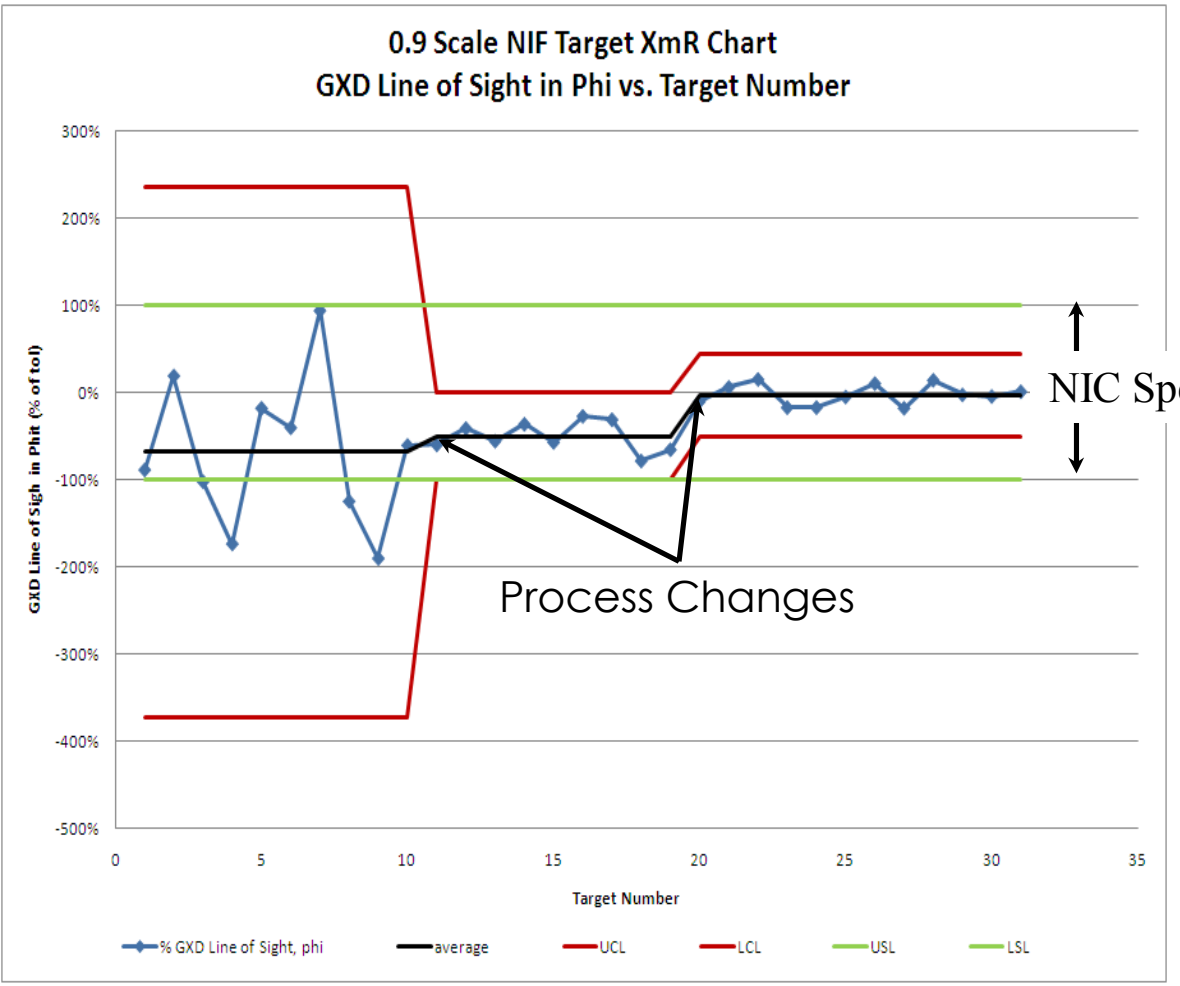
- **Outliers due to off normal events**

GXD Line of Sight in Phi Assembly Data Led to Process Improvement

- **Requirement: 315 +/- 0.5 degrees**
- **Method:**
  - OCMM
  - Measurement P/T < 0.2
  - Angle between diagnostic notch in hohlraum and alignment notch in TMP can



Measurement Method Upgrades During Assembly Improved Diagnostic Port Alignment

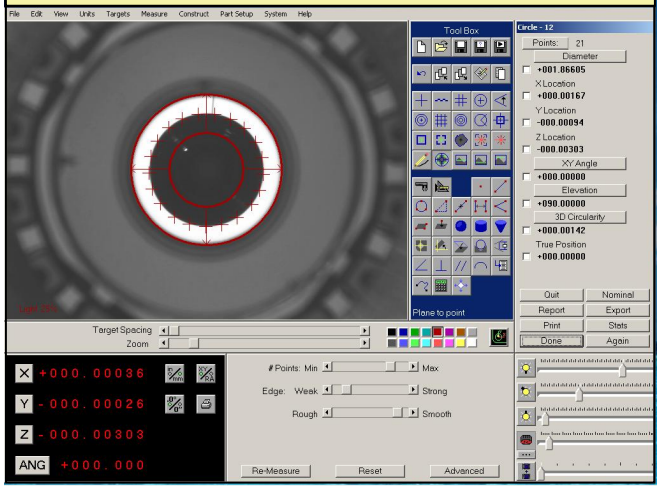


- **Assembly metrology methods included:**
  - Hohlraum notches via side mirror
  - Fiducial features on TMP shell
  - TMP shell alignment features
- **Process in control and average is now near nominal values**

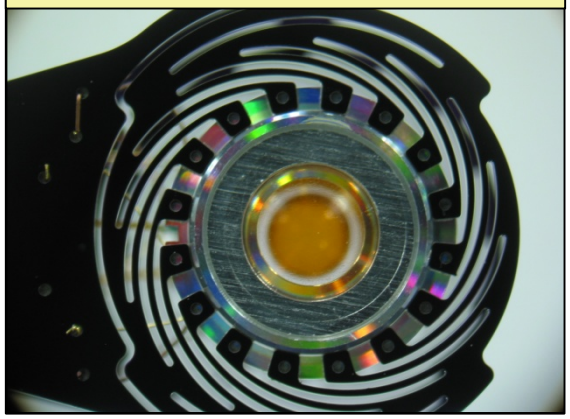
Radial Capsule Assembly Data Led to Process Improvement

- **Requirement:**
  - 0 +/- 25 µm
- **Method**
  - OCMM
  - Measurement $P/T_{x,y} < 0.2$
  - Measure the location of the capsule wrt the LEH insert in the plane of the target

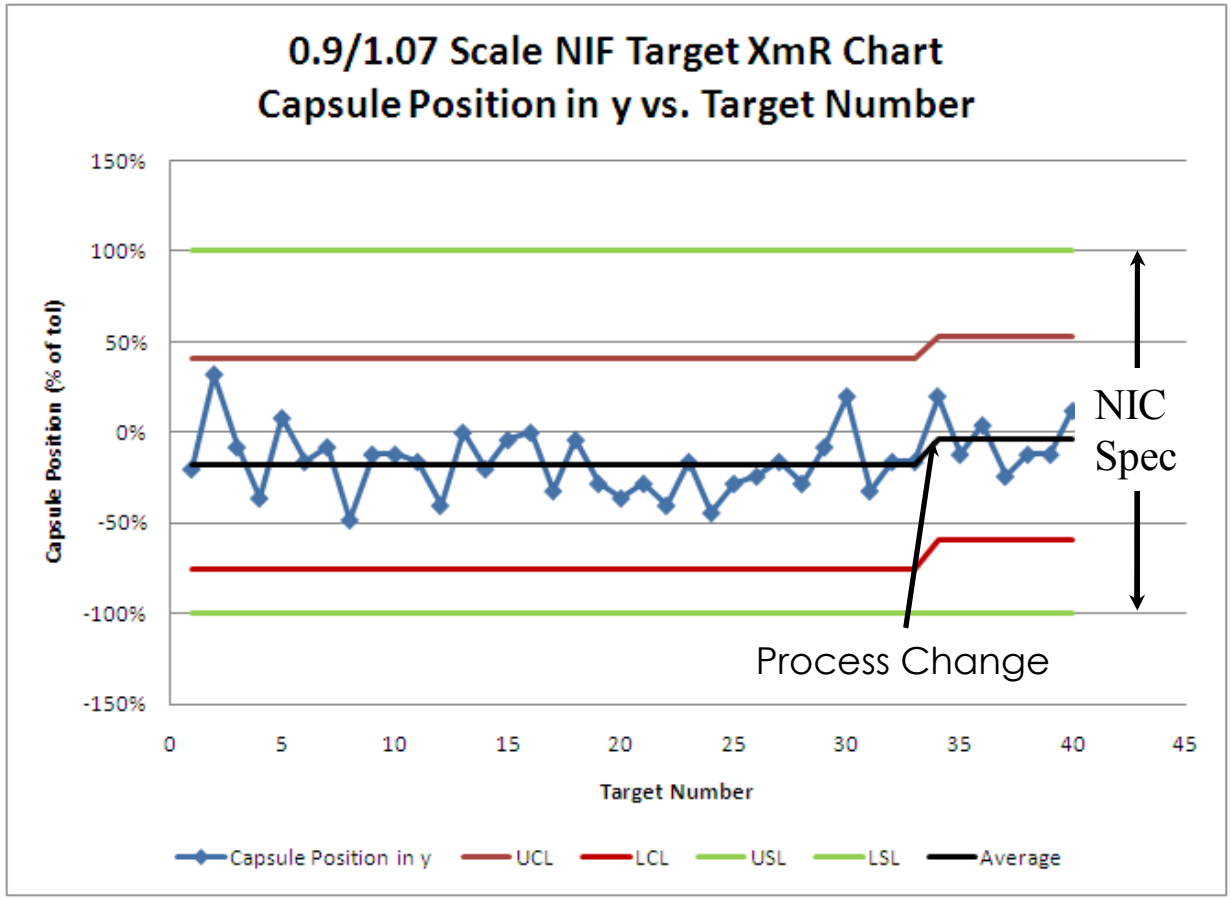
Software View of Measurement



Upper View of Target on OCMM



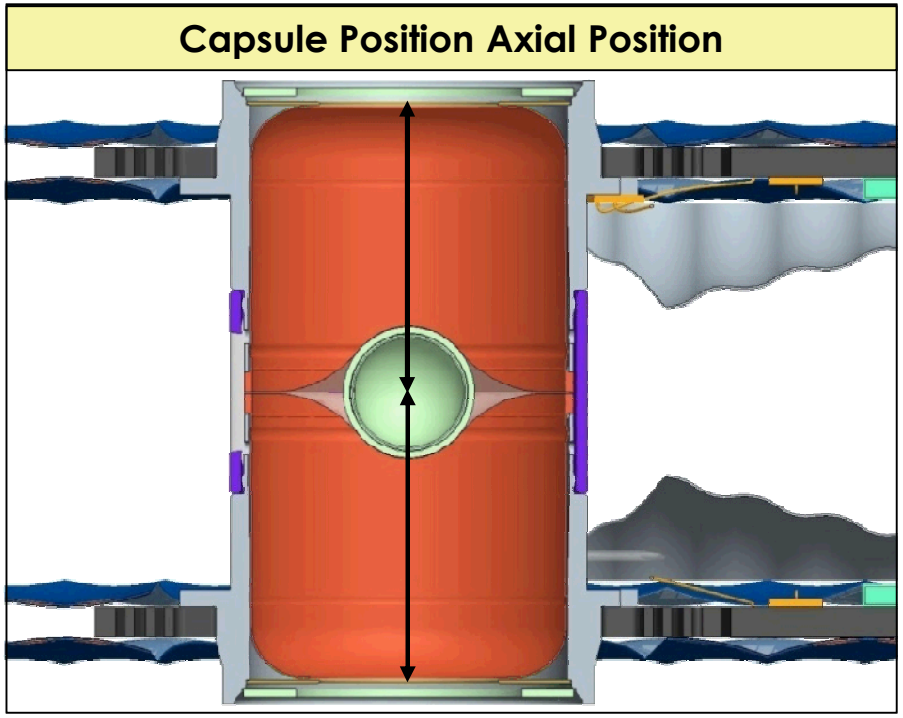
Process within NIC specification but Biased Away From the Capsule Fill Tube



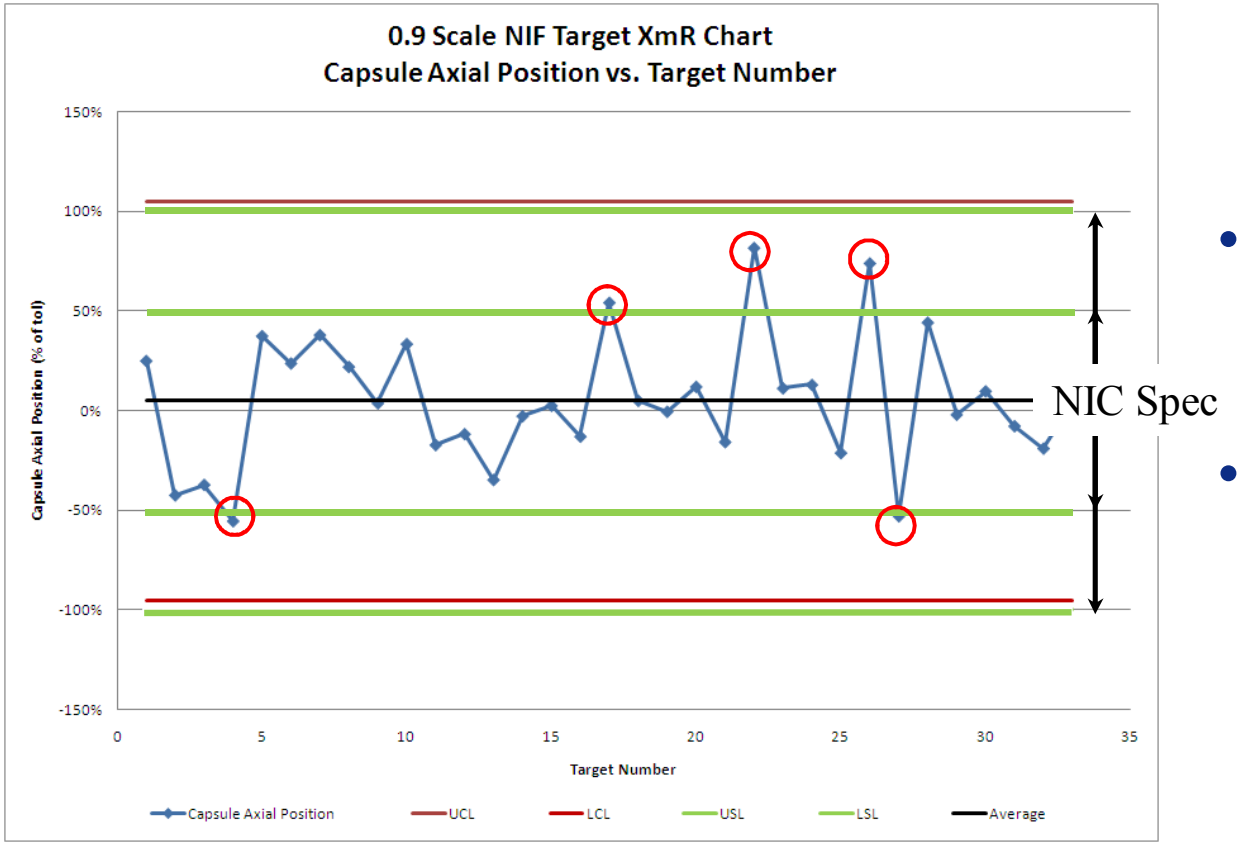
- **Limited number of targets assembled with capsule built off center toward the fill tube appear to have improved the capsule position**

Axial Capsule Assembly Data Shows That Process Improvement Needed for Ignition

- **Requirement:**
  - 0 +/- 20 um in z (axial)
- **Method**
  - OCMM w/TTL or RP
  - Measure the location of the capsule and calculate the position wrt the axial center of the LEH inserts
    - Number of measurements in calculation
  - Measurement P/Tz = 0.2-0.5



Process Improvement Required for Ignition Targets



- **Ignition target capsule position tolerances will decrease**
- **Process improvement required for ignition targets**

= 50% of Energetics campaign specifications

= Targets that would exceed ignition specifications

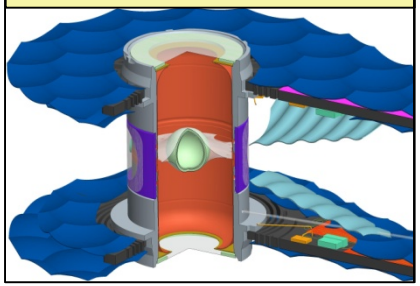
Lessons Learned

- Automation of metrology routines helps to achieve production throughput
- Real time metrology data gives actionable information that can lead to both higher yield and throughput as well as prioritize where to focus process (assembly and metrology) improvement resources
- The TTL upgrade to the OCMM will position us to meet future requirements
- The OCMM and associated instruments are necessary and sufficient tools for target production
- Improved fixturing will increase precision and throughput
- Early predictions of measurement uncertainties were validated through post campaign analysis of metrology data

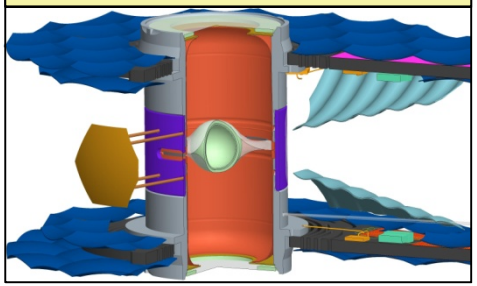
Looking Forward – Ignition Derivative Tuning Targets

- Symcaps comprised the majority of targets fielded in the Energetics campaign
- Convergent ablator targets required additional metrology steps throughout the assembly process – increasing the number of assembly measurements by 70%
- Other tuning targets including re-emit and shock timing variants will require new metrology steps, methods, and capabilities

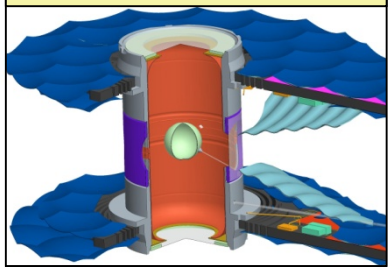
Symcap Target



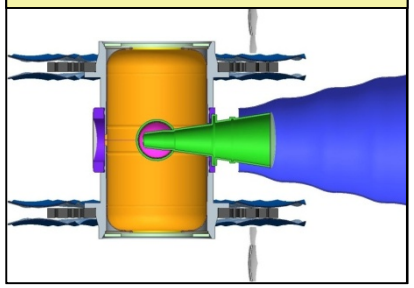
Convergent Ablator



Re-Emit Target

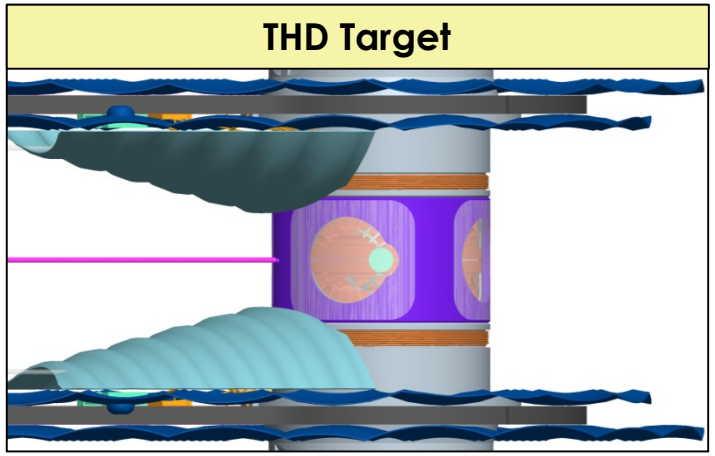


Shock Timing Target



Looking Forward - Ignition Challenges

- **Ignition target capsule position tolerances will be tightened to ~50% of the Energetics campaign requirements**
  - Assembly metrology will rely on the TTL upgrade to the OCMM to improve capsule axial position
  - During assembly the capsule will be biased toward the fill tube to improve capsule radial position



Questions?