Alternate Capsule Support for Inertial Confinement Fusion Targets

Target Fabrication Meeting 2017
Las Vegas

March 15th, 2017

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Team

Target Fab:
- Ethan Alger
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- John Bigelow
- Tom Bunn
- Chris Choate
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- Joe Florio
- Chuck Heinbockel
- Steve Johnson
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Physics:
- Louisa Pickworth
- Harry Robey
- Vladimir Smalyuk
- Chris Weber

General Atomics:
- Jay Crippen
- Martin Havre
- Javier Jaquez
- Neal Rice

Capsule support presentations:
- Aracne-Ruddle, Tu Poster
- Bigelow, Tu Poster
- Weber, Wed 10:40
- Felker, Wed 11:00
- Crippen, Wed 11:20
- Alfonso, Wed 11:40
Tents can cause perturbations that affect the implosion.

As the tent explodes and capsule ablates, they create misaligned pressure and density gradients, which produce a local vorticity perturbation.
There are three principal categories of capsule support:

- **Fill tube only**: No capsule or fill tube contact
  - Different tube material
  - 10 µm tube desired
  - Vibration and sag are issues

- **Supported fill tube**: Fill tube contact but no capsule contact
  - Stalk
  - Membrane
  - Sleeve
  - Many support variations
  - Potentially can use 10 µm tube
  - Extra mass in hohlraum
  - Vibration and sag needs study
  - Assembly development

- **Supported capsule**: Capsule and fill tube contact
  - Wire cage
  - Foam
  - Tent (modified angle)
  - Stalks
  - Many support variations
  - Potentially can use 10 µm tube
  - Capsule contact needs to be minimal
  - Foam

Ranking and down selecting based on feasibility and physic value (both near and long term) is key to making progress and assessing resource needs.
There has been no shortage of ideas on possible alternate solutions.

<table>
<thead>
<tr>
<th>Fill tube only</th>
<th>Supported/clamped fill tube</th>
<th>Supported capsule</th>
<th>Tents</th>
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<tbody>
<tr>
<td>Larger diameter fill-tube</td>
<td>Gravity support</td>
<td>Minimal wire support</td>
<td>Reduced tent angle</td>
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<td></td>
<td>Gravity support + LEH shields</td>
<td>Block foam support</td>
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<td>HDC tube support</td>
<td>Annular tent support</td>
<td>Polar contact with disk</td>
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Only a partial list of solutions is shown.
Each concept undergoes a series of evaluations

**Target Fabrication Tests**

- **Materials test**
  - Measure material properties
  - Determine basic feasibility

- **Assembly test**
  - Assemble target surrogate
  - Test centering and static stability

- **Dynamic test**
  - Perform vibration testing
  - Perform cryocycling test

- **Layering test**
  - Requires a full test target
  - Test layering on ITPS

**NIF Experiments**

- **HGR shot**
  - Measure perturbation caused by support
  - Use data to validate code prediction

- **ConA2D shot**
  - Measure perturbation growth at higher convergence than HGR shot

- **THD shot**
  - Measure change in implosion performance
Simulation gives us a prediction of performance

Replacing the tent is predicted to improve yield by up to 5x.
Supporting the capsule by only the fill-tube provides the smallest perturbation, but presents some serious issues.

Note that these movies are for a 30 µm diameter fill-tube vs. the standard 10 µm.
The first alternative support method built into a target was a free-standing 30 µm fill tube.

| Regular 10 µm fill tube | Free standing 30 µm fill tube |

The 30 µm fill tube required substantially more glue at the capsule joint, as well as a fill tube refit.

No large performance increase was expected, but the implosion shape should be affected.
“Polar contact” design uses stiff polyimide films with carbon that have a very small contact to the capsule.

Simulation predicts a smaller perturbation over a smaller angle.

Final assembly of ‘crowned’ hohlraums

Aracne-Ruddle, Tu Poster

Several 4-part hohlraum targets have been shot on NIF.
Support fill tube design use a thicker fill tube or stalk to hold the 10 µm fill tube at a distance from the capsule.

Supported fill tube subassembly

3-part fill tube subassembly

Capsule-stalk distance: 200 µm

Capsule-stalk distance: 200 µm

Bigelow, Tu Poster

Layerable test articles are being built.
The Tetracage design uses four fibers to support the capsule.

Finding an appropriate fiber material has been the primary development challenge.
Magnetic levitation is being evaluated in a longer-term project

Steig, McCall, Baker, Bayu-Aji, Bae, Kucheyev
The first two support options showed the expected shift in x-ray shape

+P4 x-ray shape from tent was removed with alternate mounts

Polar Tent

Neutron yield was similar to related experiments

More sensitive implosions and other supports remain to be tested.

+P4 is assumed to be caused by tents.
Conclusion

- We have investigated alternative capsule support strategies to mitigate perturbations caused by the tent.

- Three designs have emerged as most promising: 4-part hohlraum, supported fill tube, tetracage. Two designs have been fielded on NIF.

- Alternate support targets shot show the expected x-ray shape change.
As BT moves later and yield drops, gain from polar tent is reduced. Only 20-30% improvement.

Good performance from this high foot platform is needed to observe improvements from tent.
Other platforms are more sensitive to the tent – we would expect a larger improvement

Yield-over-clean (no $\alpha$-dep.) from a standard tent

- Largest effect at the high convergence (Low Foot and Adiabat Shaped Low Foot)
- Limited reproducibility

- Reduced tent impact at High Foot
- Established reproducibility for T-1, but questioned by recent experiments
The supported fill-tube may be the best tent replacement option

Yield/clean (no $\alpha$-dep.) for 175$\mu$m thick (T-1) high foot implosions (N140520)

- Standard tent
- 40um FT
- Polar tent
- Foam tent
- Support 100um
- Support 200um
- Support 300um

*Note: other calculations do not include a FT

Degradations from foam modulations?

Minimal degradation with $\geq 200$ $\mu$m stand-off distance

YOC=0.17 w/ $\alpha$-dep.
An alternative capsule mount is being studied to improve the performance of ICF implosions on NIF

- New mounting options exist that show promise in removing the tent perturbation
- Many unexpected observations from experiments – transforming our understanding of how perturbation develop from engineering features
- Simulation capability has been developed to evaluate these effects and understand their on performance
- More experiments are needed to expand our understand of these effects and evaluate these support options
2-part fill-tube

- 10 μm diameter
- 30 μm diameter
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