What makes a successful experiment?

- Purpose
- Driver
- Target
- Diagnostic

Results
Knowledge of a real target is critical to experimental success
R&D is the first step in the target production timeline

T-3 months

Target R&D

T-1 months

Component Fabrication and Metrology

Shot Date

Final Assembly and Metrology
Engage target fabrication early

Design

Plasma Physics

Fabrication

Material Science
Chemistry

Target Fab Scientists
Brent Blue
Abbas Nikroo
Mark Bonino
David Harding
Russ Wallace
Rich Stephens
NLUF AstroShock targets required significant R&D to determine if we could even make the targets.
It’s now time to specify the target

- **Design Finalized!**
- **We know that we can make it**
  - All R&D completed
- **Enough time to make, nominally 3 months**
  - Can be longer for complex parts
- **All parameters specified**
  - Dimensions
  - Materials
  - Tolerances
  - Metrology

T-3 months  T-1 months  Shot Date

Component Fabrication and Metrology
OMEGA target request process starts with the target request form: TRF
OMEGA target request process starts with the target request form: TRF

![Image of OMEGA target request form]

<table>
<thead>
<tr>
<th>GA</th>
<th>Fab Center</th>
<th>Component Type</th>
<th>General Descriptor</th>
<th>Primary Descriptor</th>
<th>Group</th>
<th>Secondary Descriptor</th>
<th>Due date</th>
<th>Qty.</th>
<th>Usage</th>
<th>Best Effort</th>
<th>WONO</th>
<th>GA Order</th>
<th>Cust. #</th>
<th>Order Specs</th>
<th>Status</th>
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<tbody>
<tr>
<td></td>
<td>IDC</td>
<td>Capsule</td>
<td>CH</td>
<td>CHsingle</td>
<td>A</td>
<td>40 micron SCD to CPM, 2 racks of 12</td>
<td>03/05/2009</td>
<td>24</td>
<td>Internal</td>
<td>None</td>
<td>C30272-9570</td>
<td>IDC-LEE-296-Int-Fi-09D Rev 0</td>
<td></td>
<td>Order Specs</td>
<td>Status</td>
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<tr>
<td></td>
<td>IDC</td>
<td>Capsule</td>
<td>CH</td>
<td>CHsingle</td>
<td>A</td>
<td>40 micron SCD for TCC and neutronics reference</td>
<td>04/05/2009</td>
<td>7</td>
<td>External</td>
<td>None</td>
<td>C30272-9570</td>
<td>IDC-LEE-296-Int-Fi-09D Rev 0</td>
<td></td>
<td>Order Specs</td>
<td>Status</td>
</tr>
<tr>
<td></td>
<td>CPM</td>
<td>Micromachining</td>
<td>Cone/Shield</td>
<td>Cone</td>
<td>A, B, C</td>
<td>20 mic thick Cu Cone, 25 mic thick Cu Cone, 30 mic thick Cu Cone</td>
<td>04/13/2009, 04/13/2009</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>C30272.9490</td>
<td>COM-Int-Fi-09D Cone &amp; Shell</td>
<td></td>
<td>Order Specs</td>
<td>Status</td>
</tr>
<tr>
<td></td>
<td>DDC</td>
<td>Capsule</td>
<td>Cryo</td>
<td>SCD</td>
<td>A</td>
<td>CD shells</td>
<td>04/16/2009</td>
<td>6</td>
<td>External</td>
<td>None</td>
<td>C30272 3020</td>
<td>DDC 296 DiagDev-CIS-09A</td>
<td></td>
<td>Order Specs</td>
<td>Status</td>
</tr>
</tbody>
</table>

2008 Laboratory for Laser Energetics
High level scheduling completed in close partnership with laboratory POCs, TFEs, and PIs

New TRFs

GA Production meeting

Lab POC meeting

National OMEGA CCB meeting

Shot plan/ Lab POCs

OMEGA change control board process

- Discuss all OMEGA targets:
  - Track status
  - Flag and resolve issues
  - Planning
Hohlraum and capsule production require precision mold manufacture, diverse coating and multi characterization capabilities.

1. Make Mold
2. Coat
3. Polish
4. Laser Drill, Remove Mold
5. Attach fill Tube
6. Characterization
7. Assemble
8. Characterize
9. Mandrel
10. Coat U
11. Coat Au
12. Leach mandrel
Diamond turning machining, capable of sub-micron accuracy

GA has 9 diamond turning lathes
- 7 General purpose
  - 1 Beryllium
  - 1 Uranium

SNRT target on the back of a penny
Precision milling allows us to make 3D shapes with micron accuracy.
Sample of component variety shipped Q1-FY09

http://fusion.gat.com/ift/ICF_Catalog/index.html
Many elements and compounds can be coated onto targets

Atomic Layer Deposition (ALD)

Sputter coating

Electroplating

Gold Copper

Aluminum
Boron
Boron Carbide
Boron Nitride
Carbon
Chromium
Copper
Dysprosium
Gadolinium
Gold Boron
Iridium
Iron
Manganese
Molybdenum
Neodymium
Nickel
Scandium
Silicon
Silver
Silicon Dioxide
Tantalum
Tellurium
Tin
Titanium
Titanium Dioxide
Tungsten
Vanadium
Zinc
GA produces many plastic, glass, foam, and Beryllium capsules

- Foam capsules with fill tube for Foamlmp
- Capsule and cone for Fast Ignition
- Inner trenched capsule for DlmE
- Double Shell for DynHohl
- NIF Direct Drive Fill Tube Target
- Cryo shell for NIC
### Metrology: the final critical fabrication step

#### Group B Clumpy Aluminum Oxide Ball Target

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>1</td>
<td>Foam Density (mg/cc)</td>
<td>300</td>
<td></td>
<td>296</td>
<td>296</td>
<td>296</td>
<td>296</td>
<td>294</td>
<td>294</td>
<td>4</td>
<td>Batch average: Measured on 2 witness pieces of foam for each batch</td>
</tr>
<tr>
<td>2</td>
<td>Z Distance from center of ball to drive face (um)</td>
<td>900</td>
<td></td>
<td>980</td>
<td>1117</td>
<td>1159</td>
<td>1113</td>
<td>976.3</td>
<td>885.32</td>
<td>10</td>
<td>Measured by radiography</td>
</tr>
<tr>
<td>3</td>
<td>Distance of ball center from axis of foam (um)</td>
<td>0</td>
<td></td>
<td>346</td>
<td>269</td>
<td>178</td>
<td>82</td>
<td>384.45</td>
<td>254.75</td>
<td>20</td>
<td>Measured by radiography</td>
</tr>
<tr>
<td>4</td>
<td>Diameter of Foam Cylinder (mm)</td>
<td>3.9</td>
<td>0.2</td>
<td>3.92</td>
<td>3.84</td>
<td>3.91</td>
<td>3.88</td>
<td>3.69</td>
<td>3.69</td>
<td>0.02</td>
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<tr>
<td>5</td>
<td>Minimum Length of Foam Cylinder (mm)</td>
<td>5</td>
<td>1</td>
<td>6.0</td>
<td>6.1</td>
<td>5.7</td>
<td>5.8</td>
<td>5.9</td>
<td>5.4</td>
<td>0.1</td>
<td>Length must be &gt;4000um, foam may have rough edge on the end of the foam (but drive face will be smooth)</td>
</tr>
<tr>
<td>6</td>
<td>Maximum deviation from Flatness (um)</td>
<td>&lt;30</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Best effort; Measured on drive side face on a sampling of targets at Albuquerque</td>
</tr>
<tr>
<td>7</td>
<td>Ball clump/distribution diameter (um)</td>
<td>1000</td>
<td>NA</td>
<td>1172</td>
<td>1035</td>
<td>1063</td>
<td>1062</td>
<td>911</td>
<td>903</td>
<td>200</td>
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<tr>
<td>8</td>
<td>Number of balls in clump (#)</td>
<td>46</td>
<td>5</td>
<td>37</td>
<td>46</td>
<td>21</td>
<td>34</td>
<td>30</td>
<td>43</td>
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<tr>
<td>9</td>
<td>Ball diameter (um)</td>
<td>130</td>
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<td>130</td>
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<tr>
<td>10</td>
<td>ball material</td>
<td>Ruby (Al2O3 + &lt;0.05% Cr)</td>
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<td></td>
<td></td>
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<tr>
<td>11</td>
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<td>RF090616-A RF090616-B RF090616-C RF090616-D RF090430-B RF090430-D</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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**Know what you are shooting before the shot**

**Target destroyed**

**Can’t go back**
General Atomics IFT has an experienced ICF target fabrication team

LLNL: 10
LANL: 1
SNL: 7
LLE: 2
San Diego: 80 + 22 students

GA staff are both in San Diego and onsite at various facilities

| Total Staff | 100 GA and subs
22 Students/Interns
3 Consultants
10 collaborators |
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>PhD</td>
<td>22</td>
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<tr>
<td>MS</td>
<td>10</td>
</tr>
<tr>
<td>BS</td>
<td>27</td>
</tr>
<tr>
<td>AA</td>
<td>27</td>
</tr>
<tr>
<td>Experience</td>
<td>~900 person-years</td>
</tr>
<tr>
<td>Invited presentations</td>
<td>7 (2007-08)</td>
</tr>
<tr>
<td>Peer-reviewed publications</td>
<td>231 since 2000</td>
</tr>
</tbody>
</table>
GA produces targets for all the major NNSA ICF facilities

- **Three major new ICF facilities**
  - NIF Project
  - OMEGA-EP (completed in February 2005)
  - Z-R

- **The facilities use thousands of high precision targets/year**
  - OMEGA ~ 4000 targets/year
  - ZR ~ 200 targets/year
  - NIF ~ many hundreds targets/year

**GA has over 19 years of ICF target fabrication experience**
GA annually produces thousands of components for OMEGA under a stringent Quality Management System

- Reliable fabrication of 4,000 components/year for ~70 categories
- **ISO 9001:2000 sets a management structure**
  - Customer interactions
  - Change controls
  - Documented work procedures
  - Regular internal/external audits
  - Quality Control
  - Staff training and publications
  - Quality Assurance
  - Management Review

Continual Improvement is a Key Objective