WELCOME

P D Roberts
Orion Induction Video
Evacuation Routes to the Emergency Assembly Point

Sirius Conference Room (SF12) – Do Not Remove
Agenda

9.30  Gate clearance at Orion Building

9.45  Coffee

10.15 Welcome  Peter Roberts

10.20 Academic Access to Orion  Tim Goldsack

10.30 Report from NIC review  Steve Rose/Peter Roberts
11.00 User Access to NIF  Justin Wark
11.20 Updates from university groups,  15 minutes each
   Oxford (including NIF User Access)  Justin Wark
   Imperial College
   York  Mark Sherlock
   Strathclyde  John Pasley
   QUB  Paul McKenna
12.35 Lunch and ORION tour  Dave Riley
Agenda

13.55  University reports
       Warwick
       RAL
       Tony Arber

14.25  Report from Washington IFE Meeting
       Chris Edwards

14.50  News and expectations for HiPER
       Chris Edwards
       John Collier

15.20  CLF status following RC reviews
       John Collier

15.40  Next Steps
       Discussion

16.10  Tea and depart by 16.30
CIFS Meeting March 2011

Fusion Progress

P D Roberts
&
S J Rose
NIC Review – Feb 23 - 25

- ‘Storm Windows’ designed to overcome ice on LEH
- Limited number of cryo shots since then
- THD (6% D) now have neutron yields $\sim 10^{14}$, $T \sim 3\text{KeV}$
- $T_r \sim 300\text{ eV}$, Symmetry control good
- Compression and convergence poor (?) but inconsistent
- Implosion velocity $\sim 10\%$ lower than expected
- Fast electron preheat low and late
- Mix now seems not severe
THD target with LEH storm window
THD fuel layers are formed with the target mounted in a dedicated cryogenic target positioner thermally isolated by a removable shroud.

27850001 target in layering shroud

Alignment camera for shot N110212 shows storm window

100 nm polyimide, 40 nm C

2010/09/25 17:02
THD ice layers are characterized in situ and have met specifications on four integrated experiments to date.

Independent tests have shown that the layer quality is not affected by shroud opening and quench (cooling from 18.8 K to 17.5 K in last 30s prior to shot).
On NIF this is assessed in 4 areas, with just 17 control parameters.
In a symmetry capsule, the DT or THD fuel is replaced with CH payload and high-density gas.

- 1.108 mm
- 0.5% Ge
- 1% Ge
- 0.5% Ge
- DT ice
- 0.3 mg/cm$^3$
- DT gas
- 0.911 mm
- 6.32 mg/cm$^3$
- 30% D
- 70% $^3$He

2010 Rev5 ignition

2010 Rev5 symcap
February 12, 2011 – 4th THD Fuel Target (Preliminary data)

Record neutron yield for a laser facility for an x-ray-driven capsule (1.3 ± 0.3 x 10^14 n)

Highest energy (1.30 MJ) laser drive delivered to a THD target

THD layer met specifications

Areal density ~ 0.X g/cm^2

THD symmetry controllable
Status 1/24/2011:
We have commissioned implosion tuning techniques

<table>
<thead>
<tr>
<th>Target</th>
<th>Reemit</th>
<th>Keyhole</th>
<th>Symmetry Capsule</th>
<th>Backlit Capsule</th>
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</thead>
<tbody>
<tr>
<td>Implosion Parameter</td>
<td>Shape Early</td>
<td>Adiabat (Foot and 4th Rise)</td>
<td>Shape (Peak)</td>
<td>Velocity, Mix</td>
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<tr>
<td>Sample NIF Data</td>
<td>700 eV image</td>
<td>VISAR streak</td>
<td>8 keV core image</td>
<td>8 keV Radiograph of capsule</td>
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<tr>
<td>• Adjustable laser or target parameter</td>
<td>• Laser power, inner/outer cones</td>
<td>• Shape of the pulse</td>
<td>• Laser power inner/outer, Δλ between cones</td>
<td>• Peak laser power, Capsule thickness, Capsule doping</td>
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</table>
Implosion experiments are encouraging

*based on pre-shot calculation
We have demonstrated hohlraum temperatures of 300 eV and round implosions at 1 and 1.3 MJ.
The hohlraum provides a hot, symmetric environment for the capsule

300 eV drive needed for Rev5 point design

LPI low enough to meet drive and symmetry req.

Symmetry

P2 < 4 um, P4 < 2.5 um
\( \rho R \): DSR measured by MRS and NToF20 are self consistent within the measurement error.

NTof Signal clearly shows down scatter signal on all THD shots

\textbf{THD-3: DSR = 0.027 \pm 0.005}

\begin{itemize}
  \item Background level from exploding pushers is reproducible
  \item Shorter cables planned for NToF20 will reduce uncertainty
    \begin{itemize}
      \item Lower cable induced background levels by \( \sim 3x \)
    \end{itemize}
\end{itemize}
R vs. t trajectory is delayed ≈ 400 ps and implosion velocity is 10.5% lower than expected

- Confirm velocity after shock tuning, with higher accuracy streak camera
- Assuming r vs. t delay discrepancy persists:
  - Radiograph acceleration onset as check of internal drive
  - Calibrate new shock flash – bangtime interval capability (pToF)
- Increase velocity using thinner capsule and/or more drive consistent with not crossing hot spot mix cliff
Hot electron preheat is negligible in foot, and is expected to increase adiabat by < 2% in peak

**From hard x-ray spectrometer:**
> 170 keV* Hot e- @ Hohlraum

**From polar hard x-ray imager:**
> 170 keV Hot e- @ Capsule

* Shorthand for energy content of hot electrons that could reach fuel

- Confirm low hot electron preheat at capsule when it matters, at < 17 ns before 4th shock break-out using truncated pulse
Parameters affecting interface mix (hard x-ray preheat and Atwood #) are close to design value or measurable

> 1.8 keV drive fraction from Dante vs. simulation

X-ray refraction off CH/Be curved interface provides fringe* with separation $\sim \Delta n_e^{2/3}$, hence Atwood #

Time-resolved Atwood # capability now demonstrated (OMEGA)


- Confirm hard x-ray preheat level after full tuning
- Measure ablator-fuel Atwood # in-flight if warranted
## NIF experimental working schedule – 1/24/2011

<table>
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<th>FY10</th>
<th>FY11</th>
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<td>Aug</td>
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### NIF/NIC summary schedule – FY2009-2012

<table>
<thead>
<tr>
<th></th>
<th>FY09</th>
<th>FY10</th>
<th>FY11</th>
<th>FY12</th>
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<tbody>
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<td>Q1</td>
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<td>Q2</td>
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<td>Q3</td>
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<td>Q4</td>
<td></td>
<td>2009/2010 energetics and first hydro</td>
<td>Ignition Preparation Project (IPP)</td>
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<tr>
<td>Q1</td>
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<td>Q2</td>
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<td>Q3</td>
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<tr>
<td>Q4</td>
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<td>2010/2011 THD ignition tuning</td>
<td>α-physics</td>
<td>Gain ~1</td>
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<tr>
<td>Q1</td>
<td></td>
<td></td>
<td></td>
<td>5 MJ output</td>
</tr>
</tbody>
</table>

2010/2011 THD ignition tuning campaign is focused on preparation for the transition to DT
AWE has a long history of innovative hohlraum design

Novel scheme for uniform implosion with backlighter (1985)

Complex hohlraums with baffles (1982)

Predictive hohlraum capability (1981)
‘Cocktail’ materials for hohlraum wall have been modelled

Wall loss for an experimental pulse shape using Gold, Uranium and Cocktail materials

Comparison of ‘LASNEX’ and ‘NYM’ showed excellent agreement
Asymmetric hohlraum campaign at OMEGA

Asymmetric laser drive

The jet-wall bow shock is just resolved

Simulation reproduces many features of the experiment
Existing ICF code has much of the necessary physics capability

NYM Lagrangian ICF code:

- **Hydro**
  - 1D or 2D Lagrangian + SALE, subzone options, various Qs, variable by zone. Conservative.

- **Mix**
  - Fall-line(2D), SpH perturbation, Mixed EoS

- **Data**
  - Tabular data or non-LTE opacity

- **Transport**
  - Multigroup diffusion or IMC
  - Multigroup hot electron & $\alpha$
  - Monte Carlo neutronics + depletion etc.

- **B fields**
  - $\n \times \n \times T$ source, Bohm or standard diffusion
  - Magnetic pressure included

- **Links**
  - to Eulerian or ALE codes
Work is underway to improve ICF modelling and code capabilities

**Current status of next generation Corvus ALE ICF code:**

<table>
<thead>
<tr>
<th>Package</th>
<th>Comments</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>3T</td>
<td>Necessary for NIC modelling (Integrated hohlraum and capsule-only)</td>
<td>Prototype available now</td>
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<tr>
<td></td>
<td></td>
<td>Testing underway</td>
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<tr>
<td>TN burn</td>
<td>Necessary for NIC modelling</td>
<td>Prototype available now</td>
</tr>
<tr>
<td>Alpha transport</td>
<td>Necessary for NIC modelling</td>
<td>Prototype available ~ mid CY 11</td>
</tr>
<tr>
<td>3D laser</td>
<td>Required for modelling of polar direct drive for HiPER and shock ignition on NIF. Desirable for modelling NIF hohlraums.</td>
<td>In progress</td>
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<tr>
<td></td>
<td></td>
<td>Estimate available mid CY 11</td>
</tr>
<tr>
<td>Hohlraum physics</td>
<td>Additional physics models to capture LPI in gas filled hohlraums</td>
<td>Not started</td>
</tr>
</tbody>
</table>
Recent modelling demonstrates developing ICF code capability

1D capsule-only calculations of the Rev5 CH design give close to nominal performance

Initial 2D Capsule-only calculations in Corvus (ALE) show excellent implosion symmetry
Integrated ICF capsule-hohlraum calculations have now been successfully run for the first time using NYM

- 2D Lagrangian calculations
- Performance agrees well with LLNL calculations

![Graph showing Tr/eV vs Time/μs comparison between Rev3.1 Be design and LLNL calculations.]

![Diagram showing initial configuration with labels for Ablator, U wall, Au lining blowoff, and implosion time.]
Implosion instability modelling
Cone-guided Fast Ignition Simulations (Corvus)

**FI Cone - difficult test problem**

- High density (~200g/cc) Au shield formed
- Turbulent SP interaction region
- High levels of mix
- Highly asymmetric collapse & RTI

Data from Stephens (LLNL) 2005 PoP 12. 2005
Cone-guided Fast Ignition Simulations (Corvus)
AWE are developing world-leading kinetic modelling capabilities

Kinetic models

- Some key physics of laser-plasma interaction (LPI) occurs below the temporal-spatial scales found in hydrocodes.
  - Parametric instabilities (Raman backscatter etc.)
  - Particle acceleration (e.g. plasma wakefield, and proton acceleration from solid targets)
  - Hot electron transport

- AWE Plasma Physics applies a number of kinetic codes developed in-house or in collaboration with academic partners, in particular:
  - CIFS (Imperial College London)
  - CFSA (Warwick University)
Kinetic models : EPOCH

- UK Plasma Physics code developed as part of an EPSRC Collaborative Computational Project (CCP)
  - Developers at: Warwick; Oxford; Imperial; and AWE.

- An explicit, relativistic particle-in-cell (PIC) code

- 1, 2 & 3D

- Proven scaling on AWE’s HPC systems

- FENRIS link code allows initialisation from AWE hydrocodes

- Collisional and hybrid algorithms under development

- Key role: characterisation of hot electron and proton spectra generated in short-pulse LPI
Kinetic models : VALIS

- 2D2P Direct Vlasov Solver
- Explicit, Conservative, Split scheme using PPM advection
- Multi-species (kinetic ions)
- Domain decomposition over 4D (2D2P) phase space
- BGK collision operator
- Key Roles:
  - High fidelity modelling of LPI problems
  - 1D transport problems
Transport Model: THOR

- Hybrid electron transport code
- Monte-Carlo, explicit
- Various EOS/resistivity models available
- Ionisation effects included
- Linked to CORVUS 2D ALE hydrocode
- Model hot electron heating of high density targets

Solid density electron transport (Te contours, B-field vectors)

HELEN buried layer heating experiments

Resistive collimator
Collaboration on NIC burn diagnostics

- Working on GCD, GRH and nToF development at OMEGA and NIF with LANL, LLNL and LLE

- Using Geant4, (a particle tracking code from CERN), to model the performance of these diagnostics

- AWE and STFC are funding research into CVD diamond detectors in partnership with Photek, Bristol/Leicester Universities and RAL to improve GRH temporal response

- AWE perform P.I. role on LLNL/LANL DT-ratio experiments developing GCD at OMEGA

GRH at NIF temporal response variation with gas pressure
AWE have an experienced in-house target fabrication capability

- Laser micro-machined foams
- OMEGA asymmetric-hydro hohlraum and capsule
- OMEGA EP high energy backlighter microwire
Sub-systems commissioned
Short & long pulse sync demo

Project complete ‘1+1’
≤15 months

Milestone ‘10+2’
≤12 months

Opacity data

2009
HELEN closed
Target Chamber delivered
Building complete

2010
Short Pulse demo
Sub-systems commissioned

2011

2012

2013
Routine operations

HELEN closed
Target Chamber delivered
Building complete

Short Pulse demo
Sub-systems commissioned
Short & long pulse sync demo

Project complete ‘1+1’
≤15 months

Milestone ‘10+2’
≤12 months

Opacity data

ORION Timeline
Summary

- NIF progress good and overcoming issues; key dates are IFSA (Sept 2011) and the ignition milestone (Sept 2012)
- The use of High Power Lasers at AWE to exploit indirect drive dates back about 40 years
- Collaboration with the US has been mutually beneficial throughout
- There has been no funded IFE programme but there is a strong synergy with the core programme (ignition etc.)
- AWE is keen to support the NIC & IFE efforts but there are resource issues