LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

LLNL-TR-607652

NIC Final Review November 13-14, 2012

J. H. Nuckolls

December 11, 2012

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

NIC FINAL REVIEW, Nov 13-14, 2012
FINAL REPORT to NNSA --12/9/12
---John H Nuckolls

SUMMARY

Super-Implosions designed to ignite multi MJ fusion micro-explosions are being energized by the 2 MJ NIF Super-Laser at the Lawrence Livermore National Laboratory.

Fusion ignition temperatures have been achieved in the central core of the Super Implosion. Pressure and energy must be increased two to three fold, and mix reduced, in order to achieve the "Alpha" milestone where fusion heating exceeds implosion heating. Pressure and energy may be increased by reducing excessive mix and asymmetries, and optimizing the Super-Implosion design. M/U is being increased (where M is margin, and U uncertainty).

The NIF Super Laser and diagnostic-experimental facility are extraordinarily successful. NIF teams are outstanding. Rapidly expanding mega data bases of experimental results are increasingly powerful resources.
Outstanding Nuclear Design teams are using Supercomputers (many orders of magnitude more powerful than used to develop the nuclear stockpile) to analyze complex experimental data and optimize the Super-Implosion design.

AN IMU PATH TO IGNITION

After the fusion dominated Alpha Milestone is achieved, fusion energy may be increased to achieve Ignition--by optimizing the Super Implosion design to Increase Margins relative to Uncertainties (IMU).
M is increased and U decreased by reducing asymmetries, instabilities, and mix, and by increasing the energy efficiency of the implosion and stagnation.

Super Implosion symmetry and stability improvements in the Point Design Target may enable achievement of the Alpha Milestone and Ignition.

A Second Generation Super ImplosionTarget may be developed to achieve the Alpha Milestone. A High Foot pulse shape is being tested. With a Rugby Hohlraum, and an HDC capsule, the M/U would be significantly increased. Rugby hohlraums achieve high symmetry with greatly reduced beam crossing energy transfer and smaller LPI. HDC capsules have order of magnitude improved surface finish. A High Foot pulse shape reduces convergence ratio, and is expected to reduce key hydro instability growth rates by an order of magnitude. Additional increases in M may be achieved by optimizing the scale, DT payload, and coupling of the dense unabated ablator to the DT at stagnation. A very small 20 KJ fusion yield is required for the Alpha Milestone--1000 times smaller than the 20 MJ fusion design yield of the Point Design Target.

Using data from Alpha Milestone experiments, a Third Generation Target may be optimized to achieve Ignition (2 MJ fusion yield). If U is too large and M too small to achieve Ignition in one step, an Intermediate 200 KJ fusion yield Milestone can be inserted. Results of Science experiments may also enable improvements in M/U and suggest opportunities for improved designs.

Because achieving Ignition has proven to be very difficult, a multi step strategy is preferable (as in LLNL's Shiva, Nova, NIF lasers---and NASA's Mercury, Gemini, Saturn rockets).

ALTERNATIVE target designs are essential, because the probability that single shell designs will achieve IDI in 3 years is not more than 50%. Two shell targets which utilize a different ignition mode should be developed to achieve IDI, and for SSP applications. Two shell targets may also achieve ignition in PDD experiments.

IMPEDIMENTS TO IGNITION

FUNDING decreases are a major impediment to ignition,

INSTABILITIES are major technical impediments--including laser plasma instabilities in the hohlraum and hydrodynamic instabilities in the imploding and stagnating capsule.

ENERGY INEFFICIENCIES (due to asymmetries, instabilities, suboptimal target design and fabrication, etc) are also a major technical impediment.

CALCULATIONS which do not agree with experiments for Super Implosions with M>U may be due to failure to achieve numerical convergence. For systems with excessive growth of instabilities or asymmetries. achieving agreement of calculations with experiments may not be possible(esp in high U regions).

SCIENCE experiments may have high value in special cases, eg by enabling higher Margins or smaller Uncertainties, or higher energy efficiencies, etc. IMU analyses should be used to prioritize Science experiments.