Under Secretary for Science
Washington, DC 20585

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MEMORANDUM FOR THE SECRETARY
ADMINISTRATOR, NATIONAL NUCLEAR SECURITY ADMINISTRATION
DEPUTY ADMINISTRATOR FOR DEFENSE PROGRAMS

FROM: STEVEN KOONIN
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SUBJECT: Initial Review of the National Ignition Campaign

Because achieving ignition at NIF is a goal of overriding importance not just for NNSA but also for the DOE as a whole I agreed to take a close and on-going interest in the progress of the National Ignition Campaign (NIC). In order to do so, I held a 1.5-day detailed technical review at LLNL (October 18-19, 2010) to judge NIC progress and plans. Accompanying me was a group of knowledgeable individuals who provided independent perspectives on what was presented. I anticipate repeating this exercise quarterly.

It has been more than a decade since I last looked closely at ICF, and there has been amazing progress in the field since then. In particular, the speed and efficiency with which the NIF was built and brought online, in spite of unforeseen difficulties encountered along the way, are remarkable. The substantial progress that has occurred in targets, diagnostics, and simulations in such a short time is also a very significant accomplishment. I am sure the entire ICF community shared my excitement on learning of the successful outcome of the first round of experiments on the fully operational facility in late 2009. The recent fielding of the first layered implosion experiment is another significant milestone in its own right. The highest priority must now be to build on this promising start, performing the experiments and analyses needed to reach the overriding goal of achieving ignition. With that in mind, one can make some general observations regarding the ongoing work.

In view of the extremely challenging nature of the scientific task being addressed, the planned schedule appears very aggressive. Flexibility and agility will be required to keep to this schedule, and it will be essential to "learn as we go." In the process, lines of communication among stakeholders (such as the NIC team, DOE, and Congress) must remain open so that nobody is surprised by any changes that may be required.

It is also important to have realistic expectations as we pursue our scientific goals; open, ongoing information exchange will also be essential here. To that end, I have asked the NIC team and

DOE to put into place a technical contract, akin to the useful Nova Technical Contract two decades ago, to measure and assess progress towards ignition. We must also ensure that communications remain open and active between my review meetings.

The following are my observations based upon the material presented at this first meeting. Since only a limited amount of material can be covered in a 1.5 day meeting, it is likely that there are activities underway addressing these issues that I am not yet aware of but that will be the subject of discussions during subsequent meetings.

1. It would be very useful to compare experimental and computational results for capsule performance in particular using a broader suite of codes than just LASNEX and HYDRA, the two leading ICF design codes. While there are a limited number of codes that contain the complete suite of relevant physics from laser deposition through implosion, there are a number of possible candidates that can address much of the relevant physics that have been well tested against experiment and that incorporate a variety of different physical models. These would help in assessing the uncertainties in code projections, particularly since there is often a lag between the development of new physics models and their insertion into operational codes; standard design practice does not always represent the state of the art. For example, access to a variety of alternative models would be of great value in understanding whether a flux limited diffusion model of electron energy transport will be sufficiently accurate.
2. More generally in computational modeling, both pre-shot and post-shot results should be made freely available, along with a transparent means of distinguishing between them. This would make it much easier to distinguish between simulations where only the inputs were changed to represent the exact as-shot conditions and those where adjustments to models have been made in response to the experimental results.
3. The approach being taken by the NIC team is to pursue both calibration of codes, based upon the ongoing experimental campaigns, and more *ab initio* approaches to develop the most accurate physical models for relevant processes. Given the complexity of the campaign and the aggressive schedule this is a sound and necessary component of the NIC.
4. While the ITF (Ignition Threshold Factor)[1] has proven very beneficial for optimizing the trade space of laser, hohlraum, and capsule variables to achieve the highest likelihood of successful ignition, it does not provide the degree of transparency required to communicate to the broader community. Application of a formal UQ/QMU[2] process could be useful and would be more accessible to the community that is not expert in ICF. It would also utilize common language with that used to quantify confidence in the

[1] The probability of ignition is well correlated to the four key implosion parameters of 1D peak fuel implosion velocity v, 1D burn-averaged imploded fuel adiabat α, rms asymmetry $\Delta R_{hotspot}/R_{hotspot}$ at the hotspot-main fuel interface, and fraction $\Delta R_{mix}/\Delta R_{fuel}$ of fuel mixed with ablator. The product of power laws of these four parameters, for small excursions, can be used to define an Ignition Threshold Factor (ITF).

[2] Uncertainty quantification (UQ) and Quantification of Margins and Uncertainties (QMU)

Stockpile Stewardship program, which is well understood and accepted by our stakeholders. For example, a list or "tree" of possible failure modes might be constructed, with a QMU analysis for each. The goal would be to overcome some of the difficulties of ITF — it is too complicated, and mixes in-flight properties with those of the compressed core (which is what really matters). ITFX[3] seems a much better metric —it is simple, more easily understood, and incorporates the Lawson criteria directly. These are important issues, not only for experts, but because the NIC must be able to demonstrate confidence to a non-expert audience.

5. Another point raised at the meeting was the ongoing need for "self-criticism" — in other words, the team must continually ask themselves "How could we be wrong?" To this end, a clear description and ranking of failure modes could provide clarity to risk mitigation efforts. There should also be ongoing look back at correlations between tuning parameters as the work proceeds to avoid issues downstream. The team needs to know as early as possible if the assumption of parameter independence breaks down.
6. Given the complexity of the physics issues addressed, experimental reproducibility is an important consideration. To that end, there should be plans for more direct comparisons between identical shots and ongoing direct comparisons between data and simulations.
7. Accurate measurement of ρr the capsule areal density, is of particular importance, and many outstanding questions could be answered if this were done sooner rather than later. As an integral measure of capsule compression, it could quickly lay to rest concerns about hohlraum conditions; "symcaps"[4] might be one useful approach in acquiring this data.

There are a number of topics that might be addressed at my next review. One of these would be to better understand the level of effort dedicated to particular tasks in the NIC, presented in terms of full-time equivalents (FTEs). For example, how many people are assigned to a given Integrated Experimental Team (IET) and what are the major tasks that must be addressed to prepare an experimental campaign for NIF? I would also like to see a presentation from Dr. Bruce Hammel on his work on hydrodynamics and "deep mix" and expect this topic in general will be a strong focus for the next meeting.

In closing, I would like to thank the NIC team and LLNL management for hosting a successful meeting. It's gratifying to see the NIC finally under way.

[3] ITFX is an experimentally observable ignition threshold factor that uses measurements from THD experiments (capsule implosions where the amount of deuterium present is kept deliberately low to control the amount of fusion yield produced) to predict the performance of DT ignition implosions.

[4] A symcap is a surrogate capsule that replaces the DT fuel layer by an equivalent mass of ablator to mimic the hydrodynamic behavior of the capsule. The x-ray self-emission signature from the implosion correlates well with an ignition capsule's core shape.