The National Ignition Campaign (NIC) “Blue Team / Red Team” Simulated Campaigns (Sim-Cams)

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Abstract. The Point design Target of the National Ignition Campaign (NIC) has specifications and tolerances that have been set using a multi variable sensitivity study (MVSS). The sub component interactions and sensitivities that feed the MVSS have been calculated using sophisticated target physics radiation hydro-codes. However, it is cannot be guaranteed that the point design configuration has been specified with enough precision for ignition to occur without first correcting for possible off-sets due to physics uncertainties in the data models used in these studies. For this reason the NIC includes a series of tuning experiments, which have been designed and sequenced to systematically remove potential off-sets in specified target and laser parameters as efficiently and effectively as possible. In order to test the tuning techniques and logic the NIC has been executing Simulated Campaigns (Sim-Cam’s). In the Sim-Cam’s are a Blue Team and a Red Team. The Blue Team conducts the experiments, making shot-to-shot decisions on how to adjust the laser pulse or target parameters, based on “experimental” data provided by the Red Team who simulate the laser, target and diagnostics performance. To capture a plausible off-set between nature and models the Red Team construct a new virtual reality by adjusting the physics data and models, keeping the changes within their best estimate of uncertainties. The Red Team also include much of the shot-to-shot variability due to small laser and target variations that can be expected in NIF experiments, as well as diagnostic noise. The details of all of this are kept hidden from the Blue Team. The Sim-Cam’s also serve to test and improve the infrastructure and processes for executing the NIF experiments. The role of the Simulated Campaigns in preparing for the NIC experimental plan will be described, and some of the results discussed.

1. Introduction
The National Ignition Campaign (NIC) has laid out a strategy to achieve ignition by first doing a series of campaigns that fine-tune the point design specifications for target and laser parameters. This is necessary because there is no guarantee that our data models, as implemented in the hydro-codes that specify the design, are sufficiently accurate to obtain ignition on the first try, without such fine-tuning. It is necessary then, to test this strategy. In particular, we seek to answer several questions: Principally, does the sequence of campaigns converge within a reasonable number of fine tuning attempts, or, for example, does correcting shock timing, and correcting symmetry, end up in an endless do-loop? Does the inevitable shot to shot variability in target and laser parameters compromise the process, or equivalently, will our specifications on the allowed variability prove adequate? As we prepare to enter the real experimental campaigns, are our theoretical data analysis tools in place to do the job? Are our processes properly in place to communicate all critical issues within all aspects of this very complex operation? It is all of these vital questions that we seek to answer by doing simulated campaigns (Sim-Cams).
2. The Sim-Cam methodology

We form two teams. The Blue Team will execute this virtual NIC campaign as if it were real. They will be handed “data” and make decisions, based on that data, of what the next shots will be, by specifying target and laser parameters. They will do so until they reach (virtual) ignition, or give up in frustration, or until some time limit is imposed that stops the game.

The Red Team has two roles and two phases of operation. In phase one the red team will determine a physics/data model that is reasonable yet different from the one currently implemented in the hydrocodes. They will ensure that ignition can be achieved under this new model, via a “re-design” that changes the point design target and laser parameters in acceptable ways. By acceptable, we mean, within the capabilities of target fabrication and of the National Ignition Facility (NIF).

In phase two the Red Team will then act as a virtual facility, simulating the irradiation of the targets “ordered” by the Blue Team, by a laser pulse, also specified by the Blue Team, and using their “Red Team Physics Model”. The results of the virtual experiment will be reported out to the Blue Team in terms of virtual diagnostic outputs, e.g. scope voltages vs. time, x-ray pinhole camera images, etc., all convolved with spatial and temporal blurring response functions as well as noise. The Blue team is to be kept in the dark as to exactly what target and laser was used (which vary shot to shot within the NIC specifications). They will also, obviously, not be told how the Red Team Physics Model differs from their own. A referee is put in place to ensure the efficacy of this entire exercise by monitoring the virtual campaign and maintaining separation of Red Team knowledge from the Blue team.

3. The NIC methodology / strategy

A multivariable sensitivity study (MVSS) is done to place the ignition campaign into a unified context. What emerges is an ignition threshold factor (ITF) \[1\], that if greater than 1, implies a very high probability of reaching ignition. Margin, as defined in references \[2,3\], is equal to ITF-1. The ITF involves 4 terms. Achieving a low adiabat implosion, a sufficiently high implosion velocity, a sufficiently clean (namely, only partially mixed) fuel, and a sufficiently round, symmetric, implosion. The adiabat is achieved via tuning of the height and timing of the laser pulse that leads to 4 shocks. The velocity is achieved via tuning the height and duration of the last part of the pulse, where most of the laser power and energy resides, as well as by tuning the capsule ablator thickness. The mix problem is controlled by varying the high Z dopant levels in the ablator, as well as by varying the ablator thickness. Symmetry is achieved by varying the pointing of the laser beams as well as by controlling the time variation of the power balance between the “inner beams” that hit the waist of the hohlraum vs. the “outer beams” that hit the hohlraum wall closer to the laser entrance hole.

After the hohlraum drive is “certified”, and laser plasma interaction (LPI) issues under sufficient control, the NIC strategy is to do the shock timing and symmetry campaigns in a somewhat interlaced mode, as we proceed from first through fourth shock. We then do a campaign called THD \[4\] wherein the D is minimized and replaced by H (T is still needed for beta layering smoothness of the DT ice) in order to cut down on neutron flux, so that it is easier for x-ray diagnostics to inform us of adiabat, mix and shape issues in the final fuel assembly. The THD campaign will be followed by attempts at DT ignition.

4. Let the Games Begin

The Red Team varied (via a one-time throw of the dice) the equations of state and opacities of all capsule and hohlraum materials, within the 1σ (typically 10-20%) uncertainties that exist. Far more uncertainty (∼ factor of 2) exists for non-LTE collisional excitation rates and for electron thermal conduction. Those were also varied accordingly. With this new model the point design failed. A retuned target/laser combination restored ignition to nominal robustness.

As this was the first such Sim-Cam exercise we simplified it by legislating that the hohlraum drive / LPI issues were near nominal. We also did not explore 3-D issues at this point, nor include mix issues...
at the ablative DT ice interface. Our main concern was to see if the shock timing/symmetry interlaced campaigns would converge in a reasonable number of virtual shots, and not enter an endless do-loop.

5. The Blue Team succeeds

The first experiments surprised the Blue Team in that the x-ray drive on the first foot of the pulse came in low. They ordered the next shot to have a higher laser power in the foot to establish a slope of drive vs. laser power, and by so doing could then specify the correct laser power to achieve the required first shock intensity. This is the empirical approach of the NIC strategy and it worked quite well. The Blue team attempted to formulate a new model (via an Au hohlraum wall opacity model) though the “reality” was that the discrepancy was much more due to the electron conduction changes in the Red Team model. The main point is that the tuning was done successfully, empirically. (Fig. (1))

Similar discrepancies occurred in the symmetry campaign. There too, a slope of symmetry vs a symmetry tuning parameter (in this case the color separation between inner and outer beams that controls cross beam transfer [5]) was established empirically. It was parallel to the Blue Team’s original expectations, but off-set. Again, the main point is the ability to tune empirically via this slope method. (Fig. (2)).

![Figure 1: Laser-pulse’s foot drive-level tune](image1)

![Figure 2: Symmetry tune P2 vs. color separation](image2)

After 25 shots the Blue Team was ready to specify an ignition target. Three targets were “shot”, first in THD mode, and then, to save time, the very same were then shot in DT mode. In THD mode, the X-ray self emission implied a hot, warm and very hot result, respectively. The back-lit images implied, respectively, a dense, fluffy, and very dense core. (Fig. (3)). In DT mode those 3 targets gave 4, 0.1, and 14 MJ yields respectively, thus achieving ignition on 2 of the 3 shots. In retrospect the middle, failure shot, had target parameters out of the allowed specifications. The corresponding ITFs and margins of these 3 shots are consistent with their performance.
6. Other lessons learned and Conclusions
In doing this exercise we learned many operational lessons. The need for a back-up “responsible person” for every principal campaign. The efficiency increase when campaigns are interlaced- to allow more time for analysis between shots of any given campaign. Many practical matters regarding communication and quality control between diverse elements of this vastly complex operation were identified and fixed. In conclusion, this first Sim-Cam was an extremely valuable exercise which confirmed the basic soundness of the NIC strategy for achieving ignition on the NIF.

7. References
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