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In a few months, or a few years, the National Ignition Facility (NIF) at the Lawrence Livermore National Laboratory may achieve fusion gain using 192 powerful lasers to generate x-rays that will compress and heat a small target containing isotopes of hydrogen. This event would mark a major milestone after decades of research on inertial confinement fusion (ICF). It might also mark the beginning of an accelerated global effort to harness fusion energy based on this science and technology. Unlike magnetic confinement fusion (ITER, 2011), in which hot fusion fuel is confined continuously by strong magnetic fields, inertial confinement fusion involves repetitive fusion explosions, taking advantage of some aspects of the science learned from the design and testing of hydrogen bombs. The NIF was built primarily because of the information it would provide on weapons physics, helping the United States to steward its stockpile of nuclear weapons without further underground testing. The U.S. National Academies' National Research Council is now hosting a study to assess the prospects for energy from inertial confinement fusion. While this study has a classified sub-panel on target physics, it has not been charged with examining the potential nuclear proliferation risks associated with ICF R&D. We argue here that this question urgently requires direct and transparent examination, so that means to mitigate risks can be assessed, and the potential residual risks can be balanced against the potential benefits, now being assessed by the NRC. This concern is not new (Holdren, 1978), but its urgency is now higher than ever before.

Proliferation concerns have generally centered around the technical capabilities to acquire fissile materials, primarily highly enriched uranium and plutonium, which are necessary ingredients for all nuclear weapons. The basic science and technology of uranium enrichment and nuclear fuel reprocessing, used for civilian nuclear energy programs, are also used by proliferating nations to produce these materials for weapons purposes. The proliferation risks potentially associated with ICF R&D are very different. They do not have to do with a nation developing its first, primitive nuclear weapons. What could be at risk is acquisition and dissemination of scientific data that would facilitate designing more compact, lighter and more powerful nuclear warheads. Such warheads may be able to be delivered by relatively low throw-weight, long-range missiles. In January 2011, U.S. Secretary of Defense Robert Gates highlighted concerns that future North Korean nuclear-tipped missiles may be able to reach the West Coast of the United States (NYT, 2011). Such weapons, based in North Korea and eventually in other regions around the world, would not only put the United States and its allies at risk directly, but would also constitute highly destabilizing steps in regional arms races.

With a nuclear renaissance potentially on the horizon, in addition to the 30 states currently operating nuclear power plants, 65 new states are "expressing interest in, considering, or actively planning for nuclear power" (IAEA, 2010). As illustrated in Figure 1, 21 are in Asia and the Pacific region, 21 are in the Africa region, 12 are in Europe (mostly Eastern Europe), and 11 are in Latin America. Some of the potential "newcomer" countries are in regions that are considered politically unstable today. A number of these have expressed interest in developing uranium enrichment and plutonium reprocessing technologies, or emphasize their right to do so. Proliferation concerns center around clandestine production of weapons materials, covert diversion of such materials from safeguarded facilities, and breakout from nonproliferation agreements followed by use of previously safeguarded facilities to produce weapons materials. Conceivably therefore nuclear weapons material may become available not only in South Asia and the vicinity of the Korean Peninsula, but in Southeast Asia, the Middle East, Africa, and South America. Our concern is whether data from ICF R&D, and perhaps ultimately deployment of ICF power plants, might make it easier for these materials to be fashioned into very powerful and highly deliverable weapons.

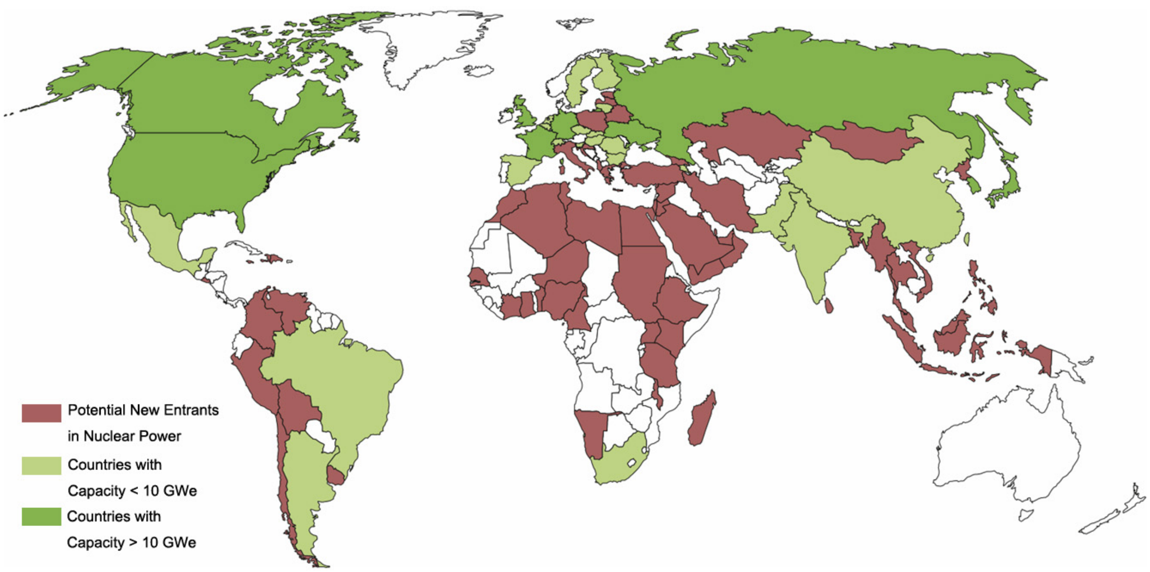

Figure 1. Existing nuclear energy states and states considering starting nuclear energy programs.

The weapons-science arguments for the construction of the NIF in the United States were compelling, and even when the price of the NIF escalated dramatically, the U.S. National Nuclear Security Administration continued to support the project, underscoring its value to the U.S. nuclear weapons program. The NIF was projected to allow access to the energy density of a nuclear weapons test, as shown in Figure 2. It would thus allow measurements of the density of materials at extreme temperature and pressure (the "equation of state"), the opacity of materials to x-rays, the flow of x-rays in specific geometries, the instability of extreme compression, and the material mixing associated with this instability. All of these were projected to be accessible to the NIF in weapons-relevant regimes (Libby, 1994).

In 1995 the United States Department of Energy conducted a review of the proliferation risks associated with the NIF (USDOE, 1995). The unclassified final report described in simple terms the operation of a modern thermonuclear weapon, and made clear the importance of the capabilities of the NIF noted above for understanding the operation of such a weapon. The subsequent addition of plans "for the use of plutonium, other fissile materials, fissionable materials and lithium hydride in experiments to be conducted at the NIF" (NNSA, 2005) extended these capabilities to include studies of the equation of state and nuclear physics properties of these additional materials in weapons-relevant conditions. Thus the NIF could provide data on each of the three items that an advanced proliferator would require in order to "pursue secondary designs, … improved capabilities in x-ray transport, equation of state, and thermonuclear reactions", according to the 1995 review. The review concluded, however, that "In general, without access to data from nuclear tests, ICF or unclassified NIF data would be of very limited utility to proliferators." The 2005 analysis indicated no change to the conclusions of the 1995 review.

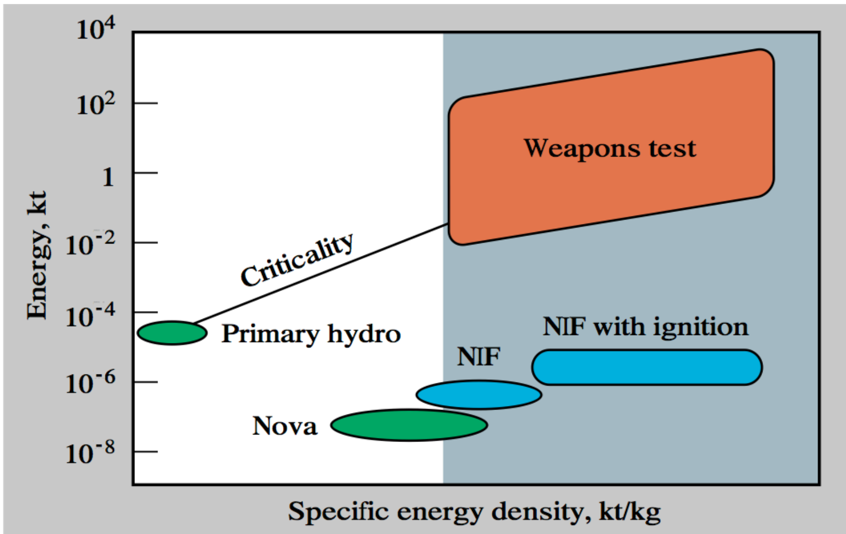

Figure 2. The National Ignition Facility is designed to reach energy densities similar to those of nuclear weapons tests, well beyond the capabilities of the previous Nova ICF facility. (Libby, 1994)

It is important to recognize, *first*, that the conclusion of these reviews left open the possibility that the full set of scientific data (both unclassified *and* classified) that could be produced with the NIF or its equivalent in another country would significantly help a potential proliferating nation improve its weapons designs. In 1993 a significant amount of information about inertial confinement fusion was declassified in order to facilitate research on energy applications, but much information available through ICF R&D remains classified. This is described briefly in Appendix II of the 1995 report (USDOE, 1995) and in more detail in the recently released history of DOE declassification document (USDOE, 2002). *Second,* it also left open the possibility that ICF data could significantly help a proliferating nation that performs its own underground tests, or has access to data from others' tests.

The first problem to consider, therefore, is that if there is a worldwide expansion of R&D on inertial confinement fusion energy, many nations will be positioned to develop their own data equivalent to the *classified* data that the United States will generate on the NIF. Even if only a limited number of states have this capability, will they be willing and able to restrict the data the United States considers sensitive? The track record on this is poor. In the 1950s, France published detailed technical papers on plutonium-separation techniques as part of the *Atoms for Peace* conferences. Sensitive centrifuge design information leaked from the Netherlands and Germany in the 1970s and 1980s to several countries, a fact that continues to haunt nonproliferation efforts to this day. Similarly, and directly relevant to the discussion of ICF R&D, before 1979 the fact that hydrogen bombs involve x-ray compression of a physically separate "secondary" component containing fusion fuel, and reference to this technique in ICF, were both classified in the United States; nonetheless during this time ICF scientists worldwide, including those in non-nuclear weapons states, knew about x-ray compression of ICF targets and its relevance to weapons (Fusion Magazine, 1979; Kidder, 2004 – 2005). The basic concept that "radiation from the conversion of the focused energy (e.g., laser or particle beam) can be contained and used to compress and ignite a physically separate component containing thermonuclear fuel" was declassified by the United States in 1979 (USDOE, 2002). During the 1980's and early 1990's, however, detailed results of international ICF research on x-ray compression were published (Murakami, 1991) that revealed information considered classified at the time by the United States. Furthermore, it should be recognized that the cost of ICF R&D systems will diminish with a worldwide R&D program and perhaps ultimately with deployment of ICF energy systems. Thus the capability to make measurements equivalent to all of those available on the NIF will become more widely dispersed.

On the second problem, underground testing, the NIF nonproliferation review stated additionally, "Without nuclear testing, it is probable that a proliferator would not be able to develop a highly deliverable thermonuclear weapon ..." Since this 1995 review, however, nuclear tests have been performed by India (1998), Pakistan (1998), and North Korea (2006, 2009). We cannot practically exclude the possibility that a proliferating state will perform underground tests even if the Comprehensive Test Ban Treaty ultimately enters into force, raising significantly the political cost of testing. We are concerned that by inserting data equivalent to what can be acquired from the NIF into programs run on inexpensive computer clusters 100,000x more powerful than those available to U.S. weapons scientists in 1970, proliferating states might be able to achieve their goals with relatively few tests, and therefore relatively little political cost.

Thus the question we are asking can be simplified to: "Could access to the equivalent of classified data from the NIF, generated through worldwide ICF R&D and perhaps ultimately deployment of ICF energy systems, accelerate the weapons program of a state attempting to develop powerful, highly deliverable nuclear weapons?" And if this is a significant risk, we would further ask, "Are there ways to limit this proliferation risk to an acceptable level?" For example, the French *Commissariat à l'Energie Atomique* has stated that it will not pursue inertial confinement fusion energy in configurations that involve x-ray compression, which is used in the second-stage of nuclear weapons, but will only consider "direct drive" inertial fusion, where lasers or particle beams impinge directly on the surface of the fusion target (Massard, 2010). The present U.S. position is that such a restriction is not necessary. We ask if this restriction alone is sufficient, since lasers originally designed for direct drive can also be used on targets designed for x-ray compression.

We, the authors, cannot ourselves assess the magnitude of the proliferation risks of widespread ICF R&D, nor can we assess whether these risks can be adequately managed or limited by some kind of agreed international restrictions or controls. But based on our reading of the 1995 NIF nonproliferation review and the history of exposure of U.S.-classified information through international ICF R&D, we do believe that these are issues have not yet been addressed and need to be addressed *before* results from the NIF have the potential to trigger a widespread international R&D effort in this area. We also believe that these issues should be addressed in as open and transparent a manner as possible. The 1995 review was a good step in this direction, but for a much more limited question having to do with a single facility under U.S. control. Since this is an issue of even greater concern, due to its potentially global ramifications, we believe that a review should be undertaken by a Panel that includes not only weapons designers and nonproliferation experts from the U.S. weapons labs, but also members of the U.S. Intelligence Community and the State Department, as well as scientists and nonproliferation experts from academia and non-governmental organizations. It should have outside reviewers as did the 1995 report, and should be commissioned in a manner that encourages the widest possible perspective.

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