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TITLE THE NEXT LOGICAL STEP IN LASER-FUSION DEVELOPMENT

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THE NEXT LOGICAL STEP IN LASER-FUSION DEVELOPMENT

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The ICF program has made significant progress in the 1980s toward the near-term goal of a Laboratory Microfusion Facility (LMF). Centurion/Halite, a classified theoretical and experimental program to investigate the design characteristics of high-performance ICF targets, has recently made excellent progress [1]. The solid-state laser Nova has produced a target gain of 0.2% (10^{13} D-T neutrons) with 17 kJ of 0.35-μm laser light, and has imploded targets with a convergence ratio of 30 in radius [1,2]. The light-ion accelerator PBFA II, a low-cost ICF driver, is currently working on power concentration and beam focusing. Aurora, the first full prototypical demonstration of a KrF laser-fusion system, is expected to illuminate targets with a few kilojoules of near-ideal 0.25 μm wavelength laser light starting in the fall of 1988 [3]. Additionally, induced spatial incoherence (ISI) appears to have resolved the issue of illumination symmetry for direct drive.

With the recent progress in existing facilities and the new facilities becoming operational in the near future, it is appropriate to begin to plan for the next facility. With the LMF as the near-term goal, the issue is whether or not the LMF should be the next facility if a laser is chosen as the driver. For the reasons stated below, it is the authors' conviction that the LMF as the next step has too high a technical and economic risk for a laser driver, and that construction and operation of an intermediate laser ICF facility is needed. This intermediate facility would substantially reduce both the cost and the technical risk for a laser-driven LMF. We note that it PBFA II achieves its technical goals, it will satisfy our energy/power definition of an intermediate driver.

Substantial uncertainties remain in the area of target performance. In particular, symmetry and mix are two areas which may have a significant impact on target performance. For example, reference 1 states that the required driver energy is 5 to 10 megajoules. This factor-of-two uncertainty in driver energy is roughly equivalent to a factor-of-two uncertainty in the cost. With an LMF cost goal of less than $200/joule [1,4], the uncertainty in the LMF cost is ~$1 billion! Such a cost uncertainty is unacceptable. An intermediate facility would address target physics issues to define precisely the LMF driver requirements and to reduce the risk of failure due to target physics reasons.

Driver energy coupling to a target is another area of uncertainty in that the absorption and x-ray conversion efficiencies for lasers as functions of the wavelength and intensity are not fully understood. A facility intermediate to the LMF would provide data and experience that would be essential to a more precise specification of the LMF driver energy.

The intermediate facility should also address the issue of direct versus indirect drive. It currently appears that direct drive has the substantial benefit of higher gain at lower driver energies, but has the additional constraint of high implosion symmetry and stability due to illumination nonuniformities. The additional cost of the direct drive option for an intermediate facility would be much less than having both direct drive and indirect drive illumination geometries in the LMF. Because of the potential for large savings in the cost of the LMF driver, the direct versus indirect issue needs to be resolved prior to final design of the LMF.

No laser-fusion driver has ever been constructed for less than $1000/joule. Nova, the largest and most recent solid-state laser-fusion system (which benefits from significant learning from the six previous large solid-state lasers built at Lawrence Livermore National Laboratory and also should have realized the most economies of scale) has a cost of ~$3500/joule or nearly 20 times the LMF cost goal. In addition, the recently completed glass laser at Limeil, France, based on Nova technology, cost $10,000/joule to complete. The Aurora laser has a cost of about $2000/joule, but is a smaller-scale, first-of-a-kind system that had no advantage of cost reductions owing to experience from previous systems. Both types of lasers have plans for future systems with substantially lower costs. In addition to low cost, the driver for the LMF must also have the capability for precise pulse shaping, large dynamic range, very low prepulse, long service life, and high availability and reliability [4]. All of these driver characteristics will need to be verified prior to committing to an LMF, and an intermediate facility would be ideal for this. The intermediate facility would provide the needed driver development, would serve as a prototype for the full LMF driver, would verify driver designs for the LMF, and would reduce the risk of the LMF.

Previous driver development steps have traditionally been reasonably sized, with driver energy increases being between a factor of three and ten. Prudence and past experience indicates that large steps can lead to degraded performance, very expensive retrofits, and significant delays. In 1986, the National Academy of Sciences reviewed the ICF program [5]. In their final report, the NAS review committee also recognized that the step to the LMF from where we are today would be too large. In their report, they stated that during the next five years, the ICF "...programs should be structured to provide affordable choices for a larger laser driver by about 1991. A reasonable goal would be about 1 MJ of energy with good pulse shaping capabilities at a cost of $200 million or less." Depending on the degree of optimism, current estimates indicate that the range of driver energy from a few hundred kilojoules to one megajoule would be in the target-ignition/breakeven/low-gain regime depending on the type of driver and target illumination. Experiments at this energy would be of substantial importance for development of high gain, and have applications for weapons physics research.

In agreement with the National Academy of Sciences ICF Review Committee, it is the conviction of the authors that an intermediate laser facility is needed before embarking on detailed design and construction of an LMF based on a laser driver. This facility might appropriately be called an Ignition Physics Facility (IPF) based on current estimates of ignition for ICF targets. The IPF could address important target physics issues such as symmetry and mix. Significant driver development and verification of low-cost designs could also be achieved with an intermediate facility. Target coupling could be precisely determined with this facility, and much needed information on target performance can be obtained. Operational experience with the IPF will generate precise specifications of the driver requirements for the LMF, which are currently uncertain in many key areas [4]. Finally and perhaps most importantly, the IPF can resolve the issue of which type of drive approach, direct or indirect, will produce a higher gain. If the calculations of direct-drive target performance are experimentally verified, it will result in a substantial cost reduction for the LMF due to reduced driver requirements. For all of these reasons, the next ICF facility should clearly be an Ignition Physics Facility, to reduce both the cost and the risk of the LMF.

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3. D. B. Harris, D. J. Dudziak, and D. C. Cartwright, "Inertial Fusion in the Nineties," Proceedings of the Fusion Power Associates Symposium "Fusion Power Development: Breakeven and Beyond," Princeton, New Jersey, 27-28 August 1987.

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