Whitepaper: Overview of IFE Workshop Submissions for Heavy Ion Fusion

This overview accompanies the three slide presentations at:

1. Needs: #1 is Office for IFE. 1. Needs ala Mabry.pptx
2. Plan: Now to Power 2. HIF Plan... Now to Power.pptx
3. HIF 1975-now: Constant improvement 3. HIF 1975-now_constant development.pptx

This submission to the IFE workshop sketches the strong position of heavy-ion driven IFE development and stresses its sweep of the keys—high-gain pellet, efficient accelerator-driver, and long-life chamber—for economical energy and water production.

To gear up and move on to energy producing IFE is the main issue at this time. NIF has ended the waiting for a pellet to ignite. The crucial, first critical requirement is a DOE Office of Inertial Confinement Fusion Energy. Some salient considerations at this inception of a dedicated IFE for Energy program are here: HIF IFE mantras

The record shows the consistent judgment since 1976 that the driver for IFE will be heavy ion beams, HIF. An important point that all interested in IFE may have missed: When the US ceased its HIF effort in 1979 to concentrate funding on NOVA, the high energy physics community HEP with HEPAP guidance stood aside, as the then-DOE director of OICF pointed out in *Physics Today*, October 2010, page 8. The abandoned RF HIF technology presented the "best bet" for IFE (Burton Richter). The HIF aura was transmogrified over the 1980s by plasma physics/MFE and pulsed power to replace the mainstream accelerator technology with a basic, technology-research effort to redevelop from the ground up NNSA's induction linac for pulsed x-ray production. Useful technology research, but no path to a viable driver for IFE like RF HIF.

We will explain the HIF IFE plan including a package of 6 demonstrations mostly using additions to existing facilities, simulations at LLNL as well as physical demonstrations and simulations of the accelerator driver configuration that we proposed in 2012 in response to an ARPA-E FOA.

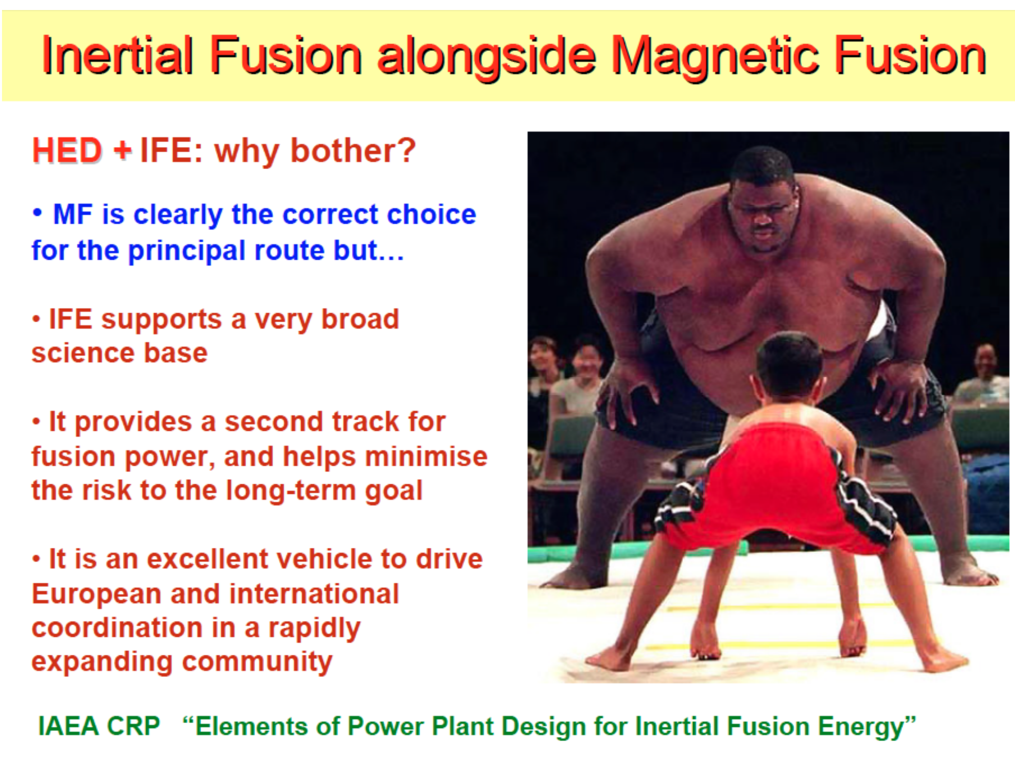
Of first importance is the high gain Russian HIF pellet, which ARPA-E was preparing to fund when NIF's shortfall in 2012 kept IFE in limbo. The "Basko" pellet was developed after the US abandoned the mainstream HIF: Meyer-ter-Vehn (Max Planck) and Basko (ITEP) took up the fast ignition in precompressed cylindrical fuel simulated by Avrorin at Chelyabinsk in 1983, shifted from hohlraums to the cylindrical pellets, and observed high gain with ~15MJ input.

The US abandonment of mainstream HIF after 1979 startled the world community, but led to Russia and Germany dropping hohlraum pellets and publishing simulation results of high gain for "lead pipe" pellets—thick-wall lead tubes containing DT, where the ions deposit 15MJ in an annular absorber layer of the pipe's wall between pusher and tamper layers. Basko uses on-axis fast ignition in 100 g/cc fuel, as first modeled by Avrorin. LLNL forbade LBNL from using HYDRA to check this "Basko" design, saying that the design was classified. However, LLNL's Classification Office under Director Dave Brown concluded in 2012, with much help from Ray Kidder (who instructed on classification guide back in the day), that the classification guide says

Basko is not classified. Kidder also tried hard without success to get LLNL to simulate Basko's configuration (maintaining secrecy if need be). In late summer 2012, ARPA-E was set to fund a thorough treatment of this pellet geometry, including added details and potentially large improvements, when such was derailed in the fallout from NIF's underperformance in 2012. If this check on Basko has been done but is still treated as classified, it would be a great service if the basic results were revealed— withholding classified code information as needed. The match of that geometry and the sprfd heavy ion driver beams is the foundation of our proposed plan. Russia still "owns" these pellet designs.

Validation of the NIF's propagating burn achievement underscores the successful development of remarkable diagnostic capabilities. Being prepared for ignition success motivated the NAS study of IFE's prospects that started in 2010 and wrapped up when ignition did not happen in 2012. Now it has happened. (Bodner "close enough." Ma "nearly." Callahan "we did it." Burke "I agree.") NAS "Prospects" concluded that this moment would be the time to start dedicated IFE development. That is the huge thing about this juncture. And why a DOE Office dedicated to Inertial Confinement Fusion Energy now is necessary.

Congress wants IFE and legislated this into law in 2018. But DOE has yet to request the IFE funding that Congress is trying to provide—for IFE in SC. The IFE office must be independent of FES as much as it needs the independence from NNSA that Congress calls for. MFE and IFE are clear competitors. Always have been. For FES to add the IFE mission makes no sense, neither technically nor culturally. HED and Lasernet do not add up to an IFE program. This needs to be understood. This strangulating convolution of research alignments is a worldwide problem, as Boris Sharkov told the Russian Academy in 2007 in this graphic:



"Advances in accelerators and targets for HED and HIF"

Boris Sharkov

ITEP-Moscow

IFE systems can be economical while MFE systems cannot because of the neutron damage that is inescapable in the necessarily bare-wall MFE chambers. The IFE chamber protection by lithium layers is self-consistent and straightforward when the pulse yields are large enough to achieve suitable power in a chamber with relatively slow pulsing like 1 pps per chamber—more than enough time for the chamber vacuum and configuration of lithium flows to recover. Using accelerator rep rate to drive say 10 chambers with a single accelerator driver, IFE economics leaps to ROI like early oil with the large yield pulses—barrels of oil equivalent—that work best with the neutron protection. Stellar EROEI as driver and chambers last, are readily maintainable, and upgradable in place. Decommissioning as currently understood will not be needed.

Bigness is used against HIF for reasons that are wrong, outdated, and hostage to the electricity industry's model of the grid with a huge number of sources.The issue is making clean energy—not to accommodate the needs and positions of the electric industry or investors' want to cut fusion energy's prodigious parameters to fit their comfort zone. The need is for lots of clean energy asap. The issue is risk management, and the record of large accelerator projects and the degree of confidence in ignition physics earn the view that the risks are manageable.

The large size of IFE sites involves the major paradigm shift to producing the full menu of energy products—not just electricity. In the HIF IFE system, electricity is the first step of an energy production sequence. It is correct that the amount of electricity is much more than the grid can accept at one point. Electricity is costly to store. HIF IFE's low cost per terraJoule/gigaWatt-year leads to electrolytic hydrogen for sale and for synfuel manufacturing, economically, because HIF IFE produces high quality heat at the low unit cost resulting from the strong economies of scale.

Fusion is the big solution to the world's big problems. To insist fusion come in smaller packages is misguided.

The benefits of large energy output accrue from economies of scale; and the large scale assists achievement of high metrics all around, including environmental, health and safety, security, etc. It is important to stress that bigness begets security when, as in this case especially, bigness causes widespread participation and scrutiny. This has unprecedented implications for progress in public acceptance of nuclear energy. The safety and environmental opportunities become locked-in through the all-stakeholder approach to conducting the IFE project from inception: DOE Office of Inertial Confinement Fusion Energy and the DOE Energy Innovation Hub for IFE with all stakeholder principles.

Paradigm shift:
A. Integrated fusion electricity and synfuel production.
B. Big output from fusion sites is good.
C. Big-clean-profitable meets climate and economic development problems head on.

D. All-Stakeholder power sharing approach to solution of “wicked problem.”* All stakeholders: technology and business, public interest, government.
*https://drive.google.com/file/d/1EMca-snmbYu4Dxg9dU5bzxoxbNdruLXn/view?usp=sharing)

Urgent Action: Establish Office of Inertial Confinement Fusion Energy. Request FY23 funding.

Submissions to the IFE workshop.

We want to provide information to apprise the workshop of the current status of worldwide Heavy Ion Fusion, HIF—long expected to be ICF’s commercial energy technology. HIF, as judged to be the way to go (all the way) to economic energy since 1976, reëndorsed as the expected driver technology by DOE ERAB in 1979, NAS in 1985, etc. In state-of-the-union speak: the state of HIF is strong. Ignition is “close enough,” “nearly done,” and “done” by NIF. IFE is ready to go on to energy production. This is the overall message of our contributions to the workshop, which fall in two arenas.

1. Essentials for a program to develop IFE: Technology and Public Support
    a. Technology: Data-supported path to economic energy production with credible “before the decade is out” vibe targeting 2035 to begin rapid build up of IFE market share for electricity, hydrogen, synfuels, etc.
    b. Public support: Open/accessible, health & safety, environment, economics, deadline.

2. HIF IFE:
    a. Big picture economics and public appeal of large scale HIF-IFE underground fusion and clean energy surface industry complexes based on Single Pass RF Drivers (SPRFD. Recommendation #1 of the RF driver group at the 2011 AHIF workshop at LBNL: [sprfd is] *the starting point to detail the RF driver design.*
    b. Physical and simulated physics and engineering demonstrations of certain component performance parameters for the accelerator driver and the large pulse chamber systems. Six topics: #1. Cylindrical pellet “Basko.” #2-5. Accelerator manipulations introduced in the Single Pulse RF Driver configuration. #6 Large pulse lithium protected chamber.

The six projects were defined for investors in Fusion Power Corporation in 2011 (CA C-corp 2009-2019) and covered patents that have become public domain. The large pulse lithium protected chamber represents 50 years of development of the falling lithium chamber first described in 1974 (*Direct Conversion Neutron Energy and other advantages of a Large Yield per Pulse Inertial-Confinement Fusion Reactor* https://www.osti.gov/servlets/purl/7172598). This pointed to the strong economics case of large pulse systems. The high energy heavy ion driver discovery in 1975-76 matched the large yield chamber dynamics, the economics of which match the accelerator’s investment requirements. The energy sites enter rare economic territory (EROEI, ROI) by the accelerator’s repetition rate to drive 10 large, high-power chambers.

Responding to an ARPA-E FOA in 2012, FPC formed international teams of experts in laboratories, universities, and companies for the demonstration six-pack. The excellence of the US and international team and the telling significance of the Basko cylindrical pellet brought ARPA-E to the edge of negotiating the 3-year contract when NIF missed the milestone and the IFE push had to wait again, until now.