Warhead assurance under CTBT constraints

PONI 2010 Fall Conference, 21/9/20

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Email: [redacted]

UK Nuclear tests and the first moratorium

- Atmospheric testing (Australia, Christmas Island)
  - 1st British test 3/10/52
  - Fission device performance and safety
  - Thermonuclear demonstration at MT class in Nov 1957
- Initial move to UGTs (NTS) enabled by 1958 MDA
  - 1st UK under ground test 1/3/62
  - 4 further tests by 10/9/65
  - Underpinning tactical & strategic warheads and R&D objectives
  - WE177 and Polaris in service – job done?
- 9 year moratorium – confidence increased as competence decreased!
    - Explicit plans and measures needed to maintain capability
    - Independent assessment and peer review are essential

Modern era and transition to CTBT

- "Modern era" UGTs 1974-1991
  - Warhead development imperative to maintain deterrent effectiveness
  - UGTs supported Chevaline, Trident, FTNW and R&D
  - Tests heavily instrumented aimed at improving understanding, validating models and developing designer experience
  - [redacted]
- Transition to CTBT
  - Last test fired 26/11/91
  - Early 90s a period of uncertainty - aspirations maintained to fire a small number of further tests
  - Trident enters service in 1994
  - Increasingly clear that the UK would not resume testing.
  - Tactical system withdrawn from service in 1998
  - CTBT ratified in 1998

Early foundations of a CTBT methodology

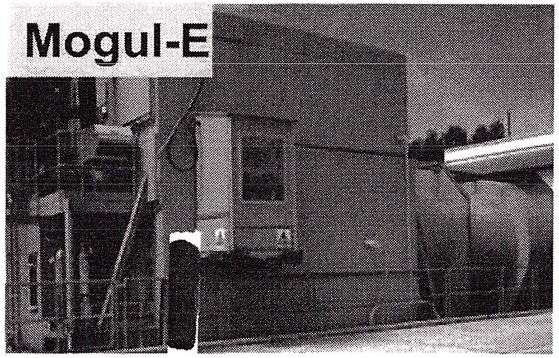
- 1955 J C Martin - internal paper on gamma radiography of imploding systems
- Diversion to assess the feasibility of achieving fusion without a fission trigger.
- From the early 1960s focus moved to the development of machines for two purposes
  - Radiography of explosively driven experiments
  - Nuclear weapon effects simulation
- Towards the end of the decade the possibility of creating even higher energy densities using focused laser beams was recognised
- Perceived threat of a CTBT ever present
- 1975 Penney review - Laboratory dense plasma (fusion) facility required for validation under a CTBT
  - ICF programme in US and Russia - lasers look like the most promising route
  - Programme well established by 1976 – decision to procure an upgrade AFL1 later christened HELEN

Partial List of Pulsed Power machines

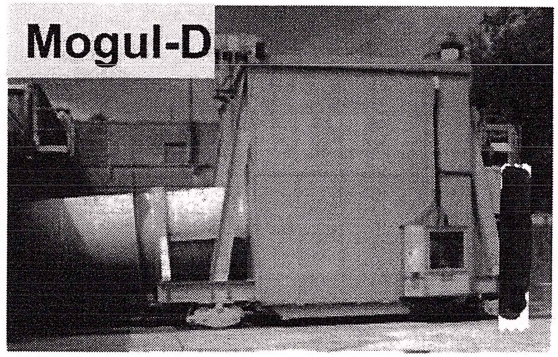
- 1963 SMOG
- 1966 WEWOBL
- 1966 PLATO
- 1967 MINI A
- 1967 MOGUL
- 1968 MINI B …MINI C
- 1980 MOGUL D
  - 1st Full Scale Core Punch
- 1995 MOGUL E
  - 1st Dual Axis Core Punch
- 1968 EROS
- 1971 SPLATLLET
- 1972 IT
- 1974 GRIMM
- 1975 ACE
- 1983 PEBBLE

Radiographic machines at AWE

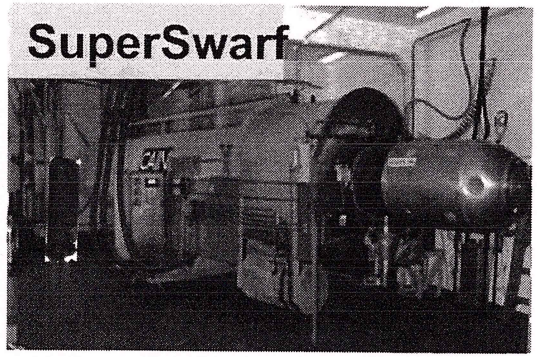
10 MV



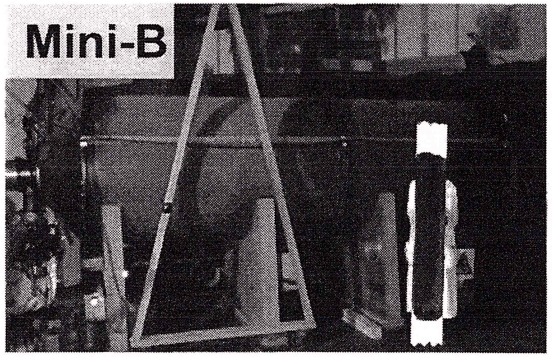
7 MV



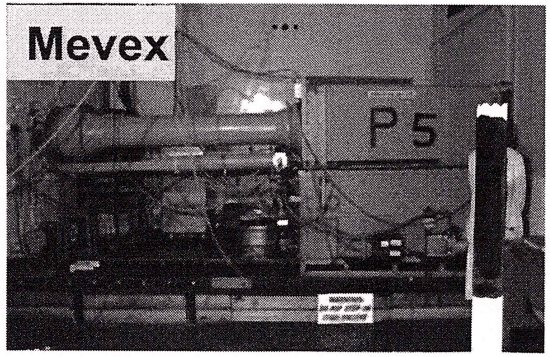
5 MV



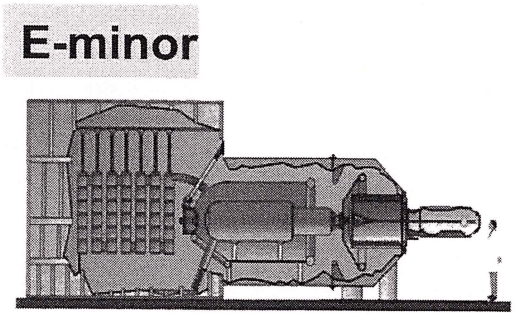
2.2 MV



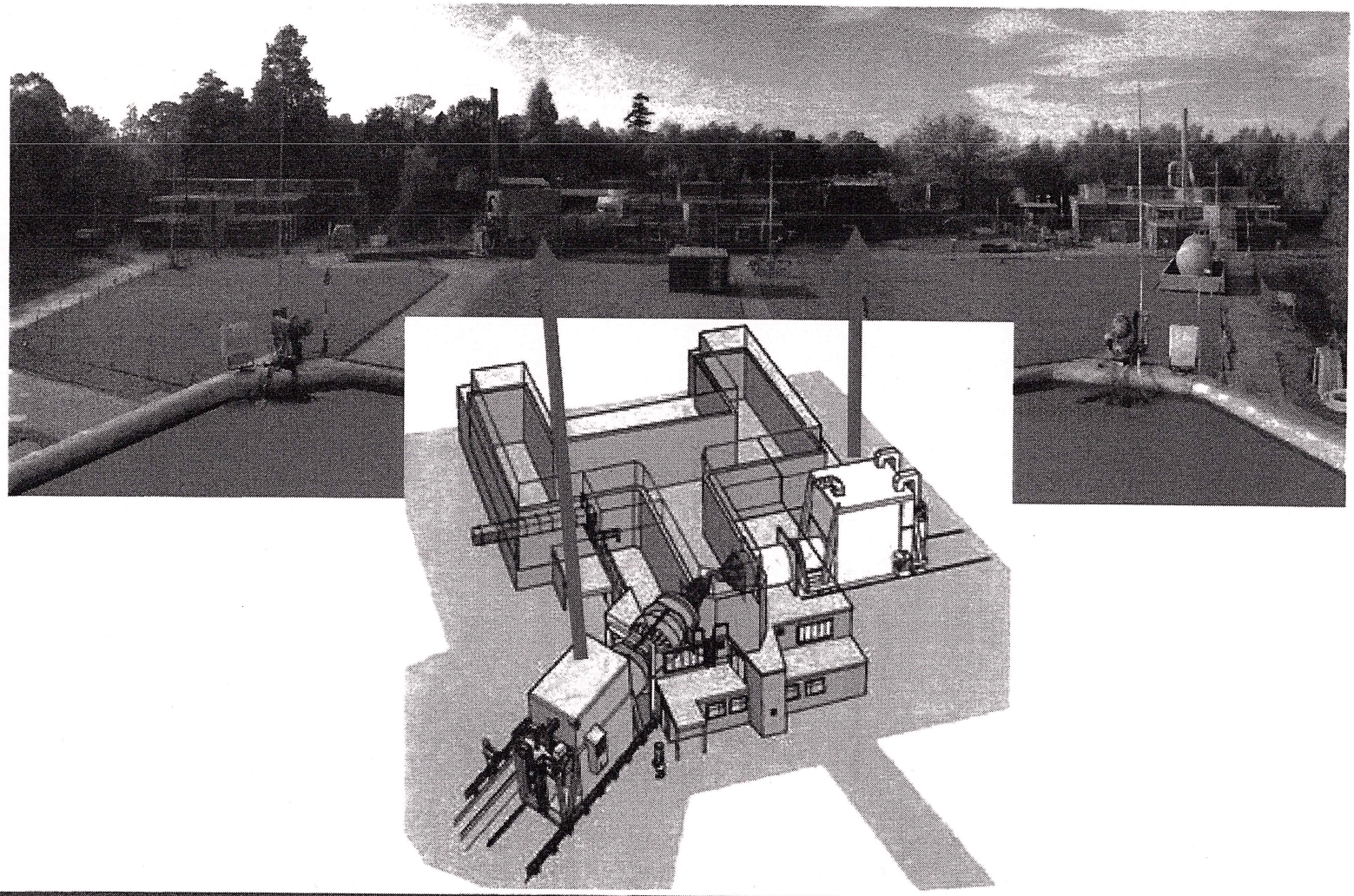
0.8 MV



5.5 MV



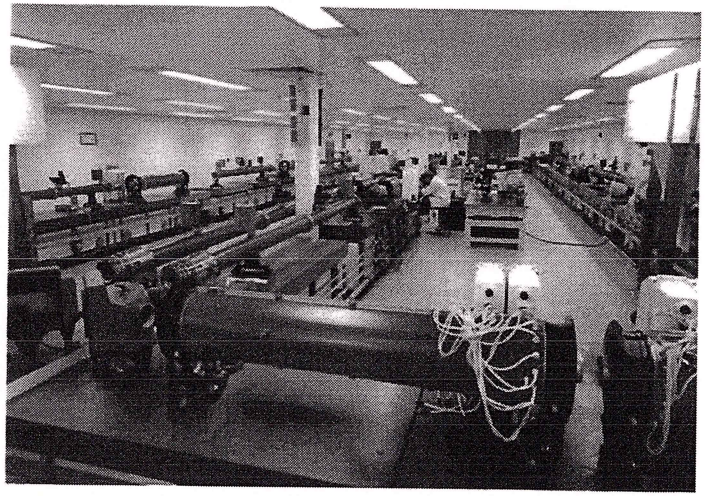
Mogul-D (1980) and Mogul-E (1995) Dual axis radiographic facility.



HELEN laser development

Specification in 1979

- 2 beams output diameter 200mm
- 100J in 100psec (1TW) at 1064nm



Specification in 2005

- 2 beams output diameter 300mm
- 1000J in 1ns (1TW) at 527nm
- Plus 1 beam output diameter 200mm
- 50J in 0.5ps (100TW) at 1054nm

A new approach

feature

Science of nuclear warheads

Keith O'Nions, Robin Pitman & Clive Marsh

Little has been published about nuclear warhead science. Here we set out elements of the programme that will underpin future assessments of the safety and performance of Britain's warheads in compliance with treaty obligations.

Britain last carried out an underground nuclear test ten years ago. The 1998 Strategic Defence Review confirmed the need for nuclear weapons until security can be assured without them. Britain signed the Comprehensive Nuclear Test Ban Treaty in 1996, ratified it in 1998, and is planning to support its nuclear weapon stockpile without further underground nuclear tests (Box 1). In the past, such testing has been fundamental to the process used for assuring warhead designs.

Now a new scientific methodology is being developed, without further nuclear tests, aimed at underwriting the safety and performance of the ageing Trident stockpile with continued high confidence. The approach builds upon previous nuclear test experience and seeks to replace the requirements for further empirical test data by developing a deeper theoretical and experimental understanding of the relevant fundamental science. This must then be drawn together and applied to the nuclear warhead system using intensive numerical modelling.

This new approach will continue to demand high [illegible]

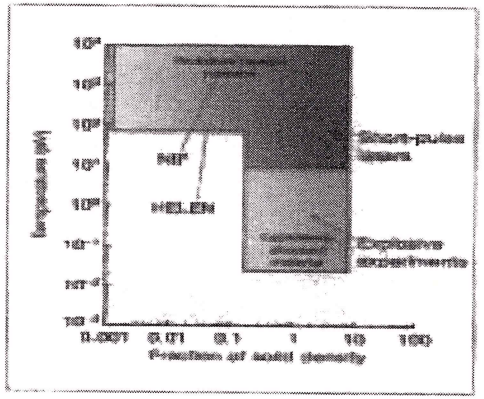


Figure 1 Conditions generated in a nuclear warhead. The green and blue areas indicate the temperatures and densities reached during the phases of operation of a nuclear warhead. Temperatures are conventionally expressed in electron volts, where 1 eV corresponds to 1.160×10^4 K. On this scale, room temperature corresponds to about 3×10^{-2} eV and 1 keV to approximately 10^7 K, a temperature found in the central region of the Sun. Also indicated are the mid-points of the regions that can be accessed currently by explosive experiments and AWE's HELEN 1-TW neodymium–glass laser. The 600-TW US National Ignition Facility (NIF) will enable much higher temperatures to be accessed. Short-pulse lasers in the petawatt power range may offer a practical means in future of generating plasma over a wide range of temperatures.

state-of-art supercomputing and visualisation facilities. This article describes the [illegible] challenge and Britain's response to it.

Britain and nuclear w[illegible]

The research for Brit[illegible] and wea[illegible]

[illegible] ability to predict [illegible] ageing [illegible] bil-

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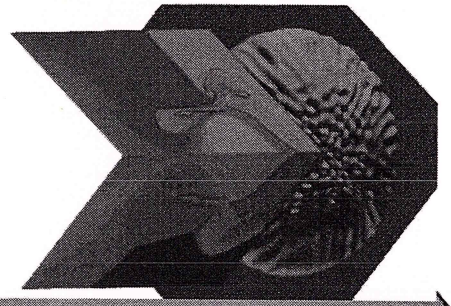
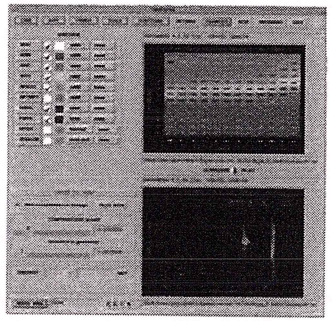
Science-based approach for CTBT era

Multi-physics Hydrocodes

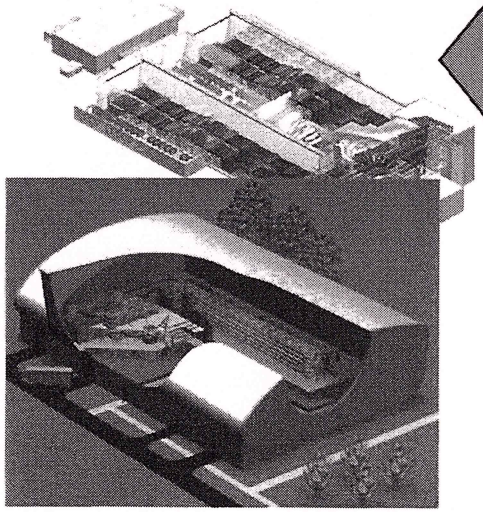
UGT Data



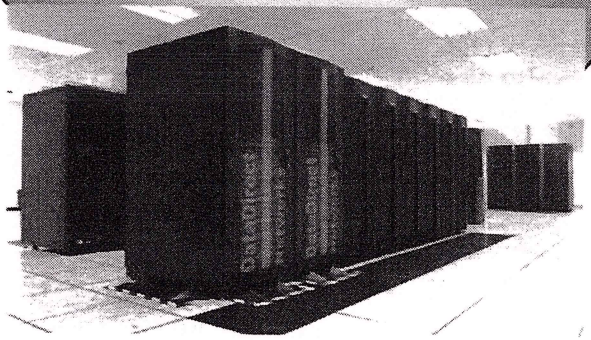


Material Data

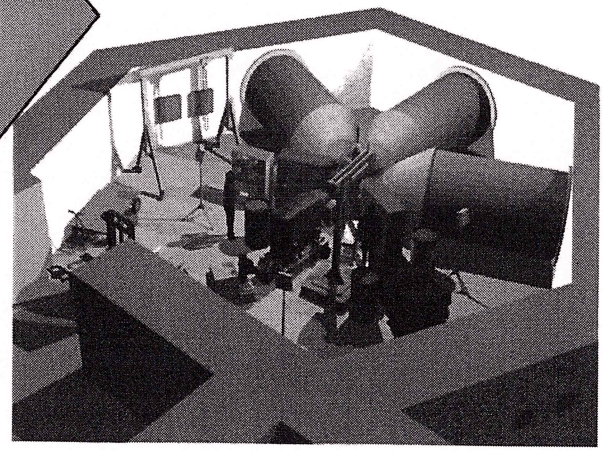
Physics Designers
Baseline models



Plasma Physics



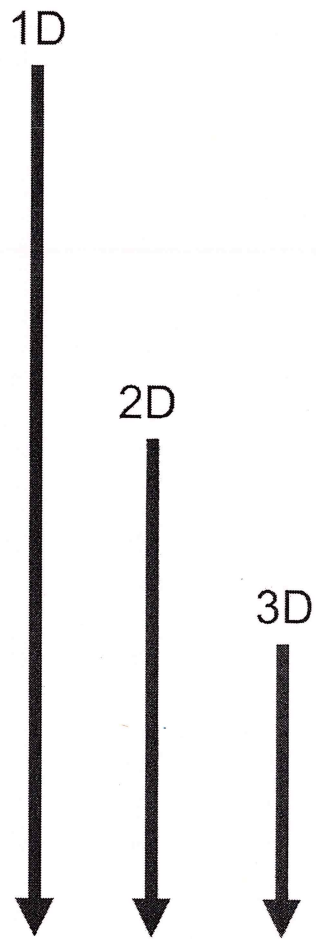
HPC



Hydrodynamics

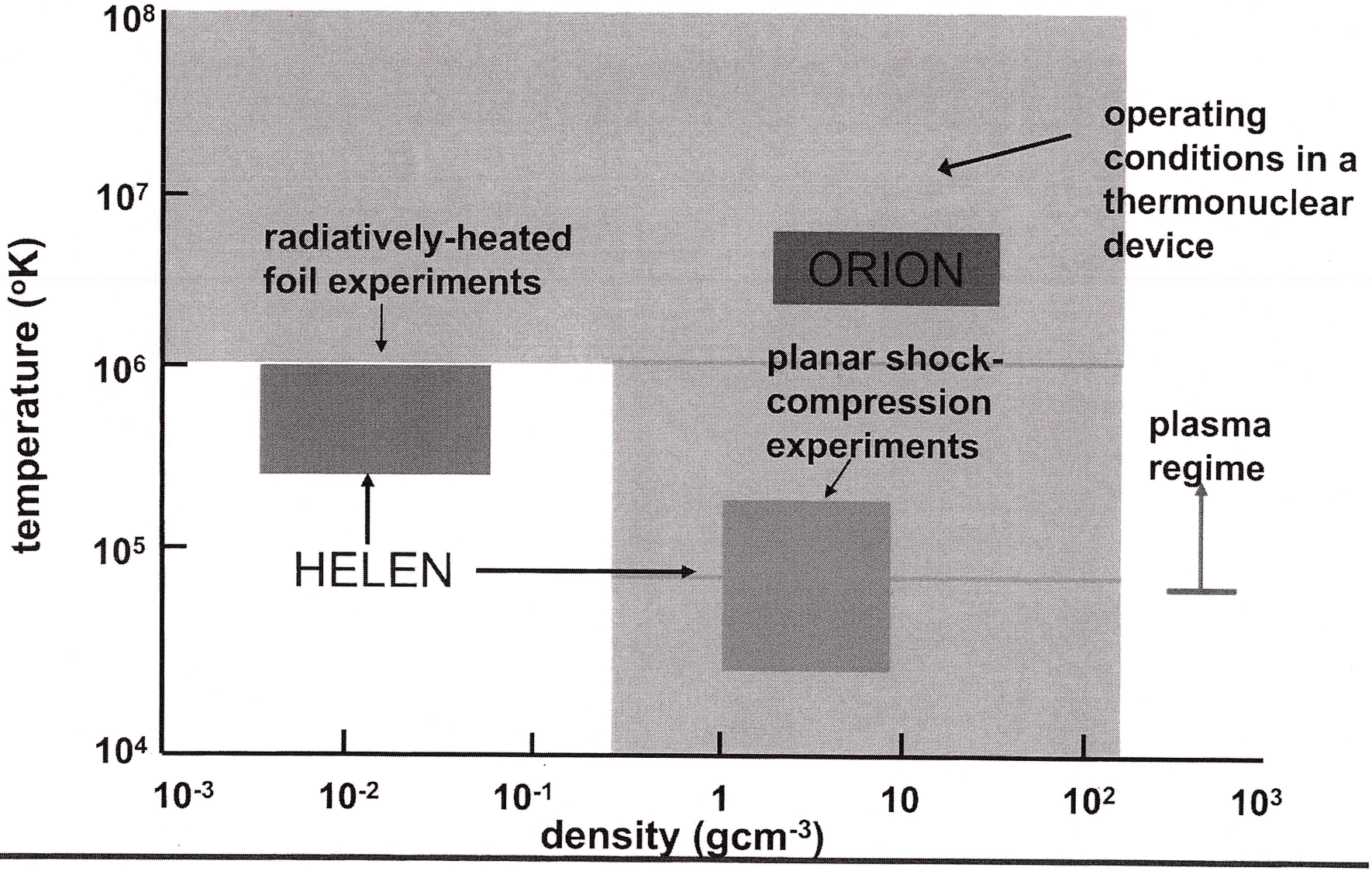
HPC development at AWE

Machine	Year	Peak Ops/s	Jump
Ferranti Mark 1*	1954	400	
English Electric Deuce	1955	500	1.3
IBM 704	1957	5,900	11.8
IBM 7090	1960	42,000	7.1
IBM 7039 Stretch	1962	150,000	3.6
IBM 60/75	1971	600,000	4.0
IBM 370/165	1972	1,500,000	2.5
IBM 370/168	1975	1,800,000	1.2
Cray 1A	1979	80,000,000	44.4
Cray X-MP-22	1984	444,444,444	5.6
Cray Y-MP 8/864	1990	2,666,666,666	6.0
Cray C98D	1995	8,000,000,000	3.0
IBM SP	1996	17,000,000,000	2.1
IBM SP (VINE)	1998	115,000,000,000	6.8
IBM SP (Blue Oak)	2002	2,880,000,000,000	25.0
Cray XT3 (Redwood)	2006	34,000,000,000,000	11.8
BullX B500 (Blackthorn)	2010	145,100,000,000,000	4.3

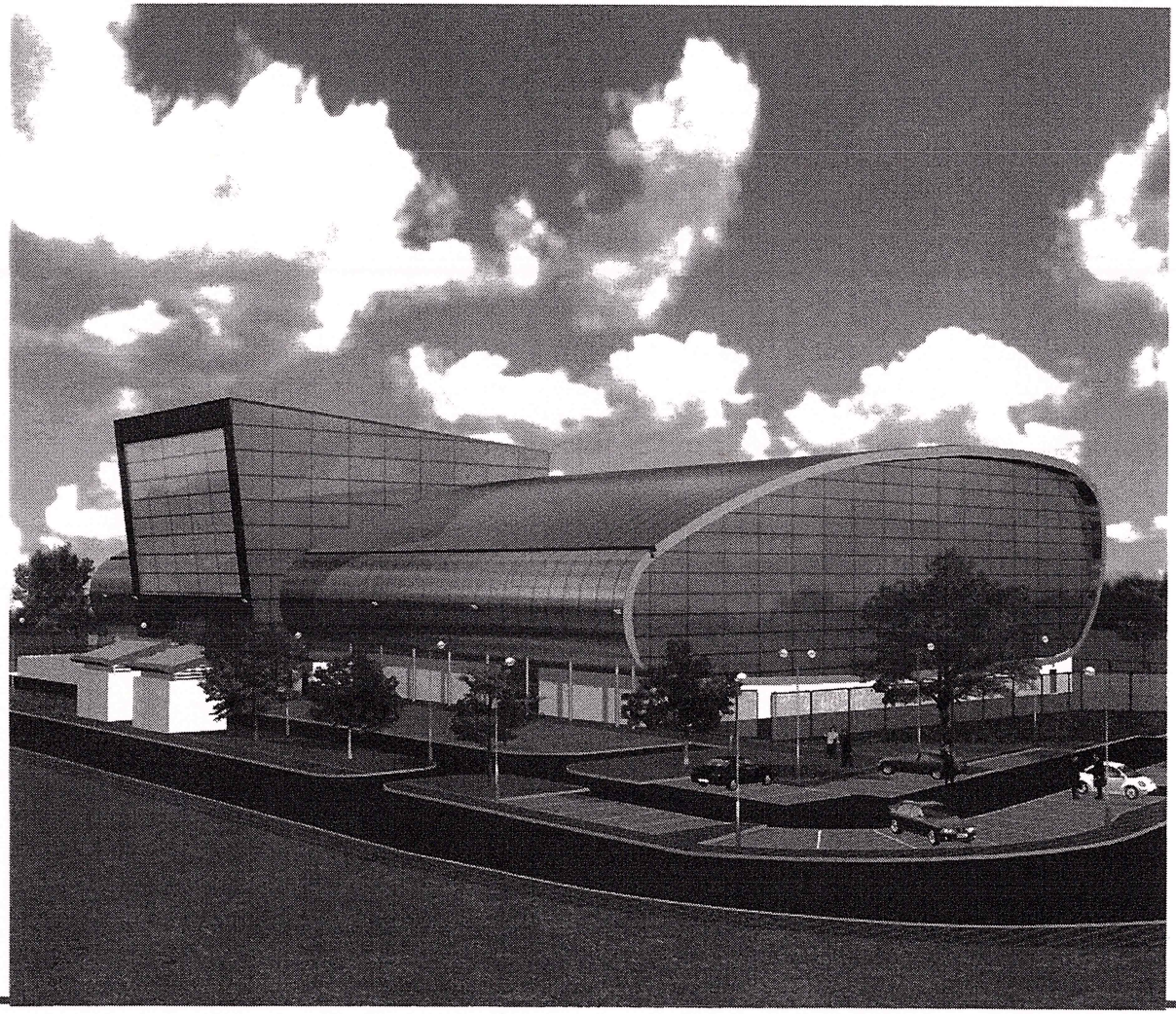


Future architectures?

Achievable conditions with ORION



Orion Laser Facility



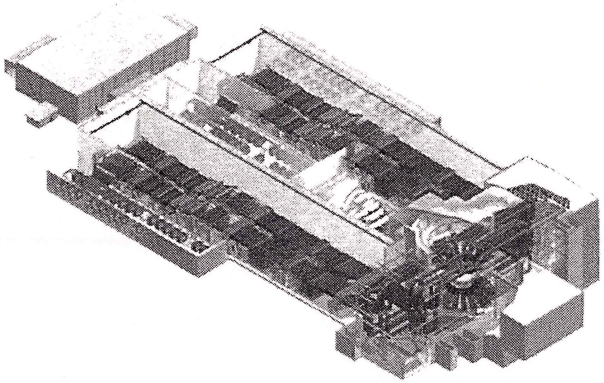
Initial Laser Specification

10 Long pulse beams - 300mm diameter, 500J per beam at 351nm in 1ns square pulse.
0.1-5ns arbitrary pulse shaping. Based on HELEN multi-pass design

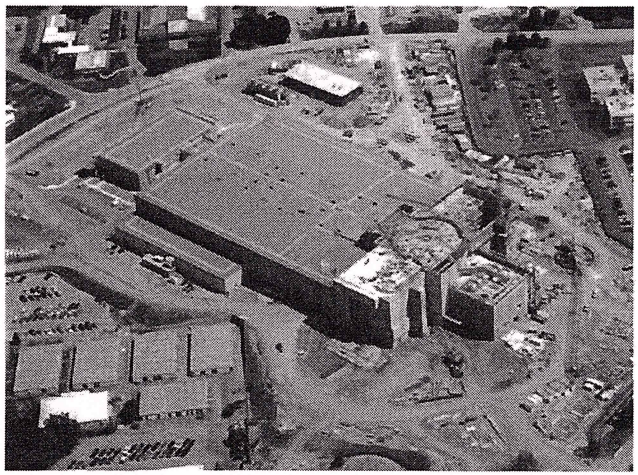
2 Short pulse beams - 600mm diameter, horizontal on-axis and orthogonal layout. 500J at 1053nm in 0.5ps pulse.
0.5-20ps pulse durations.
10^{21} Wcm^{-2} using f/3 off-axis focus parabola

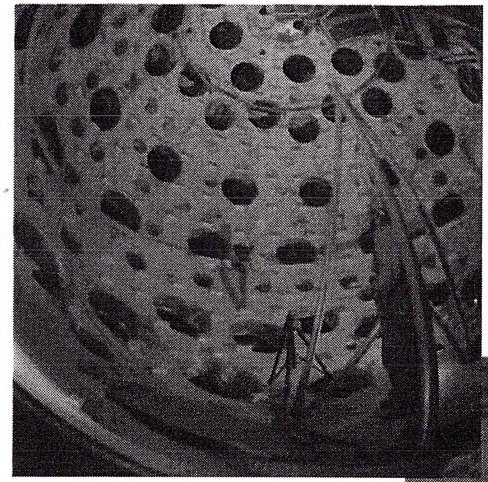
The National Ignition Facility

192 beams, ~2MJ, ~500TW laser facility at LLNL

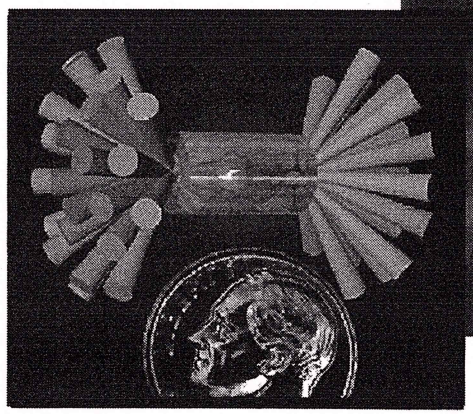


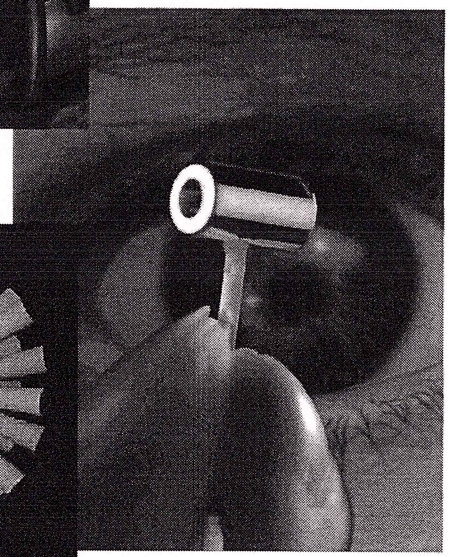
Construction site, April 2000





A 10m diameter vacuum chamber houses the 1cm hohlraum target





Recent technical progress

- 2D-full physics codes and baseline models mature
- Basic 3D capability in place, but needs further development and increased computer power
- Many ageing processes are well understood and assessed
- Some critical physics remains to be fully understood
- Design established for more powerful x-ray machine
- Orion nearing completion
- NIF a reality
- Important fissile sub-critical trials completed in [redacted]

Current assessment

- Trident stockpile performance and safety is being successfully underwritten without tests
  - Only possible because of investments in the science and the people over the past decade(s)
  - Stringent test of capability - limitations are being exposed in some areas
- Paths forward include further life extension, re-manufacture and at some stage potential replacement
- Each path is challenging and will test to the limits the scientific methodology being established
- In-depth peer review is a vital element of our confidence
- Continued vigilance is essential to
  - Monitor known issues
  - Look for the unexpected
- Continued investment in the science base and healthy international collaborations are both critical to maintain confidence in the deterrent