Project Orion: Journey to the hottest most dense place on earth

Chris Edwards, Orion sponsor, sheds light on the exciting project that will bring together the best in UK science and construction to create a laser facility at the leading edge of world capabilities...

In April 2005, the Ministry of Defence placed a contract for the construction of Orion, an ultra-high power laser facility, at the Atomic Weapons Establishment, Aldermaston. Orion will replace AWE's existing HELEN laser, generating matter at high energy density for experiments to support the science programme at AWE in the era of the Comprehensive Test Ban Treaty. The construction project is due for completion at the end of December 2010.

Introduction and historical perspective

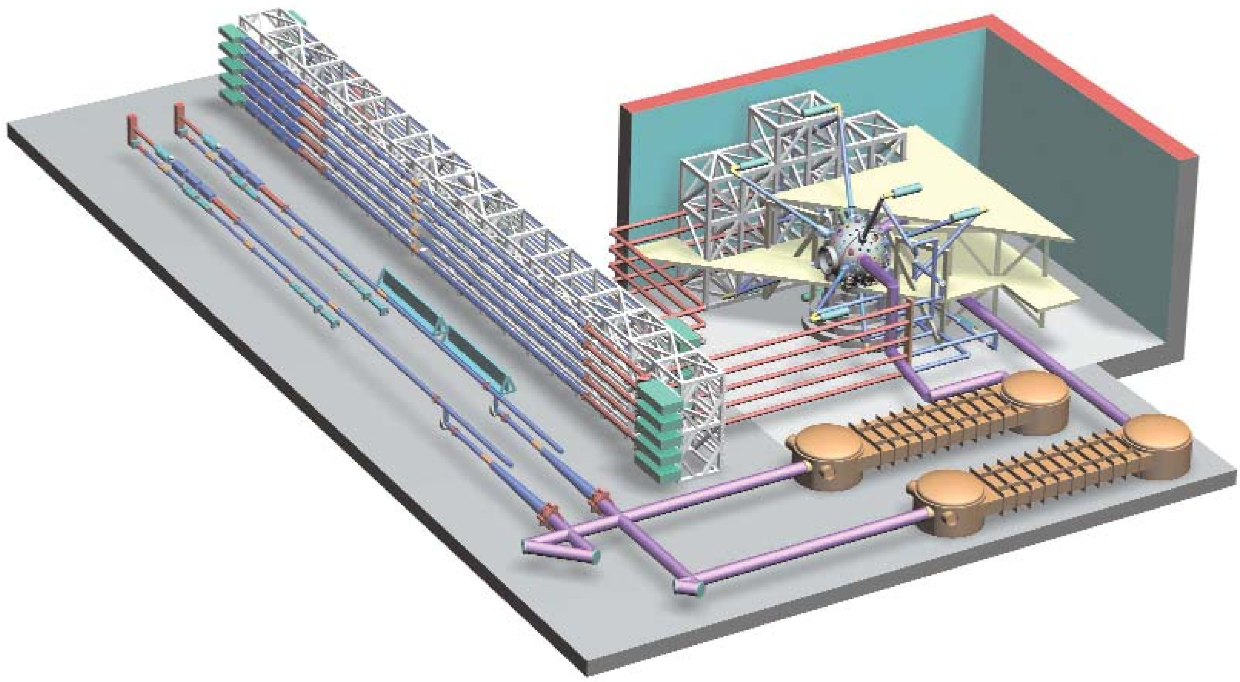
Orion is a large-scale, ultra-high power laser facility under construction for the Ministry of Defence at the Atomic Weapons Establishment (AWE), Aldermaston, near Reading, Berkshire. Due to become operational at the end of 2010, Orion's primary purpose is in support of underwriting the safety and reliability of the UK national nuclear deterrent. It will also provide the basis of essential interactions between AWE and other stakeholders, including the academic and scientific community.

In the Orion facility, laser light will be focused onto a microscopic target, which is compressed to high density by the pressure generated by the ablation of material from the target surface followed by heating to high temperature by absorption of the light energy.

Orion incorporates 10 'long pulse' beams for target compression and two 'short pulse' beams for target heating and diagnostics. Each long pulse beam will deliver up to 500J of ultraviolet light in a pulse of one nanosecond duration[1]. The short pulse beamlines will deliver 500J of infrared light in a pulse of 0.5 picosecond duration[2]. When focused, these beams produce a power density of 10^{21}W/cm^2 on target. By way of comparison, the power density delivered by the sun to the Sahara desert is 0.1 W/cm^2.

Measurements of the physical properties of the target material will be made while the temperature and density are at their highest using a range of state-of-the-art diagnostic techniques including X-radiography, optical probing, proton imaging and analysis of the particles and excited ion species emitted. Orion will be able to fire up to five shots per day during the course of normal operations.

High power lasers have been in use at AWE for nearly 30 years, providing experimental data on the physical proper-



Schematic representation of the Orion laser beamlines (left), pulse compression vacuum vessels (bottom right) and the four metre diameter target chamber (centre right)

View of the laser hall of AWE's existing laser, 'HELEN'

ties of matter under extreme conditions. This information is used to refine and test the computer models and simulations of the processes that occur in an operating nuclear warhead.

Orion: a new facility for a new era

Since the ratification of the Comprehensive Test Ban Treaty (CTBT) by the UK in 1996, confidence in the safety and operability of the stockpile and the capability to design new systems, should they be required, have relied increasingly on Above Ground Experiments (AGEX). Throughout the service lifetime of the UK's stockpile of nuclear warheads, changes occur in the composition of the component parts due to complex ageing processes, corrosion, etc. To increase the level of understanding of how this affects the behaviour of the stockpile using an AGEX methodology, it is necessary to make experimental measurements of the physical properties of materials in the extreme regimes of temperature and density that occur in an operating warhead. Orion is designed to make such measurements in this regime.

The contribution that a facility of Orion's capability would make to the UK's AGEX ability was identified in 2000. Working in partnership with the Defence Procurement Agency's Nuclear Weapons Integrated Project Team (NWIPT), and in consultation with experts in the academic community, AWE drew up an outline specification for Orion. Subsequent funding for a feasibility study enabled a full requirements capture phase followed by an outline design, preparation of three point estimates for cost and schedule and quantitative assessments of the associated risks. Throughout the process, AWE worked closely with NWIPT who commissioned the Pricing and Forecasting Group (PFG) to perform audits to ensure that the three point estimates and risk register were satisfactorily constructed. This close relationship with NWIPT is being maintained throughout the project delivery stages.

Provision of beamtime on Orion to academia is written into the mission of the new facility. There is a significant overlap between the physical processes that occur in an exploding warhead and in objects of more general scientific interest such as evolving stars, super-dense matter and high temperature systems. Orion is capable of supporting the broadest possible field of scientific exploration including particle acceleration, X-ray laser research, the production of short lived isotopes for medical applications and studies into advanced energy production schemes including fast ignition fusion.

Access to laser facilities at the leading edge of world capability plays an important part in helping UK universities to attract the highest calibre researchers and young scientists to the subject of high energy density physics. It is from this pool of expertise that future AWE scientists will be recruited and the vitality of the subject is very important to the sustainability of the deterrent programme.

Orion building

The Orion facility building will be approximately 100 metres long, 60 metres wide and 20 metres high. It incorporates the main laser bay and target area, which must be maintained to Class 10,000 cleanroom conditions, support laboratories, data processing and control rooms, office accommodation and meeting areas.

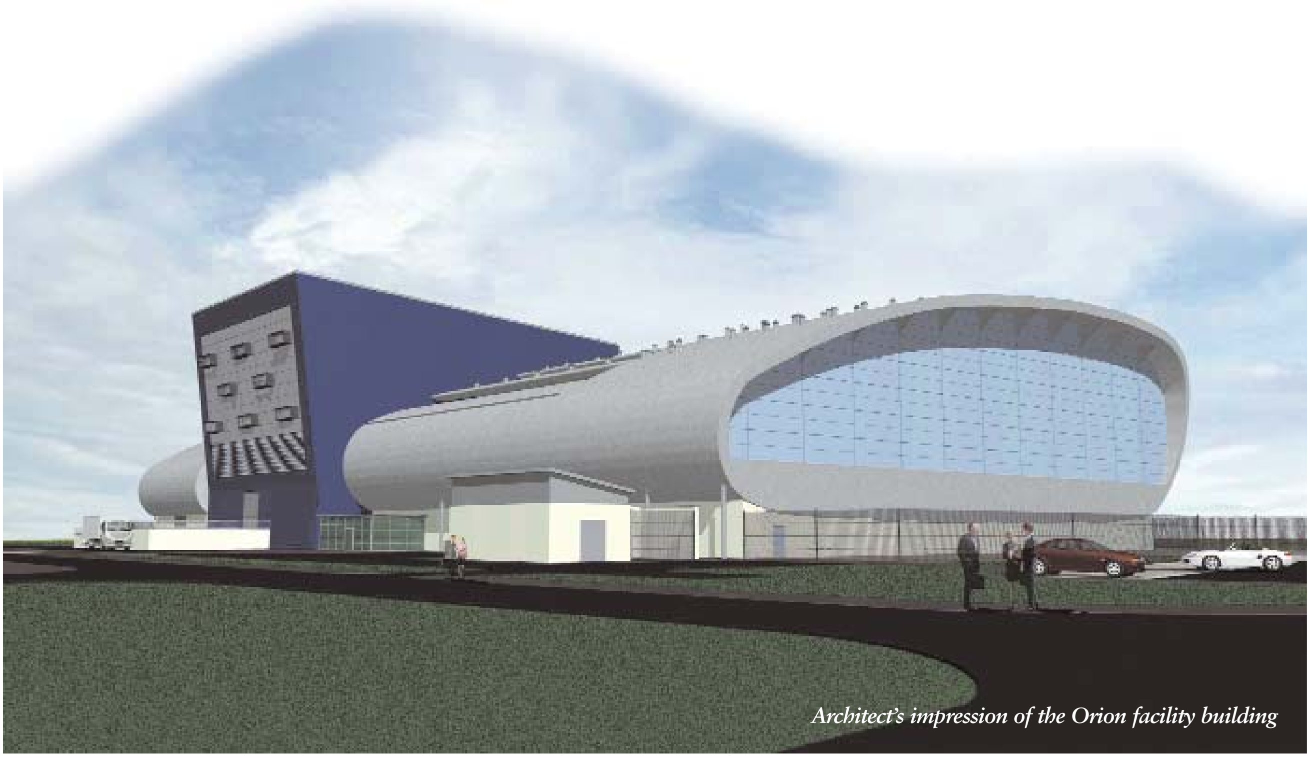
> *'High power lasers have been in use at AWE for nearly 30 years, providing experimental data on the physical properties of matter under extreme conditions.'*

Following competitive tendering, the contract for the construction of the Orion building was placed in June 2005.

The operational requirements of the facility place some unusually high demands upon the building design. For example, the floor of the building must behave as a high stability optical table upon which the laser components and associated hardware is mounted. The laser beams will be focused to an accuracy of five microns and this, in turn, puts a very tight tolerance on the displacement of the floor at key component location points. The foundations must provide isolation against ground borne vibration arising from traffic, for example, and from the effects of wind acting on the building. An extensive programme of numerical modelling has been undertaken to develop a design that performs as required. A further requirement upon the building is to provide suitable shielding from the electromagnetic and ionising radiation, which is emitted when the laser beams interact with the hot target. This shielding is provided in the form of 1.5 metre thick concrete walls, which ensure that the facility presents no radiation hazard to staff, visitors or members of the public.

Project delivery

A multi-disciplinary, co-located Integrated Project Team (IPT) has been established at AWE to deliver the Orion project. The IPT comprises scientists and engineers, project management and controls specialists, safety and assurance professionals, large-scale construction contractors, ATKINS



Architect's impression of the Orion facility building

administrative support, logistics and facility management. The team is drawn from across the company, from Jacobs Engineering in their role as strategic partner to AWE, and from AWE's major framework contractors.

Procurement of equipment and services is managed by a team of specialist buyers working within the Orion IPT. This arrangement facilitates collaboration and joint working between the project scientists, engineers and the commercial branch of AWE. Achievements to date include placement of the building contract, negotiation of the supply of Orion's laser glass and placement of contracts for the high voltage capacitor banks, the target chamber and the large aperture pulse compression optics on which Orion depends for the generation of its ultra-high power beams.

As with all projects at AWE, safety is of paramount importance during all stages of the project life-cycle from construction, through operations to the final decommissioning of the facility. A major contribution to safety derives from the management of the design process. This includes the adoption of the latest standards and regulations, specification of suitable materials, design decisions to facilitate safe construction operation and maintenance, and consideration of the need to decommission the facility at the end of its operational life.

Earned Value Management (EVM)

The Orion project will be the first major construction project at AWE to employ EVM as its performance monitoring and reporting tool. EVM is based upon a quantitative methodology that links cost and schedule through a fully resourced integrated baseline, reports performance against that baseline and controls change in a formal way. An Integrated Baseline Review (IBR), conducted by a panel of EVM specialists in March 2006, approved the Orion baseline, enabling EVM to be adopted as the primary tool for measuring performance.

Schedule to completion

Following site preparation early in 2006, piling operations commenced in June, with construction of the concrete ground slab and erection of the steel frame of the building scheduled for the end of the year.

Following the handover of the building, installation of the laser equipment and target hall systems will commence in 2008, with commissioning occurring in 2010. Completion of the project in December 2010 will be followed by handover of the facility to operations, at which point Orion's scientific mission can begin.

1 A nanosecond is one thousandth of a millionth of a second.

2 A picosecond is one millionth of a millionth of a second.

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