ARCADIS

National Satellite Test Facility

HARWELL, SOUTH OXFORDSHIRE, UNITED KINGDOM

Address:
Harwell Science & Innovation Campus, Didcot, OX11 0FA

Client:
Science and Technology Facilities Council, RAL Space

Principal Designer:
Robert Hall, Shane Aherne, Andrew Fursdon

Principal Contractor:
Mace

Design Team Partners:
Hoare Lea, Price & Myers

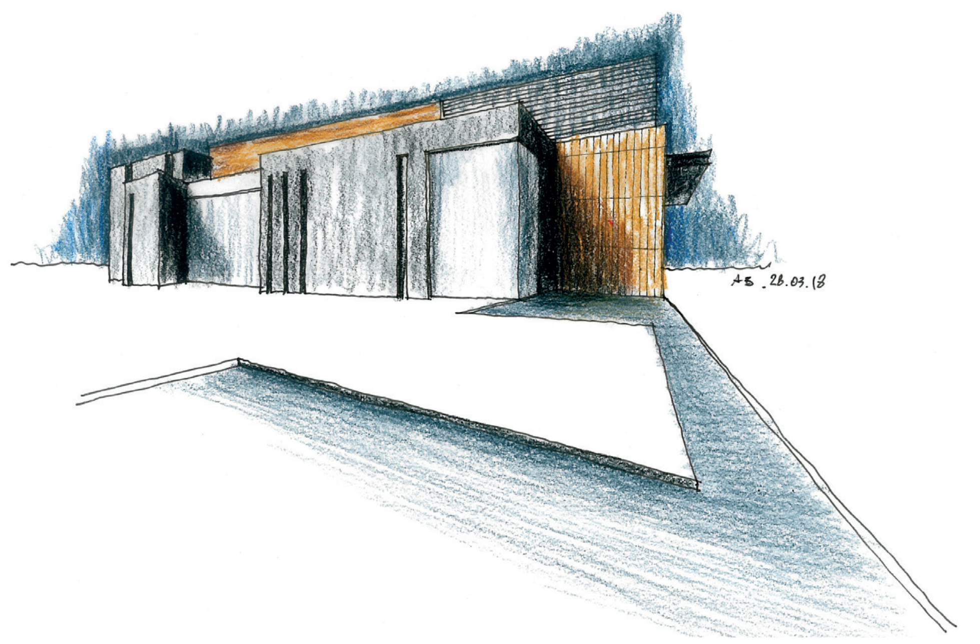
Start Date:
October 2017

Practical Completion:
January 2024

Summary

Located at the world-leading Harwell Science and Innovation Campus, the National Satellite Test Facility (NSTF), at over 8000m², is one of the largest satellite testing facilities in Europe, designed to replicate the extreme conditions in deep space. Its opening will allow UK companies to develop the next generation of large, complex satellites and test them on home soil, as well as access world-class co-located services at the campus.

The facility was developed in conjunction with RAL Space and their scientists to offer a truly unique satellite testing experience. Working through the technical challenges and understanding the processes involved in sending something into space, the building responds to streamline a complicated procedure to make the most efficient use of both testing time, and the vast resources required to properly assess whether a new design is suitable for travel out of Earth's atmosphere.



▲ *Early concept sketch of the National Satellite Test Facility*

▲ *Located in Oxford, on the world-leading Harwell Science and Innovation Campus*

Where previously testing and assembly required endless unboxing and repacking of multi-million-pound equipment, NSTF offers a technically complex, but in practice, beautifully seamless clean environment, allowing even the largest of satellites to be tested in multiple formats without the need for interruption.

Based along the frontage of Fermi Avenue, the new centre closely follows the palette of its adjacent sister building, the R100, extending the RAL space brand along the campus boulevard. The buildings facades have been crafted to exaggerate and externally convey the volumes of the individual testing chambers, each block containing a different exciting test function.

▲ *Large Thermal Vacuum Chamber - 98 tonne thermal vaccuum chamber*

> “UK satellite manufacturers will now have a state-of-the-art one-stop test facility on their doorstep with the capability to test very large satellites. The NSTF will also enable the UK to support major international efforts in fields including space exploration and Earth observation. This will enable the international space community to accelerate the development of next generation of space technologies and large-scale scientific missions.”
>
> **Professor Mark Thomson - Executive Chair of STFC**

Buildability and Assembly

The National Satellite Test Facility site stands on a site that was previously utilised by Magnox, who handle nuclear waste restoration services. As further waste is processed, more site area will become available directly adjacent to the current plot, so it was important for the design of the NSTF to allow for expansion in the future, not only to increase space at the facility but also to retrofit new technologies into the building. As such, the design of the building was modularised in terms of structural strategy, air pressure containment and its layout to offer opportunities to expand in future.

A cathedral-like central clean space with overhead cranes anchors the scheme. From this area, separate chambers radiate to form an upgradeable spine onto which new limbs can be grafted. Each chamber has an adjacent storage area and plant space above to service its technical requirements horizontally.

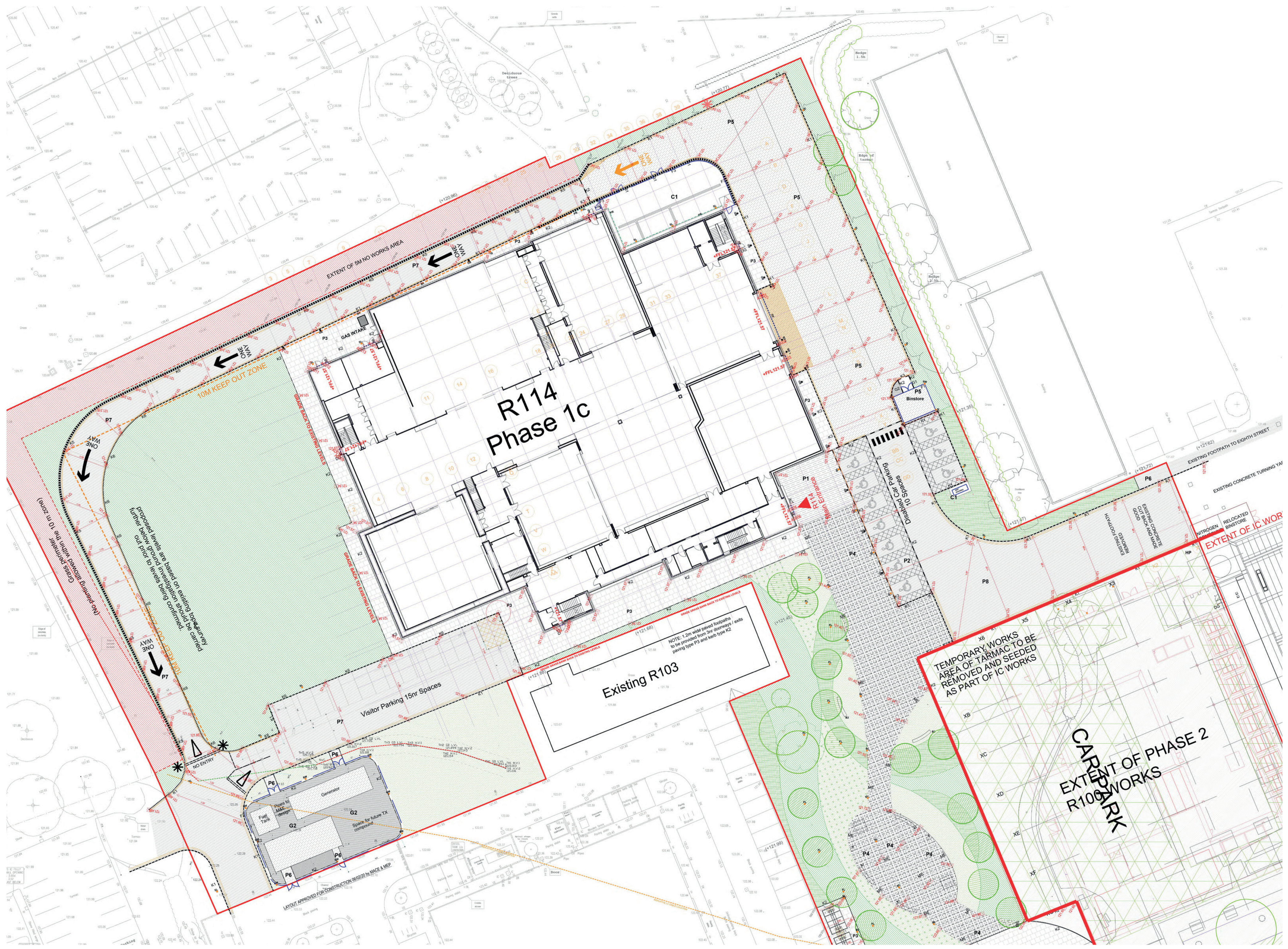
If more space is required, the end of the central spine has been fitted with pinned structural connections and removable stacking aluminium panels. This means testing can remain in operation until the perfect moment, at which point the modular wall can be disassembled and a further section of building with new chambers added. The template of chamber/storage/mechanical equipment gives a simple repeatable strategy, flexible enough to cope with future additions.

The structural shell of the building has been designed to form an exoskeleton, ensuring that each testing chamber can be individually closed off and remodeled when required and the unique requirements of each space can be individually serviced without full closure of the facility.

The core assembly of the building was also a technically challenging exercise due to its adjacency to the campus' Particle Accelerator. The accelerator is extremely sensitive and can feel the vibration of a lorry on the dual carriageway over a kilometre from the site. Therefore the design was required to minimise works which would disturb its experiments.

To reduce movements on site, the decision was made to create the building offsite in the form of a composite cross laminated timber and steelwork frame, with panellised aluminium cassette façade. This approach of offsite manufacture meant we could ensure site works were minimised and limit the number of heavy vehicles used in the delivery of raw materials to reduce disruption.

While disruption was carefully minimised on site, it was not the case for the roads while transporting the buildings vacuum chamber. At one of the largest single road movements in British history, this required the remodeling of Portsmouth docks and closure of the motorway to allow the 16m x 8m, 98-tonne chamber to be unloaded and delivered to Harwell. Once on site, the chamber was assembled and then slid into place via pinned structural elements into its final position within the building fabric with the façade then being slotted back into place around it once in situ.



▲ *NSTF reuses a previous nuclear material storage site*

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Functionality and Creativity

Functionally the building responds to the requirements of commercial satellite testing by offering a process-driven approach to its design.

In more standard satellite testing equipment is unpacked from hermetically sealed containers, tested and then returned to the confines of its container.

Through consultation with RAL Space's scientists, the decision was made to create a new process, whereby satellites could be unpacked at a single point at the start of their journey and then remain in a clean environment whilst they navigated the full gamut of testing.

A huge vehicle airlock with crane was devised to allow deliveries to be made directly into the heart of the building. Spaces are cleaned to an ISO 8 level, allowing satellites to be fully unpacked, and transported along the central spine of the building with the aid of overhead cranes to each testing chamber.

Each test chamber has its own unique set of requirements, many of which compete with each other, but had to be made to work harmoniously.

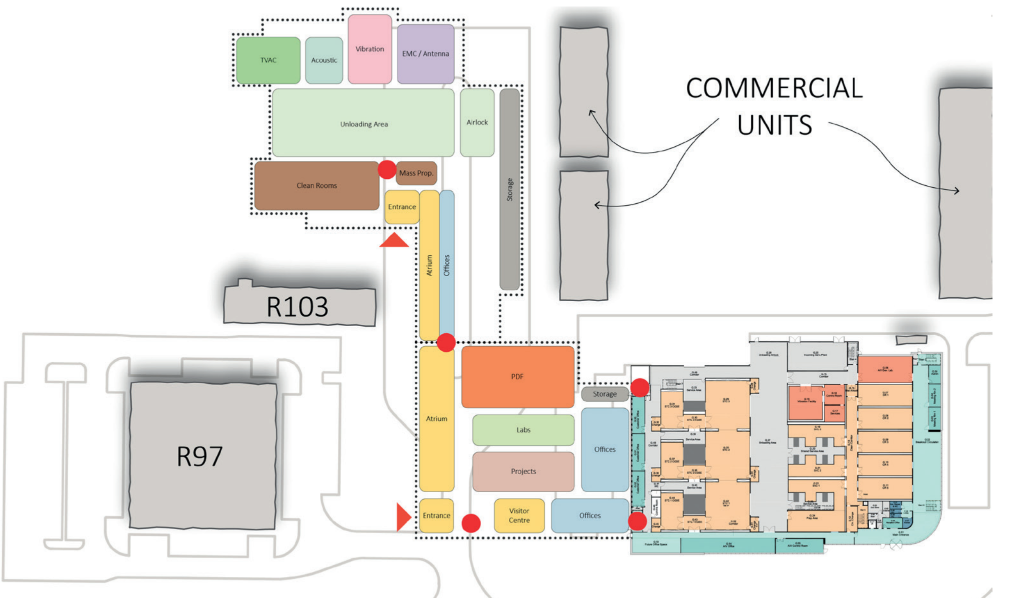
Chamber one is an ultra-clean ISO 6 rated cleanroom, 18m wide, 18m long with 14m high ceilings. The cumulative air leakage path for the room was required to be the size of a 20p piece. The chamber walls and ceiling had to be specially designed to minimise deflection at height, be detailed to seal airtight but still incorporate an enormous 12m high roller door for access.

Chamber two required full signal and electrical isolation from the outside world. The anechoic chamber required an 800 tonne fully isolated concrete floor to be constructed on a paper-thin sheet of copper, which was externally grounded via a ground mat the size of a tennis court. On top of this, a fully isolated panellised chamber was erected with every screw having to be detailed and installed precisely to the millimetre to avoid breaching the chambers isolated environment. This was supported with a hypoxic fire suppression system that depletes oxygen to prevent the high energy beams fired inside the chamber from making the acoustic cones attached to the wall spontaneously combust.

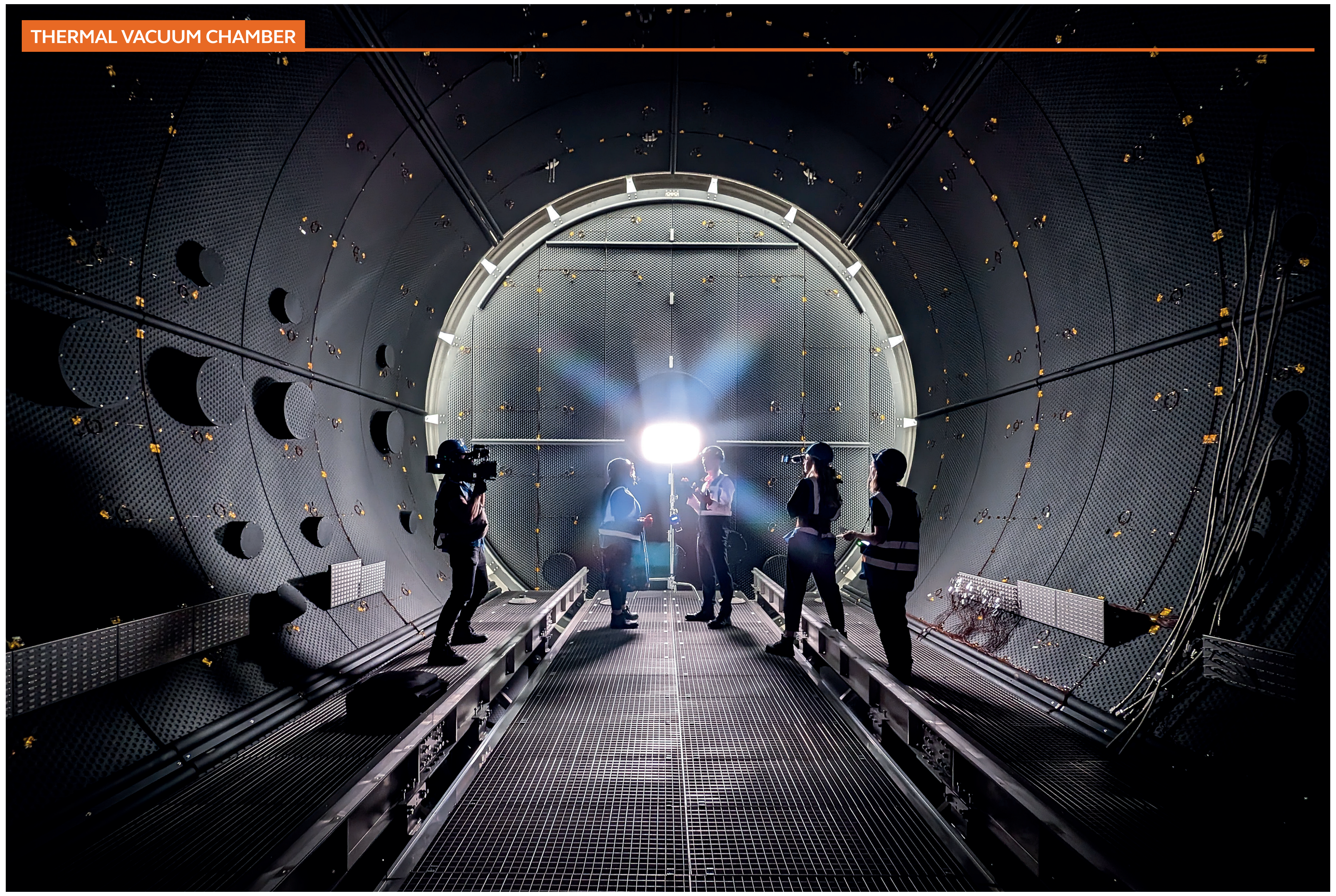
In Chamber three, equipment is subjected to being shaken on two custom made plates over twenty thousand times a second to simulate a rocket launch. The noise generated by the shaker plates is louder than a jet engine at full takeoff speed and as such the internal walls and facades had to be designed to dampen this sound energy and fully isolate the area during testing to prevent disturbance of neighbours and the other testing chambers. This required the installation of two 150 tonne isolated seismic blocks below the chambers to cancel out the power of the machinery and prevent the building being shaken to the ground, as well as a 50 tonne 12m tall acoustic sliding door to be inserted into the building's fabric.

If those tests were successful, the overhead cranes would deliver the satellites to the Thermal Vacuum chamber where they would be subjected to temperature ranges from -180oc to +100oc to simulate the cold atmosphere of space and the heat of the sun.

The chamber itself swells and cools over the course of these tests yet the envelope around it has to remain airtight due to its position as part of the cleanroom area walls.



▲ *Initial Bubble Diagram for NSTF with Campus Adjacencies*



▲ *Courtesy - BBC The Sky At Night - How the UK is keeping up in the new space race*

Additionally, there was the complexity of routing liquid nitrogen to cool the chamber and safely venting its byproducts. During testing, it can emit enough nitrogen to fill 70 million party balloons - enough for every person in the UK.

Creating a space where these competing requirements could be satisfied successfully ultimately resulted in an incredible increase in functional efficiency for those testing in the facility, saving time, movement and resources in the process.

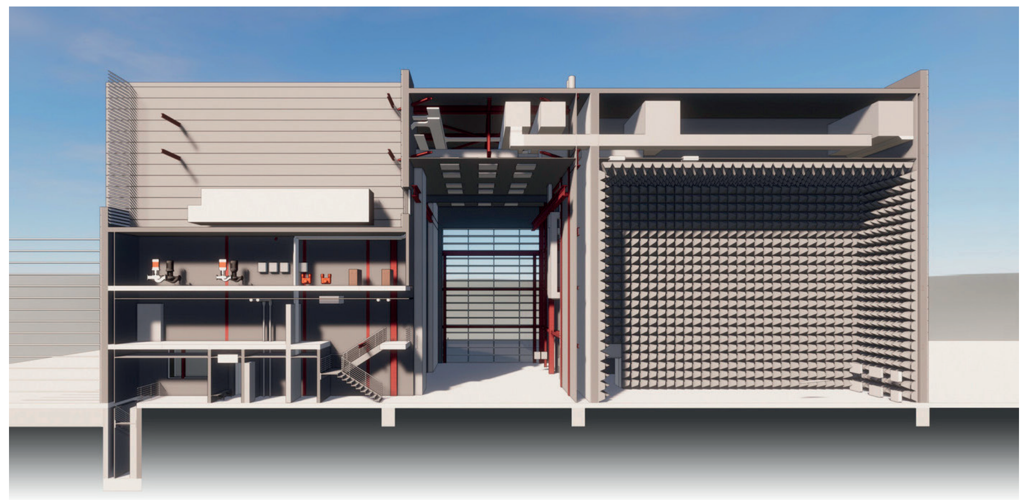
▲ *Satellite communication - Movement spine space*

Innovation and Sustainability

Almost every detail in the project required a level of innovation to satisfy the unique requirements of each space. One such innovation was the concrete dampers to the underside of the shaker tables. Weighing 150 tonnes each and sitting on hydraulic jacks that allowed them to be lifted and isolated from the building, the blocks needed to sit 5m below ground level, however on a vibration sensitive site with a programme that would not allow us the time between scheduled experiments to cast traditional concrete, the basement was created through a more innovative approach.

Instead of casing in situ, the team used a method of tunnelling utilised by Crossrail, but instead of operating horizontally the concrete lining rings would be build offsite, transported to Harwell and then inserted into the ground vertically. The ring sections being undermined to drop down until the required 5m was achieved. This approach allowed the creation of a perfectly circular basement around the dampers, while above the circle could be squared to form the testing chamber.

The main structure of the building was conceived as a hybrid of steel and cross laminated timber. The benefits were twofold; firstly the timber frame was much more carbon-friendly than traditional concrete slabs, and secondly its lightness meant that there was a reduction in requirements for the foundation size, saving both concrete pour, programme and environmental impact. Furthermore the 240mm external insulated panel construction with additional airtightness measures meant that the building is incredibly well sealed, which allows the mechanical ventilation system to work at an optimised level.



▲ *BIM Model - key coordination between multiple equipment suppliers was critical as testing equipment often formed part od the building's fabric*

Performance and Robustness

The performance of the building was an essential part of its function and success. As scientific spaces, the cleanroom chambers are highly environmentally controlled, having set temperature and humidity ranges that are painstakingly monitored via the extensive mechanical and electrical equipment housed on the spacious plant deck. This deck, formed from GRP grating, sits suspended above the cleanroom area ceiling and allows the passage of air from below where it is then treated and recycled into the chambers below.

The building and individual chambers within are also incredibly tightly air sealed to eliminate particle infiltration onto the lenses of satellites bound for space.

Construction tolerances were challenged at the very outset of the project. The scientists at RAL Space work to tolerances of 1.5 nanometres RA, or in simpler terms, the amount your fingernail has grown whilst reading this sentence! Hence, construction tolerances were decreased to single digits throughout to ensure total performance of the scientific spaces.

This attention to detail extended to all construction elements meaning the design and detailing, from drywalling to damp proofing, were created to minimal tolerances ensuring performance and longevity.

The design also had to withstand the rigours of use. Satellites up to the size of a minibus will be routinely hoisted over 5 metres into the air to be fitted onto experiment rigs and will also be rolled through the building. Every chamber surface had to be at minimum surface regularity of SR1 or above to allow airskates to function and equipment to pirouette with ease. The concourse floors themselves are high specification resin, and despite their glass-like appearance, they are designed to accommodate impact from both dropped tools and satellites over their lifetime.

The building was truly designed to meet the highest standards of robustness and overall performance in what is an industry of extreme tolerances and demands.

▲ *Vibration chamber - Isover insulation delivery*