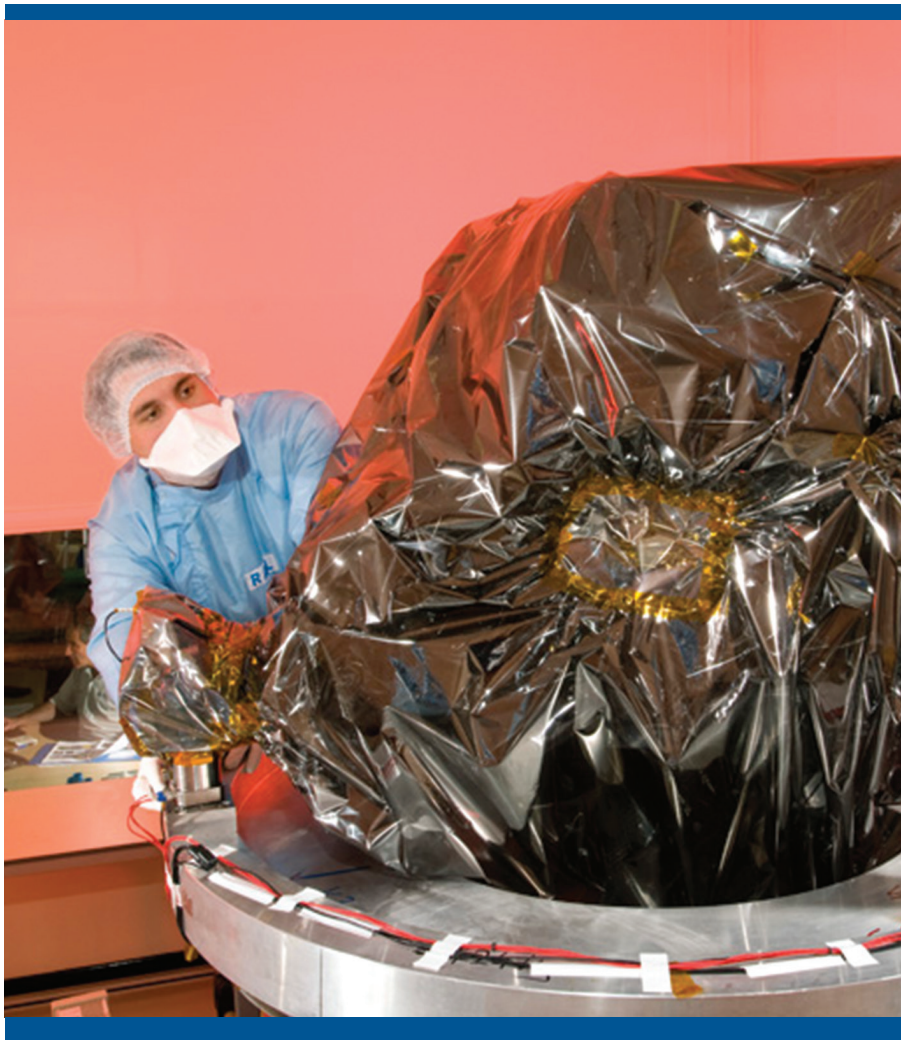


ENSURING SATELLITE RELIABILITY AT RAL SPACE WITH VIBRATION TESTS

RAL Space's contribution to the new James Webb Space Telescope faced design and development timeframes that demanded 'right first time' engineering. High quality vibration testing is critical to assuring the structural quality of satellites, and since test objects were consistently increasing in size, RAL Space required a new vibration test system.



CHALLENGE

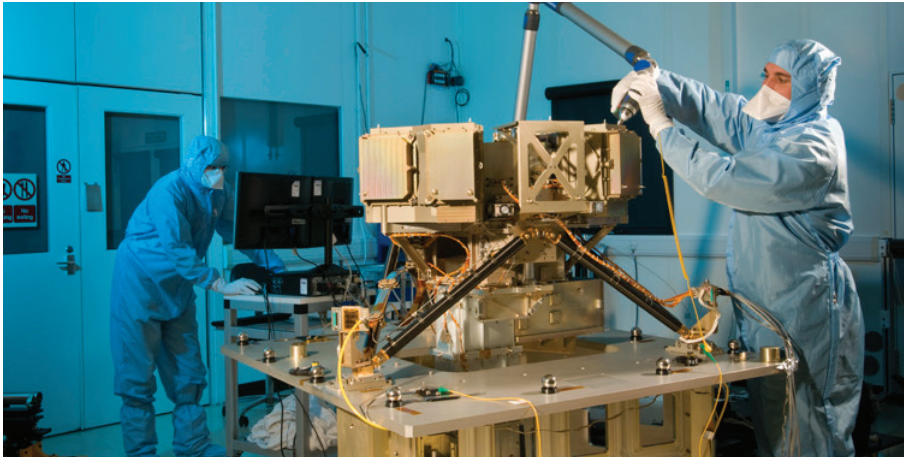
Precise vibration testing to ensure the structural integrity of satellite components during the stresses of rocket launch

SOLUTION

A complete vibration test system with a slip table and custom mounts for securing fragile test objects

RESULTS

Accurate and safe testing performed to precise levels inside a strict test schedule prior to launch



Technicians at work on MIRI (Mid InfraRed Instrument). One of the four instruments in the JWST, MIRI contains both a mid-IR camera and an imaging spectrometer
 Photo: RAL Space / STFC / Stephen Kill

BACKGROUND

RAL Space (Rutherford Appleton Laboratory) is part of the UK's Science and Technology Facilities Council, and has around 200 staff who provide world-leading space research and technology development for customers around the world. They offer space test and ground-based facilities, design and build instruments, analyse and process data, and operate ground-station facilities, as well as leading conceptual studies for future missions.

The James Webb Space Telescope (JWST) is due to be launched in 2018 as the scientific successor to the venerable Hubble Space Telescope. JWST is a NASA project with international collaboration from the European Space Agency and the Canadian Space Agency, and

includes contributions from fifteen nations. RAL Space's main involvement has been the design qualification and acceptance testing of MIRI, a mid infra-red camera and imaging spectrometer developed in Europe, which will be one of the four main instruments carried by the JWST.

CHALLENGE

JWST is a fragile mass of technology that must endure being stowed as the 6-tonne payload of a launch vehicle. The satellite and its components (such as MIRI) must endure the noise and subsequent vibration of the ~145 dB interaction between the rocket engines and launch-pad environment, the jarring transonic climb phase, pyroshock as stages separate, and turbulent boundary layer excitation. These launch forces can induce fatigue in resilient metal structures – not to mention the sensitive electrical and optical components of instruments like MIRI.

Consequently, the space industry has the most demanding requirements for vibration testing anywhere in the world. Given the fact that a damaged satellite cannot easily be repaired once it has been deployed, thorough testing is of fundamental importance before the violent ride into orbit.

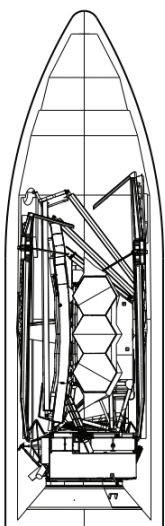
Protecting the multi-million Euro investment in the JWST project, vibration testing establishes the make-or-break robustness of components, subsystems and ultimately the fully assembled

craft. Depending on the stage of a project, different testing regimes are adopted.

To begin with, two identical versions of the test object are made, a structural model and a flight model. The first will never fly, but will instead be tested rigorously, and then the second – the flight model – will be tested just enough to qualify the assumption that it is equally resilient.

Design qualification tests

These are usually carried out on the structural model during the development phase, in order to demonstrate that the design enables the equipment to withstand the vibration level



JWST shown in its launch configuration, identifiable by the hexagonal mirrors. The resilience of components is most critical in this situation
 Image: NASA

RAL Space

RAL Space has been involved in over 150 missions in recent years, including the ground-breaking SOHO and STEREO solar missions, the Earth Remote-Sensing missions ERS-1, ERS-2 and ENVISAT, and solar system missions such as the Rosetta cometary lander, and the Cassini/Huygens mission to Saturn and its moon, Titan.

Much of its work is done in collaboration with UK university research groups and a range of institutes around the world, mostly to support European Space Agency and NASA missions.

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Senior Engineer, Paul Eccleston

it will see during launch, plus a qualification margin. In some cases they even test objects to complete destruction. In the words of Senior Engineer Paul Eccleston, “You never actually learn anything about an object unless you break it. All you would know is that you are still within its safety margins. To find out where they are you have got to deliberately break things, so occasionally that is what we will do on development models.”

The tests also allow verification of the satellite’s mathematical model by measuring motion at the resonant frequencies at which elements of the satellite’s structure are prone to amplify the vibrations.

Acceptance tests

These are performed on the flight model in order to verify workmanship and ensure that the

equipment does indeed operate satisfactorily in its final configuration, and will not degrade when subjected to the vibrations encountered during launch. Naturally, this is a critical test period.

According to Paul Eccleston, “When you are actually testing flight hardware – the stuff that is going to go up there – then it is a little nerve-wracking. Of course you have got high confidence that everything is going to be okay, but there is always that slight nervousness, in case it is not.”

Clearly, reliability of the test equipment is of paramount concern here, as causing a failure through accidental overloading of the test object would be catastrophic. This is balanced, however, with the high demand placed on the testing facilities, where time is of the essence.

MIRI

One of the four main instruments on the JWST, MIRI contains both a mid-infrared camera and an imaging spectrometer. The mid-infrared wavelength range is from 5 to 27 micrometers. Developed as a collaboration between NASA and a consortium of European countries, MIRI will assist:

- Discovery of the ‘first light’
- Assembly of galaxies: history of star formation, growth of black holes, production of heavy elements
- How stars and planetary systems form
- Evolution of planetary systems and conditions for life

Fast setup and rigorous adherence to schedules are very important considerations.

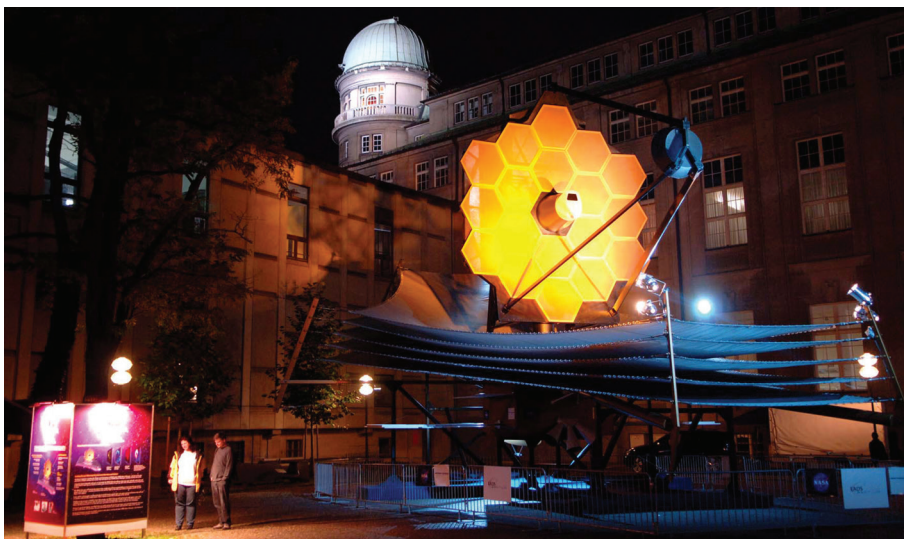
SOLUTION

In 2010, RAL Space decided to replace its existing LDS V954 Vibration System with a more powerful and flexible one to meet its increased testing needs. Their older V954 had served them well, but with increasing payload masses and more severe tests required, RAL Space needed to improve their capabilities.

The new solution provides the increased capacity necessary for modern test programmes, and is based on the LDS V8 electrodynamic shaker, which has the ability to operate in horizontal or vertical orientation. An integral slip table measuring 1200 mm x 1200 mm is coupled to the shaker as necessary, allowing large objects to be mounted securely. The slip table has nine, high-pressure hydrostatic bearings arranged on a 3 x 3 matrix. This configuration provides for maximum overturning restraint for devices under test with a high

A full-scale model of the JWST. The model is constructed mainly of aluminum and steel, weighs 5443 Kilograms, and is approximately 25 metres long, 12 metres wide and 12 metres tall.

Photo: EADS Astrium



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centre of gravity. They also have an additional, interchangeable 750 mm x 750 mm slip table for high acceleration testing.

The amplifier – a 56kVA class ‘D’ switching amplifier – is forced-air cooled and incorporates an integral DC field power supply, which is required for the shaker field coils. The shaker is also forced-air cooled and relies on a fixed blower device to pass air through the shaker for efficient cooling during operation.

The shaker cooling fan includes an all-weather acoustic enclosure that allows it to be located adjacent to the vibration laboratory, in order to separate the shaker cooling air from the ambient air in the laboratory. This is an important measure to maintain the integrity of the cleanroom environment and conditioned air. This is achieved with a sealed upper-air plenum and associated hoses to enable cooling air to be drawn from, and exhausted to, the atmosphere outside the laboratory.

The PC used for vibration test control is loaded with a software-based remote control kit that can:

- Switch the amplifier on and off remotely
- Set the amplifier gain remotely
- Remotely monitor interlocks
- Monitor armature and field coil voltage and current

When specifying the guided load support platform, RAL Space had the MIRI in mind, but also had an eye to testing large, heavy structures in future. This can be removed from the shaker and set aside when not required, and provides additional load support, and cross-axial and rotational restraint.

Brüel & Kjær supplied a set of bespoke fixture blocks to enable the MIRI to be attached to the vibration system without the need for complex and heavy attachment fixtures. This allows testing of the MIRI on its feet, using three mounts to keep it securely upright.

CONCLUSION

Choosing to replace their LDS shaker with another, more modern one was a sure vote of confidence in the brand, from a customer whose reliability concerns are among the most discerning in the world. And with an extremely tight margin for error in their final product, and potentially disastrous consequences from the slightest testing problem, it is easy to see why. Balancing time constraints and quality is always a dilemma, meaning right-the-first-time engineering is absolutely critical for RAL Space.

RAL Space's V8 Shaker with MIRI Structural Model mounted on the guided load support platform

The James Webb Space Telescope

The scientific successor to the venerable Hubble Space Telescope, the JWST's ten-year mission is to find and study the first luminous objects, the assembly of galaxies, the birth of stars, the birth of planetary systems, and the origins of life.

Unlike the Hubble Space Telescope, the JWST will not be in low-Earth orbit, but will be parked at the “semi-stable second Lagrange point”, or L2. This Earth–Sun L2 point is 1,500,000 kilometres (930,000 mi) from the Earth, or nearly four times farther than the Earth is from the Moon. At such a great distance, the Webb telescope will be considerably more difficult to service after launch than the Hubble telescope.

From JWST's point of view, the Sun will always be behind the Earth, reducing the harsh effects of solar radiation.



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