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High-Altitude Simulation Test Facility P4

DLR site Lampoldshausen

Brief description

The P4 test facility was built between 1963 and 1966 and has been modified and extended several times since then. The attached altitude simulation facility enables the entire flight phase of an upper stage engine to be tested under space conditions. The P4 test facility is unique in Europe and also a milestone worldwide for engine testing in a vacuum.

Goals

- Examination of upper stage engines for their ignition behaviour in vacuum, analysis of the thermal load on the structures and measurement of the vacuum thrust with fully developed nozzle flow.
- Carrying out development, qualification and acceptance tests on upper stage engines.

Involved

European Space Agency ESA

Applications

- Development and qualification campaigns of the Vinci® upper stage engine for the Ariane launcher since 2005
- Qualification and flight acceptance tests of the Aestus upper stage engine for transporting the ATV to the ISS or the Galileo satellites

Perspektives

- Vinci® engine campaigns: Flight support tests
- AESTUS "Ariane Research and Technology Accompaniment" (ARTA) campaign: competence development on engine and propellants
- Further tests and development of upper stage engines

Facts and Figures

P4.1
Liquid hydrogen: 135 m3 at -253 °C
Liquid oxygen: 50 m3 at -183 °C
Vinci® burning time: 820 s
P4.2
Monomethylhydrazine: 1,400 litres at 20 °C
Nitrous oxide: 1,400 litres at 20 °C
AESTUS burning time: 300 s
P4 Steam generator
Fuels: alcohol/liquid oxygen
Thermal power: 650 MW

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After stage separation, engines in rocket upper stages are operated under vacuum conditions such as those prevailing outside the earth's atmosphere. The absence of atmosphere influences thermodynamic and physical properties, especially ignition behaviour in the combustion chamber and thrust development in the nozzle. Furthermore, the heat transfer to engine components changes in space due to the lack of convection. For these reasons, it is necessary to simulate the environmental conditions during the flight phase of the engine as realistically as possible, even during tests on the ground.

The greatest challenge here is to maintain the low vacuum pressure of around 5 millibars in the system while the engine is emitting large amounts of exhaust gas. This is achieved by harnessing the energy of the exhaust jet: the supersonic flow exiting the nozzle is slowed down and recompressed by a diffuser. This is followed by extraction via steam jet ejector stages and condensation of the exhaust gases.

In addition to the simulation of space conditions, which makes the P4 test stand an extremely complex test facility, the simulation of the carrier system is the main task of the test stand. Here, too, great importance was attached to reproducing the Ariane upper stage as realistically as possible. On the P4.1, this includes not only the supply of the Vinci® engine with propellant (liquid hydrogen), oxidiser (liquid oxygen) and auxiliary gases (helium, nitrogen), but also the necessary measurement and control technology. Sub-systems of the stage, such as thrust vector control, pogo suppression and control pressure supply via onboard systems, were also retrofitted over the development period.

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