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Europe’s new upper-stage engine reaches an important milestone - DLR tests its long expansion nozzle for the first time

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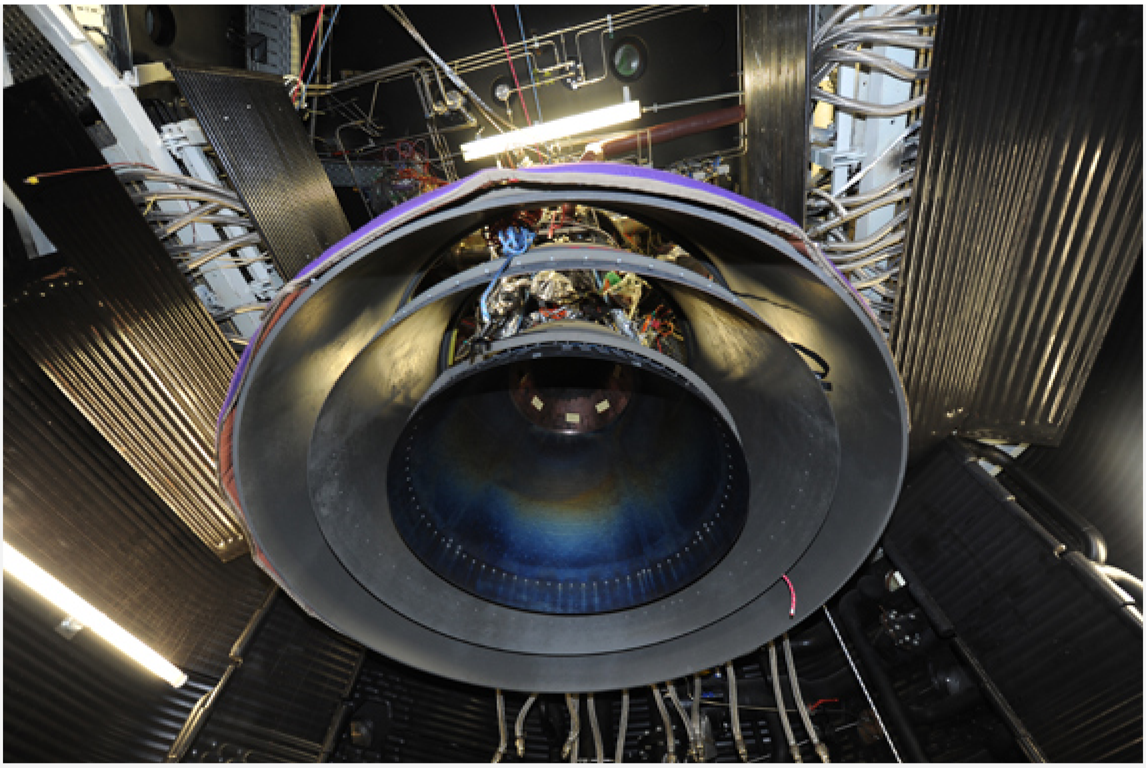
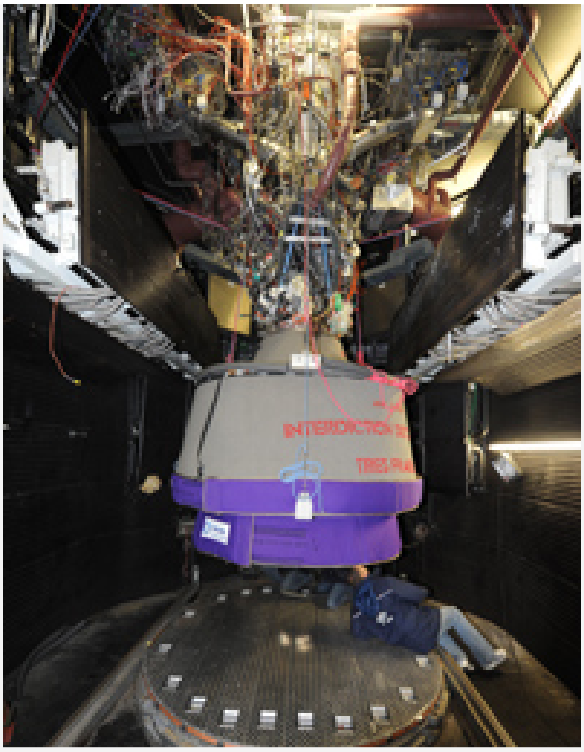


The expansion nozzle of the Vinci engine consists of three parts

The development of the Vinci engine reached a significant milestone on Tuesday, 9 November 2010, as the the long expansion nozzle was assembled and the first hot run performed. The team at the German Aerospace Center (Deutsches Zentrum für Luft- und Raumfahrt; DLR) facility in Lampoldshausen tested the Vinci engine with its complete, extendable expansion nozzle for the first time. The test was conducted at the European Space Agency's (ESA) altitude-simulation test stand P4.1, on behalf of the French engine manufacturer Snecma. The nozzle was manufactured by the French company Snecma Propulsion Solide (SPS). The main objective of this trial was a detailed examination of the behaviour of the long expansion nozzle, especially during the ignition and shutdown phases, as well as a test of the performance of the entire engine at various combustion chamber pressures and fuel mixture ratios during the combustion phase.

Vinci engine in its flight configuration – checking the engine and the test stand



Installation of the Vinci expansion nozzle

Extensive preparations took place at the altitude-simulation test stand prior to this initial test of the Vinci engine in its flight configuration. It took several days to install the almost three-metre long expansion nozzle, which consists of three parts. In addition, the researchers at the DLR Institute of Space Propulsion attached numerous sensors to the engine and the nozzle. During the trial, these sensors delivered large quantities of data, which was recorded by a computerised measurement system. Valuable insights were gained by using DLR's optical diagnostics equipment. Now, the engine manufacturer Snecma and the nozzle manufacturer SPS, can use this data to verify and refine or extend the theoretical calculations and predictions made prior to the test. This new data is also very important for the designers of the test stand itself: "The design of test stand P4.1 relies so extensively on the requirements of the long expansion nozzle that this experimental configuration offered an opportunity to verify the design for first time during the multi-year implementation process," says Klaus Schäfer, Engineering Manager at the DLR Institute for Space Propulsion.

Everything can be seen

The DLR test team used cameras in the vacuum chamber to carefully observe the behaviour of the engine during the trial. "It was exciting to watch how the ceramic-carbon composite nozzle glowed yellow immediately after ignition," said Lars Ohlenmacher, the test manager responsible for test stand P4.1. The expansion nozzle quickly reached a temperature of over 1300 degrees Celsius. The heat is radiated into the surrounding environment so, to cope with this, the interior of the vacuum chamber is lined with a water-cooled shield.

More expansion nozzle trials are planned, which will incorporate the deployment mechanism that will be used as part of the stage separation process during flight.

The Vinci engine with its long expansion nozzle in the vacuum chamber of the ESA test stand P4.1

Expansion nozzle - a key component

The Vinci expansion nozzle is made from a carbon-fibre ceramic composite known as Sepcarb® and consists of three parts, referred to as cones A, B and C — quasi-concentric rings that can be extended telescopically. When the launch vehicle lifts off, cone A is connected to the upper-stage engine, while cones B and C are stacked as one unit over the engine. Once the lower stage has separated, this unit is moved down and locks into cone A, forming the complete expansion nozzle; the engine is then ignited. This mechanism has crucial advantages. With a length of around 10 metres, the new upper stage is taller than the previous model. The deployable nozzle allows a reduction in the overall height of the upper stage and thereby reduces its structural mass. The Vinci engine design therefore enables the launcher's payload mass to be increased.

The main purpose of the expansion nozzle is to convert the thermal energy created in the combustion chamber by the release of the chemical energy stored in the propellants into kinetic energy and, subsequently, thrust. The hot combustion gas, or exhaust, produced in the combustion chamber, is at a high pressure. In the converging part of the nozzle, the exhaust gas is accelerated, reaching the speed of sound (Mach 1) at the smallest cross section, or throat. The gas then expands in the diverging part of the nozzle and accelerates to many times the speed of sound. The higher the exit velocity of the exhaust gas, the greater the thrust from the engine. The thrust is optimal when the exhaust gas expands to match the ambient pressure at the nozzle exit. For an upper-stage engine, which operates in the vacuum of space, this ambient pressure is zero. Because of this, its expansion nozzle needs to be longer and have a larger ratio between the exit cross-section and the throat cross-section than main stage engines, which begin their operations under surface conditions, with an ambient exit pressure of one bar.

Ariane 5 ME

Last December, ESA commissioned Astrium to undertake the first development phase of the Ariane 5 ME (Midlife Evolution) launcher. Astrium Space Transportation is developing a new upper stage for this more advanced and competitive launch system, which will be equipped with Snecma's re-ignitable Vinci engine. Ariane 5 ME is expected to enter service around 2017.

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