Vulcain-2 Cryogenic Engine Passes First Test with New Nozzle Extension

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On 17 August 1999, at the P5 test rig in Lampoldshausen, Germany, the new Vulcain-2 engine for Ariane-5 was tested as a complete configuration equipped with a new nozzle extension. Two previous tests had been performed with a short nozzle configuration: the first, on 17 June, lasted 7 sec and allowed the engine to reach stable operation conditions, thereby qualifying the starting sequence; the second, on 25 June lasted a total of 600 sec, as foreseen. By the end of the year, the Vulcain-2 engine had accumulated 1878 sec of running, shared between two engines and 14 tests.

Vulcain-2 is being developed by SNECMA (F), leading a team of manufacturers from 11 European countries. The French national space agency CNES manages the Ariane-5 Programme on ESA's behalf.

The development of the Vulcain-2 cryogenic engine forms part of ESA's Ariane-5 Evolution Programme, which was endorsed by the Ministers of the Agency's Member States in October 1995, at the Ministerial Council in Toulouse. Vulcain-2 is an improved version of the original Vulcain engine powering the main cryogenic stage of the Ariane-5 launcher, which increases the available thrust from 1145 to 1350 kN.

The first studies associated with the new engine began in early 1991. They covered the engine system, the oxygen and hydrogen turbopumps, the combustion chamber, the nozzle extension and other equipment. Preliminary Design Reviews of each of the new engine's main components were undertaken throughout 1997.

The oxygen turbopump developed by Fiat Avio (I) is the subsystem that has undergone the most significant changes. The combustion chamber developed by DaimlerChrysler Aerospace (D) has been adapted to accommodate the new flow rates. The mixture ratio has been raised from 5.3 to 6.1, and the expansion ratio of the nozzle extension, developed by Volvo Aerospace (S), has been increased by 30%, together with the reintroduction of the turbine exhaust gases.

The 20% increase in thrust demanded of the Vulcain-2 engine has called for a 25% increase in the power of the hydrogen turbine, corresponding to an increase of 9% in hydrogen flow through the combustion

Figure 1. Test firing of the M201 engine on the P5 test rig

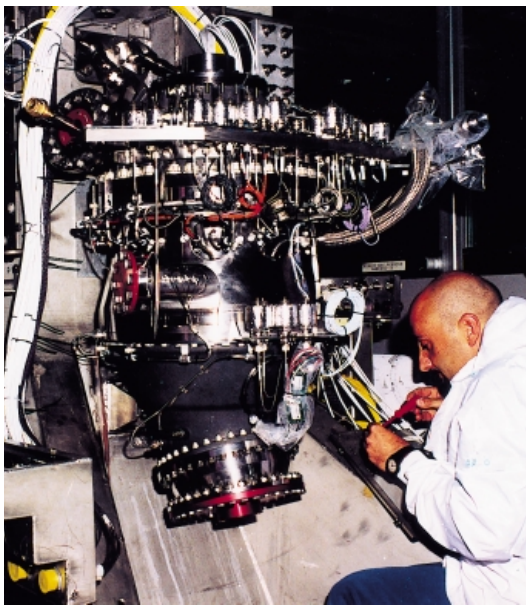

Figure 2. Vulcain-2 oxygen turbopump assembly

Figure 3. Vulcain and Vulcain-2 nozzle extensions

Figure 4. Vulcain-2 thrust chamber

chamber. This higher flow rate is achieved via a 16% hydrogen inlet pressure increase, driving the pump at 35 680 rotations per minute. The 16% gain in the hydrogen turbine inlet pressure, in turn, is produced through a 22% increase in the hot gas flow coming from the gas generator, which at the same time satisfies the 30% increase needed for the oxygen turbine. The new gas generator has 72 injectors instead of 60; doing away with the high frequency absorber has made room for these 12 additional injectors.

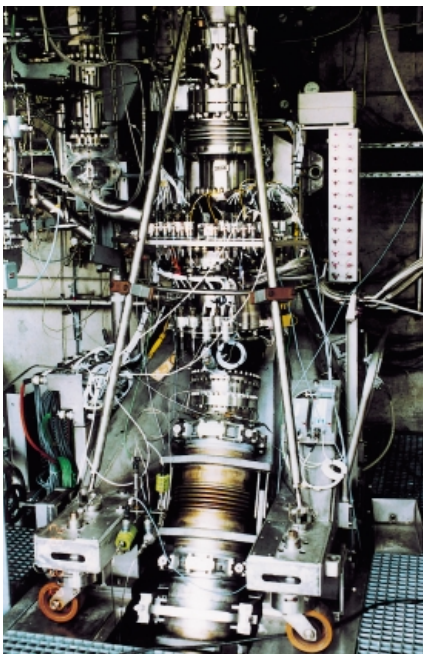

Figure 5. Vulcain-2 oxygen turbopump on the P593 test rig

The test campaigns for the hydrogen turbopump and the gas generator began on 8 September 1997 and lasted until 20 February 1998, at the PF52 SNECMA test rig. These tests demonstrated good turbine and pump behaviour under extreme loads. The latter were characterised by a turbopump speed of 40 700 rpm, developing a power of 21 MW with a hydrogen flow of 52.8 kg/s, compared with the nominal operating point of 35 680 rpm, 14.29 MW and a hydrogen flow of 44.9 kg/s. The gas generator demonstrated both stable behaviour and an important gain in margins.

As far as the oxygen turbopump is concerned, the turbine's elements were tested under both cold and hot conditions. The pump inducer was tested using water rather than liquid oxygen, and the pump itself is currently undergoing cavitation tests. The first complete turbopump was delivered in August 1998 for the liquid-oxygen test campaign, which is still in progress at DaimlerChrysler Aeropace, on the P5.9.3 test rig in Ottobrunn (D).

The Vulcain-2 nozzle extension was delivered in March 1999 for the engine test campaign, following delivery the chamber in the previous November. Preliminary assembly of the Vulcain-2 engine had also begun in November 1998, and it was delivered on 7 April 1999 to the P5 test rig in Lampoldshausen (D), operated by the German Aerospace Centre (DLR). The second PF50 test rig in Vernon (F), operated by SNECMA, received the second engine at the beginning of October 1999.

A further four test engines will be used to qualify the subsystems and the Vulcain-2 engine itself before authorisation of the first flight of the new Ariane-5 Evolution launcher, scheduled for December 2001. esa

Table 1. Technical characteristics of the Vulcain-2 cryogenic engine

Vacuum thrust	1 350 kN
Specific impulse	433 s
Chamber pressure	115 bar
Mixture ratio	6.10
Section ratio	58.5
Total propellant flow	320 kg/s
Mass	1935kg
Turbopumps:	
Rotation speed	
LOX :	12 600 rpm
LH_2 :	35 500 rpm
Turbine power	
LOX :	5 100 kW
LH_2 :	14 100 kW
Dimensions:	
Height	3.60 m
Diameter (nozzle ext. outlet)	2.15 m