First Test Firing of an Ariane-5 Production Booster

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The first test firing of a production P230 booster for the Ariane-5 launcher was conducted successfully on 16 May 2000, on the solid-propellant-booster test stand (BEAP) in Kourou, French Guiana. The test formed part of the Ariane-5 Research and Technology Accompaniment Programme (ARTA-5)*.

* For background information on ARTA-5, booster development and facilities, see ESA Bulletins 94 (May 1998), 69 (February 1992) and 75 (August 1993).

Introduction

Ariane-5 accompanying activities started in 1996 with ARTA-5, based on the experience gained from Ariane-3 and 4. The objectives of this ESA programme are to monitor the performance and reliability of the Ariane-5 launcher during its operational phase, deal with ground and flight non-conformances, and assess the validity of design and material changes.

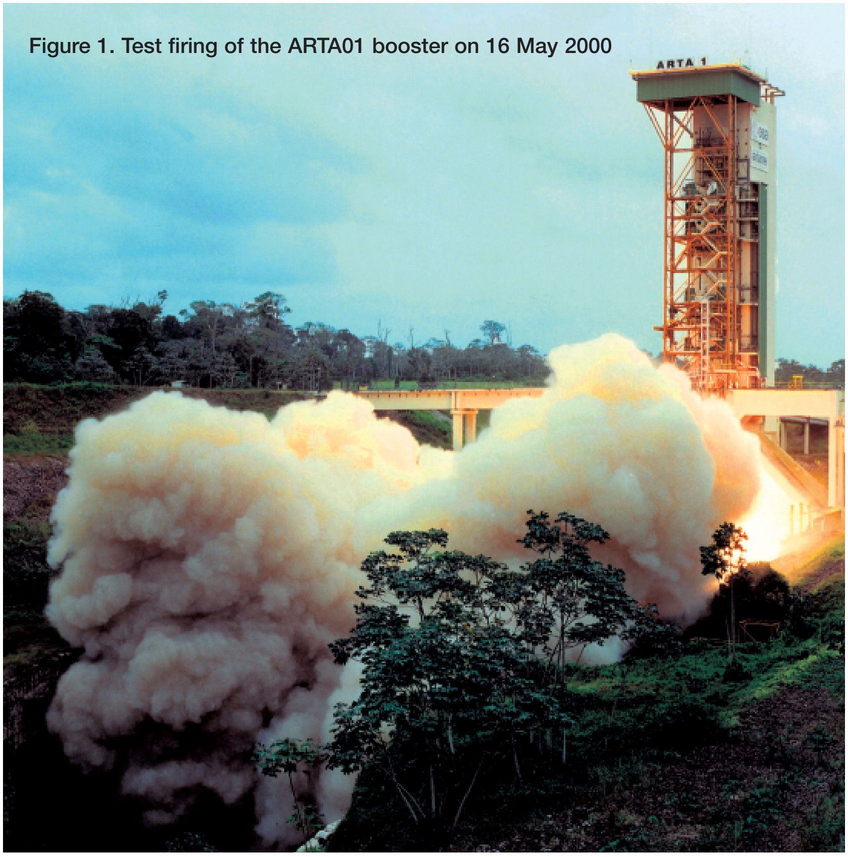


Figure 1. Test firing of the ARTA01 booster on 16 May 2000

The high reliability requirements set for Ariane-5 and the aim of reducing both production and operating costs have resulted in a launcher configuration that differs substantially from that of previous generations. The chosen configuration required a new solid-propellant booster. The initial development of the booster served to freeze its definition and establish the production procedures and hardware acceptance criteria. Five development and two qualification tests were performed. Presently three types of activities are being carried out under ARTA-5:

– analysis of in-flight measurements during operational launches
– recovery of flight specimens for inspection (thickness of thermal protection, nozzle parts, field joints)
– ground firings of full-scale production boosters.

The ground test conducted on 16 May was the first firing of a production booster. CNES, on behalf of ESA, supervised all of the test-related activities. Europropulsion was responsible for the manufacture of the booster (Fig. 1).

Test objectives

The main objectives of the test were:

– verification of the performance of the motor and of the overall stage (actuators, high-pressure vessels, cable ducts, etc.)
– qualification of a new European procurement source for the binder used in the solid propellant of the middle segment (S2)
– examination of the effects of ageing on a six-year-old nozzle and evaluation of the performances of the various mechanical components
– qualification of the forward segment (S1) loaded with an extra 2.2 tons of propellant. This segment provides about 50% of total thrust during the first phase of an Ariane-5 flight. This increase, corresponding to 10% of total S1 mass, will provide an extra

payload capacity of about 200 kg for injection into Geostationary Transfer Orbit (GTO)
– validation of a new repair process developed for the thermal insulation. A repair operation was executed on a rear booster segment (S3)
– verification of the new thrust profile with the extra-loaded S1 segment and modified ignition delay, and validation of the mathematical model used to predict this profile for operational launches.

Appraisal of a set of design enhancements, basically aimed at mass reduction, was another objective. These modifications include a new attachment system for the electrical lines (now secured directly to the booster's skin by adhesive, in place of mechanical attachments) and a stretched nozzle.

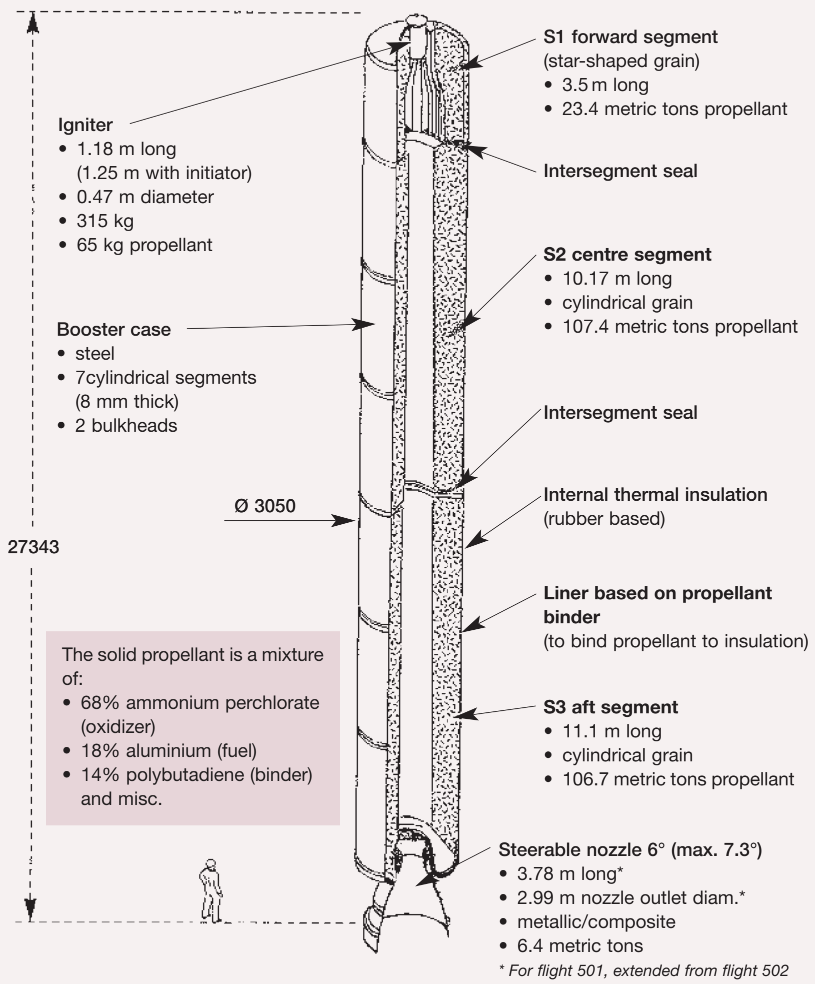
The ARTA01 motor
The Ariane-5 configuration is made up of two solid-propellant boosters attached to a cryogenic stage, the boosters providing 90% of the total propulsion at lift-off.

The P230 stage is built up from the following elements:
– solid-propellant motor (see current performance/characteristics in Fig. 2)
– nozzle control unit
– electrical and pyrotechnic subsystem
– forward and aft skirts
– forward and aft attachment devices interfacing with the cryogenic stage.

The main element is the motor, which has a metal casing in seven cylindrical sections. The casing with liner and thermal insulation is charged with three blocks of solid propellant. The nozzle has a Sepcarb throat and phenolic insulation. The igniter starts the combustion, which reaches a radial velocity of around 7.4 mm/s. The total burn time is 130 s.

For this test, the motor had the following special features:
– serial motor casing with forward segment reinforced
– thermal insulation applied using new machinery
– extra-loaded S1 forward segment
– new binder in the S2 segment
– repaired thermal insulation on the S3 segment
– new nozzle (M2R).

This nozzle is a preliminary version of the P2002 configuration due to be tested in the second test firing. Several nozzle parts have been modified, including the nose, throat and convergent inserts and the divergent. New materials have been used, namely CR 151 and Sepcarb 54-45. These modifications were driven by the need to replace obsolescent materials and optimise mass and cost.



Vacuum thrust	
maximum	6709 kN
average	4984 kN
Max. pressure	61.34 bar
Specific impulse	275.4 sec
Burn time	129 sec

Mass at liftoff:
inert : 31.2 metric tons
propellant: 237.7 metric tons

Total mass:
269 metric tons

Prime contractor:
EUROPROPULSION

Figure 2. Booster-motor performance characteristics

Test-facility preparation
The BEAP test stand was built for the development of the full-scale booster and also for use during the production phase. The stand, located near the production and launch site, was designed for test-firing boosters mounted vertically, nozzle downwards, thereby reproducing flight conditions as closely as possible (Fig. 3).

The test facilities consist of the servicing tower (62 m high), the flame trench (60 m deep, 200 m long and 35 m wide), and the test control

Figure 3. The booster test stand

building located 600 m away. The main function of the tower is to hold the booster and measure the thrust during testing. The control building houses the electrical equipment and the room from which to monitor the firing.

Fifteen people were involved in the test campaign, which commenced with preparation of the stand. The mechanical and fluid systems had been dismantled on completion of the booster development and qualification phases. They were therefore reinstalled for this test firing. Initial preparation tasks on the facility took three months, from September to December 1999. The work continued from January to mid-March 2000 to achieve the final configuration required for the test. A considerable amount of instrumentation was used, requiring the installation of 429 sensors in the booster (Fig. 4).

Test results

The test was successfully performed on 16 May 2000, after a delay due to extreme weather conditions during the rainy season in French Guiana (Fig. 5).

The visual inspection after the firing (Fig. 6) was essentially devoted to the nozzle, and it confirmed:

– integrity of the divergent extremity
– good behaviour of the phenolic carbon of the divergent, both the currently used CR 138 and the C 151 under qualification
– a preliminary measurement of mean throat erosion of 41 mm, well within the predicted range.

The full test-result analysis is being performed in three steps:

– preliminary data analysis in the days following the tests
– Level-0 data analysis at the end of June of the whole measurement set with the help of the powerful ETNA 5+ software
– Level-1 data analysis, currently being performed together with detailed hardware inspection.

The Level-0 data analysis found good correlation between the predicted and measured combustion pressures, showing good booster performance and validating the prediction model. Final analysis at Level-1 will help to qualify the booster modifications included in this test configuration.

Conclusion

ARTA-5 accompanying activities are set to continue throughout the lifetime of the Ariane-5 launcher. The analysis of flight data combined with the sample testing for key launcher

Figure 4. The ARTA01 booster prepared for firing

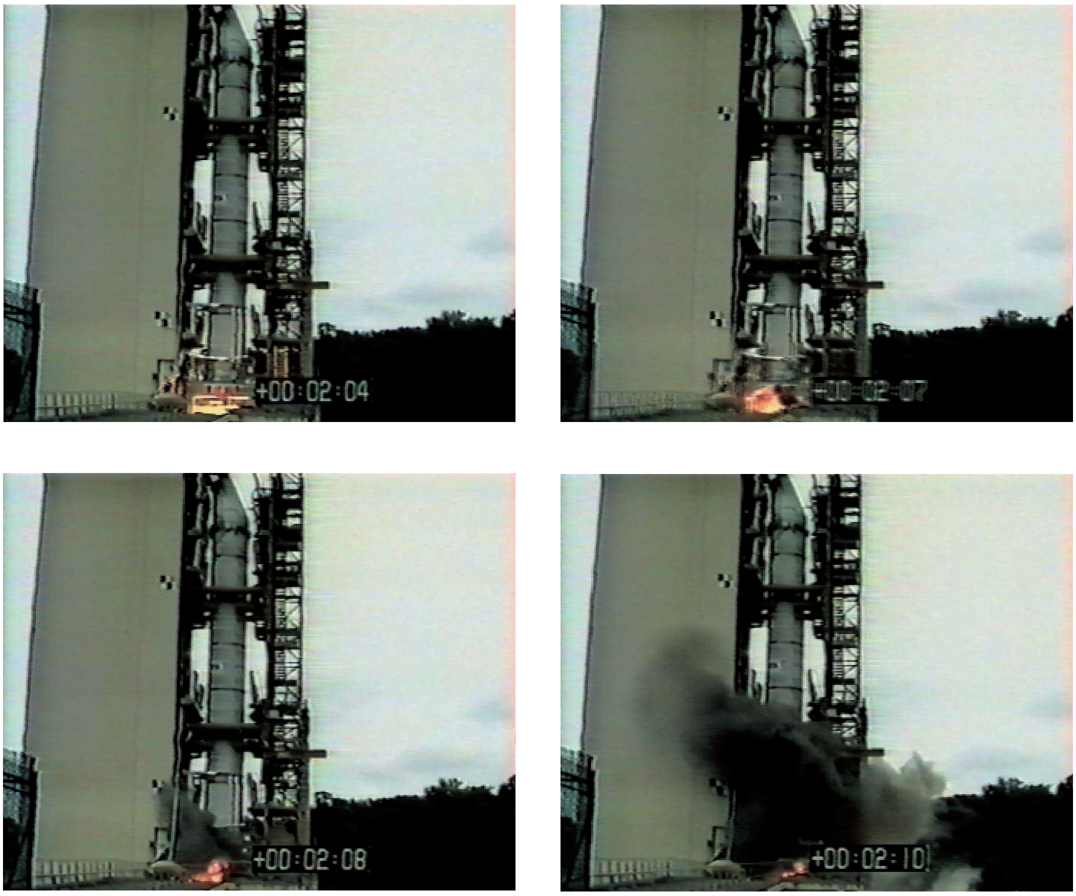


Figure 5. The booster firing sequence

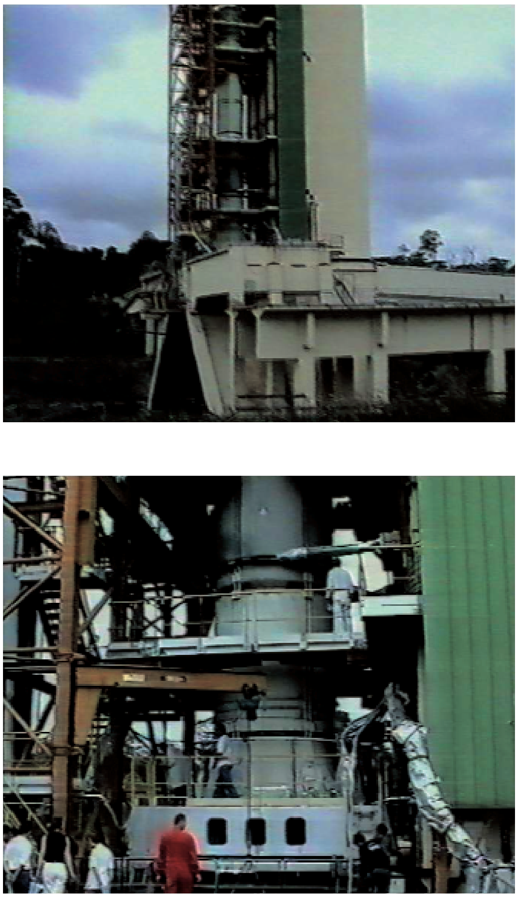


Figure 6. Post-firing booster inspection

elements will serve to maintain high reliability for Ariane-5. The test described here was a contribution to this objective in the solid-propulsion domain. This first test firing of an Ariane-5 production booster has shown the good functioning of the solid-rocket motor and validated proposed modifications.

Acknowledgements
The authors wish to thank CNES and Europropulsion for providing the photographs for this article.

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