AIAA-98-3980
LARGE SPACE SOLID ROCKET MOTORS IN EUROPE - PAST AND FUTURE DEVELOPMENTS

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34th AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit
July 13-15, 1998 / Cleveland, OH

AIAA / ASME / SAE / ASEE

JOINT PROPULSION CONFERENCE AND EXHIBIT

JULY 13-15 /1998 - CLEVELAND - OHIO - USA

LARGE SPACE SOLID ROCKET PROPULSION IN EUROPE

PASSED AND FUTURE DEVELOPMENTS

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ABSTRACT/ INTRODUCTION

The history of large solid rocket motors for space applications in Europe started in France in the early 1960's with the two upper stages of the DIAMANT launcher family.

Perigee and apogee motors such as MAGE and IRIS were then developed by European teams including France, Italy and Germany.

At the start of the 1980's Italian solid rocket boosters were selected for Ariane launcher to improve its performances.

The last huge step - the MPS P230 booster for ARIANE 5 - in cooperation between French, Italian and German partners, completed its development in 1995 and is now beginning its commercial life.

It is currently the main space application of large solid rockets in Europe and some improvements are proposed by industrial teams to enhance Ariane 5 competitiveness.

In the continuity of CNES ALD and ESL projects, SEP division de SNECMA has performed preliminary internal studies of solid rocket motors for the VEGA small launcher project.

S.R.M. for DIAMANT FAMILY

An extensive national program of Basic Ballistic Studies was conducted by french S.E.R.E.B. company at the start of the 1960's to develop the key technologies associated with the propulsion (solid and liquid propellant) and guidance of strategic missiles.

The results of this work were applied directly to the design of a satellite launcher, called the DIAMANT launcher. All versions were fitted with solid propellant rockets for their two upper stages. For stage one, a liquid motor was chosen since the amount of thrust available from solid rockets was limited at that time. It must be considered that such a stagement was directly linked to available engines and motors "on the shelf"

The masses of propellant in DIAMANT A solid rocket motors were :

- 2.2 tonnes for stage two, known as TOPAZE,
- 0.6 tonnes for stage three, based on a glass structure.

Improved versions of DIAMANT launcher included mainly propellant mass increases :

- an increase in the mass of propellant used for stage three, with a new DROPT motor between A and B,
- an increase in the mass of propellant used for stage two between B and BP4 with a new RITA 1 motor.

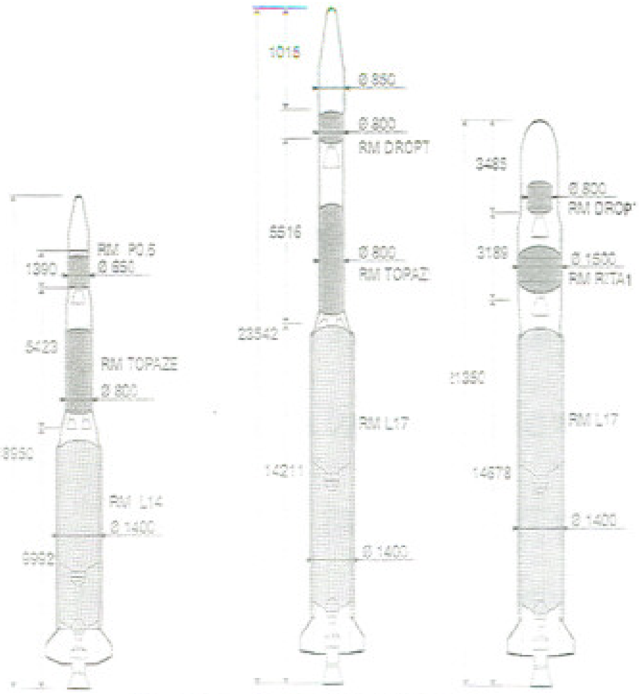

FIGURE 1 : THE DIAMANT FAMILY

The total firing activity of the launcher and its motors may be summarized as follows :

- Diamant A : 4 launches between 1965 and 1967
- Diamant B : 5 launches between 1970 and 1973
- Diamant BP4 : 3 launches in 1975.

Two launches of version B failed. One was surprinsingly due to a problem with the TOPAZE motor, whose overall reliability was very high.

P 0.6 MOTOR

This motor was developed by SUD AVIATION (AEROSPATIALE). Its principal characteristics are given in tables A and B. It implemented the following technologies :

- a prepreg glass/epoxy composite material structure, the first of this type in France
- Isolane propellant containing 22% binder (aluminized polyurethane ammonium perchlorate) produced by the Service des Poudres (SNPE)
- a fixed external nozzle with a graphite throat and an exit cone made in silica/phenolic reinforced by a glass/epoxy winding.

The stage was stabilized by spinning at 270 r.p.m.

Before the first flight of DIAMANT A42 firing tests, including 7 under simulated altitude conditions and 8 experimental flights, were carried out.

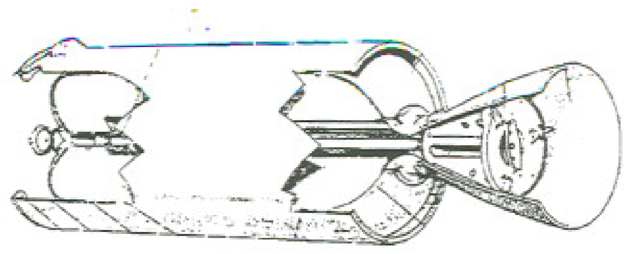

FIGURE 2 : VIEW OF THE P 0.6 MOTOR

P 2.2 'TOPAZE' MOTOR

In fact this motor was a support for maturing the technologies required for the development of the generation of large solid rocket motor for startegic missile stage one : P10 to P16. Nord-aviation (AEROSPATIALE) was the main contractor and was responsible for manufacturing the structure.Its principal characteristics are given in tables A and B. It implemented the following technologies :

- welded, Vascojet 1000 steel structure,
- Isolane propellant containing 22% of binder (aluminized polyurethane ammonium perchlorate) made by SNPE,
- thermal protection of the aft base in a graphite phenolic compound (SEPR/SEP division de SNECMA),
- swiveling external nozzles with a graphite throat and an asbestos structural exit cone (SEPR/SEP division de SNECMA).

The four swiveling nozzles were designed with a 15° angle between the thrust axis and the axis of rotation, thus making it possible to achieve three-axis steering of the stage. This was the first thrust vectorable solid rocket motor.

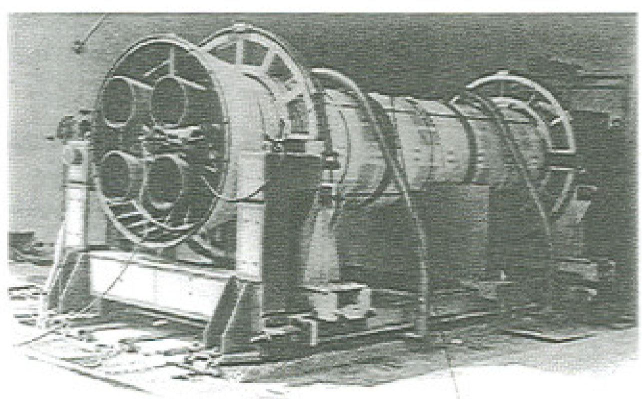

FIGURE 3 : VIEW OF THE TOPAZE MOTOR AT ISTRES

Prior to DIAMANT A flight, 61 firing tests were conducted, 2 of which were under simulated altitude conditions and 14 during experimental flights.

P 0.68 'DROPT' MOTOR

This motor was developed by SEP (start in 1965) as part of the ELDO-PAS program for the EUROPA launcher and was used as the perigee boost motor for the system. It was then used on Diamant B and BP4 to improve performance.

The following technologies were implemented :

- glass/epoxy composite material structure (SNIAS-AEROSPATIALE),
- Isolane 29/9 loading, with a machined central channel (SNPE),
- fixed, external nozzle with a graphite throat and a carbon an silica/phenolic structural exit cone.

The stage was stabilized by spinning at 180 r.p.m.

The development work started in 1966 and qualification was awarded in 1970 after about fifteen ground firings, including 3 under simulated altitude conditions and 3 in rotation.

Twelve motors have been manufactured, eight of which have been used in flight with no specific failure of the motor.

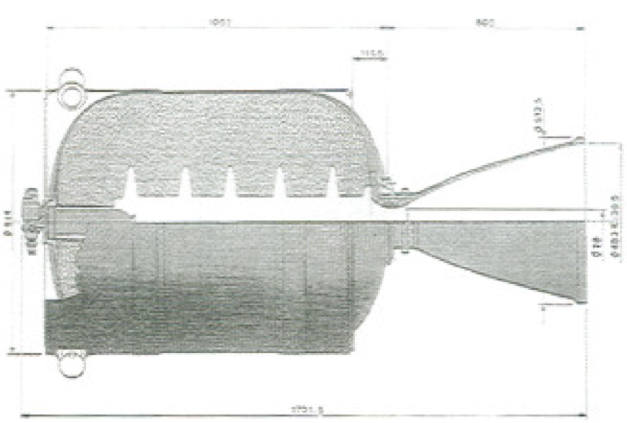

FIGURE 4 : VIEW OF THE DROPT MOTOR

P 4 'RITA 1' MOTOR

This motor was developed by SEP (division de SNECMA) as part of the deterrent force program.

Its use on the BP4 version virtually doubled the stage-two mass of propellant and produced an improvement in performance of approximately 20% (or more depending on the orbit).

Its principal technological characteristics are summarized below :

- glass/epoxy composite material structure (SNIAS-AEROSPATIALE)
- Isolane 36/9 loading, with a machined central channel (SNPE),
- fixed external nozzle with a graphite throat and an exit cone made in carbon/phenolic reinforced by an external Refrasil winding.

The motor was steered by four Freon injectors in the exit cone and roll rockets.

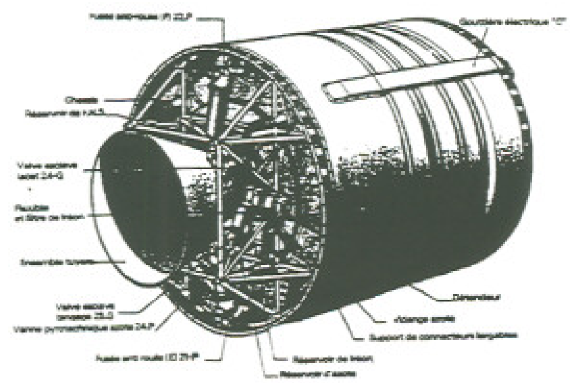

FIGURE 5 : VIEW OF THE RITA 1 MOTOR

SOLID-PROPELLANT MOTORS FOR THE DIAMANT LAUNCHERS PROPULSIVE CHARACTERISTICS

CODE	P0.6	P 2.2	P 0.68	P 4
NAME	/	TOPAZE	DROPT	RITA 1
DIAMANT VERSION	A	A and B	B and BP4	BP4
Mass of propellant	640 kg	2260 kg	685 kg	4050 kg
Inert mass	68 kg	456 kg	67 kg	745 kg
Maximum thrust	53 kN	156 kN	50 kN	180 kN
Specific impulse	274 s	259 s	275 s	274 s
Combustion duration	45 s	44 s	45 s	62 s

Table A

SOLID-PROPELLANT MOTORS FOR DIAMANT LAUNCHERS GEOMETRIC CHARACTERISTICS

MOTOR CODE	P 0.6	P 2.2	P 0.68	P 4
NAME	/	TOPAZE	DROPT	RITA 1
DIAMANT VERSION	A	A and B	B and BP4	BP4
Total length	2.1 m	3.9 m	1.6 m	2.6 m
Case length	1.4 m	3.5 m	1.1 m	1.7 m
Case diameter	0.65 m	0.8 m	0.8 m	1.5 m
Maximum pressure	4.1 MPa	3.5 MPa	5.8 MPa	5.0 MPa
Throat diameter	96 mm	92 mm	78 mm	170 mm

Table B

APOGEE / PERIGEE SOLID ROCKET MOTORS

Following the applications on DIAMANT launchers, severall motors were developped for Perigee and Apogee boost missions.

All these motors were designed with fixed nozzle and stages were stabilized by spinning.

GERS

GERS motor was developed by SNIA VISCOSA in cooperation with SEP from 1973 to 1976 for the GEOS satellite mission of ESA :

- SEP was in charge of the titanium structure and of the nozzle(based on a graphite throat and a structural carbon phenolic exit cone).
- SNIA was responsible for the propellant loading, (Butalane CTPB 10 - 14) internal thermal protection and assembly.

Ten firing tests were carried out before the first and unique flight. Despite a good motor behavior, the final orbit was wrong due to a launcher issue.

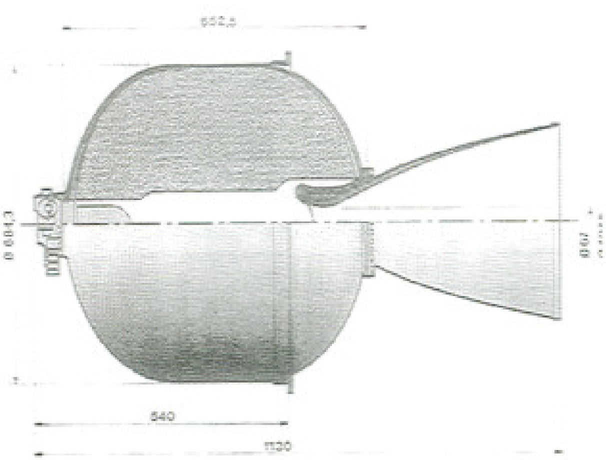

FIGURE 6 : VIEW OF GERS MOTOR

MAGE

MAGE motor family was then developped by SEP as main contractor under ESA contract with european partners :

- SNIA BPD (FIAT AVIO) was responsible for internal thermal protection, CTPB 16 -12 propellant grain and final assembly.
- MAN T was responsible for Kevlar filament wounded case.
- SEP (division de SNECMA)was in charge of igniter and nozzle designed with a 4D carbon/carbon throat and a structural carbon phenolic exit cone

MAGE 1S is an uprated version (pressure and sizes) of MAGE 1 with basically the same technologies.

On MAGE 2 increased pressure and mass figures included also a 2D carbon/carbon SEPCARB exit cone to save inert weight and increase ISP.

Development phase started in 1977 and was completed in 1983 for the three versions after 16 firing tests.

In parralell with production six firing test have been performed for controls on spare motors.

Up to know 50 motors have been manufactured and 18 flights were runned. Only one problem occured on HYPPARCOS program were the igniter does not start.

Some improvements of MAGE 2 with a streched version, are under studies at SEP with a propellant mass of 590 Kg.

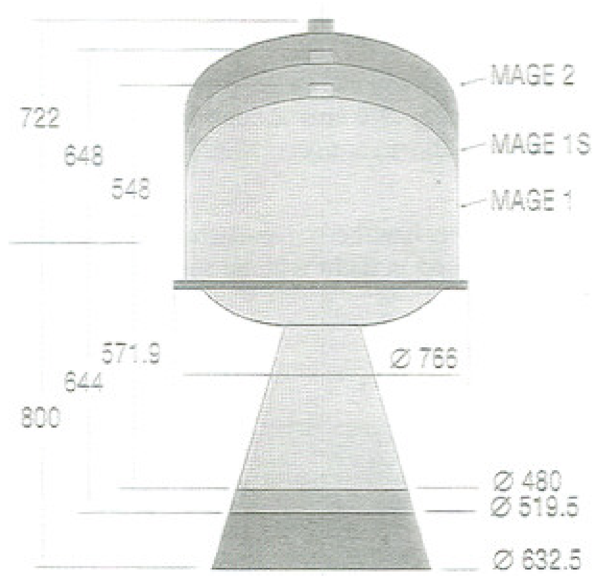

FIGURE 7 : VIEW OF MAGE FAMILY

IRIS

IRIS motor was developped by SNIA BPD (FIAT AVIO) as a perigee motor for the space shuttle launcher. It implemented following technologies :

- kevlar case (manufactured by MAN-T)
- HTPB 1813 propellant
- internal thermal protection in EPDM kevlar reinforced
- SEPCARB 4D throat insert and structural carbon phenolic exit cone.

Three ground firing tests were runned before the first and unique successful LAGEOS mission completed in 1992 (including also a MAGE 1S apogee motor).

Some improvements were proposed with the End Burning Motor and one firing test at sea level condition was runned.

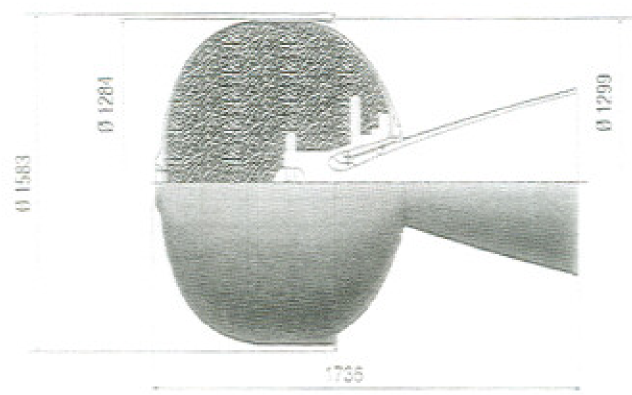

FIGURE 8 : VIEW OF IRIS MOTOR

MOTOR	GERS	MAGE 1	MAGE 1S	MAGE 2	IRIS
Max pressure	4.1 MPa	4.1 MPa	4.4 MPa	5.0 MPa	4.3 MPa
Max Thrust	27 KN	28 KN	34 KN	46 KN	66 KN
ISP vacuum	287 s	288 s	291 s	294s	291 s
Propellant mass	268 Kg	335 Kg	410Kg	490 Kg	1574 Kg
Inert weight	35.9 Kg	33.3 Kg	39.3 Kg	40.3 Kg	157 Kg
Action time	45 s	50 s	50 s	44 s	79 s
Nozzle area ratio	37	45	54	65	60
Case diameter	0.68 m	0.76 m	0.76m	0.76 m	1.25 m
Total length	1.13 m	1.12 m	1.29 m	1.52 m	1.74 m
Throat diameter	67 mm	69 mm	69 mm	78 mm	95 mm

S.R.M. FOR ARIANE FAMILY

For the Ariane program, the principle of assistance at lift-off to significantly increase the payload was implemented on Ariane 3 version with solid-propellant motors that enable the high thrust levels required for short periods at a reasonable cost.

This principle was again implemented on Ariane 4 for versions 42 P, 44 P and 44 LP in order to adjust the performance and cost of the launcher to customer's requirements.

On Ariane 5, the principle of two large booster stages, powered by solid propellant (P 230) was adopted as part of the original design of the launcher.

ARIANE 3

To increase the performance of the ARIANE 2 launcher by 20 % from 2100 to 2500 Kg in a GTO orbit, preliminary studies resulted in the selection of the concept of two solid propellant strap-on boosters (PAP - Propulseur d'Appoint à Poudre).

The design adopted was for 7.3 tons of propellant and a combustion time of less than 30 seconds, allowing the motor to be released during the sub-sonic flight phase.

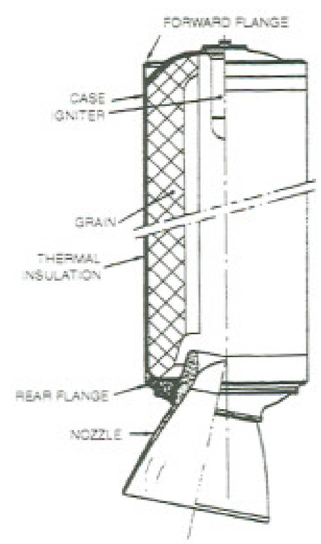

FIGURE 9 : GENERAL DESIGN OF PAP MOTOR

The technologies implemented for this motor are briefly summarized below :

- steel case made of rolled and welded sheet to frames and domes,
- EPDM reinforced by asbestos thermal protection sectors,
- six-fins star loading, obtained by casting of CTPB 71-16 propellant,
- fixed nozzle made in carbon/phenolic material with a glass/epoxy overwrapping of the exit cone.

The principal technical characteristics of the motor are summarized in the following two tables.

Geometry	ARIANE 3	ARIANE 4	ARIANE 5
Total length	7.7 m	11.2 or 9.7 m	26.8 m
Case length	6.7 m8.	7 m	24.5 m
Case diameter	1.08 m	1.08 m	3.05 m
M.E.O.P.	67 bar	64 bar	65 bar
Throat section	332 mm	337 mm	900 mm
Nozzle area ratio	8.3	8.0	11
Gimballing angle	14° fixed	12° fixed	6.6° mobile

Characteristics	ARIANE 3	ARIANE 4	ARIANE 5
Mass of propellant	7.3 tons	9.5 tons	237 tons
Inert mass of motor	1.6 tons	2.0 tons	31 tons
Maximum thrust	770 kN	700 kN	6365 kN
Total thrust	17 MNs	22 MNs	630 MNs
Specific impulse	(sea level) 241 s	(sea level) 235 s	(vacuum) 273 s
Combustion duration	29 s	40 s	130 s

The development work started at the end of 1979 at SNIA-BPD (FIAT-AVIO) and was completed in 1983 after eight firing tests.

Ariane 3 was launched for the first time in August 1984. In total, Ariane 3 flew 11 times, thus requiring 22 motors, up until 1989.

ARIANE 4

The transition from ARIANE 3's L140 core body to ARIANE 4's L220 higher core body was accompanied by a lengthening of the solid-propellant strap-on booster :

- the propellant mass was increased from 7.5 to 9.5 tons, by extending the cylindrical part of the case
- a 1.5 meter cylindrical extension was added between the fore base of this new motor and the upper interface section with the launcher

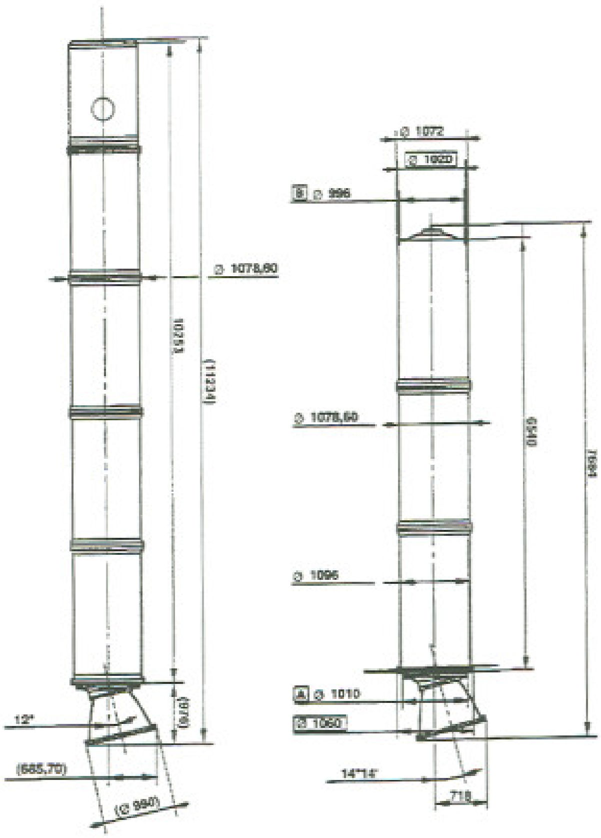

FIGURE 10 : ARIANE 3 AND ARIANE 4 PAP

This new PAP was used in combination with the liquid-propellant PAL boosters (approximately 39 tons of MMH/N204) also developed for the Ariane 4 launcher, such that different versions of the launcher could be offered more suited to customers' requirements

The following table shows the performance for each version with a H10-3 upper stage.

Configuration	PAP	PAL	Perfo. in G.T.O.
Ariane 40	0	0	2 105 kg
Ariane 42P	2	0	2 930 kg
Ariane 44P	4	0	3 465 kg
Ariane 42L	0	2	3 480 kg
Ariane 44LP	2	2	4 220 kg
Ariane 44L	0	4	4 720 kg

The addition of two PAP increased the payload in a GTO orbit of the basic Ariane 40 by 825 kg, i.e. a 40% increase. Four PAP made it possible to carry an additional 535 kg, i.e. a gain of 65 %.

Compared with version 42 L, the addition of two PAP resulted in a further 740 kg increase, i.e. an improvement of 20% in payload in GTO.

For the Ariane 4 version of the booster, the principal differences compared with the Ariane 3 version are as follows :

- CTPB propellant containing 10% aluminium instead of 16% in order to limit the erosion rates and 14% binder
- a reduction in the combustion rate and an increase in the throat diameter in order to obtain a slightly lower M.E.O.P.,
- nozzle optimisation (efficiency, degree of enclosure, simplified design, etc.),
- addition of a fourth cylindrical section onto the structure in order to increase the loaded length.

The development work started in 1983 and qualification was completed in September 1985 after 4 firing tests.

Up until flight V108, fitted with version A44P, at the end of April 1998, about one hundred boosters had been manufactured. Of the 76 Ariane 4 flights which have taken place up to the present time, 42 have been fitted with PAP : twelve 42P, eleven 44P and nineteen 44LP.

In 1997, two ground firings were conducted in order to qualify a HTPB-type propellant as a replacement for CTPB for which some ingredients had become obsolete.

ARIANE 5

During the 1980's, various studies demonstrated the advantages offered by the concept of a heavy Ariane 5 launcher based on a cryogenic core stage fitted with two large solid-rocket boosters.

The system studies lead to the final choice of a 230 tons motor with a diameter of 3 meters.

For the European propulsion industry, this motor represented a considerable quantitative leap, by a factor of about 10 compared with the experience gained in powering strategic missiles and by a factor of 25 compared with the experience gained with the PAP on Ariane 4.

Such a size imposed the need for a segmented architecture which significantly increases the technical difficulties. The selected design has a fore segment and two large central and aft segments weighing over 100 tons.

Europropulsion was prime contractor for the development work, initially as a joint venture between BPD and SEP, which is now a 50/50 subsidiary of FIAT AVIO and SEP division de SNECMA.

Europropulsion is the main contractor for the motor and is in charge of its integration at Kourou into a specific building. Main components are described hereafter :

- the case made by MAN-T in Germany consists of 7 circular sections in D6AC flow-formed steel and two domes machined in the same steel. The assembly is of clevis-tang type with a design avoiding sealing gap opening under pressure.

- the internal thermal protection is manufactured by FIAT-AVIO with SEP provided EPDM rubber, reinforced with silica (GSM55) or kevlar (EG2) depending on the zones and the thermal stresses.

- the propellant is an HTPB 68-18 type. The S1 segment weighting 23 tons (star-shaped to ensure high thrust at lift-off) is casted by FIAT AVIO at Colleferro. The S2 and S3 segments, weighing approximately 107 tons, have a simple circular cross section, and are casted in KOUROU by REGULUS, a subsidiary of SNPE and FIAT AVIO.

- the nozzle is manufactured by SEP division de SNECMA and incorporates a flexseal enabling 7° vectoring by hydraulic actuators. The throat is made from SEPCARB NOVOLTEX carbon/carbon composite material. Thermal protection components are made in carbon/phenolic or silica/phenolic material and bonded to the steel dome and the forged aluminium exit cone.

- the igniter is manufactured by FIAT AVIO

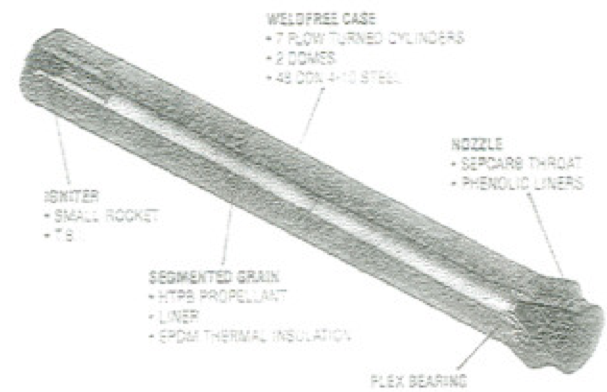

FIGURE 11 : ARIANE 5 - P230 BOOSTER TECHNOLOGIES

A scaled-down firing was conducted in 1989 on a 15 tons and 1500-mm diameter prototype before a full-scale heavy wall firing in 1993. Following this preliminary phase, four development firings and two qualification firings were conducted between 1993 and 1995.

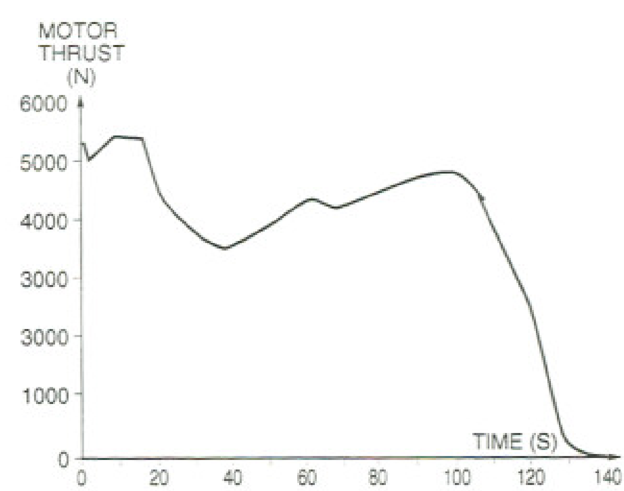

FIGURE 12 : ARIANE 5 - P230 THRUST LAW

The first production phase for the motor, involving 28 motors for 14 launchers, is well advanced and the preparatory work for the second phase (20 launchers) is under progress.

P230 EVOLUTION BY THE YEAR 2002

Three main developments are decided or proposed for application by the year 2002 as part of the A5E program :

- case : welded connections instead of CLEVIS/TANG will reduce the inert weight by 1900 kg, allow a payload gain of approximately 150 kg in a GTO orbit, and reduce the recurring cost. This program has been decided on as part of the Ariane Evolution.
- S1 grain : an overloading with an extra 1500 to 2000 Kg of propellant will generate a gain of 150/200 kg of payload in a GTO orbit.
- nozzle : design evolution are proposed mainly to reduce its recurring cost and also lower its inert mass with a possible induced gain of 50 kg in GTO payload.

A total gain of payload in a GTO orbit of 350/400 kg is possible. Ariane 5 LEO performances will also be increased and a significant drop in the recurring cost of the motor is expected.

P230 EVOLUTION BY THE YEAR 2006

The following proposals are currently under studies to identify the most suited one's to improve the mid term future competitiveness of the Ariane 5 launcher :

- grain : extra propellant overloading with for exemple a reduced S2 or S3 channel diameter, or an increased external diameter
- case : grapithe/epoxy filament winding with numerouss points to be studied (interest of composite domes, requirement in stiffeness, impact on launcher dynamic behavior, recurring price....)
- nozzle : new thrust vectoring loop with a self-protected composite shims flexseal presenting a low-torque value compatible of electromechanical actuators; leading to inert mass and price decrease and simpler launch operations

If all these modifications were implemented, the potential payload gain in a GTO orbit could be up to 1750 kg. It is to be expected that launcher-related restrictions would not allow such a gain, although an objective of over one ton would be a reasonable estimation.

S.R.M. FOR SMALL AND MEDIUM LAUNCHER PROJECTS

This chapter summarize projects of small and medium launcher that have been studied in the 1990's based on solid rocket motors. Such motors appears to be the most cost effective answer for Western standarts.

Ariane Light Derivative

CNES started studies of ARIANE Light Derivatives (Small and medium) in 1990 with the following target performance :

- ALD-P : 1000 Kg in a polar 1000 km orbit P85/P30/L6
- ALD-S : 3500 Kg in sunsynchronous 800 km orbit P230/P85/P30/L6

Two new solid rocket motors were foreseen in combination with reused A5 elements (P230 and L6 Ariane 5 upper storable stage).

The P85 was a short rated version of the P230 motor designed with the same materials (thermal protection, nozzle and propellant), using numerouss existing components (case, igniter) and benefiting from industrial manufacturing lines.

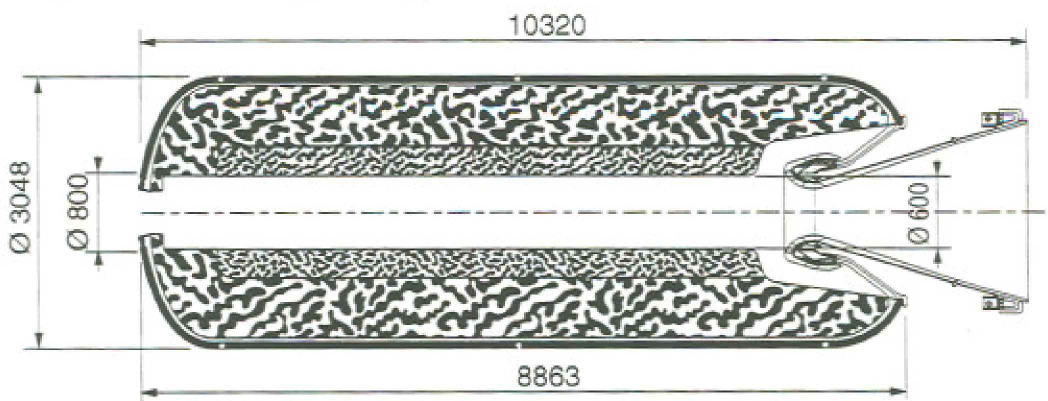

FIGURE 13 : VIEW OF ALD P85

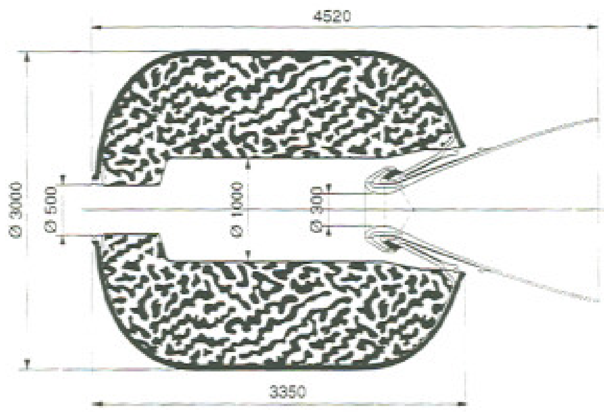

FIGURE 14 : VIEW OF ALD P30

A simple star shaped grain was selected to obtain a quite constant thrust law.

The main component to be developed was the nozzle. Its design was derived from the P230 but all the components were new due to the throat diameter reduced from 900 mm to 600 mm.

The P30 was a motor with a 3 meters diameter graphite fiber composite case to be fully developed. A low level of pressure, M.E.O.P near 6 Mpa, was selected to limit development risks. Loading, thermal protection and nozzle technologies were identical to P85 project.

The use of an unadaptated liquid upper stage (low thrust, high dry mass and high cost) leads to oversized launchers (four stage for the medium version) and solid rocket motors. The estimated recurring costs were too high for the market and studies were oriented on a fully solid configuration.

CHARACTERISTICS	ALD P85	ALD P30
Case diameter	3.0 m	3.0 m
Overall length	10.3 m	4.5 m
Propellant mass	85000 Kg	30000 Kg
M.E.O.P.	6.5 MPa	6.4 MPa
Burning time	100 s	125 s
Throat diameter	600 mm	300 mm
Nozzle exit diameter	2.49m	1.26m

European Small Launcher :

Studies of ESL started in 1993 to define a low cost small launcher in the 1ton class. A design to cost approach of the launcher leads to select a configuration with two identical P50 solid rocket motors as 1st and 2nd stages. The optimum third stage was a P7 solid rocket motor.

Following technologies were retained for these projects :

- graphite/epoxy filament winding composite case
- EPDM rubber thermal protection from Ariane 5 (GSM 55)
- HTPB 68-18 propellant from Ariane 5
- Sepcarb carbon/carbon throat materials .

For P50 a specific finocyl grain shape have been designed to comply with the two thrust level requirement : initial high level for take off (use as a first stage) and final low level to limit payload acceleration (use as a second stage).

Such a two "plateaux" thrust law shape was original but generated also a great sensitivity of launcher performance to some small motor deviations.

For the P7 , SEP proposed to select a SEPCARB exit cone exhibiting a very low dry mass leading to save more than 120 Kg of payload compared to a classical carbon/phenolic exit cone.

Following table summarizes main ESL motors projects characteristics.

CHARACTERISTICS	ESL - P50	ESL - P7
Case diameter	2.60 m	1.94 m
Overall length	8.23 m	3.23 m
Propellant mass	50000 Kg	7000 Kg
Inert mass (without TVC)	4100 Kg	610 Kg
M.E.O.P.	11 MPa	7.8 MPa
Throat diameter	370 mm	156 mm
Nozzle exit diameter	1.81 m	1.26 m
Specific impulse	288 s	296 s
Gimballing angle	6.0°	3.7°

ESL is still considered as one of the best technical answers to the market of 1 ton class payloads in LEO but leads to develop two completely new motors and involve a rather high development cost.

It would also allow to develop very quickly a medium launcher - P230 / P50 / P7 - whose performance on a 700 Km polar circular orbit could reach 3500 Kg

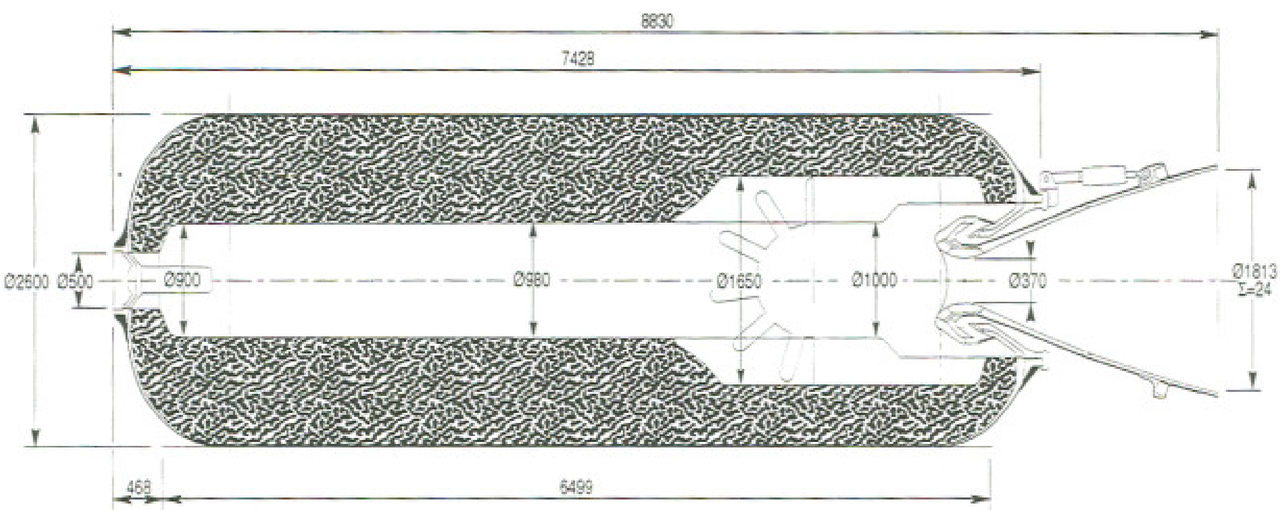

FIGURE 15 : ESL P50

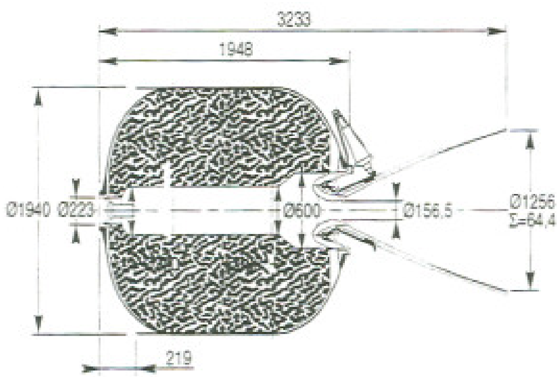

FIGURE 16 : ESL P7

VEGA launcher

VEGA launcher project is currently proposed to agencies by a joint venture AEROSPATIALE/ FIAT-AVIO with the following parameters. :

- performance : 1000 kg on a 700 Km circular polar orbit
- first stage : P85 derived from P230
- second stage : ZEFIRO motor
- third stage : seven ton class SRM

ZEFIRO is an HTPB 16 tons class SRM with a diameter near two meters and a filament wounded carbon epoxy composite case. A rear finocyl propellant loading allows to have a decreasing thrust law. The activated nozzle includes carbon/carbon throat components.

The development phase is under progress and the first successful firing test occurs recently (june 98). A qualification phase is planned to start next year for a full qualification in 2000/2001.

Sinçe 1995 SEP studied different motors to be associated with ZEFIRO as second stage. Various launcher configurations have been evaluated and finally the best compromise to minimize development costs appeared to be:

- a first stage derived from ARIANE 5 boosters (P85) and previous ALD studies.
- a third stage using a high performance composite motor (P7A) directly derived from previous military technological demonstration programs.

P85

The thrust profile has been adapted from previous P85 ALD studies. An aft end star shape for the grain that can be easily cast using a monolithic aft extracted mandrel has been selected.

The new thrust law, extending burning time and lowering final thrust level, will reduce launcher dynamic pressure (maximum level and separation of stages 1/2).

This modification, leading to a throat diameter reduced from 600 to 520 mm, allows also to reduce the weight and the price of the nozzle.

CHARACTERISTICS	P85	P7A
Case diameter	3.05 m	1.94 m
Overall length	10.6 m	3.50 m
Propellant mass	85 350 Kg	7 500 Kg
Inert mass (without TVC)	12150 Kg	670 Kg
M.E.O.P.	6.5 MPa	9.2 MPa
Burning time	128 s	78 s
Throat diameter	520 mm	170 mm
Nozzle exit diameter	2.15 m	1.25 m
Specific impulse	283 s	293 s
Gimballing angle	5.0°	4.0°

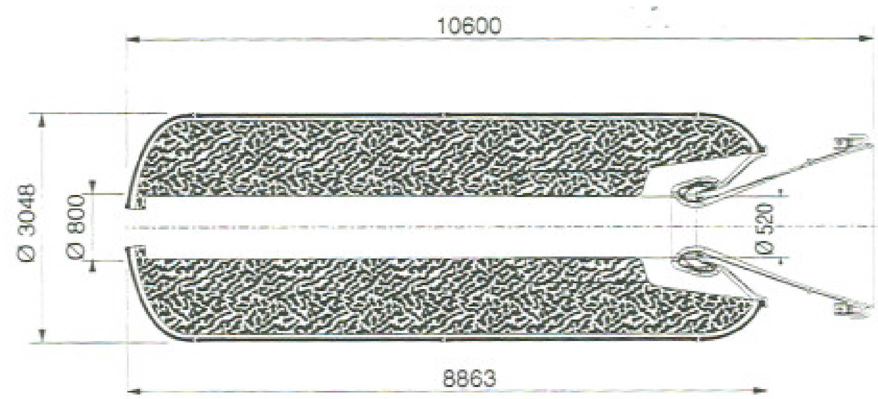

FIGURE 17 : REAR STAR SHAPED P85

P 85 technologies are described here after :

- Case: metallic (D6AC) composed of two cylinders and domes of P230 case.
- Thermal insulations: GSM55 rubber (A5 P230 type)
- Propellant: same as A5 boosters (HTPB 68-18)
- Nozzle: technologies are directly derived from P230 booster nozzle with a metallic shims flexseal and carbon phenolic exit cone insulation.

Due to the P230 background and conservative design choices for this P85, a success oriented development logic limited to one qualification firing test is possible. Such a logic will reduced development time to three years and limit drastically development cost.

P7A

A large data base of components technologies (cases, nozzles, grain configurations, propellants....) and motors behaviors has been built from military programs held during the last 15 years for strategic missile enhancement purpose.

More than ten firing tests of advanced solid rocket motors in the class of 8 tons of propellant and with a diameter near 2 meters have been performed in that period.

SNPE and SEP propose a solid rocket motor called P7A (A for Aquitain due to the industrial team located near Bordeaux city) for the third stage of VEGA launcher.

The motor design is based on already tested components and existing manufacturing tooling at SNPE (rear finocyl mandrel, HTPB 68/20 propellant ...) and SEP (submerged part of the nozzle, thermal insulation material and toolings, igniter..).

For the case an existing AEROSPATIALE component is foreseen as a baseline but some improvements are required on the filament winded capacity and skirts to reduce recurring cost, guarantee material availability and comply with launcher integration requirements.

Our industrial experience and background allow SNPE and SEP to propose a qualification logic based on a single altitude simulation firing test. Such a development would be achieved in 30 month for a very limited cost.

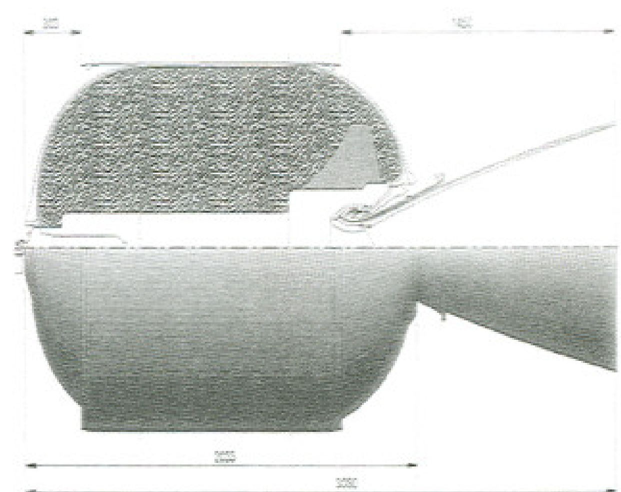

FIGURE 18 : P7A MOTOR CUT VIEW

Medium launcher

The inert mass of the P85 case is a major drawback for a P230/P85/upper stage medium launcher stagement .

SEP has designed a P73 derived from P85 (same nozzle) with a filament wounded case giving the same performance as stage one of the small launcher than the P85.

Such an evolution due to an inert mass limited to 5500 Kg only would allow to design a very efficient medium launcher P230/P73/upper stage.

Depending on the upper stage following payload range could be reached on a 700Km polar circular orbit :

- P7 (solid, 7 tons propellant)
  3500/4000 Kg
- L15 (liquid storable, 15 tons propellant)
  4500/5000 Kg
- H10 (cryogenic, 10 tons propellant)
  5500/6000 Kg

Capricornio

Two solid rocket motors are under development in Spain for Capricornio launcher whose basic stage 1 is an existing Castor IV :

- DENEB : it will be the second stage and the current project is a 5200 kg of propellant and 1 m diameter filament wounded motor.
- MIZAR : with a propellant mass of 600 kg and a 830 mm of diameter it is designed for the third stage applications.

Currently only technological firing tests and flights are planned.

CONCLUSION

For Diamant launcher, available solid rocket motor contributed to the quick and successfull access to space of France in the 1960's.

By the mid of the 1970's they started to fulfill numerous ESA satellite missions as Apogee and Perigee boost motors.

For the Ariane family of heavy launchers, solid rocket motors remains the most efficient way to obtain high lift-off thrust at limited cost.

The simple boosters used for Ariane 3 and 4 have now been adopted as a true stage one motor in the design of Ariane 5. P230 offers an interesting potential for evolution to improve the competitiveness of Ariane 5 launcher.

Solid rocket motors are perfectly suited to small and medium launcher requirements in term of costs objectives.

Ariane 3 and 4 programs with 100 % success for SRM behavior confirm their excellent level of reliability.

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