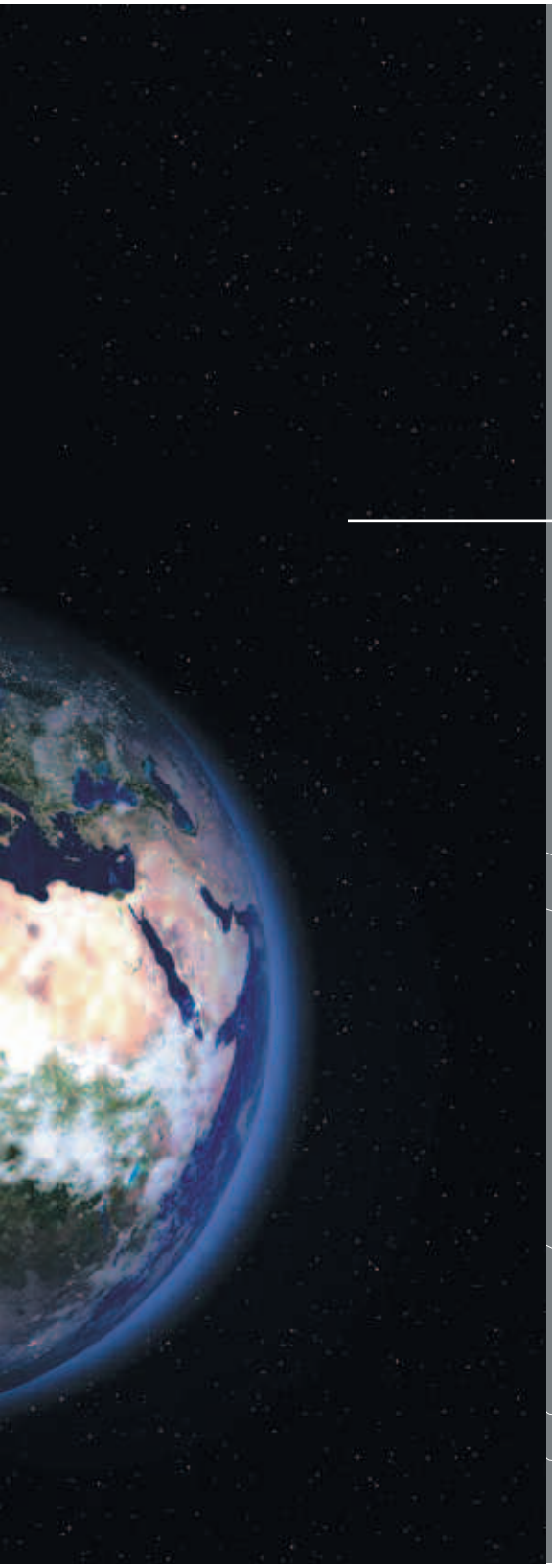
SPACE PROPULSION

PROPELLING YOU
THROUGH TIME
AND SPACE

Snecma
SAFRAN Group

For nearly six decades, Snecma has built up the technical and industrial expertise needed as prime contractor. Since the outset of the Ariane program in 1973, we have coordinated all European partners in development and production of the launcher's propulsion system. Our Viking (first/second stage and strap-on boosters) and HM7B upper-stage engines powered the Ariane 1 to 4 launcher family, and were key to its trend-setting commercial success.

From the Earth to the Moon



World-class aircraft and rocket engine manufacturer

Snecma is the aerospace propulsion specialist in the international technology group SAFRAN. We design, develop and produce commercial and military aircraft engines, as well as propulsion systems for launchers and satellites. Our products are exported worldwide.

Space engines

The best balance of performance, reliability and cost

Snecma is the lead engine supplier on Europe's Ariane launcher, with the Vulcain®2 and HM7B cryogenic engines. We are the world's second largest manufacturer of liquid propulsion systems for launch vehicles, and have also provided propulsion systems for some 350 French and European satellites to date. Today, we are increasingly specialized in plasma propulsion systems for satellites and have become the European leader in this important technology. Our PPS®1350 plasma thruster recently set the world endurance record for electric propulsion.

Commercial engines

The broadest thrust range on the market

Working with General Electric of the United States, Snecma designs, produces, markets and supports the CFM56, the world's best selling commercial aircraft engine, and has a stake in the large turbofans CF6-80, GE90 and GP7200. We are also developing the SaM146 for regional jets, and preparing a new engine concept for the high-end business aircraft market.

Military engines

Powering 20 types of aircraft in 40 countries

Snecma designs, develops, produces and supports engines for military transport, training and combat aircraft. Our flagship products are the M53-P2 powering the Mirage 2000, the M88-2 on the Rafale, and the TP400-D6 turboprop for the new Airbus Military A400M military transport.

Ariane 5 ECA, Flight 164 on February 12, 2005.

Strategy and markets

Higher **performance and reliability** at lower cost

Since Europe does not have a major government space market (launch services for scientific and military satellites), its space business is largely built on the launch of commercial satellites. For more than 25 years, the family of Ariane 1 to 4 launchers gave Europe independent access to space.

Today, the next-generation Ariane 5 heavy launcher has earned Arianespace a large share of the commercial market.

With satellites growing larger and larger, the space market demands launchers and propulsion systems offering ever-higher performance and reliability – all at lower cost! Ariane brings to the table a concrete competitive advantage, since it can launch several different sized satellites on a single mission. This significantly boosts its competitiveness, by allowing customers to share launch costs.

Propulsion, a key to **competitiveness**

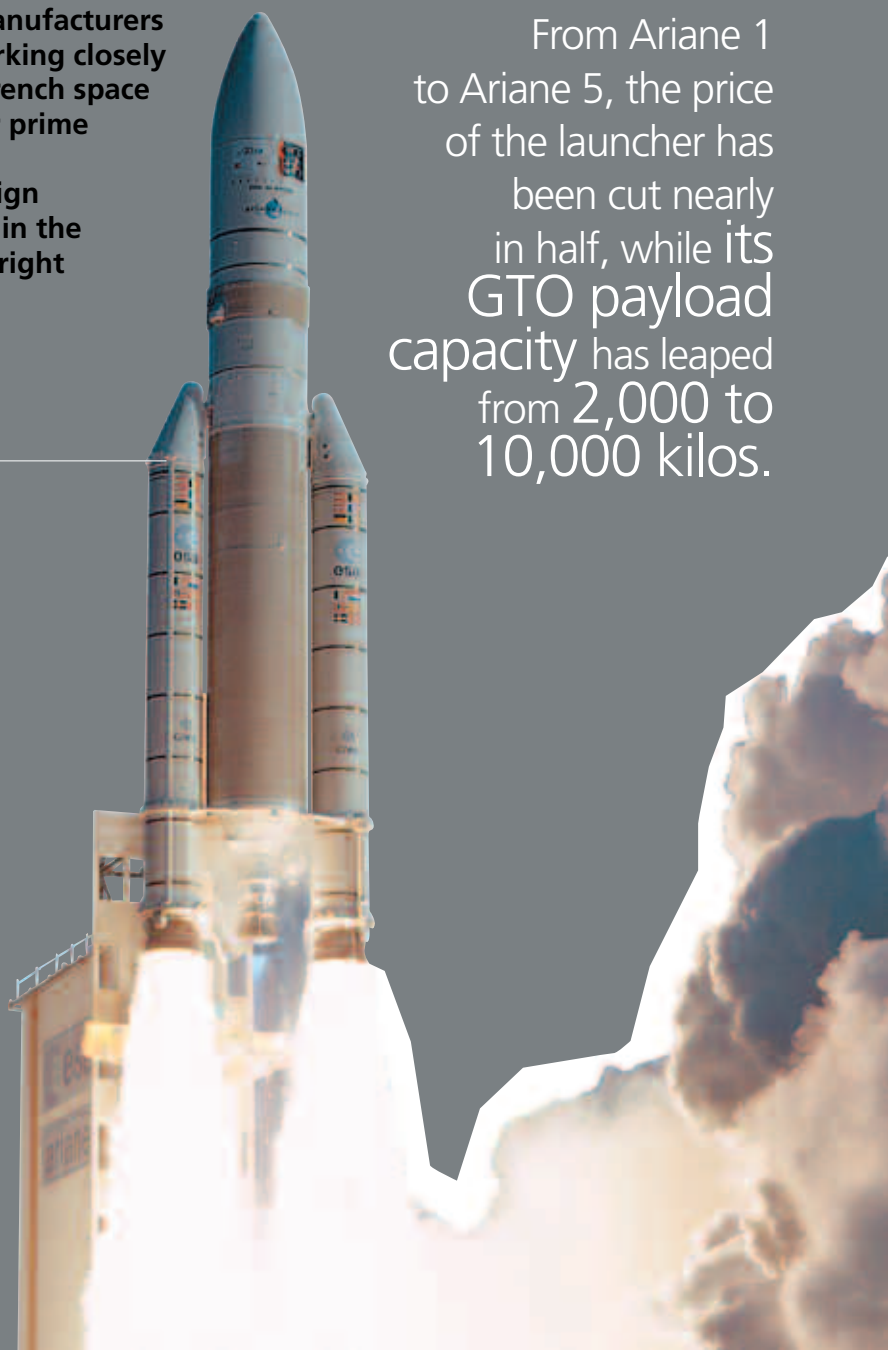
Snecma has a two-pronged mission in space: help Europe achieve its strategic goal of independent access to space; and support Arianespace in the commercial launch market, by supplying high-performance, low-cost launcher propulsion systems. We have built up considerable expertise over the past few decades, leading to today's cutting-edge propulsion solutions for a continuous reduction in costs and development time.

Market trends show widely varying launch demand, from satellites weighing less than 3 tons to the heaviest weighing more than 6 tons.

Vulcain®

Snecma's vast experience in the design of complete liquid-propellant propulsion systems goes well behind the engine itself. For the current-generation Ariane 5, like previous versions, we are in charge of all cryogenic propulsion on the main and upper stages. We oversee development and coordinate the network of European manufacturers involved in the program, while also working closely with the European Space Agency, the French space agency CNES, Arianespace and launcher prime contractor EADS ST.
By coordinating all partners we can design optimized propulsion systems, building in the upgradeability expected by the market right from the start.

Snecma continues to focus on lowering launcher costs. From Ariane 1 to Ariane 5, the price of the launcher has been cut nearly in half, while its GTO payload capacity has leaped from 2,000 to 10,000 kilos.



Ariane 5 ECA
50% more
payload capacity

Launchers continue to evolve in line with market trends, and this demands increasingly powerful propulsion systems. The standard Ariane 5 with its Vulcain main stage engine offers payload capacity into geostationary transfer orbit (GTO) of almost 7,000 kg, versus slightly more than 4,000 kg on Ariane 4. Ariane 5's first commercial launch was in 1999.

The new Ariane 5 ECA version maintains the launcher's competitiveness by boosting GTO payload capacity by almost 50%, to some 10,000 kg, mainly through the new Vulcain 2 main stage engine, and the HM7B engine on the new cryogenic upper stage. The Ariane 5 ECA was validated in flight in February 2005.

Snecma has understood and applied the complex technology behind cryogenic engines (generally using liquid hydrogen and oxygen), like the Vulcain®2, HM7B and Vinci®, for over **40 years.**

Vulcain®2 is based on the gas generator cycle, in which the turbopumps that feed propellants to the combustion chamber are driven by hot gases produced in an independent gas generator, using a small portion of the main liquid hydrogen and oxygen flows. Vulcain®2 generates thrust by the high-speed ejection of gases from the combustion chamber, where the propellants are burned at high pressure and high temperature. The gases expand in the nozzle, accelerating to a supersonic speed of up to 4,000 meters/second. The hydrogen turbopump alone has output power of 14 megawatts.

Vulcain®2
New generation

Vulcain®2 is taking over for the original Vulcain® engine on the cryogenic main stage. It is 20% more powerful, delivering 130,000 kg of thrust versus 110,000 kg, while also offering lower specific fuel consumption.

Snecma and partners developed Vulcain®2 to significantly increase Ariane 5 ECA's payload capacity, to nearly 10,000 kg into geostationary transfer orbit. This means that Ariane can continue to launch two payloads at a time, even with today's increasingly hefty commercial satellites. The higher-thrust Vulcain®2 engine contributes nearly half of the higher performance on Ariane 5 ECA, with the new cryogenic upper stage also playing a major role.

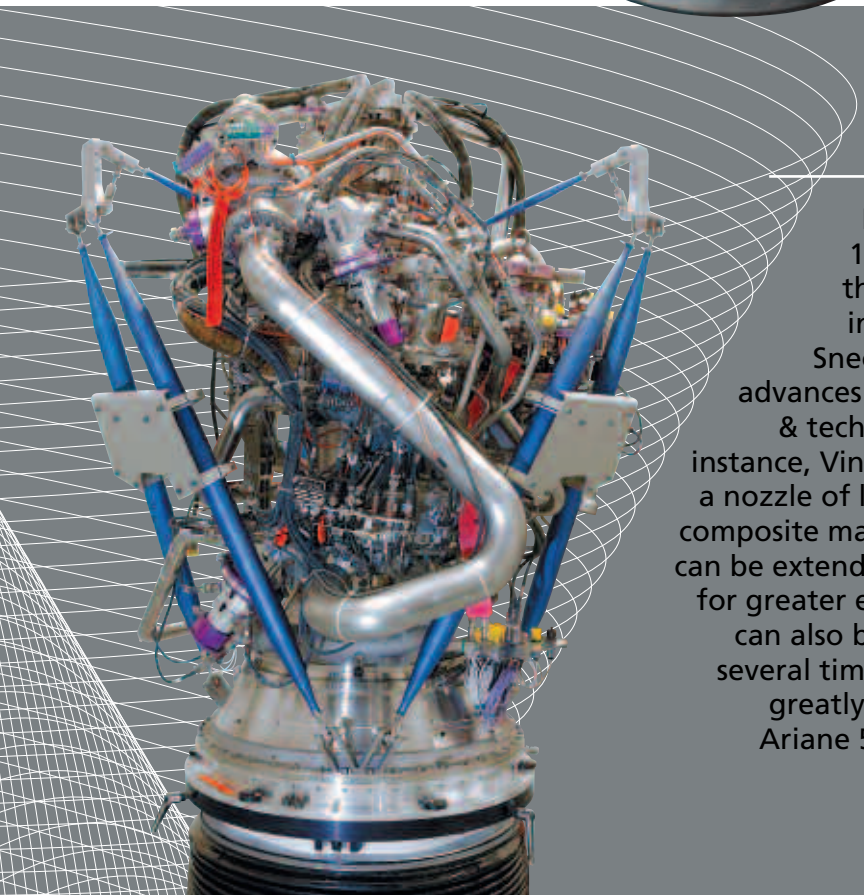
The qualification flight in 2005 validated the in-flight performance of the Vulcain®2 engine. It features a number of improvements over its predecessor, primarily concerning the oxygen turbopump, combustion chamber and nozzle.

HM7B and the new-generation Vinci®

Upper-stage engines
The HM7B, like Vulcain®2, uses the gas generator cycle. A separate gas generator produces hot gases by burning a small part of the liquid hydrogen and oxygen propellants. These gases turn a single turbine, running at 61,000 rpm, to drive the two pumps that feed propellants into the combustion chamber. The HM7B generates thrust by the high-speed ejection of gases from the combustion chamber, where the propellants are burned at high temperature.

HM7B
an **Ariane** veteran

The HM7 engine powering the third stage of all Ariane 1 to 4 launchers signaled France's entry into the select club of countries mastering cryogenic propulsion (at extremely low temperatures, generally using liquid hydrogen and oxygen). This proven engine is once again being used on the new upper stage for Ariane 5 ECA, which carries over 14 tons of liquid hydrogen and oxygen. The HM7B alone provides more than half of the overall performance increase on Ariane 5, thanks to its high thrust (6,500 kg) and specific impulse (indication of a rocket engine's overall efficiency).



Developing 18,000 kg of thrust, Vinci® incorporates Snecma's latest advances in research & technology. For instance, Vinci® features a nozzle of lightweight composite materials that can be extended in flight for greater efficiency. It can also be restarted several times in flight, greatly expanding Ariane 5's range of missions.

Vinci®

At the same time, we are developing a new-generation upper-stage engine, the Vinci®, which could replace the HM7B. Vinci® will give Ariane 5 greater operational flexibility because it can be reignited in flight, while also developing higher thrust for greater payload capacity (up to 12,000 kg into GTO). ESA approved the demonstration program for this engine at the end of 2005, and the initial ground tests under nominal flight conditions were very successful.

Vinci® represents a major new step forward in terms of reliability, cost and performance. Produced for the same cost as the HM7B, it offers three times as much thrust and is restartable.

Plasma propulsion

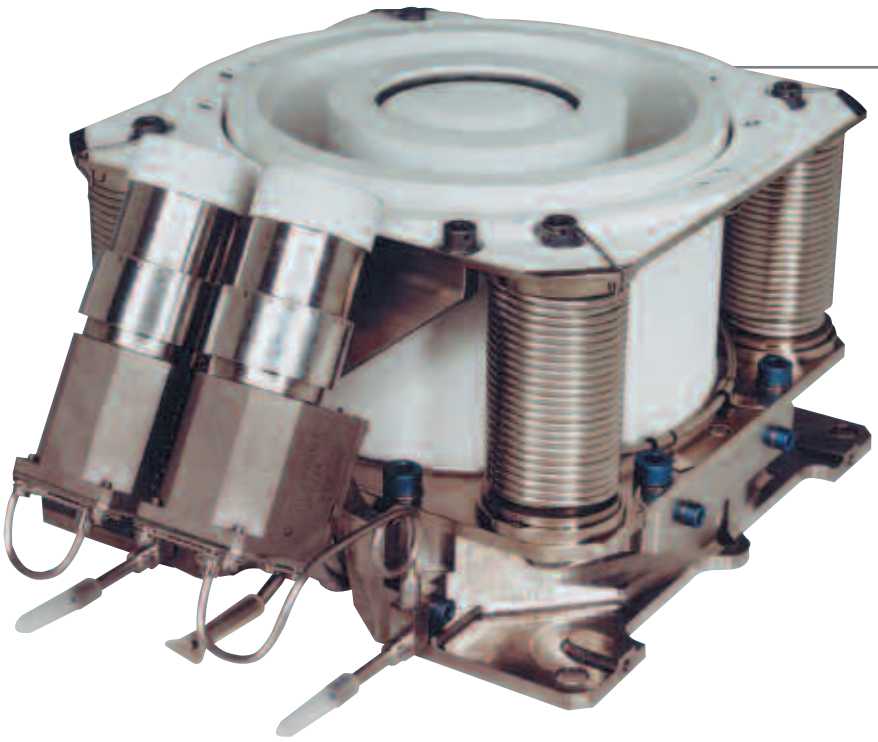
Snecma, leader in plasma propulsion

Snecma has been developing, integrating, testing and producing satellite propulsion systems for more than 30 years. Our chemical propulsion systems have been chosen for the Spot, Helios and ERS satellite families, among others.

Today, we are increasingly known as the plasma propulsion specialist. We pioneered this technology in Europe, along with our Russian partner Fakel, and we are now the European leader. Snecma provides plasma propulsion systems for Astrium communications satellites, such as the Intelsat 10 and Inmarsat 4.

The first plasma thrusters were used back in the 1970s. They consume far less propellant than an equivalent chemical propulsion system, which means that satellite life can be increased or launchers can carry larger payloads. They meet customers' current requirements, and also greatly facilitate scientific and planetary exploration missions, which demand large amounts of energy and total impulse.

Since 1993, Snecma has had exclusive distribution rights in Europe for Fakel's thrusters. Highly reliable, they are used on a large number of Russian and Western satellites.



PPS®1350
World endurance record

The PPS®1350 plasma thruster was a key to the European Space Agency's SMART-1 lunar exploration mission. This thruster was developed by Snecma, with support from French space agency CNES. It features very high specific impulse and operational stability that meets even the draconian specifications of communications satellites. The PPS®1350 consumes five to six times less propellant than an equivalent chemical thruster.

While the Vulcain®2 develops nearly 130,000 kg of thrust for about ten minutes, the PPS®1350 develops just 8 grams of thrust – but it set a new world endurance record in 2004, operating for 5,000 hours while propelling SMART-1 to the Moon and into lunar orbit. This mission was a striking demonstration of the considerable advantages of plasma propulsion.

Tomorrow's plasma propulsion

We are also conducting advanced research on higher-thrust plasma engines (30 g and more), as well as exploring new engine concepts (dual stage plasma thrusters for instance). These concepts are designed to meet the growing requirements of tomorrow's larger communications satellites and interplanetary probes.

Ariane 5 ECA, Flight 167

Building foundations for the future

The space propulsion market is small but extremely demanding. By working on Ariane 5 upgrades and new-generation launchers, as well as continuing active research into new technologies, Snecma has maintained its position of technical excellence.

Our activities draw on a broad array of in-house skills, plus a number of scientific and technological partnerships that guarantee Europe's space expertise and competitiveness. In particular, Snecma works with CNES, ESA, industry and research organizations in France, Europe and around the world.

TPX, **a new-generation** turbopompe

For example, Snecma is working on a new-generation turbopump, dubbed TPX. Our aim is to make a Vulcain class turbopump, but with production costs cut in half by simplifying the architecture and reducing the parts count. To drive this turbopump, we are also working on a new gas generator with the same objectives. Built full-scale for Vulcain, the TPX will validate a number of technologies that could be used on many different types of engines.

Towards **reusable** launch vehicles

We are also working on propulsion system concepts for tomorrow's (partly or wholly) reusable launch vehicles. Alone or in partnership, we are studying demonstrators of staged combustion engines. Two of these projects are Veda, a cryogenic engine developing 200,000 kg of thrust, and Volga, an 400,000-kg-thrust engine fueled by liquid methane and oxygen; initial studies for this engine were performed in conjunction with Russian industry.

SMART-1 lunar exploration mission

Vinci® upper-stage engine

Services based on **technical expertise**

In addition to the design and production of propulsion systems, Snecma has developed very broad technical expertise, used to help operators during launches. Some of our specific areas of high-tech expertise for space operations include:

- technical assistance during launches (telemetry analysis, etc.)
- engine tests
- design studies and computation, analyses, reliability studies
- training
- ground equipment technical support (filling of tanks, emptying, decontamination, etc.).

Services for industry: extending our space expertise to **other sectors**

We also offer the expertise and resources developed for launchers and satellites to a number of companies in other industries. Our services cover five main areas:

- Testing: test stand engineering and hardware, test execution, instrument development and supply, consulting and training.
- Metrology: measurement system checks and calibration, instrument management, consulting and training.
- Laboratories: materials, chemistry, analysis, non-destructive testing, mechanical testing.
- Risk management: assistance, consulting, training.
- Production: design, methods, machining, special procedures, pipes, assembly, inspection and testing.

Drawing on our expertise in cryogenic hydrogen propellants, we are developing technologies for other industrial applications, such as fuel cells, incinerators and low-pressure pumps for the transfer of liquefied natural gas.

Snecma has developed a number of cutting-edge solutions for space, and because of this experience we can now help other industries develop powerful solutions tailored to their own requirements.

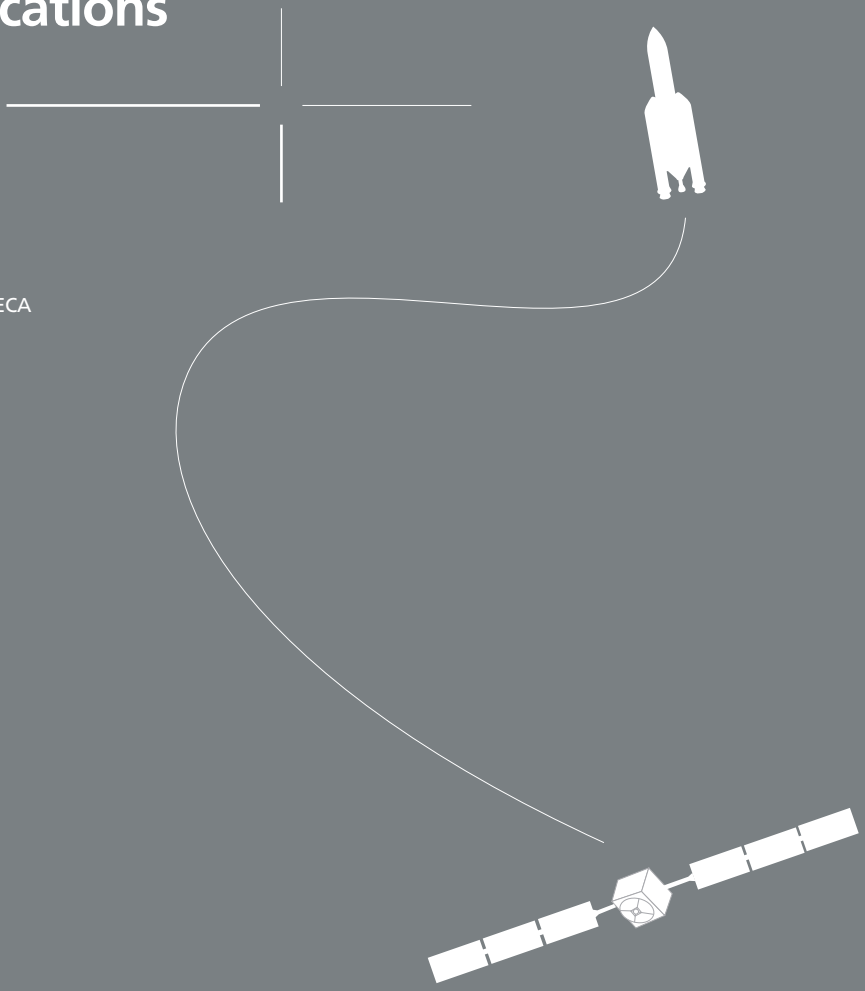
Applications

Vulcain®2
Ariane 5 ECA

HM7B
Ariane 1 to 5 ECA

Vinci®
Ariane 5 ECA

PPS®1350
SMART-1



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