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HERMES

Europe's Dream of Independent Manned Spaceflight

Luc van den Abeelen

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PRAXIS

Luc van den Abeelen
Hilversum, The Netherlands

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To Jaap Terweij
friend and mentor of all things spaceflight
and so much more

and Christian Lardier
friend and unsung hero of this book

Foreword by Jean-Jaques Dordain, ESA Director General 2003–2015

Hermes, a name having crossed a lot of centuries, a trademark of luxury, and a project which will stay unique in ESA, in Europe, and even more for all individuals and teams which were involved in it.

Unique in its ambitions, to the point that it is still difficult to make of Hermes a vehicle of the past or a vehicle of the future.

Unique in its fate, since Hermes is, to date, the only large ESA programme which was stopped before completion, for a mixture of good and bad reasons.

It was time therefore and a good thing that the legacy of this unique space programme could be preserved, for the benefit of future engineers and future transport projects. Thanks to the legacy, Hermes will have been a very useful programme, full of results and full of lessons learned.

Luc van den Abeelen has taken such legacy as a "mission", and he must be thanked both by "the Hermes generation" to have collected in this book the full history of their work and of their achievements and by the "next generation of engineers" to gain the benefits of these results and lessons learned to design the next vehicle and make it to fly for continuing to explore and to push the frontiers of knowledge.

As a matter of fact, Hermes was much more than just a crew transport vehicle; it was the central piece of the ambitions of Europe in the 1980s, at a time when Europe was so proud to have closed, in less than twenty years, the initial handicap of ten years compared to the two space powers of the 1960s, the USA and the USSR. Europe could talk to them as a credible partner, and Europe could at the same time continue to develop its independence. Hermes was therefore the central piece of the "second package deal" between the ESA Member States which included the development of Ariane 5, the launcher of Hermes, and the development of Columbus, made of a mixture of transatlantic cooperation with the Attached Pressurized Module (APM), part of the Space Station Freedom and of independence with the Man Tended Free Flyer (MTFF) and the Polar Platform (PPF), which were both planned to be serviced in orbit by Hermes.

By its design, Hermes was also much more than a transport vehicle; it was a very advanced winged vehicle, much more performant than a capsule and much more difficult than the US Space Shuttle. Performance and difficulties were a real challenge for researchers and engineers, attracting the best of them into the programme. I can say it; I was not one of them.

The programme started in the enthusiasm of all parties concerned: the ESA Member States which oversubscribed the programme at the start, the space agencies, notably ESA and CNES, which wanted to be in charge, the research centres, and industry—all wanted to be in! Bringing a lot of expertise but also some difficulties to organize. I still remember it very well, I was just arriving at ESA, in charge of the utilization of the Space Station, i.e. the customer of Hermes' capabilities, not easy to be listened to!

I have been marginally involved in the Hermes programme, in three successive steps, as the chair of the Coherence Task Force in charge of defining the necessary interfaces between Columbus and Hermes, then as the chair of the Maia project (a subscale demonstrator of Hermes) technical assessment, and finally, the preparation of the council at ministerial level held in 1991 and 1992 which were unfortunately the start of the end of Hermes.

Since then, Hermes has become a reference in ESA, a reference for lessons learned which are still alive more than 20 years later.

My involvement is therefore certainly not enough for me to be an actor but certainly enough for me to be an informed reader.

I am impressed by the work; I can find along the pages all what I knew about Hermes, which is always a reassuring sign of the quality of the work, but I have discovered much more that I did not know, which is always good about the interest of the work.

I am convinced that this book will become a reference for several generations not only of engineers but also of many who are just interested in progress in space and European cooperation.

Thank you Luc, I have learned a lot reading your book and I shall learn each time I shall open it. Your mission is a success!

Jean-Jaques Dordain
Former ESA Director General (2003–2015)

Acknowledgements

Writing this book happened mostly at my desktop computer, visualizing the mass of characters before me slowly turning into something that hopefully would make some sense. Or on my laptop, sitting at the coffee table, surrounded by notes, reminders, books, papers, and sometimes inch-thick printouts of documents, which were the results of digital quests.

It was a solitary business, but one in which I never felt quite alone as numerous people gracefully assisted me in finding materials, providing images, or just giving some much needed advice.

Realizing that my "thank you" here will never ever express the gratitude I feel towards those who have become part of my challenging project, I do feel the need to credit all involved.

First of all, I would like to thank Christian Lardier, without whom this book would not have been possible, introducing me to a number of key persons in the Hermes history.

A close second is Jaap Terweij, who first introduced me to the wonders of spaceflight all those years ago.

Thanks to those who gave access to their private archives: Marinus van Asten, Stephane Chenard, Philippe Coué, Matthias Gründer, Gerard van de Haar, Ed Hengeveld, Christian Lardier, Ron Miller, Rolf Schoevaart, Jaap Terweij, Michael Van, and Bert Vis.

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The artists: illustrators David Ducros and Sylvain Girard and model builder Jean-Marc Deschamps, who allowed me to use images of their magnificent creations.

In my contacts with industries and institutions, I was privileged to enjoy the cooperation of Arnaud Ribes at the Académie de l'Air et de l'Espace, Thierry Collin and Sandra Walther at Airbus Defence and Space, Yann Cochennec at Air & Cosmos, Philippe van Lierde and Roger Guigui at Airitage, and Claudia Hoyau at Arianespace; the VERAS drawings and photos are reproduced here with the kind permission of F. Maillot at ATMA and Gerard Leroy, David Ashford at Bristol Spaceplanes, Sandrine Cuomo and Peter Weiss at COMEX, Philippe Coué and Anne-Claire Bellot at Dassault Aviation, Pénélope Leyland at EPFL, Marc Lacoste at Herakles/Airbus Safran Launchers, Gherardo Bonini at the Historical Archives of the European Union, Christian Lardier at the Institut Francais d'Histoire de l'Espace (IFHE), Kiyo Arakawa at JAXA, Sarah Jeffery at Martin-Baker, Jörgen Olsson at the SSC Space Group, Chrystelle Dugimont and Francesca Metrangolo at Thales Alenia Space, Marie-Claire Coët and Jean Hommel at ONERA, Andreas Hauser at RUAG Schweiz AG, Ton van Ingen Schenau at the documentation centre of Ruimtevaart Museum—Aviodrome, and Victor Nikolaev for the Zvezda image.

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Hilversum, The Netherlands Luc van den Abeelen
June 2016

Contents

Introduction

The full-scale mock-up was an impressive one. Displayed proudly in front of the temporary ESA and CNES pavilions of the Paris Air Show at Le Bourget airport in 1991, Hermes certainly looked the part. Europe's spaceplane, launched on top of an Ariane 5 rocket, would enable ESA to begin an independent manned space programme. The vehicle would be a game changer for Europe and provide its space agency with the means to achieve activities in Earth orbit on a par with those of the US and Russian manned programmes.

But when the third Ariane 5, pencilled in years earlier to perform Hermes' first orbital test flight, thundered off from the launch pad in the humid jungle of French Guyana in 1998, it was carrying a modest capsule, the ARD, for a re-entry test instead of the compact winged spacecraft. Since the inception of the programme in 1985, the world had changed and ESA found itself cash-strapped and unable to bring the spaceplane to full maturity. And as a result, Hermes had been cancelled, the only major ESA project to have suffered such a fate.

At the time that Hermes was being adopted as an ESA programme, the future of manned spaceflight appeared to belong to winged vehicles only; the USA, Soviet Union, Germany, France, and Japan were flying or developing them. What appeared to be the advent of the golden age of the spaceplane would finally turn out to be the start of a only decade-long dream. Past 1995, most of these projects had been terminated with only the Space Shuttle continuing, to be replaced by capsules after its retirement in 2011.

Criticized by some to be too advanced a design and by others for not pushing the technological envelope enough, Hermes knew a very chequered history. Born in an era in which spaceplanes were expected to become commonplace and orbital manufacturing an economic certainty, Hermes started out as a purely French idea. Europe took its time to be convinced of the legitimacy of the choice for an independent manned space capability. And once started, the project was beset by various challenges. Some, it would turn out, too great to overcome.

National egos, strained relations between cooperating nations and industries, and difficulties in technical developments did not make for smooth sailing. But it seems that a small number of external events were deciding factors in Hermes' ultimate fate just as much. The loss of the US Space Shuttle Challenger, the fall of the Berlin wall, the reunification of Germany, and the subsequent collapse of the Soviet Union fundamentally changed the backdrop to the rationale for supporting an idea like Hermes. Besides these external events, the personalities of a few key figures in the programme and the management architecture of the project also played their part in both the rise and the ultimate abandonment of the further development of the spaceplane.

Although Europe appears to have overreached its abilities aiming for a reusable spaceplane, the project mobilized an impressive effort by ESA and Europe's institutions and industry in design and engineering, testing, computer simulation, manufacturing, and project management. Failing at the last hurdle even before the programme could really take off, only some structural test parts of Hermes were ever actually produced. In the end, the assembly halls already in place would never be the cradle for Europe's first manned spacecraft.

While the idea of European independence in manned space activities has receded into the background for at least the foreseeable future, Hermes still lives on in a number of technologies and current ESA projects. The experimental re-entry vehicle IXV performed a successful test flight, while Europe is sketching out the concept for PRIDE, an unmanned, reusable spaceplane that could perform diverse missions in low earth orbit. Also, the aerodynamic shape developed for Hermes has been appearing in a number of studies for suborbital vehicles.

Browsing through the 50-plus years of ESA's history, the Hermes programme seems largely forgotten today and is diminished to a footnote at best. And Hermes veterans, many of whom gave the best years of their careers to the programme, pass away, as increasing numbers of paper archives are discarded by industry and agencies.

There is a new generation of young people, potential students of science and technology, aspiring aerospace engineers, and prospective astronauts of future space missions who have never heard the story of Europe's intrepid small spacecraft.

All of which I considered to be a shame because of the scale of the undertaking, the passion and efforts exerted, and the fact that Hermes seemed so close to becoming a reality when it suddenly all ended.

I thought the story is worth remembering and telling, before the memories disappear for good with the slow but relentless passing of the years. Both to prevent repeating the mistakes of the past and to serve as an inspiration for the future. That is why I decided, when I discovered some four years ago that no single publication on the history of Hermes was available, to write one myself. I hope I have done justice to the efforts of the many engineers and managers in industry and at the agencies, politicians, scientists, and all others who at one time cared deeply for that little spaceplane called Hermes.

Chapter 1
Origins: Re-entry Vehicles and Orbital Factories (1946–1983)

If any European country was in a position to come up with a concept for a manned spacecraft in the 1970s, it was France. Mastering the technology of launching a craft into Earth orbit, re-entering and safely returning it to the Earth's surface had almost exclusively been the domain of the French aerospace industry. France had developed a domestic rocket and satellite industry and was considered by many to be the leader in aerospace matters in Europe, not least by France itself.

During the late 1950s and early 1960s, several re-entry vehicle concepts were the subject of studies by some of the major companies in the field. As this was at the start of the Cold War, most of these studies were, not surprisingly, of a military nature.

The companies Avions Marcel Dassault and SEREB (Societé pour l'Etude et la Realisation d'Engins Balistiques; Society for Study and Realization of Ballistic Devices, which would later be absorbed into Aerospatiale) studied re-entry vehicles that were to carry warheads. Forced by the 1967 United Nations' Outer Space Treaty that bans the on-orbit deployment of weapons of mass destruction, the military were considering reusable winged vehicles to deliver arms from space. In the end, the more conventional wingless re-entry vehicles were selected for operational use, providing a sound body of knowledge on high-temperature materials.

1.1 Rockets and Warheads

As a consequence of the Suez crisis, France decided in 1966 that it would no longer assign its forces to NATO and that it would withdraw from the integrated military structure. That led to a French decision to develop an indigenous nuclear strike force. A national knowledge base on rocket technology was already in place as France had started research into this technology shortly after the end of the Second World War, visiting Germany to inspect the V2 rocket, moving wind tunnels to

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French territory and hosting a small number of German engineers in France. The Laboratoire de Recherches Balistiques et Aérodynamiques (LRBA, Ballistic and Aerodynamic Research Laboratory) had been set up in 1946 with an initial goal of developing rockets with a military purpose.

In 1961, a program to develop a satellite launcher called Diamant was created under General De Gaulle. The Centre Nationale d'Etudes Spatiales (CNES, National Center for Space Studies) was formed a year later to manage space programmes and build up a French space industry. These initiatives resulted in the orbiting of the first French satellite, A1, also known as Asterix, in 1965. With that launch, France became the third nation to earn the distinction 'space power', after the Soviet Union and the United States [1]. With rocket technology available, the additional requirement was to develop re-entry vehicles, necessary to protect nuclear warheads during their dive into the dense layers of Earth's atmosphere after being launched on rockets. SEREB was responsible for providing the first French re-entry vehicle (RV), built by Sud Aviation in Courbevoie near Paris, initially using silica resin materials for thermal protection. Launched on a Saphir rocket from the Brigitte launch complex in Hammaguir (Algeria), the first RV performed a successful re-entry after a suborbital flight reaching an altitude of 60 km on March 29, 1966, the first in a series of six test flights (see Fig. 1.1). Later versions of the RV used carbon fiber and subsequently carbon-carbon as materials for the 'heat shield'.

In 1962, the French government had approached Avions Marcel Dassault to develop a ballistic missile on behalf of the State of Israel. That led to the MD 620 Jéricho project, aimed at transporting a warhead over a range of 500 km.

The first launch of the single-stage missile took place on February 1, 1965, in the Mediterranean Sea, from Levant Island. Tests on a dual-stage version in March 1966 proved successful. The MD 620 was France's first ballistic missile featuring an airborne digital computer [2]. Due to the full weapon embargo on Israel, the program was cancelled in January 1969. However, Dassault gained valuable experience in the aerodynamic and thermodynamic phenomena associated with missile flight of speeds up to Mach 6, as well as missile steering and inertial guidance.

Fig. 1.1 Saphir re-entry body exhibited at the Musee de l'air et de l'espace at Le Bourget Airport, Paris (photo by the author)

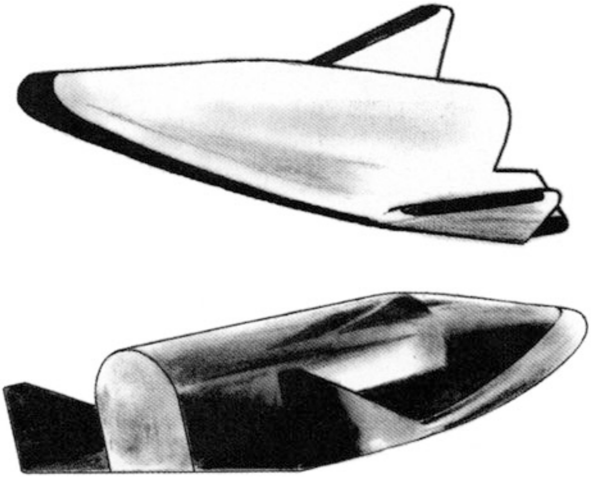

Fig. 1.2 Re-entry vehicles studied by ONERA in the early 1960s (courtesy Philippe Coué)

From 1961 onwards, research into the possible shapes of a hypersonic winged glider were performed at the long-term department of the Centre de Prospective et Evaluations (CPE: Prospects and Assessment Center of the French Minister of Research and Technology) and by a number of industrial parties (see Fig. 1.2).

At about the same time l'Office National d'Études et de Recherches Aérospatiales (ONERA: National Office for Aerospace Studies and Research) performed studies and tests at its wind tunnels. The facility of EDF in Fontenay played a key role in this research. It was set up with collaboration of American engineers who developed a similar installation for the US Air Force. The wind tunnel was intended for high-Mach research, producing a gas jet of 4000 °C and 1500 atm pressure, simulating conditions at Mach 16 to 18. The power consumption of this facility was immense, claiming the major part of electricity provided to the Paris region for 0.02 seconds during each test [4].

1.2 The Nord Aviation VERAS

In 1964 the Direction des Recherches et des Moyens d'Essais (Directorate of Research and Test Facilities) of the ministry of Defence began the VERAS programme; Véhicule Expérimental de Recherches Aérothermodynamiques et Structurales (Experimental Vehicle for Aerothermodynamic and Structural Research).

About a dozen organizations were involved in this effort to create a suborbital, non-reusable demonstrator to validate propulsion and advanced structure concepts. The vehicle was to be built using new materials, which would enable it to withstand the extremes of re-entry; about 30 minutes at temperatures around 1100 °C in a thermal flux of 100 kw/m^2.

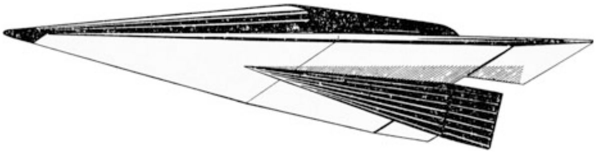

Fig. 1.3 General layout of the Nord Aviation VERAS (courtesy ATMA and Gérard Leroy)

By the middle of the 1960s, Nord Aviation started research into these technologies that could be used for winged craft servicing space stations, still in the distant future at this point. A more short-term application would be re-entry vehicles that would return to Earth featuring a mild g-load (in the case of manned systems) and necessary cross range (for accurate 'landing site' selection in the case of explosive devices). Characteristics that a simple capsule, shaped like the spherical Soviet Wostok or conical American Mercury, could not provide.

VERAS featured a high sweep delta wing carrying a cylindrical-conical body, similar in design to the US Air Force's ASSET (Aerothermodynamic/elastic Structural Systems Environmental Tests) vehicle first launched in 1963 (see Fig. 1.3). The wing extended into two elevons and was equipped with a ventral fin. To minimize thermal stresses and retain sufficient rigidity, the structure was designed in three levels. The skin, divided into 'tiles', was attached to a grid sub-structure resting freely on the load-bearing structure with a slide fastener. The nose consisted of a stack of pyrolytic graphite slices, nested into each other and fastened by tungsten plugs to resist bending and shifting. The vehicle weighed 1500 kg, including a ton of payload [3].

Nord Aviation started development of a test model, featuring a frame of nickel named Rene 41 (used in McDonnel/NASA Mercury capsules and the proposed North American/US Air Force X-15B and Boeing/US Air Force X-20 Dyna Soar vehicles) and skin of either molybdenum TZM or niobium P333 alloy, protected from oxidation by silicidation or chrome-aluminizing. For the load-bearing structure the Nord Aviation engineers envisaged using a corrugated metal laminate named Norsial. This type of 'metal sandwich' was already in use in the Diamant and Europa launchers, withstanding temperatures of over 1000 °C and in the secondary nozzles of the Olympus engines on Concorde.

Construction of the test model started in 1966 in Nord Aviation's A14 workshop in Chatillon outside Paris. It consisted of only the mid-section of the craft; the tail section, nosecone and wingtips were omitted. Several of these structures would bear the brunt of re-entry. The pyrolyzed carbon nose, leading edges and elevons made of Rene 41 were to be protected by pyrolyzed graphite felts while a gel-filled casing would protect the fuselage. In January 1967, results of the research into the viability of VERAS were presented to the French ministry of defence and Air Force.

An automatic test installation, purpose-built for VERAS at the Centre d'Essais Aérospatiaux de Toulouse (CEAT; Toulouse Aerospace Test Center) performed structural tests starting in the second semester of 1967, while ONERA performed automated vibration tests (see Fig. 1.4).

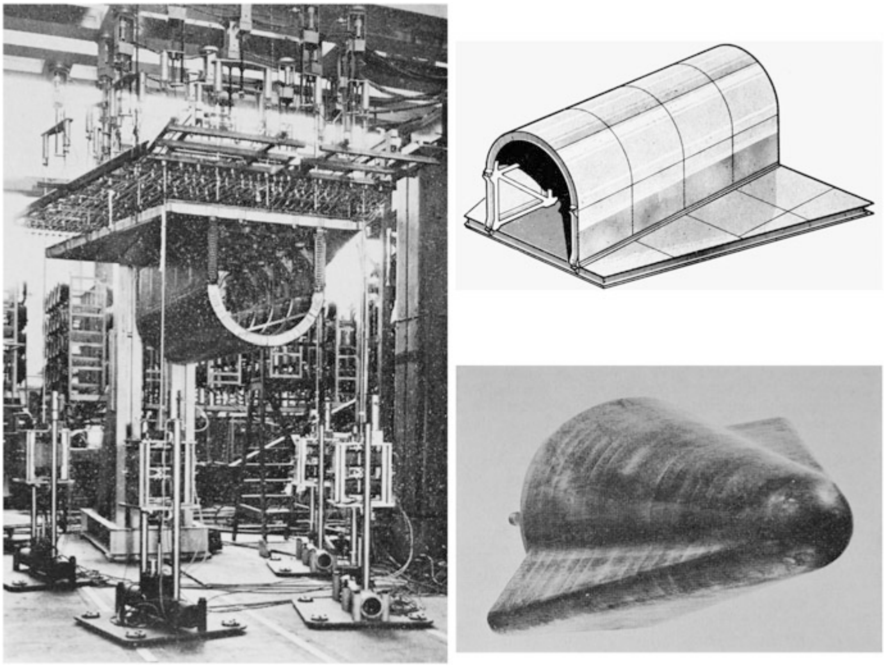

Fig. 1.4 The VERAS installed upside down in its testing rig; sketch of the test structure; close-up of the carbon nose (courtesy ATMA and Gérard Leroy)

Tests were continuing in 1968. Experiments in the fabrication of the P333 alloy of niobium, titanium, vanadium and zirconium, the manufacturing of sandwich panels and protection against oxidation of 27 by 24 cm experimental tiles, were completed [4].

A model of VERAS was exhibited at the Paris Air Show of 1969 [5]. Project officials expected flight tests of the 3-meter, 1-t vehicle to commence in late 1971 or early 1972 at the Centre d'Essais des Landes (CEL; Landes Test Centre) military rocket testing grounds near Biscarrosse, 65 km southwest of Bordeaux [6]. A ten-meter tall Emeraude launcher (basically the first stage of the French Diamant rocket) was proposed to launch VERAS on a ballistic trajectory that would provide all desired thermal loads on the vehicle during a 500 second, 40 km altitude, Mach 7.8 flight.

In the end, the use of VERAS as a prototype for a two-stage reusable launcher was considered to be too futuristic and the project was abandoned. Nevertheless, the VERAS exercise provided valuable knowledge to industry, such as new manufacturing processes in welding and assembly; experience in materials application; oxidation protection measures and greater knowledge of thermal protection [7].

1.3 The Dassault TAS

Eurospace, an association of European companies involved in space activities, established in 1961, began studies into a fully reusable launch system in 1962. It should be able to carry a three-ton payload into a 450-km polar orbit, return cargo to Earth, perform limited manoeuvres in space, launched either vertically or horizontally and land horizontally at conventionally sized airports. At the time, it was considered to be of importance to Europe to develop a capability for manned missions on reusable vehicles, both as a way to stimulate European space industry and to 'compete' with the US and Soviet space programs, neither of which were perceived to be developing reusable space systems at the time.

A number of French, German and British companies joined the initiative and several concepts were developed (see Fig. 1.5). The German ERNO design featured a booster carrying a spaceplane that bears a striking resemblance to the final Hermes concept of 1991 (see Fig. 1.6). A further spaceplane design resulting from the Eurospace studies was reportedly proposed to the European Launcher Development Organisation (ELDO) in 1966. It also featured the same general arrangement that the ultimate Hermes design would show, but it also included a separate module that contained the manoeuvring engines and other equipment that would be ejected before re-entry (see Fig. 1.7) [8]. During the Hermes development, this module would be 're-invented'.

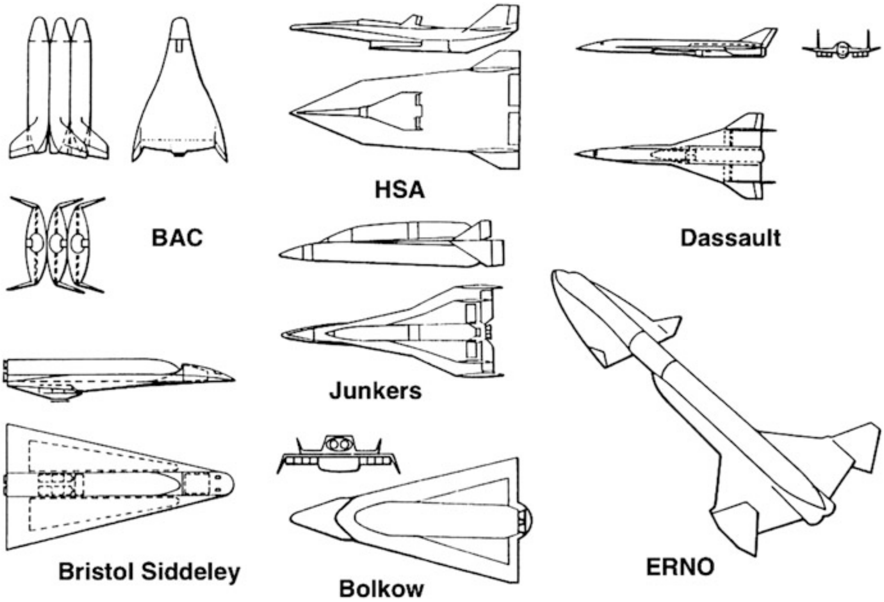

Fig. 1.5 Shuttle concepts studies by Eurospace (courtesy David Ashford)

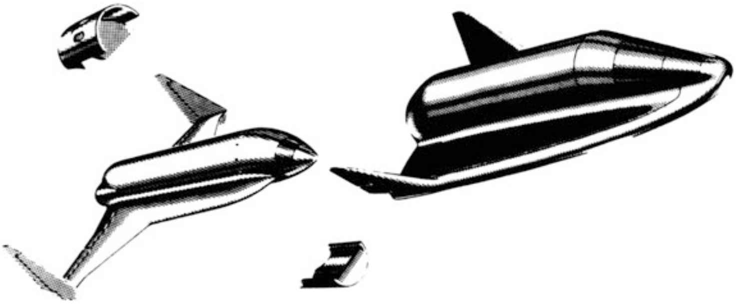

Fig. 1.6 1963 Concept for a two-stage shuttle by ERNO (© Airbus Defence and Space SAS)

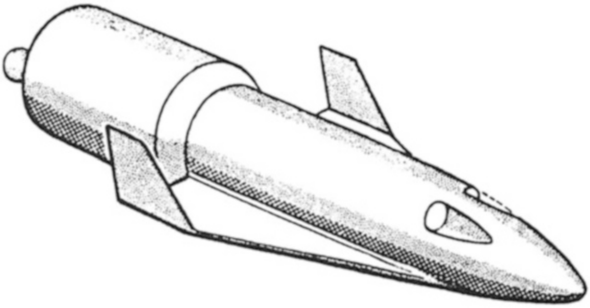

Fig. 1.7 ELDO shuttle study 1966 (courtesy Ron Miller)

For its part, the Dassault company proposed the Transporteur AéroSpatial (TAS; AeroSpace Transporter) in 1964. Inspired by the Mirage fighter prototypes, the MD-620 missile and advanced high-speed aircraft projects of the same company, TAS was a two stage to orbit system that came in two versions; fully and partially reusable.

The fully reusable version weighed in at 230 tons at take-off. A 162-ton launch vehicle (LV) would put the 68-ton orbital plane (OP) into low Earth orbit (LEO). The second version consisted of a 107-ton LV, launching a combination of a 32-ton booster and 11-ton OP; only the latter would enter a 200-km orbit.

Both concepts featured a large double delta wing carrier aircraft (the LV), equipped with six air-breathing engines. Looking like an enlarged, twin-tailed version of Concorde, it carried the OP underneath its belly (see Fig. 1.8).

The partially reusable version was studied extensively at Dassault's design office in Saint-Cloud near Paris, because of its lower development costs. This version used an expendable booster to carry the OP to orbit.

The LV's six turbofan engines were installed underneath the wing to take advantage of the air compression. Fuel tanks for these engines were located in the wings. The forward section of the fuselage was taken up by the liquid hydrogen tanks, while the liquid oxygen tank occupied the rear section. For the thermal

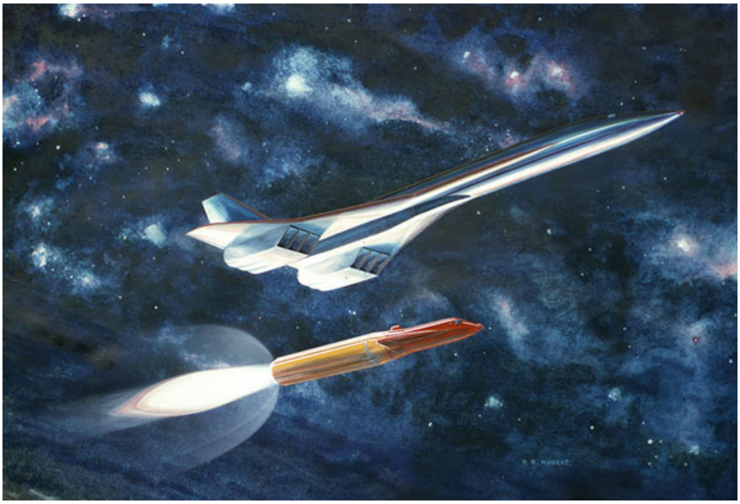

Fig. 1.8 Dassult's Transporteur AéroSpatial TAS 1964 (© Dassault Aviation)

protection of the LV during re-entry, a heat-insulated light alloy structure was foreseen for use in the most heat-exposed areas such as air intakes and the wings' leading edges. These parts were designed not to be part of the overall structure and easily removable for refurbishment after each flight.

The second stage of TAS consisted of the booster and OP in an inline configuration. The OP was a cold structure, equipped with an ablative thermal protection system. From the nose going aft, the OP contained the pressurized crew compartment, hydrogen and oxygen tanks, a cargo bay at the centre of gravity, auxiliary tanks and the engine compartment.

For landing, variable geometry wings were to be deployed while a very light turbojet would provide thrust during approach and landing. The OP was to touch down using a lightweight system of skids.

The crews of two for both LV and OP were provided with ejection seats for escape during emergencies.

A typical TAS mission would start with take off from a conventional airfield of the LV-OP combo, which would cruise for 300 km and orient itself for the desired orbital inclination. The air breathing engines would be operated until a speed of Mach 4.5 was reached.

The rocket stage would accelerate the combination while still attached to the carrier aircraft, it's engines fuelled from the tanks of the LV, igniting at Mach 4. Thrust levels would be restrained as not to exceed an acceleration of 3 g for crew comfort, until the combination reached Mach 6 at 40 km altitude. The booster and OP would separate from the LV, which would land at an airfield under propulsion of its engines. The booster engines would be re-ignited and accelerate the OP into orbit. After staging of the booster, the OP was to perform a rendezvous with the space station for servicing and cargo delivery.

Besides servicing space stations, TAS was aimed at performing Earth observation missions (for intelligence, meteorology etc.) using dedicated equipment located in the cargo bay; quick response launch operations; fast suborbital transport and automatic cargo launches. In the latter scenario, the OP would be replaced by a satellite or space station module [9].

Like VERAS, TAS never saw the light of day. However, the OP part of TAS would reappear in Dassault studies a decade later, when the company started work on a concept for a spaceplane that would become Hermes.

1.4 Bumerang and Orbiter

In what can be considered an encore to its participation in the Eurospace studies, ERNO became involved in Phase B studies of the US Space Shuttle. Building on their Eurospace work and a 1966 study of a two-stage spaceplane with the French SNECMA, ERNO had concentrated on detailed research into re-entry vehicles, building wind tunnels an performing tests in the subsonic to hypersonic speed ranges. This led to drop-tests of their LB 21 lifting body design using their Bumerang I and -II vehicles in 1971, development of computer codes for aerothermodynamic investigations and tests on re-usable thermal protection systems. In 1972, upon invitation by McDonnel-Douglas, ERNO performed both wind-tunnel tests and drop tests of models based on the American Orbiter MDC 050 design. This experience helped ERNO in proposing potential German or European participation in the development of the US Space Shuttle, with the vertical tail, payload door, nose section and wing structure being listed as candidates. Eventually, NASA's Space Shuttle was built without the use of European hardware in the orbiter: ESA's contribution to the project would be the Spacelab facility carried in the shuttle's payload bay [10, 11].

1.5 Spiral

At about the same time Dassault was working on TAS, Russia was secretly developing the similar, although smaller, Spiral system. A four turbofan-engined hypersonic launch aircraft would carry an expendable, two-stage rocket and orbital spaceplane on its back (see Fig. 1.9). The spaceplane would carry a single cosmonaut into orbit but lacked any cargo capability. It featured an escape pod and variable wings. At launch, during orbit and re-entry, the wings would be at a 60-degree angle, serving as vertical stabilizers. Once flying subsonic after re-entry, the wings would be lowered to a horizontal position [12].

The system was never fully developed, although manned drop tests of a full-scale spaceplane model were performed. Later unmanned versions (called BOR) were launched into orbit for re-entry tests as part of the Buran program [13].