Chapter 5
The Road Not Taken: CNES Decides Against Maia (1987)

Being ‘merely’ a scale model of Hermes, measuring a modest five meters in length, the proposed Maia demonstrator still represented a substantial spacecraft in its own right, and an important first for ESA. It would have been the first European spacecraft to return to Earth, flying hypersonically, withstanding the heat of re-entry and being guided to a ‘splashdown landing’. This would constitute something of a sub-programme to Hermes and that was exactly where some of the risk of doing Maia was hiding, in the view of a number of managers.

Proposing Hermes with Maia as a sub-programme might lead to a decision to approve only Maia at the next and crucially important The Hague Council Meeting at Ministerial Level planned for 1987, with a decision on Hermes itself postponed to some future date. This would be a favourable decision for industry, being given the chance to actually build and fly something in the short term. Dassault would be especially happy, as they would be the prime contractor for Maia and would be able to realise their entry into the ‘space club’. But it could mean years of continued uncertainty about the fate of the Hermes programme as a whole [1]. Moreover, should Maia be implemented, a failure to fly the vehicle successfully could potentially end the entire Hermes programme, some feared.

5.1 Maia Studies

Dassault had proposed the inclusion of a hypersonic demonstrator in the Hermes aerothermodynamic development plan, during the early definition phase of Hermes. In its 1985 proposal competing with Aerospatiale for main contractorship (see Chap. 2), Dassault had suggested including at least two 25% scale vehicles to perform two flights in the 1988–1989 timeframe and one in 1989 or 1991 [2] (see Fig. 5.1).

In the design of Hermes, two issues played a major role in conceiving Maia:
• The (lack of) availability of means for calculation and simulation that would permit designing Hermes, assuring sufficient safety on the first manned flight and eliminating any risk of encountering unforeseen aerodynamic and aerothermal problems.
• The question whether a Hermes concept designed under those conditions would meet CNES’ operational requirements.

In justifying the need for Maia, Dassault cited [3] some unexpected behaviour of the US Shuttle orbiter despite 75,000 hours of wind tunnel testing and digital simulations. In particular, during the first flight, the Shuttle’s body flap deflection needed to be twice what had been predicted in order to maintain proper trim during re-entry [4].

Towards the end of Phase B1 in 1986, Dassault and MBB performed a detailed definition of the concept, which was presented at the end of the same year to a CNES-appointed independent technical committee, chaired by ESA’s J. J. Dordain. Two models were foreseen: Maia-A would verify design tools and the overall spaceplane configuration, while Maia-B would validate the Hermes aerodynamic shape and thermal protection.

Initially, Maia was planned to share a launch on Ariane 4 with the SPOT 3 Earth observation satellite, leading to choice of a 23% scale model, as it would have to fit in the bottom half of Ariane’s fairing. This proved to provide an insufficient internal volume to accommodate the necessary equipment, which would have to be specifically designed for Maia, driving up cost and extending the lead-time.

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**Fig. 5.1** Systems of the Maia scaled demonstrator (© Dassault Aviation)
After its test flight, Maia would be recovered at sea, preferable not far from Kourou. A parachute system and floatation devices would ensure that the vehicle would splash down and remain in a proper condition to be recovered, with the aim of gaining access to the flight data collected during re-entry which were to be recorded by on-board equipment.

The shared launch with SPOT would put the 618-kg Maia into a 800 by 800 km orbit at 98.6\(^\circ\) inclination, requiring a substantial cross-range of 2900 km in order to return to Kourou, while providing insufficient coverage by ground stations. It would also entail a launch at night, complicating the ocean recovery that would take place in darkness.

A simplified Maia was subsequently considered, based on the new 5L3 Hermes shape, which featured a shortening of the spaceplane’s fuselage by 1.82 m compared to the previous Hermes 5D shape. This version of Maia would not be recoverable, which would delete the need for computer memories for registration of flight data, but did require a real-time transmission and reception of data. It would also prevent an examination of the effects on the thermal protection system used on Maia.

Studies continued on the basis of a dedicated Ariane 4 launch and a 33 \% scale Maia, which prevented the SPOT restraints with regards to the cross range requirements and launch and recuperation at night and provided better visibility of ground stations. Further refinement of the shape, to be scaled between 30 and 33 \% would be performed during Phase B2, partly driven by the aim of reducing costs.

Maia would also employ existing or minimally modified equipment to minimise both costs and development time and make maximum use of proven technologies.

The vehicle would perform 2 to 2.5-hour missions, being activated 40 minutes before launch, flying in a 400-km orbit and returning to Earth covering 120 minutes and spending 60 minutes at sea waiting for recovery. This would facilitate the collection of data and examination of the vehicle’s materials, but would require a precision landing.

Fuel tanks for the de-orbit burn would be carried on the top aft end of the fuselage, ejected after the burn before re-entry. A solid-fuel alternative was also studied.

The 5 m long vehicle, weighing between 1280 and 1440 kg would be equipped with a large number of sensors: 180–200 for temperature readings, 15–20 pressure sensors, 15–20 strain gauges, and 70–80 for measurements of spaceplane and systems parameters [5]. A device featuring a sliding weight would enable variation of Maia’s Centre of Gravity.

Data would be transmitted to the ground during the flight, with a partial backup consisting of three on-board computers memories [3].

Maia studies were completed in November 1986. The five main conclusions of the CNES Maia Evaluation Commission, lead by Jean-Jacques Dordain, were to:

- continue ground-based tests necessary for the qualification of hot, cold and transparent structures
- make maximum use of tests of the US Shuttle orbiter
• make maximum use of the experience gained by French ballistic missile programs
• improve knowledge of the atmosphere
• improve ground-based aerothermodynamic activities: enlist the best experts, develop wind tunnels at the highest possible enthalpies, improve measuring equipment

CNES approved of these recommendations and their implementation was underway by the first quarter of 1987. However, if Maia was to have an effect on the aerodynamic design of Hermes or influence the choice of materials for its thermal protection system, a Maia flight was required by 1991 if a Hermes first flight was to take place in 1996. This was a very tight requirement.

Also, Dassault and MBB had proposed to use titanium for the Hermes main structure, with its hottest parts protected by 20-mm thick tiles. This was considered to be a radically different solution compared with the materials planned for Hermes and thus not very comparable to or representative of the actual spaceplane. Some of the avionics and power plants would be obtained from the US as these were not available from Europe in time. This would need internal agreement from ESA member countries, as no industrial return would result from such an investment.

Another point CNES made against Maia was the fact that it would only partially represent a flight of Hermes. Because of its smaller size, heating of Maia during re-entry would be different and atmospheric phenomena would likely have a different effect as well. Consequently, results from Maia might remain ambiguous and inconclusive and the possibility existed that the situation regarding data on aerodynamic design constraints for Hermes would be no different after having flown Maia, CNES maintained (see Fig. 5.2). Also, a potential loss of Maia would have important implications on the progress of the Hermes program, possibly including it being called into question.

CNES could not justify the cost, schedule and other impacts of Maia on the Hermes programme. The cost of Maia, including launch, a spare model and flight analysis, was estimated by industry to amount to 250 MAU, although it was reported to be as high as 400 MAU by Air & Cosmos [6]. The expenditure would occur the 1988–1989 period, when the funding envelope would be most critical and the test vehicle would compete with the initial technology effort and subsystems development. Maia would also drain industrial resources, particularly in aerodynamics.

Performing Hermes’ first flight in an unmanned mode was considered by CNES to be a far better option as an alternative to Maia. Compared to the 250 MAU Maia, the cost of perfecting the automatic pilot would amount to around 40 MAU, required only towards the end of the program, after the peak expenditure for Hermes, which was expected in 1995 at this point. Testing the autopilot would add around ten flights to the plan of atmospheric tests, five of which had been planned earlier.

In May 1987, CNES decided to continue Hermes development without Maia [7], stating: “This strategy solves well the safety of the first manned flight. It helps to focus technical and budgetary efforts on the Hermes technologies from the startup of the program, avoiding the risk of separation or a split between the project of a
reduced scale model and the Hermes project itself. Just as much as the alternative, it requires investing in the means of calculation and aerothermodynamic tests, as well as to resort to the operational [results of] 24 flights of the US orbiter. It minimizes the cost to completion of the program, which it is feared will increase compared to the initial estimates” [8].

Fig. 5.2 Maia would have added results from an actual test flight to computational data being used to establish Hermes’ aerodynamic characteristics (© ONERA The French Aerospace Lab)
After reviewing CNES’ assessment of the Maia studies, ESA formulated its own main conclusions:

- If Maia is not developed, crew safety dictates that the first Hermes flight be unmanned.
- Regardless of a go/no-go for Maia, research and development in hypersonics and thermal protection materials, wind tunnel performance, knowledge of upper atmosphere and analysis of flight data from other programmes must improve.
- Maia cannot be considered as a demonstrator of Hermes shape; Maia-B is of lesser interest than Maia-A as its results would come too late.
- Instrumentation and flight result analysis could be improved.

And while broadly agreeing with the CNES advisory committee’s conclusions, ESA noted a number of remarks.

- The choice was not between either Maia or a first unmanned flight. A Hermes mission without crew would not bring any knowledge that could be used in time for the design of Hermes.
- Rather than a scaled-down demonstrator, Maia should be defined as a test bed to validate numerical models and wind tunnel test data. This approach had not been studied enough.
- The CNES-proposed extensive wind tunnel development programme would enable repetitive and well-instrumented ground tests, but these would not simulate all key parameters simultaneously as in actual test flight conditions.
- Just how much information could be obtained from a single Maia flight should be evaluated. In comparison, the US was able to use data from hundreds of flights by the X-15, ASSET (see Fig. 5.3) and PRIME test vehicles in preparation for the Shuttle and the Russians built up a comparable database resulting from the flights of their BOR vehicles.

![Fig. 5.3 The American ASSET demonstrator used for re-entry tests (US Air Force)](image)
ESA requested an additional three-month study from CNES in order to answer what results could be obtained from a single Maia test vehicle flight; how these results could be used to validate or improve Hermes aerodynamic design tools and how the results would compare with data that could be collected from ground-based experiments [9].

5.2 The VEH

The resulting study led by Aerospatiale still supported a single flight of a Vehicle d’Essai Hypersonique (VEH: Hypersonic Test Vehicle; the vehicle was no longer called Maia); a series of four to five flights would not fit with Hermes’ development. The study concluded that although the flight would be useful, its necessity for the Hermes program could not be demonstrated. It also stated that it would be unlikely for major aerodynamic problems to appear during the first unmanned Hermes flight if computational fluid dynamics (CFD) efforts would be intensified and coordinated. The study concluded that the strategy not to include a VEH flight was considered safe for the first Hermes automatic flight, adding that this mission would in fact represent an excellent VEH flight [10].

The Hermes Programme File that was prepared for the The Hague Council Meeting at Ministerial Level in 1987 did contain the Dassault-MBB Maia proposal [11] but it was not taken up by CNES. If Hermes were to receive the formal go-ahead at The Hague, its development would forego any prototype or precursor vehicle, having to validate its aerodynamic design as well as its thermal protection system during actual orbital flight: i.e. while performing its first unmanned mission. This decision drew mixed reactions from several Hermes veterans. CNES Hermes Programme Manager Philippe Couillard was convinced that a ‘sub-project’ such as Maia would disperse efforts and that it would be more economical to concentrate on the actual product: the Hermes spaceplane itself. Couillard considered the accelerated realisation of the hot wind tunnel Fauga and the high-enthalpy facility at Göttingen as a positive spin-off from Maia [1]. Indeed, a 22.18-MAU investment in wind tunnels and aerothermodynamic development and test facilities was projected later in 1987 [12].

Others consider the cancellation of Maia to be a major missed opportunity that not only undermined Hermes eventual chances for success, but also set back European knowledge base on re-entry, lasting until today. According to ESA Hermes Spaceplane System engineer Philippe Watillon, the fear of a Maia failure endangering the Hermes programme was a sign that transparency and confidence at political level did not exist. “It would have been better to experience difficulties on the precursor than later on the full-scale vehicle. Maia would have been a very useful exercise” [13]. Jean Gérard Roussel, Hermes veteran at Dassault at the time, also thought Maia should have flown: “Maia was a major issue for the program. Had it failed, it would have been very bad. If it had been a success, the result of the
programme would have been completely different” [14]. Hermes Programme Manager at MBB Christoph Hohage agrees: “Europe would be on a completely different track talking about re-entry vehicles than where we are today. I would consider Hermes a successful episode in my professional life if we had built and succeeded with a small number of Maia flights” [15].

The 2015 flight of IXV (see Chap. 18) eventually carried out a mission that can be considered very similar to what Maia could have done, more than a quarter century earlier.

5.3 Hermes Preparatory Programme

Meanwhile, the Hermes Preparatory Programme had officially started on November 30th, 1986 and was announced in a joint press release by CNES and ESA on December 4th. The eight-month programme was valued at 57 MAU and CNES had entered into a total of 800 consultations with 210 European and Canadian firms for Hermes, expecting around 100 firms to eventually participate in the construction of the spaceplane [16]. France had committed to a share of 40%, while Germany agreed to a 30% contribution, but stipulated the condition of receiving prime systems contracts if Hermes would get the go-ahead at the The Hague Council in mid-1987 [17].

In another attempt to strengthen Germany’s position in anticipation of The Hague, Riesenhuber urged five German industrials to set up an industrial group in order to represent themselves better in the Hermes project. To be called Hermes GmbH, the group would unite MBB-ERNO, Dornier System, ANT, AEG and MAN. While details were yet to be worked out, by February, MBB’s Ernst Högenauer and Manfred Holstein from Dornier had already been appointed directors [18]. The joint venture would eventually be named Deutsche Hermes. Such a move was a wise decision. The Germans wanted to participate in the Hermes programme on an equal footing, but already early on sensed that the French were determined to remain in the lead. Ernst Högenauer, deputy managing director of the MBB Space System Group recounted how the French had indicated to him that a German participation in Hermes should remain limited to 20 to 15%. France did not want a larger German share, in order to prevent them from gaining insight into the system [19].

5.4 Rising Costs Across the Board

In February 1987, ESA released a new cost estimate of the agency’s long-term plan for the years 1987–2000. It replaced the previous plan for 1985–1995, which had been approved at the 1985 ministerial Council meeting.

The new version for the first time included the operational costs of the new transportation systems and orbital infrastructure: Ariane 5, Hermes and Columbus.
Certainly a more realistic estimate, it would also prove to be one of the major problems besetting the spaceplane project.

Close to 30,000 MAU would be needed during the fourteen-year period stretching from 1987 to 2000, with an annual budget reaching 2000 MAU in 1990 and maximising at 2400 MAU for the years 1992–1994. The previous plan had been based on the estimate of an annual 1396 MAU, which in itself represented a 70% increase over earlier budgets. Altogether, the planned ESA annual spending had jumped some 90% between early 1985 and 1987. Still, France maintained that it would be unrealistic to assume that Europe could engage in a manned spaceflight programme without disposing of the necessary financials resources. For that reason, France opposed any capping of the annual budgets, also considering that would go against the spirit of the ESA convention establishing the principle of optional programmes: financing them according to the ambitions and the means of participants. In contrast, the UK was in favour of adhering to the 1750 MAU financial envelope agreed on in Rome as a maximum and did not want to exceed that by more than 20% [20].

5.5 The Hague Delayed

ESA’s annual budget was not the only problem facing the agency. By mid-March 1987, it had to put off the ministerial conference planned for June 22nd and 23rd until October or November, as requested by several member states, France among them. It meant prolonging the preparatory phases of Columbus, Ariane 5 and Hermes, and providing funding for the additional period, defined as Phase B3 for programme planning purposes. For Ariane 5 alone, an extension until the end of December 1987 meant an extra expenditure of some 293 MAU.

Apart from ESA’s budget worries, reasons for the delay of the next council meeting were that the programme files for ESA’s main new programmes had not been completed yet and negotiations with NASA on participation in the Space Station had been delayed because of differences between ESA and NASA about access to and utilisation of the orbital facility. A substantial projected cost growth for the station from $8000 million (8300 MAU) to $21,000 million (22,000 MAU) also gave rise to reflection and revision of the Columbus programme [21].

5.6 Revised Ariane 5-Hermes Baseline Configuration

Hermes’ mass for an MTFF servicing mission, based on July 1986 industrial data, had been estimated to be 18,000 kg. The cargo requirement for MTFF was estimated at 2250 kg to be carried up and down every six months, assuming an MTFF lifetime of 30 years. Hermes would deliver the cargo requiring a pressurized environment inside a logistics module, weighing some 1100 kg. For transfer of
the cargo inside, Hermes would berth the MTFF and connect the logistics module to
the facility, using the HERA manipulator (see Fig. 5.4).

The first Hermes-Ariane 5 launch had initially been planned for the end of 1996.
The existence of a single launcher version for all missions was considered to be a
must, as it would provide the manned mission with full benefit from the experience
acquired and the reliability demonstrated by the unmanned missions. ESA’s plan-
ning assumed at this time there would be seven or eight unmanned Ariane 5 mis-
sons prior to the first Hermes-Ariane 5 launch.

Detailed definition of the Hermes baseline concept had started in mid-1986 and
led to reappraisal of the initial design. Improved analytical models, combined with
a better evaluation of flight loads led to an increase of the structural mass and
redesign of the wings and Ariane interface. The calculation of heat flux and
temperatures during re-entry resulted in an increased thickness of the thermal
protection surfaces. At subsystem level, more accurate mass estimates were
obtained, which exceeded initial allocations in a number of cases. Improvements
and re-evaluation of equipment needed for the internal accommodations were
made. All these changes led to an increase in basic spaceplane mass of around
3.5 tons. As a result the basic spaceplane mass of 11,855 kg calculated in July 1986
had increased to 15,268 kg in December, including crew and consumables. To
arrive at the Hermes launch mass, a 2.3 t design margin should be added: 1.5 t for
the projected rescue system, 4.55 ton for a MTFF payload and 1.5 t for fuel. The
resulting 25,118 kg Hermes far exceeded the 18,600 kg capability of Ariane 5 at this
point. In March 1986, launch mass for Hermes had been put at nearly 17 t which
shot up to around 26 t only nine months later. Both its actual mass and its growth
tendency were cause for three weight-reduction measures:

- maximum upgrading of Ariane 5 performance without affecting its early avail-
  ability or competitiveness
- reduction of gross payload without significant reduction of net payload
- reduction of spaceplane mass to acceptable level, maintaining adequate margin
  for future development

Fig. 5.4 Design for the logistics module for MTFF internal servicing (ESA)
Studies showed that a rescue system consisting of large extractor rockets mounted on the adaptor between Hermes and the Ariane 5 booster was not the optimum solution from a safety point of view. Hermes, like most delta-winged planes would most likely not survive ditching at sea. It also led to an increased spaceplane mass. At this point, a jettisonable cabin seemed to be a more attractive alternative. In fact, it would entail separating the entire front section of the spaceplane, which would descend under parachutes into the ocean for subsequent crew recovery.

To cope with the increased demand in capability, five adapted versions of Ariane 5 were studied, all with both more powerful cryogenic main stage and boosters. Two of those alternatives featured two HM-60 engines in the first stage. However, these proved too expensive for commercial missions and the idea went against the ‘one-version-Ariane 5-only’ philosophy adopted by ESA. Finally, the revised Ariane 5 baseline featured a H155 central stage and two P230 boosters, containing an extra 40 tons of solid fuel in each booster and 15 tons of liquid fuels in the cryogenic stage, respectively.

5.7 Hermes 5M2

By February 1987, the new Hermes 5M2 baseline design, as described in Table 5.1, had deleted the open, unpressurized cargo bay, which had been replaced by a closed cargo hold (see, Fig. 5.5). This would:

- reduce the mass overhead, allowing deletion of the logistics module
- reduce spaceplane dimensions and structural mass, but retaining sufficient payload volume
- increase flexibility in positioning of the centre of gravity
- allow the installation of a NASA-compatible docking interface

Although the open cargo bay had been rejected, the two doors originally intended to close off the payload section were retained. These would now carry an 11.75-m² radiator each, while two additional 9.25-m² fixed heat rejecting panels were to be installed on the top of the cabin. The manipulator and high-gain antenna would be carried between the radiator sets during launch and re-entry.

The total payload capability in the new baseline design went down from 4450 kg to 3000 kg. However, 450 kg was saved by the deletion of refuelling tanks; the MTFF would now receive fuel pumped directly from Hermes tanks.

The spaceplane featured seven aerodynamic control surfaces; four elevons: one upper and one lower at the trailing edge of each wing, with the upper one deflecting 18° up, 27° down and the lower one deflecting 20° up, 25° down; two winglet rudders, deflecting 40° out, 20° in and one body flap, deflecting 27° down.

Although in a fair number of 5M2 drawings, models and artist’s impressions, the spaceplane’s flight deck appears to be equipped with only two cockpit windows, presumably as a weight-cutting measure, it appears that this particular layout was never officially considered at a technical level (see Fig. 5.6).
Table 5.1  Hermes 5M2 characteristics

<table>
<thead>
<tr>
<th>Dimensions</th>
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<tbody>
<tr>
<td>Length</td>
<td>15.43 m</td>
</tr>
<tr>
<td>Fuselage height</td>
<td>3.4 m</td>
</tr>
<tr>
<td>Wing span</td>
<td>10.07 m</td>
</tr>
<tr>
<td>Projected wing area</td>
<td>85.6 m²</td>
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<tr>
<td>Wing reference area</td>
<td>73.0 m²</td>
</tr>
<tr>
<td>Wing leading edge sweep</td>
<td>73.5°</td>
</tr>
<tr>
<td>Wing aspect ratio</td>
<td>1.18</td>
</tr>
<tr>
<td>Vehicle height on extended gear</td>
<td>5.10 m</td>
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<tr>
<td>Landing gear track</td>
<td>3.9 m</td>
</tr>
<tr>
<td>Landing gear wheelbase</td>
<td>10.2 m</td>
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<table>
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<th>Mass</th>
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<tr>
<td>Basic empty mass</td>
<td>15,030 kg</td>
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<tr>
<td>Empty operating mass</td>
<td>17,153 kg</td>
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<tr>
<td>Mass with prop and docking unit</td>
<td>18,288 kg</td>
</tr>
<tr>
<td>In orbit mass</td>
<td>21,288 kg, including 2.6 t margin</td>
</tr>
<tr>
<td>Normal re-entry mass</td>
<td>17,500 kg</td>
</tr>
<tr>
<td>Emergency re-entry mass</td>
<td>21,200 kg</td>
</tr>
<tr>
<td>Service life</td>
<td>15 years or 30 orbital missions</td>
</tr>
<tr>
<td>Orbit</td>
<td>463 km/28.5° nominal</td>
</tr>
<tr>
<td>Mission duration</td>
<td>6 days servicing plus 5 days rendezvous/re-entry/margin</td>
</tr>
<tr>
<td>Crew</td>
<td>3 crew (under review)</td>
</tr>
<tr>
<td>Operations</td>
<td>1 rendezvous, 1 direct docking/berthing, 1 fuel transfer</td>
</tr>
<tr>
<td>Payload</td>
<td>3 tons cargo of which 300–400 kg fuel in Hermes tanks, 18 m³ available for payload</td>
</tr>
<tr>
<td>IVA</td>
<td>8 hours × 3 crew per day</td>
</tr>
<tr>
<td>EVA</td>
<td>2 EVA for 2 crew, max 6 hours</td>
</tr>
<tr>
<td>HERA</td>
<td>Supports berthing Eureca, EVA and ORU transfer</td>
</tr>
<tr>
<td>Airlock</td>
<td>Capable of 2 EVA cycles</td>
</tr>
<tr>
<td>Energy</td>
<td>50 kWh to cargo, 4 kWh to Hermes</td>
</tr>
</tbody>
</table>

5.7.1 Internal Layout

The 5M2 spaceplane constituted five major sections (see Fig. 5.7 and 5.8):

Nose
including fuselage structure with TPS, from landing gear wheel, attitude control thrusters and two propellant tanks

Front Fuselage
containing the Crew Escape Module (CEM, see Chap. 23), featuring the CEM structure, windows, CEM TPS, Crew Escape Module Electrical Subsystem
(CEMES) and ejection booster(s), three seats, cockpit installations, part of the ECLSS. The rest of this fuselage section was taken up by two hydrogen tanks for the fuel cells, four nitrogen tanks, a floating device for the CEM, a rogue parachute, two extractors and three main parachutes.

**Central Fuselage**
containing the pressurised payload bay and living quarters, the latter containing the larger part of the ECLSS: O\textsubscript{2}/N\textsubscript{2} control, water pumps and container, condenser and water separator, fans, lithium cartridges and toilet, and oxygen and nitrogen storage
Fig. 5.6 The Hermes 5M2 configuration did no longer include an open cargo bay (© CNES-ESA/ Illustration David Ducros)

Fig. 5.7 Structural components of the Hermes 5M2 configuration (© Airbus Defence and Space SAS)
tanks for delivery to the station. The living quarters connected with hatches to the CEM at the front and the payload bay at the rear.

The manipulator arm (see Chap. 18) and High Gain antenna (HGA) were installed on top of the pressurised section, under the deployable radiators inside the fuselage doors. The top of the fuselage would also be covered by freon radiators of the thermal control subsystem, totaling some 42 m².

**Rear Fuselage**

containing the airlock, 340 kg docking unit and ECLSS components required for EVA and two EVA suits (see Fig. 5.9). Also tanks for helium, N₂O₄, waste water, NH₃, APU water and oxygen for fuel cells and ECLSS. The rest of the volume taken up by the water evaporator, inertial units and star sensors, lithium batteries with cold plate, fuel cells with heat exchanger, freon pumps, body flap actuators, NH₃ and APU boilers, APU’s and accumulators.

On the exterior, two thruster packages were installed in smoothed pods, for attitude and orbit control, each containing five bi-propellant 10-N thrusters, eight bi-propellant 400-N thrusters and eight cold gas thrusters. The body flap connected to the lower rear of this section.

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**Fig. 5.8** Internal layout of Hermes 5M2 (© Airbus Defence and Space SAS)
Wings
consisting of the wing structures and TPS, and containing the split elevon/airbrakes, winglets with rudders and actuators and landing gear installed mid-wing close to the fuselage connection.

Hermes’ prime structure would be made of carbon-fibre reinforced plastic (CFRP), a composite which would minimize vehicle mass. The CEM would feature a titanium super plastic formed, diffusion bonded (SPFDB) structure and the airlock would use either an aluminium alloy or CFRP.

The elements of the spaceplane that would face the most extreme heating effects of re-entry represented Hermes’ hot structure: the nose cap, wing leading edge, winglets and control surfaces. The material used here would be silicon carbide-silicon carbide (SiC-SiC) and carbon-silicon carbide (C-SiC) or carbon-carbon (C-C) for the hottest regions. The TPS would include Rigid External Insulation (REI) in the shape of shingles containing Internal Multilayer Insulation (IMI) for the forward fuselage and underside of the vehicle, and Flexible External Insulation (FEI) for the top of the fuselage and wings (see Chap. 20).

Aerospatiale’s Hermes Project manager Bernard Deloffre reiterated that Hermes would use the best of the technologies available, but that meant the technologies should be “locked in by 1988 or 1989 if we want to fly in 1995 or 1996” [22].

Payload capability was defined as 3000 kg in 16 m$^3$, including 300 kg of propellant for station refueling. Cargo would be transferred to the MTFF through the airlock in normal docked mode. ORU’s for the MTFF Resource Module (RM) would be transferred from the depressurised airlock using the robot arm, as Hermes would be berthed to the MTFF. The ORU would either be installed on the RM or temporarily stored on a support mounted on top of the Hermes fuselage. Payload mass at re-entry was put at 1500 kg.
Hermes was baselined for an eleven-day orbital mission with docking to MTFF (see Fig. 5.10), with a one-day margin, depending on its own resources. An extension to 28 days would be possible by using power and life support from the MTFF. The spaceplane was required to attain a 2000 km cross-range capability, based on the various landing sites under consideration and the maximum time required for completing an emergency re-entry.

5.7.2 Hermes Propulsion Module (HPM)

This propulsion stage consisted of the adapter skirt between the Ariane 5 and the spaceplane and contained tanks for the monomethyl hydrazine (MMH) and nitrogen tetroxyde (N₂O₄ or MON) propellants, a thrust frame with two swivelled 30 kN thrusters and associated helium bottles for pressurisation and sequencing and vector control electronics. The HPM would provide an additional 750 m/s velocity increase to Hermes after burnout of the Ariane 5 central core. It would remain attached to the spaceplane for the initial phase of the mission, correcting the trajectory during the passing period in preparation for the rendezvous with the MTFF and the subsequent circularisation of the orbit by performing another 104 m/s boost.

The module measured 4.6 m high with a 5.4 m diameter at the Ariane interface point and had a dry mass of 1148 kg. It would carry around 7 t in propellants [23] (see Fig. 5.11).
5.8 Hermes and Ariane 5

The new required Ariane 5 launch performance was put at 21,000 kg and a gross MTFF servicing cargo for Hermes at 3000 kg. For a final mass allocation, large technological uncertainties of the Hermes project had to be taken into account at this point in the development. Especially in the areas of structure, thermal protection, electrical distribution and rescue systems implementation, which could lead to a mass increase of 1 to 2 tons. Also, it was usual practice in aircraft industry to consider a 20 % margin in a new development. For cost and schedule reasons, it was needed to freeze irreversibly the Ariane 5 performance and Columbus servicing payload at this point.

The resulting required Hermes spaceplane mass is listed in Table 5.2.

In order to meet this limit, some drastic sacrifices were needed. A 5 % reduction of the fuselage dimensions, a reduction of the nominal crew size from four to three, a redefinition of the propulsion system, simplification of a number of electrical systems and the deletion of the cargo bay doors all contributed to reaching the mass goal.

A further improvement in the Ariane 5 systems was first considered at this point: a transfer stage to transport heavy, non-delicate cargo such as propellants to the MTFF or other orbital destinations. An upgraded L5 stage equipped with a payload cargo bay could take five to ten tons of fuel to the MTFF or ISS, or potentially visit

Fig. 5.11 General view of the Hermes Propulsion Module (HPM) (© Airbus Defence and Space SAS)
both on a single servicing mission. Further studies into this Ariane Transfer Stage concept were planned at this point, although not considered very urgent, provided the MTFF servicing by Hermes proved feasible. Eventually, this concept would lead to the successful but relatively short-lived series of ATV vehicles that services the International Space Station between 2008 and 2015 (see Chap. 17) [24].

Despite both the Ariane 5 and Hermes configurations experiencing drastic changes, the first Hermes contracts had been awarded to European industry. MBB had been contracted for work on propulsion; Matra for functional electronics; Etca for on-board power; Dornier for fuel cells and environmental control and life support; Dassault for thermal protection and atmospheric flight guidance and control; Fokker for the manipulator system; Aerialia for thermal control; ANT for data acquisition and communications; Aerospaziale for on-board software and Casa and Sener for work on the airlock [25].

Around April 1987, ESA decided that the first flight of Hermes would now take place by the end of 1997. This delay would create room to perform several Ariane 5 commercial flights before the first mission of Hermes and to have a less tight programme schedule than proposed by CNES [7].

### 5.9 Hermes Development Programme

Hermes development up to this point had been characterised by a number of pre-development studies, followed by industrial feasibility studies (Phase A) and pre-definition contracts (Phase B1). The ESA Declaration on the HPP had been finalized in October 1986 and was subscribed in late November. The HPP, budgeted at 48 MAU (1985 economic conditions) due to end in July 1987, corresponded to Phase B2.

In March-April 1987, ESA proposed an extension of the HPP from 1 July 1987 to the end of 1987, amounting to a 54 MAU Phase B3 and bringing the total HPP financial envelope to 102 MAU. Pending the successful completion of the HPP, ESA proposed to start the Hermes Development Programme in the beginning of 1988, which would fit nicely with an anticipated approval of Hermes at the The Hague Council meeting in November 1987.

The June 4, 1987 Hermes Development Programme proposal, describing the content and planning for the programme stated the Hermes programme to have a double purpose: to fulfil a specific purpose and considerably increase European

<table>
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<tr>
<th>Table 5.2 Hermes spaceplane mass (kg)</th>
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<tr>
<td>Guaranteed Ariane 5 performance</td>
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<tr>
<td>Gross payload in pressurized bay</td>
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<tr>
<td>Mission fuel</td>
</tr>
<tr>
<td>Mass margin</td>
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<tr>
<td><strong>Basic spaceplane mass</strong></td>
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technology capabilities, one of which was to acquire the capability of hypersonic flight, expected to be the basis for later applications such as Sänger and HOTOL. The Proposal listed a number of areas that Hermes would provide technology benefits: aero(thermo)dynamics, aeronautics, structures, structural materials and thermal protection, environmental control and life support, power supply and distribution, data acquisition and communication, navigation, data handling and management and servicing and extra-vehicular operations.

The first Hermes flight (H001) was now planned on the third Ariane 5 qualification flight. H001 and H02 (manned) are qualification flights. To be followed by at least one validation flight, in full mission configuration (equipped cargo bay, cargo tools, HERA and EVA), for operational validation of MTFF servicing. A second validation flight might be needed for further demonstration of servicing capabilities, in particular of the Space Station interfaces.

To ensure a safe return of the empty Ariane 5 H155 cryogenic stage in the atmosphere over the Atlantic, a new propulsion module L5B had been inserted between the Ariane launcher and the Hermes spaceplane. This additional stage would be developed as part of the Hermes programme and was to be quipped with two 20-kN engines, which were previously located in the rear of the spaceplane itself. The engines were part of the standard Ariane 5’s L5 stage. L5B would provide the final injection of Hermes in to a 90 by 463 km orbit, firing for a maximum of approximately 800 s and would be jettisoned afterwards. Circularisation of Hermes orbit, orbital and re-entry manoeuvres would be performed by the Hermes propulsion system.

The L5B enabled the Ariane 5 core stage to stop firing before it reached orbital velocity, so that it could fall back to Earth naturally, ending up in the Pacific Ocean. This would prevent endangering the European continent or any other populated areas [26].

A number of design issues remained to be settled at this stage. The feasibility of an ejectable escape cabin had yet to be confirmed and the choice of the location of the airlock and docking port was to be evaluated: either aft or on top of the fuselage. A possible separation of the airlock and docking unit would allow simultaneous internal cargo transfer and EVA during MTFF servicing. Alternatives of performing either direct docking or sequential berthing and docking still needed to be assessed. The crew size remained to be analysed to ensure serviceability of the MTFF in terms of available crew time and capability of simultaneous EVA and IVA.

Growth potential of the spaceplane was considered at this point: retrofitting of equipment and software were identified as possibilities as well as the introduction of improvements in a possible third flight model as a result of a growth version of Ariane 5. Launching Hermes into a polar orbit with a significant payload capability or flight duration extension would become possibilities in this case.

A total of twenty subsonic test flights were now being considered and nine Hermes models would be built:

- first mock-up (MA1)
- second mock-up (MA2)
- Cockpit Simulator (SDC)
- Systems Integration Test Bed (BIS)
5.9 Hermes Development Programme

- Identification model (MI)
- Structural and Thermal model (MST)
- Static Model (CES)
- Plane 01
- Plane 02

5.9.1 Costs

The costs of the Hermes Development Programme are shown in Table 5.3; its associated funding profile is detailed in Table 5.4.

The production cost of an additional flight unit would amount to 295 MAU.

The Hermes Development Programme was planned to start on 1 January 1988. The first Hermes qualification flight, the unmanned H001, would take place at the end of 1997, with the second, manned Hermes qualification flight H02 in mid-1998. A third Hermes flight as part of the demonstration programme would follow in 1999.

A Preliminary Requirements Review (PRR) was scheduled towards the end of Phase B-3, at which point the design of preliminary systems, missions, operations and interface requirements would be frozen, to be controlled by ESA.

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<th>Table 5.3 Hermes Development Programme Costs</th>
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<tr>
<td>Operational validation</td>
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<td>Mission related costs</td>
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<td>Fixed operating costs</td>
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<tr>
<td>Space segment</td>
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<td>ESA-CNes management</td>
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<td>Ground infrastructure</td>
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<td>Flight qualification</td>
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<tr>
<td>Total including preparatory programme and extension</td>
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<td>Preparatory programme and extension</td>
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<td>Development programme (phase C/D)</td>
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<th>Table 5.4 Proposed Funding Profile in MAU (1986 economic conditions)</th>
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<tr>
<td>Year</td>
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<td>HPP Extension</td>
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<td>Ops validation</td>
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<td>Ops</td>
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A subsequent Preliminary Design Review (PDR) was planned for the end of 1988, to update PRR documents, review and freeze contractors’ expanded requirements and preliminary design documentation.

Compared to the June 1986 Hermes configuration, the spaceplane had undergone a number of important changes. Its fuselage diameter had been reduced by 5% (see Fig. 5.12), an ejectable cabin had been added for crew escape with the crew size reduced to three, the open cargo bay had been replaced by a pressurized mid fuselage for cargo and as living area and the original cargo doors had been replaced by radiator doors. An unpressurized volume would now be available for subsystems and possibly cargo, while a US standard docking port would be used. An airlock for EVA and possible payload transfer was now also planned. Rather than docking directly, possible berthing using HERA was under consideration. Major changes in electronics had been introduced and the deployable high gain S-band communications antenna had been relocated. The introduction of the Ariane L5B stage had resulted in the deletion of two 20-kN engines from the spaceplane and a rearrangement of the propulsion system. Power during launch and re-entry would be up from 8 to 10 kW [27].

5.10 The UK and Germany Continue National Plans

While still pushing for its own spaceplane candidate HOTOL (see Chap. 8), the UK decided it would take part in the Hermes Preparatory Programme for an amount of 2 million GBP (around 3.14 MAU), representing some 6% of the total cost of this
phase. According to the British National Space Centre (BNSC), HOTOL could be ready to enter service in 2005 [28].

But the UK’s space effort was entering a rough phase. Roy Gibson, head of the BNSC resigned on 30 September 1987 [29]. Gibson, former first ESA Director General from 1973 to 1980, had headed the BNSC since November 1985 and had proposed increasing the UK space budget from 100 million to 300 million GBP (170–510 MAU) over a five-year period. In July 1987, Prime Minster Margaret Thatcher’s government had refused that budget. As a result, the UK’s involvement in Ariane 5 and Columbus would be unable to continue and that in Hermes only at a reduced rate. Gibson could not reconcile himself with that decision although he had not been a proponent of Hermes, describing it as “a programmatical abberation for which Europe has no need” earlier [30].

Nevertheless, the UK’s industry kept up an interest in manned spaceflights as BAe unveiled a low-cost alternative to Hermes: the Multirole Capsule (see Chap. 8). The seven-ton vehicle would hold a crew of four to six and would be a possible candidate for a Space Station emergency crew rescue vehicle. Launched on Ariane 4, the capsule could fly as soon as 1992. NASA was planning to award three $10 million requests for proposals for such vehicle [31].

German parliament was split over the decision whether to join Hermes or not. During the summer of 1987, MBB had already proposed Sänger, a more revolutionary project and one in which Germany would be firmly in the lead (see Chap. 8). Nevertheless, Minister of Foreign Relations Hans-Dietrich Genscher considered Hermes to be an opportunity to strengthen the French-German axis. He was supported in his view by Bavarian Prime Minister Franz Josef Strauss, who believed the European spaceplane would facilitate a leap in industrial development. Riesenhuber, not a fan of Hermes from the beginning but defenceless against this strong Hermes-lobby [32], demanded that other ministries than his own would contribute to the Hermes budget, but Minister of Finance Gerhard Stoltenberg refused, citing the other major programmes Germany was already committed to. The German government found itself torn between pledging technological allegiance to either Europe or the Americans [33].

During the summer of 1987, ESA was displaying some dissatisfaction with CNES on a number of Hermes aspects. The agency cited a large discrepancy between its Hermes mass assessment and the CNES programme file and required this to be resolved in order to demonstrate the availability of a mass margin [34]. ESA also wanted CNES to demonstrate more thoroughly the compatibility of key and backup technology development milestones with the overall spaceplane schedule. According to ESA, the schedule CNES presented in the file was very tight and might to some extent be constrained by manpower availability in hypersonics and possibly software.

ESA also felt that the potential benefits from commonality of hardware and software items with other programmes (Columbus, DRS, Ariane) were not sufficiently addressed. And ESA appeared critical of the shared industrial responsibility for Hermes, demanding that the integrity of the role of Aerospatiale as prime contractor be demonstrated in view of the direct relation of Dassault to CNES on aeronautical aspects [35].
Also during the summer, the German government suggested spreading out the
development of Columbus and Hermes, seizing an opportunity to alleviate budget
pressures in the light of the delays that the Freedom Space Station would encounter
as a result of the Challenger accident and temporary suspension of Space Shuttle
flights [36].

By August 1987, Riesenhuber had apparently overcome his initial doubts
towards Germany’s entry into the manned space arena. There still was, however,
the Finance Minister Gerhard Stoltenberg (himself a former Minister of Scientific
Research in the late 1960s), who needed convincing to go along with Riesenhuber’s
decision. The German participation in the Columbus and Hermes programmes,
projects enhancing the prospects for a new generation of German astronauts, was
not welcomed everywhere. Scientists were growing weary of the prospects these
major projects would eat away the budgets for fundamental research while the press
criticised the untouchable ‘space lobby’. Arguments justifying space stations and
man-in-space projects requiring huge investments were called into question, citing
improvable statements describing the ‘necessity to engage in high technology if a
county wants to remain a credible player in the world economically and politically’
and the riches the nascent space industry would bring once space platforms were
operational [37]. While possibly far fetched at the time, this reasoning would be
quite valid not very much later.

Shortly before the delayed The Hague meeting was to finally take place in
November 1987, D’Allest tried to stress a sense of urgency and advocated an
approval of both Columbus and Hermes: “We cannot afford to lose any more
time”, adding it would not make sense to start development of Columbus without
Hermes as the spaceplane would be the means of transport of crews to the orbital
facility.

Had so much time really been lost? Reimar Lüst hinted at a German cause for the
fact that approving Hermes had not already been approved as an ESA programme in
1985. In an interview published in Die Zeit [38], he said: “I think it would have
certainly been better for the overall situation, if the Federal Republic could have
decided in favour of Hermes already at the Ministerial Conference in Rome in
1985; Hermes would have been a European project from the outset and France
would have remained an equal partner,” at the same time acknowledging the
continued ‘France-dominated’ character of the programme.

Hermes’ costs had nearly doubled since first discussed three years earlier, to
around 5200 MAU. With the Ariane 5 and Columbus each estimated at 4150 MAU,
approval of all three major programmes would require the annual ESA budget
soaring to 3100 MAU in mid-1990s.

Meanwhile, critics were arguing that Hermes would be little more than a space
taxi and that its weight gains had caused the Ariane 5 design to be adapted, reducing
its cost-effectiveness as a satellite launcher, which still remained its primary role
[39]. In many respects, the The Hague Council Meeting at Ministerial Level would
be an event whose importance could hardly be overestimated.
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