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THE HERMES CARRIER AIRCRAFT (HCA)

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Abstract

Together with Ariane 5 and Columbus the HERMES system is developed to establish an independent European manned space transportation capability. Besides the Hermes spaceplane exists the so called Hermes Ground Segment to which belongs the Hermes Carrier Aircraft (HCA).

The HCA has to transport the Hermes spaceplane form Europe to the Guiana launching site and after landing back to Europe. In addition to this mission the first approach and landing tests will be performed by drop-launching the spaceplane from the HCA. These main missions are similar to those of the US Shuttle Carrier Aircraft and partly to those of the Russian Buran Carrier Aircraft, The AN-225.

A number of potential HCA-candidates have been investigated. Also different means for protecting the spaceplane during transport have been discussed including a container solution.

After intense evaluations the Airbus A310-300 has been chosen as the reference solution, because it requires relatively few modifications. Wind tunnel tests confirmed this decision.

I. Introduction

The Hermes System, through the development of a reusable winged re-entry vehicle and its associated ground facilities, is one element of the European In-Orbit Infrastructure (I.O.I.) as decided in Rome in January 1985 by the Council of the European Space Agency (ESA) meeting at ministerial level.

This ambitious new program was confirmed and started in 1987 on the basis of four complementary programs under the responsibility of ESA (fig. 1):

- the COLUMBUS program, which is composed of a pressurized module attached to the Freedom Station (APM) and a Man Tended Free Flyer (MTFF),
- The ARIANE 5 program, which will give Europe a means of space transport capable of launching automatic and manned space vehicles,
- the HERMES program which will provide return transport for a crew of three and a payload of 3 tons,
- then, the EDRS data relay satellite program for space and space to ground communications.

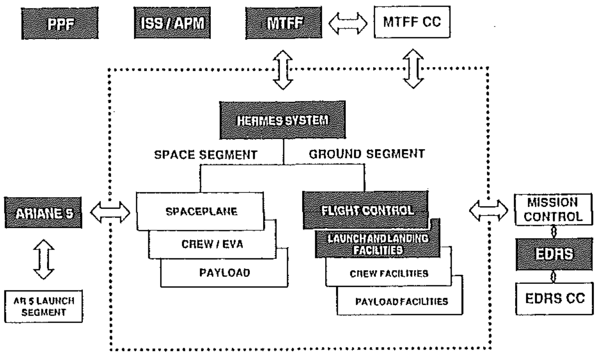


Fig. 1: The Hermes Systems within European I.O.I.

At the next ESA conference at ministerial level at the end of 1992 the continuation especially of the Hermes and the Columbus programs will be decided.

II. The Hermes Program

II.1 General objectives

The objectives on the Hermes program are to develop an autonomous manned transportation system for low earth orbit with its associated payload, crew and ground infrastructure elements (fig. 2).

These objectives are thus:

- to design, develop, qualify and test in flight a Hermes system capable of meeting the primary mission of Hermes which is the periodical supply and service of the Columbus Man-tended Free Flyer (MTFF) and when required to visit to the Freedom Station and its ESA-supplied Attached Pressurized module (APM),
- to place the Hermes system, after the development phase and a further validation phase at the disposal of the Agency for at least - 15 years operational life.

One of the two spaceplanes will be placed in orbit by Ariane 5 after have been launched from Kourou (Guiana Space Center) for an eleven days mission, six days of which it will be berthed to the MTFF station. Means will be provided for two members of the crew to get out into space for extra vehicular activities (EVA). At the end of its mission, the spaceplane will de-orbit and land at the nominal landing site in Europe or in Guiana.

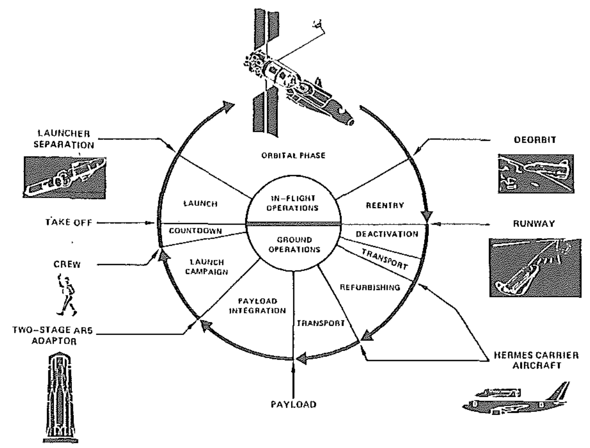


Fig. 2: Hermes life cycle

II.2. The Hermes ground segment.

Associated to the Hermes Space Segment, which comprises the space vehicle, the crew and the payload accommodation equipments, the Hermes ground segment is of critical importance to the preparation and success of all Hermes missions. It includes facilities for both the development and the operational life of the Hermes space vehicle.

The Hermes ground segment can be broken down into several main facilities (fig. 3):

- operational control facilities: The Hermes flight control center (HFCC) which monitors the Hermes flight operations, provides flight back-up to the Hermes crew and coordinates the others ground based facilities involved. The HFCC is linked to the mission control center and to the Columbus control center.
- Hermes launch facilities at Kourou (French Guiana) for the preparation and check out of the ARIANE 5 - Hermes Composite,
- the Hermes preparation facilities in Europe: industrial sites for the development maintenance and preparation of the Hermes space vehicle and its associated payloads.

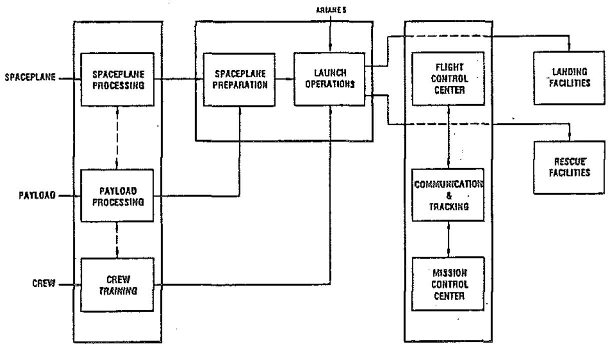


Fig. 3: The Hermes ground segment

- the landing and rescue facilities including the main landing sites of Cayenne in French Guiana, and another one in the south of Europe, and sea recovery facilities,
- the tracking and communication facilities: the Hermes System will rely on data relay satellites (EDRS) which will maintain high performance communication between the European IOI and the ground segment facilities,
- crew training-facilities: Hermes training facilities (HTC) will be installed at Toulouse for specialized spaceplane training in coordination with the Hermes Flight Control Center (HFCC) under the supervision of the European Astronauts Center at Cologne, Germany.

III. The Hermes Carrier Aircraft (HCA)

III.1 HCA - Mission requirements.

The HCA is to be used to carry out two main missions (fig. 4).

These are subsonic flight tests (Approach and Landing Test - ALT) and the ferry of the spaceplane.

MISSIONS			REMARKS	
MAIN MISSIONS	①	HSP subsonic flight test (appr./landing tests, ALT's)	Reference and priority missions for dimensioning the HCA (direct interfaces with the HSP)	
	②	HSP ferry		
SECONDARY / COMPLEMENTARY MISSIONS (OPTIONAL)	③	microgravity flights (equipmt.tests/astronaut training	deleted	shall not impose any additional constraints on the HCA design (minor modifications only)
	④	HSP safety device testing	deleted	
	⑤	personnel/freight transport (TBC)	for huge freight COMBI required	
	⑥	auxiliary services (TBD)		

Fig. 4: HCA main and secondary missions

III.1.1 ALT Mission. The main objectives are the following:

- Check of Hermes aerodynamic behavior and pilotability in the subsonic envelope up to the landing.
- Validity of the Hermes aerodynamic characteristics resulting from computations and wind tunnel tests.
- Qualification of the approach and landing procedures developed on ground simulator, then on Hermes trainer aircraft.

As for as the secondary objectives do not interfere with the above program and if they are representative, the following objectives could be continued during the ALT Mission:

- Qualification of the on-board sub-systems (for ex. generation systems).
- Qualification of the ground sub-systems.

The role of HCA in this mission is to carry the HSP in the piggyback configuration up to a sufficient altitude to separate safely the HSP from the HCA at well defined conditions (265 kts, 30.000 ft, Mach 0,7 as minimum values). The spaceplane will then glide to the test landing site at Istres, France (fig. 5).

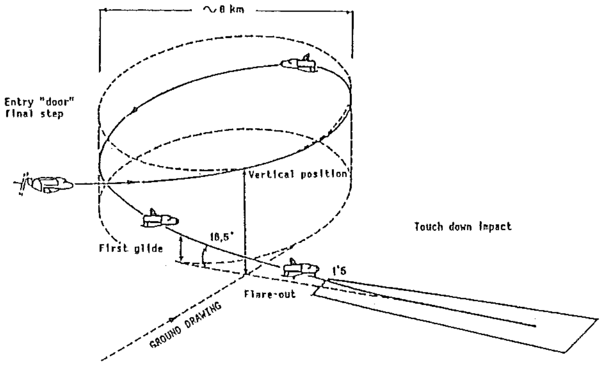


Fig. 5: The approach and landing tests

III.1.2 Ferry Mission. The Configuration to be transported on HCA is not yet finalized. Several solutions are under investigation, depending on the decision which components of the Hermes system will be built, assembled, integrated or refurbished in Europe or Kourou, French Guiana (fig. 6).

One possibility is to carry out a maximum of work in Europe and to transport the HSP connected with its resource module to Kourou. This configuration is called the Hermes Space Vehicle (HRM + HSP = HSV) and has a length of about 20 m, a mass of 22.000 kg and a maximum diameter of 5.4. m.

The other ferry solution is the transportation of the spaceplane alone. This is in general similar to the ALT mission, but some means for protection of the HSP (e.g. container) and to reduce the drag have to be added (e.g. tailcone).

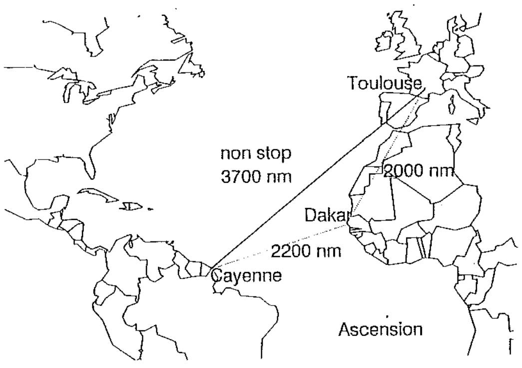


Fig. 6: The ferry mission from Europe to French Guiana

III.1.3 Other missions. In addition to the main missions there is also the possibility to use the HCA for personnel and freight transport. The selection of a Combi-Version of the HCA-candidate will support this mission. Further consideration is useful to increase economical efficiency of the aircraft when it may be used as well by other operators for commercial purposes. In this case the necessary aircraft modifications (e.g. fittings and struts) have to be designed to allow easy dismounting.

In case of availability of the HCA there are also planned other auxiliary missions like the use of the HCA as a chasing airplane.

III.2 Experience from similar programs

III.2.1 Historical background. The concept of piggyback air carriage and inflight separation is not new. At least three successfully developed configurations are known. The first one already in 1938. This configuration known as Mayo composite (Shorts S-20/S-23) was a four engine, twin-float seaplane as the upper component with sufficient fuel for the Atlantic crossing and full payload of mail. The carrier was a large, four engine flying boat with fuel for climb to altitude and return to base. Separation was accomplished at a safe altitude with both pilots coordinated through a set of cockpit instruments to release the smaller airplane at a prescribed relative lift force reading.

Other composites like Mayo were known as the Junkers JU-88H/Focke-Wulf 190 (1944) and the Leduc Ramjet/Languedoc 161 (1949).

III.2.2 NASA's Shuttle Carrier Aircraft. Rapid, cost-effective transportation of large aerospace hardware was also a problem of the NASA's space shuttle program, since the modified Boeing C-97, the Guppy, did not provide the necessary capability for shuttle transport.

After detailed studies running for years, the piggyback configuration was selected as the most suitable one in comparison with other solutions like "bolt-on" air-breathing engine systems or a twin body carrier aircraft.

Following NASA's decision to select the BOEING 747 as a basic aircraft, a variety of intensive studies were run to evaluate the necessary modifications.

990 wind tunnel hours were spent between 1974 and 1975 to obtain the necessary aerodynamic data. Further simulations and supporting analysis were made to investigate in detail the separation maneuver and special cases, such as single engine failure under different conditions.

Main modifications incorporated to the basic structure and systems have been the following:

- reinforced body bulkheads and doublers in the main load introduction areas;
- relocation and new-installation of antennas;
- horizontal stabilizer trim increased by 2°;
- additional stabilizers at the horizontal fin tips;
- additional struts for orbiter connection;
- additional monitoring displays for separation.

The significant tip fins at the horizontal stabilizers were necessary to obtain directional stability due to the reduction induced by the orbiter.

Static longitudinal stability, dutch roll damping and increase of minimum control speed remained within acceptable limits.

III.2.3 Soviet Buran Carrier Aircraft. In frame of the Soviet *Unions's space program several aircrafts have been modi*fied to be used as a carrier aircraft for outsize external cargo transportation.

The last one is the Buran Carrier Aircraft, AN-225 Mriya ("Dream") which is the world largest aircraft, spanning 88.4 m, weighting 600 t at take-off and carrying 250 t internally or externally. To achieve this enormous performance, the basic aircraft AN-124 was heavily modified.

Remarkable external features of AN-225 are the six engines and replacement of the central fin by installation of two vertical fins at the end of the horizontal stabilizers. The main landing gear consists of 14 mainwheel pairs - seven per side - extending and retracting independently to exclude the possibility of a wheel-up landing.

The russian carrier aircraft design has shown above all that external transport of outsize payload is possible up to extensive dimensions.

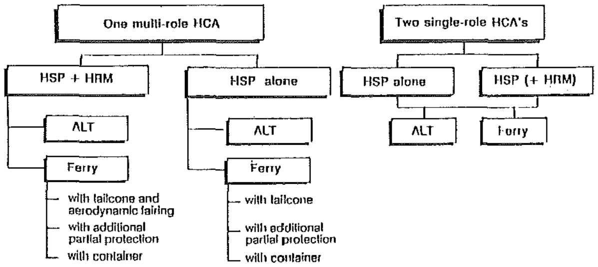
In frame of the Hermes project the requirements for transportation are easier, since the Hermes space plane is much smaller than the Buran orbiter. The necessary modifications for the Hermes carrier aircraft should be therefore less extensive.

III.3 HCA solutions

III.3.1 General remarks

When discussing all potential alternative HCA solutions one must distinguish between three problem areas (fig. 7) :

Fig. 7: HCA alternative solutions



1. to use one multi-role HCA as well for the ALT as for the ferry mission or to use two different aircraft specialized for these two missions;

2. to carry the HSP alone or together with the HRM;

3. to ferry the HSP or HSV unprotected, partially protected or inside a container.

When the ferry mission of the HSP or the HSP together with the HRM will be performed piggyback on top of the HCA always the ALT mission can be done by the same HCA candidate. So in this case the so called "one multi-role HCA" scenario is valid.

Only when the HSP or the HSV will be transported inside a cargo airplane of course two different airplanes must be used for the ALT and the Ferry mission. This is the "two single-role HCA's scenario.

The question if the HSP or HSV should be ferried unprotected, partially unprotected or inside a container does result mainly in different values for drag, weight and above all for cost.

III.3.2 One multi-role HCA scenario

In this case one HCA will be used for the ALT and the ferry mission. But it has to be distinguished between the ferry of the HSP alone or together with the HRM.

a. Ferry of HSP alone :

In this case the ALT mission is the most critical one because the HSP has not a tailcone and thus the biggest turbulent region behind the spaceplane producing the highest drag and influencing the stability and rudder effectiveness of the HCA (fig. 8).

b. Ferry of HSP and HRM together :

In this case the choice of the HCA is mainly influenced by the length of the HSV and an additional tailcone or the length of the HSV container.

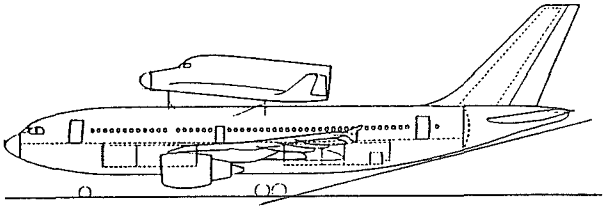


Fig. 8: Spaceplane on top of HCA for ALT

The negative influence on lateral stability and on rudder effectiveness is bigger than in the case of the ferry of the HSP alone. Especially the experience from wind tunnel testing of the HCA/HSP composite and the A300-STA indicates that a least endplates at the horizontal stabilizer of all Airbus HCA candidates and the B767 are necessary. The size of these endplates and the necessity of an additional rudder area can only be determined by additional wind tunnel testing.

c. Container solution for ferry mission

The HSP has to be transported from the European Spaceplane Assembly Facility in Toulouse to the ARIANE launch pad in Kourou and back from each landing site after its mission. Transportation will be made on top of the HCA, as well as on truck and ship.

Since the HSP is at least on top of the aircraft exposed to adverse conditions (e.g. rain, snow, hail, chill, icing, lightning strike, bird strike erosion etc..) a container solution has to be studied to protect Hermes and also to facilitate the handling (fig. 9).

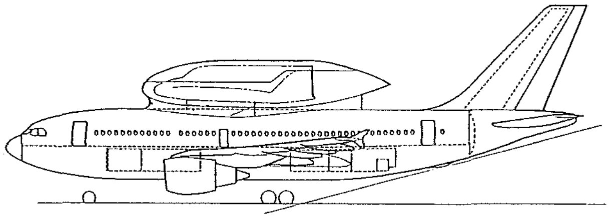


Fig. 9: The spaceplane-container solution

If the HSV is to be ferried, the container provides the possibility to reduce the drag and wake and allows to keep the HSV configuration relatively short, since no tailcone is needed (fig. 10).

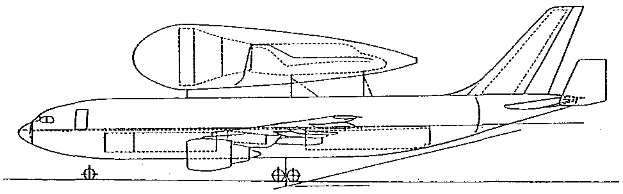


Fig. 10: The HSV-container solution

d. Partial protection

The objective is to provide protection only in the most critical areas to reduce the relatively high costs of the container.

The areas for protection are the wind screen, the nose, the leading edge of the wings and the winglets. The main problem is the fixation of the protectors to the HSP structure.

e. Discussion about protection

The decision for or against a container or to what degree a partial protection is necessary is facilitated by the fact that this choice has only limited influence on the evaluation of the HCA candidate. This is true because of the following reasons :

Every HCA candidate airplane which can ferry the HSP or HSV alone is also able to ferry these spaceplanes inside a container. Every ferry of the unprotected spaceplane requires some aerodynamic fairings like a tailcone for the HSP. So the total length of the adequate container or the modified spaceplane do not differ very much. On the other hand the performance of the HCA/spaceplane or the HCA/container composite will be different but do not contribute significantly to the HCA evaluation.

By considering the unprotected or partial protected HSP and the container solution independently from the HCA choice this evaluation depends on the precise definition of the HSP external environmental requirements. As long as these requirements do not exist the total protection of a container has to be considered. The necessary trade-off considers on one side the relatively high cost of a container and on the other side all consequences of no or only a partial protection.

The main reasons against a partial protection are the following :

- In the case of discrete fixture points parts of the TPS (Thermal Protection System) of the HSP have to be removed.
- These TPS elements must be re-assembled, sealed and checked at the final assembly building in Kourou.
- These activities in Kourou require a certain time and cost.
- Since only critical areas are protected all other areas are still unprotected and any unforseen damage by the environment or by handling during the air, land and sea transport is possible.

When considering the unprotected solution there are some additional aspects :

- o Also when the probabilities of some critical events like hail are very low this number cannot reduced to zero.
- o Because the possibility of these critical events cannot totally be neglected actions have to be taken to repair the damage at Kourou.
- o These potential activities in Kourou require also a certain time and cost.

III.3.3 **Two single-role HCA's scenario**

this scenario is only relevant if a special cargo airplane is used for the ferry of the HSP of the HSV. The ALT mission must be performed by a separate airplane.

As cargo airplanes two candidates have been considered : the Super Guppy or the A300 STA, a similar airplane as the Super Guppy, planned to be developed by Airbus Industries.

Because the wing of the Hermes spaceplane or parts of it are not dismountable both HCA cargo airplane candidates must be considerably modified to cover the full span of the spaceplane. Only future detail investigations of these necessary structural and systems modifications can result in a first rough estimation of cost. The size of the HRM does not require additional modifications.

Another problem for these cargo airplanes is the required range for the ferry mission. While it is almost impossible to solve this problem economically for the Super Guppy which has a nominal range of 760 nm additional standard fuel tanks will solve the problem for the A300-STA. This is valid when the A300 STA is based on the A300 B4 as well as on the A300-600.

III.3.4 **HCA alternative solutions**

Besides the airborne solution a number of alternative solutions have been studied.

The pure land and sea transport from Toulouse to the launch pad in Kourou has many operational disadvantages and is not compatible with the cycles specified for two operational spaceplanes. So only the airborne solution seems to be a realistic one.

For the approach and landing test also the use of a motorized Hermes spaceplane has been studied having in mind the successful tests with the motorized Buran. But the study showed that also this solution is not feasible mainly because of the high costs but also because of problems with the aerodynamic similarity.

III.4 Candidate Evaluation and Selection

After all Hermes spaceplane transport solutions have been studied and evaluated the airborne solution was chosen by CNES. Consequently all aircraft candidates had to be defined and evaluated.
As candidates had been chosen the four engined B747 and A340, and the two-engined B767, the A300-600 and the A310-300. Other candidates like the Tristar have been already deleted because of specific other reasons. The evaluation procedure used four criteria groups - functional -, performance -, operational - and cost criteria - with a total number of 23 sub-criteria. To each criteria group and each sub-criteria a weight factor has been assigned.

The detailed evaluation showed that in general the two-engined HCA candidates are in favor as compared with the bigger four-engined candidates, mainly because of cost reasons.

The HCA candidates B767, A300-600 and A310-300 differ only very slightly with a small cost advantage of the A310-300. This is true above all because wind tunnel tests proved that for this candidate tail modifications are not necessary.

So the A310-300 is the baseline aircraft for the HCA which must be proven by the Hermes program team of ESA/CNES after further investigations.

IV. Conclusions, future activities

The HCA studies which started at the beginning of 1988 showed positive results by producing an economical solution for the Hermes spaceplane transport problem. Because of the relative small size of the Hermes spaceplane as compared with the Space Shuttle, the Buran or the fuel tanks of the Energia rocket the Airbus A310-300 does not need any tail modifications. Local structural reinforcement, some fittings for the Hermes spaceplane support structure and some system modifications are sufficient. This is also valid for the spaceplane container solution which provides best environmental protection and handling qualities.

After showing the technical feasibility of these solutions the next step will be the development of the HCA and the container.

But the development phase can only start after ESA/CNES has decided about the final configuration of the Hermes, the transport of the spaceplane done without the Resource Module, and about the necessity of the spaceplane container.