HERMES PILOT TRAINING FACILITY

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Abstract

The paper discusses the organisation of the Pilot Training Facility, and describes the Hermes Training Aircraft in particular. Operational modes and strategies, concepts and technology, and support systems are elaborated.

I. Introduction

For the future manned spaceflights of the European Space Agency (ESA), an astronauts headquarter was established in Cologne, Germany.
This will be the home base for all ESA astronauts, and selection and primary training will take place here. For the astronauts of the European spaceplane Hermes, training will also take place in four other, decentralised, training centres : the Hermes Training Centre in Toulouse, where systems training is provided on system simulators, the Hermes Robotic Arm training in Noordwijk, where astronauts learn to use the manipulator arm, the Neutral Buoyancy Facility at Marseille for spacewalk training, and the Pilot Training Facility in Brussels for the piloting aspects.

II. PTF Organisation

The Pilot Training Facility (PTF) will consist of two classical major piloting training tools : a Hermes Flight Simulator (HFS), and a Hermes Training Aircraft (HTA).

The HFS will be a motion based, six-degree of freedom full flight simulator, capable of representing Hermes characteristics (performance and handling qualities) in all phases of the spaceplane flight, from ascent, over orbital manoeuvring, to atmospheric re-entry, approach and landing. It will be equipped with a high-quality computer generated visual system.

The HTA will simulate in flight the Hermes performance and handling qualities in the atmospheric part of the flight envelope. Because of the special handling qualities and low L/D of Hermes, especially in ground effect, a flying simulator is necessary to have a correct representation of the behaviour with the appropriate visual and motion cues, in a very realistic environment.

The HTA will be used on a training airfield, and on the Hermes landing sites.
With these tools, piloting from ascent to touchdown of Hermes can be trained in a realistic and efficient way.

The PTF will also house a centre to support Belgian space experiments and users.

III. Hermes Training Aircraft

HTA Operations

The HTA operation for Hermes training will consist of performing an approach and touch-and-go landing, simulating Hermes behaviour in what is called simulation mode, and after touch-and-go climbing again to the point where simulation is initiated, in what is called conventional mode. This training cycle is carried out a number of times during a training flight.

Constrained by cockpit size, aircraft inertia and payload limitations, a business-class aircraft is envisaged for this role. Faced with long climbs to the simulation start point, it is necessary to look at different operational strategies, and a methodology to evaluate the different operational strategies.

Possible Operational Strategies

The most straightforward strategy is to climb to a certain simulation start point, defined by its height, and to perform all training cycles from this point. Unfortunately, with high starting points, this will lead to long climb times when the aircraft is at high weight.
To take a lower simulation start point will lead to shorter climb times, but also to less training, and the higher part of the atmospheric phase has to be trained too.
The simulation start point does not always have to be the same : at high weight a lower height is more indicated, towards the end of the flight higher altitudes are more attainable.

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But probably most can be got from a two-flight strategy, whereby the aircraft would not take-off at maximum take-off weight, but half-fuelled, and perform two flights at lower weight instead of one longer at maximum weight.

Evaluation Method

To clearly see the difference between the strategies, define the Training Value as a measure of the training got from one particular training cycle (approach, landing, touch-and-go, and climb).

$$TV_i = ST_i . W_i$$

Where TV_i training value of cycle i

ST_i simulation time of cycle i

W_i weight factor of cycle i

The weight factor is introduced to give higher training value to longer simulation cycles. These offer more training due to higher attainable stress levels, more and complexer anomalies that can be trained, and larger excursions from the nominal trajectory.

Not the Training Value that can be got from a training cycle is important though, but how efficient the aircraft is in offering that Training Value. Therefore define the Training Efficiency as a measure of aircraft performance to deliver Training Value :

$$TE_i = TV_i / TCD_i$$

Where TE_i Training Efficiency of cycle i

TV_i Training Value of cycle i

TCD_i Total Cycle Duration of cycle i

The Total Cycle Duration encloses the whole cycletime.

To compare different operational strategies, one must compare the Training Value and Training Efficiency of the whole training flight, or in the case of the twoflight strategy, of two flights. Thereby Training Value and Training Efficiency depend on a number of variables such as aircraft weight, height of the simulation start point, but also fuel consumption.

Detailed calculations for a range of possible candidates for HTA conversion showed that almost all aircraft show similar behaviour in the various strategies, and that, from a Training Efficiency standpoint, a two-flight strategy with variable simulation start point heights for the different cycles is optimal. In that case the optimal simulation start point height is calculated to provide maximum Training Efficiency.

Flight Conditions

The HTA has to perform Hermeslike approaches in conditions as close as possible to the real conditions. Although this can be done by training at the real landing site, the travel constraint are enormous. Therefore it should be defined what conditions are required to perform realistic training at another landing site.

During the high and major part of descent no special condition should be enforced. During the landing phase the traditional pilot has a certain time between seeing the runway for the first time, and the moment of landing. This gives him a certain reaction time.
This reaction time should be as long as possible, but also reflect the real and the worst case for Hermes.
From these, and considering the Hermes trajectory, it can be shown that Visual Meteo Conditions are sufficient for the HTA operation.

Training Airspace

A dedicated Training Zone (TZ) for the HTA will be inforce when training flights take place. The TZ will be tailored to the HTA approach, provide ample manoeuver space, and sufficient separation from other aircraft.

The TZ will be reserved exclusively for the HTA during simulation descent, but as it operates as a conventional aircraft during climb, there is no reason not to allow other aircraft to operate from the same training airfield, provided that they fulfil a set of conditions. These include, for example, separation times and required aircraft equipment, although not in excess of what is commercially available.

HTA Technology

Possible HTA Concepts

The concept of the HTA was subject to a lot of thought before, and this effort is still going on. However, three main concept for in-flight simulation are considered.

The modified cockpit concept, the left-hand position of a businessclass aircraft would be modified to present the lefthand position of Hermes. The righthand position would be retained and serve as instructor station and safety position.
Of course only minor aerodynamic and structural changes would take place, but only one pilot can be trained at a time, thus precluding crew training. Generally, the cockpit environment is a low quality simulation of the real Hermes cockpit.
The STA and the ATLAS are built along this principle.

The additional cockpit concept consists of mounting an additional cockpit partly in and partly on the fuselage. This cockpit would be completely Hermes-identical.
This means of course major aerodynamic and structural changes. Although a Hermes crew can be trained, a large safety and instruction crew would have to be carried. The cockpit environment would be a very high quality simulation.
The TIFS is built along this principle.
The "fly-by-wire" concept in fact consists of the complete modification of the basic aircraft cockpit to Hermes standard. The aircraft would be flown in conventional as well in simulation mode with the Hermes controls, and a minimum of back-up instruments.
Of course, here again, only slight aerodynamic and structural changes would take place, but a very special control system would have to be developed. A high quality simulation of the Hermes cockpit would provide training to a crew, with minimal instructional crew.

Hermes Simulation System

The Hermes Simulation System will consist of following system architecture : through a Hermes guidance, navigation and flight computer the Hermes pilot would give inputs. The Hermes flight control computer establishes the required Hermes actuator and control surface commands.
Through a Hermes flight dynamics model, the Hermes response will be calculated.
A modelfollowing algorithm will then determine HTA actuator and control surface commands, by an HTA dynamics inverter.
Through the Hermes guidance, navigation and flight control computer the flight and navigation data will be presented to the Hermes pilot.

In parallel the functioning of the Hermes systems, the basic aircraft systems, and the Hermes Simulation System will be presented in synthetic way to the safety and instructor pilot. The instructor will have the possibility to inject Hermes system malfunctions.

Basic Aircraft Systems

The basic aircraft will have to be enhanced with further systems in order to perform the training, without having a direct connection with the Hermes Simulation System.
Systems identified in this class are for example additional long-range navigation systems, additional high-precision landing aids, and a flight management system able to perform a optimal simulation start point strategy automatically.

Furthermore, a number of safety systems, indicated because of HTA operations close to ground, have to be evaluated : wind-shear protection and escape, collision avoidance system, and an emergency stopping system, such as for example a crash barrier or arrester wire/tailhook combination.

HTA Support

Maintenance

A special maintenance concept is needed for this very special and unique aircraft.

Constraints imposed by the operation include an aircraft availability of 11 months per year, about 900 flighthours per year, and 2700 flightcycles per year. This will be combined with rather long periods of deployment of the HTA to the nominal landing sites.

Although special maintainability studies will be performed during the design of the HTA, some ideas can be advanced for the actual maintenance.
To maintain the HTA activity, a very precise estimation must be made of what maintenance actions are required on the aircraft, so that they can be carried out as quickly as possible.

This will be complemented with a very detailed scheduling of the aircraft utilisation. Of course, meteorological conditions impose a degree uncertainty, but this can be reduced to a quite low level. This will allow precise planning of the maintenance tasks identified.

Considerable use will be made of aircraft, engine, and system monitoring to give an accurate picture of the aircraft state.

Overhaul

With about 900 flighthours and 2700 flight cycles per year, the HTA will be the most intensively used businessclass aircraft. This mains that overhaul and repair will take place at much higher rate than on the basic aircraft.

To perform this a dedicated maintenance and overhaul facility is to be established. The layout and equipment of this facility will be designed for the HTA. A special, highly trained workforce will be used who will use highly specialized test equipment. But most of all the maintenance methods used will make sure that the overhaul task planning and scheduling will allow a maximum number of actions to be performed in parallel. With a large degree of knowledge of the aircraft status even before the aircraft comes in for overhaul, and continued adaptation of the planning in function of the progress, significantly shorter overhaul times can be achieved.

The spare parts level will be higher than in traditional aircraft operation to minimize aircraft unscheduled downtime.

Engineering Testbed

A non-negligeable part of the support activities will be performed with the aid of the HTA Engineering Testbed. This will be a complete HTA systems simulation facility, and comprise the Hermes hard- and software used in the aircraft, as well as the basic aircraft hard- and software.

It will be used to check all hardware and software functioning of the separated flight control items, to modify to a certain extent the software in those systems, to check integrated systems behaviour, and overall functioning.

IV. Conclusion

The HTA, together with the HFS, will be the main elements of the Pilot Training Facility. The quality of the manned space operations highly depend on the quality of the training of the astronauts. The continuing efforts to study, design and implement an optimal Pilot Training Facility are intended to lead to that very high level of training quality.

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