

The Flight of Phoenix

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ABSTRACT

During spring 2000, North European Aerospace Test Range (NEAT) started discussions with EADS Space Transportation at Bremen, Germany on how to carry out flight tests on a functional scaled down model (Phoenix) of a future Reusable launch vehicle (RLV/Hopper). The ultimate goal for EADS ST was to verify the performance of the Phoenix test vehicle including its flight control and navigation systems etc, by auto landing on the runway at the FMV Vidsel test site.

The way ahead to perform all necessary design, test qualification activities to guarantee airworthiness, performance, safety, quality etc to perform the task within a flight test organisation, earlier reduced in capacity by economic demands, is described. The performance included design and verification of a system including necessary test data instrumentation, capable of carrying the 1200 kg Phoenix test vehicle to the release point at app. 5 km from the runway threshold to auto land.

The presentation will also show that collaboration between different organisations within and outside the responsible test organisation can be used to fulfil a task and lead to a successfully completed mission.

Three flights were performed with the Phoenix test vehicle, all with successful landings with roll out on the runway centre line.

1.0 INTRODUCTION

The problem of continuous reduction of organisations where a specific responsibility for safety, test methodology and product quality is always under discussion. At what level will an organisation with this kind of responsibilities hit the wall, where it no longer can fulfil these requirements?

FMV Testing directorate has to fulfil these requirements in one way or another to stay in business. Its accreditation as a design and test organisation depends on this.

In this paper the experience of performing a design and flight test under these conditions is discussed.

2.0 THE TEST ORGANISATION

The contract for these tests was issued to the North European Aerospace Test organisation (NEAT). This company is cooperation between Swedish Defence Materiel Administration (FMV) and Swedish Space Corporation (SSC). The test organisation responsible for carrying out the tests was the FMV Testing directorate, a partner of the NEAT organisation. The design and qualification work was performed at the

test site at Linköping together with initial flight tests. The final test flights of the Phoenix test vehicle where Phoenix was released for free flight, was performed at RFN Vidsele test site. The main responsibility for this program was FMV Testing directorate at Linköping.

3.0 COLLABORATION

The FMV Testing directorate is accredited by the Swedish Military airworthiness authority for design and installation of test equipment and for performing flight test. However, during a number of years, this organisation has been drained of technical capacity in a number of cost reduction programmes, which have brought the test organisation to an absolute minimum. This is believed to be a common problem in the world today.

We found however that necessary competence and capacity could be recreated with the existing core of competence still available within the FMV flight test community. This meant that the competence to conduct and run the operation was still intact in spite of earlier reductions.

Specialist competence was acquired outside FMV and worked under FMV responsibility.

A close cooperation with the customer was in this case very fruitful. The customer was participating in all the work and had access to all FMV documentation and test results.

At final tests EADS ST had responsibility to monitor test data linked to the EADS ST command centre and to be responsible for initiating destruction of the Phoenix test vehicle if it started to get out of control.

The customer, EADS ST, also had the documentation or produced the necessary documentation for declaration of airworthiness for the two versions of Phoenix.

4.0 DESIGN

4.1 The helicopter

The Phoenix test vehicle had to be carried to a dedicated launch point at a specific flight condition and released from its carrier, to navigate, perform an approach to the Vidsele air base and land on a runway.

The vehicle to carry the Phoenix to the release point was chosen to be a Hkp 4, a Swedish version of a Boeing/Kawasaki CH-46 Sea knight. Hkp 4 has a max take off weight of 9,7 metric tonnes and is designed to carry an external load of 4 500 kg from its hook. Max airspeed with under slung load is 100 KIAS. This was however reduced to 80 KIAS depending on helicopter weight and altitude. 80 KIAS or 40 m/sec was needed to guarantee a successful release and flight of Phoenix.

The helicopter had to be structurally as well as system modified to carry an external load carrying device (T-bar), which could give the necessary stability to the Phoenix test vehicle during captive flight and release.

The T-bar was slung from the helicopter by three 5 m long steel wires with the aft wire attached to the standard central hook on the helicopter centreline and two forward wires attached to hooks, mounted, one on each side of the aircraft hull, at the standard weapon pylon attachments. The helicopter jettison system was modified so the external load could be jettisoned together with its steel wires. This meant that three load carrying hooks had to open simultaneously at initiation.

The helicopter was instrumented mainly with video cameras. Standard LTN-92 INS and Ashtech GPS were used for flight test data. The video cameras were used to record movements of the under slung load, which could be correlated with test data from the external load (see below).

Test data was recorded on a Racal Heim D12 tape recorder.

The design and modification was carried out in accordance to applicable military specifications and was approved for flight test.

4.2 The T-bar

The T-bar was locally designed and produced. It contained a gas-operated ejection release unit (ERU), borrowed from a fighter airplane, to which the Phoenix test vehicle could be attached to and released from.

The ERU capacity for positive separation of the carried load was not used.

The T-bar was instrumented with three-axis accelerometers and rate gyros. Data from this instrumentation was transferred to a recording device inside the helicopter.

The T-bar was attached to the helicopter via three steel wires, which were instrumented to record loads in one and each of these wires.

At a late stage in the design process, we found out that there could be an EMI problem with the electrical initiation of the ERU, caused by static discharge. This made it necessary to take away the possibility to use the ERU for jettison. This problem was later eliminated for flight tests with the Phoenix test vehicle. Jettison during the initial flight tests had to be done via opening the three hooks mentioned above and dropping the steel wires.

5.0 PHOENIX



Picture 1. The Phoenix flight test vehicle

The main dimensions of Phoenix are:

Span 3.84m, length 6.9m, height 2.56m and a maximum weight of 1200 kg.

Two versions of Phoenix were used during flight test. For verification of helicopter handling qualities and under slung load flight characteristics, a wooden mock-up of the Phoenix was used. This was an existing

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mock up which was not designed to be airborne, which meant that FMV together with EADS ST defined necessary structural reinforcements to fulfil demands on airworthiness. The structural integrity of the mock up was verified in ground tests.

Both versions of the test vehicle were equipped with standard T-lugs to fit the ERU. The wooden mock up had the correct aerodynamic configuration and did not carry any instrumentation. It was ballasted to actual weight and centre of gravity.

The Phoenix test vehicle, intended for free flight, was complete with all necessary systems and test instrumentation.

This test vehicle was exposed to a number of tests including wind tunnel tests to verify its performance systems performance as well as aerodynamic performance.

For both versions of Phoenix, we identified the necessity to de-electrify (static electricity) the hulls after flight, to make sure it was safe both for test instruments and for ground crew before touch down.

6.0 AIRWORTHINESS

6.1 Helicopter installations

All modifications to the helicopter were performed in accordance with military specifications and all work, hard ware as well as soft ware, had to be reviewed by an independent authority. Because of shortage of personnel with adequate competence, FMV Testing directorate hired this competence at the nearby defence helicopter technical dep. They also helped us to review the T-bar.

6.2 Phoenix

As mentioned earlier there were two versions of Phoenix.

The base for airworthiness for the wooden mock up was secured in close cooperation with the customer EADS ST, and was mainly about making sure that the mock up could withstand the air and mass loads for initial flight tests.

The combination of helicopter, T-bar and Phoenix mock up was accepted for initial flight tests in a Flight test permit, issued by the military airworthiness authority.

The Phoenix test vehicle was of a considerably more complex matter.

In a close cooperation with the customer, the complete Phoenix system was reviewed together with documentation of verification of sub-systems.

The demand was to show that, within a defined hazard zone, the risk to hurt personnel should be less than 1×10^{-6} at each free flight of Phoenix.

This meant that high demands were set for the Phoenix destruction system (parachute system) and the monitor and telemetry systems. The test vehicle could be destructed on data from the test vehicle telemetried to ground control or from the ground radar monitoring the flight.

Showing that demands mentioned above was covered, a Systems test permit was issued for the free flight tests.

A Systems test permit is issued when two or more sub-systems are linked together in a flight test.

7.0 VERIFICATION OF FLIGHT TEST VEHICLES

7.1 Preparation for flight test

One of the problems that had been underestimated during the planning phase was the amount of training needed for the ground crew, responsible for preparing the test vehicles, transport them to a suitable place for hook up to the helicopter and the actual hook up procedure. It turned out to be necessary to develop a procedure for how to direct the helicopter to an exact position above the T-bar, handle the three steel wires dangling from the helicopter, catch them and hook them to the T-bar loops while the helicopter was hovering 5 meters above their head and to connect the test data instrument cord and the cord to the ERU to the helicopter. The demand on the helicopter pilot was equally high, keeping the helicopter in an exact 3-dimensional position for hook up.

Once hooked up, the test vehicle had to be lifted carefully out of a ground stand, to which it, after the flight test, should be restored in the same manner. At a late stage it was discovered that the ground stand (a trolley) had to be modified, as this customer furnished item was not designed to the high nose-up attitude of Hkp4 during hover. A makeshift solution solved this problem for the initial flight tests.



Picture 2. Hkp4 and the Phoenix wooden mock up

7.2 Initial Flight Tests

Initial flight tests were performed to verify flight characteristics of the T-bar. This was believed to be the critical part as the T-bar, not aerodynamically stable as such, had to behave well after release of Phoenix. Flight tests showed that it was stable up to the maximum tested air speed 100 KIAS.

Before we could make handling quality flights with the wooden mock up, we used a ballasted drop tank from a VIGGEN fighter to simulate weight and centre of gravity of the Phoenix. It is worth mentioning that the centre of gravity is situated just some centimetres ahead of the aft steel wire.

These tests showed that there was a risk that the under slung load could perform an un-damped pitch – yaw movement at speeds 70 KIAS or higher. The load stabilized immediately as airspeed was lowered.

It was judged that lack of static aerodynamic stability for the drop tank was the reason for this behaviour. Estimation showed that the aerodynamic stability of the Phoenix should be satisfactory.

Flight tests with the wooden mock up showed that the estimations were correct. Flight characteristics and helicopter handling qualities could be verified in the complete permissible flight envelope.

As a final test during the initial flight tests, the drop tank was once more used. This time to verify ERU performance and helicopter handling qualities during release of the ballasted drop tank.

After all test equipment had been moved to the RFN test site at Vidsel in northern Sweden, handling quality tests were once again performed. This time with the actual Phoenix test vehicle.

8.0 THE FLIGHT OF PHOENIX



Picture 3. First landing of the Phoenix flight test vehicle

The helicopter, the Phoenix and all the test equipment was shipped to the test site at Vidsel, where EADS TS control functions were linked to the FMV control functions. Once the Phoenix was released, EADS ST had the responsibility to monitor the on board systems to verify its performance. Over all responsibility for command and control of the flight tests belonged to FMV Testing directorate.

A couple of flights were performed to verify the flight characteristics of the Phoenix and the handling qualities of the helicopter and performance of the helicopter-Phoenix combination before real release tests.

The flight was monitored by Vidsel control first to set up the helicopter for the test runs and after release to monitor the Phoenix test vehicle to make sure it followed its predetermined trajectory. During the first part of the trajectory, the Phoenix made a controlled free fall until it got airspeed enough to fly on its own and could manoeuvre to the predetermined approach to the approach end of the runway.

The Phoenix was on speed, attitude and trajectory and made the right decisions (it was fully automatic), and could not be influenced in other ways than to be destructed.

The Phoenix flared, reduced speed, adjusted attitude and made a very smooth touch down, lowered its nose and wheel braked, coming to rest with the nose wheel on the runway centre line.

This turned out to be not just good luck, as it was repeated twice!

As it turned out, it was a very successful flight test campaign.

9.0 LESSONS LEARNED

The curtailed FMV flight test organisation was at the start of this project a bit of a headache. The problem was, among other things, shortage of capacity in the design organisation, which had an influence on the quality of design. The problem was solved by hiring competence in specific areas (another set of eyes). We could also solve similar problems in other areas by a close cooperation with the customer, where this competence was at hand. Late in the design phase we also found technical areas not sufficiently penetrated, which had to be remedied before flight test.

Throughout the whole project there was a shortage of capacity, which together with economic demands from the project leaders, increased the pressure on all participating in this project.

The main lessons learned are:

- At project start, make a thorough analysis of the project. Use competence in all areas, especially in those areas where experience is low. Try to identify “odd” problems. For instance, in this case ground crew, training.
- Yes, it is possible to perform design and advanced flight test in a slimmed organisation, if you have a core of experienced personnel. Using competence from other organisations including the customer and temporarily include this in the test organisation will work (in this case very well).
- Beware of shortage in capacity once the tests have started.
- In a small team, it is essential that everybody has access to information available and that everybody feels they are a part of the team.

10.0 CONCLUSION

The verification of the Phoenix performance, flight characteristics etc was a complete success, with three landings at the Vidsel test range runway, and with the nose wheel of the Phoenix standing on the runway centre line marking.

These tests, including design, verification of test vehicles etc. were performed by a very limited number of people involved.

We would say that this was really a minimum organisation for advanced flight tests. Thanks to a very close cooperation between the customer, individuals in other smaller organisations, well-trained and

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experienced personnel and a common interest to succeed, it worked out very well indeed without tampering with safety margins in any sense.

It is of vital importance that this kind of project is offered to a flight test organisation like FMV Testing directorate to keep the competence of the organisation at an acceptable level within all necessary technical areas. Demanding projects are not too common to day.

The signs of success are: a happy customer (in this case euphoric) a happy test team, where everybody is satisfied, bosses patting your back and the bean counters grumbling.

In this case everything of this happened.

11.0 BIOGRAPHIES

Lt Col Bengt Persson

Mr Hilbert Gustafsson was born on the 22nd of January 1941 in southern Sweden. He received a degree in engineering in aeronautics 1960 and was employed by SAAB Aircraft Company in 1961 at the aerodynamic department working mainly with aircraft carried external stores. He has been employed by FMV Testing directorate since 1971, and has worked with flight test in different positions including Chief flight test engineer in the area of aircraft and helicopter aeronautics. During the last year he has worked as Coordination manager for test and evaluation, and plans to retire within this year.