

Retrospective review and lessons learned of System Helicopter Zero developments

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Abstract:

Airbus Helicopters has introduced System Helicopter Zero (sHC0) as a final ground-test rig to support its programs' development in the 2010s.

The sHC0 is a non-flying enhanced integration bench at multi system level to perform system integration and verification before installing the equipment to the prototypes. The objective of the sHC0 is to run tests at HC level before the prototypes' availability and anticipate the detection of remaining design issues.

A second test rig of this type has been developed recently by Airbus Helicopters, after the H160 sHC0 fifteen years ago. In two different contexts – a helicopter retrofit program versus a new helicopter program – which has led to address different challenges.

We will be presenting the key objectives of a sHC0 and the implemented solutions to meet them, as well as the solutions to overcome encountered difficulties and blocking points.

Key words: ground-test rig, system integration, digital twin

“Helicopter Zero” concept at Airbus Helicopters

Airbus Helicopters has introduced for the first time the “Helicopter Zero” in the frame of H160 development program (X4) in the early 2010's. Such “Iron Bird” or “Aircraft Zero” ground-test rigs have been used over the previous decades by the aeronautic industry [1]. The H160 was a new vehicle platform and Airbus Helicopters has defined its specific implementation of such a non-flying prototype in the frame of this program.

In the case of a new vehicle platform, like for the H160, the Helicopter Zero consists of two different test rigs: the system Helicopter Zero (sHC0) and the dynamic Helicopter Zero (dHC0).

The sHC0 hosts all actual systems of the considered helicopter, except the powerplant and transmission systems: the avionic suite with primary sensors systems, the flight commands together with all control panels and displays fitted in a representative cockpit replica, the navigation systems, the vehicle systems (electrical generation and distribution, fuel, hydraulics, landing gear, etc.), the different mission systems (radiocommunication, intercommunication, hoist, etc.). In summary, all electrically connected devices of the considered

helicopter might be installed in the sHC0. Various testing stimulators and instrumentation means allow to interface with these helicopter systems and to set them in a realistic real-time simulated environment. A hemispherical visual system surrounds the cockpit replica and is the last brick for a fully immersive testing facility for the flight crews (See Fig. 1). Such a test rig at helicopter level requires a testing hall with appropriate surface which will remain dedicated to the considered helicopter for a significant period of the whole program lifetime (common estimation 30 years).

The dynamic Helicopter Zero (dHC0) test rig, to provide ground testing capabilities on the full scope of the considered helicopter, embeds the actual engines, the transmission system as well as the actual rotors, and the relevant items of other systems required to operate it (avionics, flight commands, fuel system, etc.). It has required the construction of a dedicated building, specifically designed for dealing with air flows, noise and eventual damage when operating the test rig. Test engineers and technicians supervise the operation in a control room over video and protected by thick safety glass. Different dHC0 test rigs, specific to various

helicopters, can be exchanged within this building.



Fig. 1. Overview pictures of the sHC0 H160

Objectives of the sHC0

The initial and primary objective of sHC0 and dHC0 is to secure the global development schedule of a program.

In the test strategy of the programs before H160, Airbus Helicopters used to develop test rigs for various systems individually. Integration tests and verification at helicopter level were possible with the first flying prototype only. Late detection of remaining design issues has too often led to delayed development schedules. Airbus Helicopters has taken an example on the Aircraft Zero from Airbus Commercial Aircraft to find a solution for this.

By allowing earlier system integration tests at helicopter level, on non-flying Helicopter Zero

instead of on a flying prototype, issues can be discovered earlier, and are more easily understood in a convenient test environment. Consequently, they are solved with a decreased cost and delay when considering the program globally.

Furthermore, the sHC0 is considered as a test facility able to provide global support and de-risking capability of all downstream activities related to the helicopter development because it represents an opportunity of dry run for many activities with more accessibility and available earlier in the process:

- To prepare and secure the schedule of first helicopters' manufacturing, in particular the electrical harnesses
- To prepare ground tests and flight tests
- To reduce the workload on helicopter prototypes: integration tests, replaying and investigating flight incidents, tests of degraded modes and failures which are dangerous to perform in flight
- To provide familiarization and training to the systems for the whole development community: Flight test crew, Production staff, Customers, Maintenance staff, Technical publication staff...
- To anticipate and ease development of Flight Training Simulator
- To support handling of service bulletins
- To reduce after-delivery modifications by providing additional endurance tests, which cannot be afforded on actual helicopters.

Similarities and differences with Aircraft

Zero concept of Airbus Commercial Aircraft

The sHC0 for H160 has been developed with prior discussions and technical exchanges with Airbus Commercial Aircraft. The main decisions for sHC0 architecture have largely been inspired by the "Aircraft Zero".

The way to design the main structure of the sHC0 is largely inspired from the practices of the Aircraft Zero. It is based on a robust primary structure designed to encompass the actual envelope of the aircraft and to withstand the maximal load of the flight command actuators. The secondary structure, fitted within the primary structure, provides the links between the primary structure and the systems' devices. As far as possible, to ease initial installation and evolutions, it is made of modular aluminum profile solutions hosting plates and brackets specific to each device fitting interface.

Another main similarity has been to consider the cockpit and the vehicle/cabin as two independent sub-parts of the whole aircraft: they have been designed to be completely electrically

coupled or decoupled to each other, so as to allow for testing each sub-part individually. But major issues have brought us to remove this design decision, we will explain it later in the text.

The management of both electrical reference and protective grounding for airborne systems is also based on Aircraft Zero practices. A network of low impedance copper plates, insulated from the primary structure, fixed to the primary structure provides electrical reference and power return path. The primary structure is insulated from the concrete ground to keep representativity to the actual aircraft. Both are connected to the building's ground in a single point.

The main difference in the technical decisions taken for the sHC0 in comparison with an Aircraft Zero concerns the Electrical Wiring Interconnection System (EWIS, hereinafter called "wiring harnesses") of the various airborne systems. The Aircraft Zero embeds a set of electrical harnesses designed specifically for it, based on the aircraft definition but with significant deviations to the harnesses installed in the actual aircraft. Harnesses in the Aircraft Zero host specific laboratory test features like signal break-out, instrumentation, improved accessibility, etc. For the helicopters, wiring harness design and installation is a critical point, with major impact and dependencies with the helicopter design, especially concerning space allocation, accessibility, weight and balance. And as wiring harnesses carry all electrical signals interconnection within systems and between systems, it can be the reason for a wide range of functioning problems: connector inconsistency, harness too short, EMI disturbance, etc. To be in a position to perform global and representative integration tests at helicopter level, it has been decided to fully consider the EWIS as one of the systems under

test and thus to install the actual helicopter wiring harnesses in the sHC0. As a consequence, in the sHC0 the specific laboratory test features listed here above are provided by means of harness extensions plugged onto the actual helicopter wiring harnesses.

Adapting "Helicopter Zero" concept to a helicopter retrofit program

Our second Helicopter Zero supports a retrofit program of an existing helicopter fleet, mainly leading to a new avionics suite and new mission systems. Therefore, Airbus Helicopters global Helicopter Zero concept has been applied with simplifications according to the actual scope of the program. The main point at the beginning of the project has been to define the test intentions for the systems concerned by the retrofit, and thus the helicopter devices to be installed in the sHC0.

Several vehicle systems available in the current helicopter fleet are not impacted by the upgrade and are carried over in the retrofitted helicopters. The related test intentions are then focused on checking the correct integration with the new avionics and no functional internal tests within these specific systems are foreseen. So, in the sHC0 these systems are replaced by simulation, except crew control panels and dedicated controllers (See Fig. 2). The powerplant being one of the systems carried over, it has been decided to not develop a dHC0.

All other systems more largely impacted by the upgrade have been implemented according to the classical sHC0 concept.

The systems involved in the flight management are in this case: the sHC0 provides facilities to close the loop and immerse the crew in a highly visually and functionally representative environment (See Fig. 3).

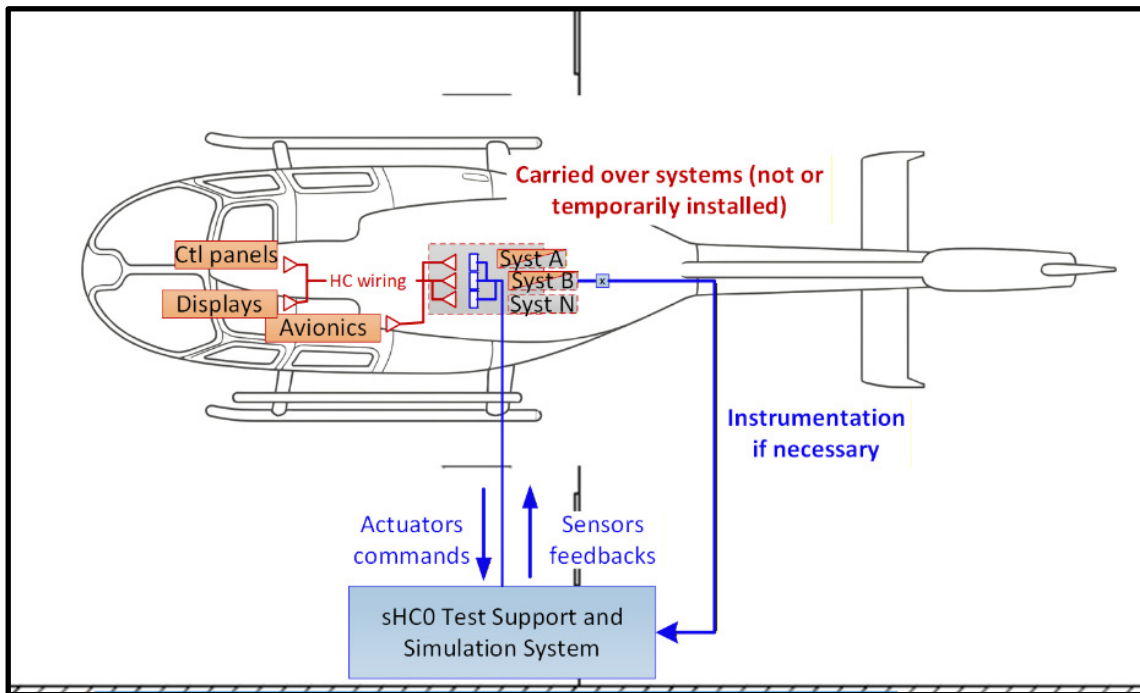


Fig. 2. Implementation of carried over systems

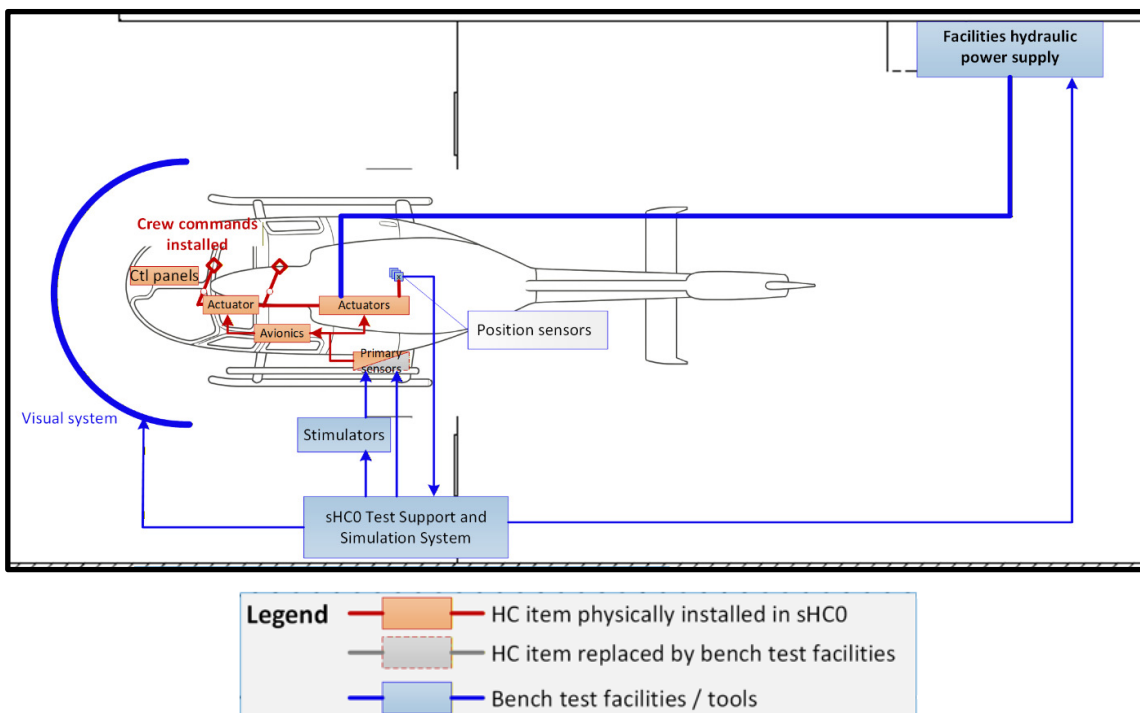


Fig. 3. Implementation of flight management system

The sHCO has also been designed to host the new mission systems. Two test modes are possible: immersive closed-loop tests with simulation of the end-of-line helicopter devices

(see Fig. 4), or open-loop tests with a complete set of actual helicopter devices and appropriate stimulators (see Fig. 5).

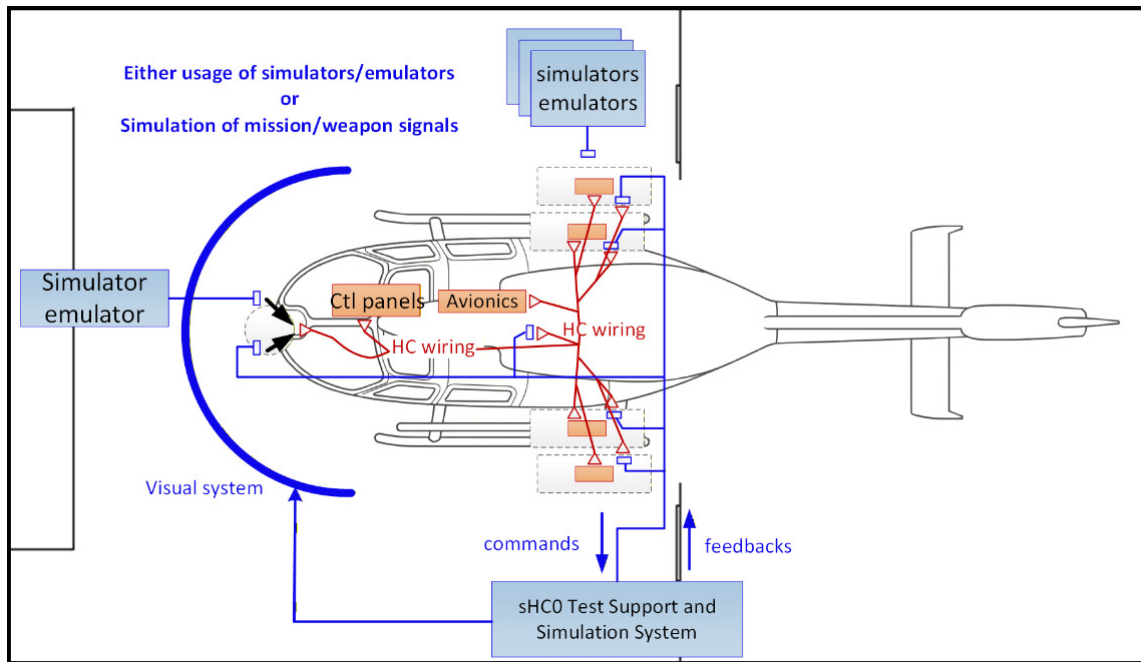


Fig. 4. Implementation of mission systems in closed-loop

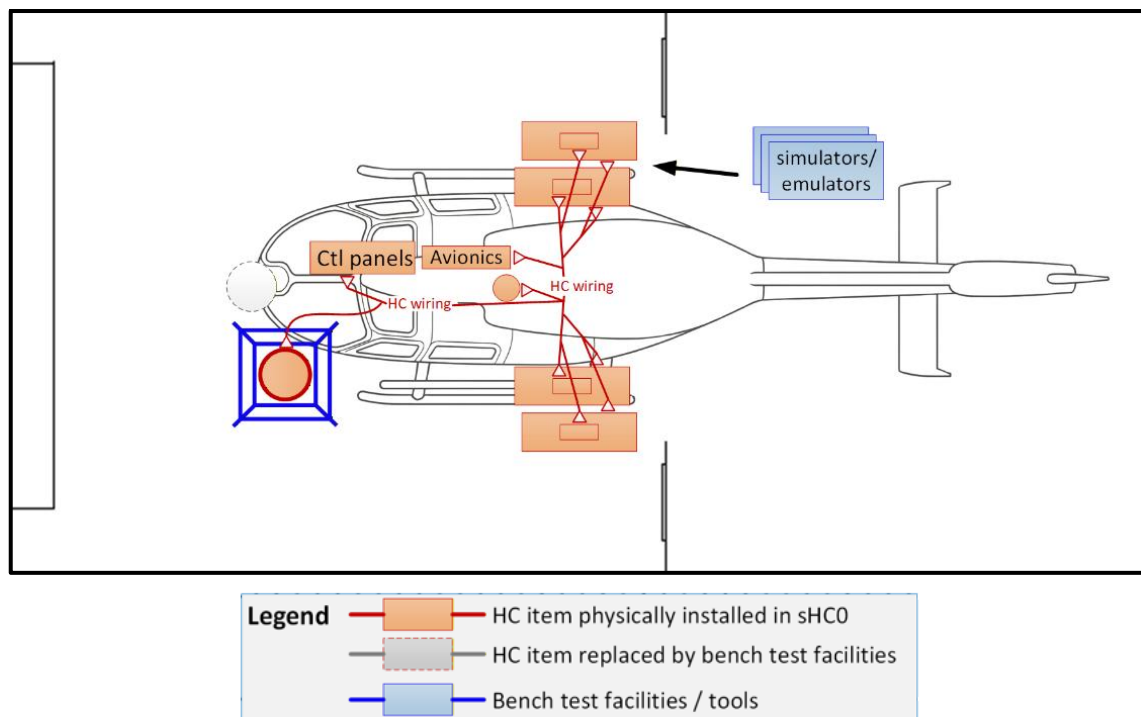


Fig. 5. Implementation of mission systems in open-loop

The cockpit ergonomics is another specificity of the considered program: the cockpit is designed with the highest care together with customers' flight test crews in order to ensure the best possible conditions for conducting the missions. The sHCO has been identified as an appropriate test means to verify the cockpit ergonomics. Therefore, the cockpit replica installed in the sHCO is requested to be highly representative: all crew control interfaces and all visible helicopter parts available and installed with ± 1 mm position tolerance, no obstruction in the

crew fields of view, ensure same color and reflection inside the cockpit, etc.

Adapting “Helicopter Zero” concept according to the lessons learnt from sHCO H160

As already explained here above, the sHCO H160 has initially been designed so that the cockpit and the vehicle/cabin can be completely electrically coupled or decoupled to each other. But this objective has been revealed incompatible with the decision of embedding the

actual helicopter wiring harnesses: the automatic switching system designed to provide this function made systems failing. Because of the constraint to be compatible with the architecture of H160 wiring harnesses, the switching system did introduce too much voltage drops on the lines (power lines more especially). So, the original idea to have two integration rigs in one has been abandoned. As a consequence, for the second sHC0, such an electrical decoupling of the test rig in two sub-parts hasn't been considered.

The same lesson from H160 sHC0 affects another topic for the second sHC0: the need to address two helicopter variants in the same test rig. Actually, the considered program concerns the variants of two customers, which differ for the mission systems from each other. Therefore, the sHC0 is requested to host both variants and to ease the switching from one to the other. The solution to make it possible is under design, and based on the lesson learnt with the previous sHC0 it will be based on manual connector exchange enriched with a monitoring system, rather than on routing signals via piloted switches.

sHC0 are designed to allow for setting various helicopter devices either simulated or actually

connected. The sHC0 H160 has provided this function by changing manually the harness connections without status indication: either connect the dedicated helicopter harness onto the actual device, or to a simulation harness for interfacing with electronic boards coupled to the Simulation System. The users of the sHC0 H160 have reported the difficulty to keep an overview of the current actual/simulated configuration, and the risk of misconfiguration for a given test intention. The technical solution introduced on the second sHC0 to solve this issue consists in a central control and monitoring system interfaced in two different manners with the helicopter systems:

- Harness extensions with automatic switching system for the devices to be the most frequently switched: electrical power sources (See Fig. 6) and some of the primary flight sensors (See Fig. 7)
- Detection of actual helicopter device presence and of the correct connection between helicopter harness and simulation harness (See Fig. 8)

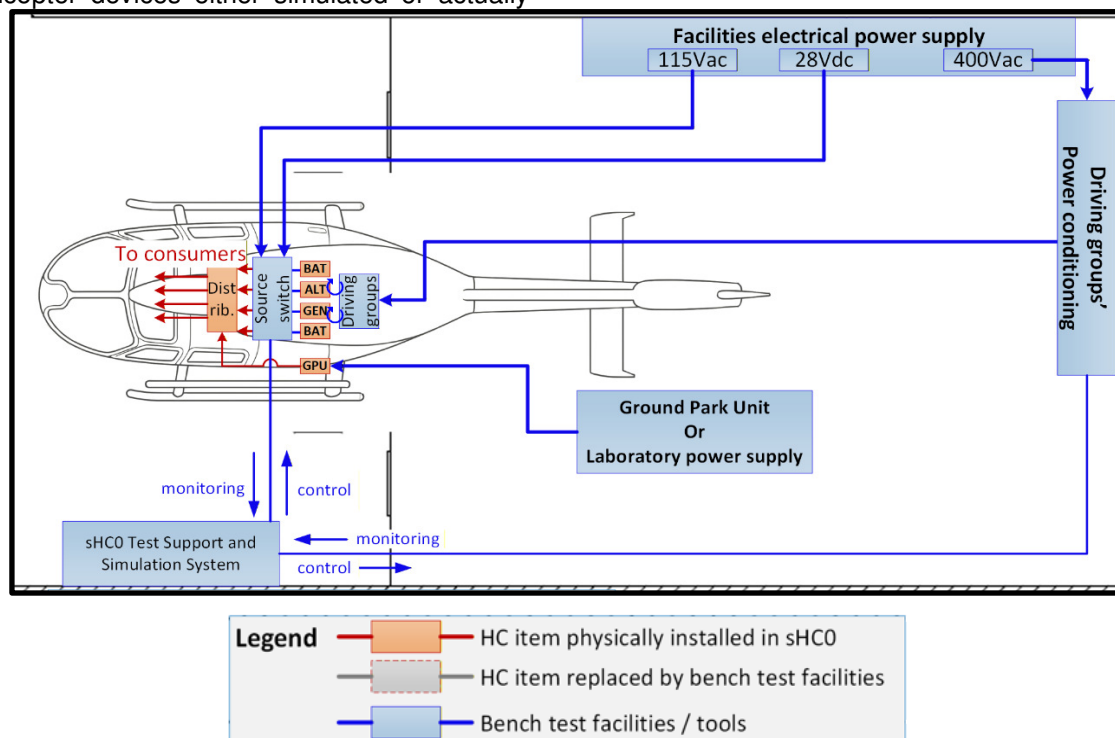


Fig. 6. Switching of electrical power sources between actual helicopter devices and building facilities

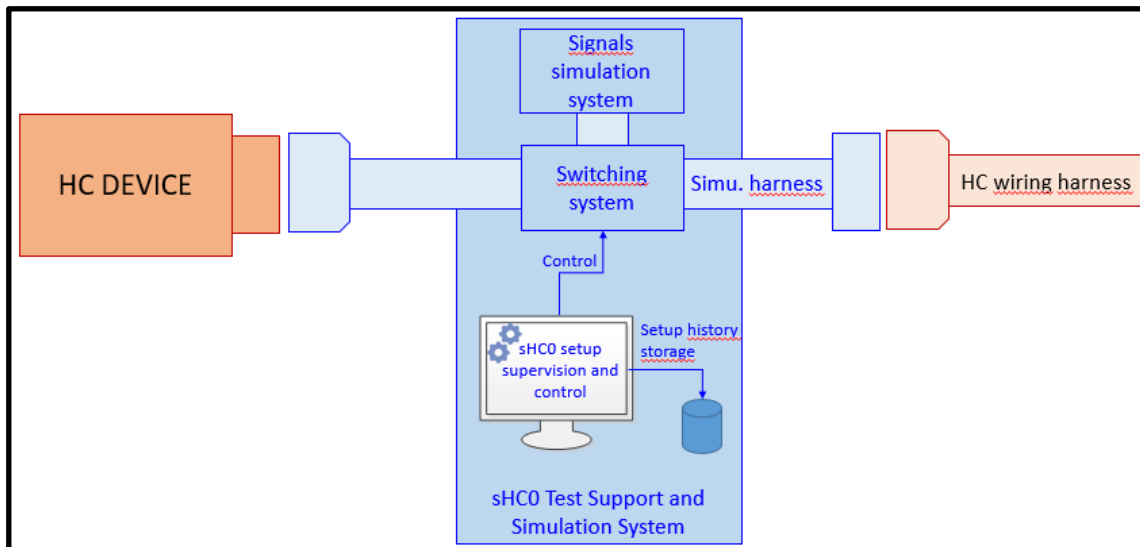


Fig. 7. Principle for automatic switching between actual and simulated helicopter device

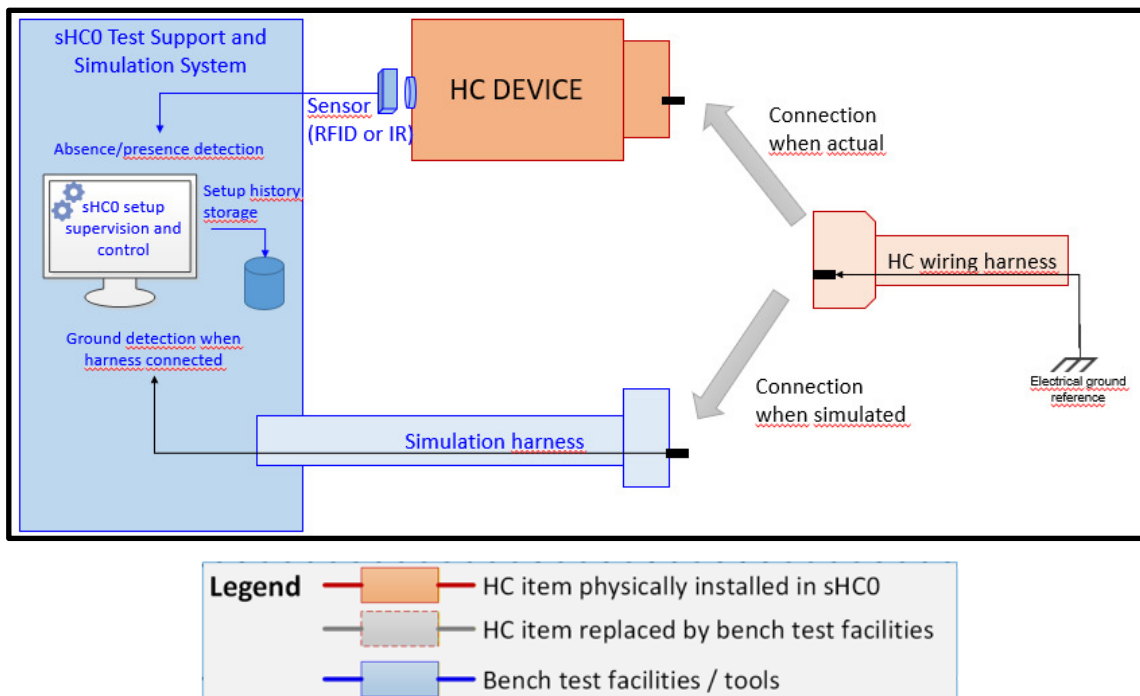


Fig. 8. Principle for manual switching between actual and simulated helicopter device

Some of the test intentions on sHCO request a representative chassis ground connection for all the helicopter devices. But the sHCO being a test facility on ground, contradictory requirements do appear. It shall then be designed to find a compromise between complying with electrical safety directives for “on ground” facilities and providing an electrical environment representative of an “in flight” helicopter:

- Ensure personal safety against electrical hazard: meaning to drain current appearing in case of electrical defect in any electrically powered device or in any intermediate cut-off connector
- Provide a testing environment which is representative enough for the test

intentions linked with chassis grounding characteristics

On H160 sHCO, the chosen solution was to neglect the impact of the residual resistivity of the actual helicopter chassis ground network and to use the industrial structure for this purpose while maintaining it isolated from the building ground.

The issue with this type of assembly comes with some helicopter devices which are not fully isolated (where chassis ground and electrical reference ground are internally connected): this implies that the ground network is connected to the industrial structure and therefore the overall

resistance is much lower than in the actual helicopter (See Fig. 9).

Consequently, we have taken following design decisions for the second sHC0 (See Fig. 10):

- The industrial structure (metallic) remains considered as the main ground network, connected to the earth
- Grounding of fully isolated helicopter devices is done through the industrial structure
- Not isolated helicopter devices are mounted on an isolator. Their chassis is connected with the electrical reference network
- The electrical reference network is connected to the grounding network for usual operation, with possibility to disconnect for specific tests requiring to be closer from an “in flight” helicopter (in this case additional safety measures to protect people and test material are necessary)

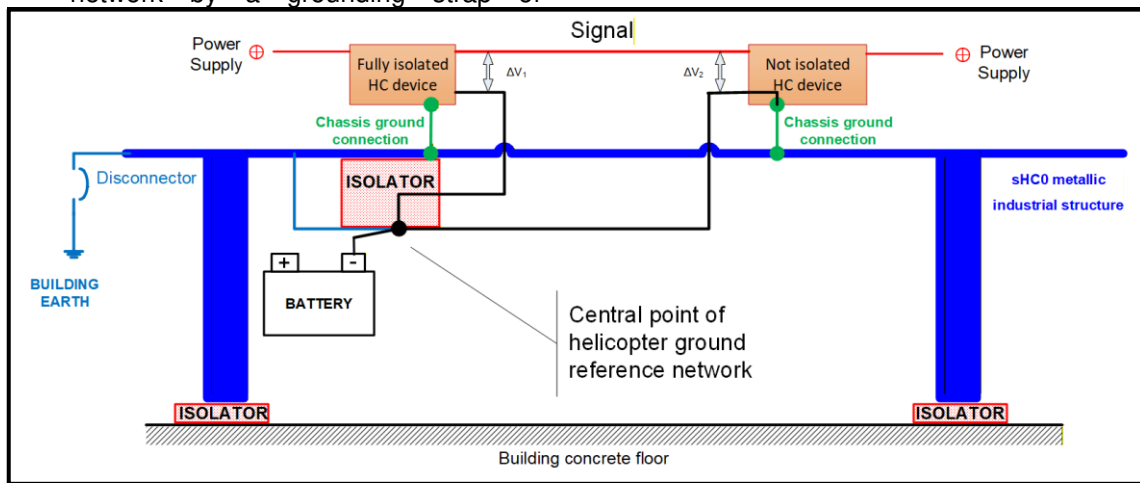


Fig. 9. Grounding principle on H160 sHC0

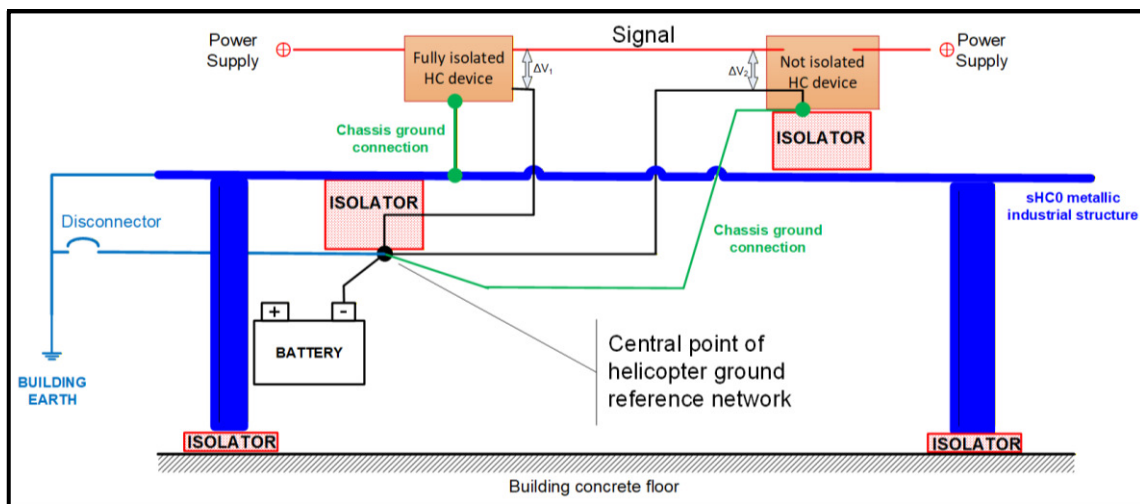


Fig. 10. Reviewed grounding principle on the second sHC0

Other challenges of the second sHC0 development

As previously mentioned in the description of the concept of sHC0, a visual system surrounds the cockpit replica to fully immerse the flight test crew. The visual system of the H160 sHC0 has been designed with the technology of a combination of video beamers projecting on a semi-spherical surface. And this system is embedded in a moveable platform so as to share it between two sHC0. The classical arrangement of the crew positions in the H160 cockpit (pilot and co-pilot side by side) has allowed the use of a hemispherical video projection surface. But in the second program, the two crew members are placed differently. The shape of the visual system of H160 sHC0 isn't suitable for it, so we have had to develop a new visual system with a specific design to comply with all constraints of size, field of view, accesses, etc.

Several technical solutions have been assessed regarding image projection technologies as well as the shape of the display surface (See Fig. 11).

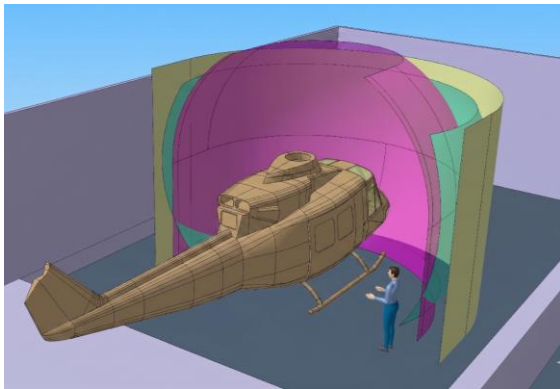


Fig. 11. Various screen type studies for the second sHC0

The usage of closely placed TV screens (flat or curved) has been soon excluded due to bad accessibility and doubts about visual comfort.

After initial study the considered solution was to realize a projection surface with a hybrid shape between a sphere and a cylinder, eventually making use of the possibilities offered by flexible LED panels.

The call for tender resulted in selecting a solution based on such flexible LED panels, but arranged in a simpler shape of a half cylinder ended with flat edges (See Fig. 12). In the current state of

the art, applying a deformation to LED panels on more than one single axis remains difficult.



Fig. 12. Overview of the Visual System developed for the second sHC0

This imposing visual system has repercussions on the accessibility to the cockpit, which has to be safe and efficient for users for all test sessions but also has to be consistent with the representativeness of the environment. Most of the engineering test sessions (80-90% of all sessions) do not need immersive conditions, but rather space for testers beside pilot and gunner to participate in the tests. And for immersive test sessions (10-20% of all sessions), there shall be no foreign objects in the crew's field of view.

To optimize users' experience with sHC0 cockpit replica, three main decisions have been taken:

- For engineering test sessions: two access platforms, easy to move and each able to host three people, can be accosted to the left and the right of the cockpit
- For immersive test session: removable step ladders dean for reaching both cockpit positions
- The canopy (part of the airframe holding the windshields, doors and windows) is fitted on a removable trolley to ease access to the cockpit

All in all, the second sHC0 hosts about 1200 actual helicopter parts. Despite a global scope reduction to the actual perimeter of the retrofit program, it's twice the number of helicopter parts installed in the H160 sHC0. It has been a tough challenge to design an ergonomic structure able to accurately host all these parts. A key success factor to master this challenge is the systematic usage of Computer-aided design (CAD) to establish a representative 3D Digital Mock-Up (DMU). In this "DMU as a master" approach, the DMU has supported the sHC0 for its whole initial

development and will be kept up-to-date for further changes in service.

The sHC0 DMU has been built in parallel to the helicopter DMU, incorporating many building blocks:

- Carried-over original helicopter parts used as is or adapted specifically for sHC0
- New helicopter parts used as is or adapted specifically for sHC0
- Testing items

Due to the age of the retrofitted helicopter, the 3D designs of some carried-over parts have originated from older CAD environments than the one used nowadays. They couldn't be fully trusted: additional checks of 2D drawings and/or actual parts have been necessary to consolidate the associated design.

And the situation of concurrent engineering, helicopter versus sHC0, has been an additional challenge: the risk has been high to miss design changes on helicopter development and generate issues for the parts installation on the sHC0. A robust configuration management system is the right mitigation to this risk. It is mandatory that the parts to be installed in the sHC0 are properly managed in configuration as soon as the development starts, and that they are managed at the right level of granularity in the configuration cascade. Managing too large assemblies around the parts of interest for the sHC0 is an obstacle for building its DMU efficiently.

Conclusion

By adapting the proven "Helicopter Zero" concept to a helicopter upgrade program, Airbus Helicopters effectively secures the global development schedule through early system integration and ground verification. Despite the inherent complexity of the aircraft and specific technical hurdles—such as redesigning the visual system for another cockpit layout or balancing flight-representative electrical grounding with ground safety constraints—the valuable lessons learned from the H160 sHC0 enabled the team to implement optimized solutions. The "DMU as a master" approach, coupled with robust configuration management, stands out as a key success factor in managing the installation of numerous actual components and ensuring the long-term supportability of the platform.

Glossary

2D - 2 dimensional

3D - 3 dimensional

AH - Airbus Helicopters

ALT - Alternator

BAT - Battery

CAD - Computer-aided design

dHC0 - dynamic Helicopter Zero

DMU - digital mockup

GEN - Generator

GPU - Ground Park Unit connector

HC - helicopter

LED - light-emitting diode

sHC0 - system Helicopter Zero

References

- [1] Iron bird (aviation)
[https://en.wikipedia.org/wiki/Iron_bird_\(aviation\)](https://en.wikipedia.org/wiki/Iron_bird_(aviation))