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# RESEARCH FLIGHT SIMULATOR FOR HELICOPTERS (RFSH):
# DESCRIPTION AND APPLICATION TO
# FIRE CONTROL SYSTEM DESIGN

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# RESEARCH FLIGHT SIMULATOR FOR HELICOPTERS (RFSH) : DESCRIPTION AND APPLICATION TO FIRE CONTROL SYSTEM DESIGN

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## ABSTRACT

The increase in avionics systems complexity requires the use of new techniques, involves enlarged financial costs and time expenditure. There is need therefore to evaluate the new concepts by simulation before their development.

In 1978, the French Official Services initiated the development of a research flight simulator for helicopters.

The main characteristics of an RFSH is to be capable of various evolutions to cover its whole field of applications.

It includes :

– a cabin with conventional instrumentation, cathode-ray tube and four axis flight controls
– an outside environment visual system
– an acceleration and vibrations simulation system
– a noise generation system
– computers with real time softwares.

The first application is to help the design of an air to air combat helicopter's system. The main objectives of the piloted simulations are the following :

– adjustment of the controls and the symbologies
– adjustment of the fire sequence and evaluation of its practical feasibility (crew workload)
– evaluation of the interactions between fire control and flight control
– study of the system's operation in back-up modes.

## INTRODUCTION

Nowadays training simulators are widely used in a number of fields : nuclear industry, aircraft, ships, machine tools, army tanks, etc. Their main purpose is to make it possible for the future utilizers of the operational systems to get to know them better, often in new situations : tactical situations, environment, cases of failure, rare operational events, etc .

The idea of using research simulators is much more recent. Originally, the idea was to assess and confirm new designs, prior to expensive developments, the costs of which are often increased by modifications made necessary by an insufficient knowledge of the initial definition and the resulting scheduling delays. This illustrates the basic difference between training simulators, which are based on an exact definition of the operational system, and research simulators which contribute to the development of definitions and which must therefore be able to absorb successive modifications. If today there are still very fèw research simulators in use, it is because the idea of spending money on research in the very early stages, with a view to spending less in the development stages, is not readily accepted.

In 1978 the Official French Authorities adopted the principle of a research flight simulator for helicopters (RFSH). The operation was broken down into two stages. The first stage was a feasibility study which resulted in the definition of the RFSH. The second stage consisted in developing the «hardware + software» defined in stage 1.

The Service Technique des Télécommunications et des Equipements Aéronautiques (STTE) was the prime contractor for all this work which was a joint operation conducted by three partners :

– the Centre Electronique de l'Armement (CELAR) in Rennes,
– the Centre d'Essais en Vol (CEV) in Istres,
– the SNIAS (helicopter division) in Marignane.

The purpose of this joint operation was to bring together the specific skills of each partner in order to reduce the costs and time required for the complete operation.

## 1 – PRELIMINARY APPROACH

The RFSH was initially defined as a simulator capable of real time operation and including the presence of a crew. In order to ensure a more exact definition three main principles were adopted :

– the RFSH must be considered as a whole,

– it must be replaced in its general context,
– for its construction it must be taken as a set of interacting elements provided with an organization.

Moreover the research and operating objectives were defined and analyzed.

**1.1 – The research objectives** were defined by taking into account the different stages characteristic of the development of a new helicopter programme and the partners tried to envisage how the RFSH could be used at each stage, by stressing the following points :

– Position of the RFSH with respect to the other research means available at this stage.
– Development stage of the aircraft and avionics.

The three guiding principles were :

– the harmonization of the simulations on the 3 sites in order to increase their effectiveness,
– the development of a modular, rearrangeable and reprogrammable product so that it can cover a wide field of application,
– the distribution of the development tasks amongst the three partners.

**1.2 – The operating objectives** adopted were :

– The RFSH must be an economical means of research
– The effort required for the software development and improvement must be included in a more general context than its use for the RFSH
– The RFSH must be readily available and easily used by operators without specialized training.

**1.3 –** A more detailed definition was established by taking all these objectives into account : the RFSH must be a research means capable of reconstructing in real time the flight, as seen and felt by a helicopter crew, in its environment and with all the flying aids which are available to them.

**The notions of «flight, seen and felt» and of «environment»** convey the decisive role in the crew's behaviour of the data obtained from seing the surroundings and from the different sensations such as vibrations and accelerations.

Remarks :

– The flight envelope of helicopters is different from that of aeroplanes ; as a result, in simulation, the reproduction of the surroundings is very different. For example, NOE flight or hover flight calls for an exact detailed reproduction of the landscape.
– The reproduction of the surroundings or of the sensations such as accelerations or vibrations may be partial according to the type of assessment or validation to be treated.

**The notion of «research means»** conveys the necessity for the RFSH to have a pluralistic capacity in its applications and in particular for it to have provision for potential integration in a weapon system.

## 2 – DESCRIPTION OF THE RFSH

### 2.1 – Work Stages

The first stage was broken down into 3 parts or processes :

**Process 1 : Feasibility**

Process 1 enables the feasibility and the general definition of the content of certain sub-assemblies to be ascertained according to the objectives and restrictions. It should also specify the way in which the simulator and its sub-assemblies can be validated.

The results of this process are essential : they define the future research possibilities, the simulator and its material content.

**Process 2 : Definition**

Process 2 represents the working out of the RFSH specifications determining the exact functions of each sub-assembly and the interaction amongst them.

**Process 3 : Design**

Process 3 represents the working out of the technical specifications and preparation of the sets of drawings for actually building the RFSH in the subsequent stage.

The second stage was broken down into two processes :

**Process 1 : Development and Implementation of the Different Sub-Assemblies**

Process 1 also includes the inspection of the sub-assemblies where they were manufactured.

**Process 2 : Integration** of the different sub-assemblies after checking the correct operation of each of them.

### 2.2 – General Description

The developments for the RFSH were divided into two parts :

– the mobile research unit which includes the software and the cabins (UME)
– the heavy research unit which includes all the rest, i.e. the means of simulating the environment : vibrations, accelerations, landscape, turbulence, noise effects as well as the data processing equipment (ULE).

In the sharing out of the development, SNIAS was responsible for producing the UME while CEV and CELAR produced their ULE in a more general simulation centre context, that is to say in accordance with the other development programmes in progress. This task sharing is due to the fact that the SNIAS is not called to have its own simulation centre. However, the UME will enable them to carry out simplified simulations with the cabin and data processing equipment, and also to prepare the simulation campaigns at CEV or CELAR efficiently.

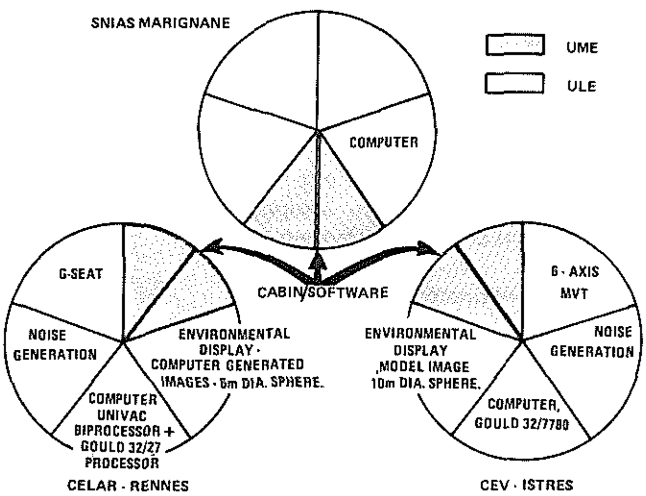
**The CELAR ULE** is composed as follows :

- Data processing equipment centered around a UNIVAC biprocessor with a GOULD 32/27 front end processor.
- A 6 m diameter sphere for projection of the environment. The image projected is a computer-generated image comprising the surrounding landscape and the targets. It is automatically controlled by the movements of the pilot's head.
- A means of reproducing the noise environment.
- A g-seat for reproducing accelerations and vibrations.

**The CEV ULE** is composed as follows :

- Data processing equipment centered around a GOULD 32/7780 processor
- A 10 m diameter sphere for projection of the environment. The image projected is obtained from a model of the ground and a microcamera automatically controlled by the helicopter simulated manoeuvres. The projected target image comes from a mobile model.
- A «spider» type 6-axis movement, each actuator of which has an authority of 1.6 m ; it is capable of a 10-ton load
- A means of reproducing the noise environment.

The UME developed by the SNIAS is composed of cabins and software.




## Cabins

The cabins are single-seater cabins. They were designed this way because of the very high cost of an environment reproducing system for a two-seater cabin, which has to overcome optical problems created by the fact that neither crew member is in the centre of the sphere-screen ; not to mention the fact that a projector is required for each crew member since they don't see the same landscape at the same time.

In fact, according to the first potential applications of the RFSH, this restriction is not disadvantageous, particulary if the reduction in development costs is taken into account. Any gaps must simply be specified in detail together with the way in which they can be made good using other development means in connection with the programme in question.

The cabins are fitted out exactly like real cabins and are of modular design. The instrument panel can easily be transformed since it is removable and can be completely replaced. It includes conventional simulated instruments (EADI, EHSI, airspeed indicator, radio altimeter, caution-advisory panel) and a «shadow-mask» multifunction cathode ray tube. A second screen may be installed.

Two side benches enable the installation of a large number of control units.

As regards the flight controls :

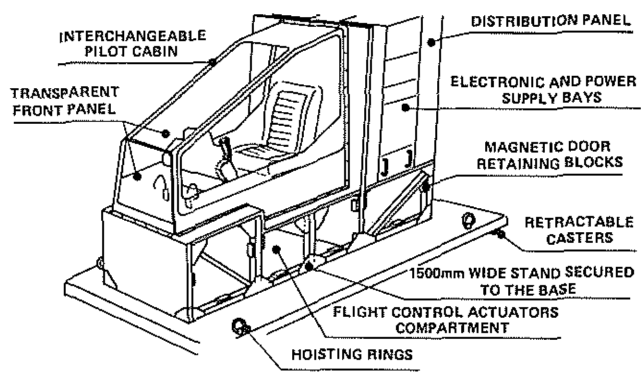
- There are programmable electro-hydraulic load simulation systems on both cyclic pitch axes. Thus, any of the load laws can be reproduced and parameters such as slope, stiffness, dry friction, etc . can be modified dynamically.
- There is a trim unit, load reproducing system on the collective pitch axis and on the yaw axis.

Moreover, for the first applications the cabins were designed to receive :

- a system of sensors for helmet-mounted sight
- a head-up display,
- a lateral joy stick,
- a g-seat.

It should be noted that all the cabin components were specified so that :

- the upper section of the instrument panel could be replaced,
- the flight controls could be relocated,
- the seat position could be modified.




## Software

The software can be divided into two sections :

- Interface and cabin management software,
- Models—autopilot, engines, flight mechanics.

- **Cabin Management Software** : it handles the parameters associated with the controls and cabin displays, not calculated by the models. It also processes the data required for programming the flight control electro-hydraulic load reproducing systems.

- **Interface Software** : It sets up all the parameters output by the other software (which as a whole may be called the application) and transmits them towards the cabin. It also receives the cabin data and sets it up for the application.

- **AFCS Model** : The AFCS model is an interface between the flight controls and the flight mechanics model. It simulates the basic standard modes, i.e. primarily the attitude hold and the heading hold. In accordance with the RFSH objectives, this software is also used in a computing centre, particularly for the simulations required for the definition and for establishing the flight laws.

  However, there is no coupler model for the AFCS additional modes, since these are specific to each application, therefore programmed by application.

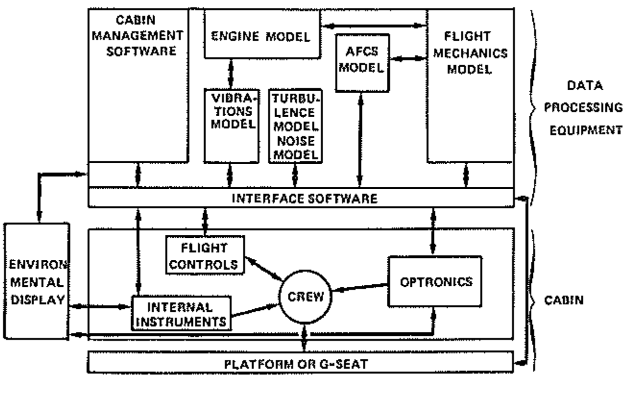
- **Engine Model** : The engine model depends on the application. The one developed for the RFSH for preliminary research is the Turbomeca model TURMO 3C4. It should be noted that the simulation of an engine may be more or less detailed, since the different types of assessment/validation of all new concepts do not require a detailed simulation of the static and dynamic behaviour of the engine(s).

- **Flight Mechanics Model** : The purpose of this model is to reproduce the helicopter behaviour throughout its flight envelope : high and low speeds, tactical flight, high incidence angles, strong side-slipping, etc . It is made up of three modules which calculate the aerodynamic loads and moments on the main rotor, the tail rotor, the airframe ; it then integrates all the data in order to calculate the attitudes and displacement.

  Aerodynamic disturbances can be introduced into this model, this enables atmospheric turbulence and turbulence due to the weapon system : gun fire, missile release, antennas rotating, etc ., to be simulated.

  The entirely modular flight mechanics model is also used in a computing centre for research, e.g. for the AFCS research or for perfecting the fire controls. It was designed so that it can be changed from one type of helicopter to another simply by entering new data such as aerodynamic coefficients, inertia moments or aircraft c.g.

  All the software operates under the control of a real time monitor. It is all written in the FORTRAN language so that it can easily be used by the research engineers. Moreover, the requirement that the flight mechanics model and the AFCS model must be put into operation in less than 15 msec. has been met (on the GOULD 32/7780 processor). This makes it possible to operate the assembly at 20 Hz.



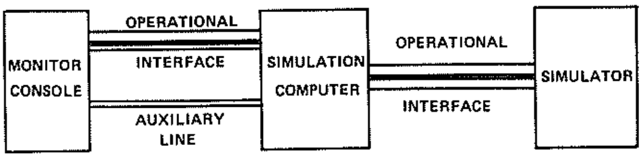

**Cabin and Software Debugging**

The cabin and software are checked out using a debugging console which is connected to the computing centre and not to the cabin. The console comprises three sections :

- a flight controls console (joy sticks) associated with conventional instruments,
- a hydraulic and electric auxiliary power units console,
- a programming console with screen, keyboard and microprocessor 8086 with which the parameters to be displayed and the type of test are defined.

Three types of tests are possible :

- simplified flight control from the console controls,
- recopying of instruments in normal cabin control
- cabin and software debugging and tests.




## 3 – USING THE RFSH TO DESIGN AN AIR-TO-AIR FIRE CONTROL SYSTEM

### 3.1 – Methodology

It should first be pointed out that a research simulator is part of a set of research equipment used in the design/development of a weapon system.

The standard procedure comprises :

- theoretical simulations in the computing centre, primarily for preceding research (modelizations)
- a system integration facility, primarily to validate the communication between the different system sub-assemblies and the system logic
- auxiliary aircraft with which the behaviour of one or more sub-assemblies can be tested in flight
- prototypes.

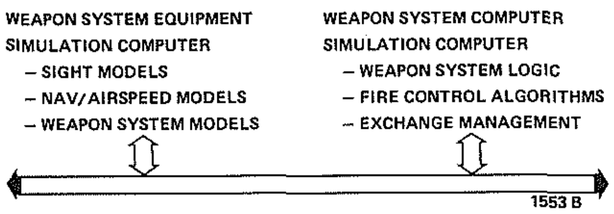
The efficiency of the whole depends on the complementarity of the equipment, hence the judicious choice of experiments, of their distribution and their scheduling.

### 3.2 – Application to Air-to-Air Fire Control (gun, missiles)

#### 3.2.1 – Preliminary Operations

To begin with modelizations in the computing centre made it possible to establish firing algorithms. The modelizations of the sensors (system inputs) and the weapons (system outputs) were designed to determine the equipment specifications and to assess the firing sensitivity to the different parameters.

Then another research operation resulted in the fire control being simulated as a whole into real time, using a computer which simulated the weapon system computer and was connected by a digital link 1553 B to a computer used to simulate the other equipment items. It was thus possible to measure the effects of delays in data propagation in the system, computing frequencies, and hence to estimate very accurately the computing load.

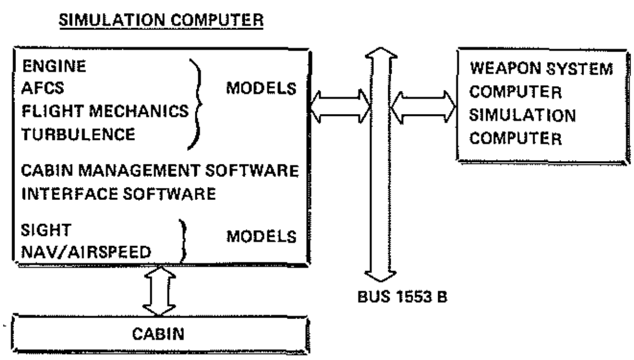



The RFSH was then used to develop and assess the fire control system (or weapon sub-assembly) with the crew in the loop.

Moreover, all the experiments concerning control only were conducted : day/night flight, with head-up-display, tactical flight, etc ...for which a single-seater cabin was particularly suitable.

- **Data Processing**

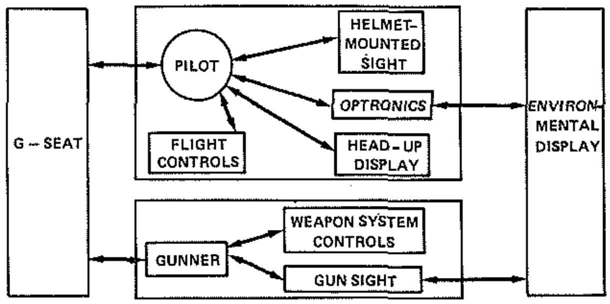
  The RFSH computer also performs the function of simulating the weapon system sub-assembly sensors. It is connected to the computer which simulates the weapon system computer by a 1553 B link.




- **Crew**

  The pilot is in the RFSH cabin. He has at his disposal his helmet-mounted sight and the head-up display. If the weapon system is to be operated by the pilot, the assembly is particularly suitable.

  If the system is to be operated by a gunner, he is established away from the sphere in a static cabin on the ground which includes his specific controls, a g-seat and a simulation of his target acquisition means (main sight). The gunner is in fact presented with the image he sees in his sight only, depending of course, on the maneuvers carried out by the pilot, but with no other display. It is in fact a portion of the image projected on the sphere, which is easily obtained when a computer generated image is used.




### 3.2.2 – Application of the RFSH

The purpose of the experiments is to determine the practical feasibility of the firing and to estimate the firing performance with the crew in the loop.

- **Practical Feasibility of Air-to-Air Fire**

  For this the RFSH is used to assess :

  – the crew/system interface,

  – the formal pilot/gunner dialog,

  – the crew workload,

  – the reciprocal fire control/flight control effect.

  A large number of situations are repeated several times, with different crews. The following are then assessed (in normal modes and back-up modes) :

  – the controls associated with the weapon system

  – the displays

  – the target acquisition equipment with in particular the firing symbols

  – the symbols for communication between the pilot and the gunner together with any form of formal communication

  – the effects of the firing on the helicopter control by high frequency recordings of the aircraft parameters

  – the effects of the helicopter control on the target tracked by the gunner using a video recorder

  – the system logic which affects the workload of the crew.

- **Firing Performance with Crew in the loop**

  This stage took place concurrently with an auxiliary aircraft and a System Integration Facility.

  The system sensors and the weapon system were assessed in flight on the auxiliary aircraft, without any notion of integration. The data collected in this way was used to readjust the RFSH theoretical models and also to determine better the fire control overall performance . It should be noted that throughout the model readjustment stage, the flight mechanics model was the one which corresponded to the auxiliary aircraft. The operational aircraft flight mechanics model will only be placed on the RFSH when all the models are representative. Throughout this stage, software modifications will first be tested on the facility, particularly those affecting the system data management.

## 4 — CONCLUSION

The first research operations carried out with the RFSH show the advantages of such a tool. However, it should be noted that its effectiveness is closely linked with a correct analysis of the requirements and restrictions which enable clear objectives for its design to be defined. The more important points are :

- the cabin modular design,
- the flexibility of the software,
- the possibility of including new functions,
- a good reproduction of the environment, closely linked to the helicopter flight envelope.

As for all multiapplication equipment, it is not nor ever will be perfect for a specific application. But the efficiency/cost ratio appears to be excellent, especially if the RFSH is set in the context of development equipment in connection with a programme.

Other uses are already planned : the assessment of flight control laws for Fly-by-Wire Controls and that of new-cabin equipment as part of research into cockpit design.