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HEPO MISSION SIMULATOR
DEVELOPMENT AND USAGE FOR NH90 HELICOPTER

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ABSTRACT

HEPO which stands for HELICOPTER : OPERATOR STATIONS EVALUATION is a real-time simulator used to represent naval missions with full helicopter crew. HEPO is designed to assess the crew concept, including tasks allocation, as well as validate the Man/Machine Interface (MMI).

HEPO is, in fact, a helicopter structure mock-up divided into a fully equipped cockpit and a cabin including two operator consoles. The weapon system is modelized for the crew to enact predefined scenarios in a given operational environment.

HEPO is composed of :

- a hardware and software part providing general ergonomics as well as initiating and following up simulation progress
- an evolutive software specific of the modelized weapon system and Man/Machine Interface.

Developed in 1988/1989, HEPO has already proved a great help in the crew concept study of the future NH90 helicopter's naval version. Significant lessons were learned as it was used by operational crews from the four nations involved in the NH90 programme while a great deal of experience was acquired as regards simulation principles, mainly on :

- the main characteristics of this type of simulator
- HEPO development and approval for operation
- Application methodology.

It has been scheduled to use HEPO again early in the NH90 Design and Development phase.

In addition, HEPO flexibility and ease of reconfiguration also helps simulate systems fitted in other helicopters.

1 - CONTEXT

Helicopter manufacturers are now having to face rapid evolution of operational needs (increasingly complex missions, performance enhancement requirements, new functions to be met) which came into being as new technologies became available (highly efficient on-board computers, multifunction displays, fly-by-wire controls, voice control and synthetization).

This new context imposes reviewing the Man/Machine Interface (MMI) concepts as a whole for best satisfaction of those operational needs. Indeed, helping a standard crew process, in difficult conditions, every data delivered by the helicopter's sensors is a major problem.

Piloted simulation then appears to be the tool of choice helping study and compare the different concepts in the upstream stages of the programme for the principal selections to be made.

Tasks allocation between the system and the different crewmembers, in particular, can only be defined satisfactorily with sufficiently realistic simulations.

It is then essential to have, in the early stages of the programme, a tool complementing the flight simulators and offering the effective simulation of a full mission, in real time, by an operational crew. This tool is a major contribution to the design and study of crew organization and Man/Machine Interface.

A preliminary simulator dedicated to naval missions' performance was developed by Aerospatiale in 1983/1984 and operated by the French Navy in 1985/1986.

The initial results mainly were :

- A description of the mission systems functions
- The date to be presented to the crew
- The crew/system dialogues.

It then seemed desirable to improve on this preliminary experience with a second simulator allowing, with better representativity, a more extensive study of Man/Machine Interface. This second simulator was HEPO (HELICOPTER : OPERATOR STATIONS EVALUATION).

2 - HEPO OBJECTIVES

As an upstream design tool, HEPO helps define with realistic simulations the options to be retained for the organization of a naval helicopter crew, tactical and sensor operator, in particular, as well as the nature and the quantity of data exchanged between the pilot(s), the mission operators and the system.

HEPO operation should provide the following results :

Refinement of crew workload evaluation

- Crew concept proposal, number of crewmembers or different crew organization according to the mission's complexity
- Proposal as regards detailed tasks allocation between crewmembers
- Definition of automation level to be allocated to the system.

. Degraded modes study

- Proposal as to the crew's mode of operation and definition of the system's automation for operational efficiency, despite failures, as well as flight safety to be ensured.

Definition of the type and nature of the interfaces

- Keyboards, scope size, number of scopes per operator (combined use of two scopes by a same operator)
- Functional definition of the symbologies (colour, white on a black background), nature and display of data as a function of the flight phase or mission : capability to reduce this data to the essential necessary in the performance of the flight mission phase, with the intention to reduce the workload, and with the ability for the crew to manually display the data.

Preliminary definition of the functions to be coded and application in the Control and Display Units (CDU) to reduce operating steps and workload.

3 - HEPO DESIGN AND DEVELOPMENT : CONCEPTS AND MAIN FEATURES

3.1 - Main Design Choices

This paragraph is an analysis of HEPO objectives as well as the resulting considerations and choices for the design of this simulator, the ergonomic realism level to be attained and the complexity of the modelizations to be developed.

This analysis was undertaken with HEPO considered as :

- a design simulator
- a mission simulator
- a crew/system interface definition simulator.

3.1.1. - Design Simulator

HEPO is a design/definition simulator and not a development or training simulator which does not mean that the definition of the system being simulated and the crew/system interface is frozen or nearly frozen but that, on the contrary, the purpose of this simulator is to significantly help establish this definition with tests and the comparative evaluation of different configurations.

To do that, HEPO's hardware and software definition is to allow a rapid evolution :

- of the functions provided by the system being modelized
- of the displays presented to the operators and the symbologies, in particular
- of the definition of the Control and Display (CDU) and the pages presented to the operators
- of the significance of the function keys and the related procedures
- of the hardware definition of the equipment represented (size, shape and position of the Multifunction Displays, definition of the equipment control units).

This flexibility is indispensable if different configurations are to be evaluated and compared in a same mission phase. The following functionalities are also available and allow for a detailed analysis of this phase :

- Simulation freeze
- State saving at any time during the simulation
- Recovery of a saved state.

3.1.2 - Mission Simulator

HEPO allows simulating the missions performed by a naval helicopter for which the pure piloting function is not fully part of the mission. There are, in particular, no terrain following aspects.

HEPO is, consequently, not a piloting simulator where every piloting related element is to be modelized and simulated in detail and

- The outside world is not displayed. The missions are thus performed «by night»
- The flight controls as well as the automatic piloting and navigation coupling laws are extensively simplified
- Flight controls are available to the pilot only
- The cabin is fixed.

However, 4 operator stations are simulated for full coherence of the missions. Even a simplified modelization of the vehicle and piloting modes helps allocate a well defined role to the pilot as well as study the interactions between the pilot and the other crewmembers.

HEPO definition generally allows working, for a same hardware/software configuration, with crews composed of 2, 3 or 4 members according to mission and, thus, studying tasks allocation between the different operators as well as interactions between crew members.

HEPO helps simulate integral missions i.e. flying to a theater of operation from the parent ship, performing the mission in the theater of operation and returning to the parent ship. This in an operational environment which cannot be changed during the real-time simulation.

To this end, the following modelizations are undertaken :

- Operational environment and parent ship, in particular
- Simplified modelization of vehicle, flight controls, AFCS and basic system (navigation and communication data)
- More extensive modelization of the mission system including :
  - Sensors
  - Tactical control system, including tactical computer

- Data link
- Armament computer.

3.1.3 - Crew/System Interface Simulator

HEPO is to help optimize the crew/system interface so as to reduce the operators' workload and suggest a crew organization as well as a distribution of tasks between operators according to missions.

A quantitative approach of the workload should thus be possible and this implies a definite ergonomic realism.

To this end, the operators are to be in a hardware environment very close to that of a helicopter and providing the same realistic functions as those of the helicopter being simulated.

Thus, the crew sits in the mock-up of a helicopter's forward section composed of a cockpit with instrument panel, interseat console and overhead panel as well as a cabin with 2 operator consoles either side by side or separate. Crewmembers can move from the cabin to the cockpit. The cockpit includes 2 doors while the cabin includes windows and a double door aft. Helicopter seats are used throughout.

Displays and controls i.e. Multifunction Displays (MFDs), Control and Display Units (CDUs) keyboards, peripherals, marker spheres, warning indicators, dedicated control units, etc .. are close to those of NH90 which is the first helicopter for which HEPO is to be used.

It has been decided to affix tactile skins on large screens onto which controls and displays (scopes, keyboards, etc..) are physically represented for a rapid modification of the configuration of the equipment being simulated (size, shape, number, etc ..).

Furthermore, the images presented are to be sufficiently realistic for the operators to extract data from a noisy image background, as is generally the case in passive acoustic mode. Significant efforts have been made for this presentation.

3.2 - Physical and Hardware Characteristics

A general view of the simulator is presented on Fig. 1 with the different cockpit/cabin operator stations as well as the simulation coordinator station.

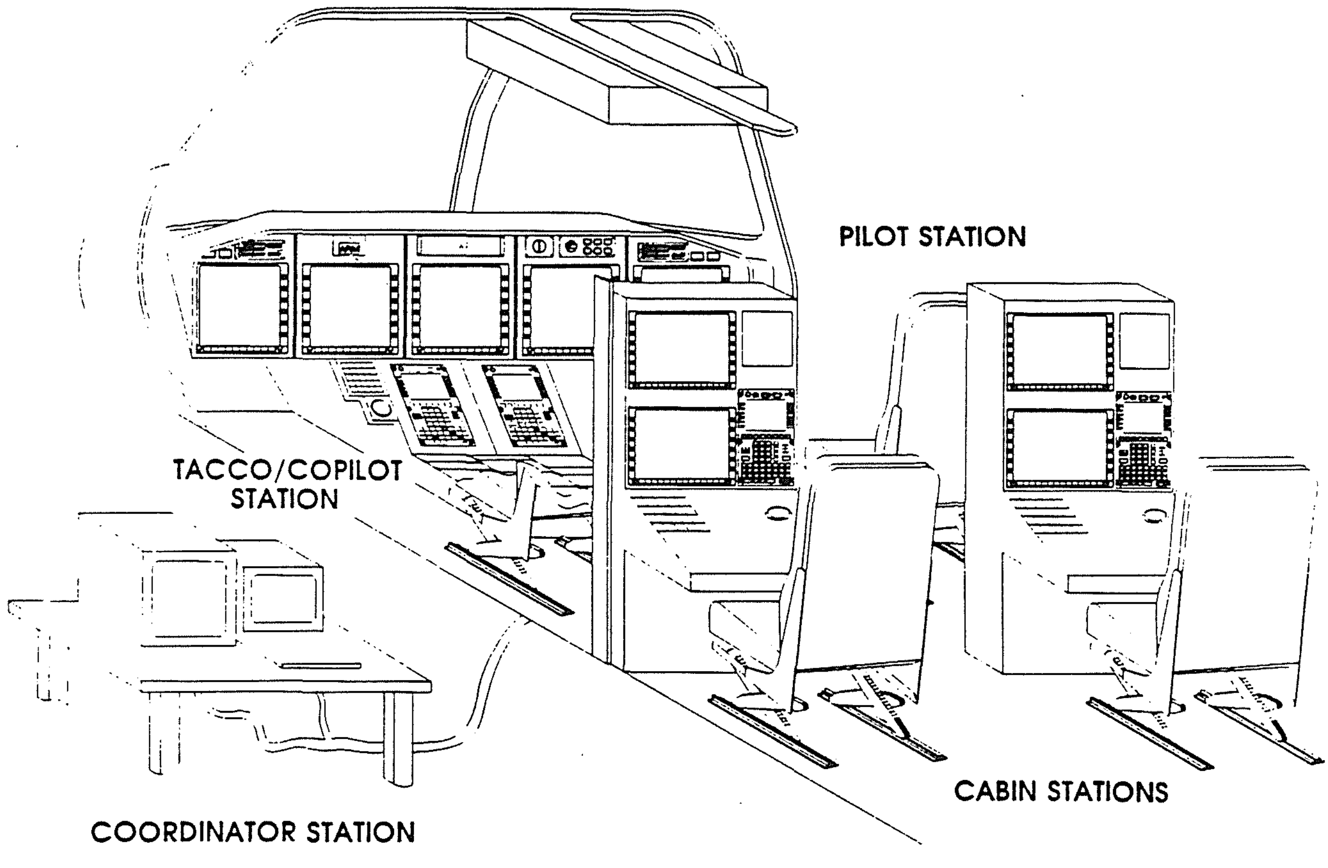

Figure 1 MOCK-UP GENERAL VIEW

The hardware architecture is presented on Fig. 2. Controls and displays are connected to a data network controlled by a central computer including the simulation management software and modelizations.
Links between the operator stations and data processing equipments are presented on Fig. 3.

3.3 - Software

The following software modules were included as the simulator was developed :

- Simulation configuration
- Simulation management during tests
- Inclusion of external parameters i.e. environment and other units
- Application of operator controls
- Displays generation
- Modelizations listed in Para. 3.1.2.

Part of the software that has been developed forms the basis of the simulator, allowing preparation and application of simulations. The remainder and modelizations, in particular, is specific of the system being designed.

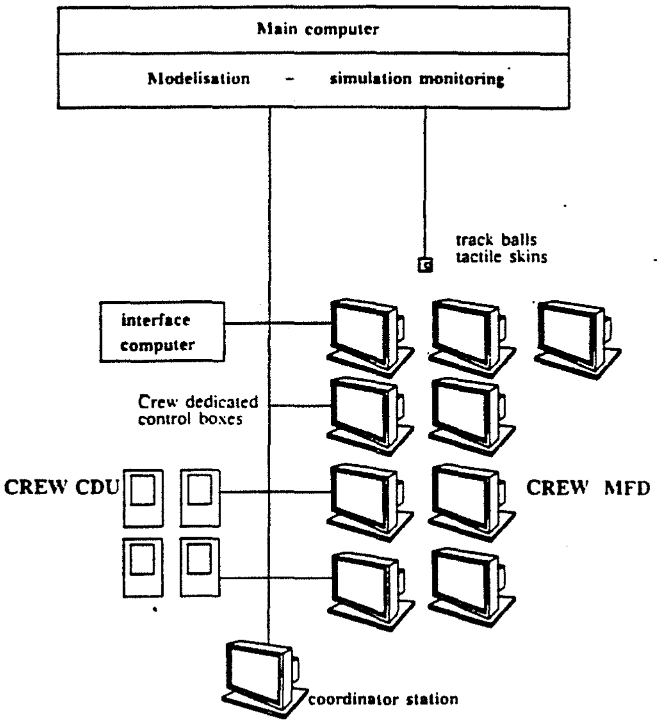

Figure 2 ***HARDWARE ARCHITECTURE***

3.4 - Synthesis of HEPO Definition

HEPO is composed of :

- A physical/software base forming its main frame and including :

- The physical/hardware environment i.e. fuselage, cockpit, consoles, displays and controls, computers and data processing equipment
- The software structure helping implement simulations and suggesting the main functionalities needed in operation.

This base provides general ergonomics and simulation applications. It must not be extensively modified, especially in the early phases of operation.

- A highly evolutive part for the successive configurations of the modelization software and the crew/system interface i.e.

- The functions of the on-board system being simulated
- The presentation of data (displays, CDU pages, etc ..)
- The appearance of the controls provided to the operators (keyboards, function keys, control units' panels).

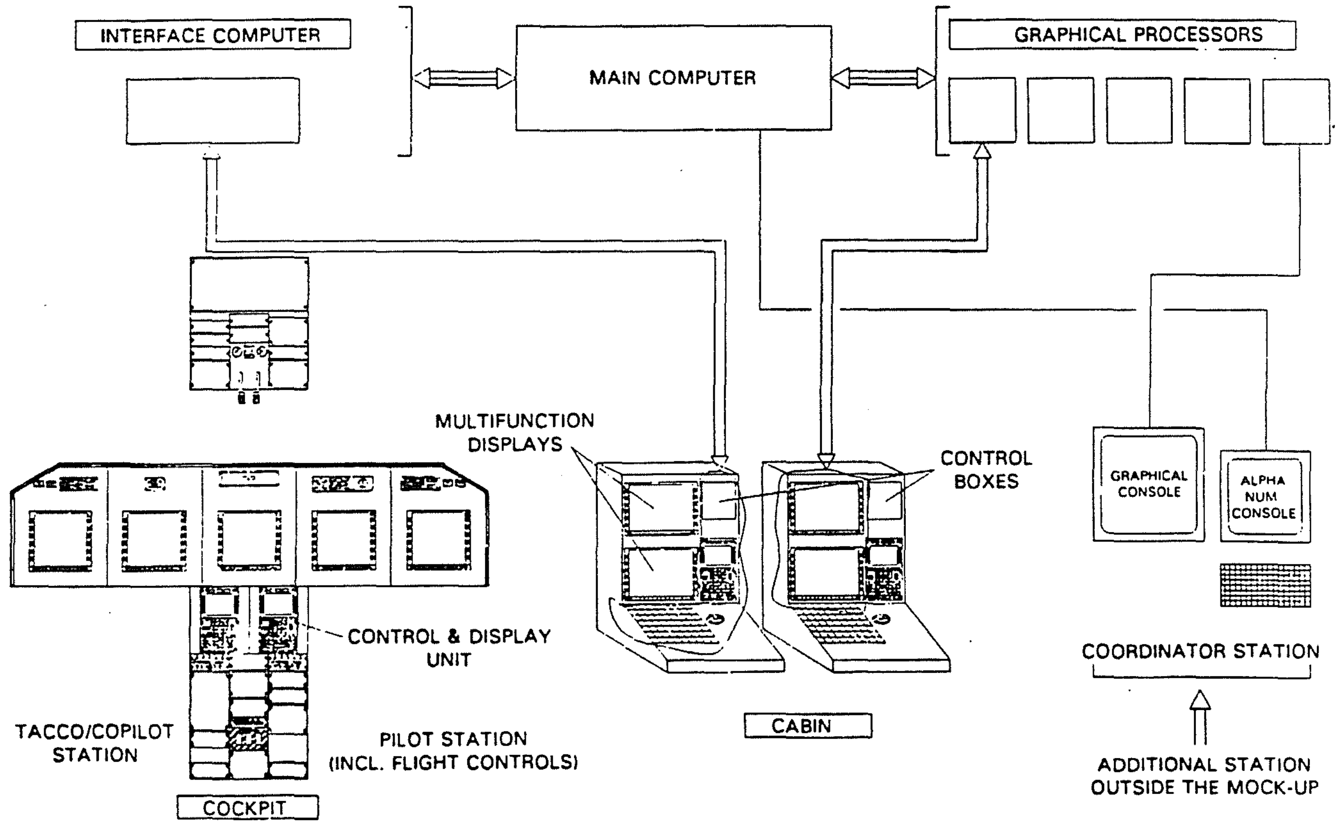

Figure 3 ***HEPO PHYSICAL DEFINITION***

The definition of HEPO' physical/software base was presented to the operators from French Navy at it progressed, as was the initial configuration of the evolutive part which helped validate the simulator.

HEPO definition allows for a highly flexible definition of this part and fast modifications of the configuration being represented. HEPO is thus not limited to the study of a single system design or not even to a single helicopter.

4 - HEPO USAGE FOR NH90 HELICOPTER

4.1 - Objectives

As the Project Definition Phase (PDP) of the NH90 helicopter came to an end, the industrialists suggested 3 crewmembers for the naval version (NFH). This allowed for a significant weight saving over the 4 crewmembers concept and it was concluded that the project was feasible within the required mass constraints.

It then became necessary to undertake NH90 mission simulations with operational personnel from the 4 countries involved to comfort the 3 crewmembers concept.

To do this, a Simulation Working Group was set up with representatives from the industrialists and the Navies involved and this Group devoted its efforts from mid)1989 to mid-1990 to :

- The definition of the objectives and activities to be undertaken
- The definition of a simulation programme and the tools to be used
- The definition of the methodology to be applied
- The definition of the scenarii and the simulators' configuration
- The performance of simulations and the drafting of reports.

The complementary operation of the HEPO design simulator and the EH 101 development simulator, representing a definition in progress of this helicopter was agreed.

The following objectives were set by the Simulation Working Group :

- Assessment of the 3 crewmembers concept's feasibility
- Support of Man/Machine Interface definition
- Precisions as to mission system functions' design.

4.2 - Simulation Programme and Methodology

4.2.1 -General

It was decided that the different Navies would work on common mission scenarii with identical simulated system configurations so as to make it easier to draw common conclusions.

It was also decided that each Navy would simulate with 3 crewmembers i.e.

- Pilot and tactical operator in the cockpit
- Sensor operator in the cabin.

A 4th Navy member acted as an observer to assess the satisfactory performance of the mission and the crew's actions as well as confirm the workload notations.

It is to be noted that each Navy crew was made up of highly experimented operational personnel.

Missions were studied by each Navy on HEPO for 2 weeks including

- A training phase
- The simulation of the different scenarii
- An evaluation of the results obtained and the preparation of a common report.

The training phase helped the crews familiarize thelselves with the simulator for them to enact the scenarii in a realistic manner and use the assessment methodology.

The crews' first reactions and comments were collected at the end of the training phase as to :

- Man/Machine Interface physical and functional definitions (general considerations)
- Initial assessment of modelization realism and ability to represent an acceptable workload.

The different scenarii were then enacted with successive evaluations described below :

a) On-line collection of workload type and level ratings during mission simulation
b) Collection of subjective comments with pre-established questionnaires (debriefing).

4.2.2 - Workload Assessment

A notation was used as regards crew workload with four difficulty levels excluding «medium» :

- Impossible
- Major difficulties
- Feasible but awkward
- Easy.

The notation scale suggested is presented in detail in Fig. 4.

The crews rated their workloads, at the observer's request, at 5 minutes' intervals and these ratings were related, at the end of each mission, to specific tasks for an accurate comparative and diagnostic assessment.

The notation device consisted of :

- 4 colour keys e.g. green, yellow, red and amber actuated by the operators
- A light actuated by the observer, for rotation request.

An additional assessment was made once each crewmember has completed a significant evaluation of the mission or an isolated segment of the mission, giving his impressions of the mental stress and time pressure he has experienced in each phase and the performance level he believed to be possible for his own tasks.

This assessment is presented in Fig. 5.

Whenever a particular mission segment appeared critical in terms of crewmember workload (impossible or major difficulties), the assessment was aimed to :

- optimize crew task allocation, if possible
- optimize task chronology during the mission (this involved shifting a particular task before or after the critical segment)
- increase the system's automation
- increase the number of tactical, graphic, etc .. aids available to the crew.
- Optimize the way some functions were used.

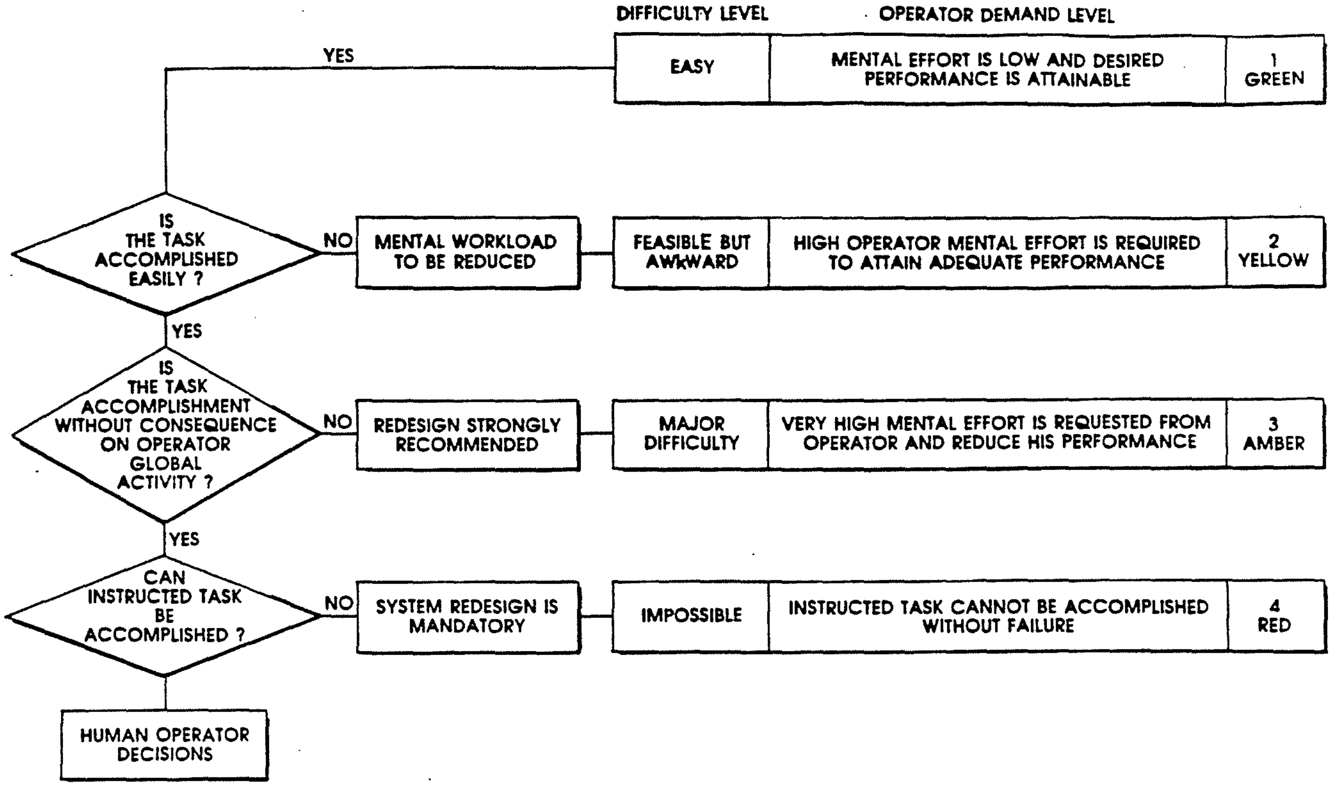

Figure 4 ***WORKLOAD LEVEL ASSESSMENT SELF-ROTATION based on modified Cooper-Harper Scale***

MENTAL DEMAND:

None — Low — Fair — High — Impossible

HOW MUCH MENTAL AND PERCEPTUAL ACTIVITY WAS REQUIRED(E.G. THINKING, DECIDING, CALCULATING, REMEMBERING, LOOKING, SEARCHING, ETC..).WAS THE TASK EASY OR DEMANDING, SIMPLE OR COMPLEX, EXACTING OR FORGIVING?

TEMPORAL DEMAND :

None — Low — Fair — High — Rushed

HOW MUCH TIME PRESSURE DID YOU FEEL DUE TO THE RATE OR PACE AT WHICH THE TASKS OR TASK ELEMENTS OCCURRED? WAS THE PACE SLOW AND LEISURELY OR RAPID AND FRANTIC.

STRESS:

Relaxed — Low — Fair — High — Tense

HOW INSECURE, DISCOURAGED, IRRITATED, STRESSED AND ANNOYED VERSUS SECURE, GRATIFIED, CONTROL, RELAXED AND COMPLACENT DID YOU FEEL DURING THE TASK?

OWN PERFORMANCE:

Failure — Poor — Fair — Good — Perfect

OWN PERFORMANCE AND SATISFACTION ARE EVALUATED THROUGH REACHED GOALS IN COMPARISON WITH INSTRUCTED TASKS.

Figure 5 ***COMPLEMENTARY ASSESSMENT***

4.2.3 - Additional Questionnaire

A questionnaire was, generally, presented to the crews at the end of each session to gather the following data :

- Workload i.e. type, cause and alternatives suggested
- Analysis of mission system functions i.e. frequency of use, usefulness, quality of representativity, system automation level, etc ..
- Man/Machine interface evaluation :
  - Generalities as to the quality of controls and displays made available as a function of the operational needs
  - Design of each equipment in terms of physical definition, philosophy of use, ease of application
- Evaluation of the representativity of the results obtained :
  - Simulator and modelization realism
  - Mastery acquired after training phase
  - Personal impressions during simulations
- Recommendations in terms of :
  - Realism improvements
  - Modelization complements to be made
  - Definition of the NH90 mission system i.e. system functions, MMI devices, etc ..

4.3 - RESULTS : CONCLUSION OF SIMULATIONS UNDERTAKEN

The summary drafted from the simulation reports approved bythe 4 Navies comforted the selection of the 3 crewmembers concept as the basic concept for the NH90 helicopter.

Furthermore, the work completed helped gather a number of data and impressions from the operational personnel of the 4 Navies involved in the programme as to the design and use of the NH90 mission system. Those results will be of great assistance during the Design and Development phase.

5 - CONCLUSION AND FUTURE PROSPECTS

The work undertaken during the development phase as well HEPO's first operation for the NH90 helicopter gave significant results. HEPO designers' expectations were met and they have confidence in this simulator and its future.

A great deal of experience has been acquired in a field which is proving essential in the definition of Aerospatiale's new products. A great deal was learned, in particular, as regards :

- The main characteristics of this type of simulator
- HEPO development and approval for operation
- Application methodology.

HEPO operation is planned early in the NH90 design and development phase to support hardware-definition of control and display devices as well as confirm the 3-crew concept selection with more accurate configurations.

Furthermore, HEPO's flexibility and ease of reconfiguration also allow simulating systems that are to be fitted in other helicopters.