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THE COCKPIT MOCK-UP (CMU)
A COCKPIT AND CREW STATION DESIGN TOOL

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ABSTRACT

The design process of an advanced helicopter cockpit is influenced by very different aspects, the most important of which are ergonomics, engineering feasibility and operational capability.

The CMU is a flexible, inexpensive design tool which can be used for low-cost development, especially for validating initial theoretical specifications before initial flight testing. The CMU represents a full-scale cockpit for a future light transport helicopter usingadvanced control system, multi-function displays etc. In the CMU the test personnel are part of a closed-loop simulation process. Therefore simulation modelswill be stimulated by user inputs, and the outputs of these models will be presented to the user mainlyon electronic multifunction displays. These outputs are information for flight guidance, navigation and system status.

This paper describes the aims and tasks, functions and design of the CMU. It also discusses the results obtained in tests with operational aircrews, test pilots and flying instructors.

TASKS AND AIM OF CMU

The Ministry of Defence of the Federal Republicof Germany is planning the development and construction of a helicopter for light transport and search and rescue (LTH/SAR). In the scope of this activity ESG was commissioned to build a design and development tool to obtain knowledge on

- ergonomic design
- technical realization
- operational capability

of the future helicopter cockpit.

In the schedule of development of a new helicopter-cockpit this design tool links the work in the concept formulation and feasibility phases with that of the development phase and pre-series production.

The task of CMU is to validate the preliminary theoretical specification of the helicopter cockpit by experiments, using the special knowledge and experience of future users, test pilots and flying instructors.

In addition to the validation of existing knowledge with help of CMU further findings can be obtained for refined specifications which form the basis of the development phase. To achieve this aim the CMU is flexible so that alternative configurations can be investigated in respect of panel arrangement and display and control functions. Changes to the existing design, the helicopter dynamics and control functions can be made within a relatively short time and with a minimum of effort.

The cockpit of the future LTH/SAR should be optimally designed in respect of the general design features shown in Fig. 1. These features therefore must be proved and evaluated for example with the help of the design tool CMU.

The results for every feature obtained by investigations possess different degrees of confidence, as shown in Fig. 1. The reason for this is that the environmental conditions of a real helicopter and helicopter missions are not fully simulated in the CMU. So the design work in the concept phase is supplemented by a flying test bed. The accompanying programme of the MOD is called HAV, which is, however, not the subject of this paper.

The experiments with a flying test bed yield excellent results, but these tests are very time consuming and expensive.

Using the design tool CMU, the number of actual test flights can be kept very low. In such a case the design and development of the helicopter cockpit will be very efficient by using CMU, for its tests can be accomplished

- without flight clearance
- independently of environmental conditions such as weather with a small number of personnel
- with a large number of test personnel to obtain results having a high degree of confidence.

Therefore CMU is a very flexible low cost design tool using commercial, but not necessarily flight-qualified equipment. It can be used very effectively in the iterative process of gaining results between theory and design, this minimizing the risk of helicopter cockpit development.

DESCRIPTION OF CMU LTH/SAR

The CMU is a full-scale model of a cockpit for a future light transport helicopter with flight-mode and flight-phase dependent presentation of information on Multi-Function Displays (MFDs) and a centralized control system. To build an environment which meets the aim of the CMU project, suitable simulation models were created for describing the helicopter dynamics and engine performance, and solving the tasks of navigation by user (pilot, copilot, flight engineer) inputs. The outputs of these models are information for flight guidance, navigation and the current system status which can be displayed if the user so desires. The CMU, with its display and control system and simulation models allows operations in real time when test personnel are part of the closed-loop process.

According to its main aim described in the previous section it is not necessary for CMU to be an expensive motion-simulator including external vision system and all environmental conditions.

Figures 2 and 3 give an impression of the design of CMU and its cockpit layout. The CMU man-machine interface, excluding simulation and test equipment, consists of

- Flight controls
- Multi-Function Displays
- Secondary controls and displays
- Back-up instruments
- optical and accoustical warnings
- Cockpit and Instrument lighting equipment

The seats, the flight control cyclic sticks, collective sticks and pedals are adjustable to an optimum ergonomic eye reference point.

Information for flight guidance, navigation and system status are presented on the MFDs. Conventional instruments are installed for back-up.

The secondary controls and displays mainly used are

- Master Mode Control Panel (MMCP) for selecting the flight mode and flight phase to determine the information content on the displays, the symbol colour and brightness

- Control Display Units (CDU) for routings, control of the flight management system, communication and navigation systems

- Incremental potentiometers for analogue data input for upper and lower height warning limits, speed command, altitude command, heading commands and QNH

- Line selector keys and function keys at the MFDs for selecting additional information

- For warnings a Master Caution Panel (MCP) and synthetic speech output have been integrated

To produce a realistic interior other panels and functions such as the intercommunication system have been installed.

To operate the CMU as a design and test tool, the whole device is accomplished by a

- computer for simulation, test control and data recording
- computer to adapt the cockpit to the test and simulation environments
- computer for synthetic speech output
- computer for the control display units
- symbol generators
- test control station for supervising and controlling the experiments and for simulating the tower etc.
- graphic workstation for off-line format development
- dark room to produce night visibility conditions

FUNCTIONS OF CMU

To use CMU as a design tool, the following functions have to exist

- mode control
- control display unit functions
- functions for simulations of helicopter dynamics, engine performance, navigation and flight management
- warnings
- display and symbol generator functions
- communication
- equipment control and monitoring
- data recording and extraction

The implemented functions represent a first step in the design of the functions of LTH/SAR. Nevertheless these functions are sufficient to permit simulation of the crew's control sequences, putting the crew in the loop of the process (Fig. 4).

By using the mode control function, information which fits the mode and flight phase is displayed on the MFD. This information is combined in a vertical and horizontal situation display, a system status display, test display and check lists. The modes implemented in CMU are visual flight rules, instrument flight rules, both for day and night, and night vision goggles. The flight phases are pre-flight, ground run, cruise, approach, hover and post-flight.

Planning and alternating of the flight route, selecting communication equipment and frequencies, switching navigation equipments and flight management functions are tasks of the centralized control system and performed by the CMU.

The simulation function of the helicopter dynamics, with characteristics of a light transport helicopter, makes it possible to compute information as a function of the inputs of the flight controls, namely attitude, velocity and acceleration. Furthermore, the system status of the engines is determined. The navigation function delivers present position, range/bearing to a selected way-point and the cross-track error. In addition, an instrument landing system approach is simulated. In the model for the flight management system best range, best range speed and best endurance speed are computed.

The following warning functions are implemented as examples:

- exceeding of height limits
- engine fire and engine failure
- hydraulic and generator failure

The warning signals are reported visually and/or acoustically. The visual warning is an optical signal on the master caution panel with additional presentation of warning information and instructions on the MFDs. The accoustic warning is a voice output.

The primary flight information is displayed on the MFDs. This information (display formats) is preselected according to the mission mode and flight phase. Other information can be displayed on either MFD as required by the crew. The design and development of these formats is carried out interactively on an off-line graphic workstation. This allows optimization and fast changes of symbol layout and arrangement prior to downloading into symbol generator.

Of course, CMU possesses communication functions which allow communication between the crew members and the simulated tower etc.

The test control functions permit the experiments to be made which are described in the next section. Using these functions as an example, system failures can be initiated during a simulation of a mission. In addition, the actions of the test personnel can be monitored.

Interesting real time data are recorded during the experiments. These data can explain durations of control sequences or number of errors.

Due to its flexibility and expandability the CMU functions can be readily increased.

EXPERIMENTAL EVALUATION

To obtain reliable results for the display and control system, experiments had been accomplished by company staff, test pilots and 6 aircrews (Fig. 5). As a result of the test pilot's investigation, CMU was modified in respect of its control, display and simulation functions and its hardware. At that stage CMU had reached a status which remained unchanged for the following experiments with aircrews to gain comparable results.

The main objects of investigation, were evaluated in respect of the ergonomic features in Fig. 2. The investigations are divided into special tasks, combined task (i.e. missions with special actions and tasks) and evaluation of the whole concept using questionnaires (Figure 6).

The fourteen-day investigation period with two aircrews at times started with intensive familiarisation with the new cockpit surroundings.

During this time the aircrews learned how to use CMU and became acquainted with its helicopter-dynamic behaviour. In the next 2 1/2 days the special tasks of the investigation programme had been accomplished with briefing, test and debriefing. For debriefing the aircrews had to fill out questionnaires. In the next three days the combined tasks (missions) took place.

Each mission contains a special order in respect of the flight route and was carried out from preflight to post-flight. During this the test leader initiated errors such as engine failure, engine fire, hydraulics, generator or display failure etc. Furthermore the aircrews received instructions to alternate the flight route, to use the functions for navigation, flight management and flight routing. In this way a sufficient work load had been created and permitted evaluation of the overall concept.

The evaluation of the overall CMU was carried out over the last 1 1/2 days. In addition, improvements were discussed and recorded.

The investigation was performed with 6 crews recruited from different squadrons. The total amount of flight hours was more than 160.

RESULTS

The results are summarized and quantified in the form of histograms in Fig. 7.

The overall concept of the cockpit design and cockpit construction with modern technology and new philosophy for display and control was received very favourably. In particular, test personnel stated that a lower workload can be expected than in other existing cockpits.

The centralized presentation of information on MFDs as a function of flight mode and flight phase was highly commended. Furthermore the requirement of four displays with a visible area of 7" x 7" was confirmed. In particular the easy interpretation of information in colour was highlighted. The information content, for instance vertical situation display, etc., based on former studies and tests, was confirmed.

The concept for centralized control with

- centralized MFD control by using the Master Control Mode Panel

- centralized controlling by using the Control Display Unit

was widely accepted following familiarisation.

Similar control sequences and the ability to include additional automation were regarded as a major advantage of the new cockpit concept.

The cockpit layout was designed and built on the basis of former experiments and investigations accomplished by the German Air Force Squadron HTG 64. The earlier results, especially in respect of the features

- adjustments of seats
- adjustment and shape of flight controls
- optimal seating and vision areas

had been confirmed to a high degree in CMU.

The expected workload as a function of the amount of information each crew member has to integrate and the automatization of routine tasks was regarded as very acceptable. This leads to the conclusion that additional functions using the new display and control concept do not result in higher workloads. The work-sharing between both crew members is a major point in the crew concept and linked to work load. The dose of given work-sharing was received very favourably. It was further considered that the required tasks could be managed safely, with excellent results.

For an optimal arrangement of units and panels further investigations of flight tests with an fully equipped cockpit have to be carried out.

The warning concept with visual warnings on the Master Caution Panel, assisted by synthetic speech and warning information and instructions on MFDs, were largely accepted. Especially in respect of warnings CMU shows a trend which has to be proved by flight tests.

CONCLUSION

The CMU offers an approach towards assessment of display and control system design before commitments to flight-qualified hardware and flights tests.

In the normal development schedule of a helicopter cockpit CMU possesses the following advantages according to test pilots and flight staff:

- high flexibility and expandability
- implementation of modification and instantaneous validation
- highly cost-effective by using not necessarily flight-qualified equipment and the loss of expensive environmental flight test conditions

Because of the favourable results and experience the design tool CMU is highly recommended for further investigation of LTH/SAR development and other programmes.

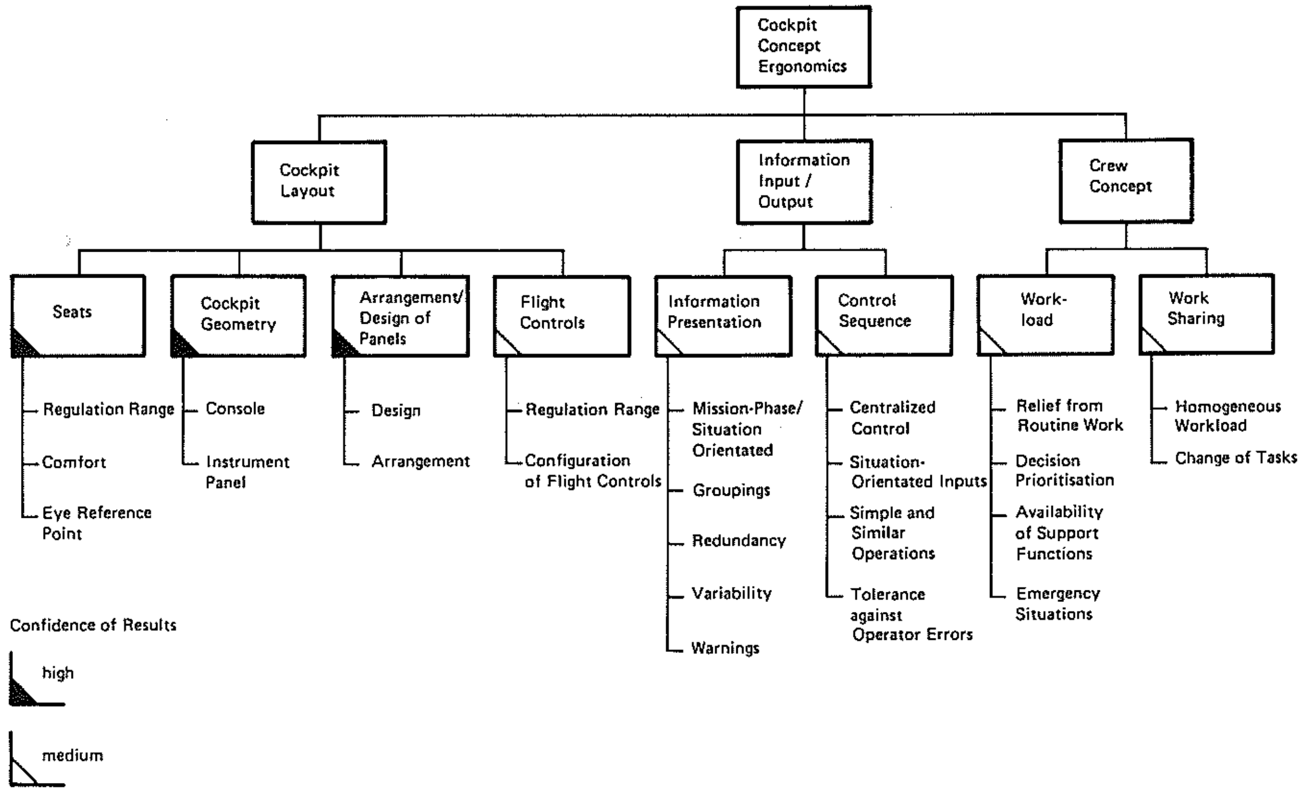

Figure 1: Ergonomic Features of Cockpit Design

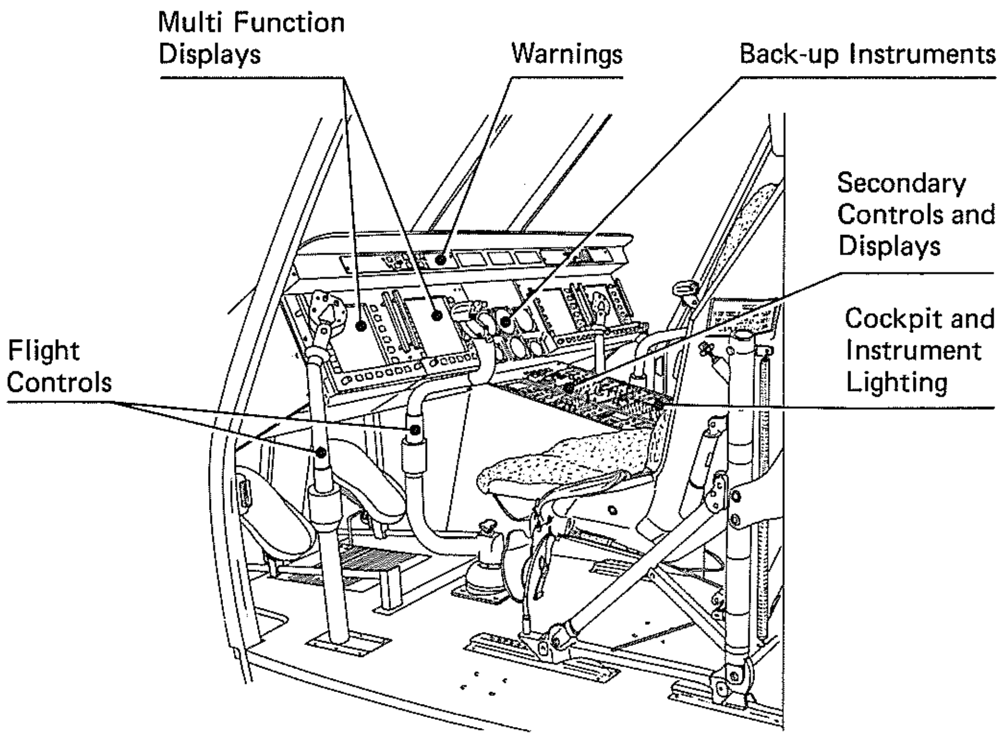

Figure 2: CMU Man-Machine Interface

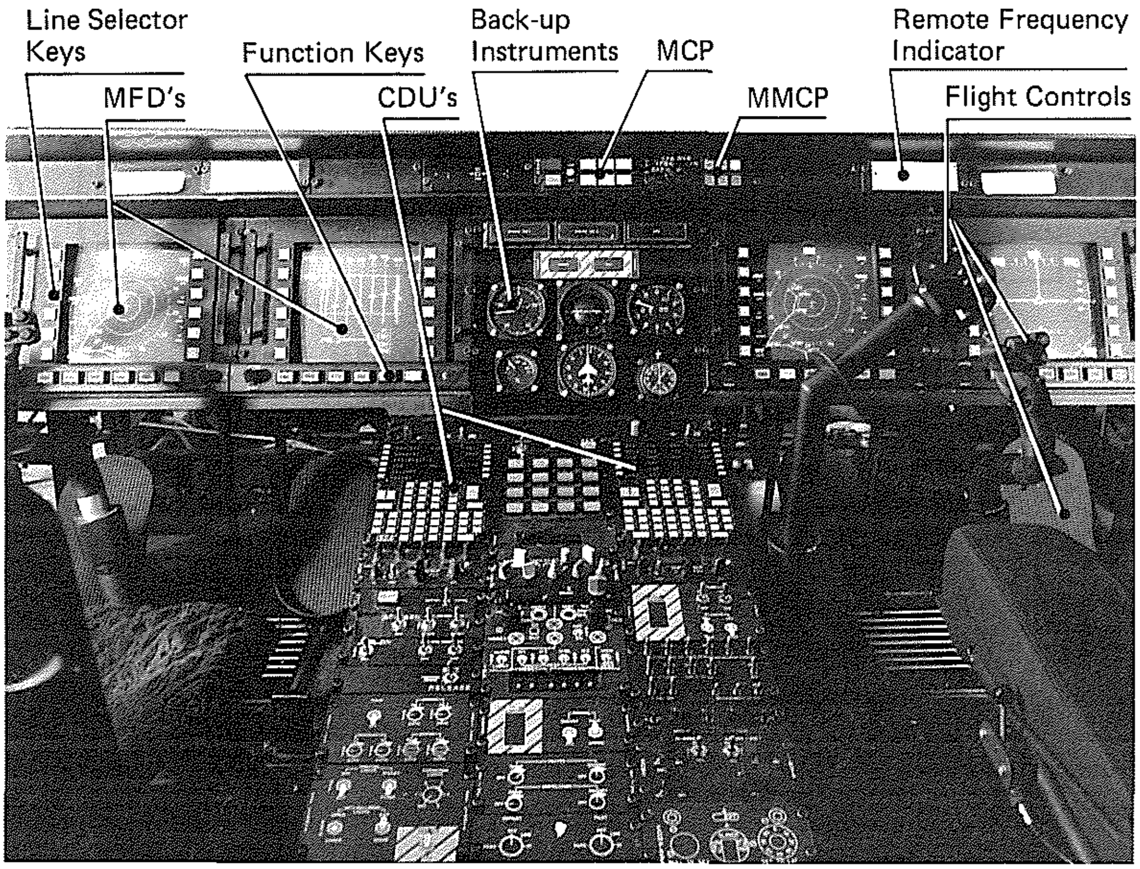

Figure 3: CMU Arrangement of Instruments and Panels

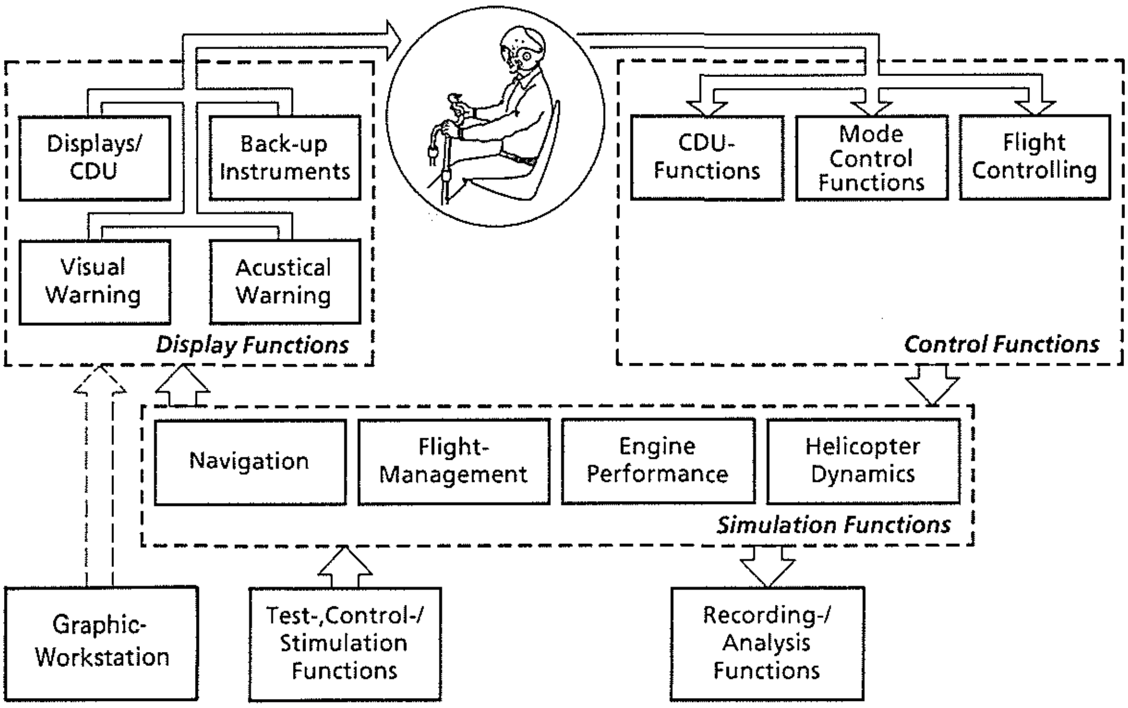

Figure 4: CMU Functions

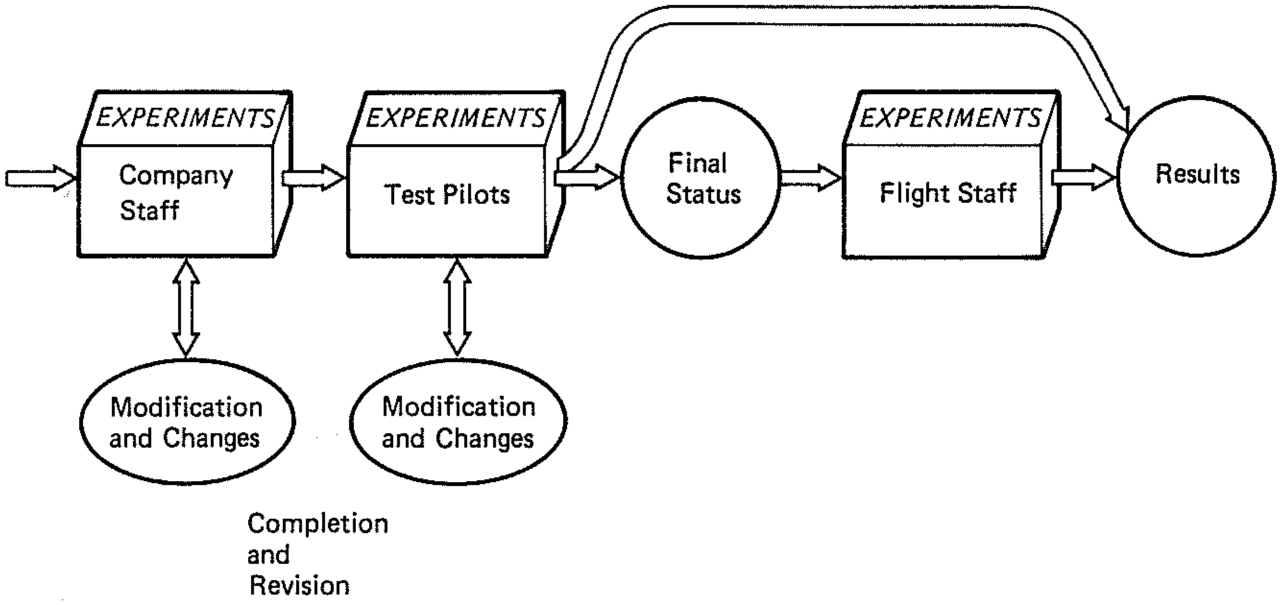

Figure 5: General Methode of Investigation

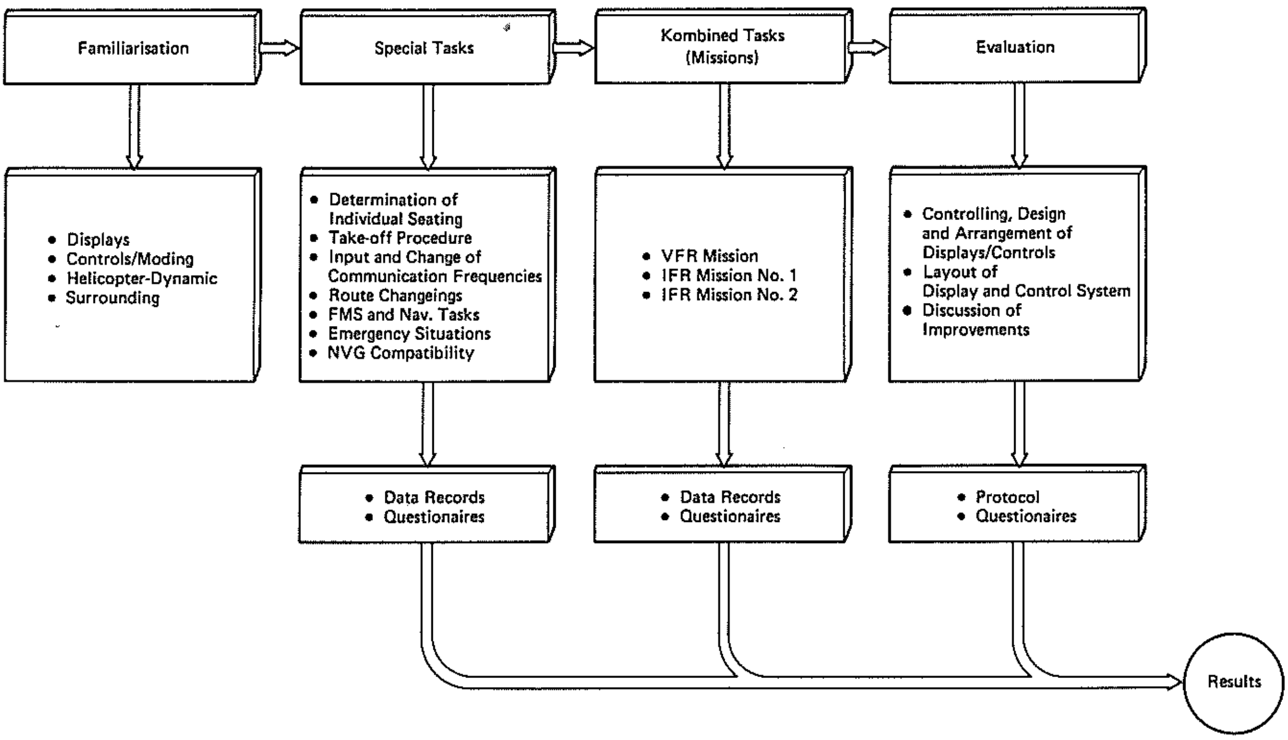

Figure 6: Investigation Programme

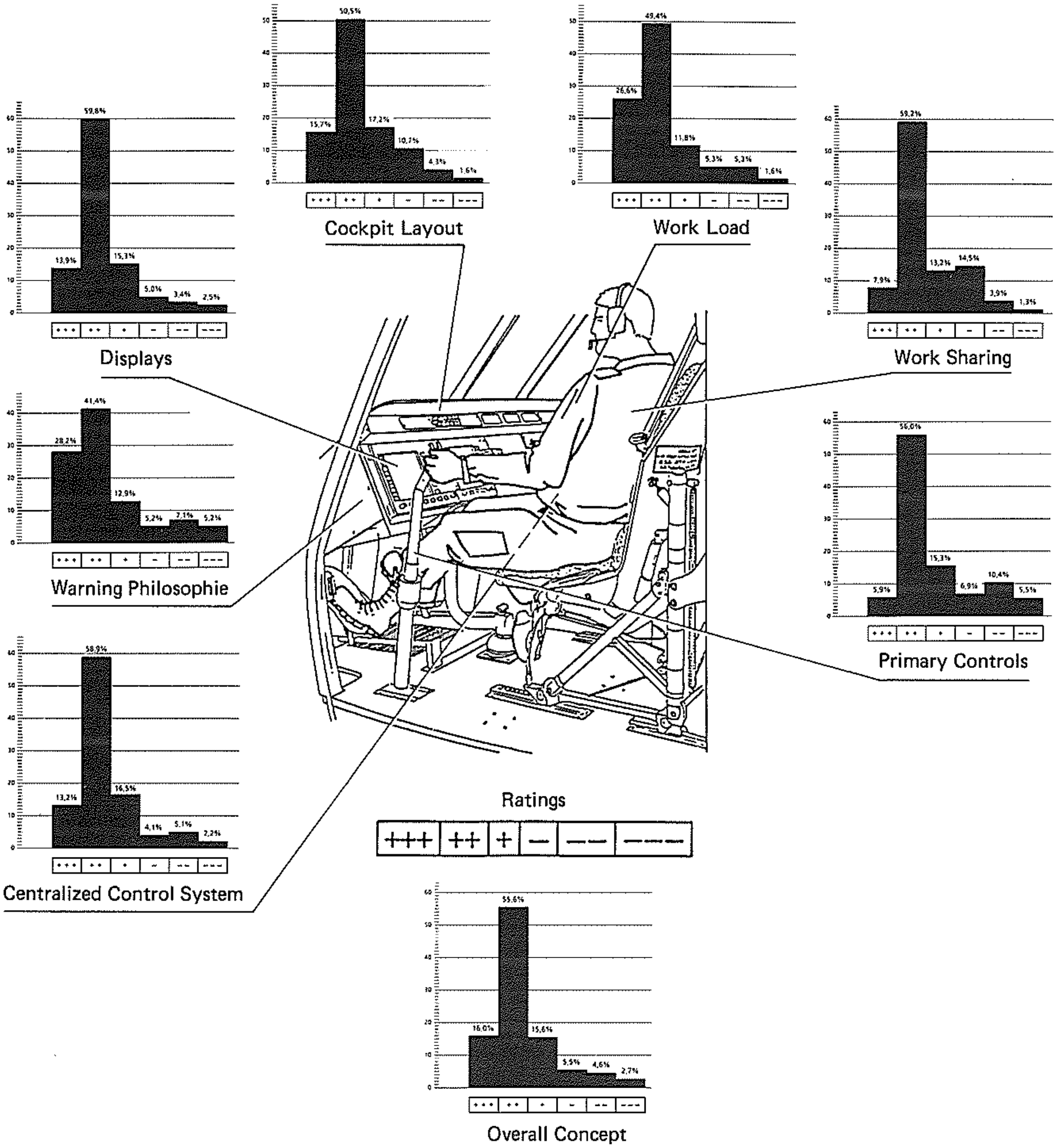

Figure 7: Summary of Results