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THE TIGER COCKPIT AND ITS SIMULATOR

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SUMMARY

In the first part the paper will describe the Cockpit of the Franco/German Anti Tank Helicopter TIGER (HAC, PAH2, HAP) with its geometric baseline and the Man-Machine-Interface.
The second part will describe the technical concept and capabilities of the Development Simulator for the TIGER.

The Cockpit:
The tandem cockpit is designed to satisfy numerous global and detailed geometric/ergonomic requirements. External vision, external detectability and internal comfort, locations for control & display equipment under reach and visibility needs, getting in and out of the cockpit, integration constraints of several installations, lighting and glareshields, seats and controls, all this and more in normal cases is contradictory! A 1:1 Engineering Mockup was mainly used as a tool to define the structure and furnishing. The paper will describe the solutions found to balance or give priority to one of the various needs.
The cockpit systems are based on one Helmet Mounted Display, two Multi Function Displays, one Control and Display Unit and priority located dedicated system controls and indicators. The paper will present the structure, the basic dialogue principles and characteristic formats of the displays, as well as system MMI basic rules.

The Simulator:
The Simulator Cockpit (SimCo) is a 1:1 copy of the Tigers front fuselage between frame 1 and 3 and above cockpit floor. For the simulation of the MMI relevant functions of the weapon system, fast prototyping capability was required. This means fast reprogramming and reconfiguration is needed. For having the simulation results early enough to be considered in the development process of the helicopter and its systems, the simulator equipment can only be an early substitute of the defined equipment with highly realistic surfaces.
Core system of the simulator is a VMEbus computer with the task to interface the cockpit systems and to run the models for simulation and stimulation of the cockpit by software models of the helicopter systems. The computer is composed of three processors and a big variety and number of interface cards. Real-time software ensures optimum configurability of the system configuration, optimized processor load and task sharing within the system. Software models are split into Flightmechanics/AFCS, I/O and system models. C is the language used.
The flight mechanics/behavior model is highly representative of the characteristic of the prototype. For the development of the display formats/symbology, a fast prototyping tool named VAPS on fast graphic workstations is used. The same workstations are acting as symbol generators in the simulation which allows very short transfer time of the software.
The SimCo is working fully stand alone, as well as in a Dome using an advanced external vision system.

GEOMETRY

Basic Characteristics:
The TIGER has a tandem cockpit. This design is mainly driven by the necessary air-to-air capability for self defence. When the gunner is concentrated into his primary task, the air-to-ground combat, the pilot has to observe the airspace and immediately react on eventual threat. For this task the pilot needs excellent outside visibility in all directions which can only be given by a tandem cockpit. To maintain crew dialogue capability some means have been taken which will be explained later.
The basic dimensions and characteristics of both cockpits are identical. Both crew members can

- control the helicopter
- operate the basic aircraft systems
- operate the basic avionics systems
- observe by using all sensors
- perform self defence

The pilot is seated in the front cockpit, the commander / gunner is located in the rear cockpit. The dimensions are based on a population of 5th to 95th percentile with growth potential beyond the year 2000.

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Basic Design:
The pilot is the only quantity in the design of a cockpit which is predetermined and unchangeable. Therefore the TIGER Cockpit is constructed starting with the pilot and working outwards.
The starting point of the design is the pilots eye point. All populations shall be seated in one eye point. For this purpose, a Seat-, pedal and stick adjustment is provided.

The Helicopter design chain:
To demonstrate the complexity of the cockpit design and impacts to the overall helicopter design the following example is given.
Starting at the eye point of the pilot, with a required angle of forward visibility of 22° for the pilot, the upper nose contour is given. Minimum necessary seat crash stroke in lowest position and largest population data define the cockpit length (1460mm) and height of eye point above floor (1110mm). The clearance needed for head motion and NVGs on top of the helmet leads to the roof height above the eye point. With a required angle of forward visibility of 21° for the gunner, the rear cockpit is placed. Head clearance to the Roof Mounted Sight above the rear cockpit defines the location of the RMS. This RMS with its highest edge possible and the clearance to the Main Rotor Blades in the most twisted and bent configuration leads to the location of the Main Rotor. Clearance to the Tail Rotor and vertical offset ends in the location of the tail rotor.

Seats:
The crew seat is armoured against small calibre projectiles. It is height and length adjustable to place all populations in the design eye point. It protects the crew in case of crash by energy absorption elements in accordance with MIL Standards. *Both seats are identical.*

Panels and Consoles:
The crew is seated 30mm right of the helicopter centreline. Left and right of the crew, there is a standard width (147mm) console. Together with the necessary clearances, the space for collective and the structure, the external cockpit width is 1100mm.
The instrument panel is located centrally in front of the pilots. It is limited at the bottom by the leg clearance and at the top by the pilots angle of view, which is 22 deg. The inclination of the panel is 22 deg.
In between the panel and the consoles, a so called desk has been implemented to improve visibility and accessibility especially for the Control and Display Unit.

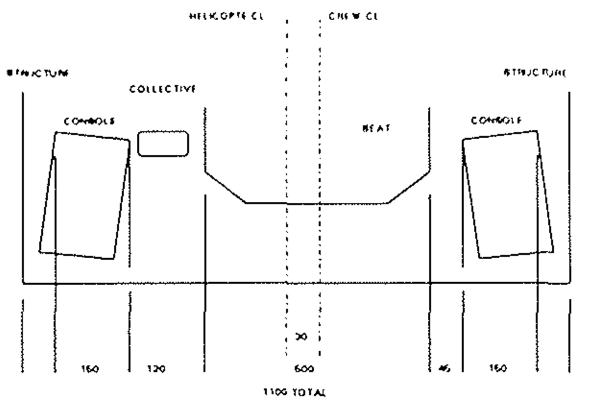

Fig.: 1 YZ plane cockpit cross section, principle

The side consoles are inclined 5 deg inward and the consoles opposite of the doors are inclined upward from sideward of the shoulder up to the desks! All these measures have been taken to optimise reachability and readability of the equipment.

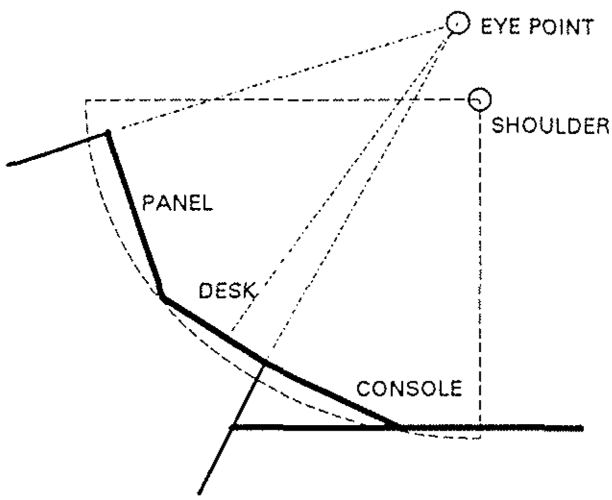

Fig.2 XZ plane cockpit crossection, internal vision and reach layout.

Glare Shields and Visors:
The instrument panel and the desks are provided with glare shields. The form of the glare shields has been designed, so that the upper contour is aligned with the eye point, while the left contour is aligned with the left eye, the right contour is aligned with the right eye. The left and right design eye point for this layout has been located slightly outside of the maximum possible eye offset. This avoids at the outward areas of the glare shields looking with *one eye from inside, with the other eye from* outside. All this has been done to minimise obstruction of external vision by maintaining

internal panel area, good light protection and avoiding negative ergonomic effects.
The portion of the glare shield located next to the desk is realised foldable to ease passing this area with the foot, while serving as a protection of the controls below (CDU). The orientation on the glare shield is used to find the eye point while adjusting the seat.

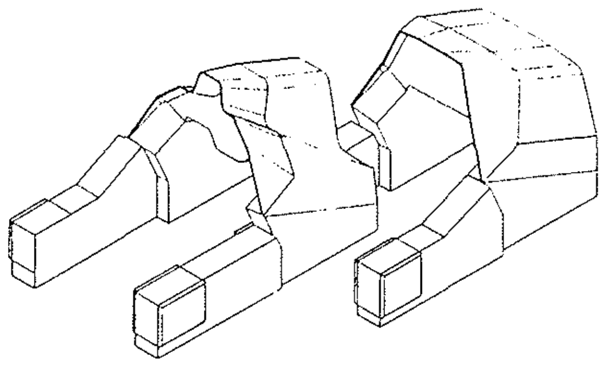

Fig.3 Furnishing and Glare shield Layout

Doors:
The door of the pilot is located on the left side, for the gunner on the right side. All four side windows can be jettisoned in case of emergency by explosive chords from inside and outside. The location of the doors is selected to allow escape of at least one of the crew members and for full observation of activities around the helicopter by both crew members when seated with open doors.
The doors span the entire length of the cockpit to avoid intermediate struts that would obstruct vision.

Windows:
The design of the windows is based on the following conflicting principles:

- largest transparent surface possible, which is not broken up by frames and structural parts
- using as far as possible plane glass surface to reduce visual detectability
- avoiding unnecessary glass surfaces to save weight, protect the cockpit from sunshine and keep the visual delectability low

The side transparencies are slightly curved to avoid vibrations.
The two front screens can be electrically heated. There are three heating film areas in each screen, supplied by independent phases.

Frame Structure:
The frame structure is formed of hollow sections made of carbon fibre. To obtain a good external visibility for the crew, the cross section of the relevant frames have been kept as narrow as the strength, the attachment of the panels and the space requirements for sealing and cutting cord allow. The shape of the cross section is wherever possible and necessary in alignment with the eye point projection.

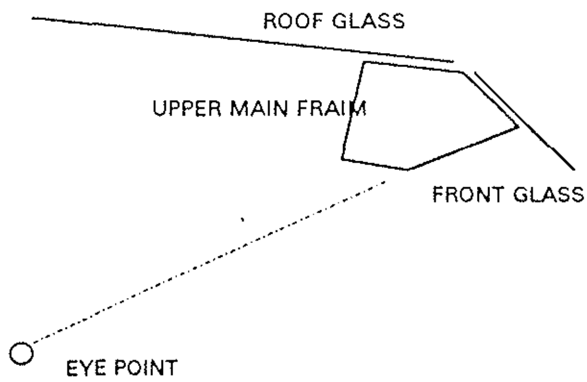

Fig.: 4 Canopy Structure layout

Size and location of the windows, shape and number of longerons and frames determine the external visibility. The following vision plots show the comparison of the requirements from MIL-STD-850 and the TIGER layout. Specific effort has been spent to improve visibility forward, downward beyond the MIL, which is the most important area for NOE flight.

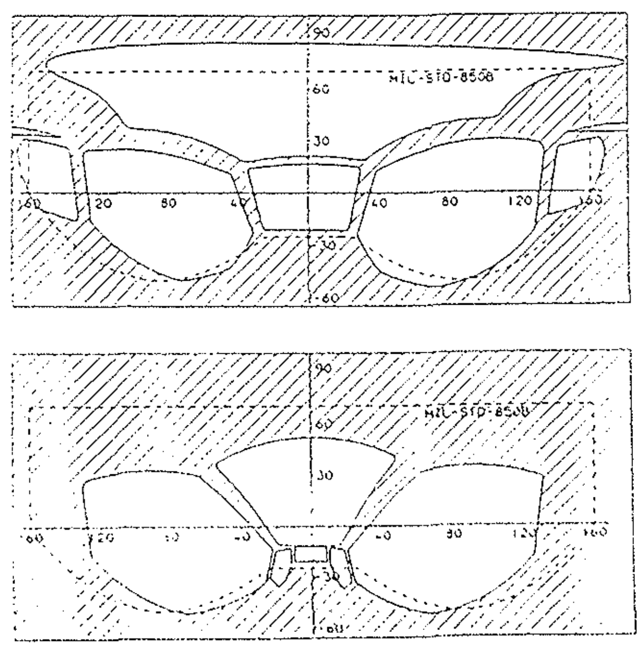

Fig.: 5 Vision Plot forward/rear Cockpit

Rearward visibility is supported by two small circular, convex internally mounted mirrors which are used mainly for tail obstacle monitoring when manoeuvring in between obstacles into hovering position.

Flight Controls:
Both cockpits are equipped with full flight controls. The cyclic control is vertically adjustable. The pedal system is coupled length and height adjustable. This design allows optimum equal leg/knee angles for all percentile pilots.

The pedals are of the swivelling type, i.e. the control inputs are made from the joint of the foot. The shoe is rotated around the heel. This allows fine control to be exercised provided the heel can rest on a base that is fixed relative to the airframe. For this purpose, a platform running parallel to the floor has been mounted in the area of the pedal pivot, which is adjusted together with the pedals. Both boots can also be placed on the pedals without using the platform. Tip pedals are provided on each side for individual wheel brake control. Adjustment of the pedals has no impact on the control motion.

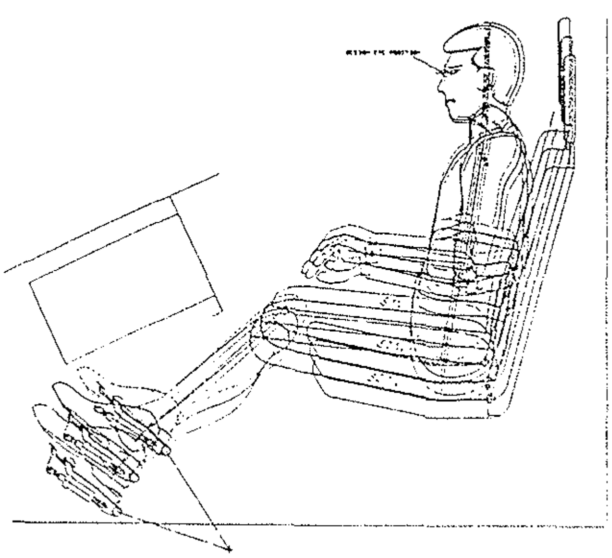

Fig.: 6 Pedal / Sitting Position

Steps and Handles:
For getting in and out of the cockpits, a number of steps/handles has been located outside and inside the cockpits. The steps are of rigid design to allow safe manoeuvring with wet and muddy boots. Long railing handles on the doors allow operation of the doors when seated.

COCKPIT SYSTEMS

Analysis Method:
A structured Top-Down method was used to finally define the location and nature of the Control & Display functions. This leads to a multi dimensional matrix. The following list only gives an overview over the various analysis categories:

- definition of the primary mission and secondary missions
- breaking the mission into phases
- defining the principle of crew task sharing
- classification of tasks into four major groups
  fly - observe - integrate - fight
- defining a principle functional sharing
- breaking the phases into crew tasks
- dedicating the tasks to a crew member
- classification of the tasks into primary, secondary and backup
- classification of the tasks into permanent, mission phase related and event related tasks
- classification of C&D media
  manual - visual - aural - tactile
- grouping the C&D devices
  primary - secondary - dedicated - standby
- categorising the panel and console area into
  primary - secondary - poor vision area
  primary - secondary - poor reach area
- classification of C&D functions into
  continuous
  on request
  on condition/event
  automatic on request
  automatic
- classification of functions into
  flight safety critical
  mission safety critical
  mission task critical
- classification of Control Functions into
  hands on control - real-time
  hands off control - immediate
  hands off controls - delayed
- location of the C&D function on the devices
- definition of the actions to be performed on the C&D devices

For further structured methodologies refer to [b] and [c].

The result of this pragmatically used methodology, together with consideration of some geometrical / physical constraints, as described in the geometry section before, led to the following cockpit instrumentation layout and Control & Display concept.

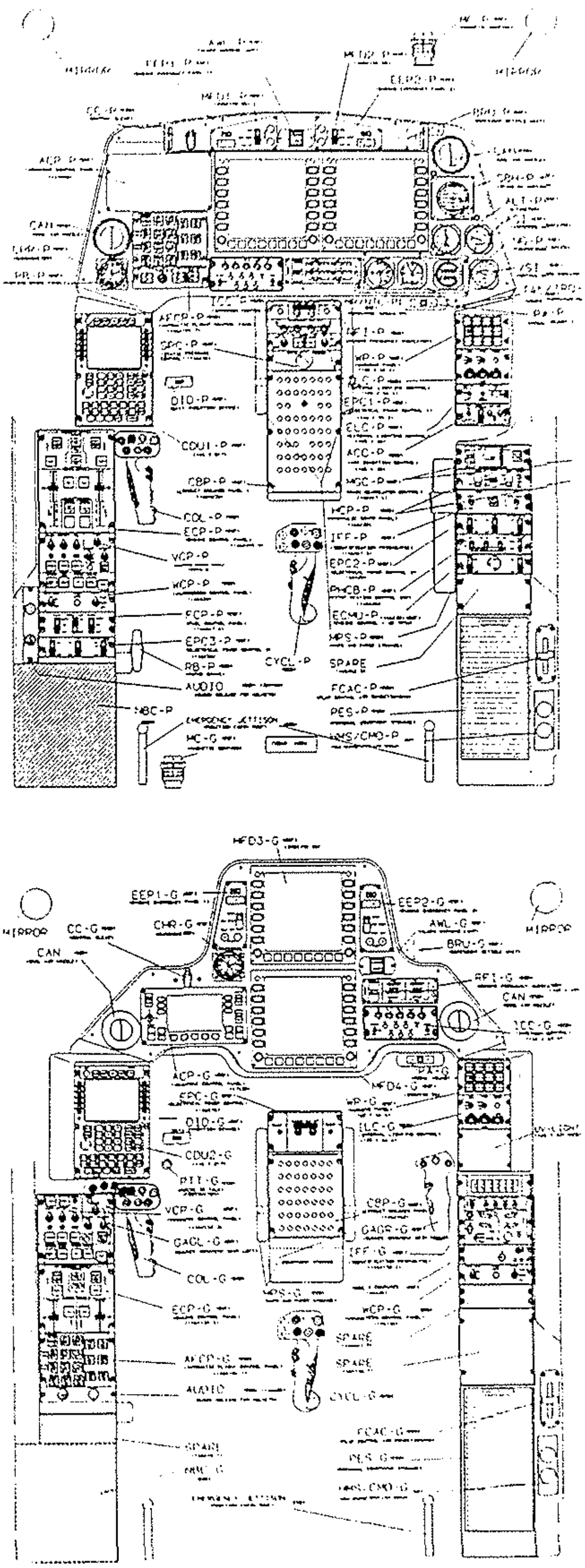

Fig.: 7 Cockpit Instrumentation of the HAC/PAH2

The principle location of the instruments for the HAP is identical to that of the Anti-Tank Versions.

Control & Display Concept:
As a principle, the C&Ds for the Armament and Visionics System as well as for the basic helicopter systems including Automatic Flight Control System are separated from the Basic Avionics C&Ds. Only secondary control and display functions are performed in addition via the basic avionics system.
A set of standby instruments for the pilot ensures the starting of the helicopter and a safe return flight in case of major failures.
The helicopter is fully "flyable" from both stations.
All sensors can be used by both crew members. The piloting crew member has the right to immediatelly select the sensor needed to support his flight path selection / obstacle avoidance task. This priority is handled via HOCAS (Hands on Collective and Stick) controls.
Unique is the possibility to select between meter and feet for all displays.

Multi Function Display:
All four (2 in each cockpit, 6"x6" usable screen) MFDs have identical capabilities, no display is limited to a dedicated functionality. This allows full redundancy.

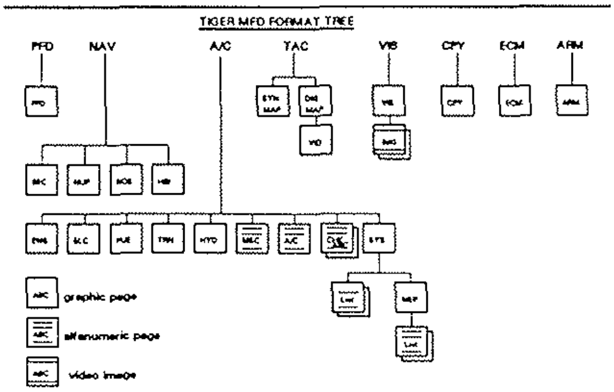

Fig.: 8 MFD Tree

The hierarchy of the MFD pages has maximum 3 levels, the top level by only one key press.
The so called Primary Flight Display switches automatically between forward flight and hover subset of information.
There are 4 Navigation Formats available depending on the area of interest of the crew. Three formats can be selected with map type underlays of the route and way points, tactical information, ECM threats, navigational aids. A conventional HSI type of format provides

standard IFR presentation.
All basic Aircraft Systems can be monitored in pictorial presentation for quick interpretation of the status. "To Lists" below the pictogram suggest immediate actions to be performed.
Check lists are available. The status of the Avionics Systems is provided on functional block diagram form.

For tactical works two types of maps are available, the synthetic map and a digital map. Both maps can be edited by the crew. The Digital Map is based on a digitized paper map and provides all kind of tactical situation presentation. The movement and rotation of the map can be slaved to the helicopter. The map can be presented in 3 scales and 3 zooming factors. By use of the gunners right armament grip as a cursor control, map overlays can be interactively generated and modified. Overlay information can be received or transmitted via radio data link.

Video memory capability , provided by the Digital Map Generator, allows replay of a sequence of sensor images for analysis work.
All sensor images can be selected to be displayed on the MFD.
To ease the crew dialogue a specific "copy" function allows the selection of the others (what ever selected at the moment) crew members MFD format.
The ECM information and library analysis results are provided on one format. The complete stores situation is provided on one format.

Control and Display Unit:
The CDU (one in each cockpit) is the centralised dialogue device to mainly perform

- initial value setting
- Radio Communication control
- Radio Navigation Control
- Autonomous Navigation control
- Mission Management
- Route Management
- Onboard System Test (for ground staff)

A alfanumeric keyboard, dedicated / direct access keys and a 14 lines monochrome display with 12 line select keys charactrize the CDU.

Helmet Mounted Sight and Display:
For the HAC/PAH2 the HMD has to be seen as the real primary flight display. All necessary and primary information, needed to fly the helicopter to the next way point is provided head up. The selection of the information can be adapted to the external visibility quality. Reduced or full symbology can be selected, depending on the amount of artificial/symbologic information which is needed to fill the gap of external vision information. Sensor images can be presented on the helmet. A helmet positioning sensor system is used for sighting and sensor steering.
For the PAH2 version a so called integrated helmet system will be used, which includes Image Intensifier Tubes. Both crew members have identical devices.

Fig.: 9 Integrated Helmet System [GEC]

Head Up Display:
For the HAP version, a HUD is integrated in the pilots cockpit, as primary flight display and for weapon aiming.

Head In Display:
For target acquisition and firing of the anti tank missiles, an ocular type HID is used, which is mounted on the roof of the rear cockpit.
Originally these oculars where used to look through sight systems via direct view optics. Today the image in the ocular is seen on a high resolution, monochrome micro display. Up to now only these displays provide the resolution needed for target acquisition.
The head, covered by the helmet is trapped between headrest and ocular. Partial movement of the ocular allows work in the cockpit. For the

target acquisition phase all necessary controls are concentrated on two armament grips; the left grip which is mounted fixed and the right grip which is a force grip to control the sight.

HOCAS:
On the flight control grips an average of 20 buttons per cockpit are provided to perform quick reaction control inputs. These controls are mainly used to control engines, AFCS and the sight system.

Warning Concept
Depending on priority and with some redundancy a subset of the following devices are used to indicate warnings:

- Master Warning Light for all red alarms
- Engine Fire Alarm Lights
- Dedicated Warning Panel for all red alarms and some amber warnings needed during engine startup
- All alarms, warning/cautions and advisories in 8 letter abbreviations on the two top lines of all MFDs
- Attention getter symbols on HMD and HUD
- Tone warnings in the headsets

Internal Lighting:
The NVG compatible internal lighting is based on three types of light: green floodlight, UV floodlight, EL integrated light. The Instrument panel is lit with all three types, where as the consoles are lit internally. The green floodlight is providing background recognition.

THE SIMULATOR

Hardware Concept:
The simulator is a 1:1 copy of the cockpit section with both crew stations. The geometric dimensions of panels, consoles and flight controls correspond to the original. Nevertheless special effort was dedicated to meet the requirements of a simulator. The cockpit is mounted on wheels and has a platform on both sides for simulation personal and observers. Integration of the cockpit control computer , power supplies and avionics equipment allows to operate the simulator on every location just by supplying electrical power. Besides this "standalone mode" it is possible to link the cockpit to the MBB simulation facilities which consists of a HARRIS NIGHTHAWK computer and a GE COMPUSCENE IV CGI. Special requirements coming out of the development aspect have been taken into account by modular design in hard and software.

Fig 10 shows the system architecture with the cockpit control computer, the symbol generators, the operator console and the MBB DOME facilities.

Because of building up the simulator at the very beginning of the development it was hard to keep in line with the actual definition of the instrumentation, but the organisation of the simulation in several phases allowed to upgrade the cockpit with equipment corresponding to the latest definition. So the simulator incorporates a mix of simulation instruments and original hardware, which represents a high degree of communality to the original.

For the first phase, which was concentrating on the core system like MFD and CDU, there was no original hardware available, so the symbol generation was build up by graphic workstations with 6"x6" simulation specific CRT monitors and a software tool which was used before for the first symbolgy layout. The CDU was upgraded from a mock-up by a commercial EL display with controller and a keyboard, the RFI was made out of the first prototype of the display. The standby instruments are simulation instruments according to the TIGER specification. Main effort for the second phase was on the software side so only some control panels are included. The third phase will incorporate original hardware like sticks, control panels, warning system, HMS/D and other cockpit controls and the fourth phase will include the mission package which consists of visionics and armament.

Heart of the simulator is an embedded computer which controls the cockpit equipment. It consists of two SPARC type CPU's and several I/O cards like VME - VME link for connection to the MBB simulation facilities, synchro interface for the standby instrumentation, digital I/O for switches, lights, remote frequency indicator or trim motors, AD converter for controls, brakes and engine power lever, MIL 1553 for HMS/D and ARINC 429 for warning equipment. The CDU's are connected by RS232 and an ethernet interface links the computer to symbol generators, operator console and standalone CGI.
The symbol generators are SILICON GRAPHICS workstations, which combine high graphic performance with the flexibility of a development tool. Another SG workstation provides via a RGB projection system a simple CGI in the "standalone configuration".

Software concept:
Beneath the flexible hardware concept there are some tools and methods, which allow to keep pace with the TIGER development like the software tool VAPS (Virtual Avionics Prototyping System), which was used on the symbol generators. It eases the prototyping of symbology which due to simulation results has to be modified steadily. All the simulator software is written in "C", which gives hard and software tool independence and a close interface to the hardware. The operating system for the cockpit control computer is VxWorks, a real-time operating system, which allows to split the simulation program in separate small tasks, which are easy to maintain. By giving priorities to these tasks the resources are best used and the behaviour of the software is predictable, i.e. tasks with low priority like sound generation or CDU output will be interrupted by high priority ones like flight mechanics or AFCS.

The software hosted on the cockpit control computer consists of a simple flight mechanical model, an AFCS, tasks for RFI, MFD and CDU operation, AC system simulation, navigation, flight management, simulation of radios for communication and navigation and weapon systems.

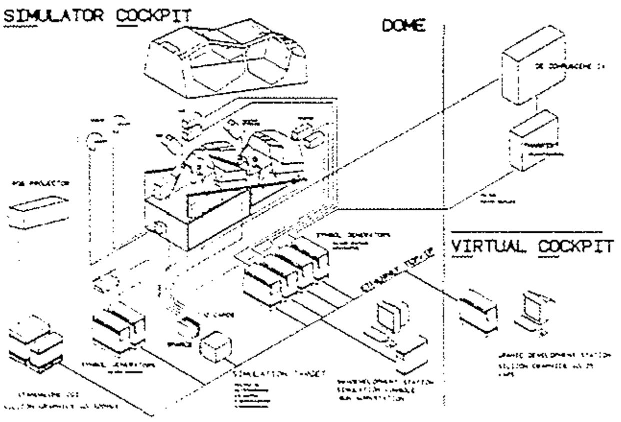

Fig.: 10 Simulator Hardware Configuration

VAPS - Virtual Prototyping System / VPI Canada	⇨	for definition and annimation of MFD/HMD/HID Symbology
Silicon Graphics Workstations	⇨	for MFD/HMD/HID Symbology
Sun Risc Workstations	⇨	as development/operator workstation
C Software Language	⇨	for MMI logics and system models
VxWorks	⇨	for Realtime Operation
Force Sparc CPUs	⇨	for realtime processing
VME - Board System	⇨	for various types of interfaces

Fig.:11 Tools used

General Flight Mechanics Model
ECD has developed a generic flight mechanics model for the interdisciplinary calculation of trim conditions, loads, stability characteristics and time history simulations.
A schematic impression of the physical content of the overall flight mechanics model is shown in the block diagram.

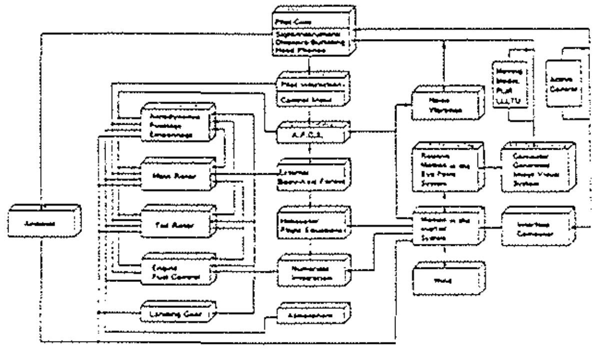

Fig.: 12 Generic Simulation Model Block Diagram

All forces and moments of the individual components like main rotor, tail rotor, fuselage, stabilisers, wing, engines and landing gear are calculated separately and summed up in non-linear equations in the body axis system.

The aerodynamic forces and moments of the fuselage are interpolated from an aerodynamic data package with respect to the angles of attack and side slip. As wind tunnel measurements usually cannot offer coefficients for extreme flow angles, the experimental data tables are expanded with help of analytical formulas or scaling of existing data from different helicopters. All the other aerodynamic parts of the helicopter are either treated in the same way as the fuselage or a lifting line theory is applied.

Interference effects from rotor wake to the stabilisers and wing, from the tail rotor to the side fin and from the wing to the stabilisers were incorporated in the model according to flight test results. Because of the outstanding features of the hingeless rotor system, first used on the BO105, emphasis has been put on the mathematical modelling of the main rotor. The non-linear behaviour of the main rotor aeromechanics is responsible for many of the typical helicopter characteristics.

The dynamics and aeromechanics representation is characterised by following most important features:

- single blade dynamics of up to 6 blades;
- blade element theory with variable distribution versus span of chord, twist, AC, CG and airfoils;
- flapping, lead lag and two torsional DOFs, modal representation by an equivalent system of the first bending modes;
- various hub to blade attachment properties (feathering axis precone, predroop, presweep);
- shift of elastic tension and feathering axes
- kinematic couplings

Aerodynamic loads of the blade elements are computed from non-linear aerodynamic coefficients, tabulated with respect to Mach number and angle of attack.
In the basic flight mechanics code the rotor speed variations are taken into account by a second order dynamics model. For the Tiger simulator an enhanced engine model of MTR 390 developed by Turbomeca was incorporated to describe the dynamics of the gas generator and the power turbine.

Model for On-Line Simulation:
For the real-time simulation the above mentioned generic model is used with exception of the time consuming lead lag and torsional DOFs. For further reduction of the frame time, the whole flight mechanics program is splitted up to run on 4 CPUs of a Harris Nighthawk computer. As the SimCo is used for development tasks most subroutines are written in FORTRAN, only some interpolation and driving programs are generated in C.
To increase the realism of real time simulation, the flight mechanics model can be complemented by a landing gear model and a simplified noise model, both of which have been investigated during simulation trials of the Tiger.

Landing Gear Model:
Such a model is necessary to perform realistic landings, take offs and ground taxiing in the simulator. Analytical landing gear models describing both the skid and the wheel landing gear have been developed. For the wheel landing gear of the Tiger a two degree of freedom model for each wheel unit is applied. The shock absorber and the tyre are modelled as a spring and a damper unit.

Noise:
In order to improve the environment of the pilot-in-the-loop simulation aural cues have been made available for the Tiger simulation. It turned out during simulator investigations, that noise cues are valuable for the assessment of certain flight conditions, especially for high g manoeuvres, flares, steep descents and autorotation.
The noise simulation via the pilot's headset is achieved by parameterized synthetic regeneration of the helicopter noise frequency spectrum. To create a comprehensive data base interior noise measurements on a BK117 have been performed.

Validation:
The validation of the simulation model for the Tiger is a still on-going process (see also [a]). It is an important and time consuming task, in order to guarantee realistic overall performance of the simulator for a representative assessment of certain system characteristics. The next figure shows as an example for validation of a hover turn manoeuvre.
It is a typical result for simulation models, that the short term reaction especially for on-axis response is predicted good, and off-axis response has sometimes a reduced correspondence to flight test results.
The real time simulation model was flown this year in the dome simulator by Tiger test pilots and has proved to be an acceptable tool for investigations of MMI.

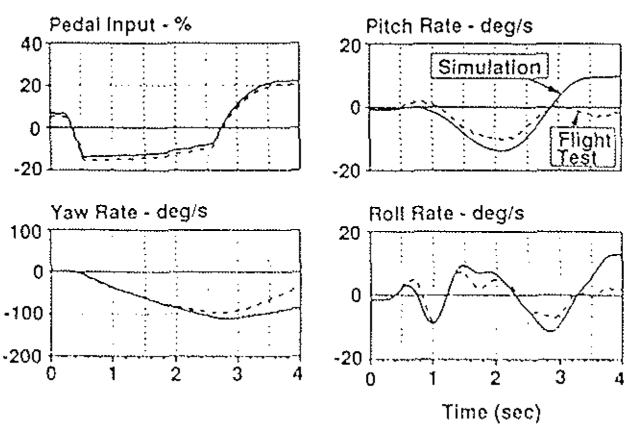

Fig.: 13 Validation of a Hover Turn Manoeuvre

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