SYNTHESIS OF AN INTEGRATED COCKPIT MANAGEMENT SYSTEM

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Abstract

This paper discusses the process used in the synthesis of an integrated cockpit management system. Areas covered include flight displays, subsystem management, checklists, and procedures (both normal and emergency). The process of evolving from the unintegrated conventional system to the integrated system is examined and a brief description of the results presented.

Introduction

One way to describe the process of designing an integrated cockpit management system is as the series of steps outlined below:

1) an analysis (functional and electrical) of all signals on-board the aircraft,

2) a feasibility analysis of each signal to determine if suitable for absorption into an integrated system based on safety of flight requirements and electronic considerations.

3) an analysis of the functions performed by the operator in a standard aircraft to determine which ones must be performed by the operator, which ones the operator must know the status of, and which can be performed automatically, and

4) following these analyses, the initial mapping of aircraft control and display functions from a conventional unintegrated cockpit to an integrated cockpit.

This last step is the first step in an iterative process in which the top down system design is continuously modified as a function of the specific detail uncovered as the process proceeds. This paper describes the application of this process in the synthesis of the integrated cockpit for the Army Digital Avionic System (ADAS). The objective of the ADAS effort is to apply in-so-far as possible, the latest advances in digital system technology to a current production conventionally designed rotary wing aircraft. The aircraft chosen to demonstrate the application of this technology is the Army UH-60A Black Hawk, a twin engined utility helicopter manufactured by Sikorsky Aircraft. The steps taken in the development of both the system hardware and system architecture are explained in detail in reference 1. At this point in the process, a system design has been established and hardware is being fabricated which integrates the following aircraft control and/or display subsystems:

a) flight instruments

b) engine instruments

c) caution/warning/advisory

d) communication/navigation/identification and security devices

e) aircraft survivability equipment (ASE)

f) electrical system circuit breakers (67)

g) secondary systems such as: cargo hook, lights (position, anti-collision), air source switching, environmental control unit, anti-ice (engine, windshield), pitot heaters, blade de-ice, attitude and heading reference system, gyros, radar altimeter, engine ignition, tail rotor servo, back-up hydraulic pump, and the hydraulic leak test subsystem.

In addition, it became apparent during the design effort that incorporation of the checklist and emergency procedures would be an important feature of this system.

The Hardware Baseline

A standard UH-60A Black Hawk cockpit is shown in figure 1. Figure 2 shows the instrument panel in detail, figure 3 shows the lower console, and figure 4 the upper console. In addition, circuit breaker panels are located above each operator. An initial top down design for a digital avionic cockpit for the Black Hawk was performed by Sperry Flight Systems and Bell Helicopter (reference 1) after performing the analysis described in steps 1, 2, and 3 in the introduction. As details in the areas of the flight displays, paging and fault tolerance schemes evolved a cockpit design emerged (step 4) with an instrument panel as shown in figure 5, a lower console as shown in figure 6, and an upper console as shown in figure 7.

The primary display elements on the instrument panel consist of four identical 6.8 inch by 6.8 inch CRT's each with eight line select keys on a side. A momentary toggle switch is located below each display. The main reasons for driving all of the primary displays to be exactly alike stems from both fault tolerance requirements and also the need for line select keys on the flight displays for a modest interactive capability. A cluster of standby instruments is contained in the center of the instrument panel for safety of flight purposes.

The lower console contains a control display unit for each operator by which all communication, navigation, and identification equipments are controlled and their status displayed, an intercom control for each operator, and a keyboard terminal unit (KTU) for each operator. In the center of the lower console for use by both operators are the stabilator controls, the automatic flight controls, and a miscellaneous control panel.

The upper control contains a number of switch functions which were not integrated for various reasons and a small (10 lights) caution/advisory panel which will be used prior to onboard auxiliary power unit (APU) start. After the APU is started, the ADAS system provides these caution/advisories.

The four CRT's are configured such that either a full screen display or half screen display can be exhibited. In normal operation the outer CRT's are reserved for the full screen flight display or full screen waypoint map. These displays can be called up by either operator or depressing the FLT DIS or MAP buttons in the OUTER column of the KTU (see figure 8).

The inner CRT's can be used either for two half screen displays or a full screen display. For interactive paging routines the lower half of the inner CRT will be the primary display. The two columns of buttons on the top left of the KTU call up the functions which will appear in the lower half (viz CAU - caution, EMGY - emergency procedures, ASE - airborne survivability equipment, CHK LST - checklist, SEC SYS - secondary systems). The top half of the inner CRT will normally be devoted to the ENG MON (engine monitor) half page. The inner CRT can also be used to display a full screen engine page (FULL ENG) or the waypoint map (MAP).

The momentary toggle located below each CRT is used for slewing through pages displayed on the lower half of the CRT. A down motion causes slewing through a set of pages (e.g., 1 of 4, 2 of 4, etc.). An up motion returns the display to the branch page one level higher.

A system block diagram is illustrated in figure 9.

The Flight Displays

One of the major tasks of the ADAS design effort was to synthesize a flight display which would serve as a primary source of both vertical and horizontal information for the pilot. In addition the display had to have the ability to display a master caution, warnings, and advisories.

The display shown in figure 10 meets the flight display information requirements for the ADAS. The display is interactive in that by pushing certain line select keys and entering numerics from the KTU the high/low bugs on the radar altitude scale can be set, barometric pressure or field elevation can be set, VOR course selected, and the navigation mode chosen. Some other features worth noting are:

a) VOR radial information is continuously displayed (if VOR tuned to a station),

b) magnetic bearing to an ADF station is continuously displayed (if ADF tuned),

c) ground track angle is continuously displayed on the heading scale when the doppler is operating,

d) both magnetic bearing to destination from current position and course information (either doppler or VOR) are displayed.

In all cases information is presented only if the specific subsystem is operating and the functional mode selected.

A full page Waypoint Map (figure 11) can be selected for viewing by either operator on either CRT (see KTU dedicated buttons, figure 8). A single heading up display on a 1:1 M scale with doppler waypoints shown is depicted. Waypoint ordering can be selected by depressing the line select key (lower left). All line connections are erased and a new waypoint order can be entered via the KTU.

Engine Displays

A full page engine display (figure 12) will be used during the engine start mode and is available for call up at any time by either operator on the inner CRT. Analogous to the "yellow" and "red" indications used in the standard Black Hawk, reverse video and flashing reverse video are used. Allowable time remaining in an "out of limits" condition is displayed as shown in figure 13.

During normal flight operation an engine monitor half page (figure 14) will be displayed on the top half of the inner CRT. RPM and engine torque are displayed continuously in both analog and digital form (see reference 2). Allowable time remaining in an "out of limits" condition is displayed as shown in figure 15.

The Paging Scheme

The primary areas for interactive functions are the lower half of the inner CRT and the integrated avionics control display unit on the lower console. This latter control display is used for all functions associated with the communication, navigation, identification, and security equipments. Five dedicated buttons (plus one spare) on the left side of the KTU are used to access the major branches of the interactive pages. The dedicated buttons are:

1) CAU - caution

2) CHK LST - check list

3) EMGY - emergency procedures

4) SEC SYS - secondary systems

5) ASE - aircraft survivability equipment

A total of 370 interactive pages were generated to map the functions associated with the above into the ADAS architecture. The process used in synthesizing the pages required a detailed knowledge of each of the subsystems, the current operator functions as described in the operator's manual, and the level of integration of the electrical/control function into ADAS.

Rules of operation and the hardware configuration were first postulated. Then as the detailed pages were synthesized, these rules and the hardware configuration were refined to provide for cases which were exceptions. Each significant change required a complete page analyses iteration. During this process the system input/output was modified several times (both by additions and deletions). Only after this process was completed could realistic flow charting for the functional portion of the operational software begin.

A brief description of some of the features of the ADAS paging scheme are:

1) Caution

When the word "CAUTION" appears in reverse video on the flight display (outer CRT), the actual caution message(s) appear on the bottom of the inner CRT (in priority order if more than one). If the operator then depresses the caution button on the KTU or a button on the cyclic (during flight), the reverse video master caution message on the flight display is extinguished and the inner CRT displays a complete half page caution message. This message will include the emergency procedure associated with the caution and, for those functions which are controlled through ADAS, interactive control provided. If a detailed procedure may be required, access to the detailed procedure is also provided. Figure 16 illustrates a caution message where both the operator procedure and access to a detailed procedure are provided. If more than one caution occurs at the same time, the messages are arranged in priority order and accessed through the paging switch. Depressing the caution button when the master caution is not exhibited will bring up in priority order all outstanding cautions (if any) or the message "NO CAUTIONS."

In addition to the master reverse video caution on the flight display, there are five reverse video warnings (ENG 1 OUT, ENG 2 OUT, LOW RTR, FIRE, HYD). In the case of a warning situation, a half page warning message is automatically displayed on the lower half of the inner CRT. There are twelve (12) warning pages to cover the various warnings and combinations of warnings. An example of a warning message with interactive capability and access to a detailed procedure is shown in figure 17.

2) Checklist

Checklist automation is accomplished in the ADAS by a series of messages which require yes (or OK) or no as operator response. The yes response (the looked for response) can always be given by depressing the left top line select (lower half inner CRT) or when on the ground a cyclic button. The ADAS checklist is divided into eight (8) branches as shown in figure 18. At system initiation (APU start), ADAS is automatically initialized to the first line of the Before Start sequence. As shown in figure 19, if the checklist requires an action normally accomplished through ADAS, the specific interactive page on which the action is accomplished is automatically displayed on the top half of the inner CRT. The checklist continues to sequence through to the end of the Before Takeoff sequence automatically. If the operator desires a detailed procedure (see figure 20), branching to the specific detailed procedure can be accomplished by depressing the line select opposite the > symbol.

3) Emergency procedures

Ninety-nine (99) pages of emergency procedures are contained in the ADAS. All can be accessed by depressing the emergency button and paging to the specific procedure. The primary purpose for this major branch is to allow the operators to gain familiarity with the ADAS version of the emergency procedures. In all cases, these procedures will appear either automatically in the case of warnings or with the caution message. In the case of a failure in the caution/warning sensors, this branch does provide a means for accessing the necessary emergency procedure if the operators ascertain the fault condition in another manner.

4) Secondary systems

Depressing the SEC SYS button on the KTU brings up a menu page which provides access to the control functions of eighteen (18) subsystems. An example of a secondary system page is shown in figure 21.

5) Aircraft survivability equipment

Depressing the ASE button, the KTU brings up a menu page which provides access to the survivability equipments on board the aircraft.

Future Plans

Functional verification of the ADAS cockpit is scheduled to take place during the first half of next year in the Tactical Avionics System Simulator (TASS) at Fort Monmouth. A complete dynamic system simulation will be performed by tying the ADAS 1553 data bus to a data bus port on a PDP 1145. Support software which simulates all the multiplex remote terminal units will be used.

After functional verification in the TASS, the system will be flight tested in the Avionics Laboratory System Test Bed for Avionics Research (STAR), a UH-60A.

Conclusions

Synthesis of an integrated cockpit management system requires an iterative multidisciplined process in which initial conceptual system design is continuously modified by the effects of the specifics of the system being addressed. This process does not end with fabrication of the system hardware but must be continued through carefully designed simulation and flight experiments. In addition, the system must possess the flexibility to incorporate changes in procedures (e.g., updated emergency procedures) which will occur during the system life cycle.

References

1. Dasaro, J. A., Elliott, C. T., *"Integration of Controls and Displays in U.S. Army Helicopter Cockpits,"* Proceedings of 32nd NATO Guidance and Control Panel Symposium on The Impact of New Guidance and Control Systems on Military Aircraft Cockpit Design, Stuttgart Bad-Cannstatt, Germany, May 1981.

2. *"Electronic Master Monitor and Display System, Human Engineering Summary Report,"* AVRADCOM Technical Report 79-0270-3, Aircraft Equipment Division, General Electric Company, Binghamton, New York, June 1981.

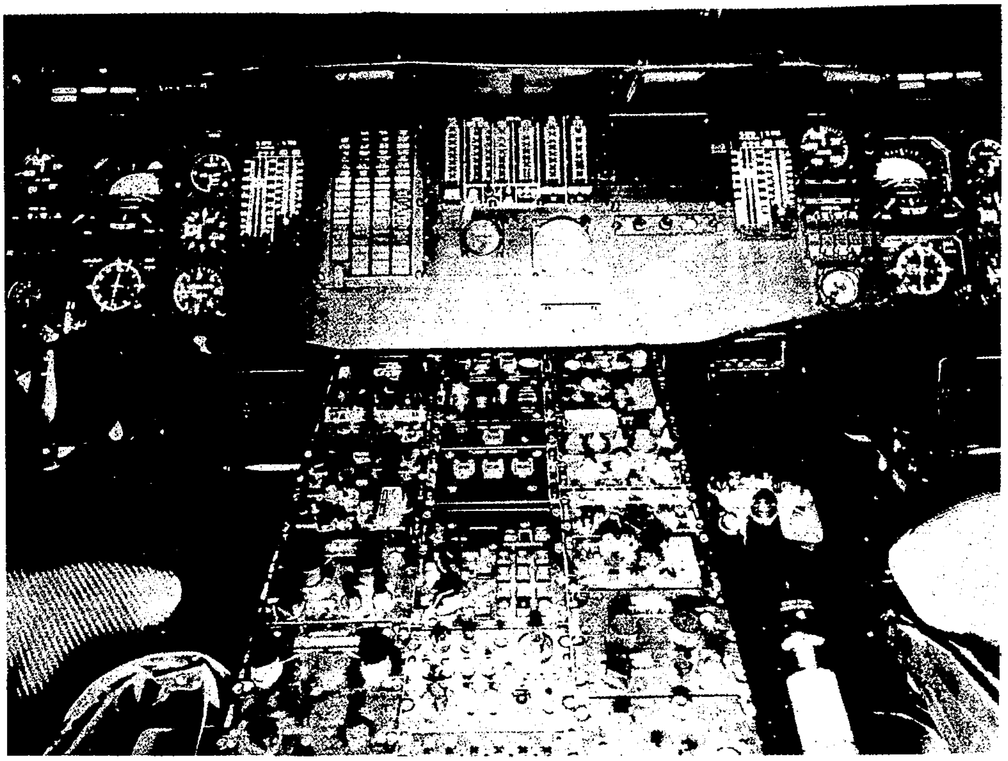

Fig. 1. UH-60A cockpit.

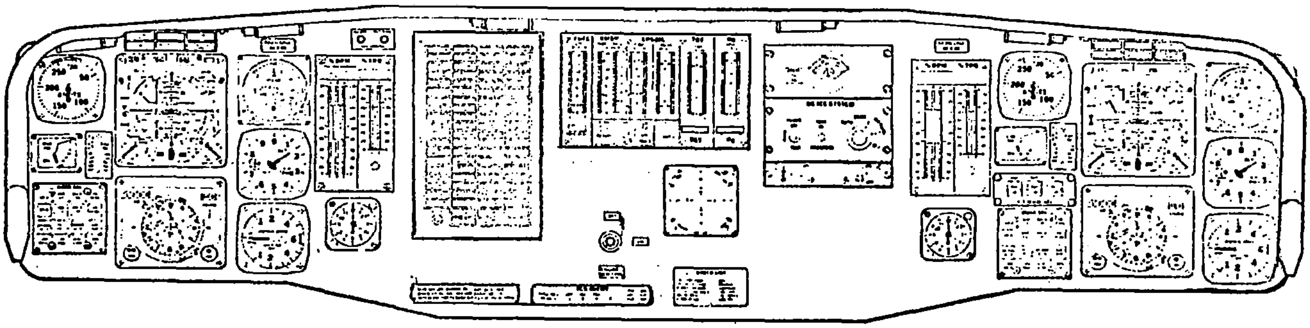

Fig. 2. UH-60A instrument panel.

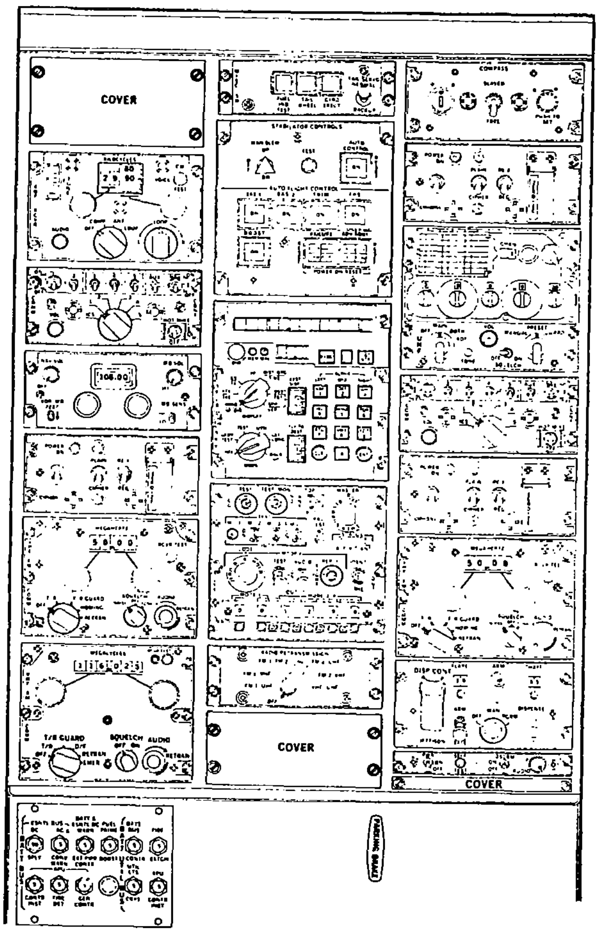

Fig. 3. UH-60A lower console.

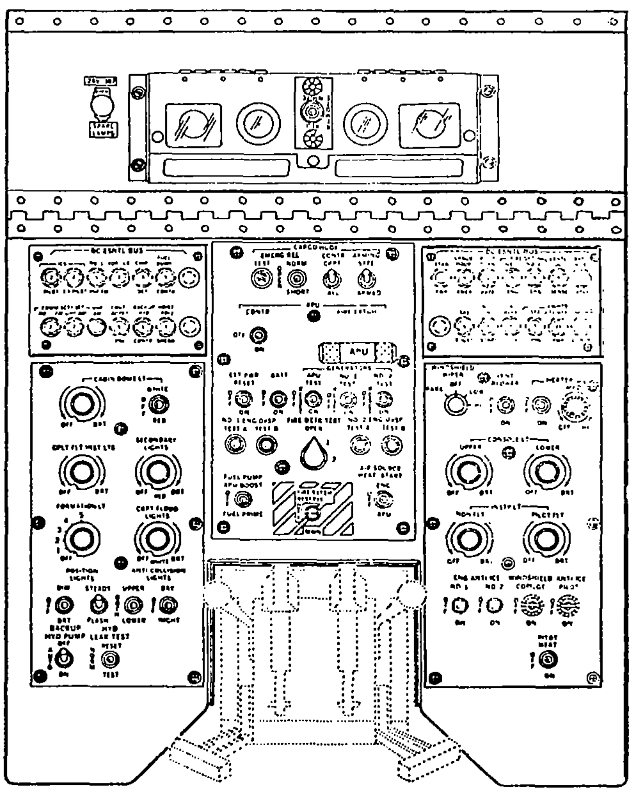

Fig. 4. UH-60A upper (overhead) console.

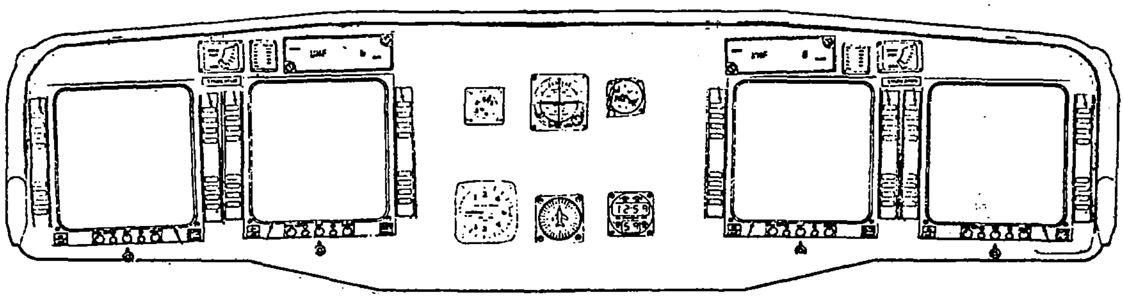

Fig. 5. ADAS instrument panel.

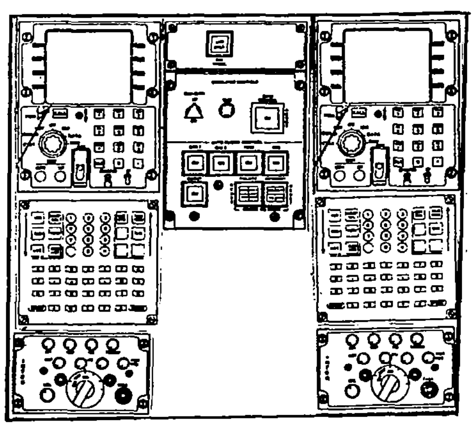

Fig. 6. ADAS lower console.

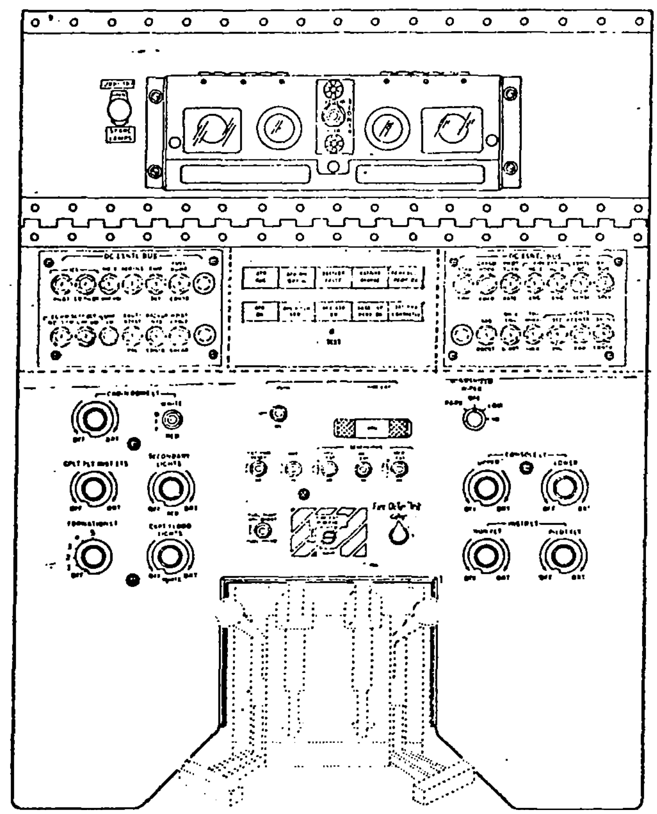

Fig. 7. ADAS upper (overhead) console.

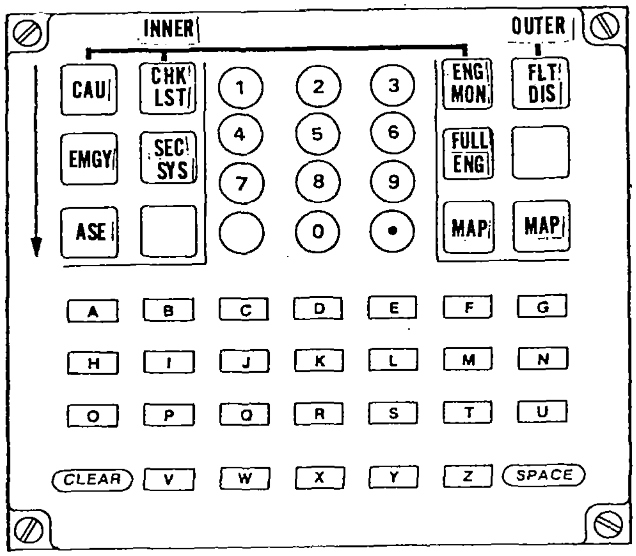

Fig. 8. Keyboard terminal unit (KTU).

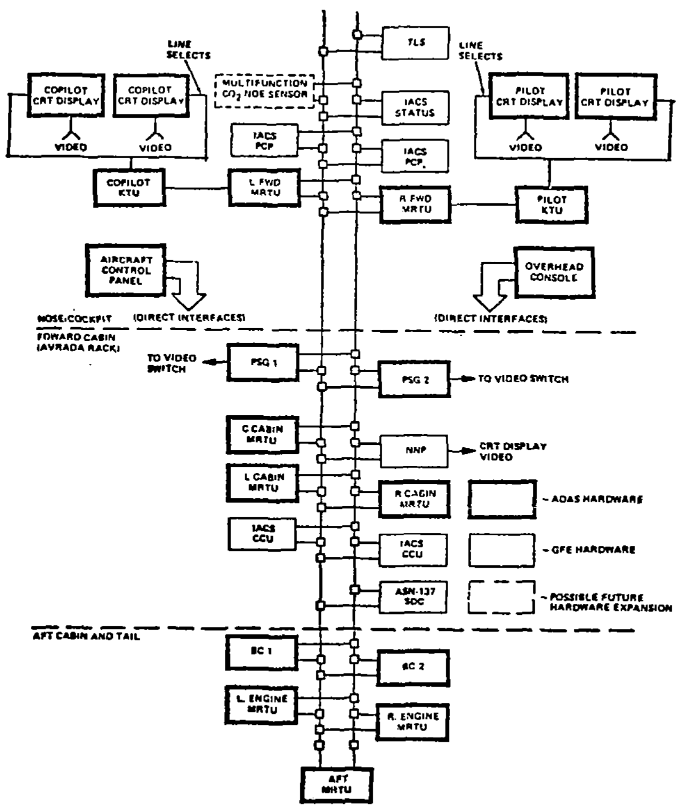

Fig. 9. ADAS system block diagram.

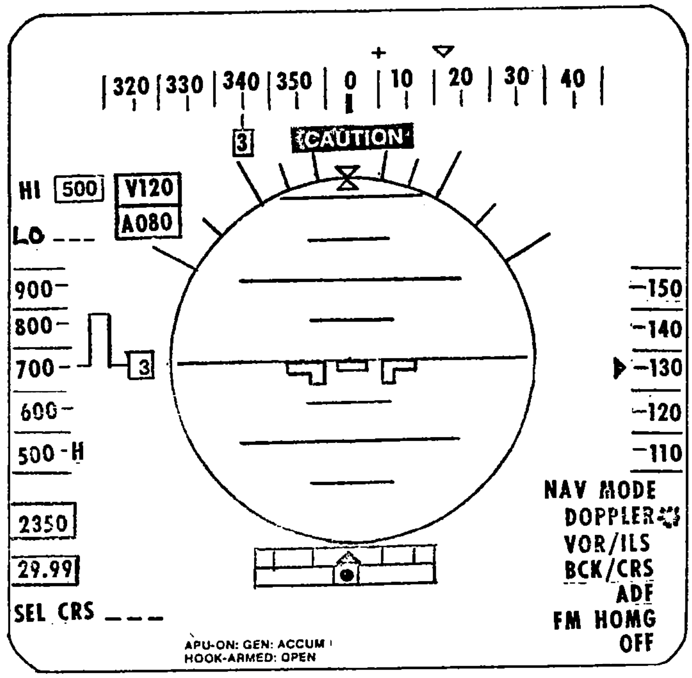

Fig. 10. ADAS flight display.

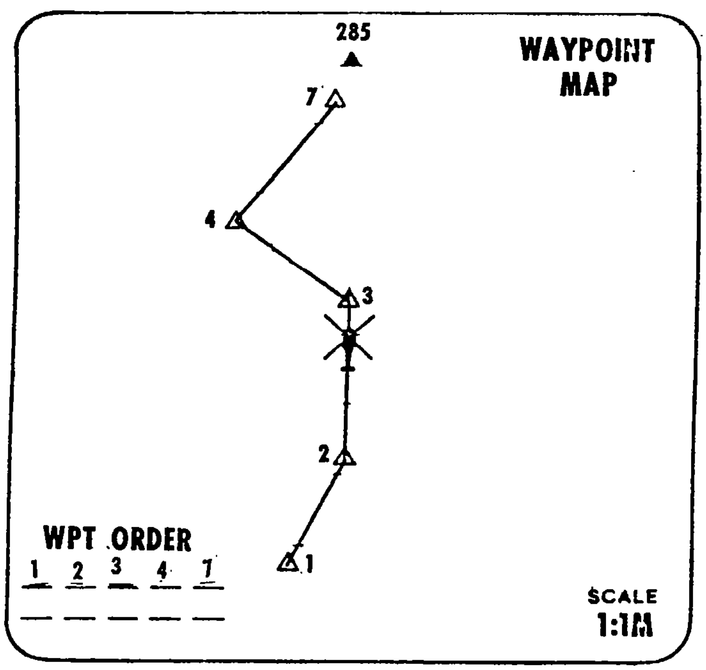

Fig. 11. ADAS waypoint map.

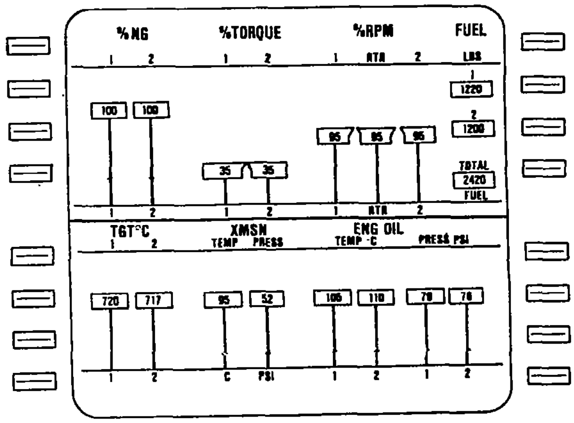

Fig. 12. Engine display (full page).

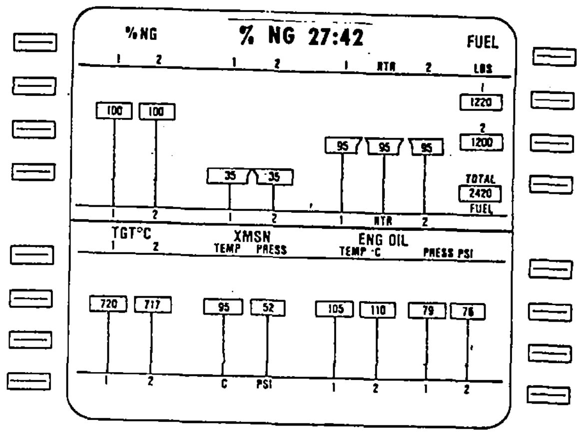

Fig. 13. Engine display without of limits condition.

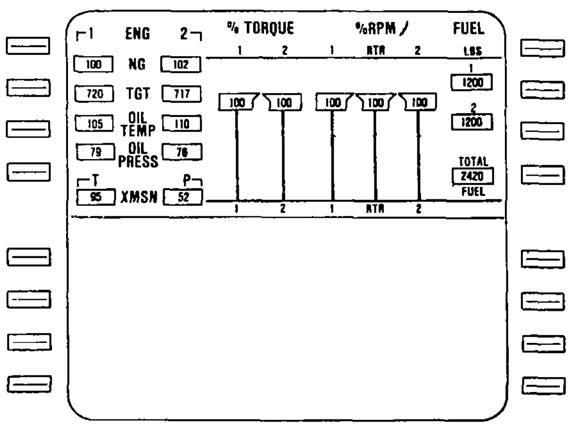

Fig. 14. Engine monitor (half page).

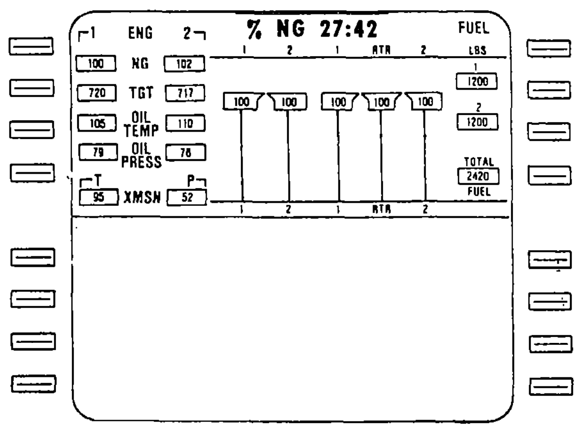

Fig. 15. Engine monitor without of limits condition.

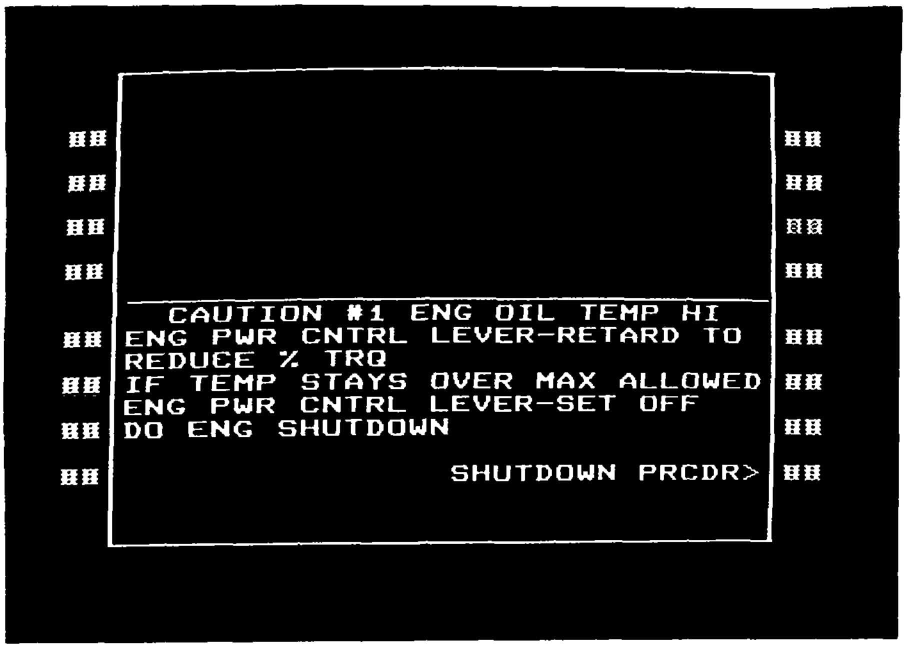

Figure 16. Caution page example.

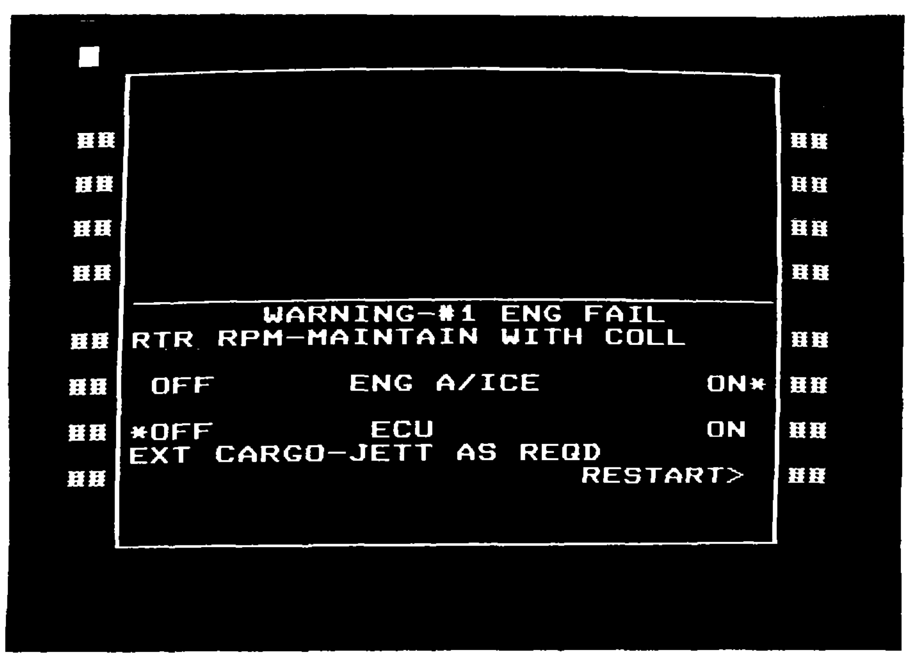

Figure 17. Warning page example.

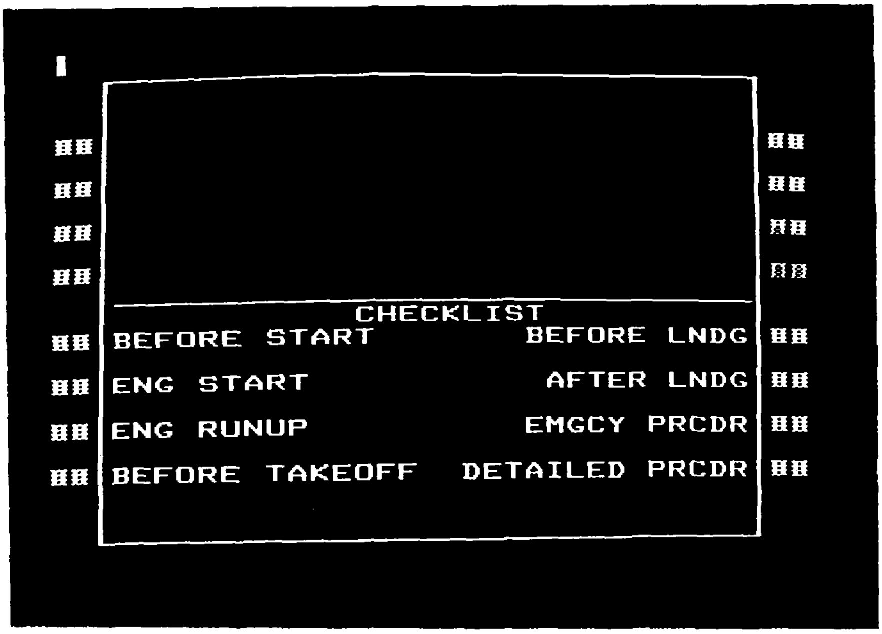

Fig. 18. Checklist (top page).

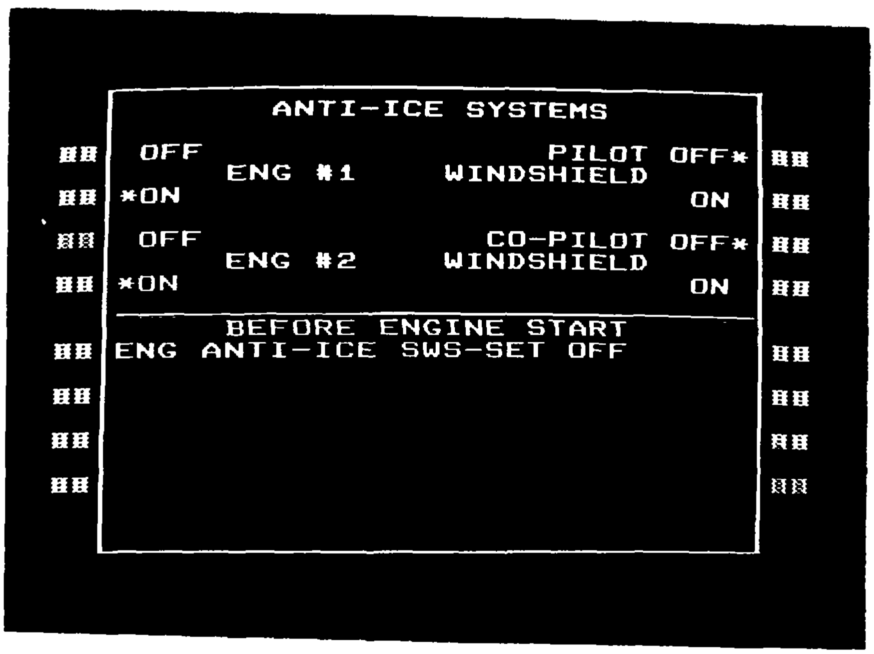

Fig. 19. Checklist example 1.

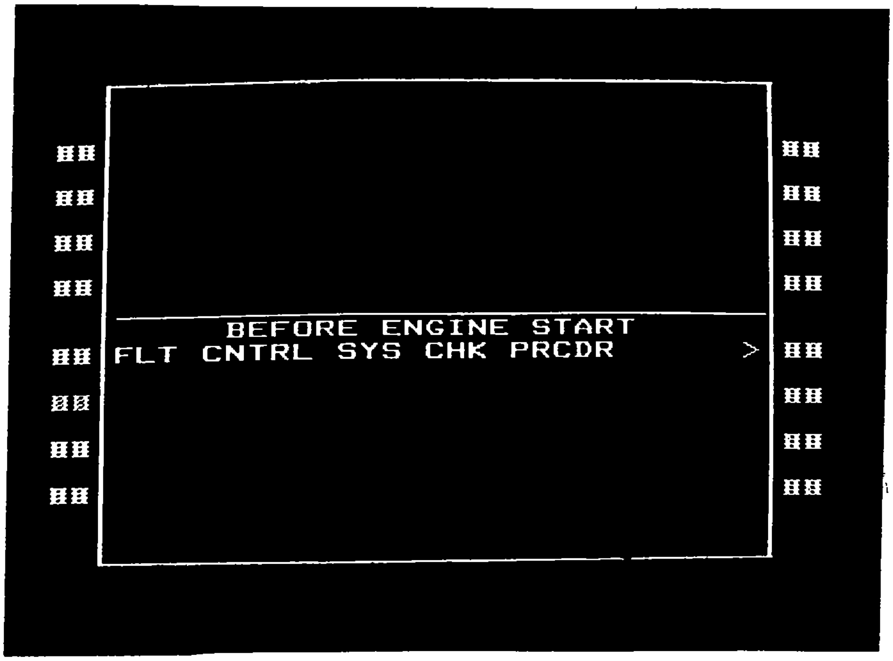

Fig. 20. Checklist example 2.

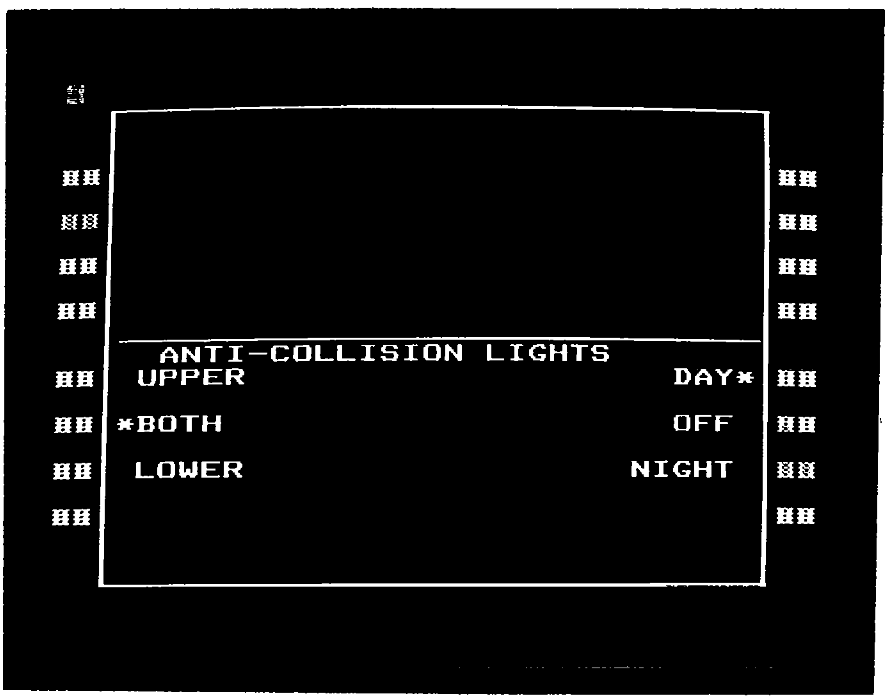

Fig. 21. Secondary system page example.