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S.A.R. SYSTEM DEVELOPED AS PART OF THE CONTRACT SIGNED WITH THE IRISH AIR CORPS FOR THE SUPPLY OF 365 F DAUPHIN AIRCRAFT

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ABSTRACT

This system has been developed to be fitted on the 365 F Dauphin aircraft to be operated by the IAC, its main purpose being the performance of S.A.R. missions («SEARCH AND RESCUE»). Its main features are :

- a fully automatic guiding function, particularly for the search patterns and the descent to hovering near the designated target, by means of a CROUZET NADIR MK 2 navigation computer and a 4-axis SFIM CDV 155 flight director coupler.
- an instrument panel fitted with a BENDIX EFIS (electronic flight instrument system) for the display of horizontal situation parameters (E.HSI : HSI, SECTOR, PATTERN-HOVER mode), attitude (EADI) and radar.

It was studied to obtain as a whole, a redundancy provided by sub-systems designed to remain operational after an initial failure to allow an isolated aircraft to perform an IMC oversea mission without any other support.

INTRODUCTION

This paper reviews the principal system features, and describes each of the three primary subsystems shown in Figure 1 :

- a navigation subsystem,
- an automatic flight control subsystem,
- a display and radar subsystem.

The complete system is organized around two SFIM interface units designated by their French acronym «BATIE».

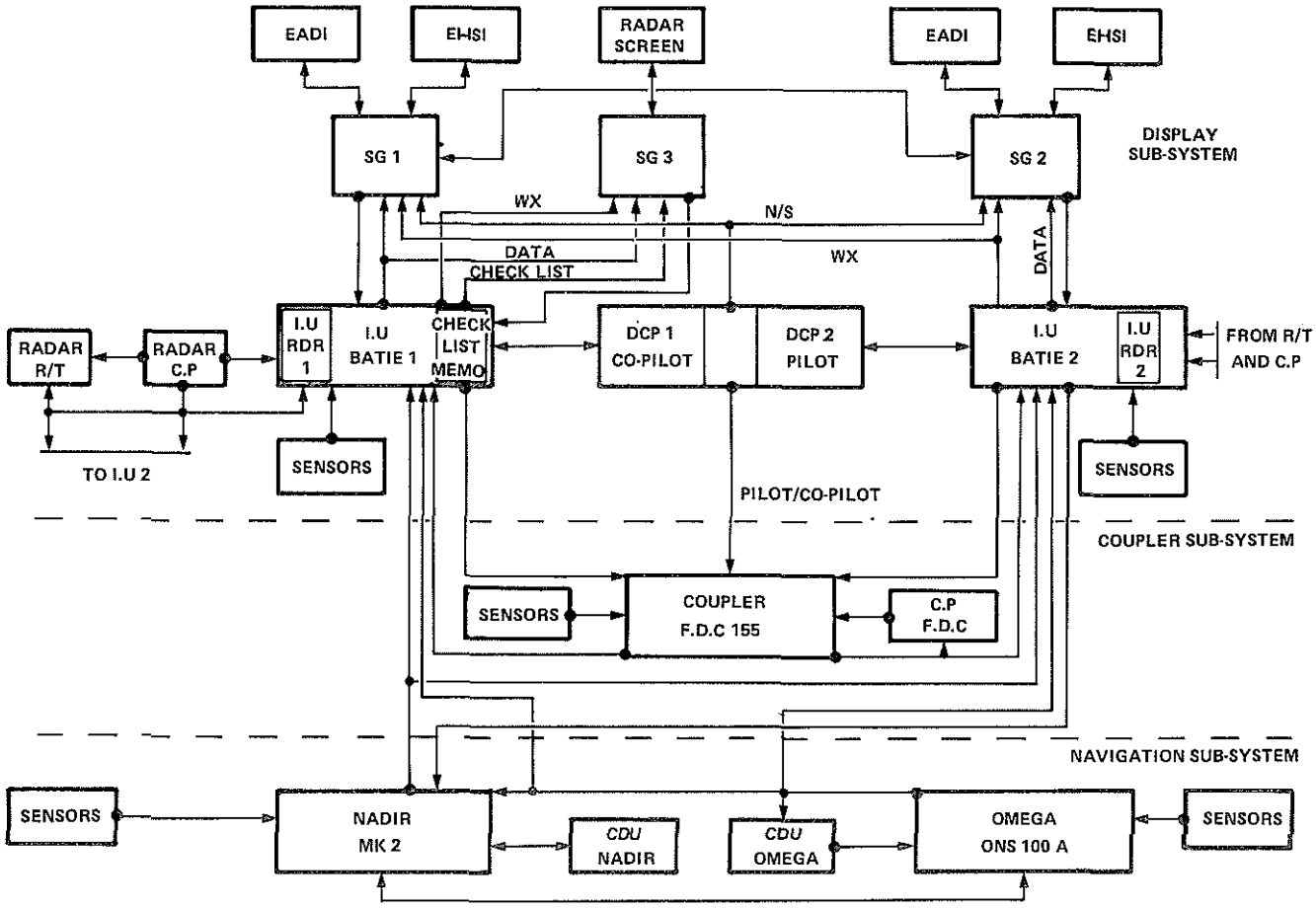

Fig. 1

1 – NAVIGATION SUBSYSTEM (Figure 2)

1.1 – GENERAL

The navigation subsystem comprises two navigation computers : the NADIR Mk 2 main computer and the OMEGA ONS 100A receiver processor, together with sensors and peripheral systems (Doppler radar, gyromagnetic compasses VOR and DME receivers, etc ...).

In normal operation, the NADIR Mk 2 computer covers all of the navigation functions, and the OMEGA receiver is used as a peripheral unit. In the event of a NADIR Mk 2 system malfunction, the OMEGA receiver reverts to its navigation computer function and automatically ensures uninterrupted execution of the current navigation mode or tracking of a preselected course.

Data exchanges between the two computers are ensured by ARINC 429 digital buses. Both computers are linked to the other subsystems over ARINC 429 buses via the BATIE interface units.

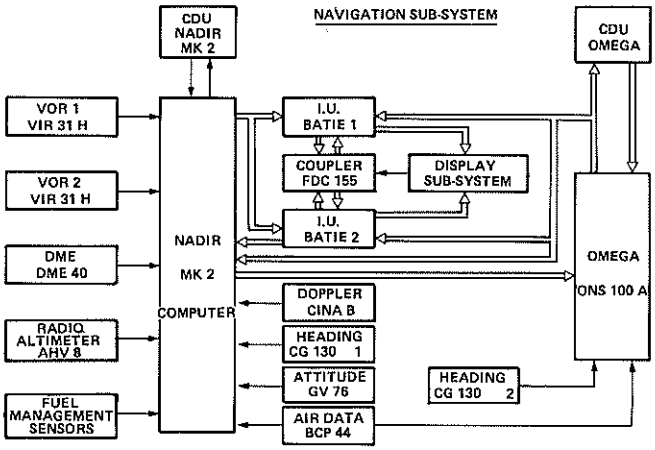

Fig. 2

1.2 – NADIR Mk 2 FUNCTIONS

1.2.1 – Present Position Maintenance

The NADIR Mk 2 processes three present position references based on three different navigation modes (Figure 3) :

- Doppler radar navigation,
- VOR/DME navigation,
- OMEGA navigation.

The three positions are continuously processed and may be displayed on the NADIR Mk 2 control and display unit (CDU). The desired navigation mode is selected by the operator.
In case of Doppler memory it uses air data.

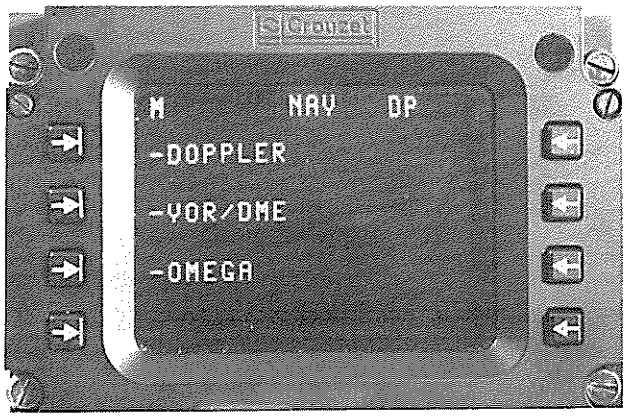

Fig. 3

Example : Pressing the third key on the LH side, labeled «OMEGA», displays the OMEGA page (Figure 4) indicating

- the OMEGA position (latitude and longitude)
- the OMEGA position groundspeed.

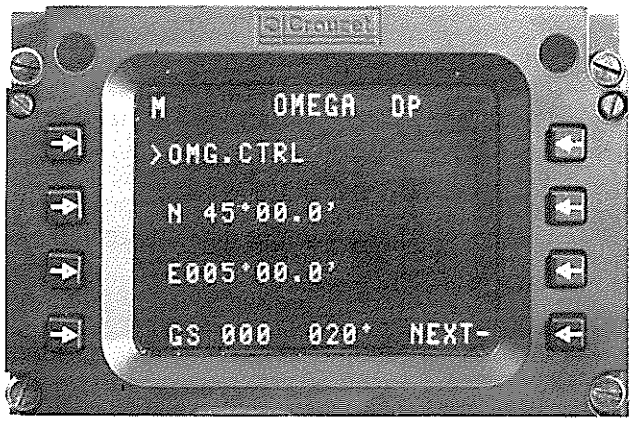

Fig. 4

Pressing the last key in the RH column, labeled «NEXT», displays the OMEGA AUX page to select the standby course transferred to the OMEGA computer for use in the event of a NADIR Mk 2 computer failure (Figure 5).

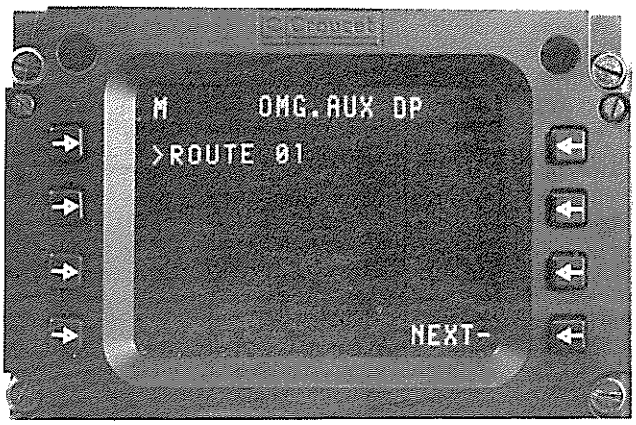

Fig. 5

1.2.2 – Waypoint Management

The NADIR Mk 2 maintains 140 waypoints :

- 50 VOR/DME stations
- 50 characteristic waypoints
- 20 auxiliary waypoints
- 20 moving waypoints.

Via the No 2 BATIE interface unit, the NADIR Mk 2 may receive a waypoint designation signal in LAT/LONG coordinates from the joystick control of the radar.

1.2.3 – Route and Navigation Mode Parameters

The NADIR Mk 2 is designed to maintain the following routes (Figure 6) :

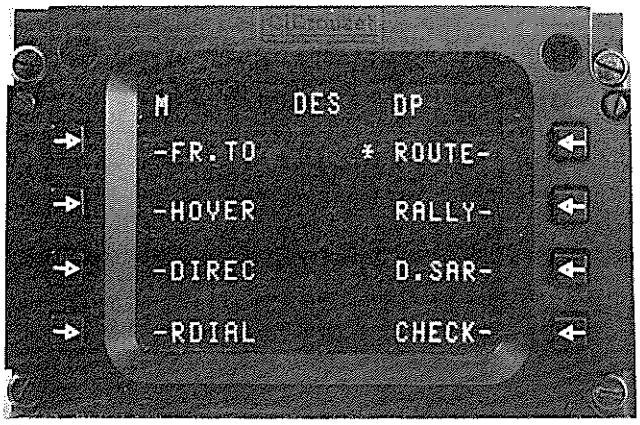

Fig. 6

- Navigation FROM-TO
- Navigation DIRECT TO (with or without a radial)
- Homing on a moving waypoint
- Route navigation (From any of the waypoints entered in the computer, except for the moving waypoints, up to 10 routes to 10 waypoints may be designated)
- Search pattern navigation :
  - creeping ladder (Figure 7)
  - expanding square (Figure 8)
  - cloverleaf sector (Figure 9)

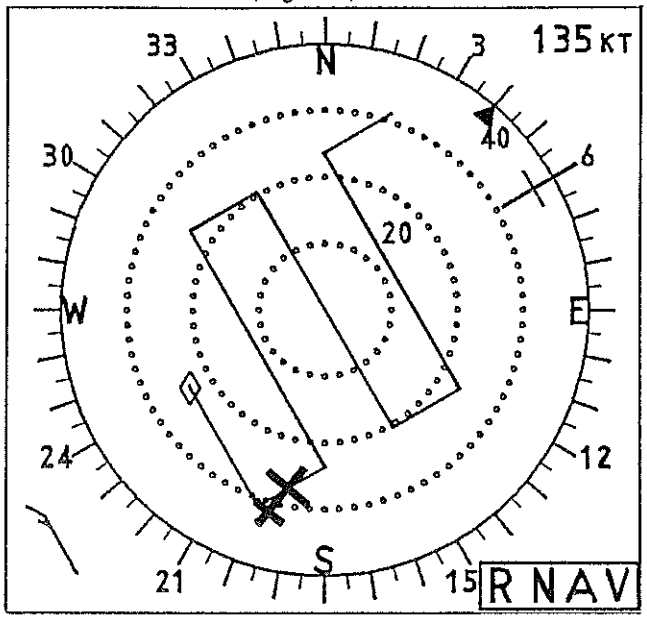

Fig. 7 CREEPING LADDER SEARCH PATTERN DISPLAY

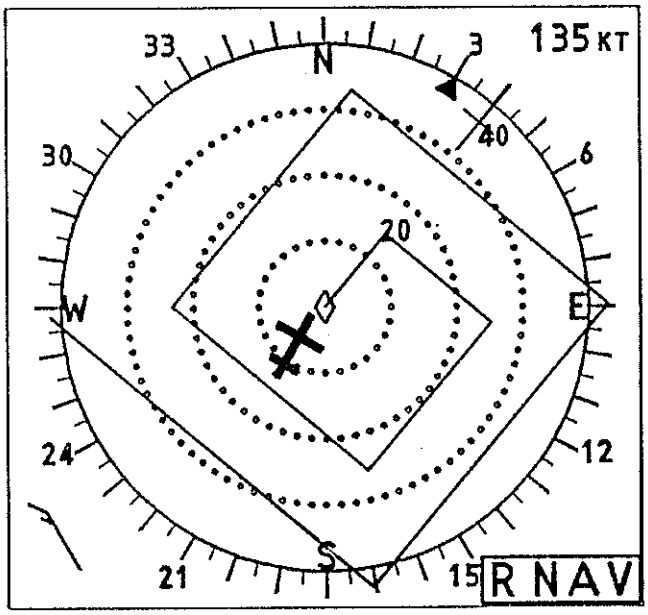

Fig. 8 EXPANDING SQUARE SEARCH PATTERN DISPLAY

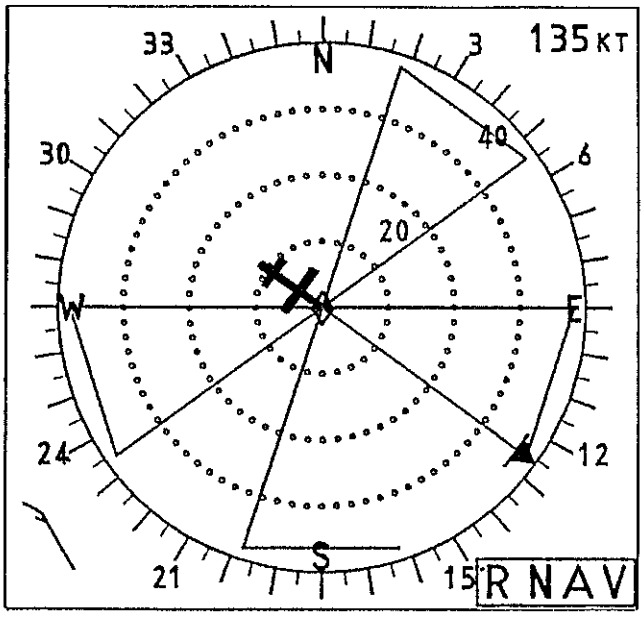

Fig. 9 CLOVERLEAF SECTOR SEARCH PATTERN DISPLAY

– **Approach to Hover**

This mode brings the aircraft to a hover configuration into the wind. The hover point (mark point) may be a waypoint of known coordinates, or a waypoint defined by marking its position on the NADIR Mk 2 CDU during fly-over.

The first step is to bring the helicopter to a turning point facing into the wind (Figure 10).

The second step consists in a downward transition from the turning point along a predefined course to hover at the mark point.

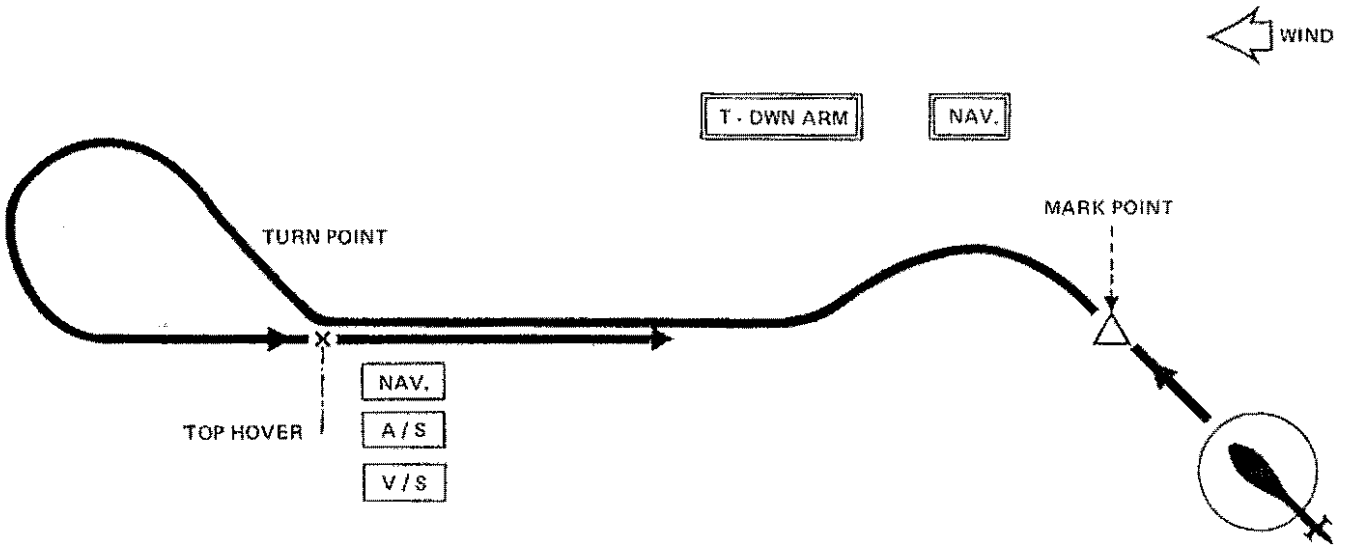

Fig. 10

During the first step, the NADIR Mk 2 supplies the Flight Director Coupler with a roll control signal. During the second step, the NADIR continues to ensure lateral guidance and monitors the mark point distance so that the Flight Director Coupler can modify the longitudinal deceleration accordingly in order to enter hover close to the mark point (Figure 11).

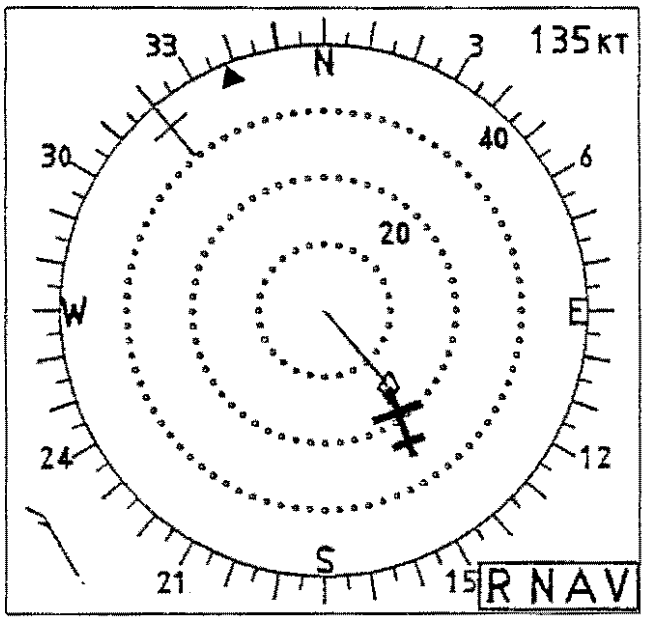

Fig. 11 APPROACH TO HOVER DISPLAY

1.2.4 – Fuel Management and Flight Aids

In addition to navigation data, the NADIR Mk 2 provides the crew with fuel management and flight aids data.

1.2.4.1 – Fuel Management

The crew first enters the following parameter values manually on the CDU keyboard,

- aircraft empty weight
- weight of crew + passengers + payload
- initial fuel weight
- reserve fuel weight
- optional equipment installed (hoist, searchlight, loudspeaker, etc ..)
- flight plan (course, altitude, predicted wind velocity and direction, etc ..).

The NADIR Mk 2 then computes and displays the following results :

- **Preflight Twin-Engine Estimates (Figure 12)**

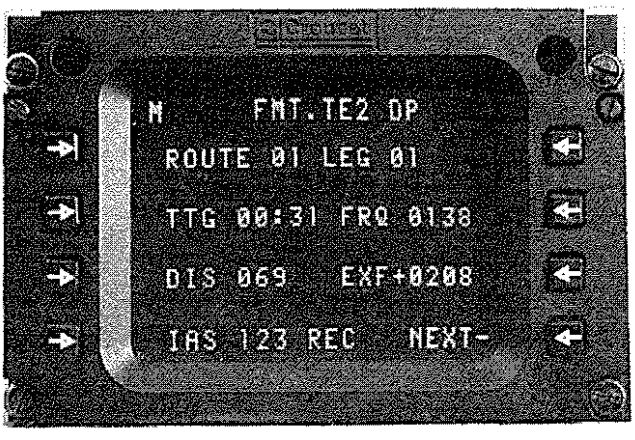

Fig. 12

- Fuel quantity required to reach the destination (FRQ)
- Remaining fuel quantity at destination (EXF)
- Recommended best-range cruising speed for the first leg of the selected route (IAS ... REC)
- FUEL ALERT warning if EXF is less than the fuel reserve

- **In-Flight Twin-Engine Calculations**

The NADIR Mk 2 recalculates the preflight parameters but using the actual flight conditions. If the crew has also designated an alternative waypoint, the computer continuously indicates the following (Figure 13) :

- Distance and heading to fly to the alternative waypoint

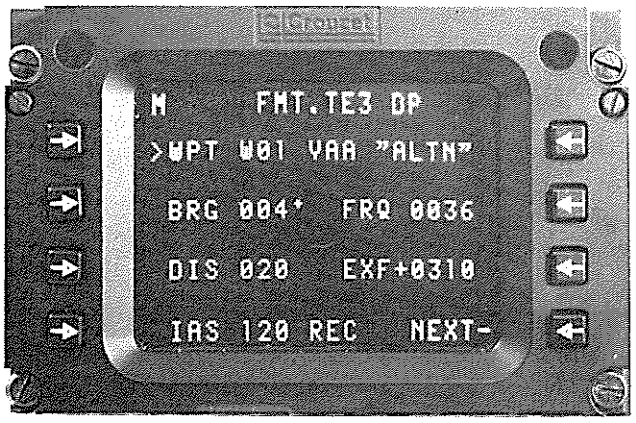

Fig. 13

- Fuel quantity required to reach this waypoint (FRQ)
- Remaining fuel quantity on reaching the alternative waypoint EXF
- Recommended best-range cruising speed
- FUEL ALERT warning if EXF is less than the fuel reserve.

– **In-Flight Single-Engine Estimates (Figures 14 & 15)**

Fig. 14

Fig. 15

In twin-engine flight the NADIR Mk 2 also estimates the following parameters :

- Distance and heading to fly to the alternative waypoint in the event of an engine failure
- Fuel quantity required to reach the alternative waypoint (FRQ)
- Remaining fuel quantity on reaching the alternative waypoint (EXF)
- Recommended best-range cruising speed
- Permissible flight time at intermediate contingency rating (D30P)
- Recommended fuel jettison (FJ)
- Maximum remaining flight time under present conditions after recommended fuel jettison (FEND)
- FUEL ALERT warning if EXF is less than fuel reserve.

– **In-Flight Single-Engine Calculations**

The same parameters are calculated with updated values. If fuel has been jettisoned, the remaining fuel quantity is determined from the fuel gauge output (UPDATE FUEL).

– **Miscellaneous Parameters Continuously Updated by the NADIR Mk 2**

- Instantaneous hourly fuel consumption
- Available fuel weight
- Remaining flight time and range under present conditions.

1.2.4.2 – Flight Aids

The NADIR Mk 2 also maintains the following flight aid parameters (Figure 16) :

– Present aircraft weight
– Twin-engine hover OGE takeoff weight at maximum continuous ratings
– Maximum OEI landing weight at super contingency rating
– Payload weight margin (MRG)

1.3 – CONTROL AND DISPLAY PROVISIONS

The navigation system control and display provisions include the following :

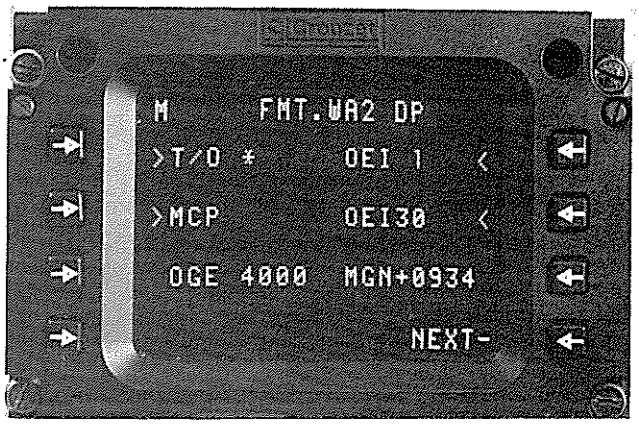

Fig. 16

- NADIR Mk 2 Control and Display Unit (Figure 17) : the CDU supports control keys, a CRT display and two warning lights
- Electronic Horizontal Situation Indicator : the EHSI displays flight and navigation data
- Electronic Attitude Director Indicator : the EADI displays the fuel management warning messages.

Fig. 17 NADIR MK 2 CDU

2 — AUTOMATIC FLIGHT CONTROL SUBSYSTEM

The automatic flight control subsystem comprises an SFIM AP 155 3-axis autopilot providing pitch, roll and yaw stabilization, and an SFIM FDC 155 Flight Director Coupler that implements navigation and SAR modes on the pitch, roll and collective channels.

2.1 — SFIM AP 155 AUTOPILOT SYSTEM

The autopilot system basically consists of the following :

- a control unit (Figure 18) that permits individual engagement and disengagement of each axis

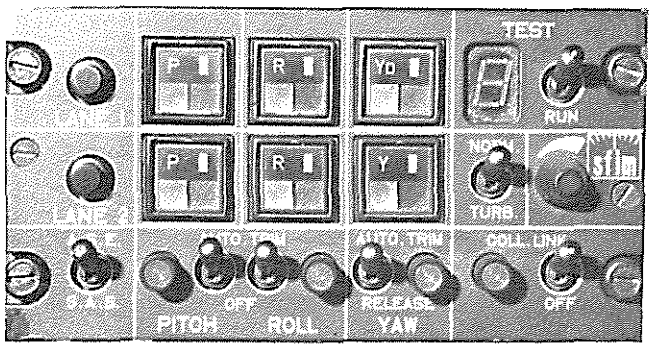

Fig. 18 AP 155 CONTROL UNIT

- a 3-axis duplex computer that ensures the following functions :
  - pitch and roll axis stabilization on attitude references supplied by the vertical gyro platforms ;
  - heading stabilization on a reference supplied by a gyro compass.

2.2 — SFIM FDC 155 FLIGHT DIRECTOR COUPLER

The Flight Director Coupler includes two basic components

2.2.1 — Coupler Control Unit (Figure 19)

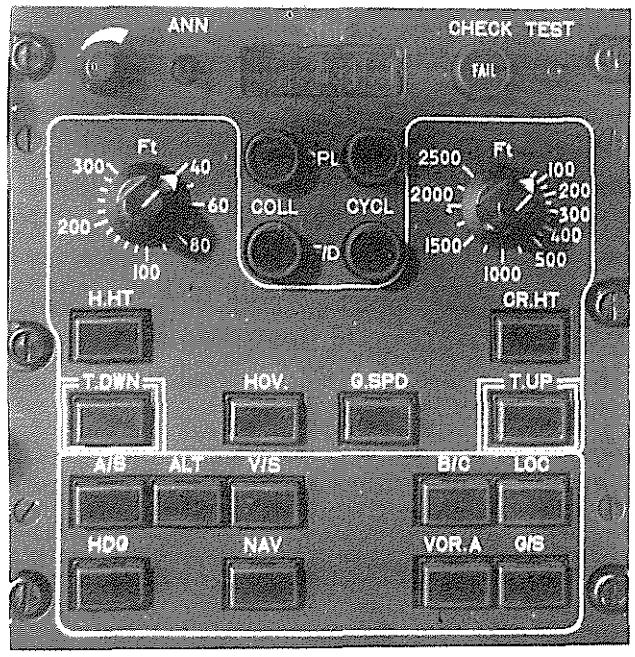

Fig. 19 FDC 155 CONTROL UNIT

Coupler control unit functions include the following :

- Cyclic and collective channel engagement in Coupler and/or Flight Director modes
- Coupler function engagement
- Radio altitude selection for the Hover Height and Cruise Height functions.

2.2.2 — Coupler Computer

A digital computer operating in duplex mode on the collective axis ensures the following functions :

- ALT — Barometric altitude acquisition and hold
- A/S — Selected airspeed acquisition and hold
- V/S — Selected vertical speed acquisition and hold
- HDG — Selected heading acquisition and hold
- NAV — Depends on the EFIS system control panel selection :
  - VOR 1 or VOR 2 radial capture and tracking
  - VLF OMEGA course capture and tracking
  - NADIR search pattern or navigation course capture and tracking

- LOC — ILS Localizer beacon capture and approach tracking
- G/S — ILS Glideslope beacon capture and tracking
- B/C — Localizer beacon capture and reverse tracking
- VOR.A — VOR radial capture and approach tracking
- H.HT — Acquisition and hold in hover mode of selected radio altitude (40-300 feet)
- CR.HT — Acquisition and hold in cruising mode of selected radio altitude (100-2500 feet)
- HOV — Zero Doppler groundspeed acquisition and hold
- G.SPD — Doppler Vx and Vy groundspeed acquisition and hold
  (The hoist operator's joystick control can be used to modify the Doppler groundspeed values in the HOV or G.SPD modes)
- T.DWN — Automatic transition to Doppler hover at a selected radio altitude
- T.UP — Automatic transition from hover to a selected radio altitude and airspeed (corresponds to simultaneous engagement of A/S and CR.HT functions)
- T.DWN + NAV — Downward transition guided by the NADIR Mk 2 computer which first heads the aircraft into the wind, then outputs a T.DWN initiation signal to the Flight Director Coupler in order to enter hover mode 300 feet downwind from the mark point (Figure 20)
- F.UP — Automatic fly-up safety mode in search operation : cancels all other functions engaged and causes the aircraft to fly up to a preselected radio altitude with no pilot intervention
- G/A — Emergency go-around mode in 4-axis operation : acquisition of a preset airspeed (75 knots) and a preset rate of climb (500 fpm).

2.3 — COUPLER CONNECTIONS TO RELATED SUB-SYSTEMS (Figure 21)

The coupler is connected to the other subsystems over ARINC 429 buses via the BATIE interface units, which ensure the following principal functions :

- HSI function : each BATIE interface unit transmits the heading error and course error signals from the master EHSI
- Annunciator function : the coupler supplies the BATIE interface units with signals indicating all functions engaged and armed, for display on the EADIs (Figure 22).
  - Active modes are shown on the top line in green, inside a green frame if the Coupler mode is engaged, or without a frame if the Flight Director mode is engaged alone.
  - Armed modes appear in white on the second line.
- Flight Director display function on the EADIs : pitch and roll command bars, collective pitch scale (Figure 23)
- Navigation signal concentrator function : transmission of navigation parameters to the coupler corresponding to the type of navigation selected on the Display Control Panel (DCP).

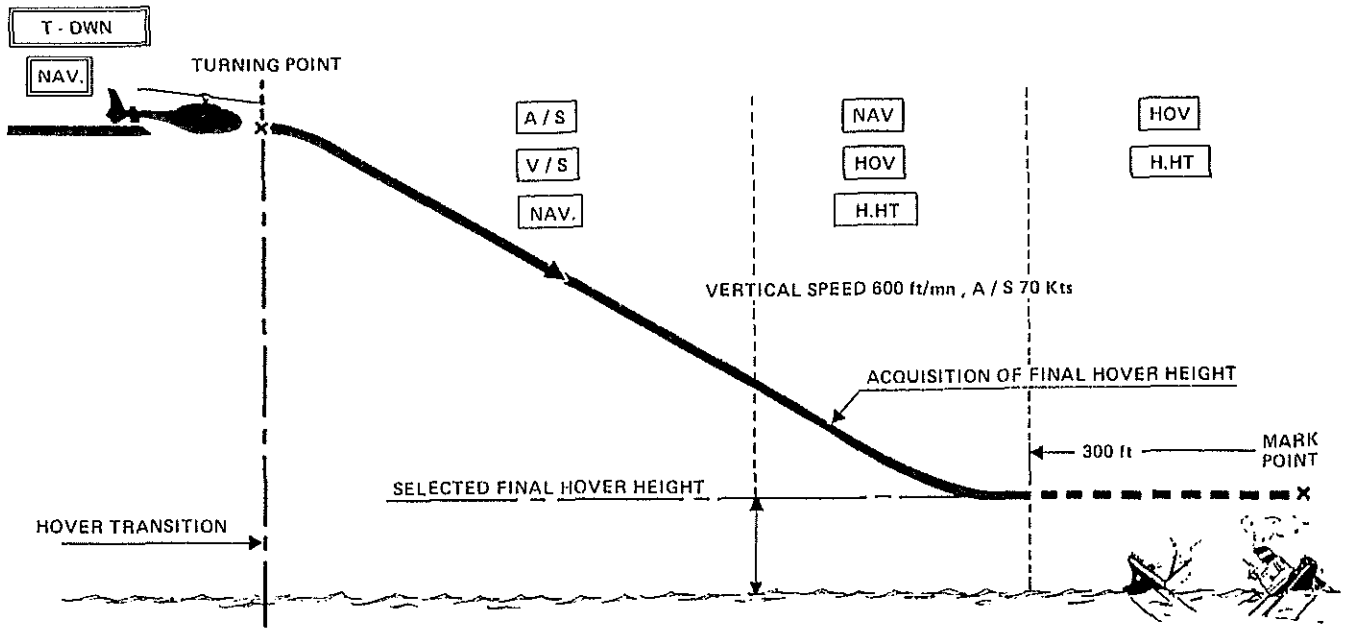

Fig. 20

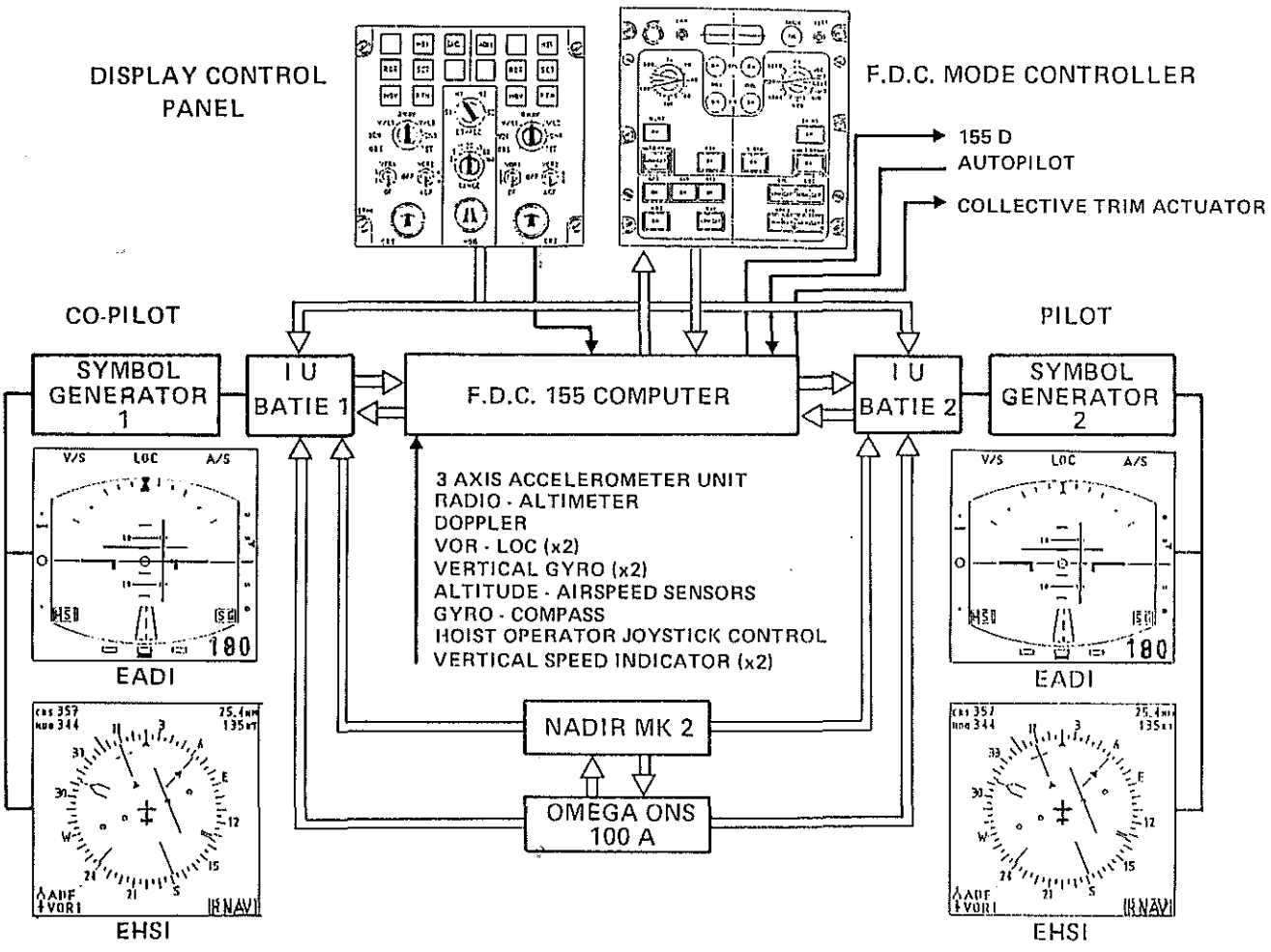

Fig. 21 FDC 155 SUB-SYSTEM

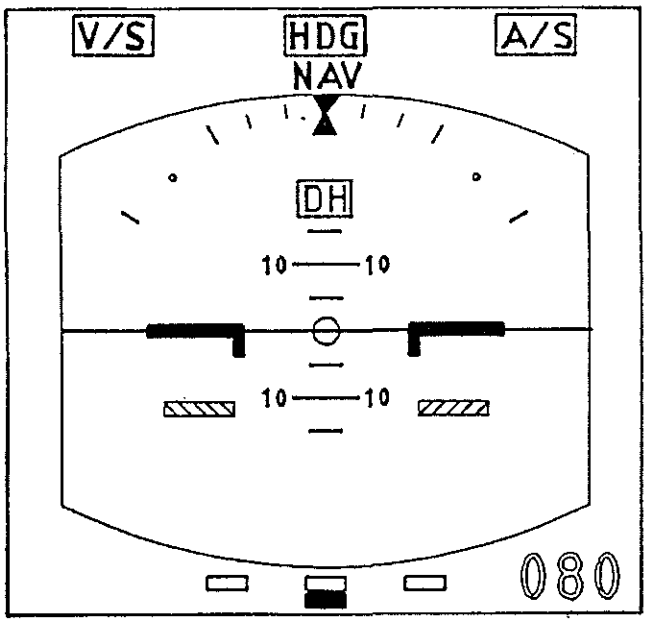

Fig. 22

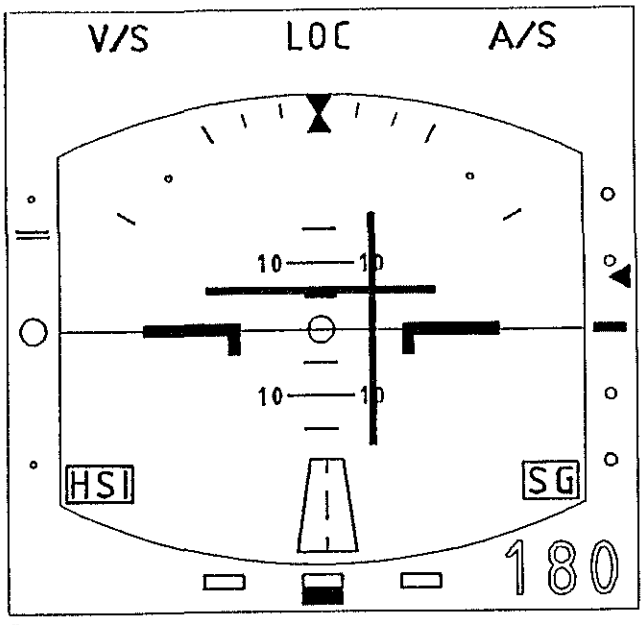

Fig. 23

NOTE : The Flight Director Coupler receives continuous inputs from the pilot's and copilot's systems (i.e. from BATIE 1 and 2). A discrete signal input from the DCP to the FDC 155 indicates whether the pilot's or copilot's system is the master system.

3 – DISPLAY AND RADAR SUBSYSTEM (Figure 24)

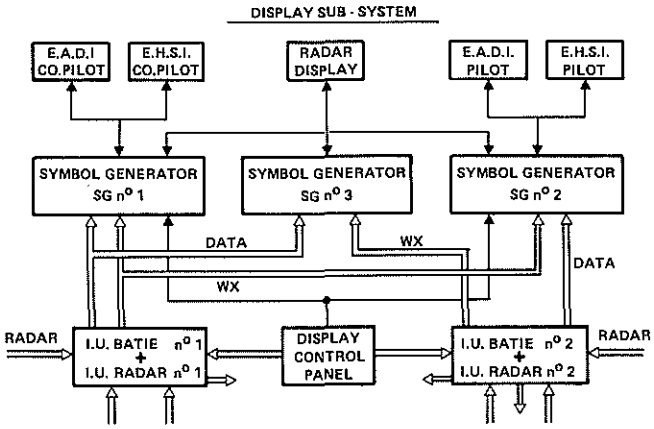

Fig. 24

3.1 – GENERAL ORGANIZATION

3.1.1 – Display Functions

The EFIS display system is a dual-pilot system comprising two identical subsystems operating independently with provision for reconfiguration in the event of a fault condition affecting either one. Subsystem No 1 is assigned to the co-pilot's instrument panel, and subsystem No 2 to the pilot's instrument panel.

Each subsystem includes the following :

- two shadowmask color cathode ray tube (CRT) displays mounted on the instrument panel and ensuring ADI and HSI functions ;
- a symbol generator unit (SGU) ;
- a BATIE interface unit ensuring input signal matching, processing and filtering ;
- a display control panel (DCP) supporting the system control provisions.

3.1.2 – Radar Functions

The aircraft is equipped with a BENDIX 1500 radar system providing search and weather avoidance functions, and consisting of the following :

- a 10 kW receiver-transmitter
- an 18-inch antenna array mounted in the aircraft nose and covering a 120° forward sector
- two radar interface units : RIU 1 in BATIE No 1 supplies radar signals to symbol generators 1 and 2 for the EHSIs in sector mode ; RIU 2 in BATIE No 2 supplies radar signals to SGU 3
- a symbol generator unit (SGU 3)
- a radar control panel (RCP)
- an auxiliary control panel with joystick and checklist functions
- a radar display screen.

3.2 – GENERAL FUNCTIONAL DESCRIPTION

3.2.1 – Display Subsystem

The display subsystem is entirely controlled from the Display Control Panel (DCP : Figure 25) which provides the following functions :

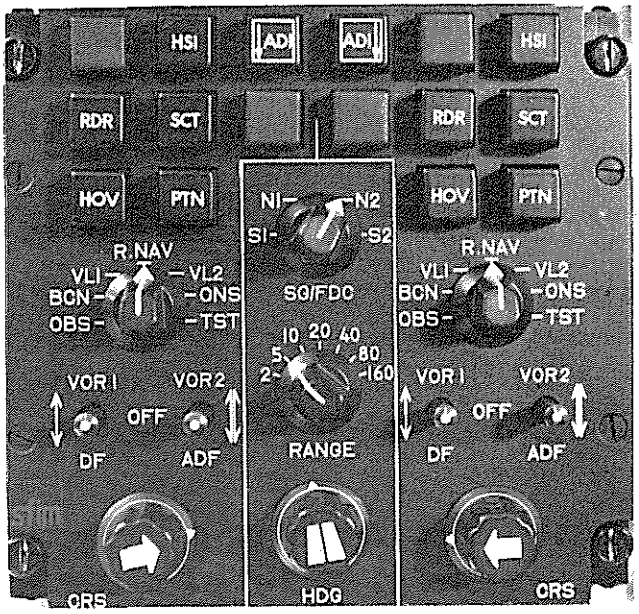

Fig. 25 EFIS DISPLAY CONTROL PANEL

– **Individually for the pilot's and copilot's systems**

- EHSI display mode selection (the EADI display mode is permanent)
- navigation and guidance source selection
- signal source assignment to each RMI pointer
- course selection
- self-test routine.

– **Simultaneously for both the pilot's and copilot's systems**

- heading selection
- range selection in SCT, SCT + RDR and PTN modes
- master system selection to drive the Flight Director Coupler
- manual reconfiguration in the event of a subsystem malfunction (the display output from the other subsystem is then supplied to the display screens in the faulty system).

3.2.1.1 – Display System Controls

3.2.1.1.1. Separate Controls for the Pilot's and Copilot's Displays

The following controls are identical on either side of the DCP.

a) EHSI Display Mode Selection

The display mode is selected by means of eight momentary contact pushbuttons, six of which are active in this version. The following modes are available :

– HSI, SCT, RDR, PTN, HOV, ADI

HSI Mode Display (Figure 26)

This configuration basically resembles a conventional HSI + RMI display, with the following additional indications :

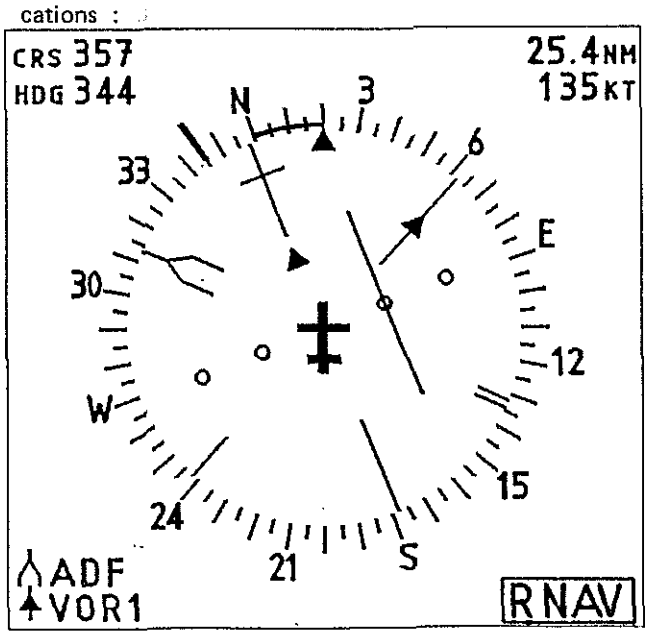

Fig. 26

– distance to next waypoint or beacon
– groundspeed
– selected course and heading
– HSI navigation signal source
– navigation signal sources assigned to RMI pointers.

Sector (SCT) and Radar (RDR) Mode Displays (Figure 27)

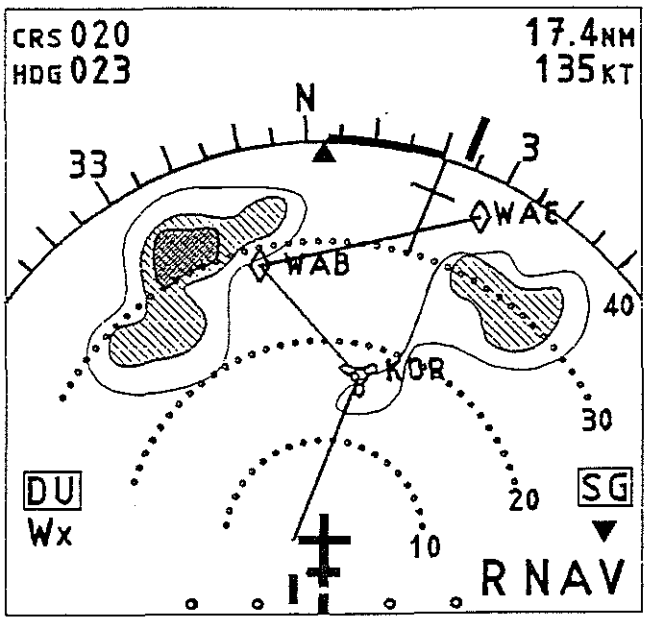

Fig. 27

The sector mode provides a map display of the sector forward of the aircraft, which varies according to the selected navigation mode. Radar data may be superimposed on this display if the RDR pushbutton is engaged.

Hover Mode Display (Figure 28)

This mode displays the information required for transition to hover and subsequent hover hold :

– aircraft magnetic heading
– hover point, NADIR target (FIX position) and/or radar joystick designated target
– Doppler groundspeed components (Vx and Vy)
– Doppler speed trend circle
– Groundspeed
– present radio altitude and selected hover height
– wind direction and force.

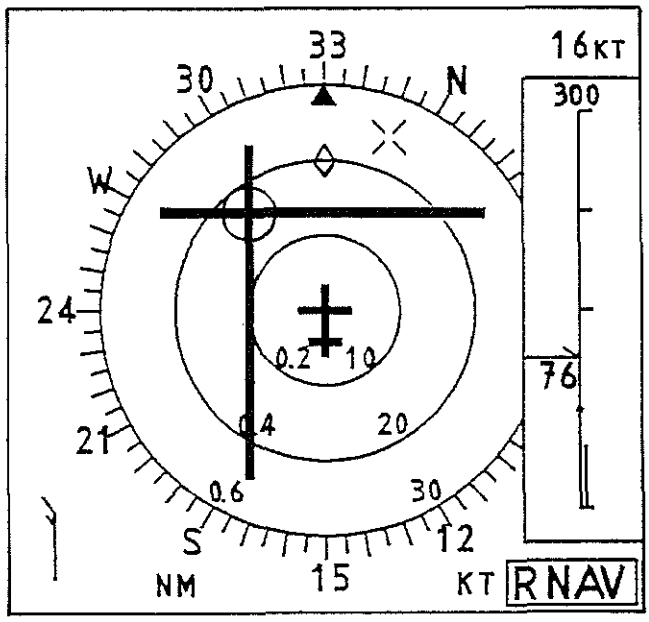

Fig. 28

Pattern Mode Display (Figure 29)

The pattern mode is a North-stabilized mode showing the outline of the pattern selected on the NADIR Mk 2 control unit, which may be one of the following :

– Creeping ladder pattern
– Expanding square pattern
– Cloverleaf sector pattern.

This display provides either visual confirmation of the data entered in the NADIR Mk 2 computer, or tracking of the aircraft along a selected pattern.

The PTN mode also displays the hover pattern used during the automatic downward transition phase (Figure 11).

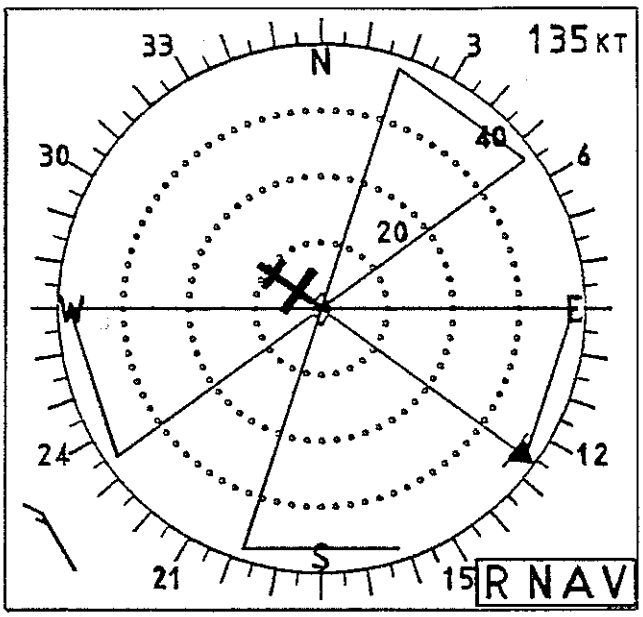

Fig. 29 EXAMPLE : CLOVERLEAF SECTOR PATTERN

ADI Mode Display (Figure 30)

The ADI display is normally presented on the EADI. However, in the event of an EADI failure, an identical display may be called up on the EHSI with the following attributes :

- engaged and armed coupler mode annunciators
- aircraft attitude indication
- Flight Director indication : pitch, roll and collective channels
- radio altitude (digital and analog displays)
- LOC deviation
- G/S deviation
- Turn rate.

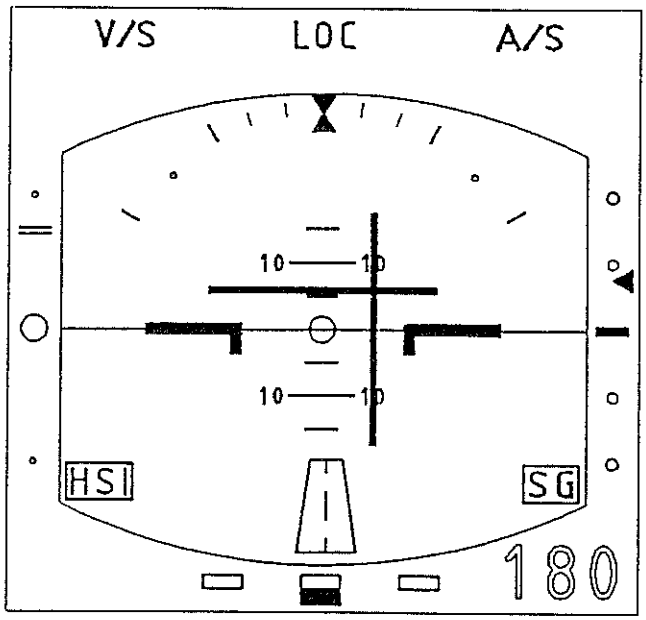

Fig. 30

b) Navigation Source Selection

Each pilot's section of the DCP includes a rotary switch for selecting the source of the navigation data displayed on the corresponding EFIS screens. The following sources are available :

- R.NAV (NADIR)

  This setting displays data from the NADIR Mk 2 according to the NADIR control unit setting. Data are displayed in HSI, sector, pattern or hover modes.

- ONS (OMEGA)

  In the event of a NADIR Mk 2 failure, the OMEGA receiver may be selected in the ONS position. OMEGA navigation signals are then displayed in HSI or sector mode.

- V/L1 and V/L2

  These settings display VOR and VOR/DME data in HSI and sector modes.

- OBS

  In sector mode, the CRS knob can be used to display a radial from the aircraft symbol indicating the new selected course.

- BCN

  In SCT + RDR mode, when the radar is in the beacon mode, the CRS knob can be used to display a radial from the beacon indicating the course to fly to the beacon.

- TST

  This setting initializes the display system self-test routine.

c) RMI Pointer Assignment

In HSI mode, two RMI pointers may be called up on the HSI display. These pointers are assigned to the desired navigation sources by means of two 3-position switches: VOR1/OFF/DF and VOR2/OFF/ADF.

d) Course Setting Knob

The freely rotating CRS knob is used to set the selected course to the desired value, as indicated on the display by an index moving on the compass card. In HSI and SCT modes, the numerical value of the selected course is indicated by a digital readout in the upper LH corner of the screen.

3.2.1.1.2. Controls Simultaneously Affecting the Pilot's and Copilot's Displays

These controls are assigned to data or functions that cannot assume two different values or modes at any given moment.

a) **NAV Range Selector**

This control selects the display range scale in SCT, SCT – RDR and PTN modes. Seven ranges are available : 2, 5, 10, 20, 40, 80 and 160 NM.

b) **SG/FDC Selector**

This four-position selector is used to assign the FDC display signals and to reconfigure the system.

– N1 or N2 Positions :

- The pilot's and copilot's screens display separate images processed by SGU 2 and SGU 1, respectively
- The Flight Director Coupler drives either the pilot's (N2) or copilot's (N1) EHSI.

– S1 Position :

- In the event of a BATIE 2 or SGU 2 failure, the copilot's display processed by SGU 1 is copied onto the pilot's display
- The FDC drives the copilot's display (EHSI 1).

– S2 Position :

- In the event of a BATIE 1 or SGU 1 failure, the pilot's display processed by SGU 2 is copied onto the copilot's display
- The FDC drives the pilot's display (EHSI 2).

c) **Heading Selector**

The freely rotating HDG knob is used to set the selected heading to the desired value, as indicated on the display by an index moving on the compass card. In HSI and SCT modes, the numerical value of the selected heading is indicated by a digital readout in the upper LH corner of the screen.

3.2.2 – Radar Subsystem

The radar subsystem is controlled from the radar control panel (RCP) and from the auxiliary joystick and checklist control panel (Figure 31).

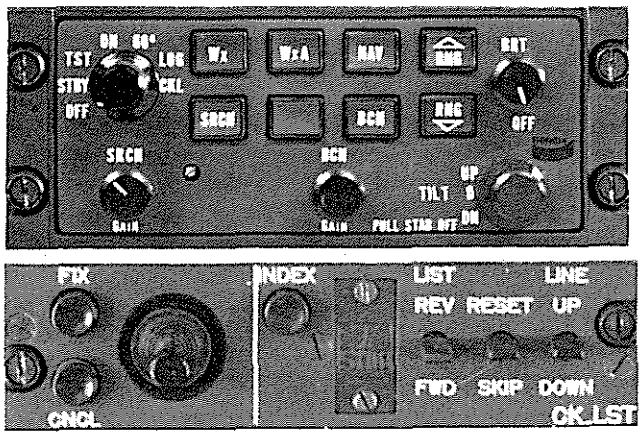

Fig. 31

3.2.2.1. Radar Subsystem Functions

– Weather Modes

- Weather avoidance mode (Wx)
- Weather alert mode (WxA)

– Search Modes

- SRCH 1 : for ranges up to 10 NM
- SRCH 2 : for ranges up to 10 NM without sea clutter rejection
- SRCH 3 : search and mapping mode available at all ranges.

– Secondary Modes

- LOG : displays waypoint coordinates for currently selected route
- CKL : checklist
- NAV : displays navigation mode selected by copilot with or without superposition of weather or search mode
- BCN : beacon mode
- JOYSTICK mode : the joystick is used to designate a point on the radar screen ; when the FIX pushbutton is pressed, this point is displayed on the EFIS screens in SCT, PTN or HOV modes, and its coordinates are transmitted to the NADIR Mk 2 computer.

3.2.2.2. Display and Radar Subsystem Features

The display and radar subsystem is designed to display :

– NAV or NAV + RADAR signals on the pilot's and copilot's EHSIs

– RADAR or RADAR+NAV signals on the radar screen located at the center of the instrument panel.

This implies the availability of two range scales simultaneously : a navigation map scale, and a radar range scale. This capability is obtained by the use of two radar interface units (RIU 1 and RIU 2) : one operates with the radar range selected on the radar control panel, the other with the range setting selected on the EFIS display control panel.

The display signals are processed in two modes :

– Normal Mode

If both range settings are identical, one of the interface units controls the receiver-transmitter and antenna array, and both interface units use the same video output signal from the receiver-transmitter

– Alternate Scan Mode

If the two range settings are different, the two interface units share half of the antenna scan time : the clockwise scan for range 1, the counterclockwise scan for range 2. In this mode, each interface unit uses the radar

R/T video output corresponding to its selected range.

Switching between the two operating modes occurs automatically as the range settings are selected.

3.3 – 365 F «IRELAND» INSTRUMENT PANEL

The instrument panel installed in the 365 F version is shown in Figure 32.

Data displays are symmetrical on the pilot's and copilot's sides of the panel, each equipped with two 5" x 5" CRT units (EADI and EHSI).

Aircraft parameters are displayed on conventional indicators ; a standby electromechanical RMI and a DME indicator are also provided.

The radar screen and control units are located at the center of the copilot's instrument panel.

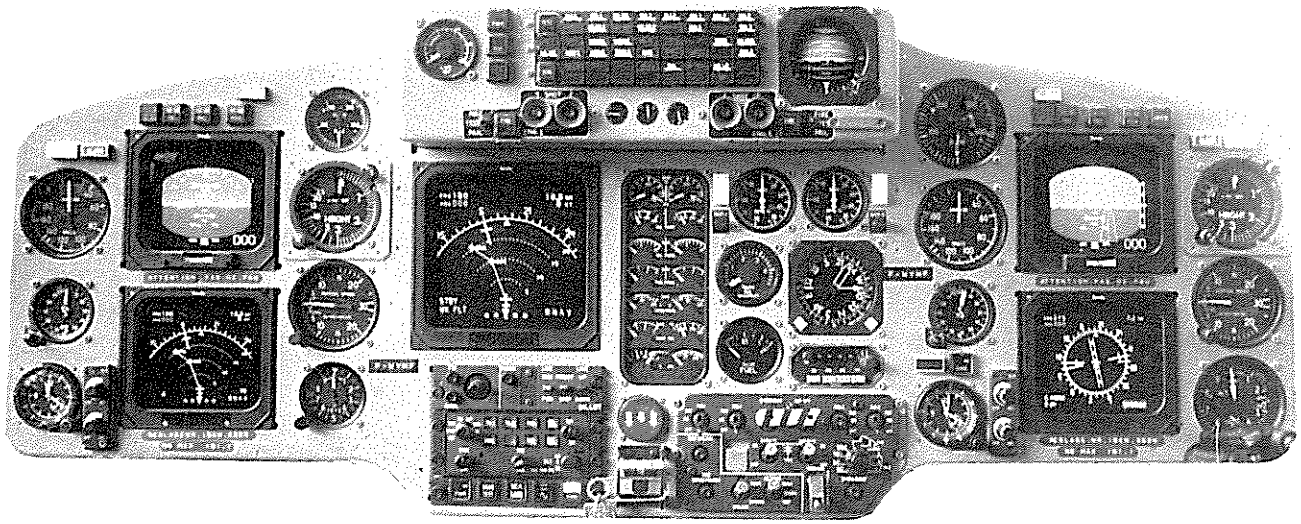

Fig. 32

4 – CONCLUSION

The system described here was designed to meet SAR mission requirements. However, the versatility of this system and the use of a symbology specially developed for helicopter applications make it compatible with a wide variety of other mission requirements, both civil and military.

Initially installed on the 365 F Dauphin, the first of which have been delivered to the Irish Air Corps, it is not limited to this helicopter, and can also be proposed on other SA 365 versions as well as on the AS 332 Super Puma.