AFFDL-TR-79-3080, VOL. II

LEVEL III

TOTAL AIRCREW WORKLOAD STUDY FOR THE AMST VOLUME II, COMM/NAV DESCRIPTION

THE BUNKER RAMO CORPORATION
ELECTRONIC SYSTEMS DIVISION
WESTLAKE VILLAGE, CALIFORNIA

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TECHNICAL REPORT AFFDL-TR-79-3080, VOL. II
FINAL TECHNICAL REPORT FOR PERIOD MARCH 1976 - NOVEMBER 1977

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

There is a growing realization within the USAF that state of the art crew systems may allow cost effective reductions in crew complements. The present study, titled the Total Aircrew Workload Study (TAWS) addresses the minimum crew complement required and conceptually, the crew systems required to support the minimum crew of an Advanced Medium STOL Transport (AMST) in the accomplishment of the tactical transport mission. The study involved the simulation of a total tactical airlift mission which was flown by operational

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19. (continued) Head Up Display; Tactical Airlift; Timing Task; Crew Complement Study; Loadmaster; Army Logistic Support.

20. (Continued) (C-130) tactical airlift aircrews in order to further refine crew complement and crew system concepts established in earlier mockup studies. The results of this study indicate that two pilots, a loadmaster and a crew chief type additional crew member can fly the total AMST mission if provided with adequate state of the art crew system capabilities, as identified in this report.

The report is presented in two volumes. Volume I describes the TAWS program and presents the results. Volume II presents a detailed description of the navigation and communication system used during the TAWS evaluation.

FOREWORD

This report documents the Total Aircrew Workload Study which addresses the issues of minimum crew complement and crew system capabilities required for the accomplishment of the tactical transport mission with an Advanced Medium STOL Transport (AMST) aircraft. The study was performed with operational (C-130) aircrews in a total mission simulation environment.

This document is Volume II of two volumes. The navigation and communication systems described herein represent candidate capabilities that were presented to subject aircrews for evaluation during the Total Aircrew Workload Study. It should be recognized, however, that the conclusions drawn on the aircrew complement for the cargo compartment and flight deck were based on equipment being flown in aircraft such as the C-130 and C-141 during the period this study was accomplished. New equipments, preferred integration techniques, advancements in technology or a change in mission requirements could alter the findings of this study. The composite results of the study are presented in Volume I.

Work was conducted under Project 6190, "Control-Display for Air Force Aircraft and Aerospace Vehicles" which is managed by the Crew Systems Integration Branch; mission simulation was synthesized by the Control Synthesis Branch, Flight Control Division, Air Force Flight Dynamics Laboratory (AFFDL/FGR), Wright-Patterson AFB, Ohio.

The report was prepared in part by the off-site Human Factors Group, located at 4130 Linden Avenue, Dayton, Ohio, Electronic Systems Division, Bunker Ramo Corporation, Westlake Village, California, under USAF Contract No. F33615-78C-3614.

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The research effort documented herein was performed between March 1976 and November 1977.

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NAVIGATION MANAGEMENT SYSTEM

A. General

The navigation management system (sometimes referred to as area nav or RNAV) provides precise navigation information worldwide, with and without external navigation aids. Additionally, it provides the capability for airway navigation, nonprecision approaches and precision approaches. The basis for the system is an inertial navigation system (INS) which is updated by all installed navigation sensors (VOR, ILS, TACAN, ADF, VLF/OMEGA) through a Kalman filter. Unreasonable or erroneous information is automatically filtered out and only the most accurate information is used for updating. If desired, navigation information may be obtained directly from any individual sensor.

Components of the system include: 1) the navigation management computer, through which all information is fed, 2) a memory system which stores prerecorded and currently entered information (nav aids identifiers and locations, air field locations, etc.), 3) the Kalman filter described above and 4) the control/display unit (CDU) which interfaces the pilot with the nav system (Figure 1).

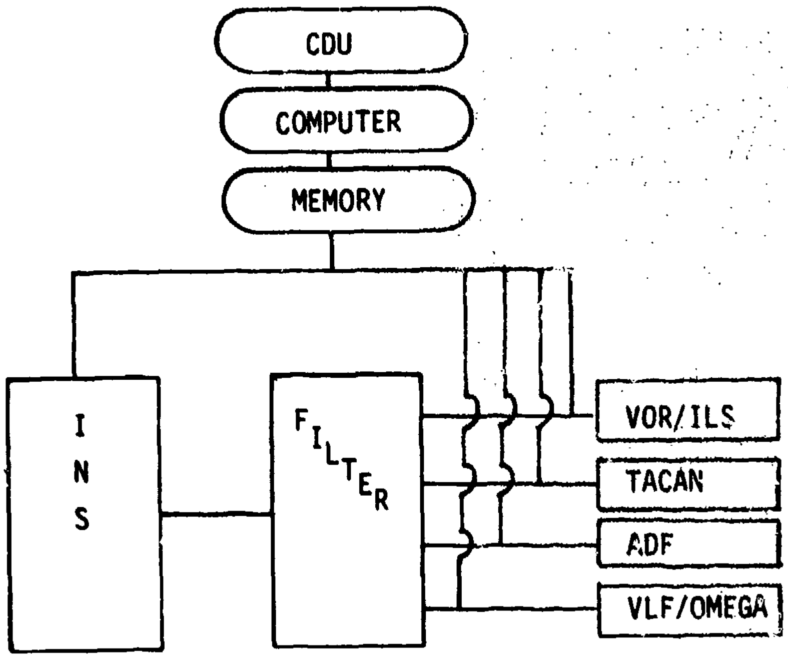


Figure 1. Nav Management System

B. CDU

The CDU or pilot/aircraft interface unit is comprised of an alphanumeric keyboard, a cathode ray tube (CRT) display (including a scratch pad), page slew, line select and several specific function keys (Figure 2).

C. Operation of the CDU

1. CDU Pages. One of several different informational formats (pages) can be displayed by pressing the specific function keys on the keyboard; i.e., Air Drop, Flight Plan, Flight Progress, Present Position and Navigation Aids. The Waypoint Data Page and Nav Aids Data Page may be displayed by first displaying "Flight Plan" or "Nav Aids" then pressing the line key adjacent to the desired waypoint. Each page has a specific function which is discussed in greater detail later. The purpose of the pages are (Figure 3):

a. Flight Plan Page. Displays the sequential list of lateral and vertical waypoints that define the aircraft route.

b. Waypoint Data Page. Displays waypoint data relevant to the presently selected flight plan.

c. Present Position Page. Displays aircraft present lateral performance data and navigation aid stations in use.

d. Progress Page. Displays progress data based on "TO" waypoint.

e. Navigation Aids Page. Displays all prestored navigation aids, airfields arranged alphabetically.

f. Navigation Aids Data Page. Displays all prestored information concerning selected navigation aids.

g. Emergency Data Page. Displays communications frequencies and navigation waypoints, which have been entered into the navigation management system to be used in the event of an aircraft emergency.

h. Air Drop Page. Displays information necessary to accomplish an air drop procedure using the nav management system and zone marker.

2. Typing the Data. Entering or changing information in the system or on a page is accomplished by 1) selecting the appropriate page, 2) typing the information on the keyboard (message is displayed on the scratch pad) and 3) inserting the information by pressing the line key adjacent to the line on the CDU where the information is required. This action clears the scratch pad and inserts the information in the necessary position. The scratch pad may also be cleared by pressing the "clear" key. Pressing the "clear" key once removes the last letter or digit. Pressing it a second time clears the entire scratch pad.

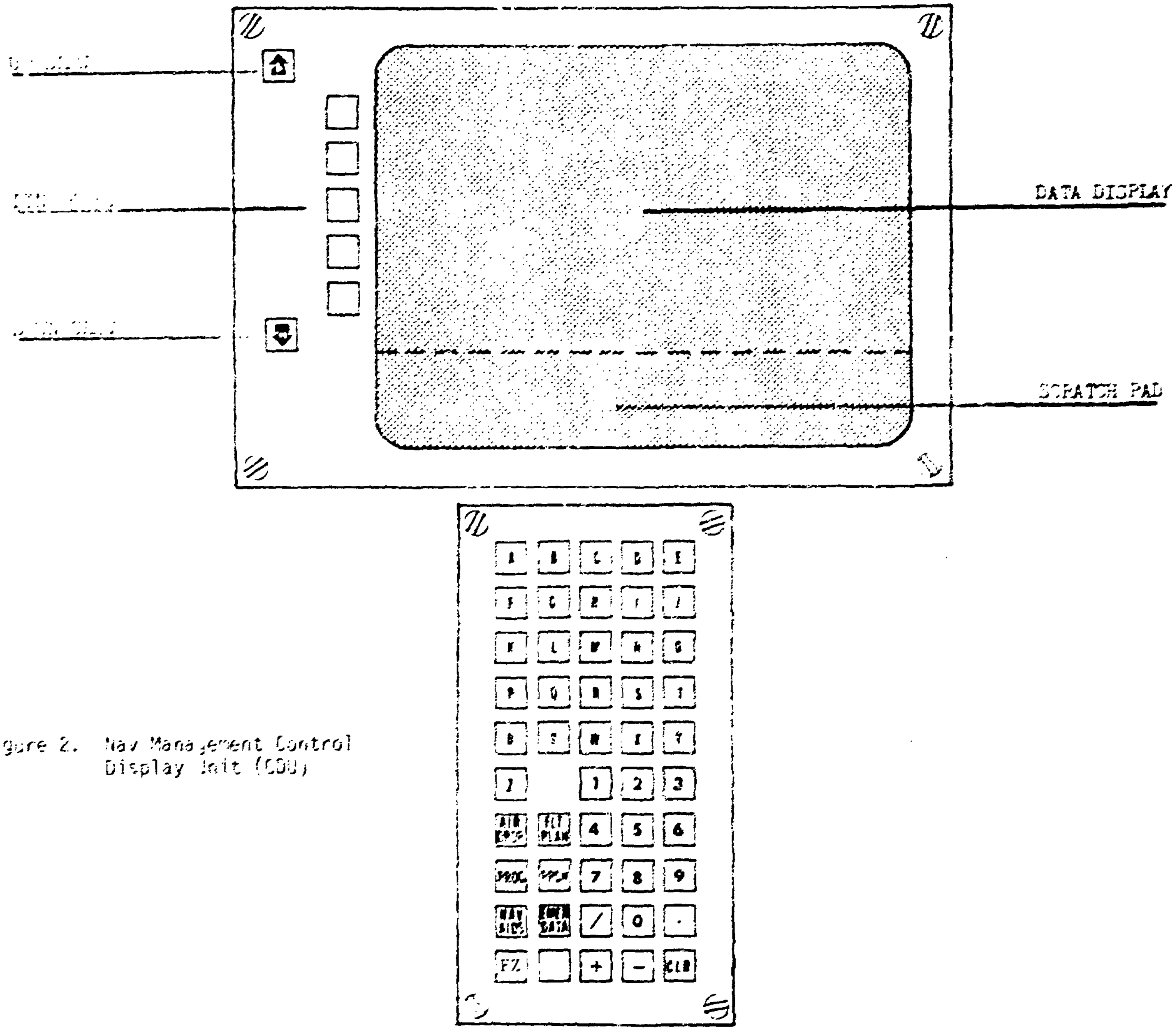


Figure 2. Nav Management Control
Display Unit (CDU)

NAV AIDS	
EDAF	
ENO	
FFM	
FSB	
HAM	

NAV AID DATA	
ID	HAM
PSN	N531140E101223
FREQ	113 1
CHAN	78
ELEV	53

*FLT PLAN

COURSE	IDENT	ALT
	EDAF	368
280	LL01	4000
037	BD01	FL70
062	BD01	FL50
351	HAM	FL100

WAYPOINT DATA

*WPT LL01		N535700 E103220
DIST 50.1	TTW 10:35	ETA 1229:45
GS 245		GMT 1219:10
PSN FROM:	LL01 100/50.1	

PRESENT POSITION

N522000 E082257	DFT COR L10
COURSE 280	*GMT 1219:10
GS 245	
WIND 228/42	
*IDENT HAM	BDG/DIST TO: 357/128

PROGRESS

COURSE	WAYPOINT	ALT
280	LL01	4000
DFT COR L10		
DTW 50.1		TTW 10:15
*VV CMD +1200		
*ALT CMD 7000		

*AIR DROP	
TEMP	-1
RATE OF FALL	+28
PIP ALT	500
VERT DIST	1500
FALL TM CNST	14.4

*EMERGENCY DATA	
UHF 2	243 0
VHF	121 5
HF 1	8364
HF 2	8364
FM	40 5

Figure 3. Nav Management CDU Pages

3. Slewing the Display. It may be necessary to slew the page forward or back since only five lines of data can be displayed at one time on the CRT. This can be accomplished by pressing the "up" or "down" slew button near the adjacent line keys.

4. Defining the Waypoint (Format). Waypoints may be defined in several ways. They must be typed in the proper format in order for the nav management system to accept them.

a. Latitude/Longitude. Identified as LL01, LL02, etc. Format - N402210/E072509/8000. Minutes and seconds must be typed as four characters. NOTE: 8000 signifies flight planned altitude and is a required entry since waypoints are three-dimensional points.

b. Bearing/Distance From a Prestored Nav Aid. Identified as BD01, BD02, etc. Format - FFO/110/30.2/5000.

c. Bearing/Bearing From Two Prestored Nav Aids. Identified as BB01, BB02, etc. Format - FFO/090/RSD/180/FL250 (FL250 symbolizes 25000 feet, FL80 would symbolize 8000 feet, etc.)

d. Prestored Nav Aid Station. Placed in memory as a Lat/Long and identified as a three-letter symbol; e.g., FFO, IND. Format - FFO/2200.

e. Route Intersection. Placed in memory as a Lat/Long, Bearing/Distance or Bearing/Bearing and identified as a combination of three alphanumerics (5EG, 3NI) or up to a five-letter name or ID (BERRY, NILES). Format - NILES/6000. (Prestored Data)

5. Asterisked Titles. An asterisk designates an item which may be changed through the keyboard. An asterisk next to a page title indicates that all items on that page may be changed through a keyboard.

D. Description of Pages

1. Flight Plan Page

	*FLT PLAN	
COURSE	IDENT	ALT
	LL01	8000
330	BD01	6000
050	BB01	7500
125	IND	14000
175	LL02	FL190
	Scratch Pad	

Figure 4. Flight Plan Page

When FLT PLAN is pressed on keyboard, the above page (format) appears. The page actually may show only the title line or it may be full or partially full from previously stored data. The "course" column is not typed in but is automatically determined and entered by the computer. For example: the course from LL01 to BD01 is 330°. The "from" waypoint is identified by a blank course as shown in the top line of the example. If the "from" waypoint does not appear when flight plan page is selected, the ↓ down slew key is depressed until the "from" waypoint appears, i.e. LL01 is the "from" waypoint in Figure 4. The waypoint following the "from" waypoint is always the "to" waypoint, i.e. BD01 is the "to" waypoint in Figure 4.

The first waypoint identified as a latitude/longitude position (N 43°12'10"/E 10°15'39") is designated by the computer as LL01, the second LL02, etc. After the flight plan has been built, if an additional Lat/Long waypoint is injected between two others, the new waypoint is designated according to when it was typed, not according to where it is placed in the flight plan. For example: a flight plan which contains 9 Lat/Long waypoints, LL01 through LL09, is entered on the flight plan page. An additional Lat/Long waypoint is required between LL02 and LL03. Its coordinates (N_ _ _/E _ _ _) are typed on the scratch pad. When the line key adjacent to LL03 is pressed: 1) LL03 moves down one space, 2) the new waypoint (designated as LL10) is inserted between LL02 and LL03, 3) the coordinates disappear from the scratch pad. The flight plan then reads LL01, LL02, LL10, LL03, etc.

The flight plan altitude must also be entered. To make a complete entry on the flight plan page you would type on the scratch pad N431210/E101539/8000 and insert it by pressing the appropriate line key. To change any part of scratch pad entry, press $\boxed{\text{CLEAR}}$ and retype. To change any part of a flight plan after it has been entered 1) type minus (-) on the scratch pad, 2) press the line key adjacent to incorrect entry (entry will be erased), 3) type new information on scratch pad and 4) press adjacent line key to enter in the appropriate position. The altitude of any waypoint may be changed by typing the desired altitude on the scratch pad preceded by a slash (i.e.,/5000) and enter on line key adjacent to desired altitude change.

2. <u>Waypoint Data Page</u>. To display information held in memory by the nav management system for any waypoint:

a. Select the flight plan page by pressing [FLT PLAN].

b. Press the line key adjacent to the waypoint for which the information is desired. This brings up the Waypoint Data Page and displays all information contained in the system for that waypoint. An example is shown below.

WAYPOINT DATA

*WPT BD01		FFO 097/27.3 N402219 W752933
DIST 28.5	TTW 2:30	ETA 1221:40
GS 245		GMT 1219:10
PSN FROM: BD01 267/20.4		

Scratch Pad

Figure 5. Waypoint Data Page

1st line - waypoint identifier and data that defines selected waypoint. When the selected waypoint is a BB or a BD, its Lat/Long is also displayed. 2nd line - distance, time (TTW) and estimated time of arrival (ETA) to the selected waypoint (computed along the route if the waypoint is in the flight plan, or direct if not). 3rd line - groundspeed and Greenwich mean time. Time must be entered with four digits--two for hours and two for minutes (0200, etc.). 4th line - bearing and distance to selected waypoint.

To erase flight plan information from memory:

(1) Select waypoint data page as described above.

(2) To erase flight plan waypoint displayed on waypoint data page, type minus (-) sign on scratch pad and enter on first line key. A series of "? ? ?" will appear in place of waypoint.

(3) Any other flight plan waypoint in memory may be erased by typing the waypoint identifier (i.e., LL01) on the scratch pad, enter on top line key, then erase that entry by typing a minus (-) on the scratch pad and enter on top line key.

(4) The above procedure allows the pilot to reuse the waypoint identifier (i.e. LL01) as a different location.

3. Present Position Page

```
                      PRESENT POSITION

N422810 W072613

TRACK                                   DFT COR
233                                     R11

GS                                      *GMT
245                                     1219:10

WIND
228/42

*IDENT                                  BRG/DIST TO:
HAM                                     357/128
------------------------------------------------------------
                         Scratch Pad
```

Figure 6. Present Position Page

When PPSN is pressed on the keyboard, the above page appears. It displays present lat/long coordinates, ground track, aircraft drift correction angle (difference between magnetic ground track and magnetic heading), groundspeed, time and wind. The present position relative to any position with a three or four-letter identifier held in memory (displayed on the Nav Aids Page) may be obtained by typing the three or four-letter identifier on the scratch pad and pressing the line key adjacent to "ID". The identifier and BRG/DIST to the point will then be displayed.

4. Progress Page

	PROGRESS	
COURSE 187	WAYPOINT NILE	ALT FL240
DFT COR L10		
DTW 53.2		TTW 10:15
*VV CMD +2000		
*ALT CMD 16000		
	Scratch Pad	

Figure 7. Progress Page

When PROG is pressed on the keyboard, the above page appears. The first line indicates a selected course of 187° to NILE where flight level 240 is desired. The second line indicates the aircraft drift correction angle (difference between magnetic track and magnetic heading). The third line indicates distance and time from present position to NILE . The fourth line and fifth line are used to command a vertical velocity to a specific altitude. To command vertical velocity (e.g., ± 2000 ft./min.) is typed into the scratch pad and inserted adjacent to "VV". The altitude to which the vertical rate is desired (e.g., 16,000 ft.) is then typed into the scratch pad and inserted adjacent to "ALT". When the aircraft reaches the commanded altitude (e.g., 16,000) level flight is commanded until that altitude is deleted by typing and inserting a minus (-). After the altitude has been deleted, vertical steering commands direct the aircraft back to the preprogrammed vertical profile (e.g., original programmed vertical path to FL240).

5. Navigation Aids Page

NAV AIDS

DOV

ENO

FFM

FSB

HAM

Scratch Pad

Figure 8. Nav Aids Page

When $\boxed{\text{NAV AIDS}}$ is pressed on the keyboard, the above page appears. It displays in the following order an alphabetical listing of all navigation aids (three-letter identifiers), airfields (four-letter identifiers) and route intersections (three or four-letter identifiers) held in memory in the navigation management system. Each of these aids has been defined with lat/long coordinates. Any of these prestored points may be used when building a flight plan by typing three or four symbol identifier on the scratch pad and inserting it in the desired position by pressing the appropriate adjacent line key.

To display prestored information on any listed nav aid, press line key adjacent to the desired nav aid. The following format will be displayed.

NAV AID DATA	
ID	HAM
PSN	N534114 E101223
FREQ	113.1
CHAN	78
ELEV	53

Scratch Pad

Figure 9. Nav Aid Data Page

6. Emergency Data Page

*EMERGENCY DATA	
PHSI	109 7
RMI 1	BDO1
CHSI	109 7
RMI 2	FFO
UHF 1	243 00

Scratch Pad

Figure 10. Emergency Data

When [EMER DATA] is pressed on the keyboard, the above page appears (five lines at one time - remainder by slewing). The information which appears on this page can be transferred to the respective "standby" windows on the integrated comm/nav panel by pressing the "emergency" button on the knob tuning panel. The communication frequencies normally remain unchanged for worldwide application; however, the navigation waypoints will normally be changed from flight to flight. The crew will determine which navigation aids or waypoints will be most advantageous to recall immediately during that particular flight. Those will be identified on the scratch pad and inserted by pressing the appropriate adjacent line key. For example: If the ILS for the departure station is desirable as an aid in the event of a takeoff emergency, the ILS frequency, 109.7, would be inserted adjacent to the PHSI; the final approach fix, BD01 (FF0 052/6.2) would be inserted adjacent to the single bar needle, RMI 1 (↑), and the same or different identifiers might be inserted adjacent to the CHSI and double bar needle, RMI 2 (⇑).

7. Air Drop Page. Air drop data is placed into the system by typing the necessary information on the air drop page on the nav management CDU. The format and information required for the air drop page is shown below. (Five data lines are on the CDU at any one time; the remainder available by slewing.) The items in the left column are preprogrammed; the right column must be typed and entered. After all air drop data has been entered on the air drop page, it is entered into the appropriate place in the flight plan by selecting $\boxed{FPN}$, typing "IP" on the scratch pad and entering the "IP" into the flight plan using the same procedure as is used to insert intermediate waypoints (described earlier under Flight Plan Page).

	*AIR DROP
DEFINE IP:	N520639 E104308 FL100
DEFINE PIP:	N521021 E105347 FL100
DEFINE TE:	N522490 E105350 FL100
DEFINE PAW:	N521030 E105400 FL100
DZ ALT SET:	29.92
TEMP:	-1
RATE OF FALL:	+28
PIP ALT:	500
VERT DIST:	9500
TIME OF FALL CONSTANT:	14.4
MEW SPEED:	-15
MEW ANGLE:	+28
FWD TRAVEL TIME:	6.1
ZM ATRK DIST:	-290
ZM XTRK DIST:	-215
ZM ALT:	515
Scratch Pad	

Figure 11. Air Drop Page

When "IP" is inserted into the flight plan, the flight plan page will automatically display the first four waypoints that were entered on the Air Drop Page as shown below:

*FLT PLAN

COURSE	IDENT	ALT
	LL03	6000
059	IP	2000
065	PIP	2000
065	TE	2000
065	PAW	2000

Scratch Pad

Figure 12. Flight Plan Page With Air Drop

When planning an Air Drop, the initial point (IP), point of impact (PIP), trailing edge of the drop zone (TE) and post airdrop waypoint (PAW) are all points on a straight line along which the aircraft will fly to complete the drop. The PAW is, by definition, located [illegible] NM beyond the PIP. This allows the aircraft to continue on course for approximately two minutes after it arrives at the drop zone. In addition to providing a steady track for the individual airdrop, it also allows other aircraft in a SKE formation to complete their drop.

<u>Freezing the Flight Plan</u>. When the aircraft gets within two miles of the "to" waypoint on the flight plan page, the navigation management system automatically changes to the succeeding waypoint. At that time, the flight director commands a turn to intercept the new course and, if the lateral mode has been selected on the autopilot, the aircraft starts to turn on course. Occasionally it is desirable that the flight plan does not automatically update to the succeeding waypoint (e.g., if it is desired to track outbound from a waypoint or if it is desired to receive distance and time countdown information closer than two miles inbound to a waypoint such as the computed aerial release point, CARP). The flight plan can be prevented from automatically updating to the succeeding waypoint by either of two methods: (1) pressing the Flight Plan Freeze key (FZ) on the keyboard will prevent automatic updating of the flight plan and pilot's HSI data until it is pressed a second time and, (2) changing the "TO" waypoint in the flight plan to be different from the waypoint being displayed in the pilot's HSI control. Whenever the two entries disagree, automatic updating will not take place. After using either of the above methods,

the "TO" waypoint and pilot's HSI waypoint must be made to agree (be the same) before automatic updating will begin.

E. Preflight Procedure

The alignment procedure should be accomplished as soon as possible after power is applied to the aircraft to permit stabilization of the system prior to taxiing. After the system is placed in the "on" position:

1) Press [PPSN] - check present position lat/long indicated on the CDU against actual aircraft present position. If not correct, type correct lat/long on scratch pad and press line key adjacent to "PPSN" to insert. NOTE: GS, wind, track and drift will display dash marks when aircraft is on the ground.

2) Type correct time at the next minute on the scratch pad. On the minute, press the line key adjacent to "GMT" to insert the time and start the digital timer.

3) Press [FLT PLAN] to select Flight Plan Page.

4) Type the present position identification and field elevation on the scratch pad.

5) Press top line key for insertion.

6) Type the first waypoint identification and desired altitude on the scratch pad and press second line key for insertion.

7) Repeat identification and insertion until all enroute waypoints and the destination are inserted. This completes a non-airdrop flight plan.

To set up a flight plan which includes an air drop mission, continue with the following procedures:

8) Select air drop page (key) - titles of required air drop information will appear along the left side of the CRT. For example: "Define IP" appears on first line, "Define PIP" on second line, etc.

9) Type data required for each title (one line at a time) on the scratch pad.

10) Press adjacent line key for insertion.

11) Repeat steps (9) and (10) until all air drop information has been inserted.

12) Select Flight Plan Page (key) - prepared flight plan will appear.

13) Type "IP" on scratch pad.

11) Press line key adjacent to the waypoint which follows location of the drop zone.

Waypoints IP, PIP, TE and PAW are all automatically inserted into the flight plan page at that point. For example: the initial point and drop zone are located between waypoints identified as LL03 and BD02. When the line key adjacent to BD02 is pressed, the four air drop waypoints will be inserted so that the Flight Plan Page will read LL03, IP, PIP, TE, PAW, BD02 (Figure 12).

The courses from LL03 to IP to PIP to TE to PAW to BD02 and the times enroute between those waypoints are automatically computed by the navigation computer. Course information appears on the Flight Plan Page. Time to waypoint information appears on the Progress Page. While enroute, the identification of the next waypoint appearing on the PHSI and CHSI along with the distance and time to go constantly based on present position and present groundspeed, appears on the digital readouts above the respective HSIs.

Change or update of any information on the Air Drop Page (including complete reidentification of a new drop zone) is made by typing the new information on the scratch pad and inserting it in the appropriate position with the adjacent line key. For programming purposes, all 16 entries on the Air Drop Page must be typed and inserted before the information can be inserted into the Flight Planning Page.

This completes an airdrop flight plan. The flight plan is activated (placed in the automatic mode), which connects the nav management system to the sensor systems and flight instruments by:

1) Select Flight Plan Page

2) Type identifier for the "TO" waypoint on the scratch pad.

3) Press the PHSI window switch on the integrated comm/nav panel. The initial waypoint will appear on the PHSI window, nav guidance will be displayed on the pilot's HSI, and the flight plan will automatically update when crossing succeeding waypoints.

SECTION II

INTEGRATED COMMUNICATION/NAVIGATION CONTROL/DISPLAY UNIT

A. General System Description

The integrated COMM/NAV unit functionally interfaces with the navigation management system (hereafter referred to as RNAV for simplicity), flight instruments, and flight data readouts. The cockpit displays include digital readouts of significant flight parameters, HSI and RMI waypoint and/or navigation aid data, and displays showing selected navigation waypoints.

The COMM/NAV control/display unit is the main element of the integrated system and is shown in Figure 13. The COMM control panel accommodates two UHF radios, one VHF radio, two HF radios and one FM radio. The NAV control panel accommodates four RNAV waypoints identified from a combination of sensors (i.e., INS, VLF-OMEGA, two VHF NAVs, TACAN and ADF). Radio modules can be added or subtracted as needed. The integrated COMM/NAV control panel has the receiver audio selector switches immediately adjacent to the respective radios for convenience.

Display readouts on the left side of the COMM/NAV control display panels show "active" COMM radio frequencies and NAV waypoints. Readouts on the right side of the panels show "standby" data. Data can be entered into either the active or the standby display windows and transferred between them as required.

Controls for the dedicated functions of UHF and FM direction finding, manual squelch, and HF radio are grouped on one panel for ease of use.

Rotary switches to select the specific communications transmitter are provided for each pilot.

The manual tuning function for all COMM and NAV digital inputs is performed through dual concentric tuning knobs connected to the central navigation computer or microprocessors to process the logic for tuning. The system is used in conjunction with a navigation management (RNAV) system and a standard complement of individual navigation radios. Input/output can be provided by the RNAV CDU, the dual concentric tuning knobs, or both. The combination system using both means of entry is recommended for most applications because of RNAV system provides the ability to operate on alphanumeric waypoints in addition to digital-only frequencies.

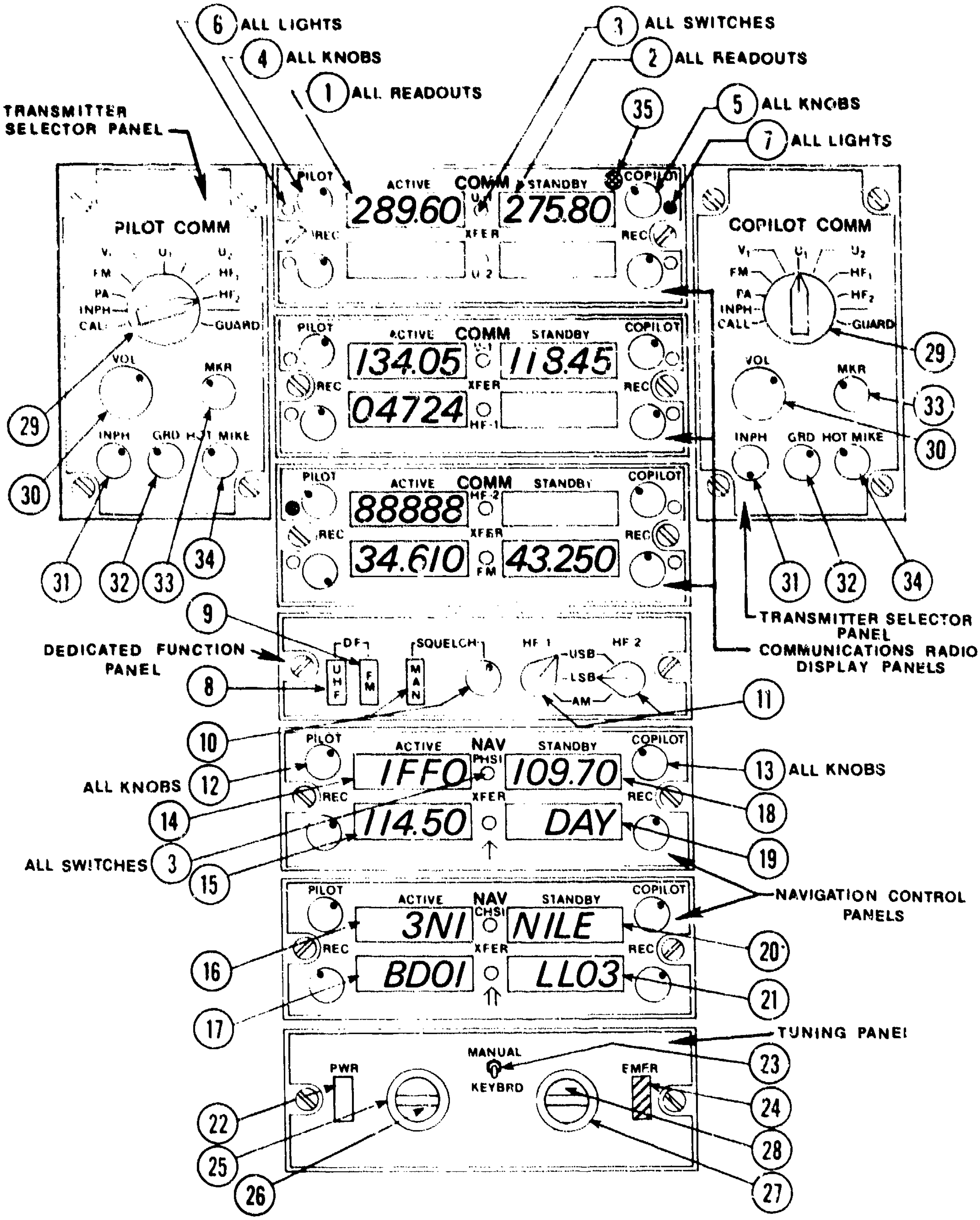


Fig. 13 Integrated Comm/Nav CDU

Identification of Components Shown in Figure 13

1. Active Communication Control/Display W
2. Standby Communication Control/Display W
3. Comm and Nav Active/Standby Transfer Switches
4. Receive/Audio Selector Switches - Pilot's Comm
5. Receive/Audio Selector Switches - Copilot's Comm
6. Transmitter Selector Lights - Pilot's
7. Transmitter Selector Lights - Copilot's
8. UHF Direction Finding Switches
9. FM Direction Finding Switches
10. Manual Squelch Controls
11. HF Mode Selector
12. Receive/Audio Selector Switches - Pilot's Nav
13. Receive/Audio Selector Switches - Copilot's Nav
14. Active Navigation Waypoint Control/Display Window - Pilot's HSI
15. Active Navigation Waypoint Control/Display Window - Single-Bar RMI Needles
16. Active Navigation Waypoint Control/Display Window - Copilot's HSI
17. Active Navigation Waypoint Control/Display Window - Double-Bar RMI Needles
18. Standby Navigation Waypoint Control/Display Window - Pilot's HSI
19. Standby Navigation Waypoint Control/Display Window - Single-Bar RMI Needles
20. Standby Navigation Waypoint Control/Display Window - Copilot's HSI
21. Standby Navigation Waypoint Control/Display Window - Double-Bar RMI Needles
22. System Power Switch
23. Manual/Keyboard Selector Switch
24. Emergency Function Switch
25. Left Outer Manual Tuning Knob
26. Left Inner Manual Tuning Knob
27. Right Outer Manual Tuning Knob
28. Right Inner Manual Tuning Knob
29. Transmitter Selector
30. Master Volume Control
31. Interphone Receiver Control
32. Guard Receiver Control
33. Marker Beacon Control
34. Hot Mike Control
35. Electric-Eye Automatic Light Control

B. Detailed Description

1. Communications Radio Display Panel. The function and operation of the COMM radio panel are described below. Numbers in parentheses are in reference to Figure 13.

a. Active Communication Control/Display Windows (#1). The active COMM control/display windows show the active frequency tuned in each communication radio. They also provide a means to synchronize the RNAV CDU or manual tuning knobs with the active radios. Each control/display consists of a transparent alternate action, push-button switch with integral frequency readout. Depressing the switch synchronizes the respective radio with the left dual concentric tuning knobs for VHF frequency entry and both pairs of knobs for all other frequency entry. If a suitable frequency is entered on the RNAV CDU scratch pad, depression of an appropriate active window will cause the frequency to be transferred from the RNAV scratch pad to that window and the R/T unit to be tuned to that frequency. (The scratch pad is a portion of the CRT where alphanumeric messages are typed and viewed before entry into the system.) The switch remains depressed until it is pressed again or until some other COMM or NAV window is depressed. The window switch has two positions; full out for "off", and fully depressed for synchronization with the manual knobs and/or for pick up of data from the CDU scratch pad. The central computer or microprocessors will prevent entering incompatible frequencies (i.e., a UHF frequency into a VHF window) when tuning with the manual tuning knobs. Software logic will prevent transfer of invalid data such as altitudes, waypoints, or inappropriate frequencies from the CDU scratch pad to the frequency window.

Internal lighting in the switch will activate when the switch is in the full depress position to annunciate which frequency window is in use. For night operation the light will have slightly increased brightness over ambient system lighting.

b. Standby Communication Control/Display Windows (#2). The standby communication control/display windows are similar to the active COMM control/display windows as previously discussed except that they do not control the R/T unit; that is, tune the active radio. Their use is to preset and store frequencies for subsequent use. Transfer from standby to active windows and vice versa is accomplished with the COMM Active/Standby Transfer Switch (#3), discussed below.

c. COMM Active/Standby Transfer Switches (#3). The active/standby transfer function is accomplished by spring loaded, momentary action, press-to-activate switches located between the active and standby frequency windows. The switch height extends slightly above the frequency select windows to prevent erroneous inputs. The frequencies are simultaneously transferred between the active and standby windows each time the switch is depressed (i.e., the preset frequency transfers to the active window and retunes the R/T unit and the active frequency transfers to the standby window).

d. Receive/Audio Selector Switches (#4 and #5). Frequency monitoring and volume control functions are provided by these push-pull-turn audio selector switches located adjacent to the frequency windows. The pilot's controls (#4) are on the left. The copilot's controls (#5) are on the right. As many different radios as desired may be monitored by pulling the individual selectors. Volume of each is adjustable by turning the switch.

e. Transmitter Selector Lights (#6 and #7). Small lights illuminate to correspond to the active transmitter selected on the pilot's and copilot's transmitter selector (#29). For example: If the pilot has HF #2 selected as shown, the light (#6) near the HF #2 frequency window will be illuminated. Similarly, the light (#7) near the UHF #1 frequency window on the copilot's side will be illuminated since UHF #1 is selected on the copilot's transmitter control.

f. Electric-Eye Automatic Light Control (#35). The electric-eye automatically adjusts the light intensity of the digital readouts in the active and standby frequency windows as a function of the ambient light condition.

2. Dedicated Function Panel. The function and operation of the dedicated function panel are presented below.

a. UHF and FM Direction Finding Switches (#8 and #9). The UHF (#8) and FM (#9) DF switches are alternate action push switches which connect the appropriate radio to the RMI. UHF #1 (if on and operational, otherwise UHF #2) is connected to the single-bar needle on pilot's and copilot's RMIs. FM is connected to the double-bar needle on both RMIs. Either switch, after being depressed, stays in the engaged position while in use. To discontinue the DF function, the appropriate DF switch is depressed a second time. When a DF switch is engaged, the internal light in the switch illuminates signifying that the DF function is engaged.

b. Manual Squelch Control (#10). This function consists of two controls; a spring-loaded, momentary action, manual squelch control switch and a rotary squelch adjustment knob. Normally, squelch for all radios is automatically preset and controlled in the set. However, when necessary to manually squelch a particular radio, the radio is identified by depressing the active frequency window (#1) for that radio. The manual squelch control switch is then depressed and the squelch adjusted with the rotary adjustment knob. These two controls are arranged so that they can be easily operated with one hand.

c. HF Mode Selector (#11). The HF mode selector controls provide the means for selecting upper side band (USB), lower side band (LSB), or amplitude modulation (AM) for the HF #1 and HF #2 radio. The switches are three-position rotary selectors.

3. Transmitter Selector Panel. The function and operation of the transmitter selector panel are presented below.

a. Transmitter Selector (#29). The position of this rotary selector knob determines which receiver/transmitter is available to that respective crew member for communicating. The respective pilot can both transmit and receive on the radio selected. For example: With UHF #1 selected the pilot receives UHF #1 transmissions regardless of the position of his receive switch (#4) and can transmit on that frequency if desired. The transmitter selector switch has provisions for selecting UHF #1, UHF #2, Guard, HF #1, HF #2, VHF/AM, VHF/FM, Public Address (PA), Interphone, Call and a position for growth. The switch is spring loaded from the "call" position to the "interphone" position.

b. Master Volume Control (#30). Volume can be adjusted for all receivers simultaneously by the master volume control. Additionally, of course, individual radio volumes may be controlled by the receive/audio selector switches (#4 and #5) adjacent to the frequency select windows as described in paragraph 1d. Relative volume between individual receive/audio selectors is maintained as the overall volume is increased or decreased with the master volume control.

c. Marker Beacon Audio Control (#33). The marker beacon audio signal can be monitored by pulling this push-pull-turn switch. Audio volume can be adjusted by turning the switch.

d. Interphone Receiver Control (#31). Aircraft interphone conversations can be monitored by pulling this push-pull-turn switch. Volume can be adjusted by turning the switch.

e. Guard Receiver Control (#32). The UHF emergency frequency (243.0 KH_Z) can be monitored by pulling this push-pull-turn switch. Volume can be adjusted by turning the switch. The guard receiver on the #1 UHF R/T unit provides the signal unless that unit is turned off or inoperative, in which case the #2 UHF R/T unit provides the signal.

f. Hot Mike Control (#34). The hot mike transmitter and receiver function for aircraft interphone can be selected by pulling this push-pull switch.

4. Tuning Panel. The function and operation of the tuning panel are presented in this section.

a. System Power Switch (#22). The spring loaded, momentary action, press-to-active, power switch is used to power up or shut down individual receiver/transmitter units. Whatever radio has been selected by depressing its active COMM control/display window (#1) can be alternately turned on or off by pushing the system power switch (#22).

Electrical power for the overall communications and navigation system is provided by a radio and instrument master power switch (not part of the integrated COMM-NAV system) located in an appropriate place in the cockpit. When power is applied to the overall system prior to flight, the individual radios return to the same configuration (either on or off, frequency tuned) as when master power was removed after the previous flight.

A radio which has been turned off has a blank frequency display window as shown in the UHF #2 display in Figure 13. A radio which is on but malfunctioning has a series of 8s displayed in the window as shown in the HF #2 display window in Figure 13.

b. Manual/Keyboard Selector Switch (#23). The manual/keyboard selector switch is a two position miniature toggle switch used to select the means of entering frequencies (i.e., by manual dual concentric tuning knobs or the RNAV CDU keyboard). Routing of entry data through this switch prevents spurious data from the RNAV CDU scratch pad from being entered into the frequency or waypoint readouts when simultaneous RNAV keyboard and manual tuning knob functions are being performed.

c. Emergency Function Switch (#24). The two position, alternate action, lighted, push, emergency function switch is used to call up emergency data for insertion into the COMM standby windows and NAV standby windows. Depressing this switch (which remains in until depressed again) stores present data from the standby windows in memory and substitutes appropriate emergency data. Emergency data includes:

UHF COMM frequency	243.00 MHz
VHF COMM frequency	121.50 MHz
HF COMM frequency	8364 KHz
FM COMM frequency	41.0 MHz
PHSI waypoint	as specified*
Single-bar needle waypoint	as specified*
CHSI waypoint	as specified*
Double-bar needle waypoint	as specified*

*Specification of variable emergency data will be on an "Emergency Data" page of the RNAV CDU. Data will be preset as required.

To use emergency data, the pilot will transfer (by depressing the active/standby transfer switch) the desired data element from the standby window to the active window. Deactivation of the emergency switch by depressing and releasing it to the out/off position, removes unused emergency data from the standby windows and returns the data previously stored in memory. Deactivation of the emergency switch will not affect emergency data transferred to the active control/display windows for use.

d. Manual Tuning Knobs (#25, #26, #27, #28). A pair of dual concentric manual tuning knobs is provided for those instances when it is advantageous to tune frequencies with knobs instead of a digital keyboard.

The knobs are shared for data entry to all radios. Synchronization of the knobs with the frequency readouts occur each time a frequency control display window (#1 or #2) is depressed. Knob turn rate ratio and digit allocation for each radio is controlled by the central navigation computer or microprocessors.

NOTE: To make the description as easily understood as possible, an abbreviation for each knob is used rather than continual reference to its number in Figure 13. The abbreviations are: #25 - Left Outer (LO), #26 - Left Inner (LI), #27 - Right Outer (RO), #28 - Right Inner (RI).

Digit allocation for knob control of communication radios is shown in Figure 14. VHF COMM frequencies (A, Figure 14) are tuned by the left-hand set of knobs. The outer knob controls the frequency component left of the decimal; the inner knob controls the component to the right.

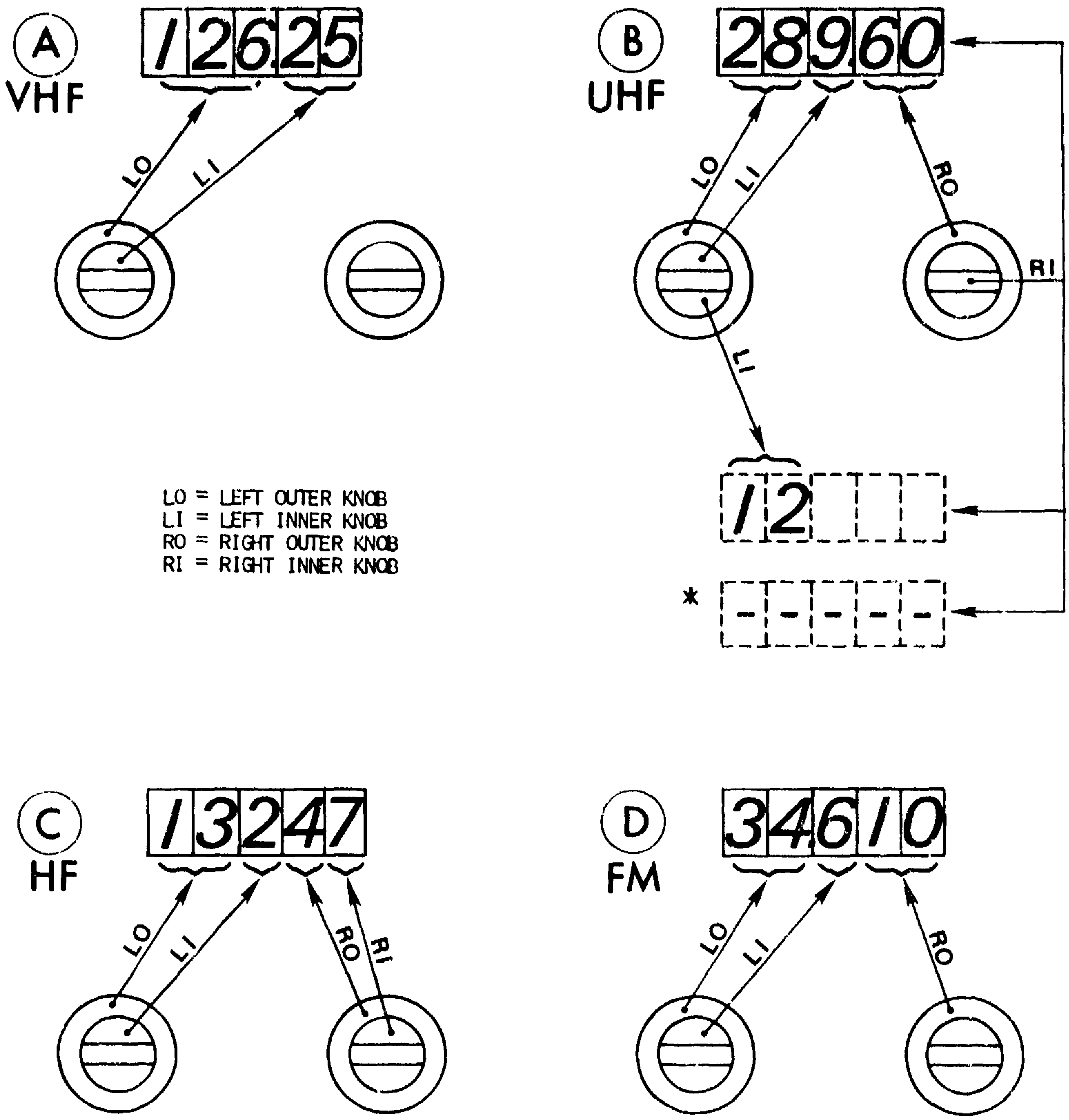
UHF frequencies (B, Figure 14) are tuned in a similar manner, except that both preset UHF channel tuning and five-digit frequency tuning are available. Selection of a five-digit UHF frequency requires use of both pairs of tuning knobs as shown (LO, LI and RO). The RI knob alternately selects preset UHF channel or five-digit frequency function. If a UHF channel is displayed, rotation of the RI knob will call/display the equivalent five-digit frequency or vice versa. For example: When rotated the display might alternately read 289.6, 12---, 289.6, 12---. A series of dashes will be displayed if no channel corresponds to the frequency.* For example: When the RI is rotated the display might alternately read 279.0,-----, 279.0, -----. Channel selection is then accomplished with the LI knob. Rotation of LI after selection of a series of dashes will give the next higher or lower channel as appropriate.

HF digit allocation requires all four knobs (C, Figure 14). FM digit allocation requires three tuning knobs (D, Figure 14). Primary data entry for navigation waypoints is accomplished through the RNAV keyboard since the navigation computer has the capability to use data from all sensors, as well as information stored in memory. Backup control of navigation radios is accomplished through the tuning knobs. When the manual tuning knobs are used, NAV frequencies are tuned in the same manner as COMM frequencies. Selection of a frequency into the active windows with the manual tuning knobs directly controls the navigation radios and displays the result on the selected flight instrument (HSI or RMI). The relationship of the navigation radios with waypoint display readouts, when the manual tuning system is used, is described later under "Numeric Station Identifiers".

Digit allocation for manual tuning knob control of navigation radios is shown in Figure 15 for VOR/ILS, TACAN, and ADF. The RI knob controls the mode*(receive, transmit and receive, and air-to-air)

* A conceptional requirement but not mechanized for simulation.

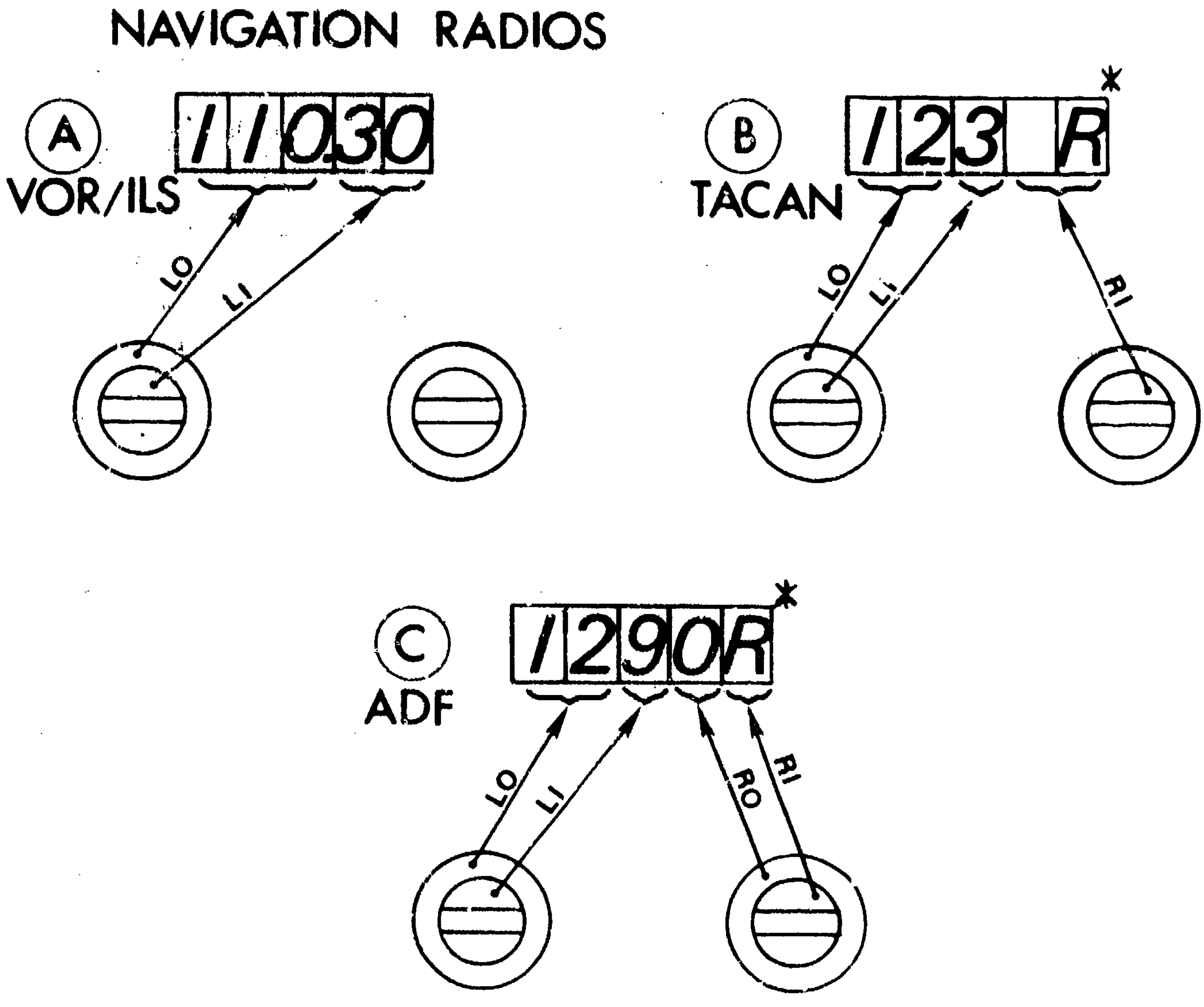
COMMUNICATION RADIOS



* A conceptional requirement but not mechanized for simulation.

Communication

Fig. 14 Digital Allocation For Tuning Knobs



LO = LEFT OUTER KNOB
LI = LEFT INNER KNOB
RO = RIGHT OUTER KNOB
RI = RIGHT INNER KNOB

* A conceptional requirement but not mechanized for simulation.

Navigation
Fig. 15 Digital Allocation For Tuning Knobs

for TACAN. For example: If TACAN channel 123 has been tuned with the LO and LI knobs, as the RI knob is turned the TACAN frequency window alternately reads 123 (normal transmit and receive), 123 R (receive only), 123AA (air-to-air), 123 (normal transmit and receive), etc. The RI knob also controls the mode (normal, receive only, test) for ADF.* For example: If ADF frequency 1290 has been tuned with the LO, LI and RO knobs, as the RI knob is turned the ADF frequency window alternately reads 1290 (normal), 1290R (receive), 1290T (test), 1290 (normal), etc. The display readouts in Figure 15 show TACAN "receive" mode (R) and ADF "receive" mode (R) as an example. A sketch to depict TACAN and ADF mode settings is shown in Figure 16.

All frequency changes start from the existing value in the control display window each time a knob selection is made. If an alphanumeric waypoint is displayed, initial rotation of the knob will switch the display to a mid-value frequency (113.00 MHz for VHF, channel 100 for TACAN, 300 KHz for ADF). Knob selection can be made in either increasing or decreasing frequency directions. Wrap-around (capability to tune from 9 through 0 to 1, or vice versa) is available in the event that the knob is turned past an upper or lower limit frequency.

Although digit allocation varies between radios, it is not apparent that memorization of the allocation by pilots will be needed. In general, left to right and outer to inner operation of the knobs will minimize tuning errors. This is due largely to the design which establishes that order as the most frequently required.

5. Navigation Control Panels. The function and general operation of the navigation control panel shown in Figure 13 are discussed in this section.

a. Navigation Waypoint Control/Display Windows (#14, 15, 16 17, 18, 19, 20, 21). The navigation waypoint control/display windows show the current navigation fixes being used for the cockpit flight instruments and provide the means to select new waypoints. The pilot's HSI "active" control/display window (#14) shows the waypoint being used as the reference for the pilot's HSI. The copilot's HSI "active" control/display (#16) shows the waypoint being used as reference for the copilot's HSI. The auxiliary windows (#15 and #17) identified with single-bar and double-bar needles, show the waypoints being used as reference for the respective pointers on both the pilot's and copilot's RMIs. This information is necessary to establish cross fixes, approach fixes, and for general navigation. The active windows (#14, 15, 16, 17) and standby windows (#18, 19, 20, 21) are similar in function to the COMM control/display windows discussed previously. Normal data entry to these windows is via the RNAV CDU keyboard since most waypoints will be composed of alphanumeric characters. The types of alphanumeric waypoint/station designators permitted are shown below. "Numeric only" entry is also discussed.

* A conceptional requirement but not mechanized for simulation.

(1) Three Character Alpha-Station Identifiers (Example: Dayton VOR - "DAY" - shown in #19). This type of entry establishes a waypoint at the location of a radio facility for navigational use. Navigation is possible even if the facility is off the air as long as the RNAV system has other means available for position fixing. Station elevations, latitude, longitude, identifiers and other data are stored in memory as required. This type of entry can be used for ILS and MLS, as well as standard waypoints. Use of an alpha-identifier for an ILS (such as IFFO shown in window #14) will give an RNAV computed optimal estimate of the ILS path. All available means such as inertial smoothing, DME multilateration, etc. will be used. Selection of identifiers, such as MFFO, can be used to select MLS with optimal estimation.*

(2) Four Character Alpha-Waypoint Identifiers (Example: "NILE " intersection shown in window #20). Four alpha-character designators, as found on enroute charts and approach plates, are used. Entry is made through the CDU keyboard. All bearing and distance calculations are made via the RNAV system. Waypoint data is retrieved from memory as required to define the waypoint.

(3) Alphanumeric Waypoint Codes (Example: "3NI intersection shown in window #16). Three character identifiers, used in air traffic control flight plan management, may be substituted for full waypoint name. Keyboard entry, instrument display, and relative position computations are the same as for five character alpha-waypoint identifiers.

(4) Latitude/Longitude Waypoint Codes (Example: "LL03" shown in window #21). Latitude/longitude waypoints are defined as a standard function of the RNAV system. Full latitude, longitude position coordinates are named with waypoint identifiers (LL01, LL02, ..., LL99) in the navigation management system. These identifiers can be inserted into the nav control/display windows to be used as reference for the navigation flight instruments.

(5) Bearing-Distance or Bearing-Bearing Codes (Example: "BD01" shown in #17). Bearing-distance and bearing-bearing waypoints are similar to latitude/longitude waypoints discussed above, except for the means of definition. In the RNAV system, these waypoints are specified as a bearing and distance from a computer recognized waypoint or as the intersection of bearings from two computer recognized waypoints. BD01, BD02, ..., BD99, or BB01, BB02, ..., BB99 may be used as waypoint names.

Navigation guidance is automatically provided to the waypoint identified in the active PHSI and CHSI windows (#14 and #16) through those respective HSIs. The waypoints identified in the active windows designated as single-bar or double-bar (#15 and #17) provide bearing information on these pointers to both the pilot's and copilot's RMIs. Repeater displays located adjacent to the HSIs and RMIs identify which waypoint is being used to provide the bearing information, and the distance and time at the present groundspeed, to that waypoint.

* A conceptional requirement but not mechanized for simulation.

(6) Numeric Station Identifiers (Example: "114.5" shown in window #15). Numeric station entry for VOR, TACAN, or ADF is used when information is desired from a specific navigation aid rather than the RNAV system or when the RNAV computer is inoperative. Numeric frequency selection connects the flight instrument and display window directly to an appropriate radio receiver. When digital navigation frequencies are selected by the CDU or tuning knobs, the most recent station or stations selected are used (equal to the number of receivers available). For example: If four digital VOR frequencies are inserted into each of the active NAV windows and only two VOR receivers are available, the last two frequencies input will directly control the VOR receivers. The first two frequencies input will revert back to VOR waypoints computed by the RNAV. When this tuning feature is used, the selected radio receivers cease to be automatically controlled by the RNAV. The RNAV system can use the resultant data, if unambiguous, but primary position fixing must be accomplished with the remaining sensors.

When numeric station entries are made with the RNAV CDU keyboard, any station can be called up on each flight instrument and control/display window. When numeric entries are made with the manual tuning knobs, only selected combinations are available, based on the complement of sensors. The allocation used during TAWS for control of sensors when knobs were used is shown below.

Navigation Radio Control Allocation (Using Manual Tuning Knobs)

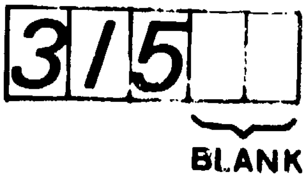
Control/Display Window	Radios Tuned
PHSI	#1 VHF NAV (unless inoperative, then #2 VHF NAV)
Single-Bar Needle	ADF
CHSI	TACAN
Double-Bar Needle	#2 VHF NAV

These allocations make possible direct control of radio navigation sensors through manual tuning knobs. This feature may be used at any time for simple navigation problems or when full RNAV utilization is not possible or desired. Whenever directly tuning the sensors by either RNAV CDU keyboard or manual tuning knob control, the station must be identified by audio code and approximate position prior to being used. If both VOR/ILS R/T units are operational, VOR #1 will provide information to the pilot's HSI and VOR#2 will provide information to the double-bar needles on the RMIs. In the event that one R/T unit is inoperative, the operable unit will provide information to either the pilot's HSI or to the double-bar needles on the RMIs with the pilot's HSI taking priority.

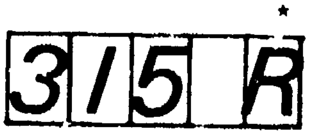
The control/display frequency readouts are also used to show mode selection for ADF and TACAN. Mode readouts and their significance for ADF and TACAN are shown in Figure 16. Mode control is accomplished through use of the RI knob as shown in Figure 15. *

* A conceptional requirement but not mechanized for simulation.

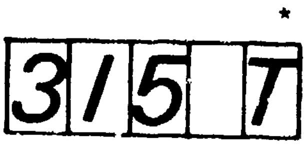
ADF



— Normal ADF mode.

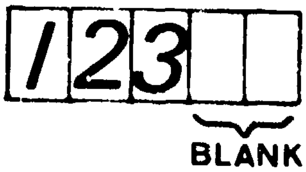


— "Receive" mode - used to identify stations - RMI needle stows at 3 o'clock position.

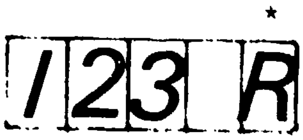


— "Test" mode - rotates RMI needle clockwise.

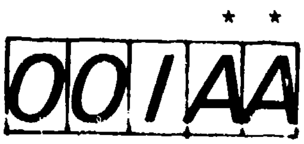
TACAN



— Normal Tacan mode - both azimuth and distance.



— "Receive" mode - azimuth only.



— "Air-to-Air" mode.

* A conceptional requirement but not mechanized for simulation.

Fig. 16 Mode Readouts

b. <u>Receive/Audio Selector Switches</u> (#12 and #13). These push-pull-turn switches function similarly to the receive/audio selector switches on the communications panel (#4 and #5); i.e., pull to monitor the audio signal and turn to control volume. When an individual navigation radio is tuned by selecting the numerical frequency (as shown in #15, "114.5"), the Morse code or voice identifier may be monitored. However, during normal operation of the RNAV system, audio identifiers are not broadcast for waypoints in memory. Therefore, no audio identification can be heard for a waypoint managed by the navigation management system.

c. <u>NAV Active/Standby Transfer Switches</u> (#3). These spring loaded, momentary action, press-to-activate switches function in the navigation system exactly as in the communications system previously described.

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