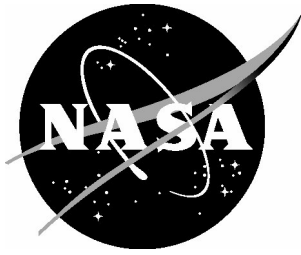


NASA/CR-2017-219593



FIM Avionics Operations Manual

Erin E. Alves
Honeywell International, Inc., Temple, Arizona

March 2017

NASA STI Program . . . in Profile

Since its founding, NASA has been dedicated to the advancement of aeronautics and space science. The NASA scientific and technical information (STI) program plays a key part in helping NASA maintain this important role.

The NASA STI program operates under the auspices of the Agency Chief Information Officer. It collects, organizes, provides for archiving, and disseminates NASA's STI. The NASA STI program provides access to the NTRS Registered and its public interface, the NASA Technical Reports Server, thus providing one of the largest collections of aeronautical and space science STI in the world. Results are published in both non-NASA channels and by NASA in the NASA STI Report Series, which includes the following report types:

- **TECHNICAL PUBLICATION.** Reports of completed research or a major significant phase of research that present the results of NASA Programs and include extensive data or theoretical analysis. Includes compilations of significant scientific and technical data and information deemed to be of continuing reference value. NASA counter-part of peer-reviewed formal professional papers but has less stringent limitations on manuscript length and extent of graphic presentations.
- **TECHNICAL MEMORANDUM.** Scientific and technical findings that are preliminary or of specialized interest, e.g., quick release reports, working papers, and bibliographies that contain minimal annotation. Does not contain extensive analysis.
- **CONTRACTOR REPORT.** Scientific and technical findings by NASA-sponsored contractors and grantees.

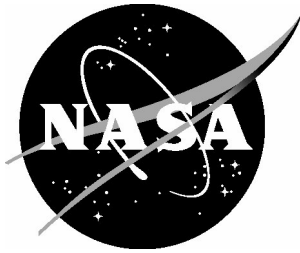
- **CONFERENCE PUBLICATION.** Collected papers from scientific and technical conferences, symposia, seminars, or other meetings sponsored or co-sponsored by NASA.
- **SPECIAL PUBLICATION.** Scientific, technical, or historical information from NASA programs, projects, and missions, often concerned with subjects having substantial public interest.
- **TECHNICAL TRANSLATION.** English-language translations of foreign scientific and technical material pertinent to NASA's mission.

Specialized services also include organizing and publishing research results, distributing specialized research announcements and feeds, providing information desk and personal search support, and enabling data exchange services.

For more information about the NASA STI program, see the following:

- Access the NASA STI program home page at <http://www.sti.nasa.gov>
- E-mail your question to help@sti.nasa.gov
- Phone the NASA STI Information Desk at 757-864-9658
- Write to:
NASA STI Information Desk
Mail Stop 148
NASA Langley Research Center
Hampton, VA 23681-2199

NASA/CR-2017-219593



FIM Avionics Operations Manual

Erin E. Alves
Honeywell International, Inc., Temple, Arizona

National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23681-2199

Prepared for Langley Research Center
under Contract NNL13AA03B, NNL15AB46T

March 2017

Available from:

NASA STI Program / Mail Stop 148
NASA Langley Research Center
Hampton, VA 23681-2199
Fax: 757-864-6500

ADVANCED TECHNOLOGY

Document / Data Item Approval Sheet

TITLE: FIM Avionics Operations Manual
Deliverable Number: 6.16

APPROVALS	DATE	SIGNATURE
PREPARED BY Erin E. Alves	11/30/2016	Erin Alves
PROGRAM MANAGEMENT Rick Berckefeldt	12/1/16	Rick Berckefeldt
PROJECT ENGINEER Jack Rahn	12/1/16	Jack Rahn
SYSTEMS ENGINEER Bill True	12/1/16	Bill True

DELIVERABLE 6.16: FIM AVIONICS OPERATIONS MANUAL

**FOR
BOEING RESEARCH AND TECHNOLOGY**

AGREEMENT NO: CONTRACT 1099212 DATED JUNE 15, 2015

IN SUPPORT OF NASA ATD-1 PRIME CONTRACT NNL13AA03B

REV B

1/16/2016

**PREPARED BY:
HONEYWELL INTERNATIONAL, INC.
AEROSPACE – DEFENSE & SPACE
1300 W. WARNER ROAD
TEMPE, AZ 85285
CAGE 59364**

DOCUMENT NUMBER: EG-003690-6.16

REVISION HISTORY

Rev	Date	Revision Summary
—	30 November 2016	Initial version
A	10 January 2017	Revision based on NASA feedback
B	16 January 2017	Edited cover page; added Appendix B

TABLE OF CONTENTS

1	INTRODUCTION	9
2	PURPOSE OF DOCUMENT	9
2.1	Common Terminology	9
2.2	Abbreviations and Acronyms	9
3	FUNCTIONAL DESIGN.....	11
3.1	Launching the Application.....	11
3.2	Initialization	11
3.3	IM Clearance Types	11
3.3.1	IM Capture Clearance.....	12
3.3.2	IM Cross Clearance	12
3.3.3	IM Maintain Clearance	13
3.3.4	IM Space Clearance	13
3.4	IM State Logic	14
3.4.1	Suspend/Resume	15
3.4.2	Terminate	18
4	USER INTERFACE DESIGN ELEMENTS.....	20
4.1	Ownship and Traffic Symbology	20
4.2	Drop-Down Menus.....	20
4.3	Entry Fields	22
4.4	Display Filters.....	22
5	SYSTEM OPERATION.....	24
5.1	Ownship Data Entry.....	24
5.2	Winds Entry	38
5.3	IM Operations.....	43
5.3.1	IM Capture Clearance.....	43
5.3.2	IM Cross Clearance	52
5.3.3	IM Maintain Clearance	65
5.3.4	IM Space Clearance	69
5.4	Changing Clearance Parameters.....	75
5.5	Speed Commands and Pilot Actions	75
5.6	IM Speed settings.....	77
5.7	Progress bars	80
5.8	IM CLEARANCE HOME messages	81
5.9	NAV DB Settings	81
5.10	About page.....	83
5.11	Predicted Spacing Interval.....	83
6	REFERENCES	83
7	APPENDIX A – DESIGN HISTORY.....	84

8	APPENDIX B – ATD-1 PROTOTYPE SYSTEM LIMITATIONS.....	86
8.1	Operationally Relevant Limitations	86
8.2	Minor Limitations	87

TABLE OF FIGURES

Figure 1. HMI startup screen.....	11
Figure 2. SUSPENDED-ARMED state	17
Figure 3. SUSPENDED-AVAILABLE state.....	18
Figure 4. CANCEL mode with dialog.....	19
Figure 5. Dialog displayed after ownship crosses the PTP.....	20
Figure 6. HMI drop-down functionality, including default and active states	21
Figure 7. Range selections	21
Figure 8. PTP Type selections	22
Figure 9. Filters Settings page	23
Figure 10. Primary navigation menus at top left	25
Figure 11. Ownship Entry Page	25
Figure 12. Dialog displayed when ownship information not entered	26
Figure 13. Destination airport selection	27
Figure 14. Selection of a letter identifier for Destination Airport	27
Figure 15. Dialog appearing when airport is not found or has incorrect syntax.....	28
Figure 16. Ownship Entry page after entry of an acceptable identifier for the Destination Airport.....	29
Figure 17. Flight Path Elements sub-page, supporting up to 10 entries across two pages	29
Figure 18. Sub-menu that appears on selection of the route segment field	30
Figure 19. Keypad appearing on selection of WAYPOINT/AIRWAY flight path element type	31
Figure 20. Flight path elements list, illustrating availability of the DONE button (replacing the BACK button), at bottom right	32
Figure 21. Example list of arrivals for the STAR flight path element	32
Figure 22. List of Transitions related to a selected STAR flight path element	33
Figure 23. Example flight path elements page with elements listed.....	34
Figure 24. Availability of the VIEW AS WAYPOINTS and DIRECT TO buttons	34
Figure 25. Example of VIEW AS WAYPOINTS selection for the flight path	35
Figure 26. List of DIRECT TO waypoint selections.....	36
Figure 27. Manual entry of DIRECT TO waypoint	36
Figure 28. Pop-up dialog appearing after entering or selecting a DIRECT TO waypoint.....	37
Figure 29. OWNSHIP ENTRY page with entries made in all required fields	38
Figure 30. IM CLEARANCE HOME page with the next six waypoints listed under OWNSHIP	38
Figure 31. Cruise Forecast Winds submenu selection.....	39
Figure 32. Cruise Forecast Winds waypoint sub-page	40
Figure 33. Keypad for data entry (DIRECTION example).....	41
Figure 34. CRUISE FORECAST WINDS page with entries made.....	42
Figure 35. DESCENT FORECAST WINDS page	42
Figure 36. IM CLEARANCE drop-down menu.....	43
Figure 37. IM CLEARANCE: CAPTURE page	44
Figure 38. SPACING GOAL entry page, which appears on selection of SPACING GOAL field.....	44
Figure 39. IM CLEARANCE HOME with SPACING GOAL entry made	45
Figure 40. TARGET ID entry page, which appears on selection of TARGET ID field	45
Figure 41. Manual entry of Target ID.....	46
Figure 42. ARMED clearance after entering Target ID for an out-of-range aircraft	47
Figure 43. Target Route field auto-populated	47

Figure 44. Available selections from the TERMINATE AT pull-down menu	48
Figure 45. TERMINTE AT WAYPOINT subpage	48
Figure 46. List of selectable waypoints for TERMINATE AT WPT	49
Figure 47. TERMINATE AT field with waypoint entered, and availability of the ARM button	49
Figure 48. IM CLEARANCE HOME page subsequent to touching the ARM button	50
Figure 49. IM CLEARANCE HOME page in the AVAILABLE state, with EXECUTE available.	51
Figure 50. IM CLEARANCE HOME indicating an active CAPTURE clearance	52
Figure 51. IM CLEARANCE: CROSS home page	52
Figure 52. SPACING GOAL entry page, which appears on selection of SPACING GOAL field.....	53
Figure 53. IM CLEARANCE HOME with SPACING GOAL entry made	54
Figure 54. TARGET ID entry page, which appears on selection of TARGET ID field	54
Figure 55. Manual entry of Target ID.....	55
Figure 56. IM CLEARANCE: CROSS page with Target ID entered	56
Figure 57. TARGET ROUTE sub-page	57
Figure 58. Selection of SAME AS OWNERSHIP for TARGET ROUTE, with DONE button available	58
Figure 59. Dialog informing that target route elements will be cleared.....	59
Figure 60. TARGET ROUTE after SAME AS OWNERSHIP has been selected	59
Figure 61. ACHIEVE BY sub-page and drop-down menu after selecting the ACHIEVE BY field	60
Figure 62. Selection of ACHIEVE BEFORE on the ACHIEVE BY drop-down menu	60
Figure 63. ACHIEVE BEFORE sub-page	61
Figure 64. Keypad for entry of a distance for ACHIEVE BEFORE and ACHIEVE AFTER.....	61
Figure 65. ACHIEVE BY waypoint entry sub-page	62
Figure 66. ACHIEVE BEFORE sub-page with entries completed	62
Figure 67. IM CLEARANCE: CROSS home page with ACHIEVE BY field completed	63
Figure 68. TERMINATE AT sub-page and associated drop-down menu	63
Figure 70. Default TERMINATE AT selected and availability of the ARM button	64
Figure 71. Selection of the ARM button.....	65
Figure 72. IM CLEARANCE: MAINTAIN home page.....	65
Figure 73. TARGET ID entry page, which appears on selection of TARGET ID field	66
Figure 74. Manual entry of Target ID.....	67
Figure 75. IM CLEARANCE: MAINTAIN home page, with spacing goal, target ID, and target route	67
Figure 76. TERMINATE AT sub-page and associated drop-down menu	68
Figure 77. Sub-page that appears after selection of TERMINATE AT WPT	69
Figure 78. Entries in all fields populated; availability of the ARM button	69
Figure 79. IM CLEARANCE: SPACE home page.....	70
Figure 80. SPACING GOAL sub-page for entry of the spacing goal.....	71
Figure 81. SPACING GOAL sub-page, with value entered via keypad.....	71
Figure 82. IM CLEARANCE: SPACE home page, with SPACING GOAL populated	72
Figure 83. TARGET ID entry page, which appears on selection of TARGET ID field	72
Figure 84. Entries in all fields populated; availability of the ARM button	73
Figure 85. A runway must be specified when ARM is cyan and all fields have been populated.....	74
Figure 86. ARMED SPACE clearance, waiting for aircraft to merge/align with approach.....	75
Figure 87. Pending speed command during the AVAILABLE state	76
Figure 88. Speed command during the PAIRED state.....	76

Figure 89. IM commanded speed in “reverse video” at top right.....	77
Figure 90. IM SPEED SETTINGS page	78
Figure 91. IM SPEED unit selection	78
Figure 92. Selection of airspace speed restriction setting.....	79
Figure 93. Subpage for setting airspace speed restrictions	79
Figure 94. Active MAINTAIN clearance in PAIRED state, illustrating progress bars	80
Figure 95. Active MAINTAIN clearance in PAIRED state, illustrating progress bars	81
Figure 96. NAV DB SETTINGS subpage	82
Figure 97. NAV DB cycle update dialog	82
Figure 98. ABOUT subpage	83

1 INTRODUCTION

This operations manual has been developed in accordance with the Boeing Supplier Statement of Work Contract 1099212 for Honeywell International dated 15 June 2015, paragraph 6.16.

Honeywell Aerospace Advanced Technology scientists and engineers developed this material in cooperation with the National Aeronautics and Space Administration (NASA) Langley Research Center Flight Interval Management (FIM) research team and Boeing Research & Technology Airspace & Operational Efficiency (BR&T AOE). NASA researchers initially developed a prototype FIM design (B. T. Baxley, 2015) to support the Interval Management Alternative Clearances (IMAC) human-in-the loop experiment, which was designed to explore, test, and validate new FIM procedures and requirements. The current project continues the avionics human-machine interface (HMI) design iteration to support flight trials implementing an electronic flight bag (EFB) device aboard multiple aircraft (i.e., a B737-NG and a B757-200) for NASA's Air Traffic Management (ATM) Technology Demonstration #1 (ATD-1), with flight tests scheduled for 2017. The FIM avionics suite also consists of a Configurable Graphical Display (CGD). The CGD design is described in a separate document (Boeing Company, 2016). Members of the engineering and design teams have iterated and developed the avionics design in order to provide the automation required for the FIM operations.

2 PURPOSE OF DOCUMENT

This document describes the operation and use of the FIM Application installed on an EFB. Specifically, this document includes: 1) screen layouts for each page of the interface; 2) step-by-step instructions for data entry, data verification, and input error correction; 3) algorithm state messages and error condition alerting messages; 4) aircraft speed guidance and deviation indications; and 5) graphical display of the spatial relationships between the Ownship aircraft and the Target aircraft.

2.1 Common Terminology

The term "Ownship" is used to refer to an aircraft that is equipped with the Interval Management (IM) spacing software and displays, and which has been assigned an IM clearance. The term "Target" is used to refer to the aircraft that the ownship has been instructed to follow during the IM operation. The term "clearance" refers to the instruction issued by the controller to the pilot of the IM-equipped aircraft, and contains sufficient information for the onboard avionics to generate information that flight crews can use to perform the IM operation¹.

2.2 Abbreviations and Acronyms

ABP	Achieve By Point
ABS	Absolute
ADS-B	Automatic Dependent Surveillance – Broadcast
ALT	Altitude
ASG	Assigned Spacing Goal
ATC	Air Traffic Control
ATD-1	Air Traffic Management Technology Demonstration One
ATM	Air Traffic Management

¹ The clearance information for test operations will be provided on the test card (only the ownship navigational clearance will be received from ATC).

BR&T COE	Boeing Research and Technology Airspace and Operational Efficiency
CAS	Calibrated Air Speed
CGD	Configurable Graphics Display
DIR	Direction
EFB	Electronic Flight Bag
FIM	Flight Deck Interval Management
FT	Feet
GFI	Government Furnished Information
HMI	Human-Machine Interface
ID	Identification
IM	Interval Management
IMAC	Interval Management Alternative Clearances
MFD	Multi-function Display
NASA	National Aeronautics and Space Administration
PTP	Planned Termination Point
REL	Relative
SFC	Surface
SRD	System Requirements Document
STAR	Standard Terminal Arrival Route
SYS	System
TGT	Target

3 FUNCTIONAL DESIGN

3.1 Launching the Application

The application will automatically launch on startup.

3.2 Initialization

The initial startup screen is illustrated in Figure 1. There are two main components to this screen:

1. The main window (left frame) displays the drop-down menu buttons, navigation view, including the ownship symbol (white filled triangle), partial range ring, and partial compass rose.
2. The right frame displays the IM CLEARANCE HOME page, which at initial startup contains titles for ownship and target flight routes (which will appear here once they are entered) and an un-selectable (cyan) ARM button. The information on this page changes dynamically as menu items are selected, thus allowing the user to enter and modify data. As depicted, Figure 1 displays winds notifications, and both CANCEL IM and ARM buttons in cyan at bottom.

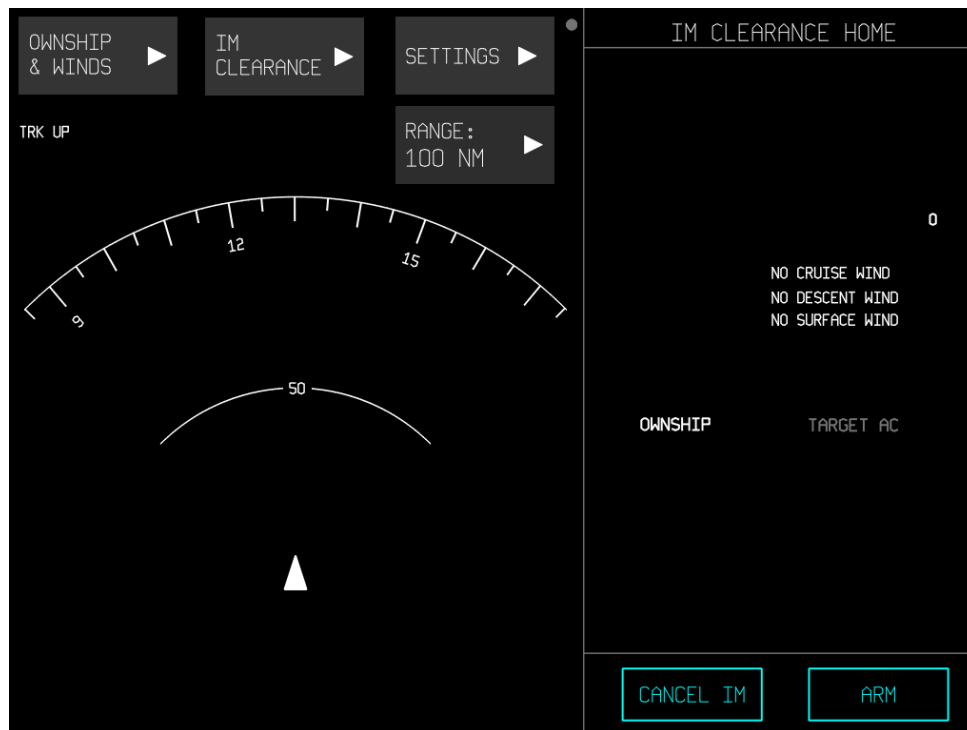


Figure 1. HMI startup screen

The map display mode is always track up, such that the ownship's track is always straight ahead, but the orientation of the ownship symbol will reflect its current heading. The IM navigation view always uses true (as opposed to magnetic) references.

3.3 IM Clearance Types

The EFB allows for selection of four IM clearance types: CAPTURE (or Capture then Maintain),

CROSS (or Achieve-by then Maintain), MAINTAIN (or Maintain Current Spacing) and SPACE (Final Approach Spacing). Each clearance type requires specific data elements as defined in the FIM Systems Requirements Document (National Aeronautics and Space Administration, 2015) and described in the following sub-paragraphs.

3.3.1 IM Capture Clearance

Per GFI 5.15 language, the CAPTURE (or Capture then Maintain) clearance type is used when the controller wants the IM aircraft to capture the Assigned Spacing Goal (ASG) and then maintain it to the Planned Termination Point (PTP). “CAPTURE” implies to accelerate or decelerate to a moderate rate of closure to the assigned spacing goal interval. The advantages of this clearance type are that it allows for faster acquisition of the ASG, and that controller workload should be reduced due to the shorter IM clearance that must be issued via voice communication.

The Target aircraft’s route is not required since the Ownship and Target aircraft are required to be flying the same route or procedure, and the Ownship aircraft’s wind information is not required to be entered into the IM avionics because the constant time delay spacing algorithm that is used for the capture and maintain clearance does not use wind forecast information.

Data elements in the IM capture clearance include the:

- IM clearance type;
- Interval spacing type (time or distance)
- Assigned Spacing Goal (ASG);
- Target aircraft identification;
- Planned Termination Point (may select default²); and
- Target aircraft routing (optional; will be provided for test procedures).

An example of a controller-issued IM CAPTURE clearance is:

- NASA01, for interval spacing, capture 120 seconds behind NASA09.

3.3.2 IM Cross Clearance

Per GFI 5.15 language, the CROSS (or Achieve-by then Maintain) clearance type is used when the controller wants the IM aircraft to achieve the ASG by a specific Achieve-by Point (ABP), and then maintain that spacing until the PTP. If the ABP and the PTP coincide, then there is no maintain phase of the IM operation.

Both the Target aircraft’s route and the Ownship aircraft’s route information is required to be entered into the IM avionics for the CROSS clearance. It is highly desirable for the flight crew to enter the Ownship forecast wind information, and a message is shown on the EFB to notify the flight crew that they have not entered the forecast en route, descent or surface winds.

Data elements in the IM CROSS clearance include the:

² The default PTP is 6.25 nm prior to the runway threshold.

- IM clearance type;
- Interval spacing type (time or distance)
- Assigned Spacing Goal (ASG);
- Target aircraft identification;
- Target aircraft routing;
- Achieve-By Point; and
- Planned Termination Point (may select default).

An example of a controller-issued IM CROSS clearance is:

- NASA01, for interval spacing, cross CTFSH 120 seconds behind NASA09 on the ANCHR2 arrival, terminate at DOGGG.

3.3.3 IM Maintain Clearance

Per GFI 5.15 language, the MAINTAIN (or Maintain Current Spacing) clearance type is used when the controller wants the IM aircraft to maintain the current spacing interval (in time or distance), as determined by the IM software. This requires the Ownship and Target aircraft to be on the same route. The Target route data field will auto-fill with the Ownship route when both vehicles are on the same route. Unlike the other three clearance types that are intended for use when aircraft metering is in effect (high-density operations), the MAINTAIN clearance is intended for use when metering is not in effect (during medium to low density operations or at airports that are not equipped with Terminal Sequencing and Spacing).

The Ownship and Target aircraft must be flying the same route. The Ownship aircraft's wind information is not required to be entered into the IM avionics because the constant time delay spacing algorithm that is used for the CAPTURE and MAINTAIN clearances does not use wind forecast information.

Data elements in the IM MAINTAIN clearance include the:

- IM clearance type;
- Interval spacing type (time or distance);
- Target aircraft identification.

An example of a controller-issued IM MAINTAIN clearance is:

- NASA01, for interval spacing, maintain current time behind NASA09.

3.3.4 IM Space Clearance

The SPACE (or Final Approach Spacing) clearance type is used when the controller wants the IM aircraft to achieve by, then maintain spacing where the ABP coincides with the PTP set at the default position for the approach case. The Ownship and Target aircraft could already be on the same route, or one aircraft will intercept the final approach course prior to the default PTP. The IM display will account for the software-determined merge point if the aircraft are not on the same route.

The Target aircraft's route is not required for this clearance type since the Ownship and Target aircraft are required to be flying the same approach. Also, the Ownship's wind information is not required because the trajectory-based control law will utilize sensed wind for both aircraft. SPACE is the only clearance where a runway *must* be entered in the Ownship route, since the PTP will be set to reference the runway threshold.

Data elements in the IM SPACE clearance include the:

- IM clearance type;
- Interval spacing type (time or distance);
- Runway;
- Target aircraft identification.

An example of a controller-issued IM SPACE clearance is:

- NASA01, for interval spacing, space three point two miles behind NASA09.

3.4 IM State Logic

There are seven IM states:

1. OFF/TERMINATE

- Clearance data must be entered into the EFB.

2. ARMED

- The IM application is waiting for all necessary constraints to be met before the IM commanded speed can be calculated.

3. AVAILABLE

- The IM speed can be calculated (the speed is displayed to the flight crew as pending, i.e., the flight crew has not yet notified air traffic control [ATC] that the IM operation has commenced).

4. PAIRED

- The IM commanded speed is displayed to the flight crew (i.e., the IM operation is active).

5. SUSPENDED-ARMED

- The IM equipment is suspended because the IM commanded speed cannot be calculated (e.g., if the target aircraft is vectored off path).

6. SUSPENDED-AVAILABLE

- IM speed can be calculated (and that speed is displayed to the flight crew as pending, e.g., if the pilot manually suspended the IM operation).

7. UNABLE

- An unrecoverable error has occurred.

If there is a hardware failure, the error message “IM SYS FAIL” will appear and the system will switch to the unable state; in this case, the only user option is to cancel the IM clearance.

The transition logic between the IM States follows the same architecture laid out in the GFI 5.15 document as well as in the FIM SRD.

It is important to note that the SUSPENDED-ARMED and SUSPENDED-AVAILABLE states are largely identical, as they were in the NASA IMAC design. While SUSPENDED states occur after an IM operation has been initiated, the ARMED and AVAILABLE states occur before the IM operation has been initiated.







3.4.1 Suspend/Resume

The SUSPENDED states are meant to be temporary states that allow for amendments or necessary corrective action to be made during IM operations. As described in GFI 5.15, the SUSPENDED-ARMED and SUSPENDED-AVAILABLE states are, from a criteria standpoint, identical to the respective ARMED and AVAILABLE states. The difference is that the SUSPENDED states indicate that an IM operation has been initiated at some point during the flight.

Most IM information is still visible in either of the SUSPENDED states. The IM State (SUSPENDED), IM Type, and the Target Aircraft text label (above its respective waypoints on the home page) are all displayed in white during either SUSPENDED state. The Target aircraft, if within range, is displayed as a white chevron with white border, and any other associated data tag information is also displayed in white. For either SUSPENDED state, the Assigned Spacing Goal is displayed in its usual cyan color.

Table 1 describes how the IM state labels as well as the designated Target's identification (ID) and air traffic symbols are displayed during each of the IM states.

Table 1. IM State Symbology

IM State	IM State Displayed on the EFB	Target Aircraft Traffic Description	Example Symbology
OFF/TERMINATE	< no label >	Basic directional traffic symbol; cyan chevron with no fill	
ARMED	ARMED	Basic directional traffic symbol with shape-conforming border; white chevron with no fill and a white border	
AVAILABLE	AVAILABLE	Basic directional traffic symbol with shape-conforming border; white chevron with no fill and a white border	
PAIRED	PAIRED	Basic directional traffic symbol with shape-conforming border; white chevron with no fill and a green border	
SUSPENDED-AVAILABLE	SUSPENDED	Basic directional traffic symbol with shape-conforming border; white chevron with no fill and a white border	
SUSPENDED-ARMED	SUSPENDED	Basic directional traffic symbol with shape-conforming border; white chevron with no fill and a white border	
UNABLE	UNABLE	Basic directional traffic symbol with shape-conforming border; white chevron with no fill and a white border	

In the SUSPENDED-ARMED state, the IM Speed is not available and is displayed as three gray dashes (see Figure 2). Additionally, the graphical route for the Target and IM special points are removed from the display during the SUSPENDED-ARMED state. Lastly, the EXECUTE button is unavailable while the IM information is being validated so that automatic transition to the SUSPENDED-AVAILABLE can subsequently occur.

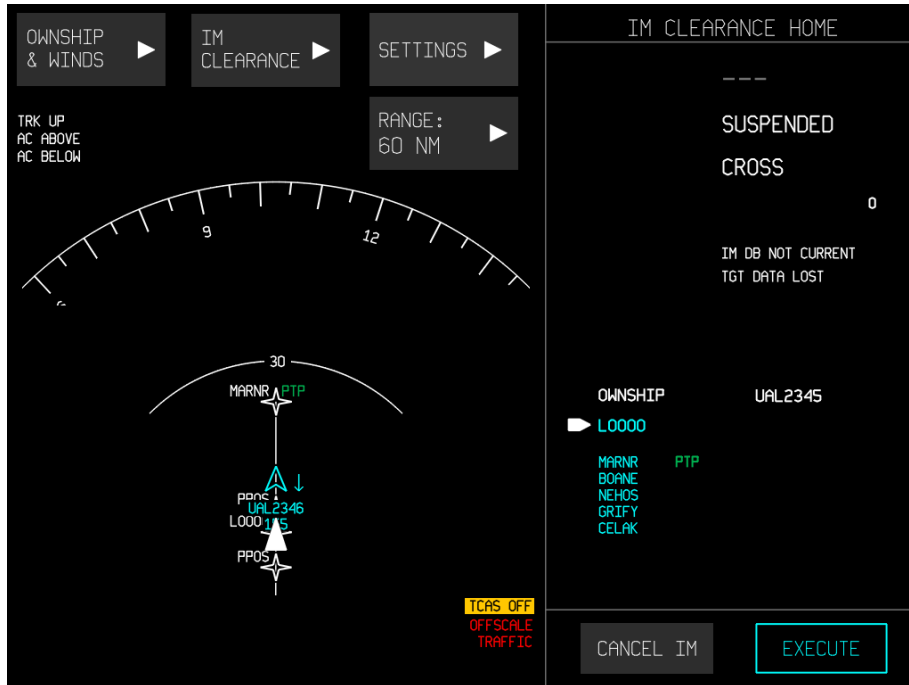


Figure 2. SUSPENDED-ARMED state

Figure 3 represents the SUSPENDED-AVAILABLE state. The Target aircraft's route can be activated via the filters menu, if desired. The IM Speed is now visible and active (i.e., it can change, although the speed change indicator is suppressed in the SUSPENDED state), but remains in gray. Lastly, the RESUME button is available for selection to resume the IM operation.

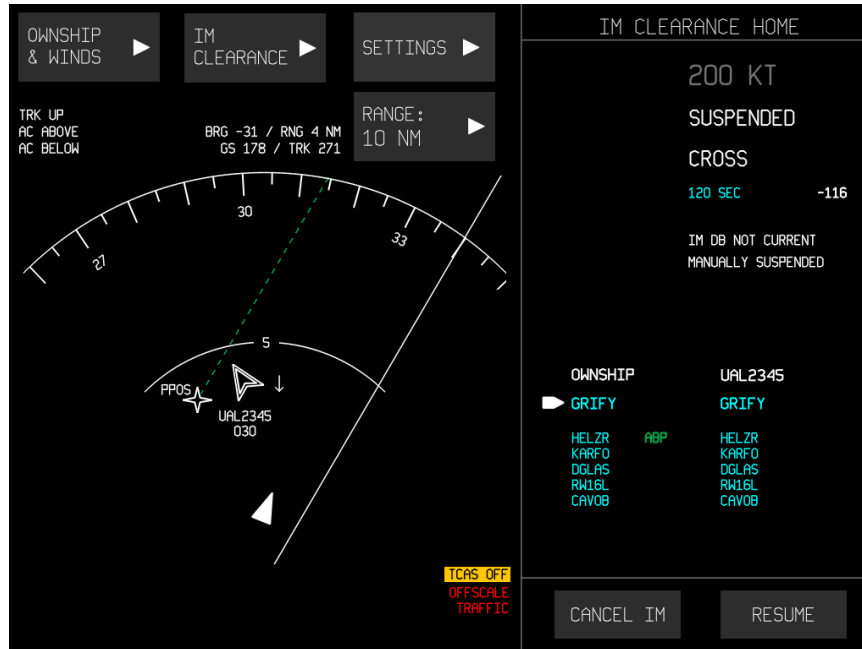


Figure 3. SUSPENDED-AVAILABLE state

The SUSPENDED states can be entered manually or automatically. Manual entry is accomplished through selection of the SUSPEND button on the Home page (see Figure 4, bottom right), which is available during the PAIRED state. On selection, the “Manually Suspended” annunciation will appear. Any changes made to the current clearance information (except for Target ID, which cannot be accessed after arming) followed by pressing the ARM button will result in transition to the SUSPENDED-ARMED state.

The system will automatically transition to the SUSPENDED-ARMED state if the Ownship or Target aircraft are off route (i.e., > 3 NM laterally or > 8000 feet [FT] vertically) or the Target data is lost (i.e., through invalidation of data; loss of data connection). Note that each of these situations includes related error messaging (e.g., Ownship off route, Target off route, Target Data Lost). Any of the error messages also causes the system to switch to SUSPENDED-ARMED from the SUSPENDED-AVAILABLE state.

In the SUSPENDED-AVAILABLE state, the RESUME button is used to return the IM Clearance to the PAIRED state (instead of the EXECUTE button that is provided in the initial AVAILABLE state). This difference in language reflects the same reasoning outlined above.

3.4.2 Terminate

The “OFF” or “TERMINATE” state of the EFB is represented by the lack of IM information displayed on the Home page (e.g., see Figure 1). That is, IM Speed, IM State, IM Type, and ASG are not displayed on the IM home screen in this state. Additionally, the area near the bottom of the Home page (i.e., where the target’s next six waypoints are listed during IM operation) is blank, and the heading for this column reads TARGET AC instead of the specific Target aircraft’s ID.

This state can be reached by crew cancellation of the IM operation, or automatically when the

ownship crosses the planned termination point (PTP) for the IM operation. This is true for all states except the UNABLE state.

To cancel the operation, the CANCEL IM button can be pressed on the Home page at any point. When pressed, a dialog box appears for pilot verification that the selection was intentional (see Figure 4). Selecting YES will cancel the IM, clearing all IM data. Selecting NO will retain the current state of the EFB.



Figure 4. CANCEL mode with dialog

Similarly, when the ownship crosses the PTP, a dialog box will inform the pilot that the IM operation has successfully completed (see Figure 5). IM information will be retained for repeating procedures (e.g., test activities).

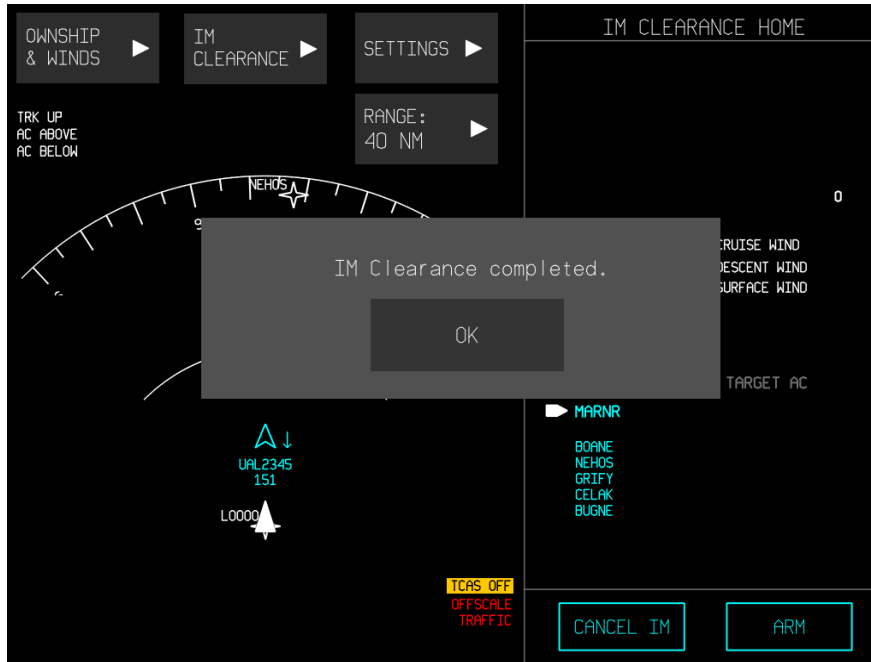


Figure 5. Dialog displayed after ownship crosses the PTP

4 USER INTERFACE DESIGN ELEMENTS

This section describes the functions and behaviors of the various user interface elements of the EFB. The majority of control elements use static or momentary green feedback to signal an active state or momentary actuation.

4.1 Ownship and Traffic Symbolology

Ownship and Traffic symbols are designed in accordance with DO-317B. The reference point, which controls its position and rotation on the display, is located at the centroid of the symbol.

4.2 Drop-Down Menus

Once any drop-down button is selected: 1) it turns green (i.e., visual feedback of actuation), 2) its arrow graphic changes so it points downward, and 3) its associated contents are displayed immediately below as a series of additional buttons.

The three drop-down buttons along the top of the traffic display (i.e., Ownship & Winds; IM Clearance; Settings) function as navigation menus. Selecting any of these buttons will result in corresponding page changes to appear on the right frame of the display. These buttons are always visible on the main window, and their functions remain constant regardless of IM page changes on the right frame. All other drop-down buttons serve as selection mechanisms with which pilots can specify one setting or value from a set of settings or values.

Selection of any of the buttons will present a momentary green feedback before executing the selected function and dismissing the drop-down's menu buttons (see Figure 6).



Figure 6. HMI drop-down functionality, including default and active states

In cases where the system requires an existing entry on startup, an option is pre-selected (i.e., a default is already entered) and the drop-down allows the user to change the default to another option (e.g., Range; see Figure 7).



Figure 7. Range selections

In other cases, the system requires a particular selection to be made, and the “SELECT” drop-down will turn green on selection to display a list in the resulting drop-down - e.g., PTP Type; see Figure 8). After a selection is made, the drop-down will be de-selected such that it will return to its original position and its text will change to the text of the selection made.

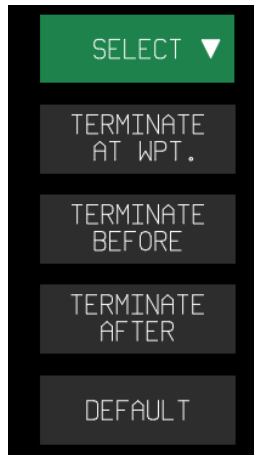


Figure 8. PTP Type selections

In the case of the navigation drop-down buttons along the top of the main window, instead of the button text changing, the title line at the top of the right frame will indicate which menu is currently being displayed (e.g., see Figure 9). If no selection is made after activating the drop-down, then it will remain active until dismissed. Dismissing of a drop-down is accomplished by touching or selecting anywhere else on the display *other* than the selections created by the drop-down. Once on a particular menu page, the BACK/DONE button (on setting and data entry pages) or the HOME/ARM button (on IM Clearance pages) will return the right frame to the Home page.

4.3 Entry Fields

Entry fields generally appear as unfilled, white rectangles. These fields may lead to a separate sub-menu page, may allow for direct input via an on-screen keyboard, or may allow for list selection. Activating a field will change its color momentarily to green (again, to convey actuation) and then lead to one of the previously identified functions in Section 4.2. In the case of data entry, either manually or through a list, the entry field will remain visible on the sub-page and will remain green to identify that it is active and ready for input.

Any field appearing in cyan text with cyan border is not available for selection. Data entry fields in cyan contain unalterable data pertaining to the element.

4.4 Display Filters

The FILTER SETTINGS page, which appears in the right frame, is accessible by pressing the SETTINGS navigation drop-down in the main window and then selecting FILTERS (see Figure 9). Pressing the DONE command button on the FILTER SETTINGS page causes the right frame to return to the IM CLEARANCE HOME page. Active filters on this page are shown in green, and multiple filters can be selected concurrently.

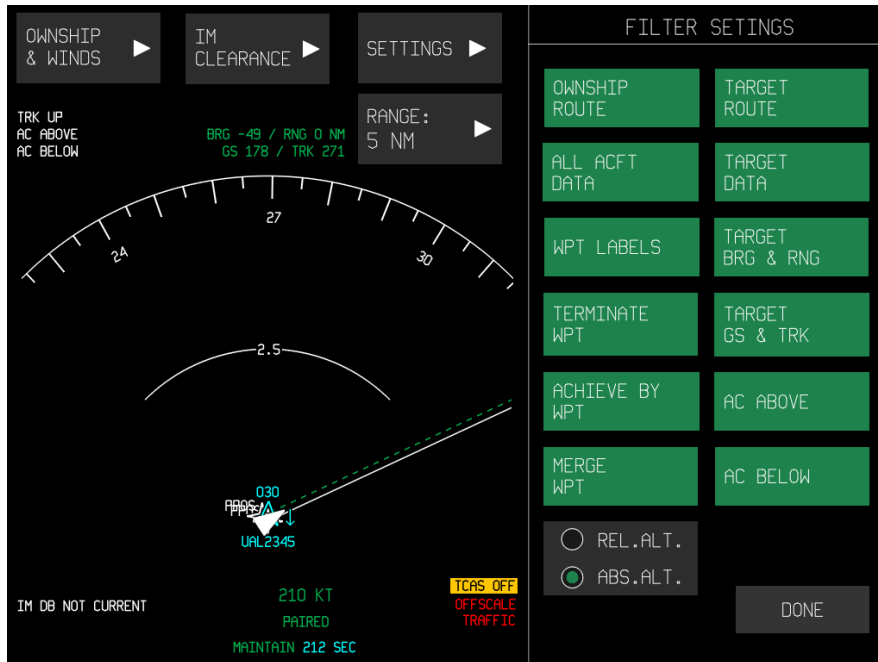


Figure 9. Filters Settings page

When selected, the filter annunciations appear on the upper left side of the navigation display, immediately below the menu buttons. Filters include:

- **OWNSHIP ROUTE**
Displays the route of your aircraft.
- **ALL ACFT DATA**
Displays data tags for all aircraft entities on the navigation display. Data tags include the aircraft identifier, relative or absolute altitude (as selected by the REL. ALT./ABS. ALT. button) and vertical trend (i.e., climb or descent).
- **WPT LABELS**
Displays waypoint names.
- **TERMINATE WPT**
Displays a label for the Planned Termination Point (PTP).
- **ACHIEVE BY WPT**
Activating this selection displays a label for the ABP.
- **MERGE WPT**
Activating this selection displays a label for the merge point (MRG).
- **TARGET ROUTE**
Activating this selection displays the route of the target aircraft.

- **TARGET DATA**

Activating this selection displays the data tag for the target aircraft. Data tags include the flight identification, relative or absolute altitude (as chosen by the REL. ALT./ABS. ALT. button) and vertical trend (climb or descent).

- **TARGET BRG & RNG**

Activating this selection shows the target's relative bearing and range information (annunciated in green below the range button).

- **TARGET GS & TRK**

Activating this selection shows the target's ground speed and track information (annunciated in green below the range button).

- **AC ABOVE and AC BELOW**

When neither of these filters is activated, traffic is displayed within the minimum visible altitude band (+/- 2,700 of the ownship). The AC ABOVE filter provides pilots with the ability to limit the aircraft shown in the navigation view to only those +10,000 feet to -2,700 feet of the Ownship altitude. When selected, the annunciation "AC ABOVE" appears on the left side of the navigation view immediately below the navigation drop-down menu. The AC BELOW filter provides pilots with the ability to limit the aircraft shown in the navigation view to only those +2,700 feet to -10,000 feet of the Ownship altitude. When selected, the annunciation "AC BELOW" appears on the left side of the navigation view immediately below the navigation drop-down menu.

The possible filter options for altitude band filtering are outlined below:

- AC ABOVE: +10000/-2700
- Neither Filter: +/- 2700
- AC BELOW: +2700/-10000
- Both Filters: +10000/-10000

- **REL./ABS. ALT.**

This filter toggles between relative and absolute altitude indications. Relative altitude is displayed with a +/- symbol and appears above or below the traffic symbol, respectively; this indicates the other aircraft's altitude relative to the ownship. Absolute altitude has no symbol in front of it and always appears below the traffic symbol; this indicates the actual pressure altitude of the traffic.

5 SYSTEM OPERATION

5.1 Ownship Data Entry

As depicted in Figure 10, the primary navigation menu is located along the top of the screen in the main window. Selection within the primary navigation menu highlights the selected item in green and causes the associated menu to appear. Selection of a sub-menu page will immediately display that page in the right frame. The drop-down menu will remain visible until a selection is made on the right side menu, or the user taps on some other area outside of the drop-down menu.

The OWNSHIP AND WINDS menu item allows the user to enter the ownship's flight information

and forecast winds information as soon as is feasible (typically prior to receiving an IM clearance from ATC); later, the user will enter the IM clearance information.



Figure 10. Primary navigation menus at top left

Selecting the OWNSHIP ENTRY item allows the user to enter data associated with the ownship route (see Figure 11).



Figure 11. Ownship Entry Page

Available fields are indicated by white entry boxes (e.g., the destination airport), and unavailable fields (or fields requiring more data before they can be filled) are indicated in cyan. The runway and flight path text entry fields cannot be entered until a destination airport has been specified (see Figure 12). Similarly, the VIEW AS WAYPOINTS and DIRECT TO buttons cannot be selected until the flight path is specified. Selection of one of the entry fields enters the sub-page for that entry, effectively clearing the other entry fields from view.

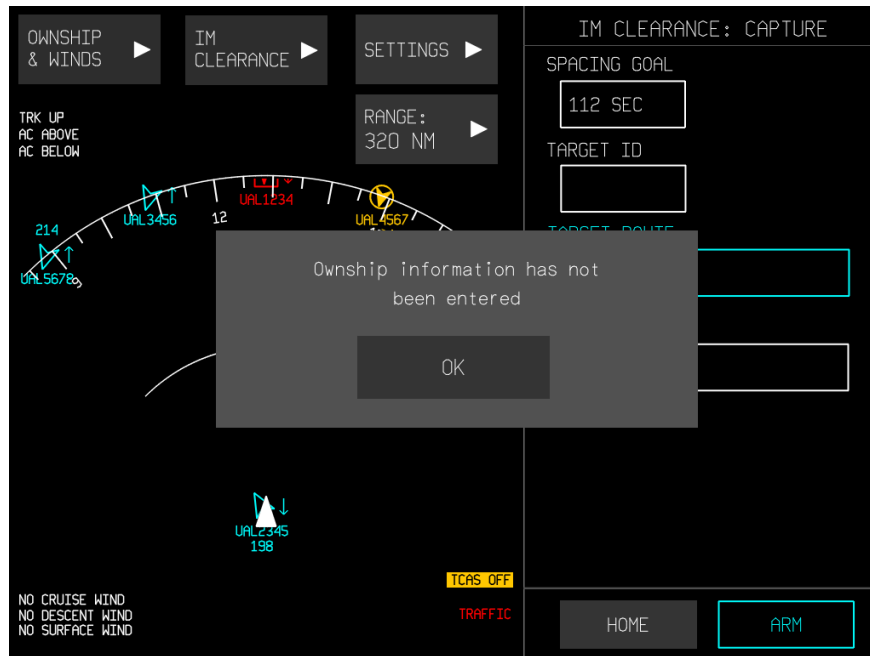


Figure 12. Dialog displayed when ownship information not entered

The BACK button will return the right side frame to the home screen. Pressing the BACK button prior to completing the OWNSHIP ENTRY task will return the right frame to its home page; any existing data entries will be retained if the user returns to the OWNSHIP ENTRY page. Selecting the DESTINATION AIRPORT item causes that data field to be highlighted in green and the keypad to be displayed (see Figure 13). When a data field is active (indicated by the green hue and underscore cursor), any value touched on the keypad is entered into that field. In this example, the user will select the first letter of the four-letter identifier of the destination airport, causing the display to change as depicted in Figure 14.

Once the desired entry has been typed into the data field, the user may:

- Select ENTER in the upper right corner of the frame. Pressing the ENTER button indicates that the user has completed this entry and wishes to input it. Selecting ENTER will validate and approve the entered destination airport and return the user to the initial OWNSHIP ENTRY page.
- Select CANCEL in the upper right corner, below ENTER. Pressing the CANCEL button will ignore any text entry and go back to the OWNSHIP ENTRY page without making a new input.



Figure 13. Destination airport selection



Figure 14. Selection of a letter identifier for Destination Airport

A warning dialog (see Figure 15) will indicate if the airport is not found or has inappropriate syntax.

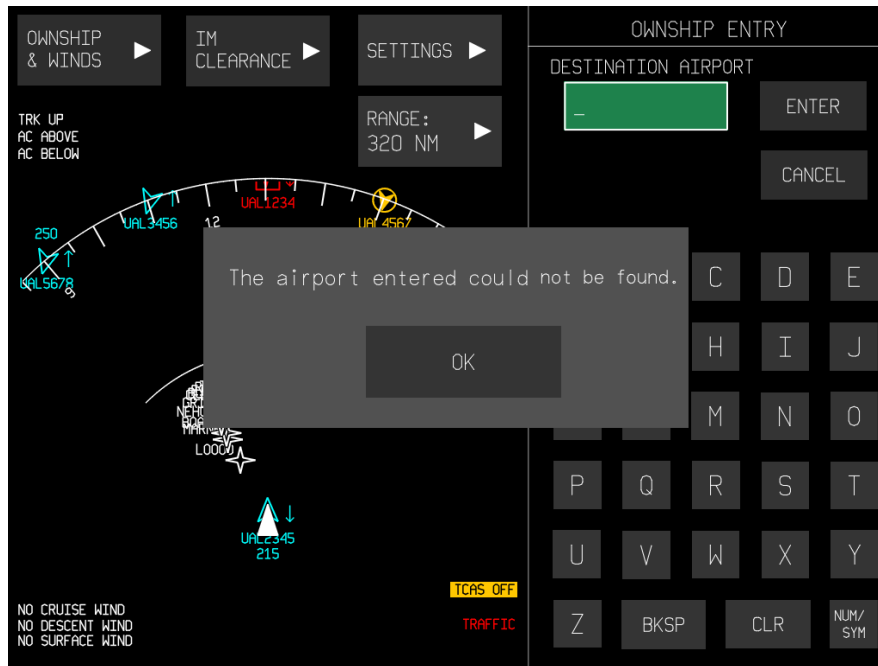


Figure 15. Dialog appearing when airport is not found or has incorrect syntax

If the dialog appears, then pressing OK will clear the entry and the user must re-enter a new entry (or use CANCEL to navigate back to the previous page).

Selecting ENTER after a valid airport has been entered will return the frame to the OWNSHIP ENTRY page (see Figure 16). The entered DESTINATION AIRPORT from the previous page is now visible in the text entry field, but no highlight or keyboards are visible. The RUNWAY and FLIGHT PATH items are now available for selection, because a destination airport has been entered.



Figure 16. Ownship Entry page after entry of an acceptable identifier for the Destination Airport

RUNWAY information may be entered either directly (by selecting the field and using the keypad) or as part of the flight path. RUNWAY is not a required field for entry. The FLIGHT PATH ELEMENTS sub-page includes a two-part list allowing for up to 10 elements to be specified for the ownship’s planned route (see Figure 17). The arrow keys allow navigation between elements 1-5 and elements 6-10. Touching any of the rows (i.e., gray boxes titled “Enter Named Route Segment”) will allow for entry of a given flight path element.

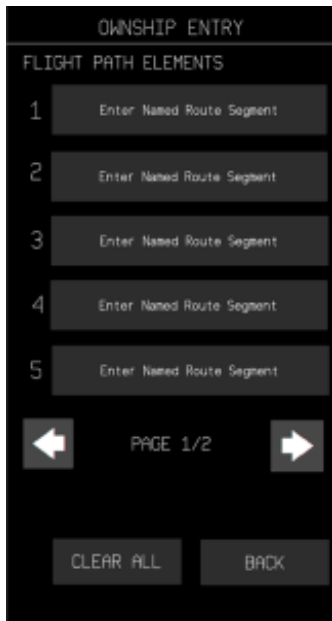


Figure 17. Flight Path Elements sub-page, supporting up to 10 entries across two pages

Pressing the CLEAR ALL button will remove all entries (i.e., Named Route Segments 1-10) in the flight path elements list. Pressing the BACK button will return the menu to the previous page. When a route segment field is selected, a sub-menu opens for that field (see Figure 18). The label at the top specifies which element is being set (e.g., "Flight Path Element #1" in Figure 18), and a list of the possible element types is provided. The number of available choices on this page will vary depending on which element types have already been entered. For example, if the arrival (Standard Terminal Arrival Route [STAR]) element has already been entered, then a second STAR may not be selected for the same IM operation.

It is important to note that RUNWAY is available as an option if no runway was specified on the OWNERSHIP ENTRY page. If a runway had been entered, then this option would not be available and the APPROACH option would filter such that only choices based on the runway that was already entered would be allowed. As mentioned above, if a runway has been entered as an element, then it will be backfilled to the OWNERSHIP ENTRY page level.



Figure 18. Sub-menu that appears on selection of the route segment field

Selecting the WAYPOINT/AIRWAY element opens the appropriate keypad (see Figure 19).



Figure 19. Keypad appearing on selection of WAYPOINT/AIRWAY flight path element type

Waypoints, airways, and airway segments can be entered through the use of appropriate names and syntax. For example:

- ANCHR2 (waypoint);
- J8 (airway);
- TARG1.J8.QUALT (airway segment).

Pressing the toggle button “123” at the bottom right of Figure 19 switches the keypad to the number pad to support entry of numerical information.

Once the desired entry has been typed into the data field, the user may:

- Select ENTER in the upper right corner of the frame, which will trigger the system to verify the entry. The system will identify if the entry is a waypoint, airway, or an airway segment and whether it is valid.
- Select CANCEL in the upper right corner, below ENTER. CANCEL will return the user to the FLIGHT PATH ELEMENTS page without an entry for this row.

Each flight path element is entered by selecting the line item field. If an element has been erroneously entered, the user can make changes by simply re-selecting the line item. Once at least one flight path element has been entered, the BACK button (see Figure 17) changes to the DONE button (see Figure 20).

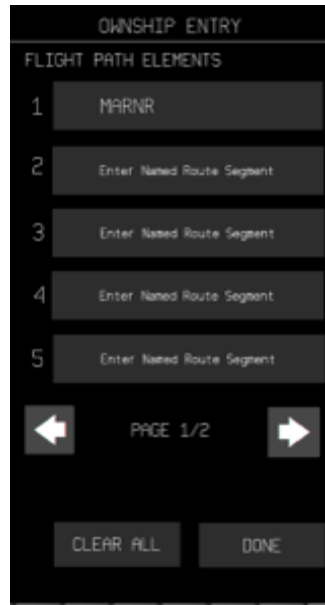


Figure 20. Flight path elements list, illustrating availability of the DONE button (replacing the BACK button), at bottom right

Selecting the DONE button will input all entries in the list for creation of the route, which will then be displayed on the air traffic display in the main window (if the appropriate filters are active).

Upon selection of the STAR flight path element type, a list of STARS is presented (see Figure 21). The STAR list is populated according to the airport selected on the OWNSHIP ENTRY page. There are two possible elements within a STAR (i.e., the STAR procedure and runway transition), which are entered sequentially. The STAR must be selected prior to identifying a runway transition.



Figure 21. Example list of arrivals for the STAR flight path element

The STAR list appears in alphabetical order from top to bottom, and then from left to right. The arrow keys at the bottom of the frame can be used to navigate through if more than six STAR choices are available.

To remove a selected STAR, the user can press the CLEAR SELECTIONS button in the lower right corner of the frame. If the wrong transition is selected, the user may select and highlight another (this will clear the highlighting from the initial selection). Pressing CANCEL will return to the FLIGHT PATH ELEMENTS page without making an entry for the flight path element.

Selection of one of the STARS will highlight the selection and the text of the selected STAR will be fed into the highlighted text entry field at the top of the page. The page will then automatically change to the TRANSITIONS step for entry (see Figure 22).



Figure 22. List of Transitions related to a selected STAR flight path element

A list of STAR transitions will then be presented for selection. The transition list appears in alphabetical order from top to bottom and from left to right. In Figure 22, only six options are available; if more than 6 options are available, then arrow keys will appear (similar to those depicted in Figure 21) for navigation through the list. It should be noted that choosing a transition is optional based on navigation clearance provided by ATC, and the user may press ENTER to continue the procedure without specifying a transition.

After selecting a transition, touching ENTER will validate and pass the specified selection into the flight path elements list. If the wrong transition is selected, the user may select and highlight another (this will clear the highlighting from the initial selection). Pressing the CLEAR SELECTIONS button will remove both transitions and arrivals from the display, and will return to the starting view of the arrivals for this sub-page. Figure 23 illustrates the FLIGHT PATH ELEMENTS page with several different elements entered.

After all flight path elements have been entered, the DONE button (see bottom right of Figure 23) will be selected. At this point, the route will be passed to the system and will become visible on the traffic display (assuming the appropriate filters are active). The right frame will populate

the appropriate field(s) and the VIEW AS WAYPOINTS and DIRECT TO buttons will become available for selection on the Ownship Entry page (see Figure 24).



Figure 23. Example flight path elements page with elements listed



Figure 24. Availability of the VIEW AS WAYPOINTS and DIRECT TO buttons

The RUNWAY text field displays what runway was selected (either directly input here or as part of the selected approach or runway entry in the flight path). The FLIGHT PATH text field contains a summary of the element list provided in the FLIGHT PATH ELEMENTS sub-page. If

the specified entry requires more space than is available on the page (i.e., needing extension beyond the top of the done button), then “...” will be placed at the end of the text field to indicate that more entries are included in the flight path than are visible.

The user may choose to view a list of individual waypoints in the flight path via selection of VIEW AS WAYPOINTS button (see Figure 25). Unlike the other lists, this list is presented in the order of flight rather than alphabetical order. If more than 16 waypoints exist in the flight path, then arrow keys will appear for navigation through the list. It should be noted that this page provides a list view of the waypoints only; no interaction with the waypoints is available.



Figure 25. Example of VIEW AS WAYPOINTS selection for the flight path

When selecting DIRECT TO, the user may choose to select a waypoint from the existing route or manually enter a new waypoint. A selectable list of current route waypoints will appear (see Figure 26).



Figure 26. List of DIRECT TO waypoint selections

As in other submenus, selecting an item in the list highlights the item and fills the entry field. Reselection of an item will deselect it (i.e., the highlight and the text will be removed from the entry field at the top). Pressing the MANUAL ENTRY button will switch the display to support keyboard entry, which supports both numerical and alphabetic entries. The text entry field includes a cursor position to represent expectation of keyed entry (see Figure 27).



Figure 27. Manual entry of DIRECT TO waypoint

On selection of MANUAL ENTRY, its button becomes WAYPOINT LIST on the keypad entry page to allow the user to return to the list selection method. If the manually entered waypoint is not part of the current route, then it will be added to the route and will become the first waypoint in the list.

After a DIRECT TO point is entered or selected, and the user selects ENTER, a pop-up dialog will appear to confirm that the user wishes to remove the route elements *before* the selected waypoint, thus treating the DIRECT TO point as the next waypoint in the route (see Figure 28).

Note that any waypoints with AT or window altitude constraints that are above the cruise altitude will be deleted.

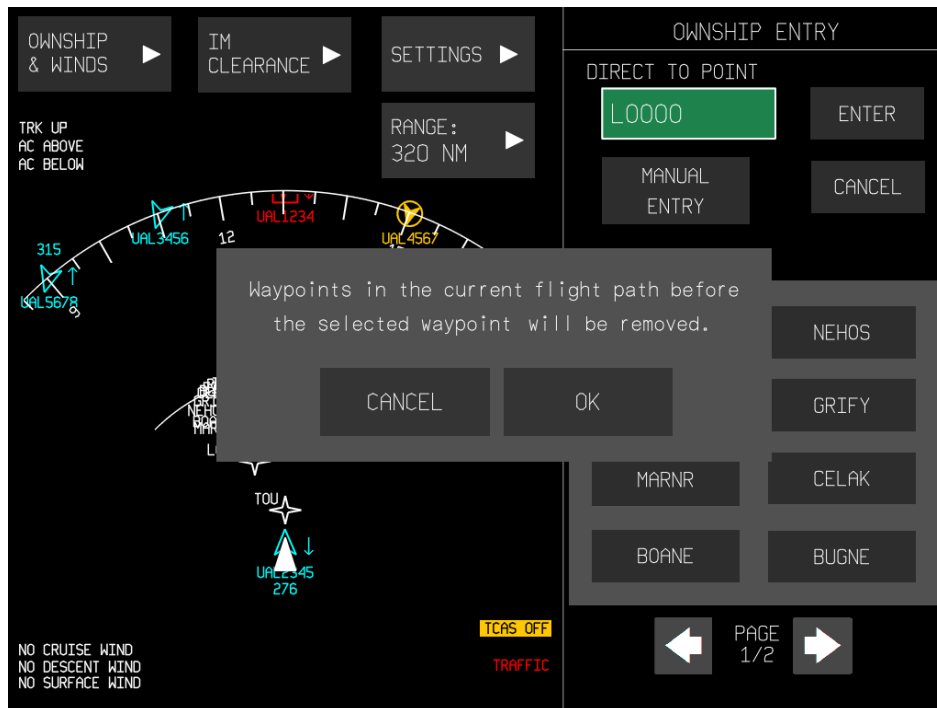


Figure 28. Pop-up dialog appearing after entering or selecting a DIRECT TO waypoint

Pressing “OK” will enter the waypoint and remove all other entries before it in the route. This action is irreversible. The text in the FLIGHT PATH text entry on the main OWNSHIP ENTRY page will be updated to reflect the changes made on the DIRECT TO page. When all required fields have been populated, the DONE button appears in the lower right corner of the main OWNSHIP ENTRY page (see Figure 29).



Figure 29. OWNSHIP ENTRY page with entries made in all required fields

On selection of DONE, the next six waypoints in the ownship route will be visible in cyan under the OWNSHIP column of the IM CLEARANCE home page (see Figure 30).



Figure 30. IM CLEARANCE HOME page with the next six waypoints listed under OWNSHIP

5.2 Winds Entry

Figure 31 depicts the sub-menu for CRUISE FORECAST WINDS. The waypoints in this menu appear automatically based on ownship flight path (if available).

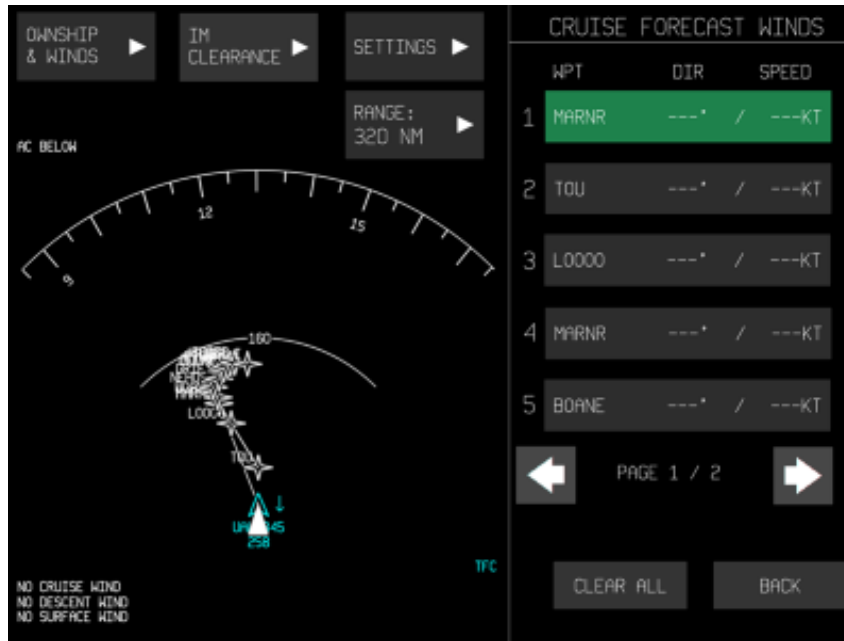


Figure 31. Cruise Forecast Winds submenu selection

From the CRUISE FORECAST WINDS sub-menu, the user may:

- Select any of the rows to start entering information for cruise forecast winds. As with the flight path elements page, there is support for a list of 10 possible entries, and the arrow keys can be used to navigate between rows 1-5 and rows 6-10.
- Select the CLEAR ALL button, which will clear entries for waypoints (WPT), direction (DIR), and speed (SPEED) for all 10 rows.
- Select the BACK button, which will return to the IM CLEARANCE HOME page.

Note that only 10 waypoints may be entered; if there are more than 10 waypoints in the flight path, the user should choose appropriate waypoints to span the route.

Waypoint data is entered by selecting the line item field. If information has been erroneously entered, the user can make changes by simply re-selecting the line item. Selecting any row will display a sub-page with fields for entering WAYPOINT, DIRECTION, and SPEED information (see Figure 32)

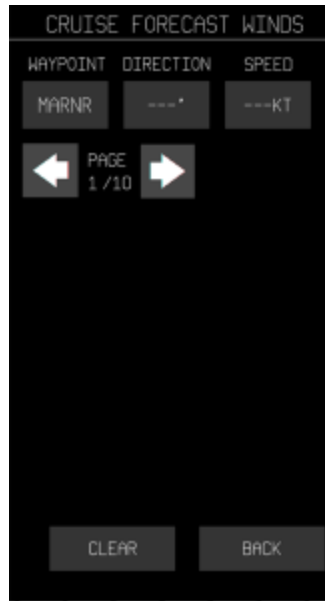


Figure 32. Cruise Forecast Winds waypoint sub-page

From this sub-menu, the user may:

- Select a field to enter data.
- Select the arrows to navigate through rows of data. Cycling back via the back arrow from the 1st row will take you to the 10th row, and vice-versa.
- Select CLEAR, which will clear all three variables (WAYPOINT, DIRECTION, and SPEED) from the currently displayed page.
- Select BACK, which will return the display to the CRUISE FORECAST WINDS page. Valid data entered will be retained (even if only one of the fields is populated). If one of the first five rows is in view, then the row 1-5 view will be shown; if one of the latter five rows is in view, then the BACK button will return to the row 6-10 view.

Selecting one of the entry fields will transition to text entry for that field, and a keypad will appear to support data entry (see Figure 33). Note that only numerical values are supported; thus, the letter key (ABC) is in cyan.

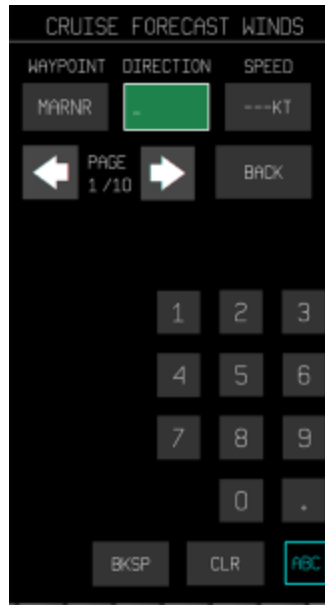


Figure 33. Keypad for data entry (DIRECTION example)

Once the entry has been completed, the user can:

- Tap any blank (black) space on the display to de-select the text entry field and return to the sub-menu view.
- Select another entry field to begin entering or editing its information.
- Select one of the arrow keys to navigate to another row.
- Select the BACK button to return to the main CRUISE FORECAST WINDS page. The current entry will be retained as long it is valid; if it is not valid, then a pop-up will appear to notify the user that the entry is invalid. This will also prevent the page from transitioning.

Figure 34 illustrates the CRUISE FORECAST WINDS page with three waypoints entered (if more than five waypoints are entered, subsequent waypoints are displayed on page two – allowing up to ten total waypoints). The user can then press DONE to indicate completed cruise forecast entries to return to the home page.



Figure 34. CRUISE FORECAST WINDS page with entries made

Figure 35 illustrates the DESCENT FORECAST WINDS page. Functionality for this page is the same as for cruise forecast winds, with the exception that the cyan text “SFC” (for the surface wind entry) cannot be changed. Note that DESCENT FORECAST WINDS and SFC FORECAST WINDS are deleted when the ownship route is changed.



Figure 35. DESCENT FORECAST WINDS page

5.3 IM Operations

The IM CLEARANCE drop-down menu supports selection of the specific type of clearance to be entered (see Figure 36). In this Figure, the traffic filter is active and the ownship's route data has already been entered. It should be noted that ownship and clearance information may be entered and saved in any order; however, the system cannot be armed until the required ownship information has been entered.

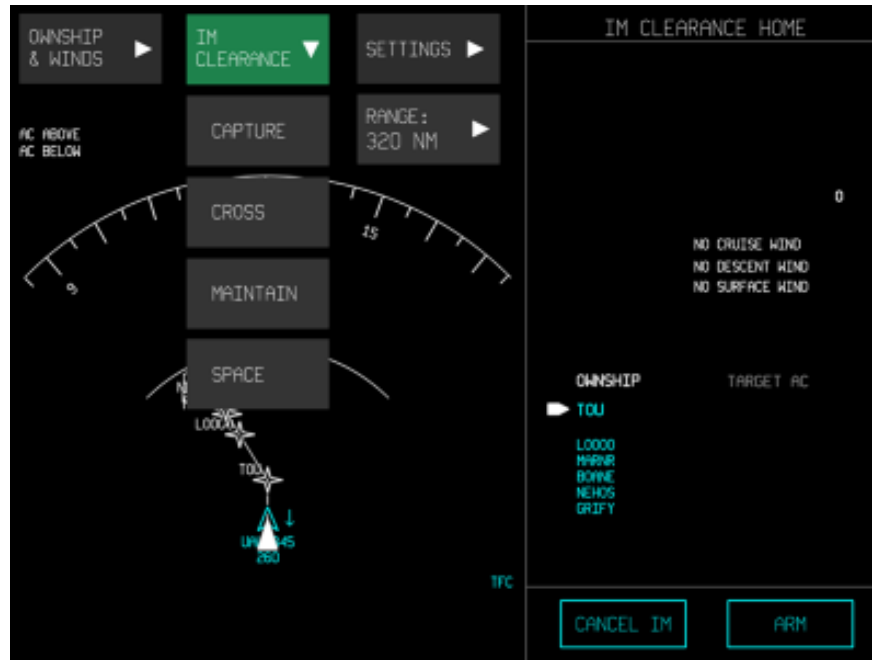


Figure 36. IM CLEARANCE drop-down menu

Once a clearance type has been selected, the appropriate home screen for that clearance will appear in the right side frame.

5.3.1 IM Capture Clearance

The IM CLEARANCE: CAPTURE page allows the user to enter a spacing goal, the target aircraft, and the IM PTP (see Figure 37). The TARGET ROUTE field is auto-populated after the target aircraft has been identified, and appears in cyan. The ARM button cannot be selected until at least the SPACING GOAL and TARGET ID values have been entered. Selecting the HOME button will return to the IM HOME page while preserving entries for future recall.

Figure 38 illustrates the SPACING GOAL entry page. The spacing goal may be entered in seconds (SEC) or nautical miles (NM) via keypad. The user must select the appropriate SEC/NM value for time- or distance-based IM operation. Note that the entire area of the SEC/NM button acts as a single touch target: touching anywhere on the button will toggle the setting to the alternate option.

The valid entry range for the IM spacing goal in time is 30-999 seconds, or in distance is 1-99 nautical miles.

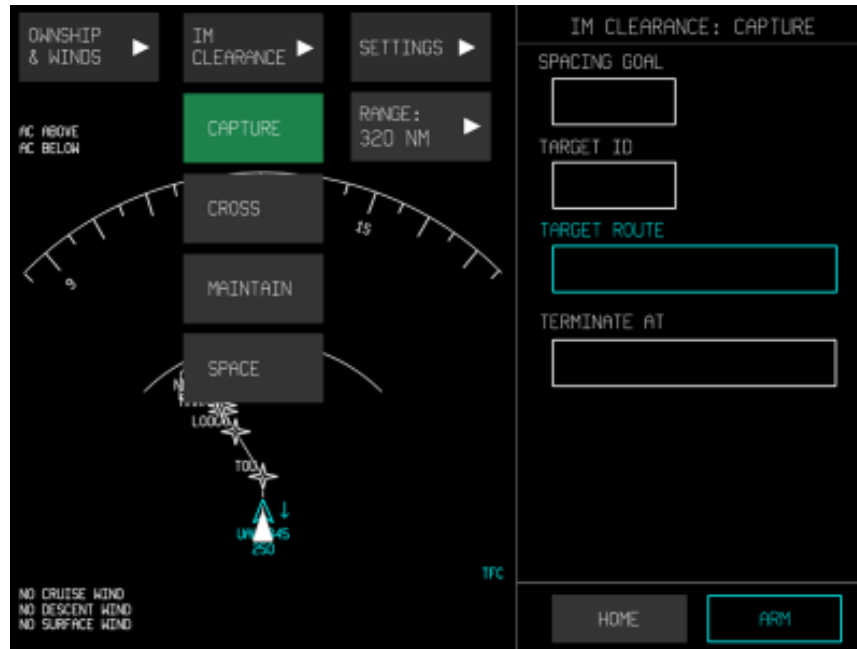


Figure 37. IM CLEARANCE: CAPTURE page

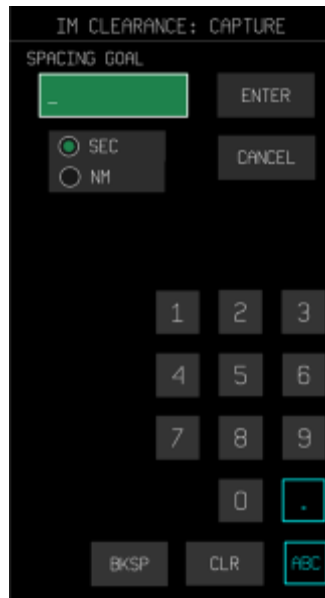


Figure 38. SPACING GOAL entry page, which appears on selection of SPACING GOAL field

Once the ENTER button is selected, the clearance home page is displayed with the data entered into the appropriate field (see Figure 39). It should be noted that for any of the input pages that are accessed from the clearance home page, no entry will be input to the top-level menu until the ENTER button is pressed. Similarly, pressing CANCEL will return to the previous level without an entry being input (in most cases, this will be the top-level page).



Figure 39. IM CLEARANCE HOME with SPACING GOAL entry made

Figure 40 depicts the TARGET ID entry page. By default, the list shown for target aircraft selection is populated with IM-capable aircraft (as identified via ADS-B scan of all aircraft in range). The pagination arrows that appear at the bottom support navigation through the list of potential targets should there be more than eight aircraft available.

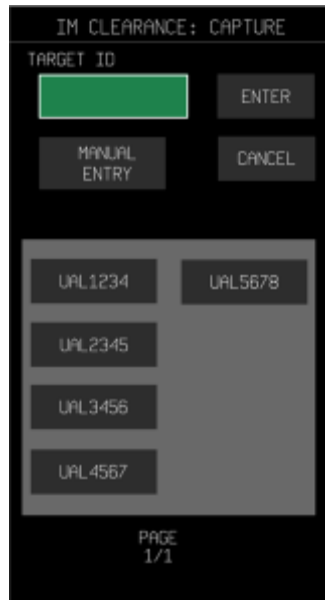


Figure 40. TARGET ID entry page, which appears on selection of TARGET ID field

The MANUAL ENTRY button supports manual input of the desired target traffic ID if it is not on the list (see Figure 41). Selecting MANUAL ENTRY opens the keypad, and the user can switch between the numeric and alpha keypads, as necessary, by selecting the 123 or ABC keys,

respectively. It should be noted that manual entry of an aircraft ID is supported even if the aircraft is outside ADS-B range.

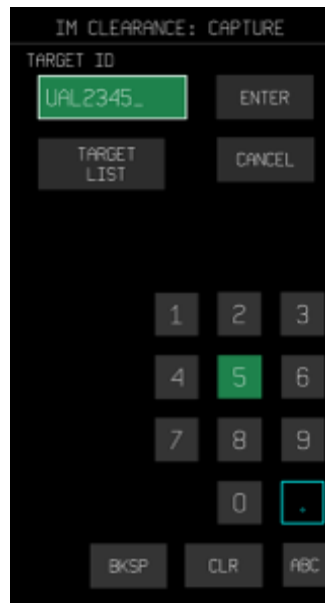


Figure 41. Manual entry of Target ID

If the user attempts to enter a target ID for an aircraft outside ADS-B range, then a WAITING TGT DATA message will appear indicating that the system will verify target aircraft data quality when it is within range (see Figure 42). The user cannot select ARM from the clearance home page until the target aircraft is in range and a stable connection can be established.

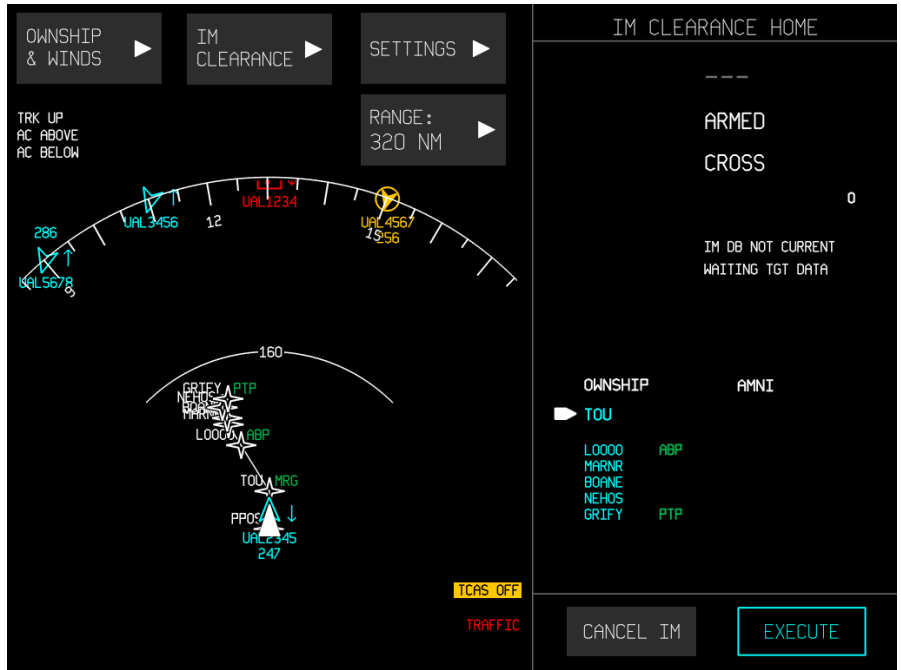


Figure 42. ARMED clearance after entering Target ID for an out-of-range aircraft

Once a TARGET ID has been specified, the TARGET ROUTE is automatically loaded for it (see Figure 43). The values within the TARGET ROUTE field cannot be modified and appear in cyan. The TERMINATE AT field allows the user to specify the type of terminate point desired (i.e., TERMINATE AT WPT, TERMINATE BEFORE, TERMINATE AFTER, or DEFAULT) (see Figure 44).



Figure 43. Target Route field auto-populated

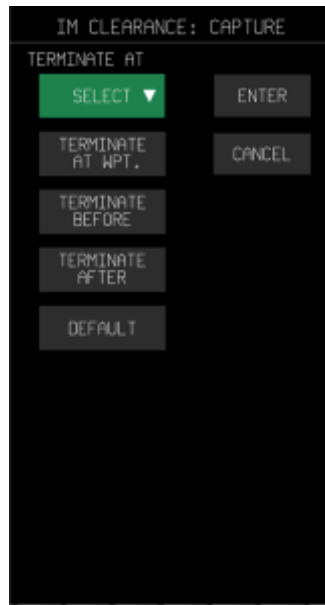


Figure 44. Available selections from the TERMINATE AT pull-down menu

Figure 45 illustrates the TERMINATE AT WAYPOINT selection.



Figure 45. TERMINTE AT WAYPOINT subpage

For the case depicted in Figure 45, there is no need for a distance specification; it remains cyan and inaccessible because the TERMINATE AT WAYPOINT was selected. Selection of either TERMINATE BEFORE or TERMINATE AFTER allows the user to modify this distance field for termination distance before or after the waypoint. The user must select the waypoint entry field

from this page.

The waypoints that appear in the TERMINATE AT WPT list is based on the airport selected in the ownship entry (see Figure 46). However, if no ownship information was entered first, only manual entry will be available. Figure 47 depicts a waypoint has been entered as the TERMINATE AT WPT and, because all required information has been successfully entered, the ARM button becomes available for selection (i.e., is no longer cyan).



Figure 46. List of selectable waypoints for TERMINATE AT WPT



Figure 47. TERMINATE AT field with waypoint entered, and availability of the ARM button

Figure 48 illustrates the IM CLEARANCE HOME page after the ARM button has been selected for a capture clearance.

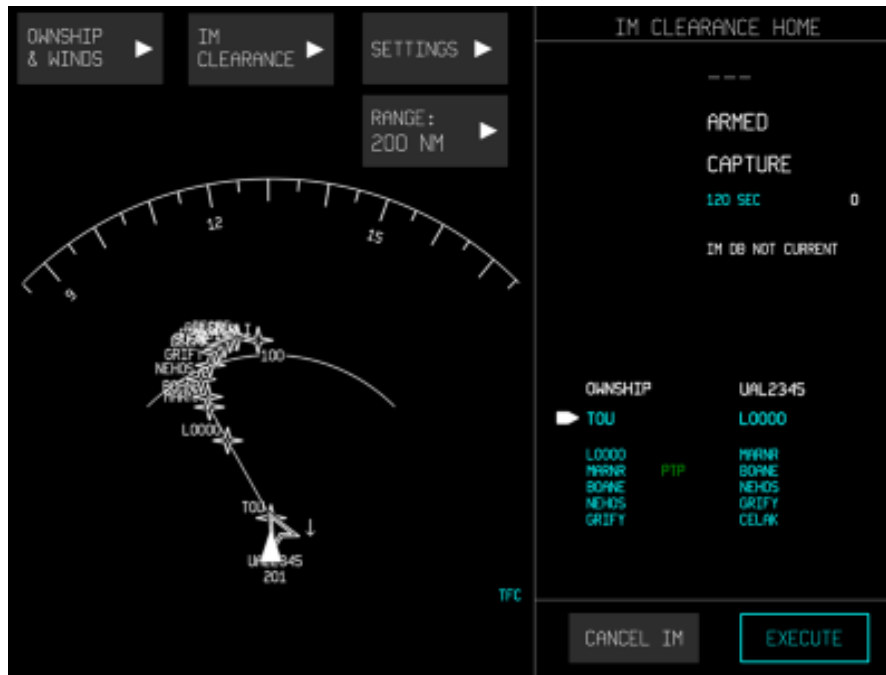


Figure 48. IM CLEARANCE HOME page subsequent to touching the ARM button

After selection of the ARM button, the target aircraft symbol on the navigation display changes to a white chevron with a white border to identify it as the designated target. The state (i.e., ARMED), clearance type (i.e., CAPTURE), and spacing goal (i.e., 120 SEC) appear as well. The target aircraft's ID and the next waypoints in its route are displayed in the waypoints section below the ID. In addition, the target aircraft's waypoints appear on the traffic display (assuming the appropriate filter is selected – see section 4.4, Display Filters).

The label for the PTP becomes visible in green if it is among the next six waypoints displayed. If it is visible on the map, and the appropriate filter is selected, a text label will also appear on the waypoint in the navigation display. The CANCEL IM button can be used to cancel the current IM clearance.

The EXECUTE button is unavailable (i.e., appears in cyan) until the IM state switches from ARMED to AVAILABLE. This transition occurs automatically once the system establishes that the software requirements are met and the system is now available to execute the IM procedure. . The IM speed is now indicated on the display, and the state changes from ARMED to AVAILABLE. The EXECUTE button is now available for selection (see Figure 49).

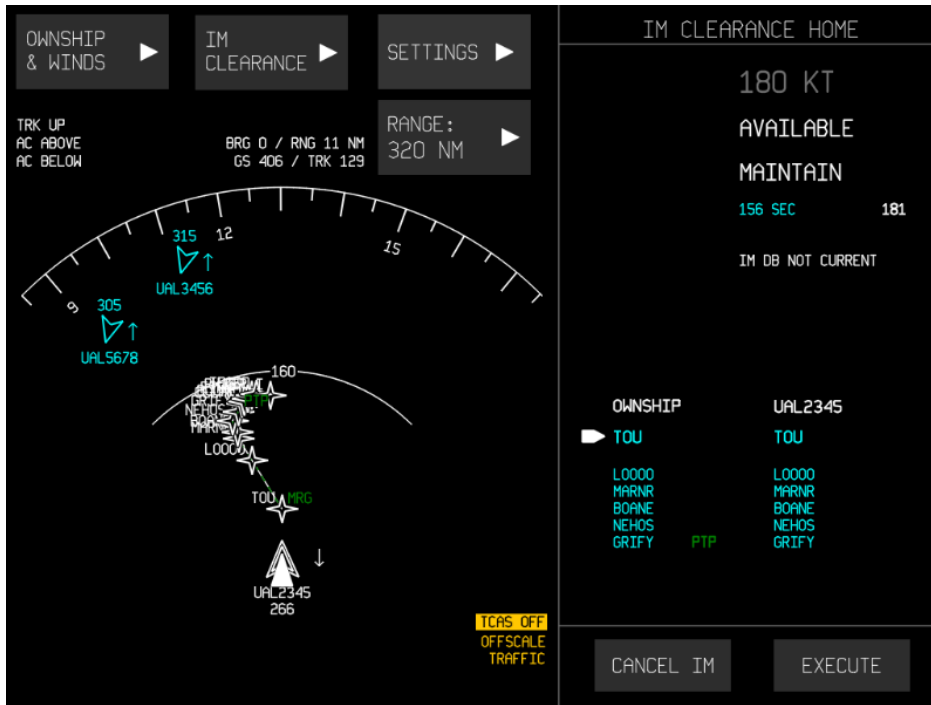


Figure 49. IM CLEARANCE HOME page in the AVAILABLE state, with EXECUTE available.

Once the user has verified all information, EXECUTE is selected. The IM operation becomes active and in the PAIRED state, indicated by green speed command, green IM state (PAIRED), and green IM clearance type (CAPTURE); additionally, the designated target aircraft's symbol changes to a green outer border, and its associated data also appear in green (see Figure 50). The SUSPEND button is now available to suspend the IM operation.

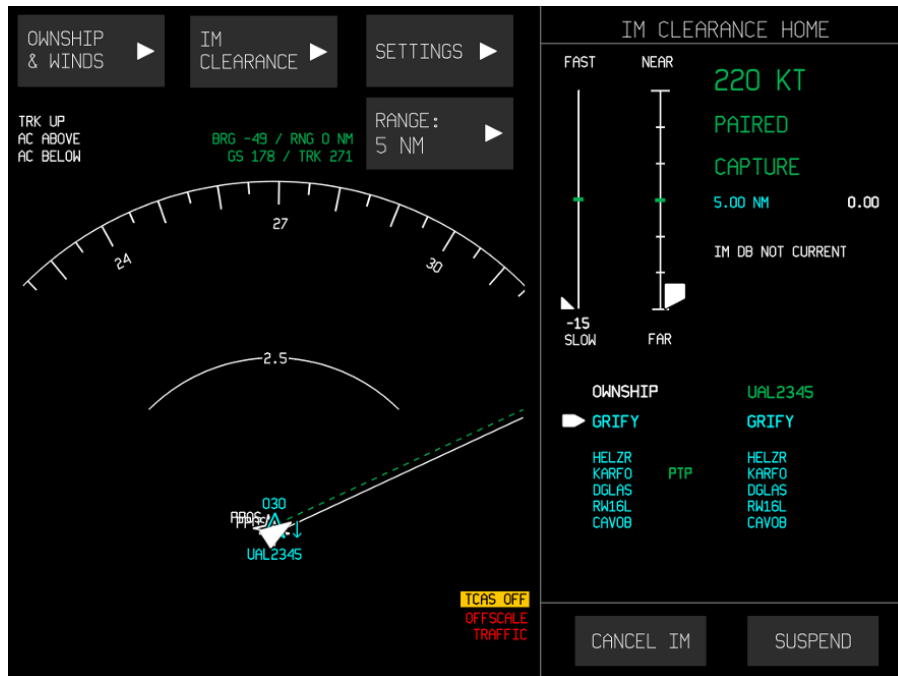


Figure 50. IM CLEARANCE HOME indicating an active CAPTURE clearance

5.3.2 IM Cross Clearance

The IM CLEARANCE: CROSS page allows the user to enter a spacing goal, the target aircraft, the target aircraft route, the ABP, and the PTP (see Figure 51).



Figure 51. IM CLEARANCE: CROSS home page

Each field has an associated sub-page, and for all sub-pages, no entry will be input to the top-level menu until the ENTER button is pressed. Similarly, pressing CANCEL will return to the previous level without an entry being input (in most cases, this will be the top-level page).

Figure 52 illustrates the SPACING GOAL entry page. The spacing goal may be entered in seconds (SEC) or nautical miles (NM) via keypad. The user must select the appropriate SEC/NM value for time- or distance-based IM operation. Note that the entire area of the SEC/NM button acts as a single touch target: touching anywhere on the button will change the setting to the alternate option.

The valid entry range for the IM spacing goal in time is 30-999 seconds, or in distance is 1-99 nautical miles. Once the ENTER button is selected, the clearance home page is displayed with the entered data in the appropriate field (see Figure 53).

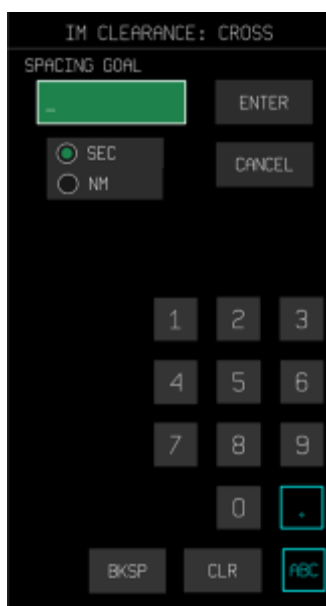


Figure 52. SPACING GOAL entry page, which appears on selection of SPACING GOAL field



Figure 53. IM CLEARANCE HOME with SPACING GOAL entry made

Figure 54 depicts the TARGET ID entry page. By default, the list shown for target aircraft selection is populated with IM-capable aircraft (as identified via ADS-B scan of all aircraft in range). Manual entry of other aircraft is allowed and the system will wait until the aircraft is within ADS-B range and quality can be checked. The pagination arrows at the bottom support navigation through the list of potential targets should there be more aircraft available.



Figure 54. TARGET ID entry page, which appears on selection of TARGET ID field

The MANUAL ENTRY button supports manual input of the desired target traffic ID if it is not on the list (see Figure 55). Selecting MANUAL ENTRY opens the keypad, and the user can switch between the numeric and alpha keypads, as necessary, by selecting the 123 or ABC keys, respectively. It should be noted that manual entry of a valid aircraft is supported even if the aircraft is outside ADS-B range.

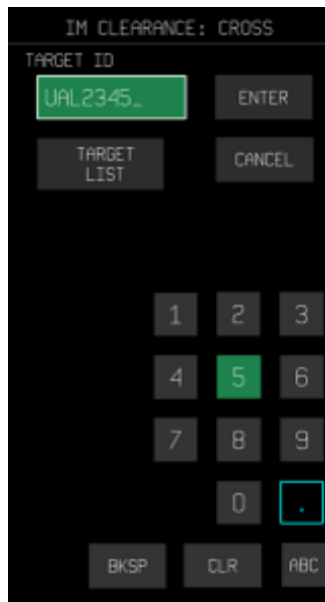


Figure 55. Manual entry of Target ID

If the user attempts to enter a target ID for an aircraft outside ADS-B range, then a pop-up dialog will appear indicating that the system will verify Target aircraft data quality when it is within range (see Figure 42, Section 5.3.1). The user cannot select ARM from the clearance home page until the target aircraft is in range and a stable connection can be established.

Figure 56 illustrates the CROSS clearance page with the TARGET ID entered.

IM CLEARANCE: CROSS

SPACING GOAL

120 SEC

TARGET ID

UAL2345

TARGET ROUTE

ACHIEVE BY

TERMINATE AT

HOME ARM

Figure 56. IM CLEARANCE: CROSS page with Target ID entered

Selecting the TARGET ROUTE element opens the TARGET ROUTE sub-page (see Figure 57). To clear elements that have been entered, the CLEAR ALL button at the bottom of the page will remove all elements that have been entered. The BACK button returns the user to the previous page (retaining any previously entered data).

If manually entering the target route, the entry process will be the same as for ownship route entry (see Section 5.1) with the exception that only five route elements may be entered (as opposed to 10 for the ownship route).



Figure 57. TARGET ROUTE sub-page

Selecting SAME AS OWNSHIP will set the target route to be the same as the ownship route, which will then appear in cyan below the selection (see Figure 58). The CLEAR ALL button is no longer displayed since the SAME AS OWNSHIP selection does not have individual elements to be modified or cleared. The BACK button changes to DONE to indicate that sufficient information has been input to complete the sub-page and return to the clearance menu page. Pressing the toggle button again will revert the selection to the previous option (i.e., ENTER TARGET ROUTE).



Figure 58. Selection of SAME AS OWNERSHIP for TARGET ROUTE, with DONE button available

Note that the entire area of the ENTER TARGET ROUTE / SAME AS OWNERSHIP target route selection acts as a single touch target: touching anywhere in this area will change the setting to the alternate option.

In the case that TARGET ROUTE elements have already been entered and then SAME AS OWNERSHIP is pressed, a dialog will appear to notify the user that those elements will be cleared if the setting is selected (see Figure 59). Figure 60 depicts the target route after SAME AS OWNERSHIP has been selected.

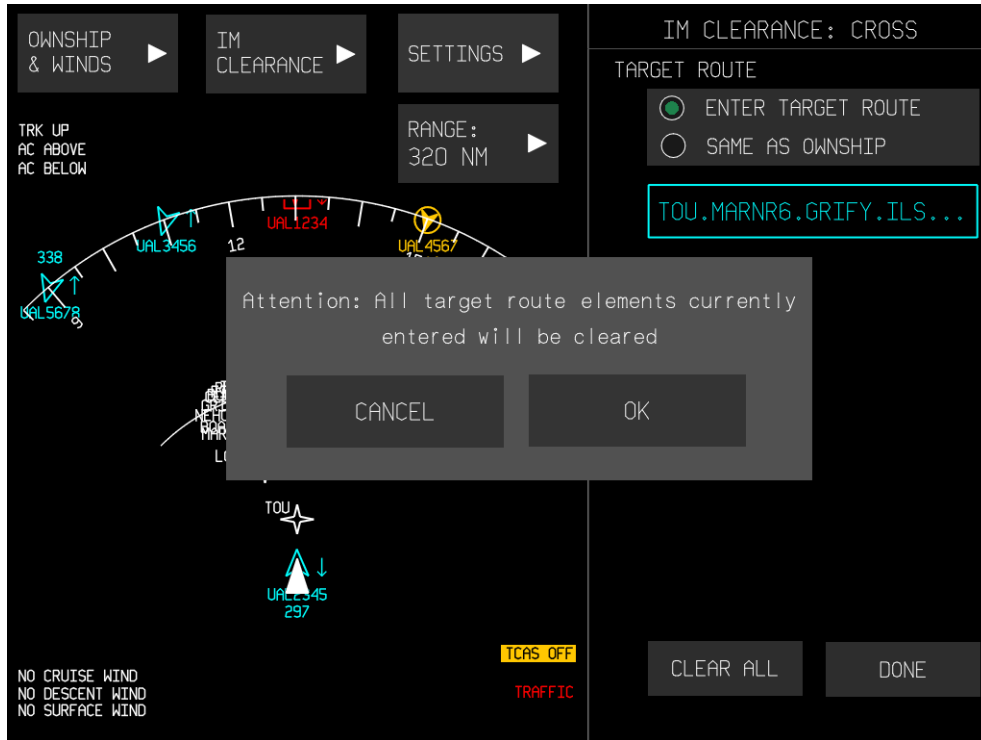


Figure 59. Dialog informing that target route elements will be cleared



Figure 60. TARGET ROUTE after SAME AS OWNERSHIP has been selected

Figure 61 depicts the drop-down menu for entering the ABP on the ACHIEVE BY sub-page after selecting the ACHIEVE BY field. The user can select ACHIEVE BY WPT to immediately enter the waypoint for ABP (see Figure 64 and Figure 65 for examples of waypoint entry).



Figure 61. ACHIEVE BY sub-page and drop-down menu after selecting the ACHIEVE BY field

If there is a distance constraint associated with the waypoint, then the user should select ACHIEVE BEFORE or ACHIEVE AFTER to enter the constraint as well as the waypoint (see Figure 62).

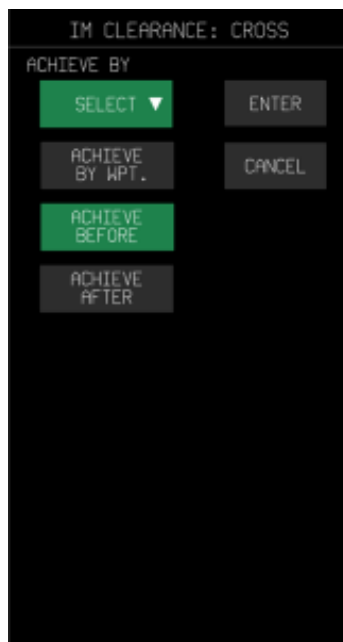


Figure 62. Selection of ACHIEVE BEFORE on the ACHIEVE BY drop-down menu

ACHIEVE BEFORE and ACHIEVE AFTER entries are made through a sub-page linked to the text entry field. Figure 63 depicts the ACHIEVE BEFORE entry sub-page; the process for ACHIEVE AFTER is exactly the same.

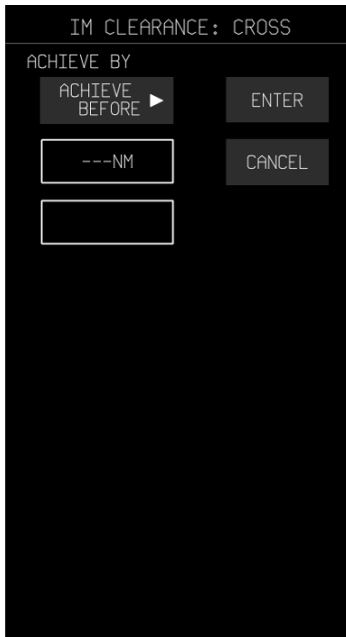


Figure 63. ACHIEVE BEFORE sub-page

Selecting the upper field (--NM) on this page opens the distance entry field and its associated keypad (see Figure 64).

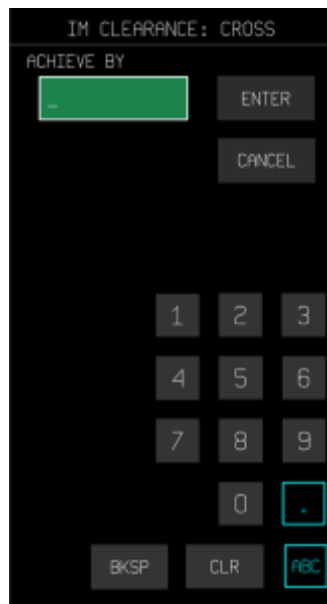


Figure 64. Keypad for entry of a distance for ACHIEVE BEFORE and ACHIEVE AFTER

Selecting ENTER automatically transitions to the ABP waypoint entry screen (see Figure 65). The ABP waypoints listed are common to both the ownship and target routes and appear in alphabetical order. The list is based on the ownship route elements; if no ownship information was entered first, then only manual entry would be available here.



Figure 65. ACHIEVE BY waypoint entry sub-page

Figure 66 illustrates the ACHIEVE BEFORE entry sub-page with both fields completed.



Figure 66. ACHIEVE BEFORE sub-page with entries completed

Now that all ACHIEVE BY entries have been made, ENTER can be selected to navigate back to the clearance home page. The completed selection for the ABP is summarized in the text field (see Figure 67).



Figure 67. IM CLEARANCE: CROSS home page with ACHIEVE BY field completed

On selection of the TERMINATE AT field, a sub-page opens with a drop-down menu that is very similar to that of the ACHIEVE BY menu, except that there is also an option to select “DEFAULT” (see Figure 68).

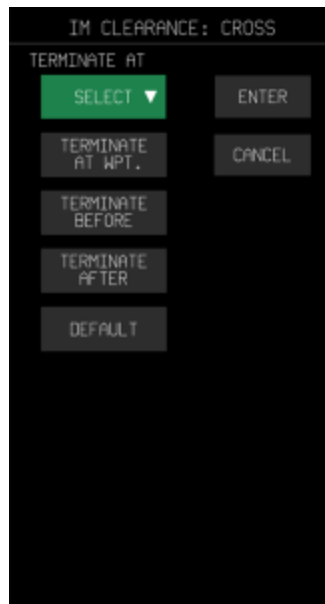


Figure 68. TERMINATE AT sub-page and associated drop-down menu

If the user selects TERMINATE AT WPT, then the display will change to the waypoint entry sub-page. If the user selects TERMINATE BEFORE or TERMINATE AFTER, then the display will change to a summary sub-page from which the distance and waypoint fields can be selected.

The process here is exactly like the process for ACHIEVE BEFORE / AFTER.

If the user selects DEFAULT from the TERMINATE AT menu, then the display will return to the clearance home page with the default termination point described in the field (see Figure 69). In this case, the user chose to select the default PTP, so no distance to a waypoint would be specified. Because the DEFAULT PTP was selected, the PTP field describes the system default PTP, which is 6.25 NM before the threshold of the specified runway. In the case that no runway or approach procedure was specified in the ownship route, then the last waypoint in the route will become the default PTP. If the PTP selected does not appear in the ownship route, a dialog will inform the user.

Figure 69 shows the Cross clearance home page with all fields completed. As with the ABP, the PTP selections are summarized in the text field.



Figure 69. Default TERMINATE AT selected and availability of the ARM button

If all information has been successfully entered, the ARM button can be selected (see Figure 70).



Figure 70. Selection of the ARM button

5.3.3 IM Maintain Clearance

The IM CLEARANCE: MAINTAIN page allows the user to enter a spacing type (in time or distance), the target aircraft and the PTP (see Figure 71).

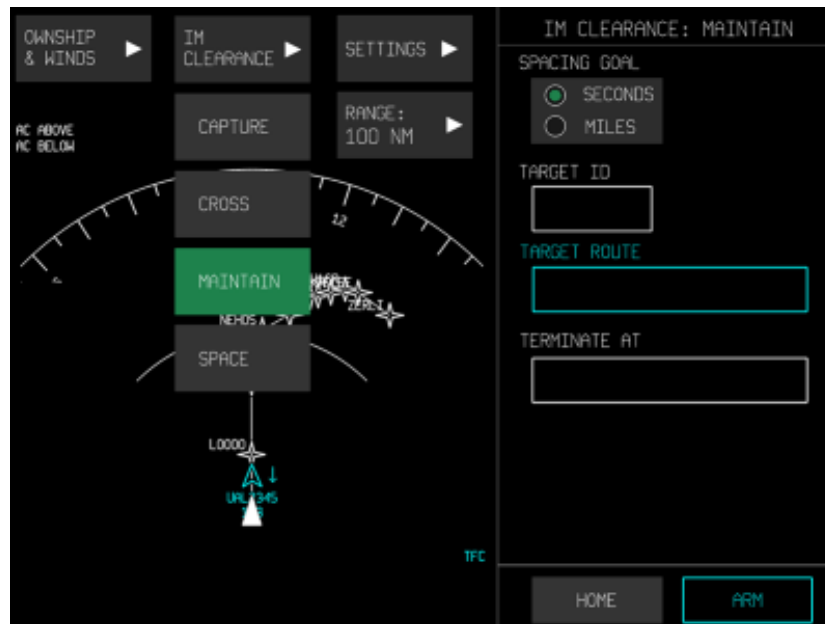


Figure 71. IM CLEARANCE: MAINTAIN home page

The spacing unit can be selected as either seconds (time-based spacing) or nautical miles (distance-based spacing). Unlike the other IM Clearances, the value of the spacing goal is not

specified - only the units. Note that the entire area of the SEC/NM button acts as a single touch target: touching anywhere on the button will change the setting to the alternate option. The valid entry range for the IM spacing goal in time is 30-999 seconds, or in distance is 1-99 nautical miles.

On selection of TARGET ID, a sub-page opens to select the target aircraft. By default, the target list (populated with a list of local ADS-B, IM-capable aircraft) is shown for target aircraft selection (see Figure 72).

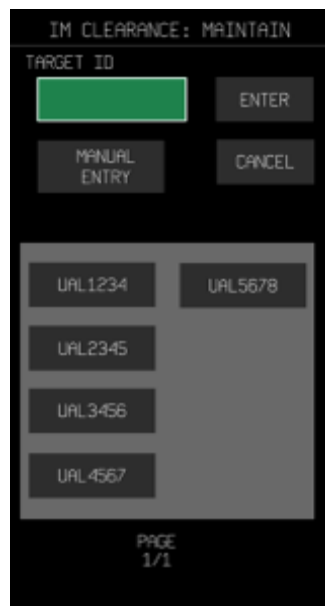


Figure 72. TARGET ID entry page, which appears on selection of TARGET ID field

The list shown for target aircraft selection is populated with IM-capable aircraft (as identified via ADS-B scan of all aircraft in range). The pagination arrows at the bottom support navigation through the list of potential targets should there be more aircraft available. The MANUAL ENTRY supports manual input of the desired target traffic ID if it is not on the list (see Figure 73). Selecting MANUAL ENTRY opens the keypad, and the user can switch between the numeric and alpha keypads, as necessary, by selecting the 123 or ABC keys, respectively.

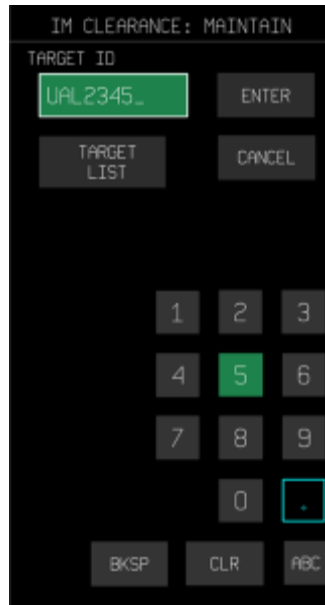


Figure 73. Manual entry of Target ID

Once a TARGET ID has been specified, the TARGET ROUTE is automatically loaded for it (see Figure 74). The values within the TARGET ROUTE field cannot be modified and appear in cyan. It should be noted that manual entry of a valid aircraft is supported even if the aircraft is outside ADS-B range.

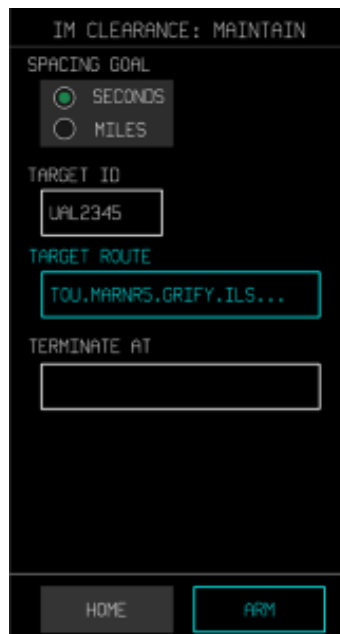


Figure 74. IM CLEARANCE: MAINTAIN home page, with spacing goal, target ID, and target route

If the user attempts to enter a target ID for an aircraft outside ADS-B range, then a pop-up dialog will appear indicating that the system will verify Target aircraft data quality when it is within range (see Figure 42, Section 5.3.1). The user cannot select ARM from the clearance home page until the target aircraft is in range and a stable connection can be established.

On selection of the TERMINATE AT field, a sub-page opens with a drop-down menu that (see Figure 75) allows the user to specify the type of terminate point desired (i.e., a waypoint, before, after, or default).

If the user selects TERMINATE AT WPT, then the display will change to the waypoint entry sub-page. The TERMINATE AT waypoint list is based on the airport selected from ownship entry (see Figure 76). The user may also elect to enter the PTP manually by selecting MANUAL ENTRY, after which a keypad will appear to enter the PTP. It should be noted that if no ownship information was entered first, only manual entry for TERMINATE AT WPT will be available.

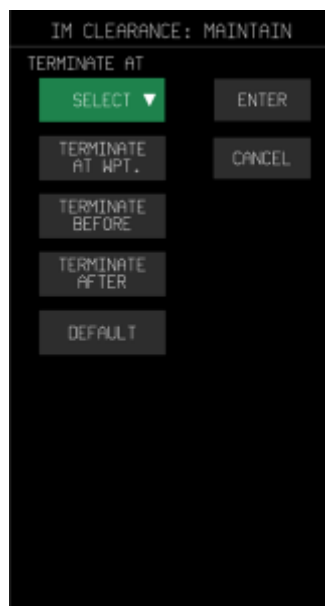


Figure 75. TERMINATE AT sub-page and associated drop-down menu



Figure 76. Sub-page that appears after selection of TERMINATE AT WPT

Once the PTP is entered or selected, selecting the ENTER button will return to the clearance home page. Now that all the required fields have been populated, the ARM button becomes available (see Figure 77).



Figure 77. Entries in all fields populated; availability of the ARM button

5.3.4 IM Space Clearance

The IM CLEARANCE: SPACE page allows the user to enter a spacing goal, the target aircraft, and the target route (see Figure 71). Unlike other IM Clearances, SPACE does not require the

entry of PTP information. The ownship route must contain an approach procedure.

The SPACE clearance is an achieve-by procedure with ABP defaulted to the PTP and PTP set at the default position for the approach case. It should be noted that for all sub-pages tied to the fields listed on the clearance page, no entry will be input to this top-level menu until the ENTER button is pressed; similarly, pressing CANCEL will return to the previous level without making an entry (in most cases, that will be the top level page).



Figure 78. IM CLEARANCE: SPACE home page

Selection of the SPACING GOAL field opens a sub-page where the spacing goal value can be entered via keypad (see Figure 79). The spacing unit can be selected as either seconds (time-based spacing) or nautical miles (distance-based spacing). Note that the entire area of the SEC/NM button acts as a single touch target: touching anywhere on the button will change the setting to the alternate option.

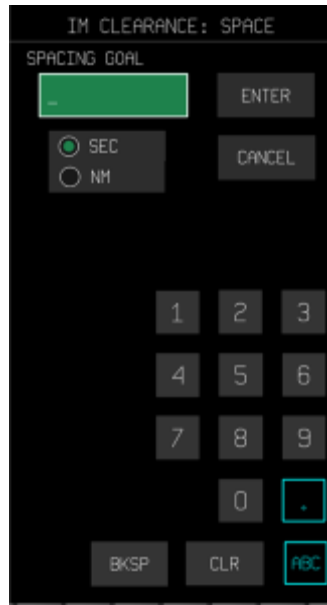


Figure 79. SPACING GOAL sub-page for entry of the spacing goal

The SPACE clearance requires the user to enter the value of the spacing goal (see Figure 80).

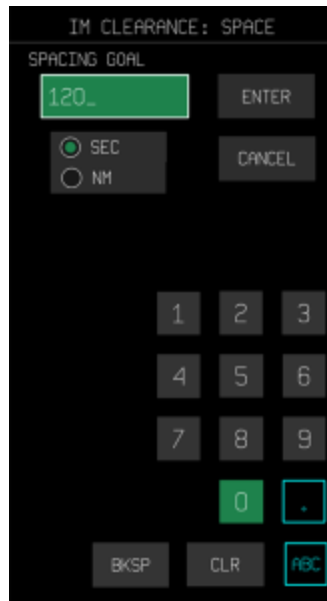


Figure 80. SPACING GOAL sub-page, with value entered via keypad

Once the spacing goal is entered, selecting the ENTER button will return to the clearance home page with the SPACING GOAL field populated (see Figure 81).

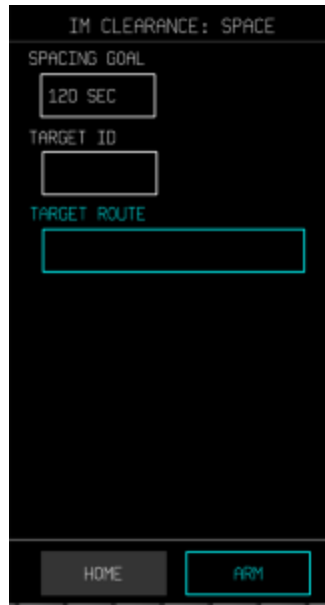


Figure 81. IM CLEARANCE: SPACE home page, with SPACING GOAL populated

On selection of TARGET ID, a sub-page opens to select the target aircraft. By default, the TARGET LIST is shown for target selection aircraft (see Figure 82).



Figure 82. TARGET ID entry page, which appears on selection of TARGET ID field

The list shown for target aircraft selection is populated with IM-capable aircraft (as identified via ADS-B scan of all aircraft in range). The pagination arrows at the bottom support navigation through the list of potential targets should there be more aircraft available. The MANUAL ENTRY supports manual input of the desired target traffic ID if it is not on the list. Selecting

MANUAL ENTRY opens the keypad, and the user can switch between the numeric and alpha keypads, as necessary, by selecting the 123 or ABC keys, respectively.

Selecting the ENTER button after entering or selecting the Target ID will return the user to the clearance home page. Once a TARGET ID has been specified, the TARGET ROUTE is automatically loaded for it (see Figure 83). The values within the TARGET ROUTE field cannot be modified and appear in cyan. Now that all the required fields have been populated, the ARM button becomes available.



Figure 83. Entries in all fields populated; availability of the ARM button

It should be noted that manual entry of a valid aircraft is supported even if the aircraft is outside ADS-B range. If the user attempts to enter a target ID for an aircraft outside ADS-B range, then a pop-up dialog will appear indicating that the system will verify Target aircraft data quality when it is within range (see Figure 42, Section 5.3.1). The user cannot select ARM from the clearance home page until the target aircraft is in range and a stable connection can be established.

Either an approach or runway procedure is required to execute a SPACE clearance type. If the approach/runway has not been entered with the Ownship route information, then even after filling out all the required information for the SPACE clearance, the ARM button will not be available (i.e., it will be cyan, as depicted in Figure 84). The user must return to the Ownship page to specify the approach/runway to make the ARM button available for selection.

IM CLEARANCE: SPACE

SPACING GOAL

90 SEC

TARGET ID

UAL1234

TARGET ROUTE

[Empty field]

HOME ARM

Figure 84. A runway must be specified when ARM is cyan and all fields have been populated

In order to EXECUTE the clearance, either the ownship or the target aircraft must be aligned on, or its track within 45° of, the final approach (and the other aircraft must be merging with the approach course). In this case the alert “WAITING MERGE TO FINAL” will appear until the aircraft are properly aligned to course (see Figure 85). The EXECUTE button will not be selectable until the aircraft are in such a position that the merge point can be calculated.

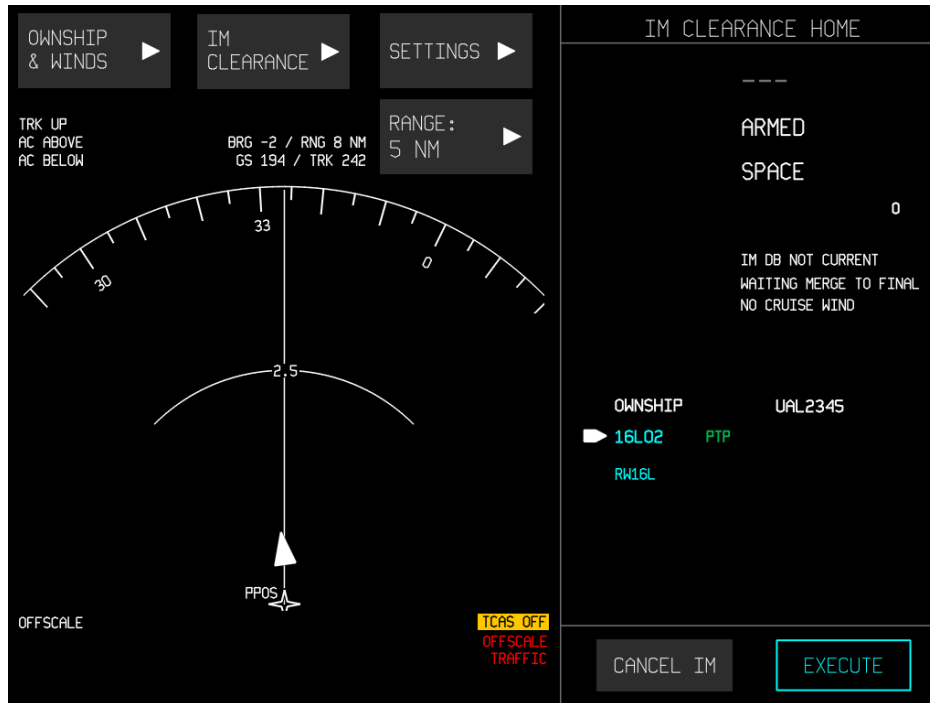


Figure 85. ARMED SPACE clearance, waiting for aircraft to merge/align with approach

5.4 Changing Clearance Parameters

The spacing goal for CROSS, CAPTURE and SPACE clearances may be modified per ATC instruction without suspending the IM clearance. Changing the spacing value can be accomplished by selecting the clearance page, entering the new value, selecting ARM and then EXECUTE. When implementing other clearance changes (such as changing the clearance type from a MAINTAIN to a CAPTURE or CROSS), **the user must first select “CANCEL IM” to suspend the operation**, then select the appropriate clearance page and enter any necessary data, then select ARM and EXECUTE.

If the user fails to cancel the IM before making the change, the software may not properly calibrate the constraints of the new clearance.

If the Target ID and/or Ownship route is changed, previously entered clearance information will be deleted and will need to be reentered. If the Target ID or Ownship route are not changed, other previously entered clearance information such as route and Target ID will be retained. The user must verify all the data is correct before attempting to ARM and EXECUTE the clearance again.

5.5 Speed Commands and Pilot Actions

A pending IM-commanded speed is presented in gray when the IM state is either AVAILABLE or SUSPENDED-AVAILABLE (see Figure 86). The flight crew must press the EXECUTE button to switch the IM state to PAIRED. This will result in display of an active IM speed command in green, as depicted in Figure 87.



Figure 86. Pending speed command during the AVAILABLE state



Figure 87. Speed command during the PAIRED state

When an IM-commanded speed change occurs, the colors of the green text and black background are reversed to provide a salient cue to the flight crew (see Figure 88). The reverse video is maintained until the speed is adjusted accordingly (as measured by the aircraft response via speed conformance monitoring). If the correct speed is not set within 10 seconds,

then the normal and reverse video configuration is alternated (or will blink) at approximately 1 Hz until the aircraft is trending toward the desired target.



Figure 88. IM commanded speed in “reverse video” at top right

The annunciation “AIRCRAFT TOO SLOW” appears in white text below the IM clearance information on the home page if, for example, the flight crew did not notice the speed change in a timely fashion (see Figure 88). This annunciation indicates that ownship speed is more than 0.02 Mach or 10 KTS lower than the IM instantaneous speed. Along with this annunciation, a numerical indication will appear below the speed conformance (FAST/SLOW, NEAR/FAR, or EARLY/LATE) indicator to inform the flight crew how much slower the actual speed is (see Section 5.7, Progress bars).

5.6 IM Speed settings

The IM speed limits and units may be set by selecting IM SPEED under the settings menu (see Figure 89). The + and – buttons adjust the speed setting in increments of 10 KTS or .01 M. As shown in Figure 90, the IM Speed unit selector allows the user to choose whether to display Mach, CAS, or the default setting. Speed settings are described below.

In the CAS setting,

- The default upper limit (in knots) is set to V_{MO} .
- The default lower limit (in knots) is set to the final approach speed.

In the MACH setting,

- The default upper limit (in Mach) is set to M_{MO} .
- The default lower limit (in knots) is set to the final approach speed.

In the DEFAULT setting, the aircraft position relative to crossover altitude will determine the limits in use. When the aircraft is above the crossover altitude, the upper limit in use will be in Mach; when the aircraft is below the crossover altitude, the upper limit in use will be in CAS. The lower limits will always use CAS.

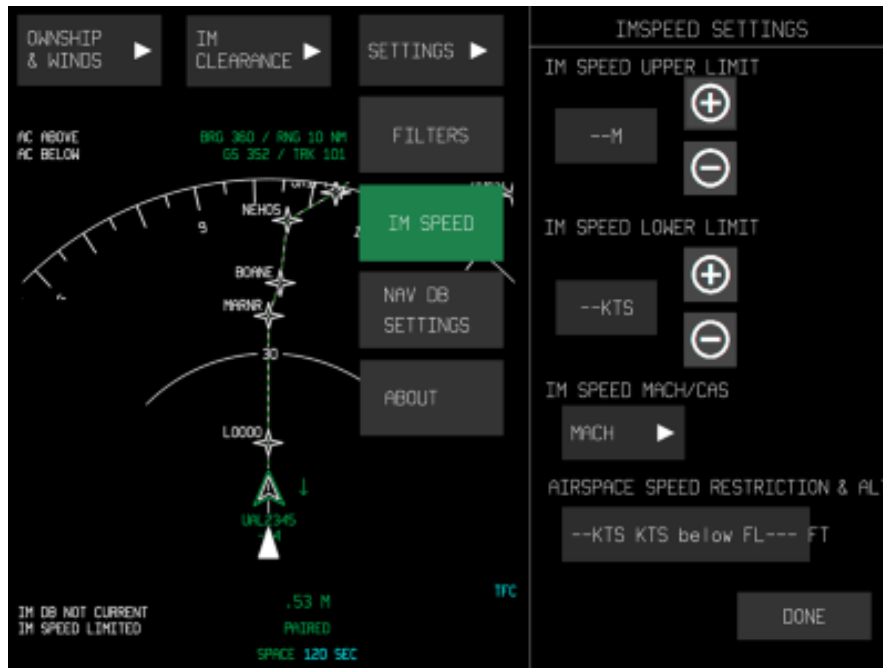


Figure 89. IM SPEED SETTINGS page



Figure 90. IM SPEED unit selection

The AIRSPACE SPEED RESTRICTION & ALT field (see Figure 91) allows the user to set speed restrictions associated with an altitude (e.g., maximum 250 KTS below 10,000 feet). These fields (see Figure 92) are editable by the user. As with other pages, selection of the field opens a keypad which allows the user to enter the restriction parameters.



Figure 91. Selection of airspace speed restriction setting

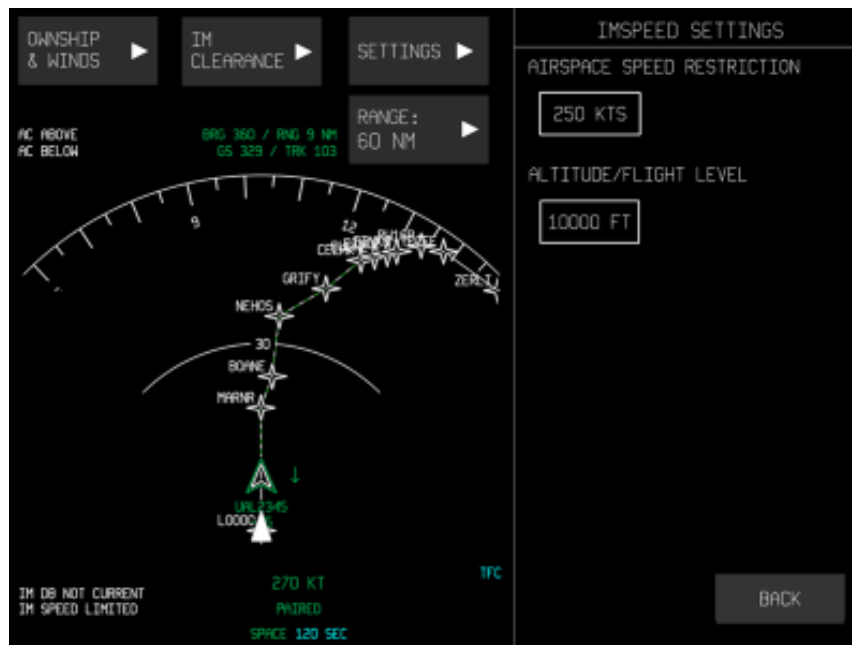


Figure 92. Subpage for setting airspace speed restrictions

5.7 Progress bars

Progress bars located in the upper left of the IM HOME page indicate ownship progress along the cleared procedure. The center of the scale is represented by a green dash.

From 30 nautical miles prior to the Achieve-By Point until the aircraft is within 210 seconds of the Achieve-By Point, the scale of the display is ± 2 minutes, with tick marks at zero, +60 and -60 seconds. The white caliper is located at the current spacing error value and its height is equal to 20 seconds.

From 210 seconds prior to the Achieve-By Point until the Termination Point, the scale is ± 45 seconds with tick marks at +30, +15, 0, -15, and -30 seconds. The caliper is located at the current spacing error value; its height is equal to 20 seconds.

The FAST/SLOW indicator depicts the ownship's speed relative to the IM speed, with deviation (in Figure 93, -15) appearing in CAS. The EARLY/LATE indicator depicts deviation from the assigned spacing goal (when the goal is time-based) at the ABP if the current speed is maintained.

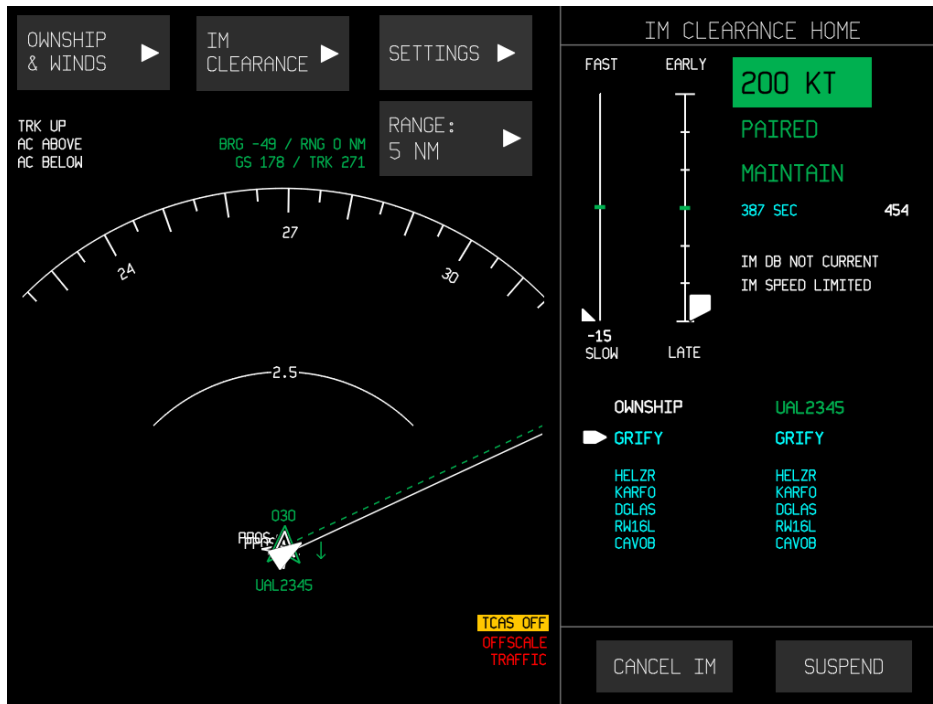


Figure 93. Active MAINTAIN clearance in PAIRED state, illustrating progress bars

Progress towards a distance-based goal would also be illustrated here, and would be indicated by a NEAR/FAR progress bar, as illustrated in Figure 94.

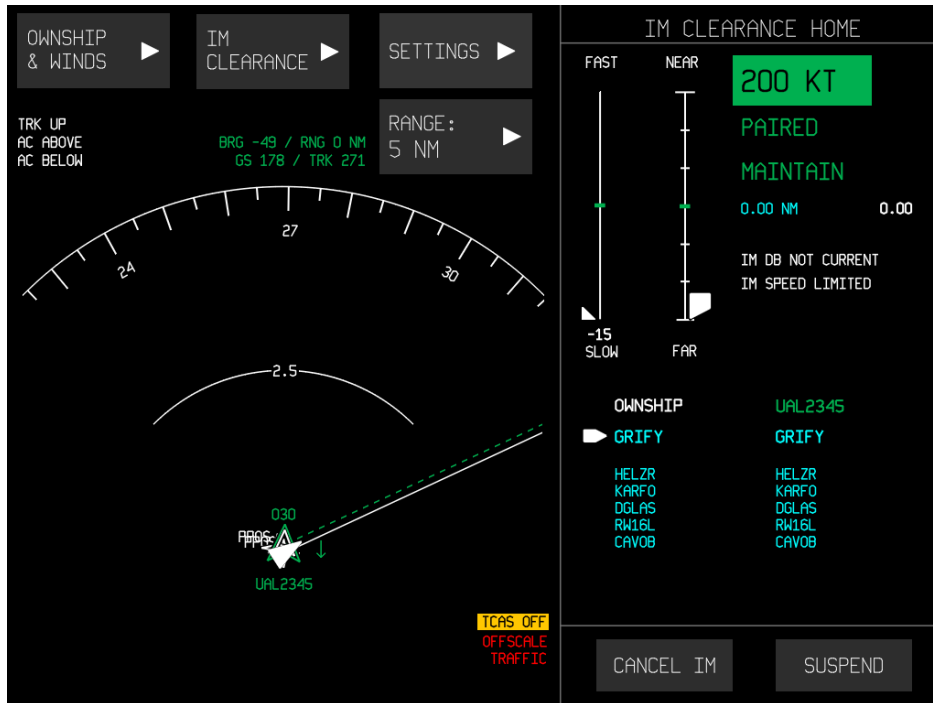


Figure 94. Active MAINTAIN clearance in PAIRED state, illustrating progress bars

5.8 IM CLEARANCE HOME messages

Notifications related to the current FIM operation will appear in the clearance home page below the clearance information. A list of messages that may appear in the clearance frame is presented below:

- NO SURFACE WIND
- NO DESCENT WIND
- IM SPEED LIMITED
- TGT DATA LOST
- TGT OFF ROUTE
- OWNSHIP OFF ROUTE
- TGT BAD ROUTE
- OWNSHIP BAD ROUTE
- MANUALLY SUSPENDED
- WAITING TGT DATA
- WAITING TGT WPT
- WAITING OWN WPT
- IM DB NOT CURRENT
- IM SYS FAIL
- AIRCRAFT TOO SLOW
- AIRCRAFT TOO FAST

5.9 NAV DB Settings

The NAV DB SETTINGS page (see Figure 95) allows the user to load cycle 1 or cycle 2 of the navigation database, and displays the effective date and expiration date of both databases.

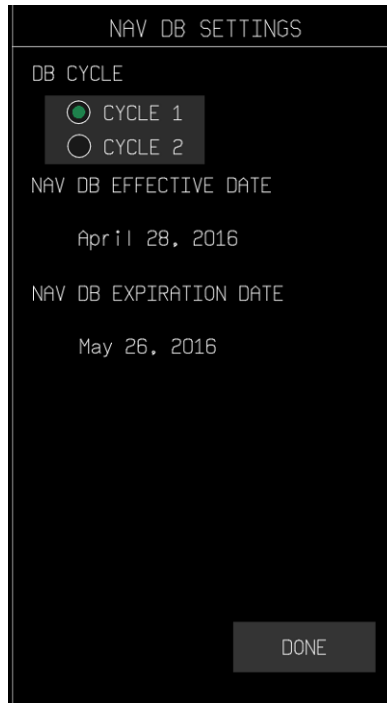


Figure 95. NAV DB SETTINGS subpage

Cycling the navigation database reloads the software. If the user selects a new navigation database, a dialog will display indicating that all entered data will be cleared (see Figure 96).

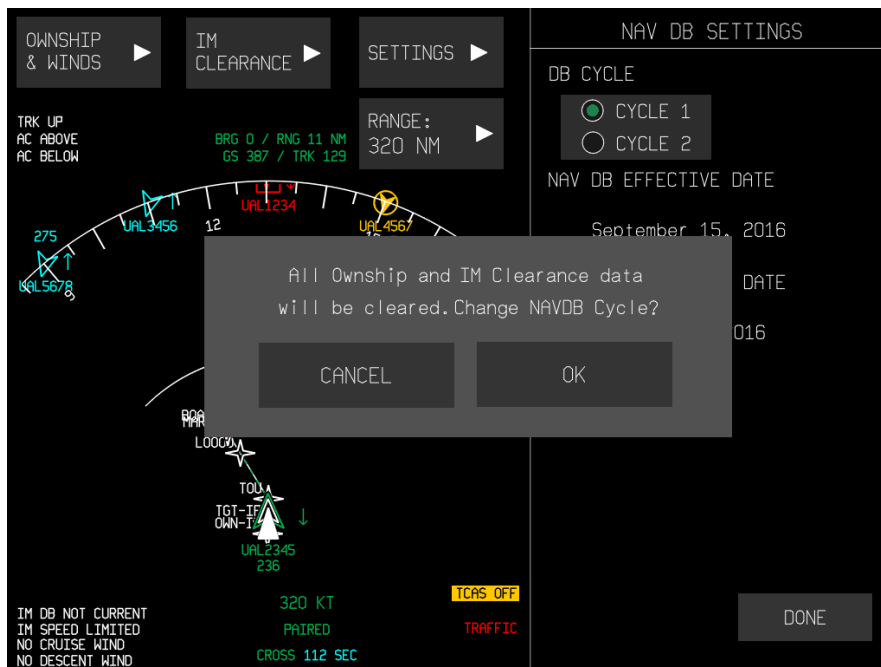


Figure 96. NAV DB cycle update dialog

5.10 About page

The ABOUT page (see Figure 97) provides EFB mode for this device software (Master or Slave) as well as software version information.

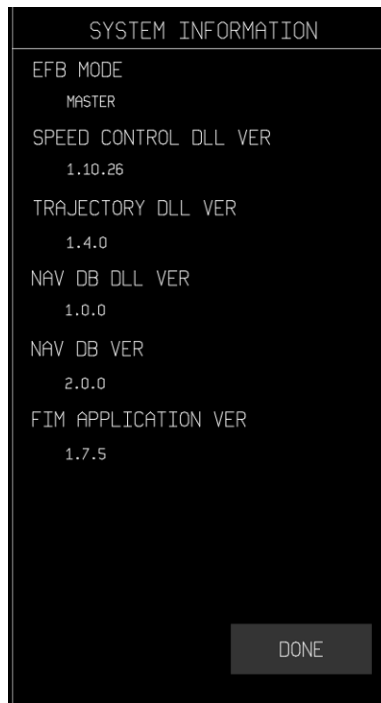


Figure 97. ABOUT subpage

5.11 Predicted Spacing Interval

It should be noted that white values appearing to the right of the spacing goal represent the Predicted Spacing Interval (PSI) of the algorithm, and are used for flight test purposes only to assist in scenario setup.

6 REFERENCES

B. T. Baxley, M. T. (2015). *Cockpit Interfaces, Displays, and Alerting Messages for the Interval Management Alternative Clearances (IMAC) Experiment (NASA/TM-2015-218775)*. Hampton, Virginia: National Aeronautics and Space Administration.

Boeing Company. (2016). *Boeing Air Traffic Management Technology Demonstration – 1 (ATD-1) Phase II, Configurable Graphical Display (CGD) Software Design Description (SDD)*. ATD-1 Deliverable D780-10409-1 Rev A (CDRL 4.4d).

National Aeronautics and Space Administration. (2015). *Air Traffic Technology Demonstration-1 (ATD-1) Flight Deck Interval Management (FIM) System Requirements Document (SRD), Version 2.1*.

7 APPENDIX A – DESIGN HISTORY

This appendix outlines the similarities and differences between the current EFB HMI design and the HMI design outlined in Government-Furnished Information (GFI) document 5.15 (“Cockpit Interfaces, Displays, and Alerting Messages for the Interval Management Alternative Clearances [IMAC] Experiment”, NASA/TM-2015-218775).

Design Principles Similar to the NASA IMAC HMI

- Buttons on multiple pages that perform the same action appear in the same position as much as possible.
- Buttons displayed in the same location as a previously selected button will not result in an irreversible / unrecoverable action.
- Keyboards only appear when a data entry field has been selected (i.e., the field is active) and the field requires a text entry.
- The “Alpha” keyboard design was used to ensure alignment with other aircraft avionics standards.
- The button selection behavior matches that of the Boeing B-777 multi-function display (MFD) button selection behavior.
- Selectable buttons appear as solid-shaded light gray.
- Un-selectable buttons appear in cyan text with a cyan outline.
- Selecting a data entry field that has a value already entered results in navigation to its sub-page, activates the field (i.e., showing a green fill), displays the current value, and places the cursor at the end of the text value.
- The cursor is distinguishable from other text characters, and blinks at 1 Hz (i.e., 0.5 sec visible, 0.5 sec invisible).
- Validation of entered information is performed as soon as the entry or selection of data has been completed (as described above).
- Notification of invalid data is provided immediately.
- Data validity notifications are displayed as a boxed message. When triggered, they result in the page remaining on the same text entry sub-page and with clearing of the text field contents, thus allowing only valid entries to be made.
- If a page change is forced while a validity notification is active, then the responsible data entry field will be cleared of the invalid value.
- Due to space restrictions, “SUSPEND” is used instead of “SUSPENDED” for the IM State label when the system is in either the SUSPENDED-ARMED or SUSPENDED-AVAILABLE states.

Design Principles Different from the NASA IMAC HMI

- There are no soft-key buttons on the EFB bezel with which to make line select-style user

entries.

- The EFB display orientation is horizontal / landscape. Note that no vertical design or capacity to auto rotate display orientation was integrated.
- The EFB's navigation display and a set of page navigation controls are always visible on the left two-thirds of the display. The Home page and other navigable pages are restricted to the right one-third of the display. This arrangement maximizes the visibility of navigation elements and ensures the consistent display of IM data.
- Each text entry is made through a dedicated sub-page. This was judged necessary to allow sufficient space for the keypad to appear as well as to maintain consistency for entries across the HMI. As with the original NASA HMI design, the text entry field is shaded green when it is active (i.e., indicating "currently selected").
- While explicit symbols (e.g., ">") are not used to indicate that a button/touch target will result in a page change, selection of available text entry boxes results in navigation to a sub-page specific to that entry (e.g., CANCEL, BACK and HOME result in page changes as described by the label) on which a keyboard is available to support text entry.

8 APPENDIX B – ATD-1 PROTOTYPE SYSTEM LIMITATIONS

8.1 Operationally Relevant Limitations

Operationally relevant limitations are listed below.

1. IM SYS FAIL displayed on-ground (#2)
 - Description: Aircraft True Track is not valid when aircraft speed is below 20 knots. This is a required parameter for the IM system so IM SYS FAIL message will be displayed at all times when the aircraft is parked or maneuvering on the ground. (This is related to system test issue #2)
 - Pilot action: None - awareness only; to the extent possible engineering will be responsible for ensuring the system is operational before starting each flight test but final GO/NO-GO status of the system may not be confirmed until the aircraft is airborne.
2. Incorrect Control Law running when switching clearances (#203)
 - Description: The FIM system uses two distinct control laws for IM depending on whether it is in an achieve stage or a maintain stage. When switching between a Maintain or Capture clearance and a Cross or Space clearance without explicitly completing or canceling the active clearance, the currently active control law remains running.
 - Pilot action: Always explicitly cancel the active clearance if it hasn't already terminated before entering a new clearance.
3. Procedural Speed Limits not always enforced in the absence of speed change commands (#232)
 - Description: The Constant Time Delay control law (CTD) may not always be respecting the +/-15% speed limits. This can happen when the aircraft is flying a clearance and the speed error has been reduced to the point that the control law is providing a steady state command and the aircraft sequences a waypoint with a new speed constraint. The new speed limit won't be checked by the system until the error has built up to the point that a new speed command needs to be issued. (Note that RF leg speed restrictions and the 10,000'/250 knot airspace speed restriction are always checked.)
 - Pilot action: Monitor aircraft speeds against published route speed limits, particularly in the maintain stage.
4. PTP ABP selection At/Before/After Runway not working correctly (#250)
 - Description: The HMI allows entry of a relative distance before or after a named waypoint for the ABP and PTP. The first time a point of this type is entered, the system behaves correctly, but if the function is used again, a software error causes the system to lock up and a power cycle is required to recover.
 - Pilot action: Do not use distance before/after waypoint for either the ABP or PTP

(flight test cards will respect this limitation).

5. HMI can show inconsistent Runway and Flight Path elements (#254)

- Description: If the runway selection is changed after the STAR or Approach is selected, the HMI will show the new runway as selected but will not indicate that this is inconsistent with the rest of the IFPI (Intended Flight Path Information) / Flight Path data field. Note that the trajectory will always be built from the items displayed in the Flight Path data element and is shown correctly in the View as Waypoints dialog box. (The system should probably catch this inconsistently and either pop up a message or clear the Flight Path element when a new runway is selected but that has not been implemented.)
- Pilot action: Always enter IFPI in the order indicated on the flight test cards. For targets of opportunity, be aware that when an approach auto populates the runway field, simply changing the runway field manually is not enough to cause the system to use a different runway. Select “view as waypoints” or observe the route on the CDTI if there is any question about the route in use.

6. Not able to see all STARs associated with an Airport once a runway has been selected.(#256)

- Description: The STARs and Approaches displayed in the IFPI (Intended Flight Path Information) menus are filtered by the runway selected. There is a software error that retains the previously entered runway information even though the field is shown as cleared on the HMI. This effectively hides the STARs and approaches at the selected airport when the runway field is not entered.
- Pilot action: Always select the runway first, before selecting the STAR or approach. (The STARs and approaches at Moses Lake can always be found by this method; it is not know if other airports might have STARs that can't be found because they aren't associated with a runway.)

8.2 Minor Limitations

Minor limitations are listed below.

1. Non IM Eligible Targets can be manually selected (#43)

- Description: Non IM Eligible Target ID's can be manually entered and accepted for a Clearance. Only IM Eligible targets will be in the pick list, but entry of a target that is in the DTIF but not qualified is allowed.
- Pilot action: None – awareness only; CDTI may show traffic that is not IM eligible and those IDs can be manually entered, however the system will not allow the clearance to EXECUTE. (Waiting target data will be displayed.)

2. Traffic not removed upon TCAS failure (#81)

- Description: Upon failure of the TCAS computer or TCAS OFF, the traffic symbols are not being removed from the CDTI. TCAS FAIL and IM SYS FAIL messages will be displayed.

- Pilot action: Do not use CDTI information if TCAS FAIL or IM SYS FAIL is displayed.
3. ABP and PTP entry selection shows waypoints that are not common to TGT and Ownship routes (#104)
 - Description: The menus for ABP and PTP are pre-populated with all waypoints from ownship route, even though only waypoints that are common between ownship and target route are valid selections.
 - Pilot action: Always select ABP and PTP per the flight test cards. For targets of opportunity, always make sure the ABP and PTP are on the common route. (The system will display an error message when attempting to ARM the clearance if the ABP or PTP is not on the common route.)
 4. Default Planned Termination Point insertion (#209)
 - Description: For the SPACE clearance, if the default PTP (6.25 NM before the runway) falls on a turn, the system can not correctly place the PTP on the flight path.
 - Pilot action: None – awareness only; the flight test cases all respect this limitation. For targets of opportunity this could potentially come up depending on the airport and runway selected.
 5. Speed Commands sometimes shown in non-rounded values (#219)
 - Description: Under some conditions, Speed commands are given in “non-rounded” values. The values are actually rounded by 10 knots, but not at even 10 knot boundaries. This only appears at the start of an IM procedure and will clear up after some time.
 - Pilot action: None – awareness only; always entered the displayed commanded speed even if it isn’t a round 10 knot value.
 6. Erratic display of Target Absolute Altitude (#236)
 - Description: Target Absolute Altitude displayed on the CDTI will occasionally oscillate between two values. The average value will be correct, but the instantaneous displayed value may not be smooth.
 - Pilot action: None – awareness only.
 7. When selected PTP does not have a speed constraint, the wrong default is sometime applied (#246)
 - Description: When a route that includes an approach procedure is entered but the PTP is set far upstream of the FAF, a limit of 170 knots is assumed for the PTP. This is not expected and may be an incorrect interpretation of the requirements.
 - Pilot action: None – awareness only; all flight test cases respect this limitation. For targets of opportunity, this could show up if en-route IM procedures are attempted and the IFPI entered includes an approach or runway assignment and the selected PTP doesn’t have any other speed constraints. The symptom would be an unexpectedly low commanded IM speed, but the value would not be lower than the

IM SPEED LOWER LIMIT.

8. Sudden Change in Nominal profile limit during Transition to After PTP (#249)
 - Description: In a distance based achieve stage, when speed control transitions to ground speed matching after the target crosses the PTP, the speed limit based on the nominal profile changes from a value based on ownship's end speed for the current segment to one based on ownship's current position in the segment. Depending on how long the current speed segment is, and what correction is being applied, the commanded IM speed may change more than would normally be expected.
 - Pilot action: None – just be aware that speed commands may change trend after the target aircraft passes the ABP.
9. Default PTP selection when no runway is entered in IFPI (#252)
 - Description: When no runway is present in the IFPI, default PTP selection results in destination airport(last waypoint in IFPI sequence) designated as PTP. Although this is per the program requirement however this requirement may not be consistent with the context of IM operations
 - Pilot action: Always enter the defined PTP from the flight test cards when performing defined flight test cases. When attempting IM against targets of opportunity, always check the PTP. If the DEFAULT selection doesn't give the expected result, manually select another PTP.
 - DEFAULT may be used for CROSS, CAPTURE and MAINTAIN if desired but clearance would have to be terminated manually if the airport ends up as the PTP. (This is consistent with IM ConOps when a clearance is issued with the expectation that the it will superseded later with a new clearance.)
 - For SPACE clearance, DEFAULT is always appropriate because a runway is required.
10. Navigation database cycle dates annunciation (#255)
 - Description: NavDB Effective Date and/or Expiration Data will not be shown correctly for some months (e.g. December) or if the cycle spans the year boundary (e.g. Dec 12 2016 – Jan 4 2017)
 - Pilot action: None – awareness only. (If there are any questions about NavDB dates during the flight test, check with project engineering to make sure the right file is loaded. This should not be a pilot responsibility.)

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

The public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.
PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE (DD-MM-YYYY) 01- 03- 2017		2. REPORT TYPE Contractor Report		3. DATES COVERED (From - To)	
4. TITLE AND SUBTITLE FIM Avionics Operations Manual				5a. CONTRACT NUMBER NNL13AA003B	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Alves, Erin E.				5d. PROJECT NUMBER	
				5e. TASK NUMBER NNL15AB46T	
				5f. WORK UNIT NUMBER 330693.04.10.07.09	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) NASA Langley Research Center Hampton, VA 23681-2199				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) National Aeronautics and Space Administration Washington, DC 20546-0001				10. SPONSOR/MONITOR'S ACRONYM(S) NASA	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S) NASA-CR-2017-219593	
12. DISTRIBUTION/AVAILABILITY STATEMENT Unclassified - Unlimited Subject Category 03 Availability: NASA STI Program (757) 864-9658					
13. SUPPLEMENTARY NOTES Langley Technical Monitor: Denise K. Scarce					
14. ABSTRACT This document describes the operation and use of the FIM Application installed on an EFB. Specifically, this document includes: 1) screen layouts for each page of the interface; 2) step-by-step instructions for data entry, data verification, and input error correction; 3) algorithm state messages and error condition alerting messages; 4) aircraft speed guidance and deviation indications; and 5) graphical display of the spatial relationships between the Ownship aircraft and the Target aircraft.					
15. SUBJECT TERMS ATD-1; Airspace managment; Aviation; Operations manual					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			STI Help Desk (email: help@sti.nasa.gov)
U	U	U	UU	94	19b. TELEPHONE NUMBER (Include area code) (757) 864-9658