Computer Based Instruction is provided at:

http://www.aaainnovate.com/IMAC.html
INSTRUCTIONS TO SUBJECT PILOTS
Interval Management Alternative Clearances
NASA Langley, June - July 2015

Interval Management Pilot Guide

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INTERVAL MANAGEMENT (IM)

DESCRIPTION

Using another aircraft’s precise position, altitude, velocity and route data, pilots are given speed cues to follow that will position their aircraft at a precise time interval from the other aircraft. During the Interval Management Alternative Clearances (IMAC) experiment three alternatives for achieving the desired interval will be explored. The interval can be achieved by simply maintaining the current interval, it can be achieved by capturing the desired interval as quickly as possible or it can be achieved when the pilots aircraft crosses a specific point along the LNAV path. Interval management operations are designed to work under both visual and instrument flight conditions and do not change the pilot’s or the controller’s responsibility for maintaining safe separation. Airspeed prompts will be received from the onboard IM system instead of Air Traffic Control (ATC). The system is designed to maintain within 15% of the charted profile descent speeds.

ABBREVIATIONS & DEFINITIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
</tr>
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<tbody>
<tr>
<td>ADS-B</td>
<td>Automatic Dependent Surveillance – Broadcast</td>
</tr>
<tr>
<td>ADS-R</td>
<td>Automatic Dependent Surveillance – Rebroadcast</td>
</tr>
<tr>
<td>AOC</td>
<td>Airline Operations Control</td>
</tr>
<tr>
<td>ASTAR</td>
<td>Airborne Spacing for Terminal Arrival Routes</td>
</tr>
<tr>
<td>ATC</td>
<td>Air Traffic Control</td>
</tr>
<tr>
<td>Capture Clearance</td>
<td>This clearance is given when the Target aircraft is directly in front of the Ownship on the same arrival and is used to adjust the current interval and is used when the controller wants the IM aircraft to achieve the spacing goal without identifying an achieve-by waypoint. The Ownship will attain the required spacing then maintain that spacing until the Ownship crosses the final approach fix.</td>
</tr>
<tr>
<td>CDTI</td>
<td>Cockpit Display of Traffic Information</td>
</tr>
<tr>
<td>Cross Clearance</td>
<td>This clearance is given when the controllers wants Ownship to achieve the desired interval from the Target aircraft when Ownship crosses a specific point along the arrival route and then maintain that spacing until the termination waypoint. If the achieve-by and terminate waypoints coincide, there is no maintain phase of the IM operation. The Target aircraft and Ownship may be on different arrival routing to the same runway.</td>
</tr>
<tr>
<td>EFB</td>
<td>Electronic Flight Bag</td>
</tr>
<tr>
<td>FAA</td>
<td>Federal Aviation Administration</td>
</tr>
<tr>
<td>FIS-B</td>
<td>Flight Information Services – Broadcast</td>
</tr>
<tr>
<td>IFD</td>
<td>Integration Flight Deck; NASA’s NextGen 737 simulation platform that is used to test, evaluate, and integrate NASA developed technologies into the flight deck in a realistic environment</td>
</tr>
<tr>
<td>IM</td>
<td>Interval Management</td>
</tr>
<tr>
<td>IM Commanded Speed</td>
<td>Commanded Speed that is displayed to the pilot. Pilot flies this speed to meet either an RTA or a spacing interval behind another aircraft</td>
</tr>
<tr>
<td>IM WAYPOINT</td>
<td>Position in space that spacing will occur</td>
</tr>
<tr>
<td>IM GOAL</td>
<td>Spacing Interval in seconds or distance that is to be achieved between aircraft at the IM Waypoint</td>
</tr>
<tr>
<td>LNAV</td>
<td>Lateral Navigation</td>
</tr>
</tbody>
</table>
| Maintain Clearance | This clearance is given when the Target aircraft is directly in front of the Ownship on the
same arrival and the current spacing is acceptable and is used when the controller wants the IMM aircraft to maintain the current spacing interval (in time or distance), as determined by the IM software. The Ownship will maintain current spacing until the Ownship crosses the final approach fix.

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAS</td>
<td>National Airspace System</td>
</tr>
<tr>
<td>NASA</td>
<td>National Aeronautics and Space Administration</td>
</tr>
<tr>
<td>NextGen</td>
<td>FAA’s Next Generation Air Transportation System</td>
</tr>
<tr>
<td>OPD</td>
<td>Optimized Profile Descent; An arrival where aircraft are cleared to descend from cruise altitude to final approach using the most economical power setting at all times</td>
</tr>
<tr>
<td>Ownship</td>
<td>Ownship is used throughout this document to reference the aircraft that is equipped with the IM spacing software and displays. The term Target Aircraft is used to reference the aircraft the Ownship has been assigned to follow.</td>
</tr>
<tr>
<td>Paired Mode</td>
<td>Ownship is receiving valid ADS-B information from Target Aircraft and is actively spacing</td>
</tr>
<tr>
<td>STA</td>
<td>Scheduled Time of Arrival over a waypoint</td>
</tr>
<tr>
<td>Target Aircraft</td>
<td>Target Aircraft is used throughout this document to reference the aircraft the Ownship has been assigned to follow. The Target Aircraft is selected and information about the Target Aircraft is entered into the IM system. Ownship will achieve a desired spacing interval behind this aircraft.</td>
</tr>
<tr>
<td>TIS-B</td>
<td>Traffic Information Services – Broadcast</td>
</tr>
<tr>
<td>VNAV</td>
<td>Vertical Navigation</td>
</tr>
</tbody>
</table>
BACKGROUND

Managing the spacing between aircraft along their arrival path is essential to improving the productivity of individual airports as well as the National Airspace System (NAS). Interval Management (IM) is a new tool help aircraft air traffic controllers manage the spacing between aircraft by delegating spacing tasks to properly equipped aircraft. Assigning spacing intervals to individual aircraft delegates the task of making the multiple speed adjustments needed to achieve the desired spacing. During IM operations pilots will enter the spacing clearance into the onboard avionics and then follow the speed guidance the IM equipment provides. The delegation of speed changes that are needed to achieve a desired spacing, between aircraft, along the arrival path is expected to enable precision spacing between aircraft. Precisely spacing aircraft along the arrival path will increase aircraft separation accuracy and help air traffic controllers ensure safe separation. In addition it will allow controllers to manage traffic without giving multiple speed changes to every aircraft.

Different spacing intervals can be assigned to individual aircraft. This will give ATC another method to help address operational issues such as; runway configuration changes, runway occupancy times, meet wake turbulence separation requirements and weather conditions. In addition to assigning specific intervals to be achieved ATC and also a method for achieving the desired interval. ATC can ask the pilots to simply “Maintain” their current spacing, “Capture” a specific spacing interval in an expeditious manor or achieve the desired spacing interval when the aircraft “Crosses” a specific point along the arrival route.

Interval management (IM) concepts were derived from development activities within the FAA and the global aviation community. IM is designed to facilitate the needs of aircraft operators while providing Air Traffic Controllers with an easier way to manage the sequence and spacing of aircraft into any airport. This is done by providing the flight crew with automated speed guidance to fly during IM operations. By following IM speed guidance precise time intervals can be achieved between successive aircraft on approach.

IM employs a new onboard avionics system that provides speed guidance to the flight crew. This speed guidance is generated by the NASA Langley Airborne Spacing for Terminal Arrival Routes (ASTAR) algorithm. ASTAR uses relatively small speed changes to achieve the desired spacing interval. During the IMAC experiment speed guidance is presented to the aircrew on an auxiliary display located in the forward field-of-view. Speed guidance is also presented on a side mounted Electronic Flight Bag.

Both IM operations and Optimized Profile Descents (OPDs) are part of the FAA’s Next Generation Air Transportation System (NextGen). Many of the NextGen applications will rely on the predictability of an aircraft’s speed and vertical path for separation assurance. To ensure the predictability of vertical paths during IM operations, flight crews will be required to modulate thrust and drag to stay on both the IM speed profile and the OPD vertical path.

During the IMAC experiment, flight crews will fly a charted Optimized Profile Descent (OPD) to an ILS approach or an RNAV RNP approach into Denver International Airport (KDEN) airport while following IM speed guidance. IM avionics and the ASTAR algorithm will be accessed through an Electronic Flight Bag (EFB).
UNDERLYING TECHNOLOGIES

♦ Automatic Dependent Surveillance - Broadcast (ADS-B)

In commercial aviation the basic ADS-B signal is sent out from the aircraft using the same 1090MHZ frequency as TCAS. When a commercial aircraft is equipped with ADS-B the transponder is expected to send, among other things, the aircraft’s registration number, altitude, squawk code and the aircraft’s position. In most cases the aircraft’s position data is to be based on the Global Positioning System (GPS). This basic data is referred to as the aircraft’s “State Data”. It is possible for the transponder to send more data and other ADS-B concepts are being developed to take advantage of an expanded ADS-B data set.

♦ Automatic Dependent Surveillance – Rebroadcast (ADS-R)

Non-commercial aircraft are expected to use a Universal Access Transceiver (UAT) data link to transmit their state data and ground stations will be used to receive data over the UAT data link and rebroadcast that information over the 1090MHz data link used by commercial aircraft. This will enable aircraft equipped with a 1090MHz ADS-B receiver to receive data from aircraft transmitting using the UAT data link.

♦ Traffic Information Services – Broadcast (TIS-B)

Data concerning aircraft that are not equipped with either the UAT or 1090MHz transponder will be obtained using conventional radar. This radar data will be converted into ADS-B message sets and then transmitted from ground stations. Transmission of radar data over the ADS-B data link is known as Traffic Information Services – Broadcast (TIS-B). TIS-B will enable aircraft equipped with a 1090MHz ADS-B receiver to receive data concerning aircraft that are not equipped with an operable ADS-B or UAT.

♦ Flight Information Services – Broadcast (FIS-B)

Flight Information Services-Broadcast (FIS-B) is an automated, digital data link system. The system provides non-control advisory information needed by pilots to operate more safely and efficiently in the National Airspace System and in international airspace. FIS provides pilots with necessary weather graphics and text, Special Use Airspace (SUA) information, Notices to Airmen (NOTAMs), and other information.

♦ Cockpit Display of Traffic Information (CDTI)

Regardless of its source, the display that contains data about the surrounding aircraft is known as the Cockpit Display of Traffic Information or CDTI. The CDTI can include the traffic’s altitude, speed, direction of flight, and call sign.

♦ ASTAR and IM Technologies

IM uses ADS-B, CDTI and a unique algorithm developed at NASA’s Langley Research Center known as Airborne Spacing for Terminal Arrival Routes (ASTAR). ASTAR computes 4-D trajectories for both the ownship and target aircraft, and uses them to compute speed guidance that can be used to achieve a precise time interval behind a target aircraft at a specific geographical location. This speed guidance is based on data from the target aircraft which includes its current state (position, altitude and velocity). The ASTAR algorithm also considers Ownship configuration, stabilized approach criteria, wind profile, and the planned arrival route. If the aircraft is asked to achieve a precise spacing interval behind a lead aircraft at the runway threshold, ASTAR must have knowledge of the target aircraft’s final approach speed along with the previously mentioned information.
EXPERIMENT PURPOSE AND DESCRIPTION

The purpose of this experiment is to explore the various clearance types of the Interval Management system; specifically focusing on the CAPTURE, CROSS, and MAINTAIN clearances. The IM Clearances will be received verbally over the radio and entered into the IM system via an Electronic Flight Bag (EFB). The data elements of the voice clearance will vary dependent on the type of clearance issued. Once valid ADS-B data is received from the target aircraft, the IM system will “pair” with it and the IM Commanded Speed will be displayed. The speed displayed to the pilots will enable the aircraft to achieve the spacing interval stipulated in the clearance type. Interval management operations are designed to work under both visual and instrument flight conditions and do not change the pilot’s or the controller’s responsibility for maintaining safe separation. Airspeed prompts will be received from the onboard IM system instead of ATC. The system is designed to maintain within 15% of the charted profile descent speeds. The assigned spacing interval will meet wake vortex and IFR separation criteria.

CLEARANCES

Maintain Clearance

This clearance will be given when the target aircraft is on the same arrival as you, directly in front of you, and the current spacing is acceptable to the controller. Only the target aircraft callsign is provided in the clearance. You will maintain current spacing until the Ownship crosses the final approach fix.

NASA 07, maintain current spacing behind NASA 06.

Capture Clearance

This clearance will be given when the target aircraft is on the same arrival as you, directly in front of you, but the current spacing is not acceptable to the controller. The target aircraft callsign and required spacing interval in time will be provided in the clearance. You will attain the required spacing then maintain that spacing until Ownship crosses the final approach fix.

NASA 07, for interval spacing, capture 87 seconds behind NASA 06.

Cross Clearance

This clearance is given when the controllers wants Ownship to achieve the desired interval from the Target aircraft when Ownship crosses a specific point along the arrival route and then maintain that spacing until the termination waypoint. If the achieve-by and terminate waypoints coincide, there is no maintain phase of the IM operation. The Target aircraft and Ownship may be on different arrival routing to the same runway.

NASA 07, for interval spacing, cross DYMON 90 seconds behind NASA 06 on the FRENCH 2 arrival.

The merge to the same lateral path behind the target aircraft landing on the same runway may occur at altitude, during descent, or in the terminal area. IM speed guidance is only given until Ownship reaches the FAF. IM operations automatically terminate when Ownship reaches the FAF. Pilots are expected to configure the aircraft with landing flaps and landing airspeed. During IM operations, the separation between aircraft should never be less than the standard separation criteria used today. ATC is still responsible for separation assurance and may discontinue IM spacing if separation is a concern.
Equipment & Avionics

SIMULATORS

The Interval Management experiment will be conducted using the NASA Langley Research Center Integration Flight Deck (IFD), the Development and Test Simulator (DTS), and the Aircraft Simulation for Traffic Operations Research (ASTOR). Refer to the IFD, DTS, and ASTOR Users Guide for more information.

Figure 1 NASA 737NG Integration Flight Deck (IFD)

Figure 2 NASA Development and Test Simulator (DTS)
OVERVIEW OF IMAC IM DISPLAYS AND PAGES

This section describes IM unique displays, and the top-level pages of the EFB and CGD.

IM AVIONICS

Two key pieces of avionics will be used to conduct the IM operation: the Electronic Flight Bag (EFB) and the Configurable Glass Display (CGD). Pilots will use the EFB to enter ownship and target aircraft information. The EFB is also used to activate, suspend, resume, and cancel IM spacing operations. Additionally the EFB displays the IM commanded speed, a Fast/Slow Indicator, information about the IM Clearance, an IM progress indicator and a CDTI showing the location of the target aircraft and all other aircraft transmitting valid ADS-B information.

The CGD is positioned in the forward field of view of each pilot and displays the commanded speed, a fast/slow indicator, and system messages. When the IM commanded speed changes, the pilot will manually set it in the speed window of the Mode Control Panel (MCP).
ELECTRONIC FLIGHT BAG (EFB)

Bezel Buttons and Soft Buttons
The EFB has a series of Bezel buttons that surround the perimeter of the EFB. When a Bezel is collocated with a soft button either button can be used to make a selection. The MENU bezel button always returns the EFB to the MAIN MENU page (not shown). Figure 4 shows the IM HOME page with data entered and speed guidance displayed. Pressing the OWNSHIP & WINDS bezel button or soft-key (L1) causes the OWNSHIP AND WIND ENTRY page to be displayed. Pressing the IM CLRNCE bezel button or soft-key causes the IM Clearance selection page to be displayed. Pressing the FILTERS bezel button or soft-key (R7) causes the FILTER page to be displayed.

BACK (      )
The BACK arrow bezel button (      ) always returns the EFB to the previous page. If information is typed and entered into a data field the information is retained in that data field if the Back arrow is used. If the data had been typed but not entered that data is not retained if the Back arrow is used.

Page Up and Page Down
Page Up and Page Down bezel buttons (PGUP & PGDN) can be used to navigate multiple pages and are intended to align with typical flight management system operations. The IM sub-pages where the Page Up and Page Down function may be needed are:

• Ownership Arrival Route
• Achieve By Point
• Select Target Aircraft
• Target Arrival Route
• Terminate Point

Transfer (XFR)
Pressing the transfer (XFR) bezel button allows pilot to force their EFB to display the same page as the other EFB (that is, pressing the XFR bezel button causes that pilot’s EFB to “pull” the page and data from the other EFB). Once the two EFBs have the same IM page displayed, the pilot not entering information will see data after the other pilot has entered the information.

Enter (ENTER)
The ENTER button is functional for IM procedures and causes the same effect as pressing the ENTER soft-key

Power On (PWR)
The Power On (PWR) bezel button is functional in the IMAC experiment, however it is not used as part of normal flight crew operations (the EFBs were always on).

Pan Keys (lateral and vertical arrows)
The pan keys were not used for any IM page or display.

Zoom Out and Zoom In (minus and plus icons)
Causes the display to zoom out or in in the indicated direction. Available only to view surrounding traffic on the IM HOME page.
IM DISPLAY FILTERS PAGE

The IM Display Filters page (Figure 5) is accessible by pressing the FILTERS button on the IM HOME page (Figure 4). Pressing the IM HOME button on the IM DISPLAY FILTERS page causes the display to return to the IM HOME page. Buttons are active when shown in green and multiple filters can be selected concurrently.

Filter Selection
When a filter is selected to on the button turns green,

Identification and Altitude
Causes the Target aircraft’s identification (callsign) and relative altitude (in thousands of feet) to be displayed on the EFB next to the Target aircraft icon (double chevron). A message is also shown on the IM HOME page immediately below the IM Clearance information to indicate this filter has been selected.

Bearing & Range
Causes the Target aircraft’s absolute bearing (magnetic) and range (nautical miles) to be displayed on the IM HOME page immediately below the IM Clearance information.

Groundspeed and Track
Causes the Target aircraft’s ground speed (knots) and track (magnetic) to be displayed on the IM HOME page immediately below the IM Clearance information.

Target Route
Causes the Target aircraft’s route to be displayed as a series of stars representing the location of each waypoint, and the name of the waypoint immediately next to the star.

Ownship Route
Causes the Ownship aircraft’s route to be displayed as a series of stars representing the location of each waypoint, and the name of the waypoint immediately next to the star.

Merge Waypoint
Causes the location and name of the Merge waypoint to be displayed (CROSS operation only).

Terminate Waypoint
Causes the location and name of the Terminate waypoint to be displayed.

Aircraft Above
All aircraft regardless of altitude is shown on the EFB.

Aircraft Above
limits the aircraft shown to only those within plus 9900 feet to minus 2700 feet of the Ownship aircraft’s altitude. A message “AC ABOVE” is shown on the IM HOME page immediately below the OWNSHIP & WINDS information. This filter cannot be selected simultaneously with the Aircraft Below filter.
Aircraft Below
Limit the aircraft shown to only those within minus 9900 feet to plus 2700 feet of the Ownship aircraft’s altitude. A message “AC BELOW” is shown on the IM HOME page immediately below the OWNSHIP & WINDS information. This filter cannot be selected simultaneously with the Aircraft Above filter.

Aircraft Near Route
This filter was not implemented for IMAC experiment

All Aircraft Identification
Displays the ADS-B transmitted callsign immediately next to all of the aircraft shown on the IM HOME page. A message “ALL AIRCRAFT IDS” is shown on the IM HOME page immediately below the OWNSHIP & WINDS information.

Map Orientation
The filter described below is not depicted in this document.

North Up
Causes the display on the IM HOME page to be shown in North Up instead of Track Up (default setting)
IMAC INTERVAL MANAGEMENT (IM) EFB APPLICATION

There is a large variety of research conducted in the Air traffic Operations Laboratory at NASA Langley and as a result the EFB was designed to support many different functions. The EFB is programmed to open at the Main Menu when the ASTOR is powered up. To access the IMAC IM application from the Main Menu, select the Applications Menu and then select the Interval Management application. This cause the Interval Management Home page to be display on the EFB (Figure 6, Note: Active IM spacing illustrated).

1. Ownship icon
2. Target aircraft icon
3. Commanded Speed: Shows the current speed that is to be entered into the MCP speed window
4. FAST/SLOW indicator
5. EARLY/LATE indicator
6. Status Box: Displays the current mode of the IM equipment. The clearance type is shown in green, all other information shown in white
7. Message Window
8. OWNSHIP & WINDS: Pressing the OWNSHIP & WINDS bezel button or soft-key (L1) causes the OWNSHIP AND WIND ENTRY page to be displayed
9. Ownship clearance
10. IM CLRNCE: Pressing the IM CLRNCE bezel button (R1) or soft-key causes the IM Clearance selection page to be displayed
11. IM clearance
12. CANCLE: Pressing the CANCLE bezel button or soft-key (L7) causes the IM operation to be canceled
13. OWNSHIP & WINDS: Accesses the Ownship route entry page and winds entry page
14. FILTERS: Pressing the FILTERS bezel button or soft-key (R7) causes the FILTERS to be displayed
15. Traffic & Situation Display: Display Information on the Map is controlled by the Filters button

Figure 6: IMAC EFB
**EARLY/LATE Indicator**

The EARLY/LATE indicator provides the flight crew an awareness of their ability to meet the assigned spacing goal within the expected tolerance and is not used to actively control the aircraft. The EARLY/LATE indicator is only presented on the side-mounted EFB. When the aircraft a long way from the Achieve By Point there is a lot of time available to correct for errors in the spacing interval. The ASTAR spacing algorithm avoids making changing to the aircraft’s speed when the aircraft is at a great distance from the Achieve By Point there. This is done to prevent making a change when no speed change is warranted. If the EARLY/LATE indicator is displayed when the aircraft is far from the Achieve By Point and the ASTAR spacing algorithm is not requiring a speed change the EARLY/LATE indicator will drift up and down the scale depending on current wind conditions, the relative position and velocity of both the Ownship and Target aircraft. To prevent the display of these spurious spacing errors and only provide the pilots with meaningful information the EARLY/LATE indicator is not displayed when the aircraft is more than 30 nautical miles from the Achieve By Point. The EARLY/LATE indicator is displayed once the aircraft is within 30 nautical miles from the Achieve By Point and is then removed from the display when the aircraft crosses the Termination Point. As the aircraft approaches the Achieve By Point there is less and less time to correct for a spacing error. To account for the ever-diminishing amount of time to correct for spacing errors and provide the pilots with a meaningful and salient display the scale of the EARLY/LATE indicator changes when the aircraft is within 210 seconds of the Achieve By Point.

When the aircraft is between 30 nautical of the Achieve By Point and more than 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 “bug” is located at the current spacing error value, is a circle with a diameter equal to 20 seconds (left panel of Figure 7). From 210 seconds prior to the Achieve By Point until the Termination Point, the scale is ± 45 seconds with tick marks at zero, +15, +30, -15, and -30 seconds. The “bug” is located at the current spacing error value, is a circle with a diameter equal to 20 seconds (right panel of Figure 7).
Configurable Glass Display (CGD)

During the IMAC experiment the Configurable Glass Display is used to display speed guidance, indications and warnings.

1. Commanded Speed. Displays IM Commanded Speed. When an IM speed change occurs the speed will be highlighted for 10 seconds. If the pilot does not respond within 10 seconds, the commanded speed will blink until the displayed speed is set in the MCP.

2. FAST / SLOW Speed. Displays difference between actual and IM Commanded Airspeed. During deceleration this value may be used to see how closely you are to the desired deceleration rate.

3. FIM Status Indication. Will display CALCULATING, SPACING, or SUSPENDED.

4. Clearance type, Target aircraft callsign and route

5. System Caution and Information Messages

**FAST/SLOW Indicator**

The FAST/Slow indicator displays the relative speeds of both the aircraft’s current speed and the IM instantaneous speed and is used by the pilots to ensure the aircraft’s current speed is in concert with the IM instantaneous speed. The solid white triangle is the aircraft’s current airspeed, and the hollow green triangle is the IM instantaneous speed and displayed as the reference speed (i.e., it remains fixed in the middle of the vertical FAST/SLOW display). The IM instantaneous speed takes the discrete IM command speed, adds compensation for the delay due to pilot recognition and reaction time, then estimates the deceleration rate of the aircraft to produce a smooth and continuous value. The relationship between the aircraft’s current speed and the IM instantaneous speed was chosen to present an intuitive cue to the pilots. When the aircraft’s speed does not match the IM instantaneous speed the pilots are expected to move the throttle in the direction towards the green reference speed in the center of the display. In the example shown in Figure 8, the pilots would pull the throttles aft, which would slow the aircraft and resolve the error calculated by the ASTAR algorithm.

Then panels in Figure 8 represent from left to right 1) an aircraft on speed at 270 knots, 2) an IM speed change to 240 knots occurs and the IM instantaneous speed calculated by the ASTAR algorithm is not yet expecting the aircraft to decelerate, 3) the algorithm is expecting the aircraft to have begun slowing but the aircraft has either not begun or is not slowing quickly enough, and 4) the aircraft is now considerably faster than what the ASTAR algorithm expected, therefore the alerting message AIRCRAFT TOO FAST is also displayed.

**IMAC IM OPERATIONS**

During the IMAC experiment aircraft will perform Interval Management between cruise altitude and the final approach fix (FAF). Once valid ADS-B information is received from the target aircraft, the IM system will provide commanded speeds for the pilot to fly to achieve the desired interval clearance behind the target aircraft.

Once pilots start actively following the IM speed guidance pilot actions are basically the same as they are today. During IM operations speed changes to achieve the ATC desired spacing is provided to the pilots through the onboard avionics instead of receiving speed changes over the radio from ATC. Pilots will fly IM commanded speeds while maintaining the vertical profile to meet all restrictions.
If ATC expects you to fly IM Procedures, they will issue one of the IM clearances. The amount of data required to be entered into the EFB changes depending on what type of IM clearance is issued.

When a MAINTAIN clearance is issued the controller wants the IM aircraft to maintain the current spacing interval (in time or distance) from the Target aircraft, just ahead of the Ownship, on the same route. It is not necessary to enter wind information because Ownship and Target aircraft are proximate to each other and they are on the same arrival and approach procedure. The data elements required to conduct a MAINTAIN clearance include:

- The IM clearance type;
- The interval spacing type;
- The Target aircraft identification.

An example of a controller issued IM maintain clearance is

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

When a CAPTURE (capture and then maintain) clearance is issued the controller wants the IM aircraft to achieve the spacing goal without identifying an achieve-by waypoint. A CAPTURE clearance may be issued when the Target aircraft and Ownship are on different arrivals. The Ownship and wind information is required if the Target is on a different arrival or approach procedure than the Ownship aircraft, and not required if they are on the same procedure. The data elements in the IM capture clearance include:

- The IM clearance type;
- The assigned spacing goal;
- The Target aircraft identification;
- The Target aircraft routing (optional);
- The IM termination waypoint (optional).

An example of a controller issued IM CAPTURE clearance is

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

When a CROSS (achieve and then maintain) clearance is issued the controller wants the IM aircraft to achieve the spacing goal at an achieve-by waypoint, and then maintain that spacing until the termination waypoint. If the achieve-by and terminate waypoints coincide, there is no maintain phase of the IM operation. A CROSS clearance may be issued when the Target aircraft and Ownship are on different arrivals. Ownship and wind information is required if the Target is on a different arrival or approach procedure than the Ownship aircraft, and not required if they are on the same procedure. The data elements in the IM capture clearance include

- The IM clearance type;
- The achieve-by waypoint;
- The assigned spacing goal;
- The Target aircraft identification;
- The Target aircraft routing (optional);
- The IM termination waypoint (optional).

An IM CROSS clearance where the Achieve By Point and Terminate Point are both the default of the Ownship final approach fix (and therefore the controller does not need to issue them) is

- Callsign, for interval spacing, cross FRONZ 120 seconds behind NASA09 on the ANCHR2 arrival.
An IM CROSS clearance where the Achieve By Point and Terminate Point are not the default of the Ownship final approach fix (and therefore the controller does need to issue them) is

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

Each clearance type will contain the required information to conduct the particular IM Clearance. An aircraft is considered paired with a target aircraft once valid ADS-B information from that target aircraft is received, and a commanded airspeed is displayed. Once paired to a target aircraft, the ownship speed is compared to the information known about the target aircraft and an IM commanded speed is generated for the pilot to fly that will achieve the assigned spacing interval. The system is designed for limited airspeed changes and to conform as closely as possible to an Optimized Profile Descent (OPD). At airports saturated with arrival aircraft, the greatest capacity benefits may be realized by having sequences of aircraft operating in IM mode, with each aircraft actively spacing off the aircraft ahead of it.

Speed guidance is displayed on the EFB in the IM Commanded Speed block and is duplicated on the CGD located in the pilot’s forward field of view. The aircraft’s airspeed is controlled by setting the IM Commanded Speed in the MCP speed window. The pilot flying (PF) will fly the arrival and instrument approach on autopilot. The use of the autopilot system reduces pilot workload and allows precise spacing intervals to be established. For a majority of the descent the aircraft will descend in VNAV SPD mode with the throttles in the HOLD mode. To ensure the predictability of vertical paths during IM operations, flight crews will be required to modulate thrust and drag to stay on the IM speed profile and the OPD path. The aircraft will pitch to maintain the speed window’s set speed. Throttles and drag devices will be used to nominally maintain the aircraft within ±400 feet of the VNAV path.

After crossing the FAF, IM speed guidance will be removed from the display and the pilot will configure the aircraft for landing.

**IM PROCEDURES**

**Overview**

1. Program FMC with arrival routing, VNAV descent, and forecast winds. Tune radios
2. Program ownship information into the EFB
3. Program Descent Forecast Winds into EFB
4. Program Spacing Clearance into EFB
5. Program Target Aircraft Callsign into EFB
6. Program Target Aircraft Arrival routing into EFB
7. Activate IM in EFB
8. Fly IM Commanded airspeed on arrival while maintaining VNAV path
9. At FAF configure airplane for landing
DETAILED PROCEDURES

This IM experiment begins near the terminal area of Denver International Airport (KDEN). Your arrival clearance will consist of the STAR and approach you are to fly and an approach. An example is: French 3 RNAV arrival and the RNAV Z approach to 35R

You are expecting a continuous descent from cruise to the runway threshold. LNAV and VNAV will remain engaged until established on final where approach mode will be selected at pilot’s discretion.

The scenario begins at cruise altitude with autopilot and auto throttles engaged. LNAV and VNAV PATH will be active.

1. Verify FMC Route

Program the arrival and approach into the FMC. Tune Navigation radios.

2. Verify Cruise & Descent Speeds

Program the FMC VNAV cruise speed of .80 and descent speed of .80/300.

3. Load Descent Winds

Request and load Forecast Descent Winds in the FMC VNAV Forecast Page.

4. Program EFB With Ownship Information

Ownship information is normally programmed earlier in the flight.
When the EFB is first powered up or when the MENU bezel button is pressed, the NASA EFB MAIN MENU page is displayed (Figure 11). Pressing the NASA APPLICATIONS MENU (L2) bezel button or soft-key causes the list of cockpit-based procedures to be displayed to the flight crew (Figure 12). The Application Menu page displays the available procedures. To access the IMAC IM application Press the INTERVAL MANAGEMENT (L1) bezel button or soft-key causes the IM HOME page to be displayed (Figure 13).

Pressing the OWNSHIP & WINDS bezel button or soft-key (L1) on the IM HOME page causes the OWNSHIP AND WIND ENTRY page to be displayed (Figure 14).
Enter the destination airport by first selecting bezel button or soft-key (L1) and then using a keypad to enter the airport code. Programming the Arrival routing is accomplished by first selecting bezel button or soft-key (L2) on the Ownship and Wind Entry page and then selecting the appropriate arrival routing (Figure 15), approaches and appropriate transitions (Figure 16) form the list. When a selection is made the selected item turns green.

Once all route selections are complete (Figure 17) return to the Ownship & Winds page by pressing the bezel button or soft-key (R8). With the route selection complete the route description will appear on the second line of the ARRIVAL ROUTE soft key at (L2) as see in figure 18.
5. DESCENT FORECAST WINDS

For IM to work efficiently it must have good wind information. This wind forecast will be provided normally by the aircraft’s company and will be at altitudes that have major wind shifts. Proceed to the Descent Forecast Winds page and enter the winds by pressing the bezel button or soft-key (L3). Winds can be loaded manually or loaded automatically by pressing the bezel button or soft-key (R6). Pressing the LOAD DEC FCST WIND bezel button or soft-key (R6) causes 1) the data from the ACARS message to be auto-loaded into the appropriate data fields, 2) the time of the message to be displayed in the page title, 3) activates the next data field (surface wind direction), and 4) causes the keypad to appear for manual data entry (Figure 20). Surface Winds are loaded Manually (Figure 20). Once Ownship data entry is complete return to the IM Home page by bezel button or soft-key (R1) as shown in figure 21.
Figure 22 illustrates the IM HOME page with the Ownship information entered. The three Ownship data elements shown on the IM HOME page are 1) the next waypoint from the flight management system, 2) the arrival procedure, and 3) the instrument procedure.

![Figure 22 IM Home - Ownship Data](image)

### 6. IM CLEARANCE

When ATC issues an IM clearance the clearance will be given by ATC over the radio. The clearance will include the clearance type and the necessary data elements for entry into the EFB. In this example, ATC issues a Cross clearance which will include the following data elements:

- The IM clearance type; = Cross
- The achieve-by waypoint; = FRONZ
- The assigned spacing goal; = 120 Seconds
- The Target aircraft identification; = NASA 68
- The Target aircraft routing (optional); = ANCHR 2 RNAV RNP Z RWY 35R
- The IM termination waypoint (optional).= FRONZ

ATC will issue this Cross clearance using the following phraseology”

‘NASA 12, when able Cross FRONZ 120 seconds behind November Alpha Sierra Alpha 68 who is on the ANCHR 2 RNAV RNP Z RWY 35R Advise when paired behind November Alpha Sierra Alpha 68

The Pilot Not Flying (PNF) will enter the clearance into the EFB using the following steps:
Pressing the IM CLEARANCE bezel button or soft-key (R1) in Figure 22 causes the initial IM CLEARANCE ENTRY page to be shown (Figure 23).

Selection of the Clearance Type is made by first pressing the bezel button or soft-key (L1) and then selecting the appropriate clearance type from the list (Figure 24). In this example selection of the CROSS clearance type is illustrated. Clearance types are listed in alphabetical order. Available clearance types are shown in gray. Pressing the appropriate bezel button or soft-key (L2 for CROSS clearance in this example), causes a page to appear that displays those data elements relative to that clearance type (Figure 25).
Selection of the Achieve By point (Figure 26), Entry of the Spacing Goal (Figure 27) and selection of the Target ID (Figure 28) are accomplished in similar fashion as other date entry fields.

If the desired Target aircraft can not be found in the list of Target Aircraft check to see if it is located on Page 2 or subsequent pages. If the Target aircraft does not appear the Target ID can be entered manually on first pressing the bezel button or soft-key (R7) and using the key pad to enter it (Figure 29).
Once the IM Clearance information is complete (Figure 30) the bezel button or soft-key at (R1) changes to “ARM IM HOME” press it returns to the IM HOME page (Figure 31) and arms the IMAC IM application for Active Speed Guidance.

Figure 31 IM Clearance Data

Figure 30 IM Home – Armed for IM

7. ACTIVE SPEED GUIDANCE

Once the system has received valid ADS-B data from the Target aircraft and the Target aircraft has crossed a constrained waypoint the system becomes available for Execution. With concurrence from both pilots the Execute bezel button or soft-key at (R8) is pressed and the system begins providing active speed guidance.

Figure 33 IM Available

Figure 32 IMAC - Active Spacing
Active speed guidance is also provided in the Forward Field of View on the CGD (Figure 34). When Ownship is “Paired” with the Target aircraft and Speed Guidance becomes active the Pilot Flying (PF) enters the IM Commanded speed into the MCP Speed Window.

When Ownship is Paired ATC must be informed by using the following phraseology”

“NASA12, paired behind NASA 12, Airspeed 200 knots.”

If the correct speed is not set in the MCP within 10 seconds, the normal and reverse video configuration is alternated at approximately 1 Hz on both the CGD (Figure 35) and EFB (Figure 36) until the speed is set in the MCP.
8. INTERVAL MANAGEMENT PROCEDURES

- (PF, PM) Airspeed Requirements
  - Observe and announce IM Speed changes and mode changes on CGD/EFB
    - Speed changes will highlight for 10 seconds than will blink if not set
  - Set IM commanded speed in speed window on MCP
  - Maintain ±10 knots of IM commanded speed during speed changes

  **NOTE:** When IM is active, fly the IM commanded speed and disregard any charted speeds on the arrival. Use the FAST/SLOW indicator for deceleration/acceleration rate guidance.

  - Configure aircraft as necessary to maintain IM commanded speed
  - Airspeed is safe and acceptable to the pilot for current conditions (See non normal below for action)

- (PF, PM) Vertical Path Requirements
  - Verify VNAV SPD is active mode
  - Ensure aircraft starts a descent at Top of Descent (TOD) Point
  - Use drag devices and thrust as necessary to maintain VNAV path within ±400 feet (PF)
  - Monitor that aircraft stays on path and all restrictions will be met

- (PF, PM) Spacing Requirements
  - No Caution messages on EFB (See non normal below for action)
  - Notify ATC when initially spacing behind target aircraft
  - Notify each new ATC check in with “Paired with”
  - Notify ATC if no longer IM spacing

9. Final Segment Interval Management Procedures

- (PF, PM) Configuration and Energy Management
  - Extend Flaps as necessary
  - VNAV PTH will engage at flap extension
  - Maintain least amount of flaps required to maintain IM speed and vertical path

  **NOTE:** IM commanded speed may increase above current flap max speed. Reduction of flaps may be required.

  - When IM commanded speed blanks at the FAF
    - Gear down
    - Target Speed set in MCP Window
    - Configure as necessary to be stable by 1000 feet AGL

- Automation Procedures
  - Aircraft will transition to VNAV PTH when flaps are extended
  - Arm approach mode between 6-2 miles prior to FAF
  - Ensure aircraft will capture both the localizer and glideslope

  **NOTE:** If aircraft is on VNAV PTH profile the aircraft will be on or slightly below glideslope when established on final

  - Set Target Speed in MCP speed window when crossing the FAF and IM Commanded Speed is removed from the EFB and CGD.
Communication

Interval Management spacing commencing
NASA 6: “NASA 6 IS PAIRED BEHIND UNIFORM ALPHA LIMA TWO-FIVE-FOUR. AIRSPEED IS 290 KTS.”
ATC: “NASA 6, ROGER”

ATC might have to suspend interval spacing for a length of time for various reasons. If this would occur, ATC will provide an airspeed for the aircrew to fly. The aircrew should assume that spacing would recommence at a later time.

ATC SUSPENDS the FIM operation
ATC: “NASA 6, SUSPEND INTERVAL SPACING, SLOW TO 230 KNOTS.”
NASA 6: “NASA 6, SUSPEND INTERVAL SPACING, SLOW TO 230 KNOTS.”

ATC RESUMES the FIM operation
ATC: “NASA 6, RESUME INTERVAL SPACING BEHIND UNIFORM ALPHA LIMA TWO-FIVE-FOUR.”
NASA 6: “NASA 6, RESUME INTERVAL SPACING BEHIND UNIFORM ALPHA LIMA TWO-FIVE-FOUR.”

UNABLE Interval Spacing
NASA 6: “NASA 6, UNABLE INTERVAL SPACING DUE TO <reason>”
ATC: “NASA 6, MAINTAIN CURRENT SPEED, ADVISE WHEN ABLE TO INTERVAL SPACE.”

Interval Spacing Available (after reported UNABLE)
NASA 6: “NASA 6, IS ABLE TO INTERVAL SPACE BEHIND UNIFORM ALPHA LIME TWO-FIVE-FOUR”
ATC: “NASA 6, RESUME INTERVAL SPACING BEHIND UNIFORM ALPHA LIME TWO-FIVE-FOUR”
NASA 6: “NASA 6, ROGER, RESUME INTERVAL SPACING BEHIND UNIFORM ALPHA LIME TWO-FIVE-FOUR”

Interval Spacing Amendment
ATC: “NASA 6, AMEND SPACING CLEARANCE, WHEN ABLE SPACE 120 SECONDS BEINF UNIFORM ALPHA LIMA TWO-FIVE-FOUR”
NASA 6: “NASA 6, WHEN ABLE SPACE 120 SECONDS BEINF UNIFORM ALPHA LIMA TWO-FIVE-FOUR”

Terminate Interval Spacing
ATC: “NASA 6, CANCEL INTERVAL SPACING, MAINTAIN CURRENT SPEED”
NASA 6: “ROGER, NASA 6 CANCEL INTERVAL SPACING AND MAINTAIN CURRENT SPEED”
Additional Procedures

The following procedures may be requested by ATC.

AMENDMENT OF SPACING GOAL

ATC may amend the Interval Management Clearance with a new IM STA or IM GOAL.

NASA 6, space 110 SEC behind DAL 877

Press IM GOAL and enter the new value into the system. The other pilot will check the new value after it has been entered.

SUSPEND AND RESUME

ATC may need to suspend Interval Management Spacing for a period of time. If a Suspend instruction is received the aircrew will assume that Interval Management Spacing will resume at a later time.

‘NASA 6, Suspend Interval Spacing and slow 10 knots’

Upon receiving a Suspend Instruction, press the SUSPEND Button on the IM PAGE.

All speeds are removed from the EFB and AGD and SUSPENDED is displayed in the IM Page Status Box. Follow ATC instruction for airspeed.

‘NASA 6, Resume Interval Spacing’

Upon receiving a Resume Instruction, press the RESUME button on the IM Page.

All IM airspeed information is displayed on the EFB and AGD. Follow the IM CMD SPD at this time.

UNABLE SPACING

If the CMD SPD disappears due to a caution, fly current airspeed and advise ATC. ATC will decide on the appropriate action. If ATC instructs, “advise when able to resume spacing,” the crew will monitor the CMD SPD block. If a value returns to the block the aircrew will advise ATC and follow instructions.

“Center, NASA 6, Unable spacing due to target off path”

“NASA 6, Fly current speed, advise when able to resume spacing”

Once CMD SPD returns aircrew reports to ATC:

“NASA 6, is able to space behind DAL 877”

ATC may instruct aircraft to resume spacing:

“NASA 6, resume interval spacing behind DAL 877”
CANCEL SPACING

ATC may cancel the Interval Management Clearance. This may be followed by airspeed/heading instructions or a new IM clearance.

NASA 15, Cancel Interval Spacing

Upon receiving a Cancel Instruction, press the SUSPEND button on the IM Page.

Press the CANCEL IM button to cancel the IM clearance. This will remove all information from all fields. A new clearance will have to be entered to Activate Interval Spacing.

CANCEL SPACING PROCEDURE

Cancel due to crew preference or ATC instruction.

1) Flight crew notifies ATC they are canceling the IM clearance
2) Aircrew cancels spacing on the EFB
3) Flight crew flies the last IM speed until receiving further instructions from ATC
Alerts: Cautions, Advisory and Memos

The IM system and its associated ASTAR algorithm have the following alerts:

Table 1. IM Caution Messages shown on the EFB and CGD

<table>
<thead>
<tr>
<th>Message</th>
<th>Criteria</th>
<th>Pilot Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOO FAST</td>
<td>This flag is set as true when the aircraft is faster than 0.02 Mach or 10 kt above the IM instantaneous speed for more than 10 seconds.</td>
<td>no action</td>
</tr>
<tr>
<td>TOO SLOW</td>
<td>This flag is set as true when the aircraft is slower than 0.02 Mach or 10 kt below the IM instantaneous speed for more than 10 seconds.</td>
<td>no action</td>
</tr>
</tbody>
</table>

Table 2. IM Caution Messages shown only on the EFB

<table>
<thead>
<tr>
<th>Message</th>
<th>Criteria</th>
<th>Pilot Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>IM SYS FAIL</td>
<td>A failure of the IM software or hardware has occurred, or the Ownship data is not valid.</td>
<td>Notify ATC unable to initiate or must terminate the IM operation</td>
</tr>
<tr>
<td>IM DB NOT CURRENT</td>
<td>Navigation database (DB) used by IM system is not current, therefore IM speed will not be calculated. This check occurs when IM application is initially selected (prior to entry of either Ownship data or IM clearance data).</td>
<td>Notify ATC unable to initiate or must terminate the IM operation</td>
</tr>
<tr>
<td>OWNSHIP</td>
<td>An Ownship bad path is detected as true when there is a valid Ownship</td>
<td>Notify ATC unable to initiate or must terminate the IM operation</td>
</tr>
</tbody>
</table>

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Interval Management Alternative Clearances
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### Message Criteria and Pilot Action for IM Advisory Messages

<table>
<thead>
<tr>
<th>Message</th>
<th>Criteria</th>
<th>Pilot Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAD ROUTE</td>
<td>Traffic record, an Ownship route definition exists, but the calculated trajectory is invalid.</td>
<td>Initiate or must terminate the IM operation</td>
</tr>
<tr>
<td>TGT BAD ROUTE</td>
<td>A Target bad route is detected as true when there is a valid Target traffic record, a Target route definition exists, but the calculated trajectory is invalid.</td>
<td>Notify ATC unable to initiate or must terminate the IM operation</td>
</tr>
<tr>
<td>OWNSHIP OFF ROUTE</td>
<td>An Ownship off path error is detected as true when there is a valid Ownship traffic record, the Ownship's calculated trajectory is valid, and the data indicates the Ownship is greater than 2 nautical miles laterally or greater than 8000 feet vertically for the intended flight path. Note: a new Ownship trajectory is calculated once the aircraft is greater than 4000’ vertically from the current trajectory. The OFF ROUTE vertical deviation criteria is triggered when the aircraft is greater than 8000’ from the trajectory required to meet an altitude constrained waypoint.</td>
<td>No action, Update route in IM application if req.; if not able, notify ATC to suspend IM operation</td>
</tr>
<tr>
<td>TGT OFF ROUTE</td>
<td>A Target off path error is detected as true when there is a valid Target traffic record, the traffic's calculated trajectory is valid, and the data indicates the Target is greater than 2 nautical miles laterally or greater than 8000 feet vertically for the intended flight path. Note: a new Target trajectory is calculated once the aircraft is greater than 4000’ vertically from the current trajectory. The OFF ROUTE vertical deviation criteria is triggered when the aircraft is greater than 8000’ from the trajectory required to meet an altitude constrained waypoint.</td>
<td>No action, Notify ATC must suspend IM operation</td>
</tr>
<tr>
<td>TGT DATA LOST</td>
<td>After the presence of a valid ADS-B track file for the Target aircraft, if that track file is subsequently removed (data invalid or no longer received for a longer time period than the Air Traffic Computer allows), the TGT DATA LOST flag is set. If the track file becomes valid again, the message is removed and the IM state changes to SUSPENDED-AVAILABLE.</td>
<td>n/a, Notify ATC must suspend IM operation</td>
</tr>
</tbody>
</table>

**Table 3. IM Advisory Messages shown only on the EFB**

<table>
<thead>
<tr>
<th>Message</th>
<th>Criteria</th>
<th>Pilot Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>OWNSHIP OFF ROUTE</td>
<td>An Ownship off path error is detected as true when there is a valid Ownship traffic record, the Ownship's calculated trajectory is valid, and the data indicates the Ownship is greater than 2 nautical miles laterally or greater than 8000 feet vertically for the intended flight path. Note: a new Ownship trajectory is calculated once the aircraft is greater than 4000’ vertically from the current trajectory. The OFF ROUTE vertical deviation criteria is triggered when the aircraft is greater than 8000’ from the trajectory required to meet an altitude constrained waypoint.</td>
<td>No action, Update route in IM application if req.; if not able, notify ATC to suspend IM operation</td>
</tr>
<tr>
<td>TGT OFF ROUTE</td>
<td>A Target off path error is detected as true when there is a valid Target traffic record, the traffic's calculated trajectory is valid, and the data indicates the Target is greater than 2 nautical miles laterally or greater than 8000 feet vertically for the intended flight path. Note: a new Target trajectory is calculated once the aircraft is greater than 4000’ vertically from the current trajectory. The OFF ROUTE vertical deviation criteria is triggered when the aircraft is greater than 8000’ from the trajectory required to meet an altitude constrained waypoint.</td>
<td>No action, Notify ATC must suspend IM operation</td>
</tr>
<tr>
<td>TGT DATA LOST</td>
<td>After the presence of a valid ADS-B track file for the Target aircraft, if that track file is subsequently removed (data invalid or no longer received for a longer time period than the Air Traffic Computer allows), the TGT DATA LOST flag is set. If the track file becomes valid again, the message is removed and the IM state changes to SUSPENDED-AVAILABLE.</td>
<td>n/a, Notify ATC must suspend IM operation</td>
</tr>
</tbody>
</table>
### SPC GOAL TOO LARGE

The assigned spacing goal cannot be attained, even with the Ownship flying its slowest possible speed profile. This message is triggered when the Infeasibility Flag is true and the Ownship’s current position is closer to the Achieve-By Point than its nominal position by >15% of the distance-to-go. This infeasibility check is performed from IM operation initiation until the Progress Indicator is turned on.

**Pilot Action**

Notify ATC unable to initiate or must terminate the IM operation

### SPC GOAL TOO SMALL

The assigned spacing goal cannot be attained, even with the Ownship flying its fastest possible speed profile. This message is triggered when the Infeasibility Flag is true and the Ownship’s current position is further from the Achieve-By Point than its nominal position by >15% of the distance-to-go. This infeasibility check is performed from IM operation initiation until the Progress Indicator is turned on.

**Pilot Action**

Notify ATC unable to initiate or must terminate the IM operation

### Table 4. IM Informational Messages shown only on the EFB

<table>
<thead>
<tr>
<th>Message</th>
<th>Criteria</th>
<th>Pilot Action</th>
</tr>
</thead>
</table>
| IM SPEED LIMITED | The IM speed limited message is displayed when the IM software calculated speed is being limited by one of the criteria below:  
  - regulatory (i.e., 250 knots or less < 10,000’)  
  - airframe (M\textsubscript{mo}, \text{V\textsubscript{mo}}, maximum speed for flap setting)  
  > 15% difference from the published speed for that segment | none                                                                        |
<p>| NO DESCENT WIND  | No forecast descent wind is entered, either via data comm or manually.   | Enter wind if available       |
| NO SURFACE WIND  | No forecast surface wind is entered.                                      | Enter wind if available       |
| WAITING OWN WPT  | The waiting Ownship waypoint message is displayed when the Ownship aircraft is on the specified route, however has not yet passed a speed constrained waypoint (only relevant during achieve-phase with the trajectory-based algorithm). During an achieve phase, IM speed guidance may be inaccurate prior to crossing the first speed constrained waypoint if the IM application does not have access to the Ownship cruise Mach and Mach to CAS transition. | No action                     |
| WAITING           | The waiting Target waypoint message is displayed when a valid Target is not set. | No action                     |</p>
<table>
<thead>
<tr>
<th>Message</th>
<th>Criteria</th>
<th>Pilot Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>TGT WPT</td>
<td>track file exists and the Target aircraft is on its specified route, however the aircraft has not yet passed a speed-constrained waypoint (only relevant during an achieve-phase when the trajectory-based algorithm is used). During an achieve phase, IM speed guidance may be inaccurate prior to crossing the first speed constrained waypoint if the IM application does not have access to the Target aircraft’s cruise Mach and Mach to CAS transition.</td>
<td>no action</td>
</tr>
<tr>
<td>WAITING TGT DATA</td>
<td>The waiting Target data message is displayed when the no Target data flag is set, which occurs when there has never been ADS-B data received for that aircraft. (This message is different from the TGT DATA LOST message in that IM guidance has not previously occurred.)</td>
<td>no action</td>
</tr>
<tr>
<td>MANUALLY SUSPENDED</td>
<td>Indicates the IM operation was manually suspended by the pilot. This message is retained until the pilot either resumes or terminates the IM operation. That is, the message is still displayed even if the software state changes to Suspended-Armed state (for example, the Target aircraft is off its route). The button to SUSPEND the IM operations (R8) is only visible on the EFB when in the PAIRED state.</td>
<td>none</td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>Alert Level</th>
<th>EICAS Message</th>
<th>Meaning</th>
<th>Pilot Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caution</td>
<td>IM DISENGAGED</td>
<td>Loss of ownship flight path data, failure of the interface between the spacing algorithm and the aircraft avionics, ADS-B receiver failure, or other aircraft avionic failures</td>
<td>Fly Current Airspeed and advise ATC “Unable Spacing due equipment failure”</td>
</tr>
<tr>
<td>Caution</td>
<td>IM TGT OFF PATH</td>
<td>Target aircraft is not on the flight path given by the ATC IM clearance</td>
<td>Fly Current Airspeed and advise ATC “Unable Spacing due to Target off path”</td>
</tr>
<tr>
<td>Caution</td>
<td>IM TGT ADSB LOST</td>
<td>Target aircraft ADS-B information is lost</td>
<td>Fly Current Airspeed and advise ATC “Unable Spacing due to Target ADS-B Loss”</td>
</tr>
<tr>
<td>Caution</td>
<td>IM OWN OFF PATH</td>
<td>Aircraft is greater than 2.5 NM laterally, 6000’ vertically, or 90 degrees of heading from the planned flight path</td>
<td>Fly Current Airspeed and advise ATC “Unable Spacing due to Ownship off path”</td>
</tr>
<tr>
<td>Advisory</td>
<td>IM SPD LIMITED</td>
<td>IM would command a different speed but is limited by the 15% constraint</td>
<td>Advisory only. No crew action.</td>
</tr>
</tbody>
</table>