

September 8, 2014

Ms. Margaret Gilligan
Associate Administrator for Aviation Safety
Federal Aviation Administration
800 Independence Avenue
Washington, DC 20591

Dear Peggy:

At the request of the FAA and Industry the Performance-based Operations Aviation Rulemaking Committee (PARC) has developed recommendations for design considerations for Optimal Profile Descent (OPD) Procedures which are intended to maximize the safety and efficiency of arrival traffic flows. The attached recommendations contain detailed guidance and rationale for each design.

The PARC Vertical Navigation (VNAV) Action Team was assigned these tasks which they completed in August 2014 forwarding recommendations to the PARC Steering Group (SG). The SG reviewed and concurred with the recommendations at their August 22, 2014 meeting.

The recommendations are supported by the PARC SG, and the detailed recommendations are attached. PARC has retained a history of meetings and backup substantiation of conclusions on the PARC website.

The next steps of the VNAV Action Team are to develop recommendations for design consideration for Standard Instrument Departures (SIDs). Once complete, and a recommendation is approved by the PARC Steering Group, we will forward to you. As always, please feel free to contact me with any questions.

Regards,



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Design Considerations for Optimal Profile Descent Procedures

Recommendations from the PARC VNAV Action Team

1 May 2014

Background

Optimal profile descent (OPD) procedures are intended to maximize the safety and efficiency of arrival traffic flows, benefitting operators and airports, while considering noise and carbon emissions, benefitting local communities.

There are also more specific safety and efficiency benefits, such as a reduction in required communications between controllers and flight crews, and reduced time and fuel burn for individual aircraft to complete the procedure.

Each OPD is a unique procedure based on local airspace constraints, historical wind patterns, noise considerations and air traffic de-confliction requirements. However, as more OPDs are implemented nationwide, it is important to develop them with best practices in mind to improve both standardization and safety.

The goal of this document is to capture best practices from the design of successful OPDs. These best practices will ultimately reduce both training and development costs and time. Using these guidelines provides a means, but not the only means, of ensuring a successful OPD project. Some of these guidelines must be followed because collective operational experience has shown them to be limiting factors to flyability and/or safety. Other guidelines should be followed in the spirit of recommended guidance. These guidelines have been developed to supplement existing procedure design criteria for developing OPDs such as FAA Order JO 7100.9E (*Standard Terminal Arrival Program and Procedures*).

In order to maximize the benefits of OPDs, it is necessary to:

- (a) maximize utilization of the OPD by designing it to be flown by most aircraft operating in the National Airspace System (NAS) today, and
- (b) minimize the potential for unintended consequences that could result in decreased safety or decreased utilization of the procedure.

The best practices are based upon a few key principles:

- 1) OPDs are optimized for the overall traffic flow, not for the individual aircraft. While individual aircraft will see time and fuel savings, the overall benefits are maximized when most aircraft obtain some of the benefits by using the procedure most of the time. If an OPD is designed too specifically for certain aircraft, that will limit the number of potential users. Performance characteristics of a variety of aircraft need to be understood and factored into the procedure design.
- 2) Different flight management systems (FMSs) have different levels of lateral and vertical navigation capabilities, even though they meet the required avionics design standards. Some OPDs uncover latent differences between FMS logic. The OPD should be robust to normal variations between FMS boxes. Use of these guidelines will help to mitigate the effects of different FMS boxes.
- 3) Overall workload for both flight crews and controllers should be considered and addressed. There are many sources and types of workload to be considered, such as the workload of programming the FMS, communication workload, and the workload of maintaining positional awareness along the OPD. Positional awareness includes awareness of speed and energy in addition to altitude and lateral position. Task/Workload management includes managing all the steps that need to be completed and managing priorities amongst these tasks (e.g., FMS programming, verification, and monitoring). Workload should be manageable under normal conditions for the procedure.
- 4) Flight crews and controllers should be able to detect whether the planned flight path is being executed as planned, and if not, then get back onto a desired flight path. Again, the procedure must be robust to normal variations, such as changes in the weather or unintended compression in the aircraft spacing. Less common, but necessary, variations such as a change to the procedure clearance in flight should also be manageable.

The guidelines are separated into different aspects of instrument procedure design:

- Lateral Path
- Vertical Path
- Speed
- Transitions
- General

Within each topic, each guidance statement identifies the priority or type of information in the statement.

- **Requirements** are guidance statements that are minimum acceptable practices.
- **Recommendations** describe highly preferred methods or mechanisms. Compliance with recommendations produces a better design, but lack of feasibility may deter some designers from implementing them.
- **Suggestions** are options that should be considered, but may not be appropriate in all circumstances.
- **Tradeoffs** are descriptive because they do not specify a “correct” or “best” solution, in contrast to requirements, recommendations, and suggestions, which are prescriptive to various degrees.

Rationale for the guidance is also provided to explain its motivation and intent. While some procedure designs may require additional input from experts with significant experience in designing and implementing procedures operationally, the rationale provides baseline information and context for typical procedure designs.

Some of the guidance in this document can be traced back to Appendix B (*Standard Terminal Arrival Design*) of FAA’s Order JO 7100.9E (*Standard Terminal Arrival Program and Procedures*). Order JO 7100.9E makes some general assumptions about arrival procedures, including OPDs, which should be highlighted. First STARS must not require automated vertical navigation (Appendix B.1.a (5)). Second, STARS should be developed to accommodate as many different types of aircraft as possible (Appendix B.1.b (1)), as stated above.

Order 7100.9E also makes some general recommendations, which are expanded in this document. These include:

- “Use the minimum number of fixes, turns, and speed or altitude changes necessary to depict the route.” (Appendix B.1.b (4)).
- Section Appendix B.1.b (8), which provides additional guidance for the design of OPDs in particular.
- “Limit the number of altitude and speed requirements to the minimum necessary.” (Appendix B.4.b (4) (a)).

References to these and other specific subsections of Order 7100.9E are called out as appropriate elsewhere in this document. Additional reference documents are listed at the end of this document.

Highlights

Historically, procedures that are simple tend to be safer through reduced controller and pilot workload and ease in flying the procedure. This document has captured the lessons learned from successful OPDs already in use with the essential elements being:

- Use the minimum number of required waypoints.
- Use only fly-by waypoints except as required (e.g., STAR termination waypoint)
- Use a segment and procedure vertical flight-path angle of approximately 2.2 to 2.7 degrees.
- Use aircraft cruise Mach, 280 KIAS above 10,000 feet and 240 KIAS below 10,000 feet.

Using these guidelines provides a means, but not the only means, of ensuring a successful OPD project that maximizes safety and efficiency while considering noise and carbon emissions.

Lateral Path

Requirement(s)

- Related requirements from 7100.9E Appendix B.4.b:
- Fly-by (FB) waypoints must be used, except the last waypoint on a STAR that terminates at a point in space must be coded as a fly-over (FO) waypoint.
 - STARs terminating at an Initial Approach Fix (IAF) or Intermediate Fix (IF) on a Standard Instrument Approach Procedure (SIAP) must end in a fly-by waypoint.
 - When a procedure terminates at an IAF, but vectors may be issued to alternate runways, use a fly-by waypoint.

Recommendations

- The OPD should not extend more than 200 nm from the airport to allow for descent from enroute airspace in varying environmental conditions and to reduce overall complexity.
 - Use the minimum number of waypoints to define the lateral track. Place waypoints only where necessary, for example, at crossing flows, TRACON and ARTCC boundaries, and for route de-confliction.
 - Space waypoints as far apart as possible. The minimum recommended time between waypoints is 90 seconds or greater. Table 1 provides example guidelines for the recommended minimum distance between waypoints.
 - Maximize use of fly-by waypoints and minimize use of fly-over waypoints.
 - If the OPD terminates with a connection to an IAP IAF or IF, the type of waypoint at the last fix (fly-over or fly-by) should match the type of waypoint (fly-over or fly-by) at the start of the approach procedure.
- Related recommendation from 7100.9E Appendix B.4.b (1):
- Design STARs using the fewest number of waypoints (WPs) necessary to depict the route.

Indicated Airspeed (no wind)	Distance traveled in 90 Seconds	Recommended Minimum Distance Between Waypoints
280+ Knots	9.95 NM	10 NM
250 Knots	7.4 NM	8 NM
210 Knots	5.8 NM	6 NM
180 Knots	4.75 NM	5 NM

Table 1 – Example Guidelines for Recommended Minimum Distances Between Waypoints

Tradeoff(s)

Flight crews prefer to have fewer waypoints along the procedure to reduce their workload, but air traffic may prefer to have more waypoints so that they can be sure the aircraft is following the correct path. The number of waypoints along the path may have to be balanced between air traffic needs and flight crew needs.

Rationale

Lateral Extent of OPD

Limiting the lateral extent of the OPD allows crews more time to prepare for the arrival and allows more flexibility for Air Traffic. In addition, OPDs that are too long can result in aeronautical charts that require

additional space, such as a bi-fold or tri-fold pages, which are difficult to use on the flight deck, whether they are in paper or electronic format on an Electronic Flight Bag. Finally, crews can stay more focused on completing the OPD if it is not too long. Long procedures could result in pilot complacency. OPD briefings will also be fresher in the pilot's mind if the procedure is not too long.

Number of Waypoints

Additional waypoints are discouraged for a variety of reasons. First, using a minimum of waypoints will reduce flight crew workload because crews are responsible for verifying that each waypoint is correctly depicted in the FMS and that speed and altitude constraints at the waypoints are met. Second, excessive numbers of waypoints have resulted in some FMSs becoming overloaded and losing all FMS navigation capability until reprogrammed by the pilot, creating additional crew workload. Also, drawing many waypoints can sometimes require special graphical techniques such as split sections on the page or insets, even on a single chart page or image. Pilots may find it difficult to follow the procedure across the sections of the chart.

Waypoint Spacing

Waypoint spacing affects pilot workload. When waypoints are too close together, and the crew has to verify that each waypoint is passed appropriately, the crew lacks time for other necessary tasks, such as completing necessary checklists without interruption. The net result may be that either the waypoint review or the other necessary tasks are not completed.

Closely spaced waypoints can also create visual clutter on the aeronautical chart, making it difficult for pilots to read and use the chart. (See Volpe Center reports listed in References).

Greater waypoint spacing is helpful for achieving both lateral and vertical compliance with the procedure.

Additional guidance on segment lengths for performance based navigation (PBN) instrument procedures is provided in FAA Order 8260.58.

Fly-By versus Fly-Over Waypoints

Use of fly-by waypoints makes the procedure less vulnerable to variations in FMS equipment performance and provides the controller with more options for rejoining the path from a different point. Some FMS equipment deletes the fly-over requirement if it is rejoining the path from a point that is not along the defined path.

In order to ensure a smooth transition from the STAR to the IAP, the types of waypoints at the end of the STAR and beginning of the IAP should match; either they should both be fly-over waypoints or fly-by waypoints.

Evaluation

- Does the OPD extend any further than 200 NM from the airport? If yes, can the OPD be shortened?
- Are there any waypoints that could be removed without significant impact to the safety and efficiency of the procedure? If yes, are there any barriers to deleting the waypoints and can they be overcome?
- Are there any waypoints that are closer than 90 seconds apart at the speeds in Table 1? If yes, can these waypoints be separated further?
- Is there a fly-over waypoint at any location other than the termination of the STAR at a point in space? If yes, can it be replaced with a fly-by waypoint?
- Does the last fix on the STAR match the type of fix at the beginning of the approach (fly-over or fly-by)?

Vertical Path

Requirement(s)

- Altitude restrictions must be chosen such there exists a vertical flight-path angle solution between 2.0 and 3.0 degrees for a given landing direction for the entirety of the procedure. See figures below.
- The vertical flight-path angle for each individual path segment between two waypoints with constraints on the OPD may be less than 2.0 degrees but not greater than 3.0 degrees for a given landing direction.

Recommendations

- Use a minimum number of altitude constraints to define the vertical profile.
- The initial vertical constraint should be at the lowest possible altitude, ideally no higher than the low FL200s to provide the best FMS performance for vertical path calculation and compliance.
- First preference is to use “at-or-above” altitude constraints.
- Second preference is to use mandatory block (window) altitude constraints.
- Third preference is to use mandatory altitude constraints.
- At-or-below constraints should be avoided.
- The vertical path should generally be within a 2.2 – 2.7 degree flight-path angle from the runway touchdown zone or the lowest altitude constraint on the OPD.
The vertical flight-path angle in the terminal airspace should be on the lower end of this range to alleviate the impact of speed reductions. The flight-path angle may be higher in the enroute airspace. The range will vary based on terrain, historical winds, the location of Special Activity Airspace (SAA), required procedural separation, etc.
- If the OPD terminates with a connection to an IAP IAF or IF, the altitude restriction at the last fix should match any altitude restriction at the start of the approach procedure. Otherwise, the altitude restriction at the last fix should be a mandatory “at” altitude restriction.

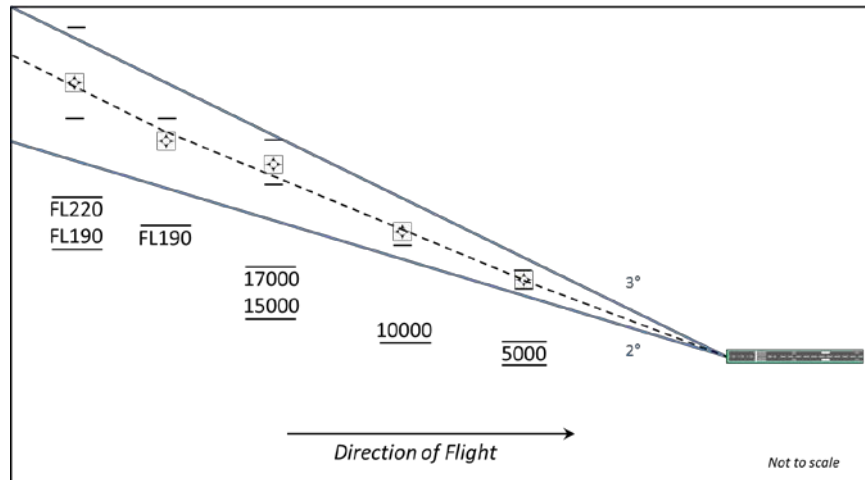
Related recommendation from 7100.9E Appendix B.1.a (7) d:

- The STAR termination fix attitude must be the same as that published on the SIAP.

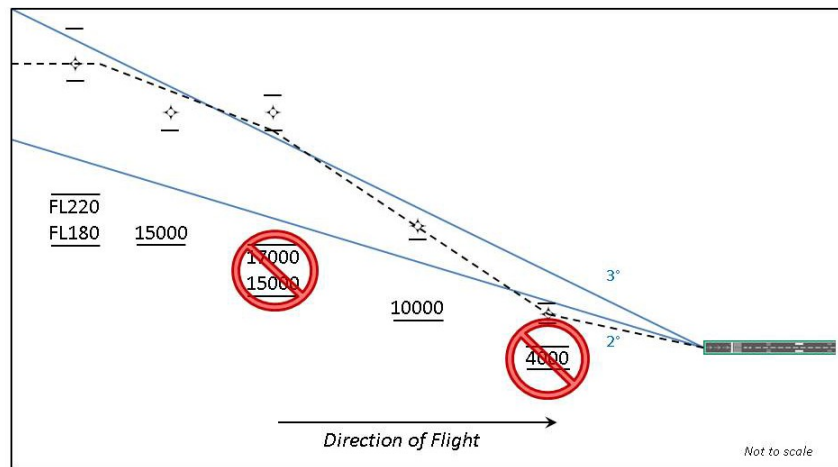
Related recommendation from 7100.9E Appendix B.4.b (4) (a):

- Limit the number of altitude and speed requirements to the minimum necessary. Limit the use of both “at or above” and “at or below” restrictions on a STAR to avoid complexity and confusion.

Related recommendations in 7100.9E Appendix B.4.e provide guidance on descent gradients and deceleration segments



Example: Procedure restrictions that permit a flyable solution between 2° and 3° descent path angle.



Example: Procedure restrictions that do not permit a flyable solution between 2° and 3° descent path angle.

Rationale

Vertical Flight-Path Angles

The vertical flight-path angle requirements and recommendations provided here are used to design the procedure. They were constructed to allow a majority of aircraft to comply with the vertical path. The flight-path angle that the aircraft flies may be different and is not specified.

The recommended envelope of vertical flight-path angles should be used in most cases. The required envelope of vertical flight-path angles should be sufficient for all cases. If there are only at-or-above altitude constraints, then only the lower boundary of the vertical flight-path angle guidance applies.

Flight-path angles outside the recommended (or required) envelopes could reduce the number and types of aircraft that are able to comply with the procedure. If the envelope is tightened, some aircraft could not comply because they need a steeper vertical flight-path angle, especially under head wind conditions (which have slower ground speeds and later tops-of-descent). If the envelope is expanded, the vertical flight angles used in the procedure design may be too steep for some aircraft to fly, especially if there are no head winds (when ground speed may be relatively higher and a shallower flight-path angles would be needed).

Vertical flight-path angles that are outside of the aircraft's performance range can require either above-idle thrust or use of drag devices such as speed brakes. Although pilots can manage these situations effectively, there are negative consequences in terms of fuel inefficiency (with increased thrust) and pilot workload (in terms of using manually deployed speed brakes). In addition, increased thrust increases noise and carbon emissions while drag devices increase airframe buffet and passenger discomfort. These conditions are indicative of procedures that may be unstable for landing.

The actual vertical flight-path angle selected for the procedure will be based upon historical winds as well as the other factors mentioned above. For example, if the area historically has a pattern of tail winds, the procedure design flight-path angle will take this into account. This may mean that the procedure is more difficult for the pilot to manage when unusual wind conditions are present (such as excessive tail winds or a head wind).

It is important to ensure that as many aircraft as possible can fly the procedure, not only to increase procedure utilization, but also because there is no mechanism to communicate to the crew whether the procedure design will be at the edge of that aircraft's capabilities. It is important that the crew be able to depend upon the aircraft and FMS to be capable of flying a procedure that they are assigned because it is difficult for the crew to make that assessment in real time.

The requirements and recommendations for vertical flight-path angles do not imply that it is the basis for flight crew tracking. In other words, crews should not be required to fly specified vertical flight-path angles.

Number of Altitude Constraints

As stated in Order 7100.9E, the number of altitude requirements should be limited to the minimum necessary (Appendix B.4.b (4) (a)).

Numerous altitude constraints in sequence may be problematic because they can have different effects on vertical performance from different FMSs and can therefore significantly increase pilot and controller workload. Excessive altitude constraints, especially those that result in a sequence of differing types of altitude constraints can prove problematic. For example, consecutive "at-or-below" altitude constraints have been shown to prove challenging for aircraft with limited VNAV capability.

As mentioned in Order 7100.9E (Appendix B.1.a (5)), automated vertical navigation is not a requirement to comply with an OPD. Pilots may be operating aircraft without auto-throttles and without vertical guidance coupled to the autopilot system. Excessive altitude constraints are challenging for these pilots with limited or no vertical guidance. The pilot's mental workload is high because he/she must mentally calculate whether each altitude and speed constraint will be met.

Charting of numerous altitude constraints can also be problematic, especially when the constraints are closely spaced. For example, it may be difficult to identify which constraint applies to which waypoint, or the constraint may have to be drawn far from the waypoint (connected by a long leader line, again increasing error potential).

Priorities amongst Types of Altitude Constraints

Use of "at-or-above" altitude constraints allows the most flexibility to optimize the individual aircraft performance, even for aircraft without vertical navigation flight guidance. Note, however, that some older FMSs treat "at-or-above" altitude constraints as an "at" constraint, so some of the flexibility in the procedure design could be lost in the FMS's interpretation of the constraint.

Window altitude constraints are useful for when path definition is needed and flexibility is still achievable. However, there are some downsides to this flexibility. For example, crews may be less aware of their altitude as they pass through a window constraint, and they may not be able to predict whether downstream constraints will be met with difficulty or ease based on the aircraft altitude through the window. The computed target crossing altitudes will change based upon variables such as weather and aircraft weight, so they will vary each time the procedure is flown, so crews will not be able to learn or anticipate what the target crossing altitudes should be, limiting their ability to cross check the automated systems. When flying without vertical navigation capabilities, crews may be confused about the optimal altitude at which to cross the window. Intuitively, pilots may prefer to cross in the middle of the window constraint, but the FMS vertical guidance may choose to fly at the high or low end of the window, possibly confusing the pilot. In addition, FMSs handle windows differently, some more effectively than others. Window constraints should not be used at the last fix on a STAR since some FMS VNAV

systems default to crossing the fix at the higher, “at or below” element of the constraint, which could result in the aircraft being excessively high at the end of the STAR.

Mandatory “at” restrictions may produce a “dive and drive” behavior that can result in a non-optimal descent. Unless necessary, mandatory altitudes should only be used at the last fix on the STAR. A mandatory “at” restriction may be desirable at the last fix on the STAR when the STAR does not connect to the IAP (e.g. the fix is followed by a “vector-to-manual termination” VM leg) to support the computation of the VNAV path by some FMSs.

At or below constraints should be avoided because they have proven challenging for aircraft with limited VNAV capability. “At or below” constraints may be handled by the FMS such that the minimum enroute altitude (MEA) is exceeded because the FMS is not aware of the MEA and is not required to honor it today. This may be especially problematic when there are tail winds. There is also a risk of additional mental workload for the crew if there are consecutive “at or below” constraints. If there is a need for an “at or below” constraint, a window constraint should be considered instead, where the top of the window is the top of the “at or below” altitude.

Initial Vertical Constraint

Having the initial vertical constraint for the OPD in the low FL200’s provides the best FMS performance for vertical path calculation and compliance. It also allows more path flexibility at higher altitudes.

Matching Altitude Constraints Between STAR and IAP

In order to ensure a smooth transition from the STAR to the IAP, any altitude constraint at the end of the STAR and beginning of the IAP should match.

Evaluation

- Are the vertical flight-path angles, for each segment of the OPD and for the entire OPD, within the recommended and required parameters?
- At what altitude is the first vertical constraint? If it above about FL250, could it be lowered?
- Are there any altitude constraints that could be removed without significant impact to the safety and efficiency of the procedure? If yes, are there any barriers to deleting the altitude constraint and can they be overcome?
- Are there altitude constraints that could be adjusted to improve the safety and efficiency of the procedure? If yes, what are the barriers to changing the altitude constraint and can they be overcome?
- Are there any “at-or-below” altitude constraints? If yes, can these be eliminated or changed to a different type of altitude constraint?
- If there is an altitude constraint on the last point of the STAR, does it match any altitude constraint on the adjoining approach procedures?
- If the STAR does not connect to an adjoining approach, is the altitude constraint at the last fix a mandatory “at” altitude?

Speed

Recommendation(s)

- Use the minimum number of published speed constraints. Use speed constraints only as required to help eliminate aircraft compression or to help with traffic management in approach sequencing.
 - When necessary, use “at” airspeed published constraints at the lowest possible altitude to allow for more flexible aircraft energy management on the OPD.
 - Avoid use of published speed constraints above FL200.
 - The Mach transition point should not be coded in the navigation database using a dedicated waypoint. If a specific Mach transition is desired, use the following chart note:

“Turbojet aircraft descend via Mach number until intercepting 280 KIAS. Maintain 280 KIAS until slowed by the STAR.”
 - After the Mach transition, do not exceed 280 KIAS (knots indicated airspeed) until first STAR speed restriction. For waypoint speed constraints below 10,000 feet MSL, use 240 KIAS.
 - If the OPD terminates with a connection to an IAP IAF or IF, the published speed restriction at the last fix should match any published speed restriction at the start of the approach procedure.
- Related recommendation from 7100.9E Appendix B.1.a (7) e:
- Ensure consistency between speeds/altitudes for shared fixes.
- Related recommendation from 7100.9E Appendix B.1.a (9):
- When necessary to manage speed compression, establish speed restrictions to assist managing deceleration or descent speeds. Limit speed restrictions to one per fix per STAR segment.

Note: Facilities utilizing Trajectory Based Management tools that recommend aircraft speeds for spacing (e.g., TSS or TBFM) may exercise some latitude in applying the guidelines when these tools are in use because charted speed restrictions may not be in agreement with the tool-based suggestions.

Rationale*Number of Speed Constraints*

Consistent speeds are necessary to assist ATC in managing compression in the spacing between aircraft. However, as stated in Order 7100.9E, the number of speed requirements should be limited to the minimum necessary (Appendix B.4.b (4) (a)). Managing speed and energy during descents can be challenging for both the FMS and the crew.

Speed constraints can increase crew workload because crews need to be especially aware of the speed and energy state of the aircraft, they need to be aware of how the FMS is handling the speed constraints, and they may need to execute timely manual interventions if the FMS is not handling the speed restriction as intended.

Managing speed constraints requires crews to be especially familiar with how the FMS works. They need to know whether to intervene, how, and when. For example, some FMSs treat a speed restriction as an at-or-below speed, which may not comply with the procedure design. In other cases, the FMSs cannot handle a speed restriction without a corresponding altitude constraint. Crews may have to add an artificial altitude constraint to get the FMS to comply with the speed constraint. FMSs also prioritize between meeting speed and altitude constraints, and they may do this differently. In some cases, the pilot may need to override the cost index in order to meet a mandatory speed constraint.

Pilots also need to maintain awareness of where the speed constraints apply. The charted location of speed constraints appears to be inconsistent; sometimes the speed restriction is shown near the point at which it applies, other times it is a note written elsewhere on the chart. Sometimes the speed restriction is shown at point, but downstream, the crew may not recall that the constraint is still in effect.

Where to Place Speed Constraints

Speed constraints on descending flight path can be especially challenging. For example, manual deployment of speed brakes may be necessary to meet the speed constraint. Even if the FMS notifies the crew that this action is needed, crews may miss the notice. This can lead to the crew not noticing that the FMS switches modes, from VNAV PATH to VNAV SPEED, setting the crew up for potential future errors.

Ideally, an OPD should allow aircraft to fly from cruise Mach to 280 KIAS and then to decelerate to 240 KIAS below 10,000 feet MSL and to meet any subsequent speed constraint without the specific use of additional drag devices such as speed brakes.

Having no speed constraints for the OPD above the low FL200's allows more path flexibility at higher altitudes.

Mach Transition

The recommended speed of 280 KIAS balances fuel economy with the timing needs of Air Traffic.

Speeds Constraints Below 10,000 ft

Below 10,000 ft, the recommended constraint is 240 KIAS because some aircraft FMSs default to that speed at those altitudes.

Evaluation

- How many speed constraints are placed on the procedure? Can any speed constraints be eliminated? What are the barriers to removing the speed constraint?
- If there is a speed constraint on the last point of the STAR, does it match any altitude constraint on the adjoining approach procedures?
- Are the recommended transition speeds of 280 KIAS and 240 KIAS used as described? If other speeds were chosen, can they be changed to the recommended speeds?

Transitions

Recommendations

Related recommendations from 7100.9E Appendix B.1.c (4):

- Include runway transitions where operationally beneficial. Avoid a radar transition to one airport and a runway transition to another airport from the same fix.
- All runways served by the STAR must be coded when developing runway transitions. For seldom used runways, consider developing RNAV procedures that end with a radar vector.
- Evaluate use of approach transitions in place of runway transitions if operationally feasible and beneficial.

Related recommendation from 7100.9E Appendix B.4.b (4) (c):

- Fixes on the procedure can only have one speed and altitude restriction per fix. Do not allow a fix to have multiple speed or altitude restrictions.

Related recommendation from 7100.9E Appendix B.4.a (3):

- Runway transitions are segments of the STAR from the last fix/waypoint of the common route or common point and ending at a termination point for radar vectors or a fix/waypoint on an instrument approach procedure. If required runway transitions should be developed to all instrument runways. Consideration must be given to the requirement for ATC to assign the runway a minimum of 10 nautical miles (NM) prior to the beginning of the runway transition(s).

Suggestion

The use of OPDs that are specific to a landing direction is discouraged. Procedures should have transitions that allow access to multiple arrival runways.

Ideally, all OPDs should terminate with a transition to allow a seamless lateral track from STAR to the approach, rather than terminating in vector legs.

Tradeoffs

Changing enroute or runway transitions in flight may create workload and confusion for flight crews. These types of changes should be infrequent, and should occur with as much lead time for the crew as possible.

Procedure designers may prefer to combine several transitions into one procedure, which may reduce the number of chart images. However, this can create chart clutter and difficulty in using the chart to obtain required information quickly. (See Volpe Center reports in References.)

When designing transitions, keep their relative lengths in mind. Some chart manufacturers draw STARs to-scale, while others do not. If the STAR is drawn to-scale, a transition that is much longer than other transitions may have to be drawn differently (e.g., not-to-scale). If the STAR is drawn not-to-scale, the relative lengths of the transitions will not be readily apparent based on the graphic depiction, so crews may not realize how long the transitions are.

Rationale

Procedures associated with a specific to a landing direction can increase both controller and pilot workload if and when the airport runway configuration in use changes.

OPDs that terminate in vector legs could increase both flight crew and controller workload. Vector legs also require the flight crew to make multiple flight guidance roll-mode changes, which increases the potential for error.

Vectors may be necessary for seldom-used runways as described in 7100.9E Appendix B.1.c (4) (a) above.

Evaluation

- Are vector transitions only used when going to seldom used runways?
- How many transitions are there? Can they all be depicted clearly without excessive clutter and use of special graphical techniques (such as insets)?

General Procedure Design

Recommendation(s)

- Where possible, renegotiate or reevaluate airspace constraints between facilities to improve the procedure design across facilities.
- Some OPDs benefit from having runway assignments far from the airport, while the aircraft is still in the ARTCC airspace. This may be a new process that will require coordination among air traffic control facilities.

Tradeoff(s)

Flight crews prefer to have fewer instrument procedure options for the airspace, but air traffic may prefer to have more procedure options.

Crews are responsible for reviewing and following the procedure, but if the procedure changes mid-flight, this creates workload and could create confusion for flight crews.

Instrument procedures must be designed around external constraints, such as special activity airspace. The external constraint may or may not be dynamic and it may or may not be negotiable. When designing around external constraints, it is useful to verify whether the constraint is negotiable, rather than to assume that it is not.

The number of OPD procedures must balance the need to maximize efficiency with the need to manage air traffic. For example, directional OPDs will require ATC to reissue clearances to all aircraft if an airport changes runway configurations even on a temporary basis, which can be a significant controller workload.

Rationale

Sometimes the design of an OPD is constrained by pre-existing air traffic facility or sector boundaries. These constraints may create, for example, additional waypoints, additional altitude constraints, or additional speed constraints, all of which should be minimized. When designing the procedure, it is helpful to explore whether these constraints can be altered to improve the procedure design. The process of changing, for example, a letter of agreement between two facilities, may be additional work during the procedure design process, but small adjustments to the procedure constraints and design could substantially improve its safety and efficiency. This may also be an opportunity for air traffic to balance workload across sectors while they are making changes to accommodate new procedure designs.

Evaluation

- Examine constraints at facility boundaries. Are there any that constraints that could be eased by adjusting agreements between the facilities?
- How and when is the pilot informed about the runway assignment? Does the pilot know when to expect a runway assignment?

ReferencesFAA Documents

Federal Aviation Administration. (27 September 2013). Order JO 7100.9E, *Standard Terminal Arrival Program and Procedures*.

Federal Aviation Administration. (2007). Advisory Circular 90-100A, *US Terminal and En Route Area Navigation Operations*.

Federal Aviation Administration (2012). Order 8260.58. *United States Standard for Performance Based Navigation (PBN) Instrument Procedure Design*.

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