

AERONAUTICAL CHARTING FORUM
Instrument Procedures Group
October 27, 2009
HISTORY RECORD

FAA Control # 09-02-289

Subject: Use of Leg Combinations and Altitude Constraints on RNAV Departure Procedures.

Background/Discussion:

NBAA is concerned with the use of altitude constraints in combination with certain RNAV path-terminator leg types in on RNAV Departure Procedures as currently allowed by the criteria contained in FAAO 8260.44A and FAAO 8260.46D.

Two recent examples illustrate our concerns:

1. The initial departure routing of the original RUUDY ONE RNAV SID at Teterboro, NJ (TEB) – (see attachment) used a heading to altitude (VA) leg followed by direct-to fix (DF) leg. However, the VA altitude constraint (at or above 1500 ft) was also followed by a hard (at) altitude constraint of 1500 ft at WENTZ.

While a few autoflight systems (with climb-capable VNAV) were able to manage this sequence of altitude constraints, many others experienced leg-sequencing issues due to the need to level at 1500 ft on the departure route to WENTZ. These leg-sequencing issues resulted in wide variations in the geographic location where the aircraft initiated the right turn direct to WENTZ.

Due to the procedure's close proximity to the Newark, NJ airport, numerous ATC interventions were required to manually initiate the turn before traffic separation was affected. As result, this procedure was withdrawn from use after approximately 48 hours.

2. The initial departure route of the DUUKE ONE RNAV SID at Santa Ana, CA (SBA) – (see attachment) employs a heading to course intercept (VI) leg followed by a course to fix (CF) leg terminating at the DUUKE waypoint. The initial departure route instruction is to "climb heading 194 (runway heading) to **at or above 540**, then intercept the 175 course to DUUKE". A 540 ft "AT or ABOVE" altitude constraint is located by FAA source at the VI-CF intercept point and is designated on the chart.

The charting of the 540 ft "at or above" altitude constraint can be a source of confusion for pilots who are accustomed to initiating a leg change when an "at or above" note is published on a chart. The instruction "fly xxx to at or above" is often associated with a heading-to-altitude (VA) procedure leg. However, in this case, the altitude restriction is being used on a VI to CF leg combination.

Pilots of high performance aircraft will frequently climb above the published constraint (in this case 540 ft) well prior to reaching the intersection of a VI-CF leg combination. As a result, pilots may be tempted to manually initiate a course change and proceed direct to the terminator fix defined by the CF leg. The SNA ATCT

issued a severely flawed Letter to Airman (attached) admonishing against manual intervention and advising pilots to fly the procedure as published.

The use of altitude constraints is permitted on several leg types (VA-CF, VA-DF, and VI-CF combinations) per FAAO 8260.46D (Tables A-1: and E-1)

08/20/09

8260.46D
Appendix A

Table A-1. Permissible Leg Types.		
FROM	VIA (leg type)	TO
AER	VI ¹	See ¹
AER	VA ²	ALT
AER	VM ⁸	HDG
ALT	CF ³ , DF ⁴	FB/FO
AER	CF ³ , DF ⁴	FB/FO
FB	TF ⁵	FB/FO
FO	DF ⁴ , TF ⁵	FB/FO
IF ⁴	DF ⁴ , TF ⁵	FB/FO
FO	VM ⁸	HDG
FB	RF ⁶	FB

¹ VI (Heading-to-intercept) may only be used as the first leg of a departure and must be followed by a CF leg.

² VA (Heading-to-an-altitude) may only be used as the first leg of a departure and must be followed by either a CF or DF leg.

³ CF (Course-to-fix) may only be used as the first leg of a departure or as the leg following a departure VI or VA leg.

⁴ DF (Direct-to-fix) may be used as the first leg of a departure, the leg following a departure VA leg, and for any leg thereafter preceded by a FO WP only.

⁵ TF (Track-to-fix) is not used as the first leg of a departure. TF is the preferred leg after the first leg of a departure.

⁶ RF (Constant radius arc) may only be used when necessary because some users do not have RF capability. An RF leg may only be used after a TF, CF, or another RF leg.

⁷ IF (Initial fix) is used to designate the first fix of a departure transition, i.e., the IF is coincident with the DP termination fix. IF is also used to designate the point at which RNAV begins when used in conjunction with radar vectors.

⁸ VM (Vector-to-fix) legs are only to be used in conjunction with ATC radar vectoring.

Note: AER - approach end of runway, ALT - altitude, FB/FO - fly-by fix/fly-over fix.

Table E-1. Leg Type Wording and Required Information.		
8260-15C Leg Type	8260.15B Wording	8260.15B Required Information
VI	"heading"	heading/altitude*
VA	"heading"	heading/altitude
DF	"direct"	turn direction**/distance***
CF	"course"	course/distance/turn direction****
TF	"track"	course/distance/turn direction****
VM	"heading"	Heading/altitude

- * Altitude only required if needed in procedure design.
- ** Do not specify turn direction when a DF leg is used as the first leg of a DP.
- *** Do not specify distance when part of a VA-DF leg combination.
- **** Only specify turn direction for CF or TF legs when amount of turn exceeds 90°.

Examples:

VI leg followed by CF leg – “TAKEOFF RWY 32R: CLIMB HEADING 317.66 TO INTERCEPT COURSE 041.20 TO LARRY.”

VI leg with an altitude constraint, followed by CF leg – “TAKEOFF RWY 32R: CLIMB HEADING 317.66 TO AT OR ABOVE 1000, THEN INTERCEPT COURSE 041.20 TO LARRY.”

VA-CF leg combinations are problematic because climb rates that exceed the departure procedure’s minimum climb gradient (standard or otherwise) will result in the aircraft reaching the altitude termination point of the VA leg **prior to** reaching the interception point of the subsequent CF leg. In those cases, autoflight and FMS/GPS course intercept logic may result in unexpected turns away from the VA heading in an effort to intercept the CF leg.

Designation of an “at” or “at or above” altitude constraint is not necessary to assure compliance with a minimum crossing altitude at a VI-CF intersect point. The guidance and example in Table E-1 may lead to inappropriate application of criteria and confusing notes on charts. The preferable and far simpler alternative is to specify a climb gradient limitation. Use of a climb gradient will assure that departing aircraft reach the VI-CF intersection at or above the desired altitude.

It should also be noted that most VNAV systems cannot by themselves assure compliance with an “At or above” altitude restriction published at the VI-CF intercept point. VNAV systems may be capable of triggering an advisory message – e.g., “UNABLE NEXT ALT” – but those messages will generally be displayed too late for the crew to take effective corrective action. Thus, charting an altitude constraint associated with a VI/CF leg combination has no technical or operational benefit and only tends to confuse pilots with respect to anticipated leg sequencing.

Finally, in order for the VA-DF leg combination to function properly in airborne equipment, the altitude constraint for the VA must be designated as an “at or above” altitude **and** any altitude constraint for the subsequent DF leg’s termination fix **must be higher** than the VA leg’s altitude constraint.

Recommendations:

Until such time that FAA Orders 8260.44A and 8260.46D may be amended, issue an AFS-400 Policy Memorandum affecting Tables A1 and E1 of FAAO 8260.46D to:

1. Prohibit the use the VA-CF leg combination.
2. Remove the option to specify an altitude restriction on a VI-CF leg combination. When necessary, designate a mandatory climb gradient to establish a minimum crossing altitude at the VI-CF intercept point. This climb gradient must **not** be annotated (ATC).
3. When a VA-DF leg combination is necessary, require that the VA climb-to altitude used be designated as an “**at or above**” altitude. Require any altitude constraint at the subsequent DF termination fix to be higher than the VA altitude constraint. It is recommended that any altitude constraint at the DF terminus fix be at least 500 ft above the VA altitude constraint. If this is not possible, the suitability of an alternative VI-CF leg combination should be examined.

NBAA notes that these recommendations are short-term fixes for longer-term issues associated with suitability of path-terminator leg combinations on RNAV departure procedures (see NBAA’s related ACF-IPG agenda item)

Comments: This recommendation affects FAA Orders 8260.44A and 8260.46D.

Submitted by: Richard J. Boll II

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Date: October 2, 2009

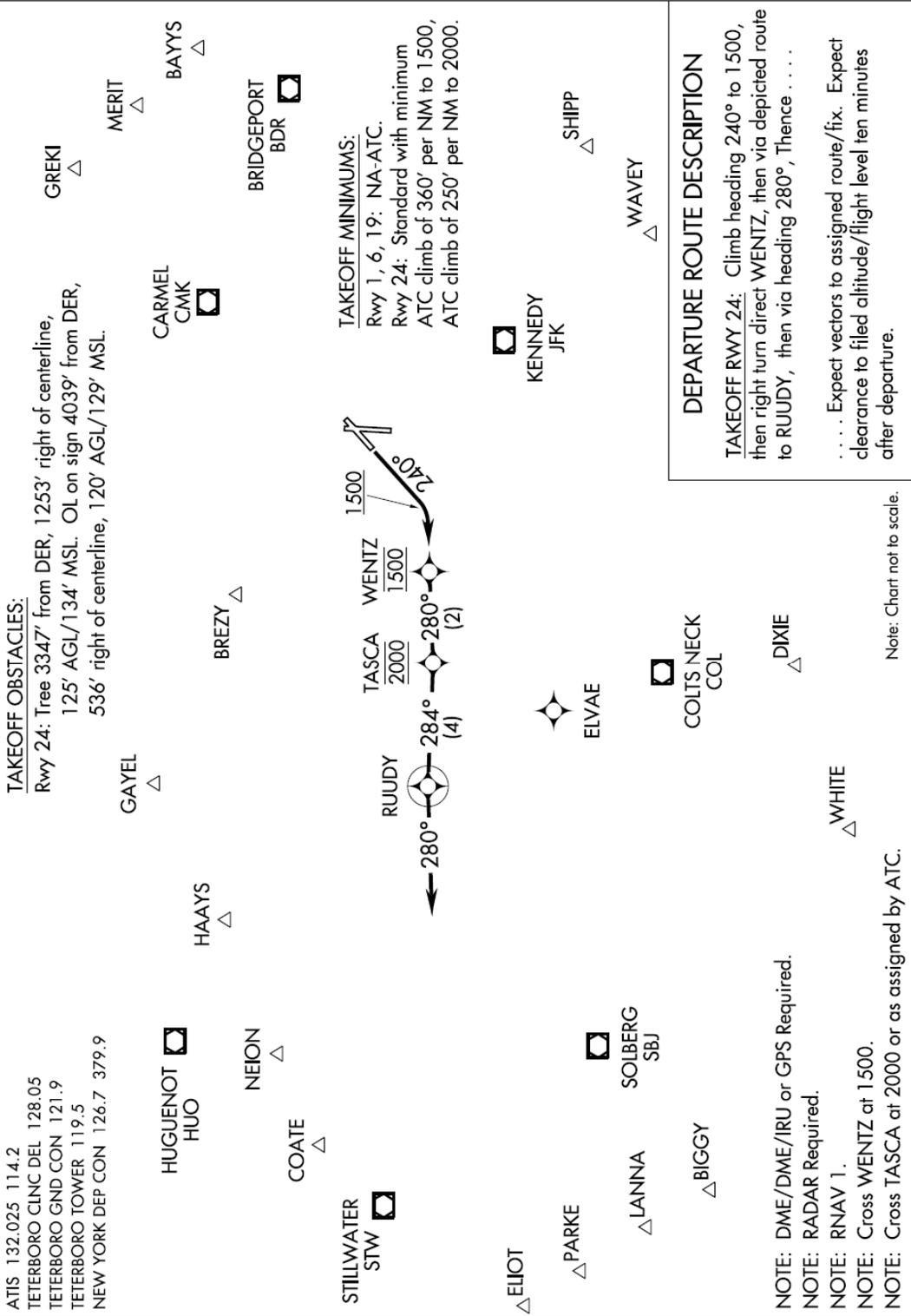
(RUUDY1.RUUDY) 09015

SL-890 (FAA)

RUUDY ONE DEPARTURE (RNAV)

TETERBORO (TEB)
TETERBORO, NEW JERSEY

NE-2, 15 JAN 2009 to 12 FEB 2009



RUUDY ONE DEPARTURE (RNAV)
(RUUDY1.RUUDY) 09015

TETERBORO, NEW JERSEY
TETERBORO (TEB)

NE-2, 15 JAN 2009 to 12 FEB 2009

(DUUKE1.DUUKE) 09239

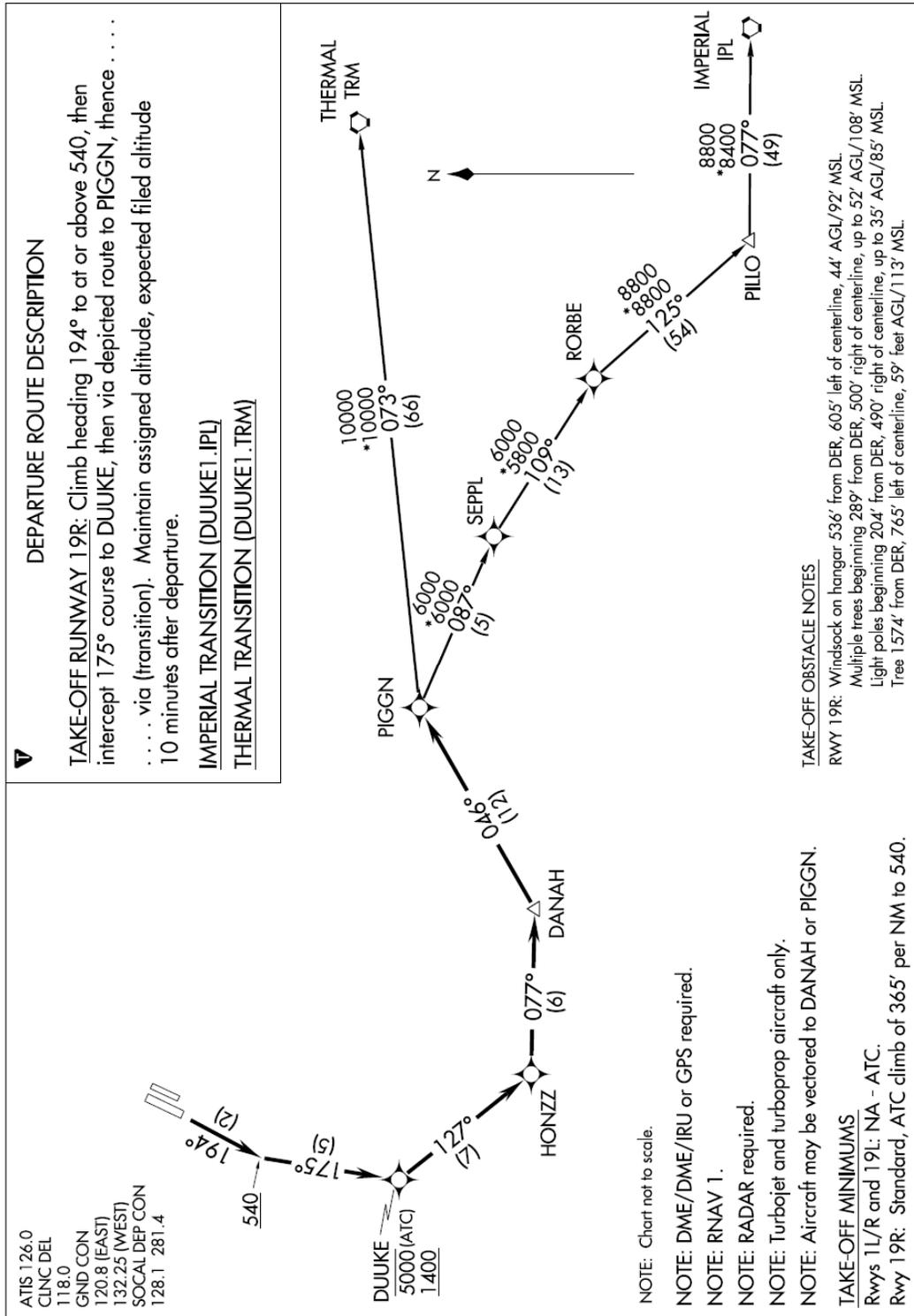
SANTA ANA/ JOHN WAYNE ARPT-ORANGE COUNTY (SNA)

DUUKE ONE DEPARTURE (RNAV)

SL-377 (FAA)

SANTA ANA, CALIFORNIA

SW-3, 27 AUG 2009 to 24 SEP 2009



DUUKE ONE DEPARTURE (RNAV)

SANTA ANA, CALIFORNIA

(DUUKE1.DUUKE) 09239

SANTA ANA/ JOHN WAYNE ARPT-ORANGE COUNTY (SNA)

SW-3, 27 AUG 2009 to 24 SEP 2009

JOHN WAYNE TOWER LETTER TO AIRMEN NO. 09-03

**DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION**
John Wayne Airport Traffic Control Tower
370 Paularino Avenue
Costa Mesa, California 92626

ISSUED: September 18, 2009

EFFECTIVE: September 18, 2009

JOHN WAYNE TOWER LETTER TO AIRMEN NO. 09-03

SUBJECT: NEW RNAV DEPARTURE PROCEDURE AVAILABLE AT SNA – “DUUKE”

CANCELLATION: September 17, 2011

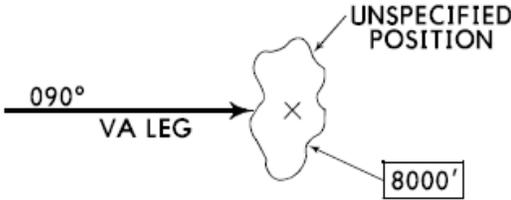
The DUUKE RNAV departure is now available for use at SNA by appropriately equipped aircraft and properly qualified air crews. Pilots planning to utilize the DUUKE departure are reminded that:

- **Pilots must review the procedure thoroughly.** Please call the Control Tower at 714-668-9845 if you have any questions on how to fly the procedure.
- DUUKE RNAV departure FMS programming is a Vector to Intercept (VI) a Course to Fix (CF) leg.
- **To properly fly the DUUKE departure, aircraft must fly runway heading until intercepting the 175-degree course to DUUKE WP.** This means all aircraft will fly straight ahead for approximately one mile beyond the departure end of the runway before initiating any turn.
- **The 540' altitude specified on the published procedure as a note is an obstacle clearance point and is NOT the altitude that the turn shall be initiated.** It is the minimum at or above altitude that must be attained to avoid terrain before starting the turn at the appropriate point to join the 175-degree course to DUUKE WP.
NOTE: In most instances the aircraft will have reached an altitude significantly above 540 feet prior to starting a turn to intercept the 175-degree course to DUUKE WP.

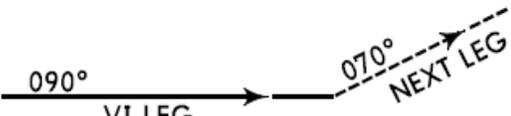
If you have any questions, please contact Anne Leonard at 714-668-0141.

Douglas K. Blaul
Manager, John Wayne Tower

Heading to Altitude (VA) Leg:

VA		<p>Figure 15: Heading to an Altitude termination or VA Leg. Defines a specified heading to a specific Altitude termination at an unspecified position.</p>
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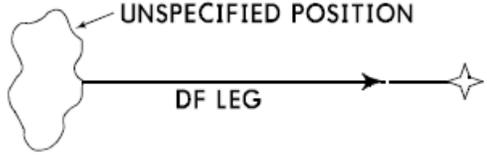
Heading to Intercept (VI) Leg:

VI		<p>Figure 17: Heading to an Intercept or VI Leg. Defines a specified heading to intercept the subsequent leg at an unspecified position.</p>
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Course to Fix (CF) Leg:

CF		<p>Figure 3: Course to a Fix or CF Leg. Defines a specified course to a specific database fix.</p>
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Direct To Fix (DF) Leg:

DF		<p>Figure 4: Direct to a Fix or DF Leg. Defines an unspecified track starting from an undefined position to a specific database fix. Note: See also Table 1.3, Leg Sequencing, for other uses of the DF Leg.</p>
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Initial Discussion - MEETING 09-02: New issue presented by Rich Boll, NBAA. Rich stated that many new RNAV departures are designed using leg types and altitude restrictions that are incompatible with many FMSs. For example a VA-to-CF leg does not provide a static turn point, altitude restrictions in a VI-to-CF leg present problems, and many FMSs cannot handle mandatory altitudes. Rich provided several examples using current SIDs; the DUUKE ONE RNAV SID at John Wayne Airport-Orange County (KSNA) and the RUUDY ONE RNAV SID at Teterboro, NJ (KTEB). Tom Schneider, AFS-420, stated that some 'legacy FMSs' are not capable of flying a VI leg. Accordingly, changes to FAA Order 8260.46D specify documenting the desired leg type (VI) and allowing use of a VA leg instead. Brad Rush, AJW-372, stated that he doesn't support eliminating all the available options for SID design, rather limit the application of the various options. Brad added that the VA-CF combination is rarely used, but is necessary to support certain situations. Dan Diggins, AJT-28, agreed with the recommendation and added that recent incidents at Dallas/Fort Worth prove that VA-to-CF legs don't work as planned. He also agreed that a Letter to Airmen published by John Wayne Tower provided incorrect guidance. Gary Fiske, AJT-28, stated the letter had been corrected. Tom agreed to forward this issue to the US-IFPP for consideration. **ACTION: AFS-420 (US-IFPP).**

MEETING 10-01: Tom Schneider, AFS-420, briefed that Jack Corman, AFS-420, and Executive Director of the US-IFPP, has advised that, "within the US-IFPP, this issue will be worked jointly with 09-02-290. Both issues have been referred to the US-IFPP Coding subgroup for resolution recommendation." Jack will keep the Forum apprised of progress. **ACTION: AFS-420 (US-IFPP).**

MEETING 10-02: Tom Schneider, AFS-420, provided the following update from Jack Corman, the AFS-420 TERPS RNAV criteria specialist: "AFS-420 action is to remove leg type designators VA-CF from design criteria until such time that all avionics implement these leg type designators in a manner that will generate the same path guidance. Currently, there is no regulatory standard for ARINC leg type designator implementation." Kevin Allen, USAIR, stated that Honeywell changes VA-CF to VA-DF. Vince Massimini, MITRE, that this will not assure repeatable ground tracks as FMS' treat this coding differently. Brad Rush, AJV-3B, stated that using VA-DF to a waypoint 2 NM from the DER provided the best track. John Moore, AJV-3B, expressed concern over what options are left if VA-CF is eliminated. He asked when we started changing regulatory guidance based on box performance. Kevin Allen, USAIR, responded that there are lots of options to replace VA-CF and the change is not solely tied to box performance. Mike McGinnis, APA, noted that there only seems to be a problem with VA-CF when there are parallel runway operations. Mike Cramer, MITRE, stated that all boxes fly VI legs the same under similar conditions. Al Herndon, MITRE, provided additional test information regarding LGA. Mike McGinnis asked whether the change from VA to VI resolve the problems at DFW. Al said MITRE had also studied VI-CF and there is a problem with magnetic variation (mag var) application. The VI leg uses the airport mag var of record; however, the CF leg will use the assigned mag var of the NAVAID. Tom advised the issue would continue to be addressed by the US-IFPP Database and Coding Working Groups. **ACTION: AFS-420 (US-IFPP).**

MEETING 11-01: Tom Schneider, AFS-420, provided the following update that applies equally to this issue and 09-02-290 from Ron Brumback, AFS-420 (ISI), departure criteria specialist: "Based upon feedback from AFS-470 and AIR-130, RNAV departure criteria that

outlines leg-type coding methods will be withdrawn. Coders can use whatever ARINC implementation their box requires to adhere to the path of the described construction." Brad Rush, AJV-3B, asked whether procedure designers would continue to document the leg type used in the procedure design. Ted Thompson, Jeppesen, asked whether this was discussed through the ATA CNS Task Force for input. Tom responded that he didn't think so, but AIR was a participant in the US-IFPP discussion. John Moore, AJV-3B, stated that when missed approach icons first appeared on the scene, there was much confusion regarding interpreting the text on the procedure source to be depicted as a symbol. Likewise here, the intent of the procedure designer must be crystal clear for coding purposes. John added that it would be beneficial for the US-IFPP to bring industry into this conversation. Brad added that designers are putting the leg type used in the design and to be coded on the forms now. Don't change something that is working; additionally, a change will affect several ACs. Ted interjected that some avionics, especially older systems, may not be able to support the specified leg types. Rich Boll, NBAA, responded that pilots must always be ready to intervene if an aircraft is not going where it is supposed to. He also cautioned that the FAA must be careful in allowing coders to change the leg type specified to be coded and didn't believe that this allowance is good idea. Brad closed by saying that if coders are allowed to unilaterally change leg types from the specified source, then that practice must be sanctioned by AIR. The ACF-IPG comments will be addressed by the US-IFPP. **ACTION: AFS-420 (US-IFPP).**

MEETING 11-02: Tom Schneider, AFS-420, provided the following update that applies equally to this issue and 09-02-290 from Jack Corman, AFS-420, and Ron Brumback, AFS-420 (ISI): "Order 8260.19 will continue to require procedure specialists to list the type leg used in the design of the procedure on the associated 8260-series form. However, AFS cannot, at this time, mandate how manufacturers apply the designated code. The US-IFPP Database and Coding working group (WG) has been working on establishing an FAA coding standard. However, many US-IFPP initiatives have been halted because of the impact any regulatory guidance (standards) would have on the proprietary nature of existing navigation databases and systems. For example, the US-IFPP Coding WG did address the issues and drafted a letter to AVS for a formal tasking to develop regulatory guidance for coding. However, after the last Coding WG meeting, the letter was cancelled and there has not been any progress since then due to Nav Lean priorities. Until such a coding standard is established, PBN criteria will only contain example ARINC combinations that may or may not guarantee track compliance since all FMSs may not implement the codes in the same manner." There was much discussion on this issue centering around the fact that not all manufacturers code the path terminators specified on the procedure source. Brad Rush, AJV-3, emphasized that procedure developers know best the intent of the procedure design and document that on the source 8260-series form using ARINC 424 path terminators. If an FMS manufacturer can't accomplish the specified type path terminator, then they must get approval to deviate. Mike Cramer, MITRE, stated that there is an ARINC 424 standard that everyone has implemented; however, there are still differences. He questioned whether this means the FAA must set standards. Rick Dunham, AFS-420, stated that it is a difficult challenge to create criteria and policy that can be used by all. Basically the agency provides the information of what we want the aircraft to do, and expect industry to make it happen. Brad emphasized that ARINC 424 has allowable path terminators listed. If an FMS can't accomplish the maneuver as specified, then it is a Certification issue under AC 20-153. Rich Boll, NBAA, responded that all systems don't play by the same rules and procedures that can't be flown should not be designed. Rich added that only two of NBAA's issues and recommendations were addressed by the recent changes to the .46D. The issue that

remains open is the continued use of VA legs to a hard "climb & maintain" altitude. Certain combinations of FMS/GPS and Flight Guidance Systems do not sequence appropriately in this situation. Rich volunteered to draft language for the 8260.46D concerning the use of VA path terminators in conjunction with hard altitudes. Rich said the issue may be closed when this third concern is resolved. **ACTION: NBAA and AFS-420 (US-IFPP).**

MEETING 12-01: Tom Schneider, AFS-420, briefed that NBAA has forwarded the following recommended change to Order 8260.46D, Appendix A, which has been accepted by AFS-420 and the US-IFPP. Tom briefed that it will be included in draft change 3:

² VA (Heading-to-an-altitude) may only be used as the first leg of a departure and must be followed by a DF leg. The altitude must be an at-or-above altitude; a mandatory (i.e., "at") altitude must not be used at the first fix.

Gary Fiske, representing AJT-2A3, stated that this change can't be used at places like Teterboro where two mandatory altitude restrictions are necessary for ATC separation between Teterboro departures and Newark arrivals. Rick Boll, NBAA, stated that some FMSs will never reach a mandatory altitude. Tom advised that all will have an opportunity to comment when Change 3 to Order 8260.46 is circulated for comment. **ACTION: AFS-420.**

MEETING 12-02: Tom Schneider, AFS-420, briefed that the change forwarded by NBAA for Order 8260.46D, Appendix A (as briefed at the last meeting), has been included in Change 3, which entered formal coordination on October 11, 2012. AFS-420 will track the change until published. **ACTION: AFS-420.**

MEETING 13-01: Tom Schneider, AFS-420, briefed that the issue was resolved with publication of Change 3 to FAA Order 8260.46, which was signed on December 31, 2012. **Issue CLOSED.**
