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Safety Study Report on Houston to Atlanta Area Navigation (RNAV) Route

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12. Abstract

Houston Air Traffic Control (ATC) has proposed an RNAV route between the heavily traveled city-pairs of Houston and Atlanta. The Flight Operations Simulation and Analysis Branch, under the sponsorship of ATO-P, was asked to evaluate the feasibility of such a route, primarily using the Flight Standards developed computerized RNAV screening tool, RNAV-Pro. RNAV-Pro was used to evaluate the following safety factors affecting the route: basic flyability of the route, DME/DME availability for aircraft so equipped, and ATC radar coverage. (Since the operational altitudes of the proposed route are well above any obstacles, a TERPS obstacle clearance analysis was not performed.) The RNAV-Pro analysis results confirmed the feasibility of the proposed route for DME/DME/IRU navigation and RNP 2.0 (based on DME/DME/IRU) operations. The RNAV-Pro analysis for DME/DME only navigation showed a 1.5 NM coverage gap. This report recommends that appropriate organizations within the FAA address the acceptability of DME/DME only navigation and any attendant DME coverage gaps for RNAV routes.

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EXECUTIVE SUMMARY

Many of the aircraft operating in the high altitude structure, i.e. above 18,000' Mean Sea Level (MSL), of the United States National Airspace System (NAS) are equipped with RNAV systems. These systems include Flight Management Systems (FMS's), Global Positioning Systems (GPS's) and Required Navigation Performance (RNP). These systems allow enroute operations between user defined/selected waypoints rather than between permanently placed ground-based navigation aids, such as VOR's. RNAV routes have the potential to save fuel due to more efficient routing and can help alleviate increasing congestion on existing jet airways. The focus of this report is on FMS's and RNP RNAV systems which rely on multiple Distance Measuring Equipment (DME/DME) inputs.

Seeking to take advantage of the benefits of RNAV, Houston Air Traffic Control (ATC) proposed an RNAV route between the heavily traveled city-pairs of Houston and Atlanta. In order to evaluate the feasibility of such a route, many safety factors need to be considered. Foremost among these factors are: basic flyability of the route, DME/DME availability for aircraft so equipped, and ATC radar and communication coverage. (Note: Obstacle clearance via a TERPS evaluation would ordinarily be an important factor, however, operations along this route are proposed at altitudes well above obstacles/obstructions.) This report details the results of a safety analysis of the proposed route using the Flight Standards developed computerized RNAV screening tool, RNAV-Pro, which is used to assess the factors stated above. This analysis was requested and funded by the Air Traffic Organization, Operations Planning - Performance Analysis (ATO-P). This report does not address procedural separation from other routes.

The RNAV-Pro analysis results confirm the feasibility of the proposed KIAH-KATL route. The entire route is flyable. DME coverage exists to support DME/DME/IRU navigation and RNP 2.0 (based on DME/DME/IRU) operations for aircraft so equipped. RNAV-Pro analysis for DME/DME only showed a 1.5 NM coverage gap. Appropriate organizations within the FAA need to address the acceptability of DME/DME only navigation and any attendant DME coverage gaps along RNAV routes. With operating costs of large civil aircraft in the $50 to $70 per minute range, small distance and time savings through the use of more direct RNAV routes could have a substantial cumulative effect on operating costs. Additional routes afford ATC more flexibility in dealing with peak enroute demand and can provide alternative routing during periods of high convective weather activity. This is especially important as additional high altitude aircraft, such as regional jets, join carrier fleets. RNAV-Pro can be an important enabler of RNAV procedures and operations.

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Safety Study Report on Houston to Atlanta Area Navigation (RNAV) Route

1.0. INTRODUCTION

Many of the aircraft operating in the high altitude structure, i.e. above 18,000' Mean Sea Level (MSL), of the United States National Airspace System (NAS) are equipped with RNAV systems. These systems include Flight Management Systems (FMS's), Global Positioning Systems (GPS's) and Required Navigation Performance (RNP). These systems allow enroute operations between user defined/selected waypoints rather than between permanently placed ground-based navigation aids, such as VOR's. RNAV routes have the potential to save fuel due to more efficient routing and can help alleviate increasing congestion on existing jet airways. The focus of this report is on FMSs and RNP RNAV systems which rely on multiple Distance Measuring Equipment (DME/DME) inputs.

Seeking to take advantage of the benefits of RNAV, Houston Air Traffic Control (ATC) proposed an RNAV route between the heavily traveled city-pairs of Houston and Atlanta. In order to evaluate the feasibility of such a route, many safety factors need to be considered. Foremost among these factors are: basic flyability of the route, DME/DME availability for aircraft so equipped, and ATC radar and communication coverage. (Note: Obstacle clearance via a TERPS evaluation would ordinarily be an important factor, however, operations along this route are proposed at altitudes well above obstacles/obstructions.) This report details the results of a safety analysis of the proposed route using the Flight Standards developed computerized RNAV screening tool, RNAV-Pro, which is used to assess the factors stated above. This analysis was requested and funded by the Air Traffic Organization, Operations Planning - Performance Analysis (ATO-P). This report does not address procedural separation from other routes.

2.0. BACKGROUND

2.1. RNAV-PRO

RNAV-Pro is a computer program that provides procedure developers with a screening model to aid in the development of RNAV routes. While not intended to serve as the final authority in RNAV route design and approval, the model serves as a convenient, high-fidelity, high-speed tool to assess the following aspects of procedure design:

a. Flyability. RNAV-Pro contains a high-fidelity model of a generic airframe and FMS which can assess the flyability of procedures including minimum segment length, amount of turn at waypoints, and altitude restrictions. Flyability is the ability of the aircraft model to physically and aerodynamically perform the intended operation.

b. DME/DME Assessment. For those aircraft dependent upon DME/DME or DME/DME aided by Inertial Reference Units (IRUs) for position determination, RNAV-Pro performs a check along the intended route of flight for the availability of DME stations which meet certain geometric (with respect to the aircraft) and performance standards (line of sight unobstructed, standard/expanded service volume, and lack of co-channel interference). DME station locations and characteristics are available to RNAV-Pro via an extensive database. Line of sight determinations are made using Digital Terrain Elevation Data (DTED). RNAV-Pro is able to perform the DME assessment not only on the centerline of the proposed route but also at the extremes of the route, usually ± 4 NM. For DME/DME/IRU equipped aircraft, RNAV-Pro accounts for IRU drift during periods of inadequate or unavailable DME coverage.

c. ATC Radar and Communication Assessment. Similar in concept and execution to the DME/DME assessment, RNAV-Pro performs a check of the ATC radars and communications facilities which theoretically can observe/communicate with the aircraft along the route of flight and at the proposed altitude. Again, an extensive database of ATC facilities and DTED make this possible.

2.2. PROPOSED RNAV ROUTE

Personnel from Houston ATC defined the makeup of the proposed Houston (KIAH) to Atlanta (KATL) route. Table 1 contains the waypoint coordinates of the route. (Table 1 also serves as the RNAV-Pro flight plan. WP refers to waypoint and TF refers to a Track-to-Fix leg type between the waypoints.)

Table 1: Definition of Waypoints

Name	Type	Latitude	Longitude	Altitude (Ft.)	Speed (Kts.)	Turn Type	Leg Type
KIAH	WP	N 29º 58' 49.71"	W 95º 20' 22.98"	30,000	280	Fly Over	TF
BPT	WP	N 29º 51' 0.00"	W 94º 2' 0.00"	30,000	280	Fly By	TF
WP2	WP	N 30º 6' 0.00"	W 90º 57' 0.00"	30,000	280	Fly By	TF
SJI	WP	N 30º 43' 0.00"	W 88º 21' 0.00"	30,000	280	Fly By	TF
KATL	WP	N 33º 38' 25.60"	W 84º 25' 37.00"	30,000	280	Fly Over	TF

Figure 1 gives an overview of the route showing its relationship to the Southeastern United States.

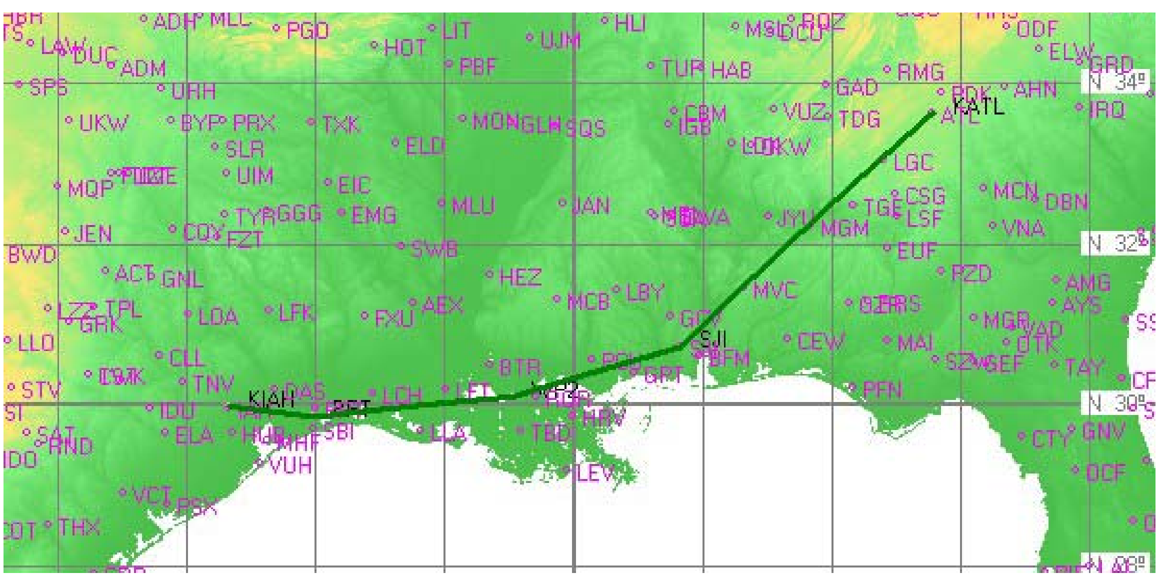


Figure 1: KIAH - KATL Route Depiction

2.3. OTHER MODEL ASSUMPTIONS

The RNAV-Pro analysis was carried out at Flight Level (FL) 300. This is representative of the operational altitudes expected to be used over the route.

For RNP equipped aircraft, current FAA expectations and planning efforts are directed toward defining RNAV routes as RNP 2.0. That is, RNP aircraft must maintain a total system error (TSE) of 2.0 NM for 95% of the time. This TSE value is further composed of Path Estimation Error (PEE) and Path Steering Error (PSE). For RNP 2.0, PEE is 1.75 NM and PSE is 1.0 NM. For readers more familiar with traditional error terms, PEE is analogous to Navigation System Error (NSE) and PEE is comprised primarily of Flight Technical Error (FTE). The RNAV-Pro analysis was carried out for RNP 2.0.

3.0. SUMMARY OF ANALYSIS

3.1. FLYABILITY RESULTS

Table 2 contains the results of the RNAV-Pro flyability assessment. As Table 2 shows, the entire track is considered flyable by RNAV-Pro.

Table 2: Flyability Results

Flight Type:	EnRoute
Aircraft Category:	Cat D
Wind Velocity:	0.0
Wind Heading:	30.0
Climb Gradient:	*none assigned*
Ground Speeds:	Table: **200.0 Kts** up to **11,000.0 Ft, 240.0 Kts** up to **18,000.0 Ft** **260.0 Kts** up to **25,0.0 Ft, 340.0 Kts** up to **99,900.0 Ft**
Entire track is fly-able	

3.2. DME/DME ASSESSMENT

3.2.1. DME/DME/IRU SCREENING RESULTS

A summary of the RNAV-Pro DME/DME/IRU assessment results is found in Table 3. As Table 3 shows, a total of 30 individual DME facilities were used by RNAV-Pro over the KIAH - KATL route. The maximum error, as computed by RNAV-Pro's error algorithms, is reported as 0.466 NM which is well within the NSE required for RNAV enroute operations.

RNAV-Pro also checks for "critical" DME's. A critical DME is one whose absence from the navigation solution results in a NSE in excess of that required for the intended operations. As Table 3 indicates, no critical DME facilities were found.

Appendix 1 contains a complete listing of the DME facilities used by RNAV-Pro as its computer program "flies" along the proposed KIAH-KATL route. As previously stated, RNAV-Pro is not the final approval mechanism for a given procedure. That function is primarily vested in FAA Flight Inspection which must verify that facilities, whether navigational, surveillance, or communication, as reported by RNAV-Pro, is indeed available for aviation purposes. In order to aid Flight Inspection in this task, RNAV-Pro outputs a DME listing grouped by 5 DME stations. These 5 DME groupings correspond to the number of DME facilities which can be inspected at any given time by present Flight Inspection airborne equipment. Appendix 2 contains the Flight Check DME selection list for the KIAH-KATL route.

Table 3: DME/DME/IRU Screen Results

User Defined		
Screen Settings:	RNP: 2.0 NM Flight Mode: Manual DTED Used Restrictions Used Initial Drift: 0.558 NM IRU Drift Rate: 8.00 NM/Hour OSV Used Co-Frequencies Checked RNP Edges Checked	Min DME Range: 3.0 NM DME Types: VOR/DME, VORTAC, TACAN, User DOD Facilities (Not in NAS) Not Used Foreign Facilities Not Used Flight Check DME Selections Used Checked at Higher Altitudes
Total Number of DMEs Used:		30
Max. DME Error Using ALL 30 DMEs:		0.466NM
No CRITICAL DMEs Were Found!!		

Another way to view the DME screening results is shown in Figure 2. Figure 2 is a plot of computed NSE using DME/DME/IRU navigation versus flight plan distance.

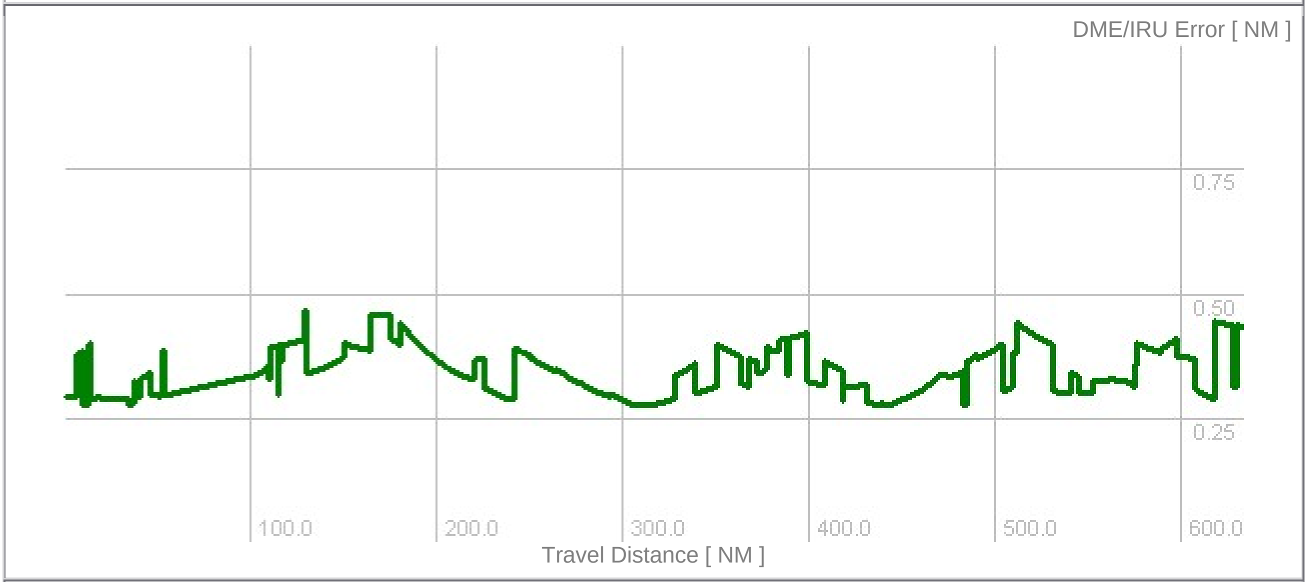
3.2.2. DME/DME SCREENING RESULTS

RNAV-Pro has the ability to screen for performance based solely on DME/DME navigation with IRU aiding disabled. Table 4 shows the results of the DME/DME analysis. While the results in Table 4 for DME/DME are similar to those for DME/DME/IRU as shown in Table 3, a notable exception is displayed in Tables 5 and 6.

Table 5 shows that RNAV-Pro has detected a 1.5 NM DME/DME coverage gap between the positions shown. This gap occurs early in the "flight" and, as Table 6 shows, is based on the non-availability of facility LFK. The reason LFK is not flagged as critical for this run, is that RNAV-Pro has been programmed to accept gaps of 4 NM. Notwithstanding this RNAV-Pro programming algorithm, as of the writing of this report, the FAA is developing policy for the use or non-use of DME/DME only navigation along RNAV routes.

DME/IRU Error [NM]

DME/IRU Error [NM]



Available DMEs: CWK, HUB, LFK, TNV, IAH, DAS, ELA, LCH, AEX, SWB, HRV, LEV, MCB, SJI, GCV, CEW, MEI, MGM, JYU, LGC, PZD, RMG, VUZ, ATL, MCN, AHN, GQO, IRQ

Figure 2: Graphical Presentation of DME/IRU Error vs. Distance

Table 4: DME/DME Screen Results

User Defined		
Screen Settings:	RNP: 2.0 NM Flight Mode: Manual DTED Used Restrictions Used IRU: Disabled OSV Used Co-Frequencies Checked RNP Edges Checked	Min DME Range: 3.0 NM DME Types: VOR/DME , VORTAC , TACAN , User DOD Facilities (Not in NAS) Not Used Foreign Facilities Not Used Flight Check DME Selections Used Checked at Higher Altitudes
Total Number of DMEs Used:		30
Max. DME Error Using ALL 30 DMEs:		0.466NM
No CRITICAL DMEs Were Found !!		

Table 5: DME/DME Navigation Coverage Gap

Gap	Start Location		End Location		Length
1	N 29º 56' 36.72"	W 94º 57' 21.61"	N 29º 56' 26.57"	W 94º 55' 37.91"	1.5 NM

Table 6: DME/DME Error Attributed to LFK

								Usage By	
#	Name	Location	SV / Range	Source	Critical	Err.[NM]	Status	Time	Distance
1	LFK	N 31º 9' 44.48" W 94º 43' 1.04"	H	Database	NO	Gaps <4	Enabled	15.2%	15.2%

3.3. RADAR SCREENING RESULTS

As the KIAH - KATL route is wholly contained within Class A airspace, radar and communication coverage is required and has already been assured by the FAA. However, Figure 3 is included as an example of RNAV-Pro's radar screen output. As Figure 3 shows, RNAV-Pro predicts a minimum of four enroute radars can observe an aircraft operating on the proposed route.

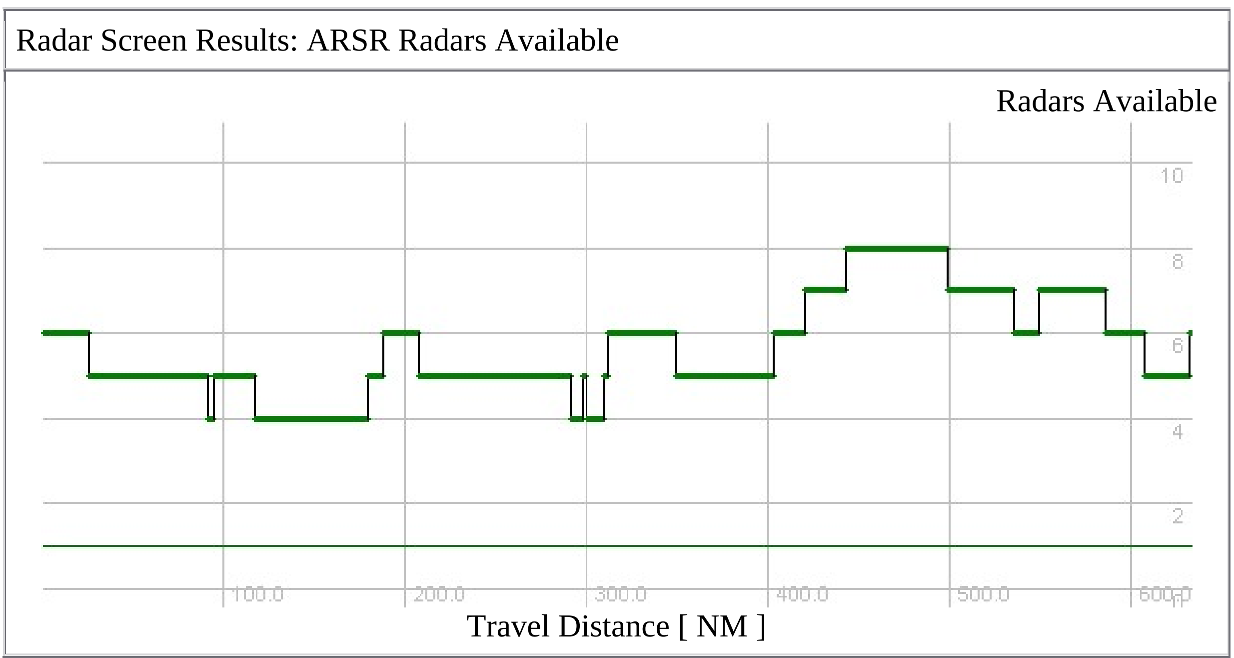


Figure 3: Radar Screen Results

4.0. RESULTS AND CONCLUSIONS

Based upon the RNAV-Pro analysis, the following results and conclusions regarding the feasibility of the proposed KIAH-KATL route are offered:

a. The entire route is flyable.

b. DME coverage exists to support DME/DME/IRU and RNP 2.0 (based on DME/DME/IRU) enroute RNAV operations for aircraft so equipped and approved.

c. Without the aid of an IRU, DME/DME navigation shows a coverage gap along the proposed route. The acceptability of coverage gaps and indeed the acceptability of DME/DME navigation for enroute RNAV operations must be addressed by the FAA.

d. With operating costs of large civil aircraft in the $50 to $70 per minute range, small distance and time savings through the use of more direct RNAV routes could have a substantial cumulative effect on operating costs.

e Additional routes afford ATC more flexibility in dealing with peak enroute demand and can provide alternative routing during periods of high convective weather activity. This is especially important as additional high altitude aircraft, such as regional jets, join carrier fleets.

f. RNAV-Pro is an important enabler of RNAV operations. This tool combined with other FAA resources which are existent or in the advanced planning stage can make RNAV enroute operations a safe and efficient reality.

APPENDIX 1: DME/DME/IRU Screen Results by Individual Facility

								Usage By	
#	Name	Location	SV / Range	Source	Critical	Err.[NM]	Status	Time	Distance
1	LFK	N 31º 9' 44.48" W 94º 43' 1.04"	H	Database	NO	0.466	Enabled	15.2%	15.2%
2	TNV	N 30º 17' 18.67" W 96º 3' 29.63"	H	Database	NO	0.466	Enabled	2.2%	2.2%
3	HUB	N 29º 39' 20.25" W 95º 16' 35.94"	H	Database	NO	0.466	Enabled	1.1%	1.1%
4	LCH	N 30º 8' 29.45" W 93º 6' 20.05"	H	Database	NO	0.466	Enabled	9.9%	9.9%
5	CWK	N 30º 22' 42.78" W 97º 31' 47.45"	H	Database	NO	0.466	Enabled	0.7%	0.7%
6	IAH	N 29º 57' 24.90" W 95º 20' 44.59"	H	Database	NO	0.458	Enabled	3.2%	3.2%
7	DAS	N 30º 11' 22.99" W 94º 38' 42.07"	H	Database	NO	0.466	Enabled	7.3%	7.3%
8	ELA	N 29º 39' 44.83" W 96º 19' 1.79"	H	Database	NO	0.466	Enabled	1.3%	1.3%

9	PSX	N 28º 45' 51.93" W 96º 18' 22.25"	H	Database	NO	0.466	Enabled	0.0%	0.0%
10	AEX	N 31º 15' 24.22" W 92º 30' 3.51"	H	Database	NO	0.467	Enabled	7.4%	7.4%
11	SWB	N 31º 58' 23.50" W 92º 40' 37.52"	H	Database	NO	0.444	Enabled	4.7%	4.7%
12	HRV	N 29º 51' 0.70" W 90º 0' 10.74"	H	Database	NO	0.487	Enabled	12.9%	12.9%
13	MCB	N 31º 18' 16.03" W 90º 15' 29.53"	H	Database	NO	0.579	Enabled	22.1%	22.1%
14	LEV	N 29º 10' 30.81" W 90º 6' 14.47"	H	Database	NO	0.466	Enabled	11.4%	11.4%
15	GCV	N 31º 5' 52.66" W 88º 29' 10.06"	H	Database	NO	0.466	Enabled	16.8%	16.8%
16	SJI	N 30º 43' 33.53" W 88º 21' 33.46"	H	Database	NO	0.466	Enabled	11.3%	11.3%
17	CEW	N 30º 49' 34.22" W 86º 40' 44.93"	H	Database	NO	0.473	Enabled	13.0%	13.0%

18	MEI	N 32º 22' 42.41" W 88º 48' 15.37"	H	Database	NO	0.466	Enabled	12.1%	12.1%
19	MGM	N 32º 13' 20.22" W 86º 19' 11.03"	H	Database	NO	0.466	Enabled	6.8%	6.8%
20	JYU	N 32º 20' 40.60" W 86º 59' 28.57"	H	Database	NO	0.466	Enabled	5.6%	5.6%
21	LGC	N 33º 2' 56.74" W 85º 12' 22.30"	H	Database	NO	0.466	Enabled	1.6%	1.6%
22	PZD	N 31º 39' 19.10" W 84º 17' 32.80"	H	Database	NO	0.466	Enabled	13.2%	13.2%
23	RMG	N 34º 9' 45.25" W 85º 7' 9.92"	H	Database	NO	0.466	Enabled	5.7%	5.7%
24	VUZ	N 33º 40' 12.67" W 86º 53' 59.28"	H	Database	NO	0.466	Enabled	3.4%	3.4%
25	ATL	N 33º 37' 44.66" W 84º 26' 3.89"	H	Database	NO	0.466	Enabled	1.8%	1.8%
26	GQO	N 34º 57' 40.57" W 85º 9' 12.13"	H	Database	NO	0.466	Enabled	0.4%	0.4%

27	MCN	N 32º 41' 28.40" W 83º 38' 49.85"	H	Database	NO	0.466	Enabled	1.0%	1.0%
28	AHN	N 33º 56' 51.30" W 83º 19' 29.10"	H	Database	NO	0.502	Enabled	5.8%	5.8%
29	ODF	N 34º 41' 45.14" W 83º 17' 51.58"	H	Database	NO	0.466	Enabled	0.0%	0.0%
30	IRQ	N 33º 42' 26.47" W 82º 9' 43.43"	H	Database	NO	0.466	Enabled	2.2%	2.2%

APPENDIX 2: Flight Check DME Selection

Flight Check DME Selection:							
Distance	Selected DMEs						Alternate
0.0	LFK	TNV	IAH	CWK	HUB		DAS
20.1	LFK	DAS	IAH	ELA	LCH		PSX
50.7	LFK	DAS	HUB	AEX	LCH		IAH
110.1	IAH	DAS	SWB	AEX	LCH		LFK
145.9	HRV	DAS	SWB	AEX	LCH		LEV
166.1	HRV	MCB	SWB	AEX	LEV		LCH
199.1	HRV	MCB	LCH	AEX	LEV		
239.5	HRV	MCB	GCV	SJI	LEV		MEI
337.7	CEW	MCB	GCV	MEI	LEV		SJI
367.5	CEW	HRV	GCV	MEI	MGM		MCB
387.9	SJI	HRV	GCV	MEI	JYU		MCB
408.4	SJI	MGM	CEW	MEI	JYU		GCV
428.5	SJI	MGM	CEW	MEI	GCV		JYU
468.7	SJI	MGM	CEW	JYU	GCV		MEI
488.9	SJI	MEI	CEW	JYU	LGC		VUZ
510.3	PZD	RMG	CEW	VUZ	LGC		JYU
536.1	PZD	MGM	ATL	VUZ	LGC		MCN
561.9	PZD	AHN	ATL	RMG	MCN		GQO
590.0	PZD	AHN	JYU	RMG	VUZ		MCN
615.1	PZD	AHN	IRQ	RMG	GQO		MGM