Implementation challenges for Flight Procedures

A Data-house perspective for comprehensive Procedure Design solution: A need today

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ICAO MID Region Flight Procedures Program Workshop

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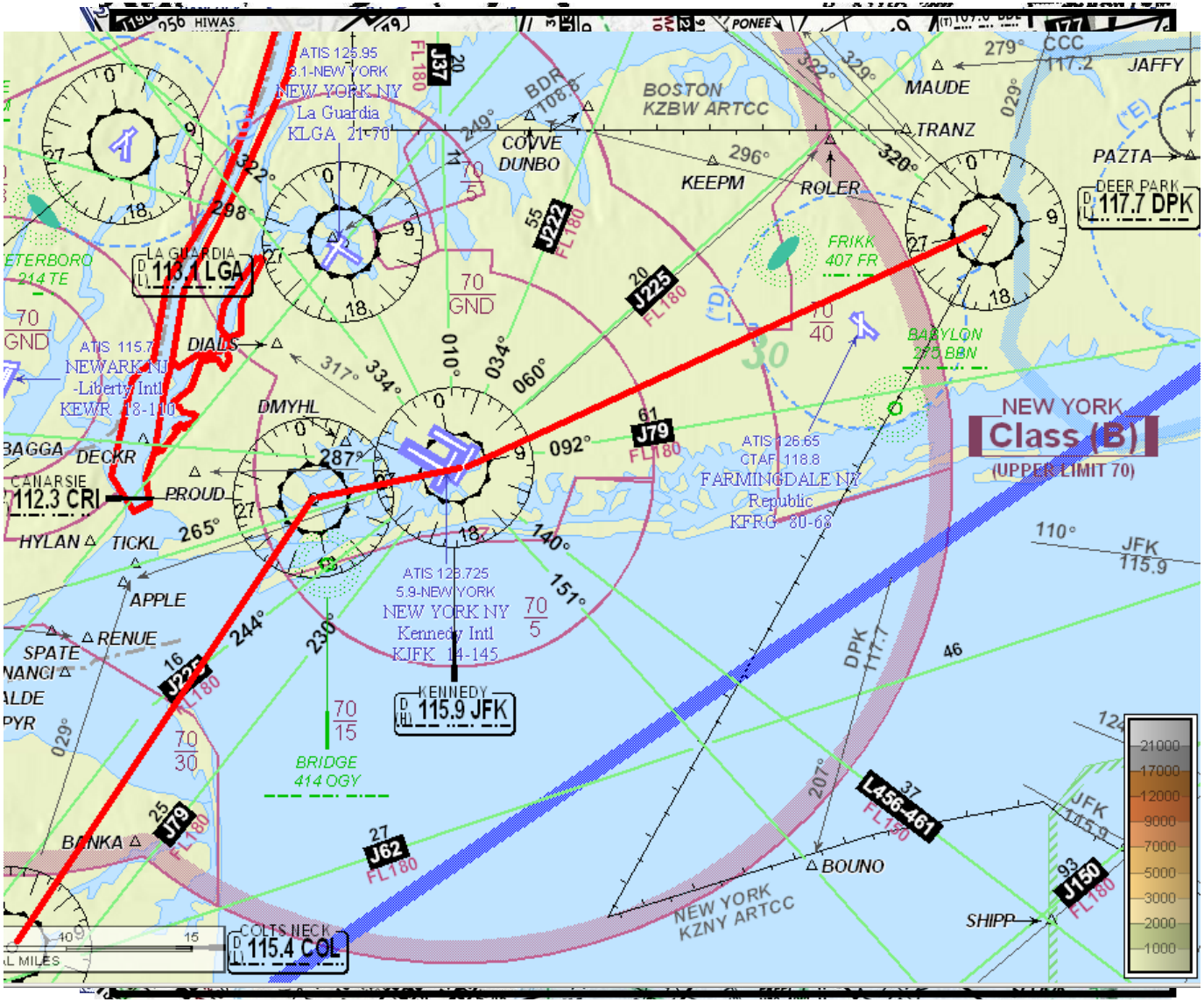
Problem Statement: A Piece of Traffic Growth History



1962

1977

2002

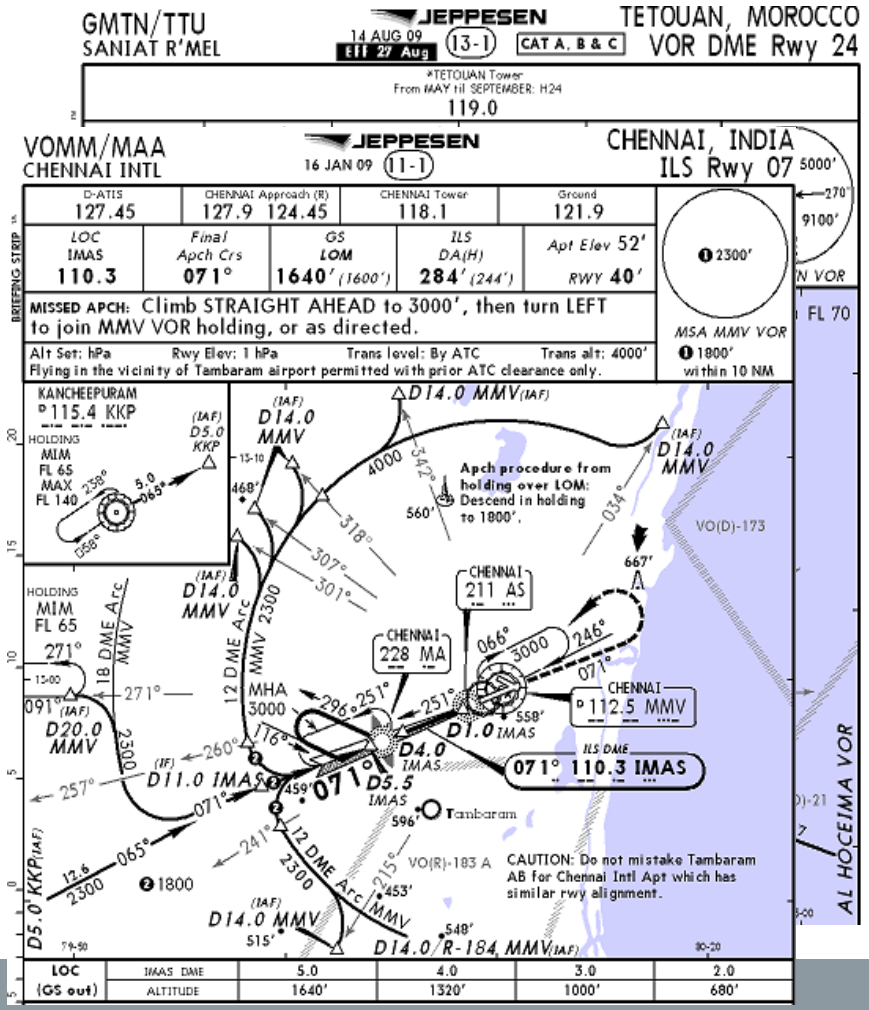
2006

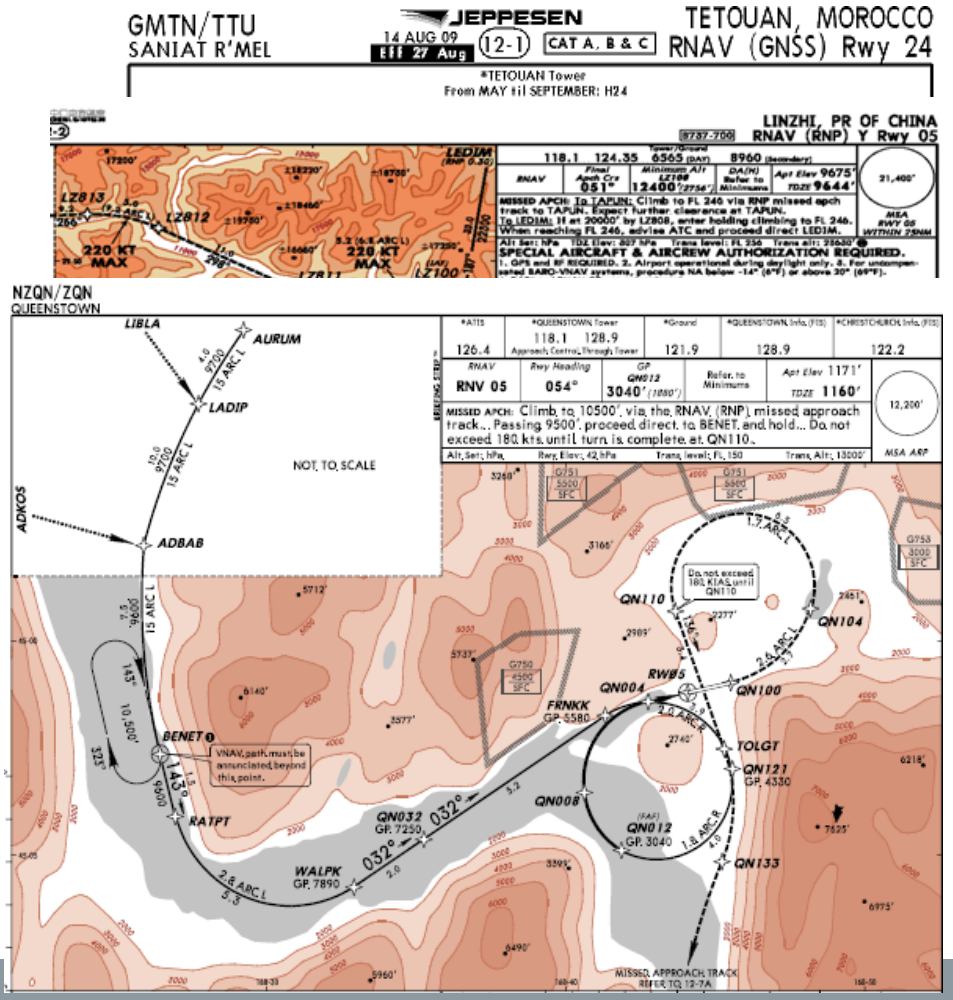
Digital

Evolution of Procedure Design criteria

Ground-Navaid, Complicated, Rigid paths, Non-standard, Manually flown: Analog World

Satellite, Simple, Flexible paths, Standard shape, database-driven: Digital World





Enabler for airspace constraints solution

ICAO Assembly A37-11 Resolution:

States complete a PBN implementation plan as a matter of urgency to achieve:

1) Implementation of RNAV and RNP operations (where required) for en route and terminal areas according to established timelines and intermediate milestones;

2) Implementation of approach procedures with vertical guidance (APV) (Baro-VNAV and/or augmented GNSS), including LNAV only minima, for all instrument runway ends, either as the primary approach or as a back-up for precision approaches by 2016 with intermediate milestones as follows: 30% by 2010, 70% by 2014 and,

3) Implementation of straight-in LNAV only procedures, as an exception to 2) above, for instrument runways at aerodromes where there is no local altimeter setting available and where there are no aircraft suitably equipped for APV operations with a maximum certificated take-off mass of 5,700 kg or more;

Navigation Database

- RNAV/RNP (PBN) implementation requires onboard systems capable to retrieve the procedures from a navigation databases;
- Navigation database should be obtained from a qualified supplier that complies with RTCA DO-200A/EUROCAE ED-76A standard;
- Letter of Acceptance type 1 issued by the appropriate regulatory authority:

European Aviation Safety Agency

LETTER OF ACCEPTANCE TYPE 1

REFERENCE: EASA.LOA.0002

The Agency has investigated

Jeppesen GmbH

Frankfurter Strasse 233
63263 Neu-Isenburg
Germany

to the procedures defined in LOA Exposition Jeppesen GmbH,

which have been found to comply with

"CONDITIONS FOR THE ISSUANCE OF LETTERS OF ACCEPTANCE FOR NAVIGATION DATABASE SUPPLIERS BY THE AGENCY.

Published as OPINION OF THE EUROPEAN AVIATION SAFETY AGENCY Nr. 01/2005 dated 14 January 2005.

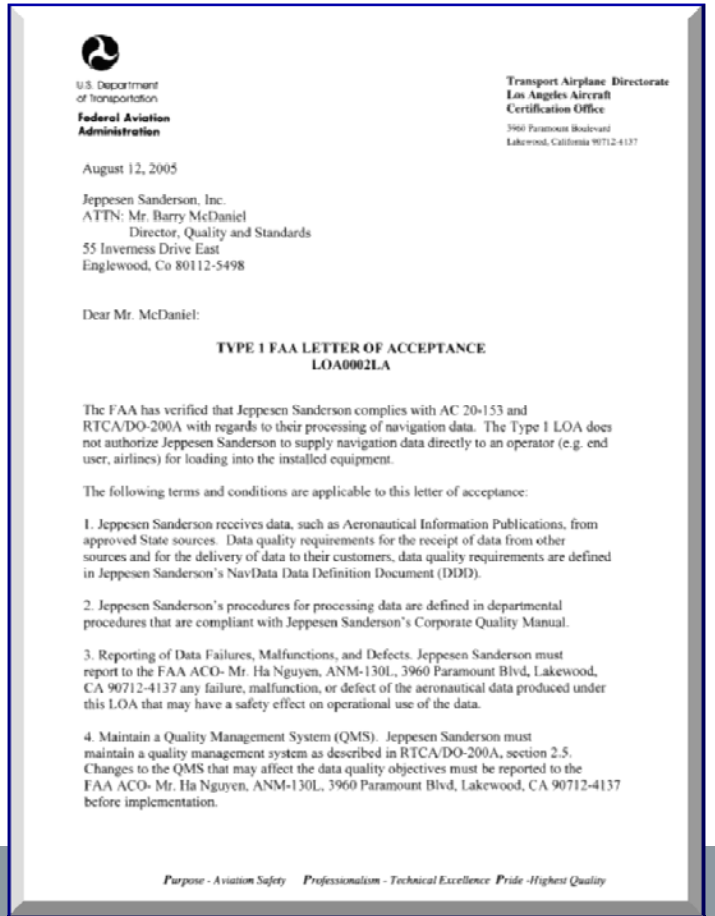
This Type 1 LOA does not authorise the supply of navigation databases directly to end users/operators.

CONDITIONS

1. This acceptance requires compliance with the procedures specified in the LOA Exposition; and
2. This acceptance is valid whilst the accepted Navigational Database Provider remains in compliance with the Conditions for the issuance of Letters of Acceptance for navigation database Suppliers by the Agency" (Further in this LOA referred to as "Conditions") and the documented Data Quality Requirements.

Date of orginal issue:	Date of this issue:	Signed:
3 August 2005	3 August 2005	For EASA Dr. N. Lohl

EASA LOA Nav. Database Suppliers – Sheet A



U.S. Department of Transportation
Federal Aviation Administration

Transport Airplane Directorate
Los Angeles Aircraft Certification Office
3960 Paramount Boulevard
Lakewood, California 90712-4137

August 12, 2005

Jeppesen Sanderson, Inc.
ATTN: Mr. Barry McDaniel
Director, Quality and Standards
55 Inverness Drive East
Englewood, Co 80112-5498

Dear Mr. McDaniel:

TYPE 1 FAA LETTER OF ACCEPTANCE
LOA0002LA

The FAA has verified that Jeppesen Sanderson complies with AC 20-153 and RTCA/DO-200A with regards to their processing of navigation data. The Type 1 LOA does not authorize Jeppesen Sanderson to supply navigation data directly to an operator (e.g. end user, airlines) for loading into the installed equipment.

The following terms and conditions are applicable to this letter of acceptance:

1. Jeppesen Sanderson receives data, such as Aeronautical Information Publications, from approved State sources. Data quality requirements for the receipt of data from other sources and for the delivery of data to their customers, data quality requirements are defined in Jeppesen Sanderson's NavData Data Definition Document (DDD).

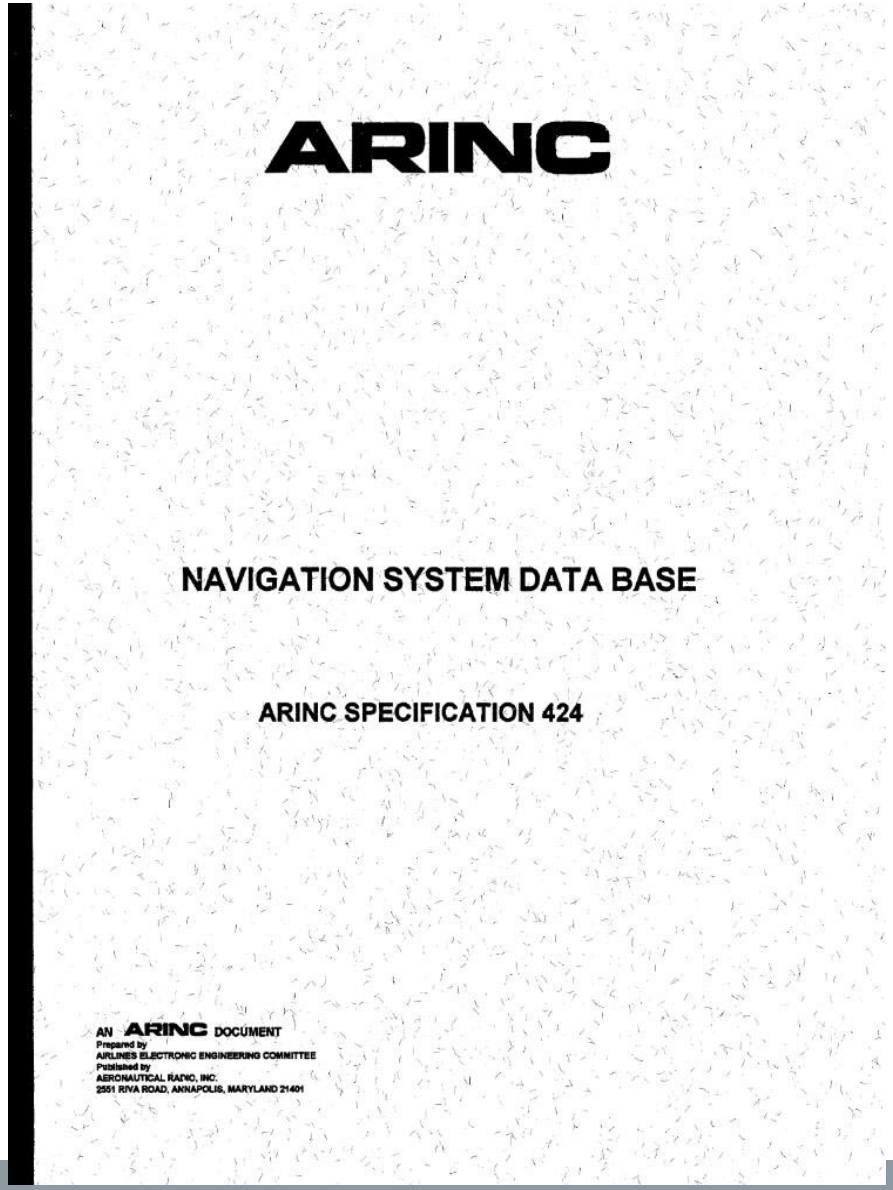
2. Jeppesen Sanderson's procedures for processing data are defined in departmental procedures that are compliant with Jeppesen Sanderson's Corporate Quality Manual.

3. Reporting of Data Failures, Malfunctions, and Defects. Jeppesen Sanderson must report to the FAA ACO- Mr. Ha Nguyen, ANM-130L, 3960 Paramount Blvd, Lakewood, CA 90712-4137 any failure, malfunction, or defect of the aeronautical data produced under this LOA that may have a safety effect on operational use of the data.

4. Maintain a Quality Management System (QMS). Jeppesen Sanderson must maintain a quality management system as described in RTCA/DO-200A, section 2.5. Changes to the QMS that may affect the data quality objectives must be reported to the FAA ACO- Mr. Ha Nguyen, ANM-130L, 3960 Paramount Blvd, Lakewood, CA 90712-4137 before implementation.

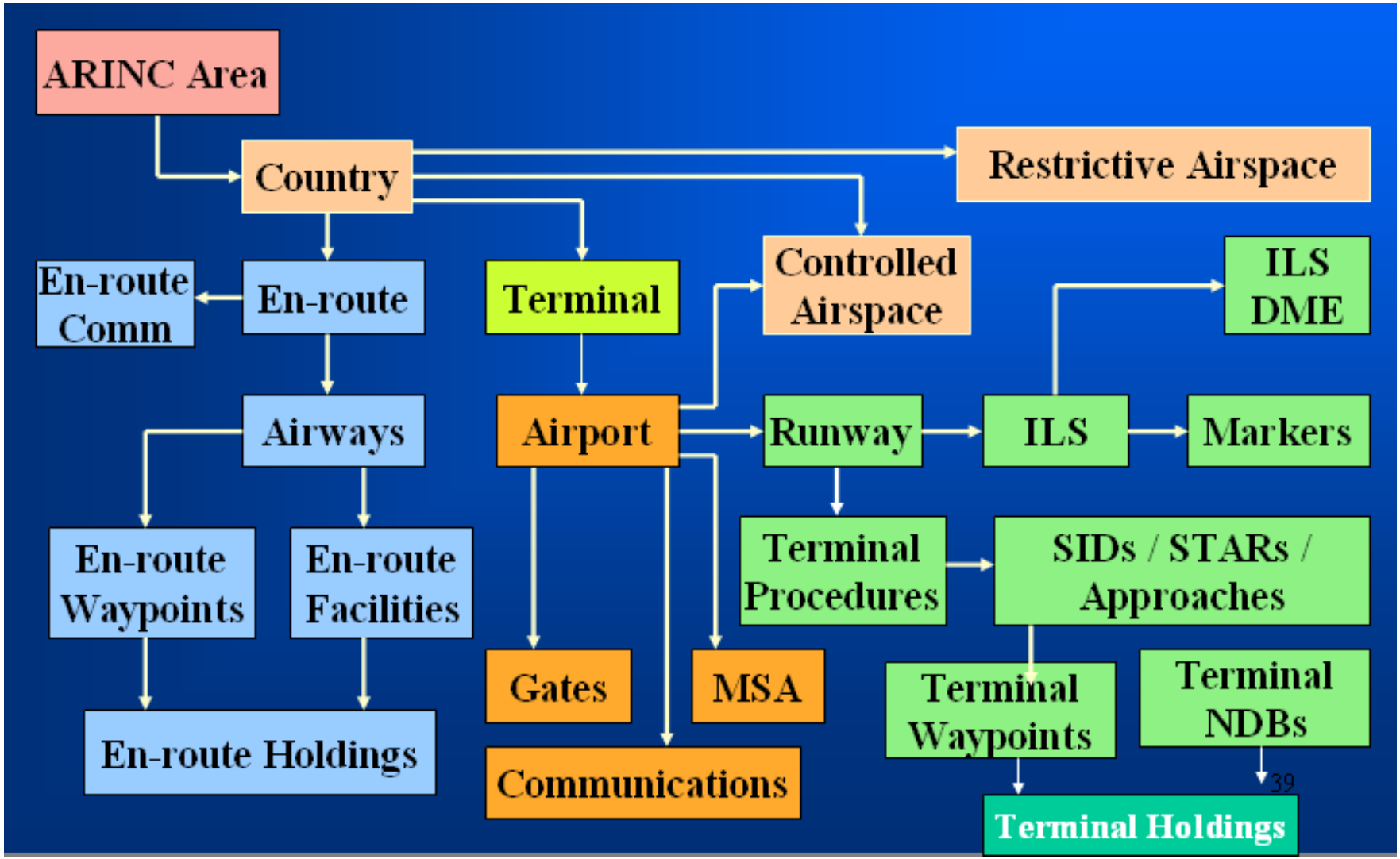
Purpose - Aviation Safety Professionalism - Technical Excellence Pride -Highest Quality

ARINC 424 Worldwide Industry Standard



- September 1973: First ARINC 424 Meeting
- July 1975: First “Gray Cover” published
- July 1976: ARINC 424-1
- ARINC 424-3: First "Air Mass" Application
- ARINC 424-4: Added Simulator Capability
- ARINC 424-5: Added Computer FPL
- ARINC 424-16: Added Path Point Record
- ARINC 424-17: Adopted April 30, 2004
- ARINC 424-18: Ready for Adoption consideration Dec 2004
- ARINC 424-19: Published Dec 19, 2008
- ARINC 424-20: Published Dec 5, 2011

ARINC 424 Database Structure: Hierarchy Concept



ARINC 424 Records

ARINC Files can be composed of the 'Standard' records or 'Standard' and 'Tailored' records (list below not complete).

Section/Sub-Section codes

Section Code	Section Name	Subsection code	Subsection Name
A	MORA	S	Grid MORA
D	Navaid	Blank	VHF Navaid
		B	NDB Navaid
E	Enroute	A	Waypoint
		M	Marker
		P	Holding Pattern
		R	Airways + Routes
		T	Preferred Route
		U	Airway Restriction
		V	Communication
H	Heliport	A	Heliport
		C	Terminal Waypoints
		D	SIDs
		E	STARs
		F	Approach Procedures
		S	MSA
		V	Communications

Section code	Section Name	Subsection code	Subsection Name
P	Airport	A	Airport
		B	Gates
		C	Terminal Waypoints
		D	SIDs
		E	STARs
		F	Approach Procedures
		G	Runways
		I	Localizer/Glide Slope
		L	MLS
		M	Localizer Markers
		N	Terminal NDBs
		P	Pathpoint
		R	Flt Planning ARR/ DEP
		S	MSA
		T	GLS Station
		V	Communications

ARINC 424 Path & Terminators

'Path/ Terminator' Concept (23) permits coding of Terminal Procedures (no en-route segments) and includes a two-character codes and data associated.

1. Path – logically describes how the aircraft gets thru air to the Terminator (track, course, heading);
2. Terminator – is the event or condition (fix, altitude, distance, manual) that causes the system to switch to the next leg;

✓ Twelve (12) P/T acceptable for RNAV procedure design

✓ Smaller sub-set of four (4) used for RNP AR applications i.e. IF, TF, RF, HM

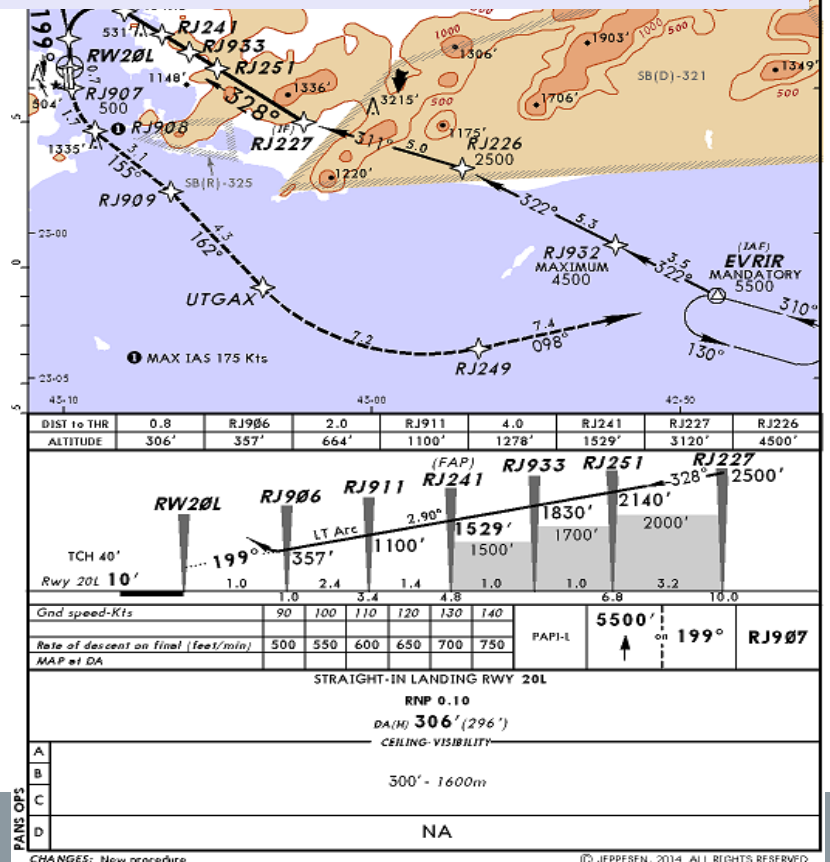
P/T leg behavior heavily dependent on the specific FMS implementation!

ARINC 424 Procedure Coding Process

```
SSAMP SBRJSBFN20RX AEVRIR 010EVRIRSBPC0E  A    IF                                  05500                                0  S   187191313
SSAMP SBRJSBFN20RX AEVRIR 020MIA  SBD 0V       TF                                  03000                                0  S   187201313
SSAMP SBRJSBFN20RX AEVRIR 030D344ESBPC0E       TF                                + 03000                                0  S   187211313
SSAMP SBRJSBFN20RX AEVRIR 040VURUKSBEA0E       TF                                + 02300                                0  S   187221313
SSAMP SBRJSBFN20RX AEVRIR 050YLA  SBDB0EE B    TF                                + 01700          160                   0- S   187231401
SSAMP SBRJSBFN20RX N      010YLA  SBDB0E  I    IF YLA SB                   DB    + 01700          160                   0- S   187241313
SSAMP SBRJSBFN20RX N      020FN20 SBPC0E  F    CF YLA SB       20000020DB        + 01590                   YLA    SBDB0  S   187251313
SSAMP SBRJSBFN20RX N      030PP   SBDB0E  M    CF YLA SB       20000030DB          00716            -300                 0  S   187261313
SSAMP SBRJSBFN20RX N      040MIA  SBD 0V M     CF MIA SB  0000000012600150D          03000          160                   0- S   187271313
SSAMP SBRJSBFN20RX N      050MIA  SBD 0VE HR   HM                  1000T010                                                 0  S   187281313
```

Identification	Aerodrome	Chart Code	AIRAC AMDT	TAB Version
IAC RNAV(RNP) X RWY20L	RIO DE JANEIRO / Santos Dumont (SBRJ)	RJ01G-16	26 JUN 14	01

Seq	Transiction	Path Terminator	Navaid / Fix / WPT	Type / Function	Flyover (Y/N)	REC Navaid	Course Mag (True)	Dist (NM)	Turn	IAS (KT)	Altitude (FT)	Vertical Angle	Perform.
010	Inicial Initial	IF	EVRIR	IAF	Y	---	---	---	---	---	=5500	---	---
020	Inicial Initial	TF	RJ932	SDF	N	---	322 (300.0T)	3.5	---	---	-4500 +2500	---	RNP 1.0
030	Inicial Initial	TF	RJ226	---	N	---	322 (300.0T)	5.3	---	---	+2500	---	RNP 1.0
040	Inicial Initial	TF	RJ227	IF	N	---	311 (288.5T)	5.0	L	---	+2500	---	RNP 1.0
010	Aproximação Approach	IF	RJ227	IF	N	---	---	---	---	---	+2500	---	---
020	Aproximação Approach	TF	RJ251	---	N	---	328 (305.4T)	3.2	R	---	+2000	---	RNP 0.5
030	Aproximação Approach	TF	RJ933	SDF	N	---	328 (305.4T)	1.0	---	---	+1700	---	RNP 0.5
040	Aproximação Approach	TF	RJ241	FAF	N	---	328 (305.4T)	1.0	---	---	+1529	---	RNP 0.5
050	Aproximação Approach	TF	RJ911	SDF	N	---	328 (305.4T)	1.4	---	-140	+1100	-5.07 (-2.90°)	RNP 0.1
060	Aproximação Approach	RF	RJ906	SDF	N	---	---	2.4	L	---	+357	-5.07 (-2.90°)	RNP 0.1
---	---	---	RJ915	RF center	---	---	---	Radius 1.1	---	---	---	---	---



Considerations Procedure Tabular Description

The procedure designer should take some factors into considerations to ensure an unambiguous translation of the design intention into NavData:

Serial Number	*Path Descriptor*	*Waypoint Identifier*	*Fly-over*	*Course °M(°T)*	*Magnetic Variation*	*Distance (km)*	*Turn Direction*	*Altitude (m)*	*Speed (km/h)*	*VPA/ TCH*	*Navigation Specification*
001	IF	SUSER	—	—	+2.2	—	—	+1 550	–470	—	RNP APCH
002	TF	EF974	—	048 (045.7)	+2.2	12.0	—	+1 400	—	—	RNP APCH
003	RF Centre: EF991 r =5.240 NM	EF975	—	—	+2.2	13.7	R	—	–450	—	RNP APCH
004	TF	EF976	—	348 (345.8)	+2.2	9.6	—	@900	–270	—	RNP APCH
005	TF	RW35L	Y	348 (345.8)	+2.2	9.3	—	@150	—	–3.0/50	RNP APCH
006	FA	RW35L	—	348 (345.8)	+2.2	—	—	+250	—	—	RNP APCH
007	DF	SUSER	Y		+2.2	—	L	+1 550	—	—	RNP APCH
008	HM	SUSER	—	048 (045.7)	+2.2	7.4	R	+1 550	–450	—	RNP APCH

Ground and Flight Validation

(quote from PANS-OPS)

Validation

Validation is the necessary final quality assurance step in the procedure design process, prior to publication. Validation normally consists of ground validation and flight validation. Ground validation shall always be undertaken.

Ground validation

Ground validation is a review of the entire instrument flight procedure package by a person(s) trained in procedure design and with appropriate knowledge of flight validation issues. It is meant to catch errors in criteria and documentation, and evaluate on the ground, to the extent possible, those elements that will be evaluated in a flight validation.

Flight validation

Flight validation should be carried out as part of the initial certification and should also be included as part of the periodic quality assurance program as established by the individual States.

Navigation Database validation program

Initial Data Validation

1. The Operator must identify the responsible manager for data uploading, establish process for accepting, verifying and loading into the aircraft;

2. The Operator must validate each approach procedure before flying in IMC;
3. As a minimum, the Operator must:

   - ✓ Compare the navigation data of the procedure to be loaded into FMS with the respective published procedure chart;
   - ✓ Validate the navdata of the loaded procedure, either on the flight simulator or in the actual aircraft under VMC. The depicted procedure on map display must be compared to the published procedure;
   - ✓ The entire procedure must be flown to ensure fly-ability and eliminating any discrepancies/chart inconsistencies;

4. Once the procedure is validated, a copy of the validated data shall be kept and maintained in order to be compared with subsequent data updates;

Navigation Database validation program

Data Updating

1. Before using data update on the aircraft, the Operator must compare the update with the validated data;

2. If there are significant changes, the Operator must validate the amended route in accordance with the steps described in the initial validation data process;

3. If an aircraft system is modified e.g. change/update of software, Operator is responsible for validation of the APV/Baro-VNAV approach with the navigation database and the modified system. The FMS vendor should confirm impact or no effect on path calculation (if no confirmation, initial validation may be performed).

Test Database (ref. ICAO Doc. 9901)

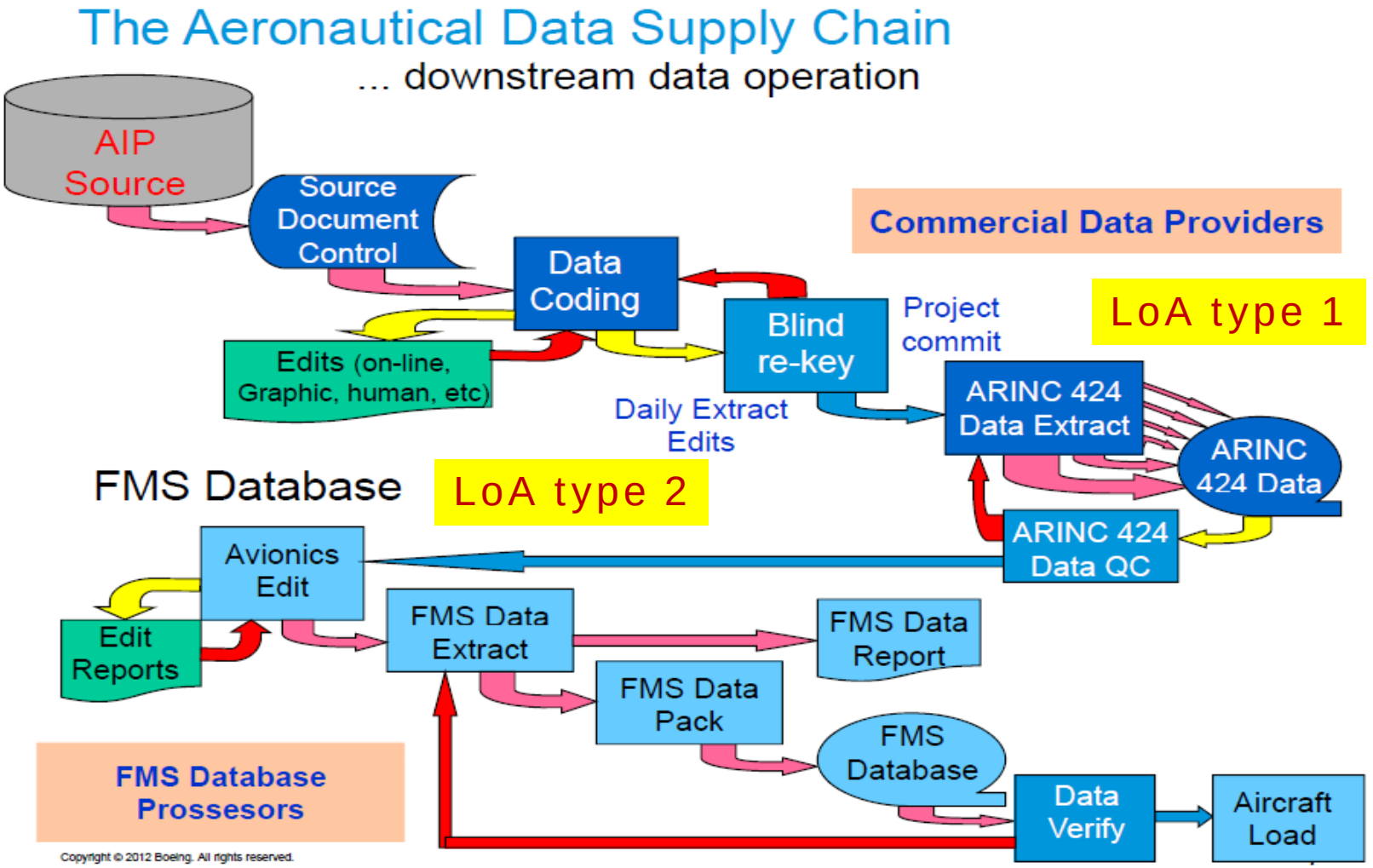
PBN Procedures to be validated should be contained in the suitable navigation system i.e. FMS. The procedure may be on a "*pre-production*" tailored NavData Database file:

1. Custom navigation database (*preferred method*) – most desirable because it will contain a normal operational DB & new official source coded IAPs;

2. Electronic media – some PD tools output ARINC 424 coding of the final designed procedure that can be input (CRC driven) to commercial FMS;

3. Entered manually – method should be used sparingly and limited to LNAV only. As soon s available, coded procedure provided by an official DB supplier should be used to confirm appropriate coding prior to public use.

Test Database: How the process works?



Test Database: Handling by FMS vendors

FMS Manufacturer	Tailored Codes DB	Extract/Remarks
GE Aviation	Yes	Mid cycle extract possible, thru GE Tool input (limited # procedures)
Honeywell Aerospace	Yes	Mid-cycle if customer makes arrangements directly with Honeywell
Rockwell Collins	Yes	Mid-cycle possible under arrangements
Universal Avionics	No	Tailored codes handling no, but trial procedures are included in UNSFLTIN.pc test file
Garmin	Yes	No mid-cycle possibility. Recent capability implemented, needs a new packing s/w release to accept tailored codes.

Note: Tailored codes database = tailored in content!

Test Database: Lessons learned

The use of “T” as a multiple indicator for flight validation procedures:

When we coded the first few flight validation procedures we decided to add a “T” to distinguish the flight validation procedures. For example: The LPV procedure for KDCA RNAV (GPS) RWY 33.


KDCA/DCA
RONALD REAGAN
WASHINGTON NATL

JEPPESEN

15 MAY 09 (12-1)

WASHINGTON, DC
RNAV (GPS) Rwy 33

Source was provided to Jeppesen as KDCA RNAV (GPS) T RWY 33. The procedure would be coded as R33-T. This would allow our system to include both the R33 (LNAV/VNAV) procedure and R33T (LPV/LNAV/VNAV). After further evaluation and coordination many of the avionics manufacturers, it was determined that the T would not be a good solution for the flight validation procedures identification issues. The avionics systems packing software deletes procedure data associated with T suffix. Their systems would delete the T procedures thinking that the T would be a TRUE runway procedure verses a T for TEST procedure.

The use of “F” as a multiple indicator for flight validation procedure:

Source to be provided as KDCA RNAV GPS F RWY 33. Jeppesen will code the procedure as R33-F. This would allow our system to include both the R33 (LNAV/VNAV) procedure and (LPV/LNAV/VNAV).

For multiple flight validation procedures to the same runway, start with F and use subsequent letters (G, H, I ...):

Source to be provided as KDCA RNAV GPS F RWY 33. Jeppesen will code the procedure as R33-F. Additional LPV procedure with different VNAV angle, the procedure identifier is KDCA RNAV (GPS) G RWY 33. This would allow our system to include all three procedures to the same runway. Existing R33 (LNAV/VNAV), R33-F (#1 LPV/LNAV/VNAV), and R33-G (#2 LPV/LNAV/VNAV).

FPD Solution: A comprehensive multi-step plan (I)

	Steps	Jeppesen	Others	Jeppesen's philosophy
1	Obstacle & Terrain data survey	✓	--	Jeppesen eTOD contain a complete terrain model and man-made and certain natural obstacles covering for each airport ICAO Annex 15 Area 2 extracted from commercially available satellite imagery. Jeppesen eTOD accommodates discrete point, line and polygon obstacles consistent with the accuracies published by the DO-276B/ICAO Annex 15 Chapter 10, Appendix 8 i.e. 5m horizontal/3m vertical.
2	Stakeholder requirements & objectives	✓	X	Jeppesen pays special attention to this step to ensure customers have a clear understanding of what to expect at the project's conclusion. The planned work gathers airport infrastructure, airspace, ATC, local operators and environmental requirements. Feedback from stakeholder is valued & used to design all IAPs.
3	Design	✓	✓	Depending on the customer, Jeppesen design can be ICAO PANS-OPS, US TERPS or MIPS criteria. Jeppesen is certificated IFP provider for UAE GCAA, UK CAA, US FAA, NavCanada & CASA.
4	Ground validation	✓	X	Ground validation must always be undertaken. Jeppesen designers use computer desktop application and full-motion simulators to check flyability.
5	Simulation & Modeling	✓	--	Although an optional step, Jeppesen TAAM® is a great value-added IFP projects, especially, in case of complex TMA projects. TAAM® evaluates the implication/validation of introducing new procedures before even starting the calculations.
6	Pre-Coding	✓	--	Jeppesen prepares ARINC 424 test file for each specific FMS software format in support of customer flight trials. This step is mandatory for PBN implementation and sensor-based RNAVs.

FPD Solution: A comprehensive multi-step plan (II)

	Steps	Jeppesen	Others	Jeppesen's philosophy
7	Flight validation support	✓	✓	Flight validation should be carried out as part of the initial certification and also as part of the periodic QA program. Jeppesen is providing a complete package to FV crew and it has a 100% pass rate on FV i.e. reduces significantly customer airborne hour costs.
8	Charting	✓	--	Final product of any IFP project is the procedure chart. Jeppesen provides charting compliant with ICAO Annex 4 or it has the technical ability to customize charts e.g. HEL charts content and/or format.
9	The Regulator approval	✓	X	The step is critical to getting a new procedure into service, especially PBN applications (e.g. RNP AR). Jeppesen prepares necessary approval documentation and supports the customer thru authorization process.
10	Maintenance	✓	X	Published procedures shall be subjected to a periodic review, including validation. Many providers simply build a procedure and then never touch it again. Jeppesen is offering long-term partnership in ensuring for customer an IFP maintenance plan.
11	Obstacle evaluation	✓	--	Jeppesen can support States in starting an obstacle evaluation program as part of existing procedure review plan. We can advise the customer when to approve or disapprove the building of the structure.
12	Quality Control	✓	--	Jeppesen maintains quality and process certification under FAA and EASA LoA type 1 and ISO 9001:2008

✓ = fully provided; X = partially provided; -- = not provided;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Thank you!