29 February 2020

Mr. Ali Bahrami
Associate Administrator for Aviation Safety
Federal Aviation Administration
800 Independence
Avenue, S.W. Washington,
D.C. 20591

Dear Ali,

The Performance-based Operations Aviation Rulemaking Committee (PARC) is pleased to submit the following information for your review. The PARC Navigation Work Group (NAV WG) recently completed an analysis for conducting instrument approach procedures (IAPs) using two separate RNAV procedures that are constructed using radius-to-fix (RF) legs or track-to-fix (TF) legs respectively, and flying those procedures to the same runway end concurrently. The analysis provided is the result of tasking requested by the NextGen Integration Work Group (NIWG). The NIWG is a working group which reports to the NextGen Advisory Subcommittee (NACSC).

Details and methodology are outlined within the document following this page. There is no specific action requested by the PARC, however the PARC agreed that it was important to acknowledge the immense amount of work and time, much of which is completed voluntarily, that was required to deliver the results. The results of the document serve to answer technical questions concerning concurrent TF/RF operations that have and will arise and helps to mitigate technical issues from being the "long pole in the tent." The PARC web site is the logical repository for the document.

I personally commend the NAV WG for their continued diligence and dedication as they worked through all the challenges related to RF/TF concurrent operations.

The PARC appreciates your continued support of our activities.

Sincerely,

Mark Bradley
Chairman, PARC

Cc: Mark Steinbicker
    Chris Hope
    Mike Cramer
    Merill Armstrong
    TJ Nicholas

Contents

1   INTRODUCTION & HISTORY

1.1 Executive Summary

The PARC Navigation Working Group (Nav WG) has been working on RNP transitions to precision final (RNP to xLS) operations since 2010. Much of this work directly relates to the RF.TF Instrument Flight Procedure (IFP) Concurrent Operations concept. The work has shown that some aspects of the RF.TF Concurrent Operations idea are technically feasible, with some exceptions; and recent work has shown that those can be resolved and are thus technically feasible as well. Since 2017 the Nav WG has defined a concept that would allow non-RF capable aircraft to mirror an RF path in the approach environment with TF transitions. The goal

has been to increase participation by allowing procedures to be coded either way without defining a separate procedure for the TF operators.

The genesis of the concept was in work done by the Nav WG beginning in 2010, when the PARC Steering Group directed the Nav WG to develop methods to use an RNAV transition to an ILS final which would work for all aircraft / avionics combinations operating in the NAS at that time. Ideally the path construction and the operationally derived constraints for that construction would place any aircraft in a position to capture the localizer and glideslope through a range of temperature and lateral / vertical accuracy conditions. Since the variations in avionics had differing capture conditions (lateral and vertical) a study was done to identify and satisfy those conditions for each aircraft. Since this was to accommodate as many aircraft as possible, it had to include the ability to code the lateral path without using RF (i.e., using flyby fixes or TF construction) and path construction needed to bring aircraft in under the glideslope for a range of above ISA temperature conditions. Once this was done, testing in simulators was used to validate the constructions and to identify operational conditions that would restrict certain elements of the path construction.

Following that work, knowing that both RF and TF constructions would be necessary and that two procedures would be required, the SG tasked the Nav WG with determining possible ways to implement the operations using a single procedure. Once all the options were identified, along with difficulties of implementing each, the SG asked the Nav WG to recommend the best option to use for implementation. Validating that choice is the primary content of this report. It is organized as follows:

1. Section 1.2 traces the details of the history summarized above.
2. Section 3 provides validation of the technical aspects of RF.TF Concurrent implementation; procedure design & publication, ARINC 424 database construction, Aeronautical charting, and flight operations.
3. Section 4 provides an overview of work outside of the technical feasibility elements that will still need to be done to implement RF.TF Concurrent Operations.

1.2   History of Development

The following is a list of the relevant research that the PARC Nav WG has done to date with the specific conclusions that apply to RF.TF Concurrent Operations identified. Each topic heading is a hyperlink to the formal recommendation document which is located on the PARC website.

RNP to ILS Action Team Report Revision (20 March 2012)

This recommendation laid the design basis for using RNP to turn from downwind to final and placing the aircraft in a position (laterally and vertically) to capture both localizer and glideslope of an ILS. It spans all aircraft / avionics eligible for RNP operations that have ILS capability because the capture criteria of each aircraft's avionics was evaluated and the procedure design

satisfies all aircraft requirements for captures. This is directly applicable to RF.TF operations since they are intended to accomplish the same operation, i.e., turn from downwind to final with a capture when on the final approach course. The analysis defined the minimum radius for the RF turn to final and the minimum distance from the final roll out point to the runway based on the RNP value, as well as defined the temperature compensating segment that assures glideslope capture from below. This was an analysis not a trial or simulation.

RNP to xLS Recommendation Final (28 August 2014)

This recommendation defined the specific criteria for FAA to incorporate into Order 8260.58 to implement RNP to ILS procedures based on the analysis completed in 2012. It detailed the shallow segment design criteria which assures glideslope capture from below for a range of ISA deviation and provides for deceleration. It also details the lateral path design, speed constraints, etc. for a procedure designer to create these procedures. This work is directly applicable to the RF.TF Concurrent Operations RF type designs. At the conclusion of this work FAA asked the PARC to validate the designs by simulations both in the lab and in aircraft flight simulators to determine how non-RF capable aircraft could be included (see next section).

RNP to ILS Guidance material (5 October 2015)

This activity developed the TF overlay method for a sample of the RF procedures that had already been developed, and then proceeded to do simulation trials of all the variants under standard day temperature, non-standard day temperature, and differing wind conditions to evaluate flyability and the actual operation by flight crews and engineers. The aim was to determine any operational or design considerations in addition to the basic criteria requirement that might be necessary for the operations to succeed. The types of aircraft and avionics evaluated included the B737, B747-400, B787, A320, A330, CRJ200 and ERJ145. This provided testing of aircraft with the most restrictive capture criteria (A330, B737), an older model without RF capability (B747-400), an aircraft with the newest avionics (B787), a single aisle aircraft with two different avionics suites (A320), and aircraft/avionics from two TF only operators with the least automation for capture of the ILS (CRJ200 Collins ProLine and ERJ145 Honeywell Primus). This recommendation provides additional procedure design requirements beyond the original analysis and criteria recommendation, such as mitigations for excess fight crew workload in some aircraft (e.g., RJs). This work is all directly applicable to RF.TF Concurrent Operations since the TF overlays were part of the testing.

RNP to GLS and RNP to LPV Recommendation (24 April 2017)

The final phase of the WG's tasking prior to the initiation of the RF.TF Concurrent Operations work was to confirm that the criteria and the design / operational guidance developed for RNP to ILS could apply to RNP to GLS and RNP to LPV. Testing at Collins (LPV), Honeywell (LPV and GLS), Boeing (GLS) and Universal (LPV) confirmed that the ILS criteria and considerations were

adequate. The recommendation lead to an update of the Order 8260.58A Appendix 3 RNP to ILS guidance by adding GLS and LPV final segments as an option.

A large body of work showing feasibility of RF.TF Concurrent Operations has previously been accomplished, however, there were still items which needed attention to realize the goals of single procedure, single clearance, two design implementations to begin RF.TF Concurrent Operations. For example, a change to ARINC 424 specification was needed to accommodate two implementations of the same procedure in the ARINC 424 master file. These have now been resolved by the RF.TF Concurrent Operations Demo Action Team as described in Section 3 of this report.

The remainder of this validation report will summarize the technical details from the previous recommendations. It will also add the new work the action team has done to determine technical feasibility of the RF.TF concurrent operation (see Figure 1 below).
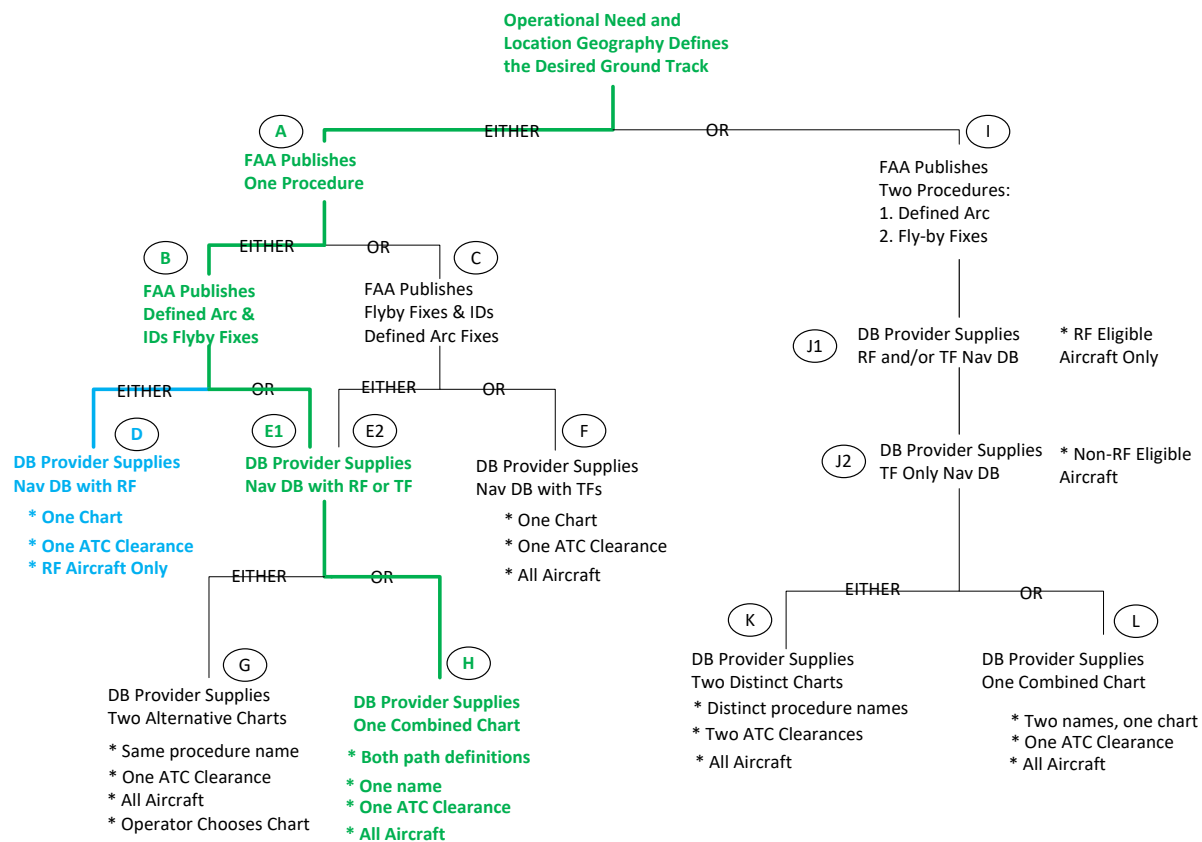

Figure 1 RF.TF Concurrent Operations Options Map

2 ACTION TEAM TERMS OF REFERENCE

The stated objective from the action team ToRs is the following: "The most recent recommendation re. concurrent RF/TF operations highlighted the process for producing appropriate charting and the onboard Nav Databases to support RF.TF Concurrent Operations. The PARC Nav WG needs to validate the process prior to an initial implementation or the live, operational implementation at multiple locations." The scope lays out use of previous work, simulations, and providing assurance that technical issues are resolved.

3 RF.TF CONCURRENT OPERATIONS - TECHNICAL FEASIBILITY

The following sections address the issues and resolutions achieved at each of the affected nodes in Figure 1 RF.TF Concurrent Operations Options Map.

3.1 PROCEDURE DESIGN

The procedure design methods recommended in 2014 and 2015 (see links in section 1), have been adopted by FAA and were published in Order 8260.58A Appendix C. The addition of GLS and LPV to the ILS in that appendix has been accepted and appears in Order 8260.58A Change 2. However, the Order only covers the design of the RF implementation. For RF.TF Concurrent Operations, a TF 'shallow segment' must be designed prior to the FAF per Order 8260.58 for RNP to xLS. This may be perceived to penalize the RF track distances but should lead to an overall net increase in efficiency as the participation rate of the RF.TF procedure goes up. It also results in providing a deceleration segment prior to the PFAF and allows capture of the glideslope from below in most conditions with no intervention.

The Nav WG recommends that a 180-degree RF turn be approximated by three 60-degree turns for flyability and robustness. Figure 2 shows one method for placement of flyby fixes to allow non-RF capable aircraft to emulate the RF lateral path using TF legs for a 180-degrees turn from downwind to final. For this design (and others) to be realizable, there are minimum radius considerations for the RF as well as the standard leg length considerations for the TF legs per current guidance (Order 8260.58). To fully implement the design to guarantee glideslope capture from below in above ISA temperatures, a shallow segment needs to be added between the end fix of the RF (end of segment F below) and the final approach fix; the length and glidepath angle are determined by the airport elevation and the highest delta ISA being design into the procedure. It was recommended that plus 40C delta ISA be used for the design.
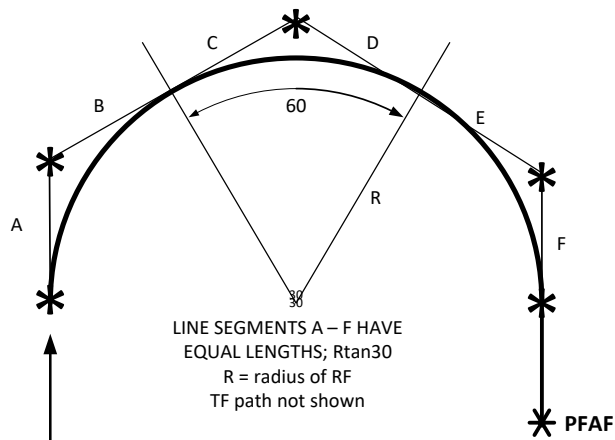
Figure 2 Recommended TF Overlay Design

During the RNP to ILS testing in 2014-16, the above method was used by the WG to design the TF versions of the RF procedures. There should be alternative methods allowed, since Established on RNP (EoR) applications using TF must be considered in finalizing the design criteria. EoR compliant design criteria (Order 8260.3) currently requires an additional shallow angle TF turn to final. Consequently, the TF design for EoR might drive a change to an optimal RF path version. Some consideration for revisiting the shallow intercept design should also be considered for EoR given the RF.TF concurrent operation design which found that such a segment was unnecessary. However, the technical feasibility of these designs is not in doubt, so alternatives can be included in the final criteria.

3.2   PROCEDURE PUBLICATION

Referencing the (A) and (B) nodes on Figure 1, it was the intent that FAA formally publish the RF version of the procedure, with the flyby fixes identified in the "Notes" section of the published FAA 8260-3 form for use by the data packing houses when their customers are not RF capable or approved. The team has found that there is no technical issue with this method; i.e., it is possible, and the data suppliers can accept that as formal definition of the overlay procedure.

3.3   ADDITION TO ARINC 424 MASTER DATABASE

In order to store two differently coded versions of the same procedure (same name for both), it was necessary solve the indexing problem that would cause. The Nav WG members proposed a method to the ARINC 424 working group in July 2019. During the ARINC WG meeting in July 2019, the ARINC WG discussed and revised the proposal in a way that all the suppliers could agree with and wrote a formal change paper for the next release of ARINC 424 specification, Version 23. They released the final approved change proposal on July 29, 2019. [ARINC 424 Change to Support RF.TF Concurrent Operations]. This will allow the ARINC 424 data file to

contain two versions of the approach transition for the same procedure name at an airport, supporting the RF.TF Concurrent Operations need for a single procedure name and a single ATC clearance.

3.4 PACKING AIRBORNE DATABASES

The additional definitions of the Route Type Identifier (RTI) will allow database suppliers to differentiate between transitions with RF implementation and the same transition path implemented with TF legs. The TF version will have an RTI of "Y" and the RF version will use an RTI of "A". Both will have the same transition identifier. The database suppliers for the airborne data already distinguish between RF capable avionics/aircraft, so the RTI can be used to direct the TF version to the aircraft / avionics which are not capable (or approved) for RF legs.

Packing programs for the airborne databases will need modifications to recognize the new values for RTI; software development timing and costs are left to a later section regarding considerations that are not technical and broader than the PARC Nav WG.

3.5 AERONAUTCAL CHARTING

The Nav WG Action Team devised some possible charting methods for RF.TF Concurrent Operations to retain the same procedure name (and hence clearance) for both versions of the procedure. They are presented in Section 6, however, it is not the intention of the Nav WG to limit the discussion, these are simply three possible examples. The scope of charting is broader than the Nav WG; see 4.3 below.

3.6 RF.TF CONCURRENT OPERATIONS

Previous Nav WG recommendations have assured the procedure design flyability in all tested aircraft / avionics suites and have provided design constraints that assure that there should be no additional workload issues for flight crews. The work in 2014-2016 provided recommendations that assure smooth transitions from the RNAV segments to the ILS final segment with a high probability of precision guidance capture across all the different avionics and a range of temperatures up to plus 40° C ΔISA. Testing was done in flight and engineering fixed based simulators with line pilots during development of the recommendations. With the help of ARINC 424 committee updating the database route type indicator, we can now have a single procedure name that has its approach transition coded in two different ways in the same ARINC 424 database. This allows the use of a single ATC clearance regardless of the actual database coding in the aircraft.

Three ATC issues remain to be resolved; the radar display of the expected track (what will it look like on a scope), the acceptability of the differences that will possibly be seen in the RF vs. the TF tracks when flown, and possible spacing issues if the track lengths are too different. These are not technical issues per se and may require work (e.g., HITLs) outside of the Nav WG for evaluation.

4   RF.TF CONCURRENT OPERATIONS – IMPLEMENTATION

4.1   TIMELINE CONSIDERATIONS

Adoption of the new values for the RTI in the ARINC 424 specification is only the start of the process of updating programs to support RF.TF Concurrent Operations. Although OEMs do not have to wait for the final publication of Version 23 of the 424 specification to update their packing programs (the change has been formally approved by the 424 committee), some may delay software updates until the timeframe for implementation of the first RF.TF concurrent procedures becomes more clear. Some OEMs update their packing software yearly, others only when a new change to 424 is published, which will directly affect the earliest date procedures could be put into use in the NAS. Although recognizing the new RTI is not a technical issue, recognizing the new values requires making software changes to database packing programs.

The implementation timeline will be affected by multiple factors (some of which may be done in parallel). Some of these factors are:

1. The time to develop procedure design criteria and procedure design software
2. The time to select the first site for implementation
3. The time to complete development of the new procedures
4. The time needed to reach agreement on the charting of the procedures
5. The time to first procedure publication by FAA
6. The delay until OEM navigation database packing programs are updated to recognize the new Route Type Indicator (RTI) values

Estimating this time will require discussions with the OEMs, with the FAA as to how and when they might want to perform a pilot program and analyze its effectiveness, and with the various operators for any aircrew training they may deem necessary.

While most new aircraft are being delivered with RF capability, they may not yet be qualified to operate on RF turns (some GA etc.). Thus, the time elapsed until implementations can be put into general use should be compared to the expected retirement dates of the non-RF fleets as they are phased out by operators but taking into account that some aircraft may not be RF approved for a much longer time. Forecasts show non-RF CRJ200 and ERJ145 retirements mostly completed over the next ten to fifteen years, however some new deliveries in the RJ fleets that have RF capability may not be submitted for approval to operate on RFs.

4.2   COST CONSIDERATIONS

There will be costs associated with the implementation of RF.TF Concurrent Operations.

1. OEMs and ARINC suppliers will have to update software to allow for the revised definition of the RTI,
2. Operators may incur costs relating to training and OEM packing software upgrades,

3. There will be costs associated with broader based human factors testing for ATC and operators related to charting and depiction on radar scope,
4. There will be costs of training for FAA designers, and
5. Additional IFP development may create additional charting and associated costs.

The Nav WG cannot assess all these costs nor assess how those costs might be distributed among the participants, however it is not expected that the costs will be prohibitive.

4.3   CHARTING AND PHRASEOLOGY CONSIDERATIONS

The Nav WG has developed charting examples which are given in Section 6. The examples are:

1. Two charts, same procedure name but RF on one and TF on another. Operators will only get the chart that their equipment and crews are authorized to use. (Not shown in the examples),
2. A single chart with an inset showing the alternative path definition, (this method is in use at Schiphol, however there are concerns such as the ability to geo-reference the inset for electronic displays and competition for space with missed approach etc.),
3. A single chart with all fixes shown but either the flyby fixes and path or the RF fixes and path in greyscale.

Final charting and phraseology will need vetted in various forums outside of the PARC. For example, the ACM, the IFPP, the PCPSI, and perhaps VOLPE (human factors) are examples of industry/FAA forums that could have a part in this work. The Nav WG believes that no changes to approach clearance phraseology will be needed.

4.4   ATC & PERFORMANCE CONSIDERATIONS

Prior work has shown that implementing TFs to overlay an RF track to very closely follow the same paths is possible. Establishing how closely the overlay needs to duplicate the RF has been done generally, but they will need to be evaluated qualitatively by controllers for questions of "how close is close enough". The difference in track length could also be a factor if the difference between the RF and TF implementations is too great, affecting in trail spacing. This could be examined through computer modeling in a simulated environment and corroborated, if necessary, through HITLs. Several years ago, live trials were flown in Atlanta where TFs were used to overlay RF turns to final. The track conformance was shown to be acceptable in the trials, which were however halted for other reasons.

The bank angle behavior will also need to be assessed, since the RF will be flown at nearly a constant bank angle where the TF version will bank up for each flyby and roll more level between the fixes. This may need to be visualized for both tower and radar controllers to set their expectations relative to visual following of the aircraft.

This evaluation needs to be done once to determine the final allowable track differences that procedure design criteria will incorporate. Once the design criteria is final, selection of an airport for trial implementation and evaluation would be a logical next step.

All of this is outside the ability of just the Nav WG to assess, however, none of it will technically prevent RF.TF Concurrent Operations.

5   SUMMARY & RECOMMENDATIONS

The key take-aways from this report are as follows:

1. RF.TF Concurrent Operations as described herein are both technically and operationally feasible,
2. Prior simulation testing of the TF versions of the RNP to xLS procedures using RF in B747-400, CRJ200 and ERJ145 provided the design constraints necessary for successful operation in TF aircraft and thus did not need to be repeated,
3. There may need to be differences between RF and TF implementations relative to TCAS (see recommendation #2 below),
4. Recent Order 8260.58A revisions cover the operational design considerations that are needed to build either RF or TF operations for these transitions to final. The Nav WG developed and analyzed the means for overlaying the RF turn and developed the foundational criteria for building the TF overlay, but there will be a need for new procedure design criteria to fully cover implementation.
5. Charting RF and TF versions with single name will need to be addressed (two charts may be needed).

The Nav WG recommends that:

1. SG task the NavWG with developing performance measures we would want to track in implementation of RF.TF Concurrent Operations,
2. FAA and industry review the SMS for EoR to possibly revise TF implementation EoR by removing the 10-degree intercept to final which was shown not to be necessary in Nav WG testing,
3. FAA consider criteria for other angular extent RF turns (other than 180, examples have been developed at KBNA).
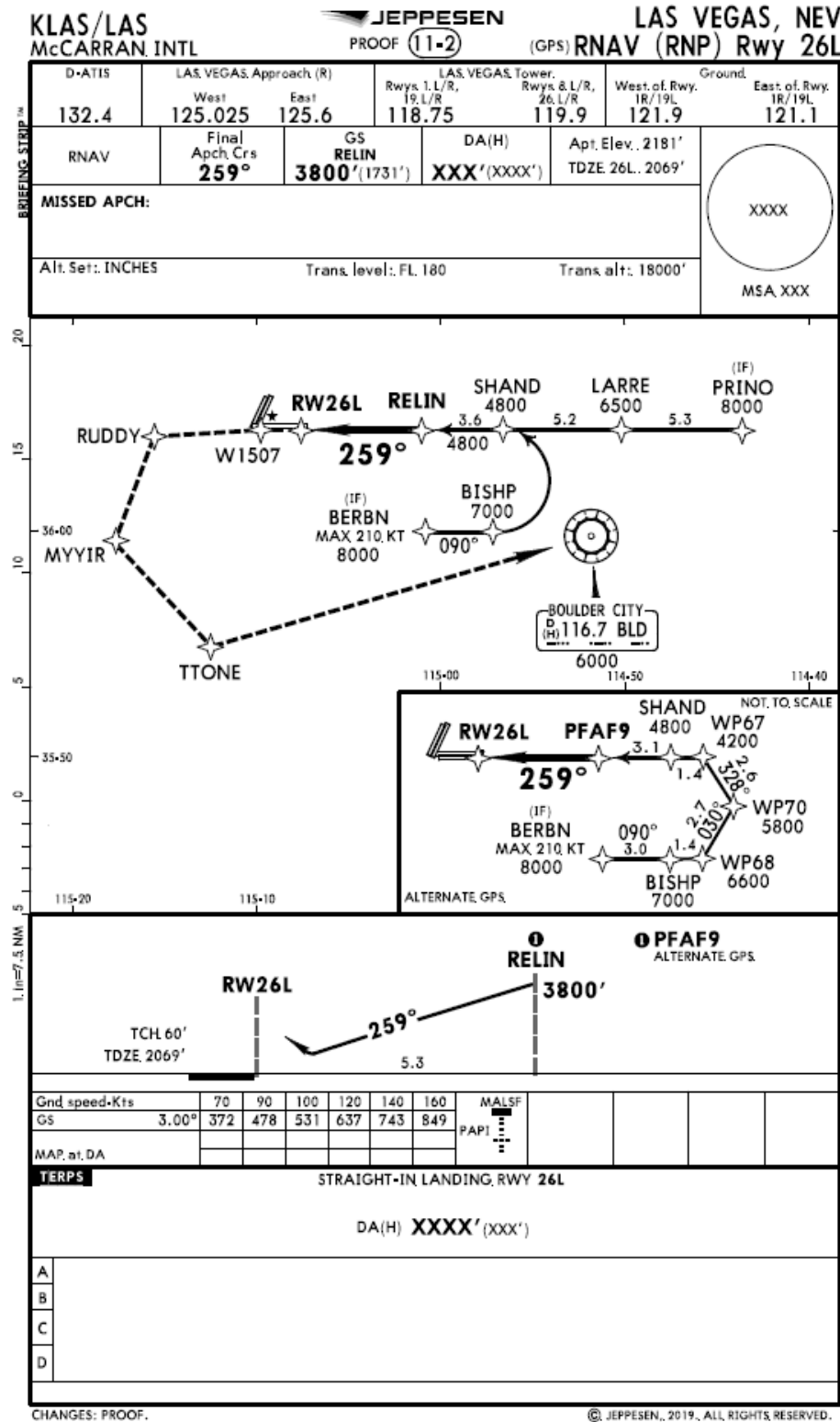
6 EXAMPLE CHARTS

6.1 INSET METHOD

Figure 3 RF Transition Main Chart, TF Transition Inset
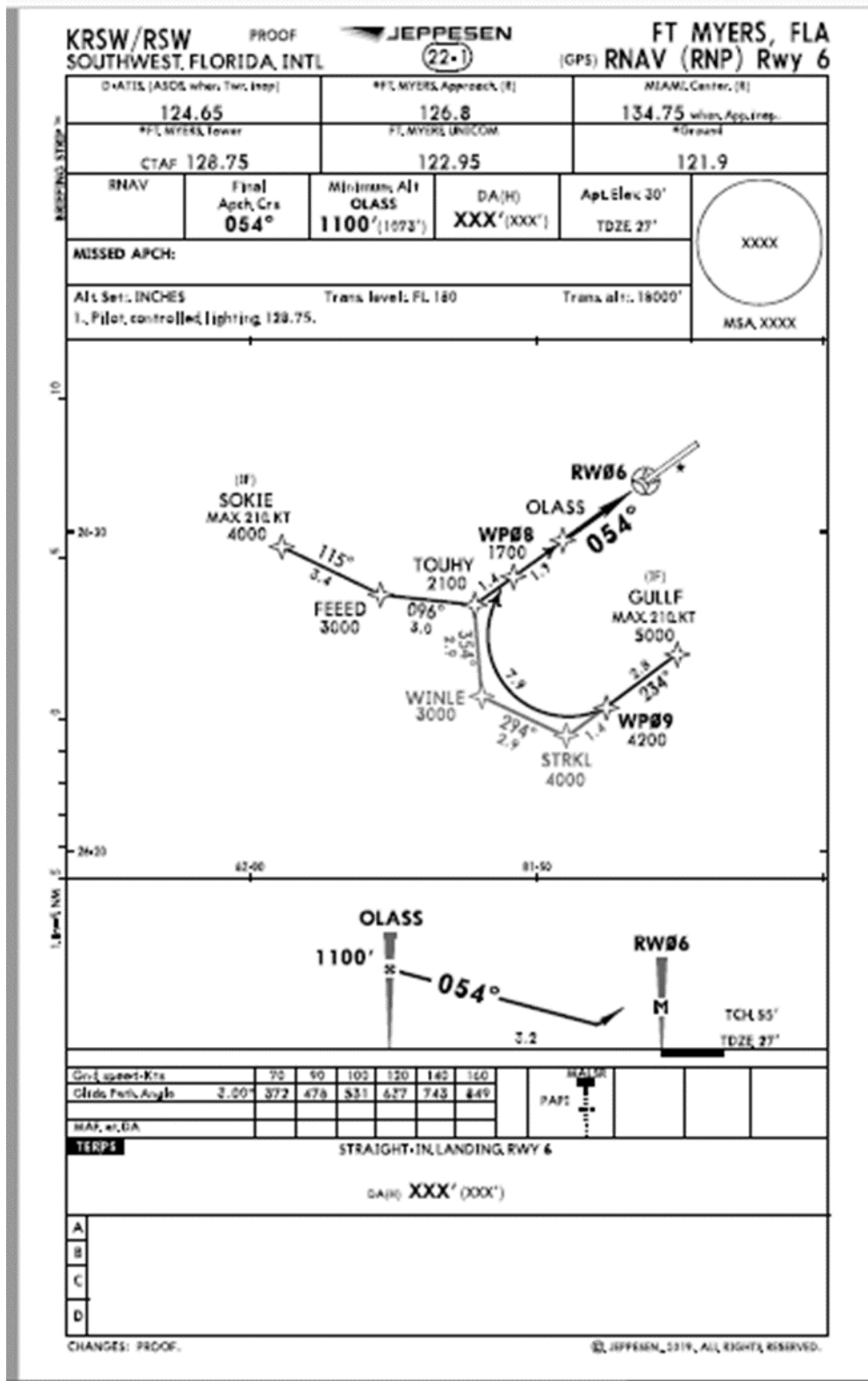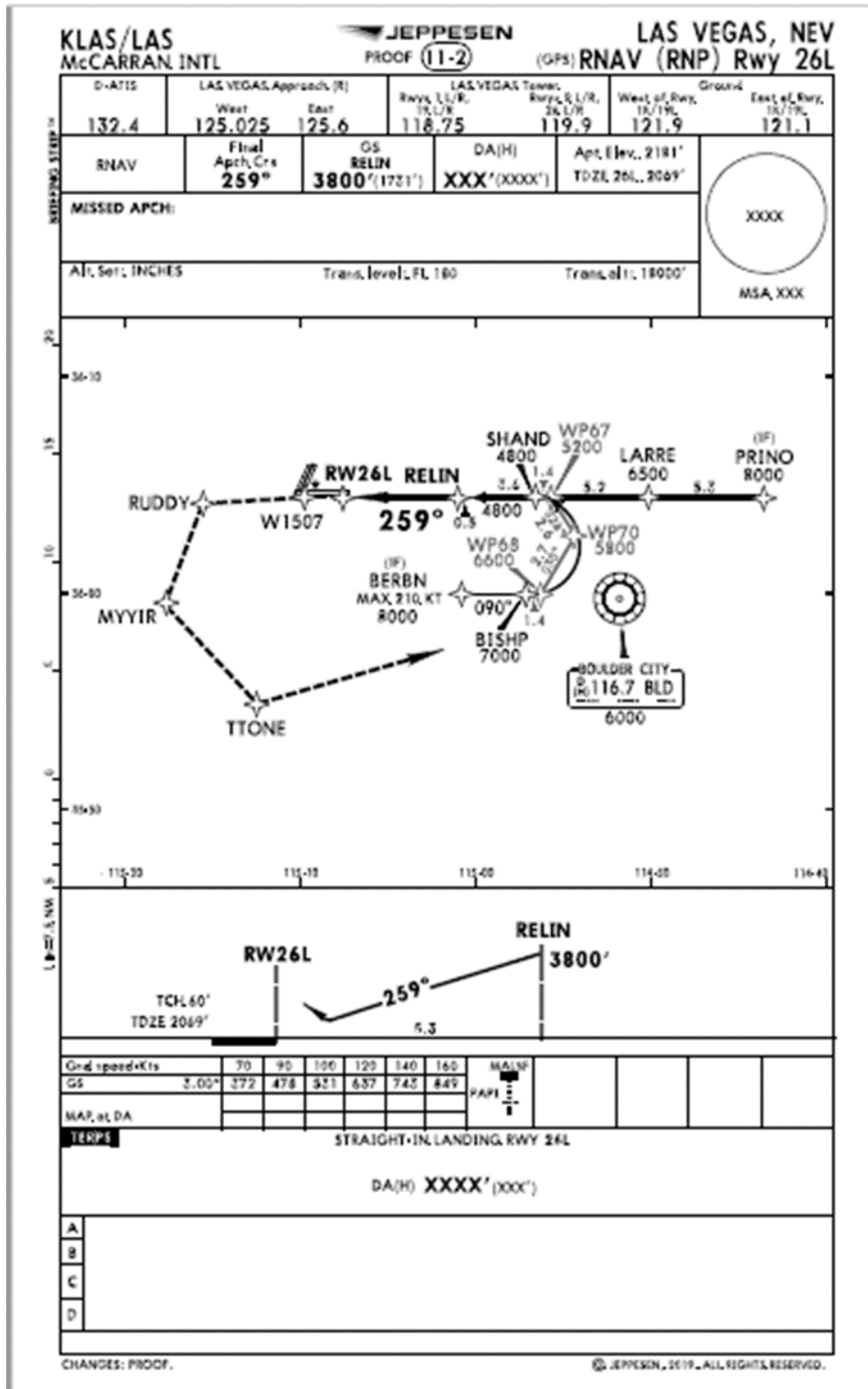
6.2   GHOSTING METHOD

Figure 4 RF Transition Bold, TF Transition Greyed

Figure 5 RF Transition Bold, TF Transition Greyed

7 EXAMPLE 8260-3 FOR CONCURRENT OPERATION

Notes section on second page contains the flyby fixes to overlay the RF.

FEDERAL AVIATION ADMINISTRATION
FLIGHT STANDARDS SERVICE
RNAV - STANDARD INSTRUMENT APPROACH PROCEDURE DATA RECORD
TITLE 14 CFR PART 97.33

Bearings, headings, courses, tracks and radials are magnetic. Elevations and altitudes are in feet, MSL, except HAT, HAA, TCH, and RA. Altitudes are minimum altitudes unless otherwise indicated.
Ceilings are in feet above airport elevation. Distances are in nautical miles unless otherwise indicated, except visibilities which are in statue miles or feet RVR.

AIRPORT		AIRPORT ID		PROCEDURE NAME		ORIGINAL/AMENDMENT		CITY	STATE
SOUTHWEST FLORIDA INTL		KRSW		KRSW RNAV (RF/TF) Rwy 06		Original		FORT MYERS	FL
AIRPORT ELEVATION		**TDZE**	**SUPERSEDED**	**ORIGINAL/AMENDMENT**		**DATED**		**MAG VAR**	**EPOCH YEAR**
30		N/A	N/A	N/A		N/A		-4.0	2000
FACILITY		**COORDINATES OF FACILITIES**		**ACTUAL EFFECTIVE DATE**		**REQUIRED EFFECTIVE DATE**		.	
N/A		N/A		N/A		N/A			

TERMINAL ROUTES

FROM	FIX TYPE	TO	FIX TYPE	LEG TYPE	FO/FB	RNP	COURSE	DISTANCE	ALTITUDE
SOKIE_	IAF	SOKIE_		IF	FB	1.00	120	0.000	400
SOKIE_	IAF	FEEED_		TF	FB	1.00	120	3.650	3000
FEEED_	IAF	TOUHY_		TF	FB	1.00	99	2.740	2100
TOUHY_	IF	WP08		TF	FB	1.00	58	1.450	1700
WP08	IF	OLASS_		TF	FB	1.00	58	1.943	1100.0
GULLF_	IF	GULLF_		IF	FB	1.00	238	0.000	5000
GULLF_	IF	WP09		TF	FB	1.00	238	2.754	4200
WP09	IF	WP08		RF	FB	1.00	238	7.852	1700
OLASS_	PFAF	KRSW:RW06:AER		TF	FB	0.30	58	3.198	81.6
KRSW:RW06:AER	MAP			CA	FB	1.00	58	0.000	430.0
	MAP	GALVE_		DF	FB	1.00	58	3.700	1000
GALVE_	MAP	RUTHY_		TF	FB	1.00	122	7.508	2300.0
RUTHY_	MAP	CORFU_		TF	FB	1.00	213	6.810	2300.0

MISSED APPROACH

MAP:
1.35 NM from threshold RW06

MISSED APPROACH INSTRUCTIONS:
Climb to 2300 Feet Direct to GALVE_ and via 122 track to RUTHY_ and right turn via 213 track to CORFU_ and hold

ALTERNATE MISSED APPROACH INSTRUCTIONS (DO NOT CHART):

PROFILE:
1. PT   SIDE OF COURSE   OUTBOUND   FT WITHIN   MILES OF   (IAF)
2.
3. FAC: 54.1   PFAF   OLASS_ DIST PFAF TO MAP: 1.9   DIST PFAF TO THLD: 3.2
4. MIN ALT: 510
5. DIST TO THLD FROM PFAF: 3.2   MM: N/A   IM: N/A   150 HAT: N/A   HAT: 1.35
6. MIN GP INCPT: 1100   GP ALT AT PFAF: MM: N/A   IM: N/A
7. GP ANGLE: 3   34:1:   IS CLEAR   20:1:   IS CLEAR   TCH: 55
8. MSA FROM: RW06

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AIRPORT	AIRPORT ID	PROCEDURE NAME	ORIGINAL/AMENDMENT	CITY	STATE
SOUTHWEST FLORIDA INTL	KRSW	KRSW RNAV (RF/TF) Rwy 06	Original	FORT MYERS	FL

PBN EQUIPMENT REQUIREMENTS NOTES:
RF Required

NOTES:
Chart: STRKL_: N26° 23' 38.850000000" W81° 48' 52.660000000"
Chart: WINLE_: N26° 24' 52.380000000" W81° 51' 48.260000000"
Procedure Flight Validated IAW FAA AC 90-113A.

ADDITIONAL FLIGHT DATA:

MINIMUMS:
TAKEOFF: SEE FAA FORM 8260-15A FOR THIS AIRPORT
ALTERNATE: NA

CATEGORY:

FINAL TYPE	DA/MDA	A VIS	HAT/HAA	DA/MDA	B VIS	HAT/HAA	DA/MDA	C VIS	HAT/HAA	DA/MDA	D VIS	HAT/HAA	DA/MDA	E VIS	HAT/HAA
S-RW06	510	1/2	483	510	1/2	483	510	3/4	483	510	1	483			

CHANGES - REASONS:
N/A

COORDINATED WITH:

A4A ALPA AOPA APA HAI NBAA

FLIGHT CHECKED BY	OFFICE	DATE	
N/A	N/A	N/A	

DEVELOPED BY	OFFICE	DATE	
Tim Lovell	MITRE PARC NAV WG		

APPROVED BY	OFFICE	DATE	TITLE
Mike Cramer	MITRE PARC NAV WG Lead		

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