Federal Aviation Administration

Safety Study Report of ORD Runway 22L Departure and MDW Runway 13C RNAV (RNP) Instrument Approach Separation

Flight Systems Laboratory
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April 2009

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Flight Systems Laboratory
Flight Technologies and Procedures Division
Flight Standards Service

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Technical Report

Technical Report Documentation Page

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12. Abstract

This report analyzes the separation between aircraft utilizing the Chicago O'Hare Int'l (ORD) One Departure from Runway 22L and aircraft flying the Chicago Midway (MDW) RNAV (RNP) Y Runway 13C Instrument Approach Procedure (IAP). The study focused on aircraft departing ORD Runway 22L with assigned headings ranging from 090 to 270. Some of these assigned headings intersected with the path of the MDW RNAV (RNP) Y Runway 13C IAP. The separation criteria for this analysis is established in FAA Order 7110.65S, Air Traffic Control, paragraph 5-5-4a.1 for lateral separation of 3-nautical-miles (NM) and paragraph 4-5-1a for vertical separation of 1,000 feet. [1] At least one of these requirements must be met at any given time, meaning that the aircraft must be separated laterally by a distance of 3 NM when they are within a vertical distance of 1,000 feet or they must be separated vertically by a distance of 1,000 feet when they are within a lateral distance of 3 NM.

13. Key Words Lateral separation, Vertical Separation, Required Navigation Performance (RNP)	**14. Distribution Statement** Controlled by AFS-450
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Executive Summary

This report analyzes the separation between aircraft utilizing the Chicago O'Hare Int'l (ORD) One Departure from Runway 22L and aircraft flying the Chicago Midway (MDW) RNAV (RNP) Y Runway 13C Instrument Approach Procedure (IAP). The study focused on aircraft departing ORD Runway 22L with assigned headings ranging from 090 to 270. Some of these assigned headings intersected with the path of the MDW RNAV (RNP) Y Runway 13C IAP. The separation criteria for this analysis is established in FAA Order 7110.65S, Air Traffic Control, paragraph 5-5-4a.1 for lateral separation of 3-nautical-miles (NM) and paragraph 4-5-1a for vertical separation of 1,000 feet. [1] At least one of these requirements must be met at any given time, meaning that the aircraft must be separated laterally by a distance of 3 NM when they are within a vertical distance of 1,000 feet or they must be separated vertically by a distance of 1,000 feet when they are within a lateral distance of 3 NM.

The analysis concluded that the initial proposed operations in July 2007 did not provide for required separation, but later improvements to the departure and arrival procedures have been effective in assuring required separation is maintained procedurally. Separation is still maintained when the arrival aircraft is 1.0 NM left of the RNP centerline and the departure aircraft is climbing at the minimum required rate to meet the O'Hare Three departure requirements.

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1.0 Introduction

In July 2007, the Required Navigation Performance/Area Navigation (RNP/RNAV) Program Office, WAJR38000, requested a brief analysis of aircraft using the Chicago O'Hare Int'l (ORD) One Departure from Runway 22L to determine if their assigned headings and resultant flight track impacted the separation of aircraft flying the Chicago Midway (MDW) RNAV (RNP) Y Runway 13C Instrument Approach Procedure (IAP). The request placed an emphasis on aircraft departing ORD Runway 22L with assigned headings ranging from 090 to 270. Some of these assigned headings intersected with the path of the MDW RNAV (RNP) Y Runway 13C IAP.

The separation criteria for this analysis is established in FAA Order 7110.65S, Air Traffic Control, paragraph 5-5-4a.1 for lateral separation of 3-nautical-miles (NM) and paragraph 4-5-1a for vertical separation of 1,000 feet. [1] The FAA Order 7110.65S mandates that at least one of these requirements must be met at any given time, meaning that the aircraft must be separated laterally by a distance of 3 NM when they are within a vertical distance of 1,000 feet, or they must be separated vertically by a distance of 1,000 feet when they are within a lateral distance of 3 NM.

This report presents the results of the requested analysis, conducted by the Flight Systems Laboratory (AFS-450) located at the Mike Monroney Aeronautical Center in Oklahoma City, Oklahoma. The analysis was conducted using computer modeling and fast-time simulation software, Airspace Simulation and Analysis Tool (ASAT), to determine if the above separation requirements could be met. This report addresses all work performed to date, including the initial findings which were shared with the RNP/RNAV Program Office and the subsequent changes to various parameters of these two procedures. These changes increased the likelihood for assured safe separation between the aircraft flying the procedures and, therefore, produced new results. The initial parameters (July 2007), the initial findings based upon those values, and the progression of changed parameters of these values, are included and current as of this report's publish date.

2.0 Description of the Airspace Simulation and Analysis Tool (ASAT)

The primary analysis tool for this safety evaluation was ASAT. ASAT is a multi-faceted terminal area fast-prototype and fast-time simulation tool for aviation-related safety assessments. ASAT uses high-fidelity models of all components of an aviation scenario to achieve the most realistic simulation possible with the information provided. A wide range of Design Elements (DE) covering operational aspects, such as aircraft performance, atmospheric conditions, navigation, ATC monitoring and surveillance equipment, and Human-In-The-Loop (HITL) performance, allow for very efficient prototyping and modeling of complex operational scenarios. Each DE contains parameters related to its component of the operation. For example, the Atmosphere DE has parameters for wind velocity, temperature profiles, and Eddy Dissipation Rate (EDR) that can each be defined with a constant, histogram, or a probability density function (Normal, Uniform, Johnson, etc…). These parameter definitions can be used globally or specifically for certain aircraft. When available, data provided by the manufacturer is used as a basis for the components of the simulation. Empirical data from relevant tests is used, to the extent possible, as a basis for some components of the simulation.

The environment in which ASAT scenarios are run is defined by official FAA databases. These databases provide precise geographic locations of airports, runways, navigational aids (NAVAIDs), routes, fixes, waypoints, and other facilities, such as radar site locations. Where an actual airport is being studied, ASAT uses the FAA databases to establish runway coordinates (including elevation), localizer, and glide slope antenna positions. The ASAT flight dynamic models automatically compensate for altitude effects based on the airport elevation and for any wind or turbulence conditions. Additionally, the airport's aircraft fleet mix is requested and incorporated into the simulation. For studies unrelated to a specific airport, generic airports are constructed with the desired runway separations and localizer headings.

For wake vortex analysis, ASAT also includes a wake vortex model based on the National Aeronautics and Space Administration (NASA) Aircraft Vortex Spacing System (AVOSS) Prediction Algorithm (APA), version 3.2. This wake vortex model simulates the wake generation, transport, and decay characteristics of the wake turbulence aircraft classes. The APA accepts aircraft and meteorological data to compute transport and decay times for wake. The decay time expresses the decrease in wake strength versus time.

2.1 ASAT Modeling Methodology

For purposes of this evaluation, ASAT conducted simulated departures from ORD Runway 22L with headings ranging from 090 clockwise to 270. The departure aircraft from Runway 22L banked toward its assigned heading after a randomly determined altitude between 400 and 1,000 feet AGL was achieved. These simulated departures were given climb rates that met the minimum altitude requirements of the applicable

departure procedure. The final analysis of the latest proposal used aircraft specific characteristics, such as takeoff indicated airspeed and runway takeoff distances, included in the model. The initial brief analyses used constant parameters as defined in Table 1.

Table 1: Initial Analysis Input Values

Aircraft Type	Boeing 737-800
Departure IAS	190 knots
Takeoff Distance	3,000 feet
Maximum Allowable Bank Angle	20 degrees

The simulated tracks were terminated once the departure aircraft had reached an altitude equal to 1,000 feet greater than the maximum allowable altitude of the MDW RNP Runway 13C approach path. Considering that the maximum allowable altitude is not constant along the entire RNP approach, the maximum allowable altitude at the point along the approach laterally closest to the departure aircraft was used for determining vertical separation. For example, if a simulated departure track terminated at 3,000 feet MSL and the laterally closest point at the approach path (with a maximum allowable altitude of 2,000 feet MSL) is at a lateral distance greater than 3.0 NM, then separation has been properly maintained.

3.0 Description of Proposals and Analysis Results

This section covers the proposals and results chronologically, including the progression of changed parameters of these values as of this report's publish date.

3.1 Initial Proposal and Results (July 2007)

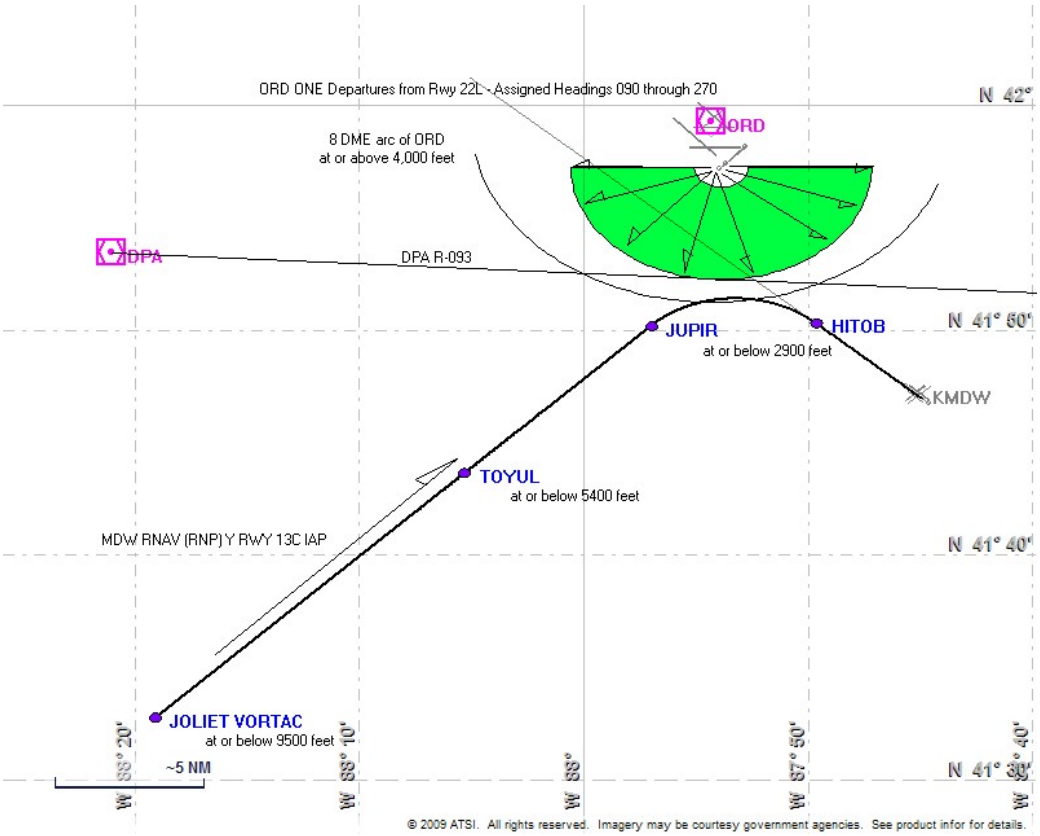


Figure 1: Initial Proposal Diagram

The range of analyzed headings for ORD ONE Departures from Runway 22L is depicted in Figure 1. As required by the ORD ONE Departure, all DME-equipped aircraft on this departure must cross the 8 DME arc of ORD at or above an altitude of 4,000 feet MSL. All non-DME aircraft must cross the DPA R-093 at or above 4,000 feet MSL. Aircraft along the MDW RNAV (RNP) Y Runway 13C IAP have altitude ceilings of 9,500 feet MSL at JOLIET, 5,400 feet MSL at TOYUL, and 2,900 feet MSL at JUPIR.

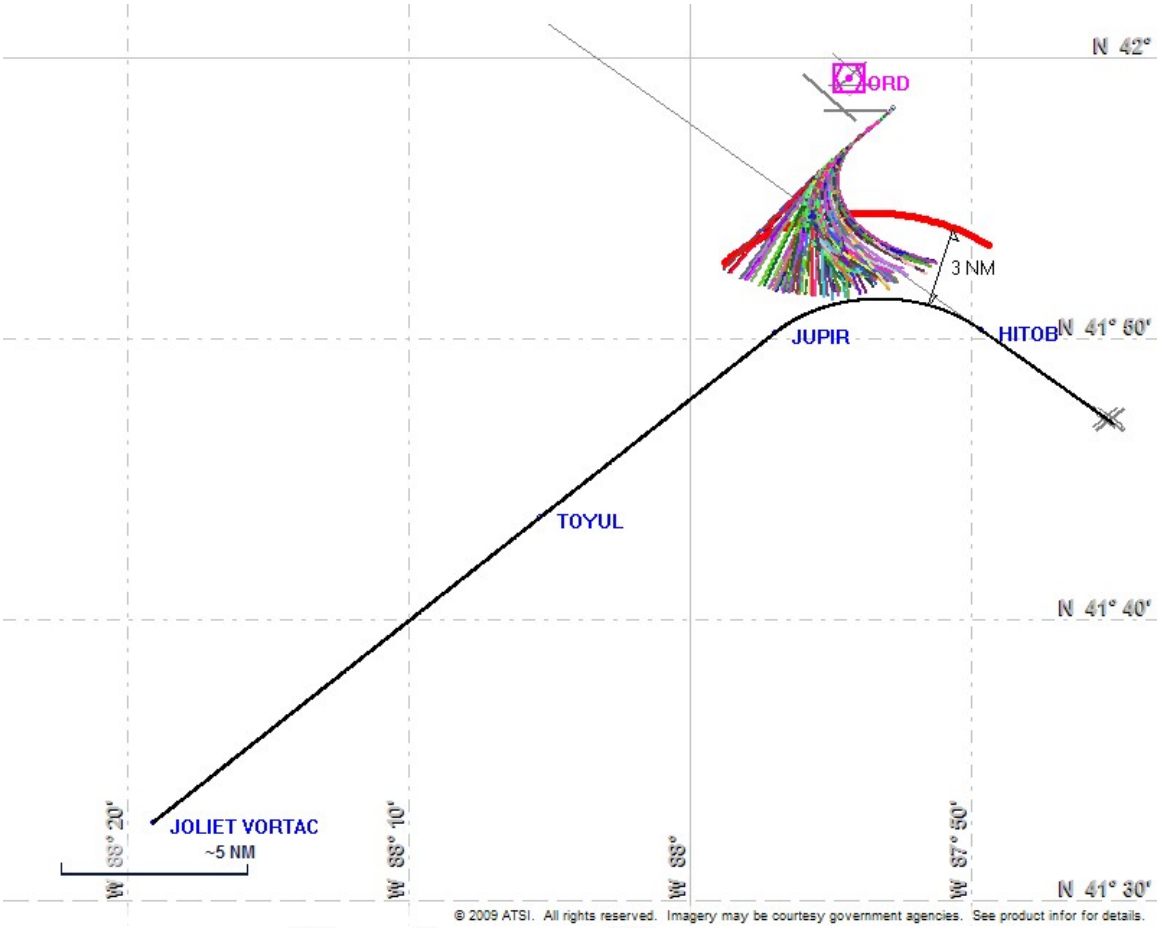


Figure 2: Initial ASAT Results

Using ASAT, a quick analysis was performed to determine how separation would be impacted when these procedures were run independently. (The input parameters used in ASAT for these quick analyses are shown in Table 1.) Figure 2 shows the simulated departures from ORD Runway 22L with the tracks terminating at an altitude of 3,900 feet MSL. If separation is maintained, the tracks would terminate before intersecting the red arc, representing the 3 NM lateral offset distance from the RNP centerline of the MDW Runway 13C RNP approach. The ASAT results showed that the ORD Runway 22L departures do not maintain 3 NM lateral separation from the MDW Runway 13C RNP approach while the procedures are within a distance of 1,000 feet vertically.

3.2 Prototype Approach Analysis (March 2008)

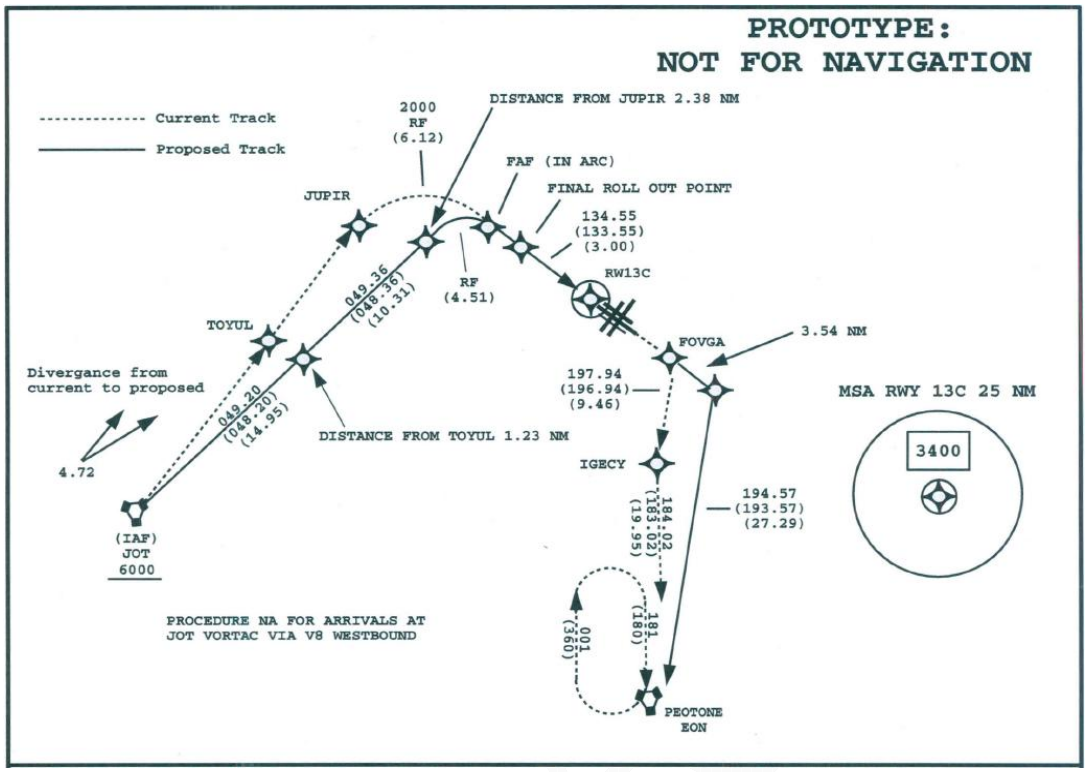


Figure 3: Prototype MDW RNAV (RNP) Y Runway 13C – March 2008

After the initial findings were shared with the RNP/RNAV Program Office, some changes were proposed to the MDW RNAV (RNP) Y Runway 13C IAP by the Program Office. As shown in Figure 3, the new prototype procedure relocated waypoints, TOYUL and JUPIR, to the southeast. This change allowed the ORD Runway 22L departure aircraft a greater distance to climb, and therefore, increased the likelihood for maintaining required separation. The altitude restrictions along the prototype RNP approach were not defined with the exception of JOLIET, where it is required to stay at or above 6,000 feet. An ASAT analysis was conducted to determine the maximum allowable altitudes for the prototype fix locations.

Table 2: ASAT Results for Prototype RNAV (RNP) Y Runway 13C Maximum Altitudes – March 2008

Waypoint Names	Maximum Altitude with Additional Waypoint	Maximum Altitude without Additional Waypoint
TOYUL	4,000 feet	2,500 feet
New Fix	2,500 feet	-
JUPIR	2,000 feet	2,000 feet

The analysis concluded that the prototype RNP approach to MDW Runway 13C did allow the opportunity for proper separation with the maximum altitudes shown in Table 2. Additionally, it was concluded that the prototype approach would benefit from the inclusion of an additional fix at the midpoint between TOYUL and JUPIR. This additional fix is labeled as "New Fix" in Table 2 and Figure 4 (below). The inclusion of this fix increased the maximum allowable altitude at TOYUL from 2,500 to 4,000 feet. The maximum allowable altitude at "New Fix" was then found to be 2,500 feet as shown in Figure 5 (below).

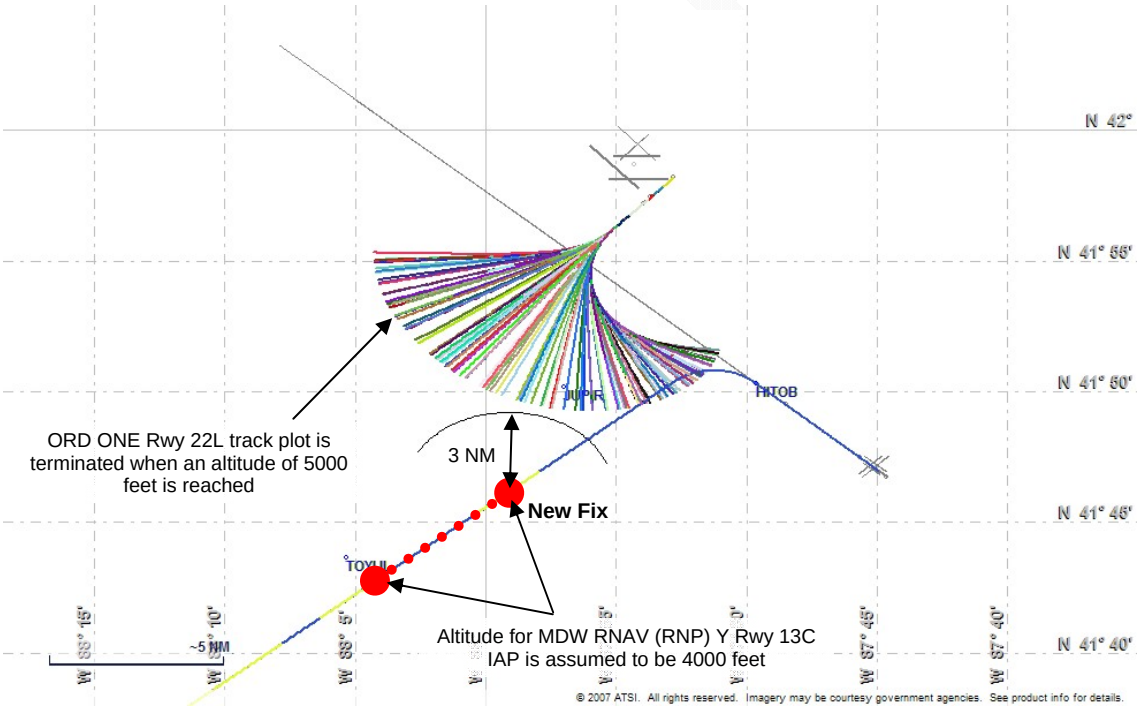


Figure 4: Maximum Allowable Altitude at TOYUL with Additional Fix

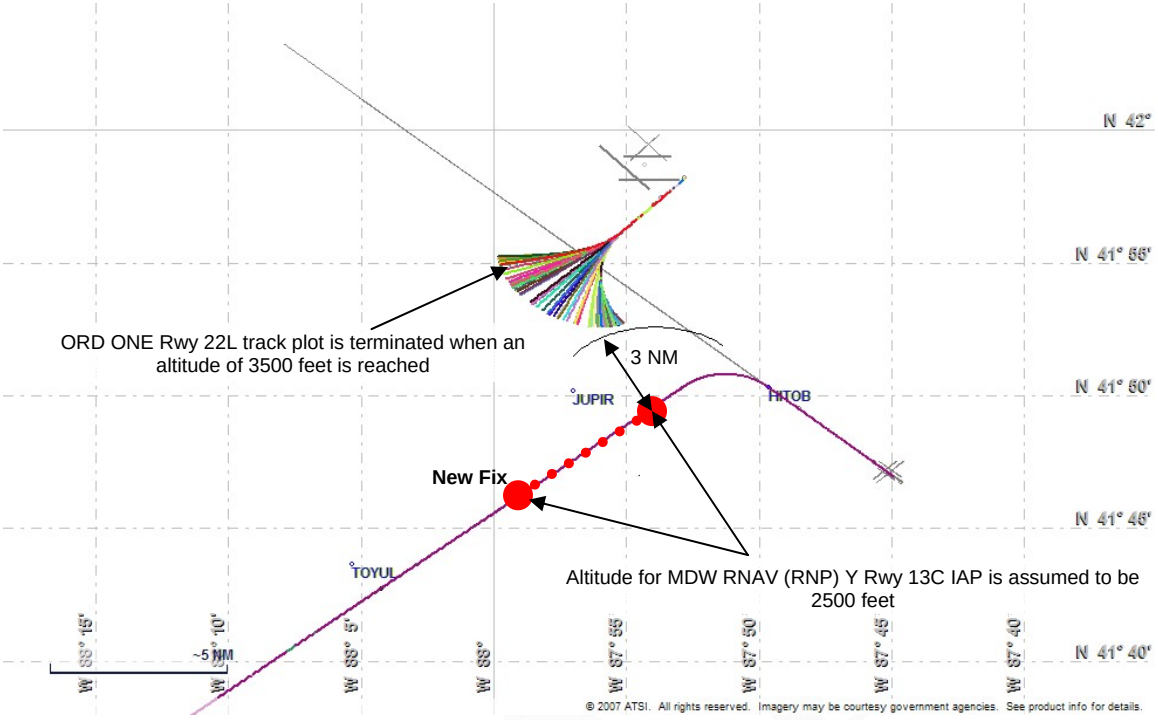


Figure 5: Maximum Allowable Altitude at the Additional Fix

3.3 Current Prototype Approach Analysis (April 2009)

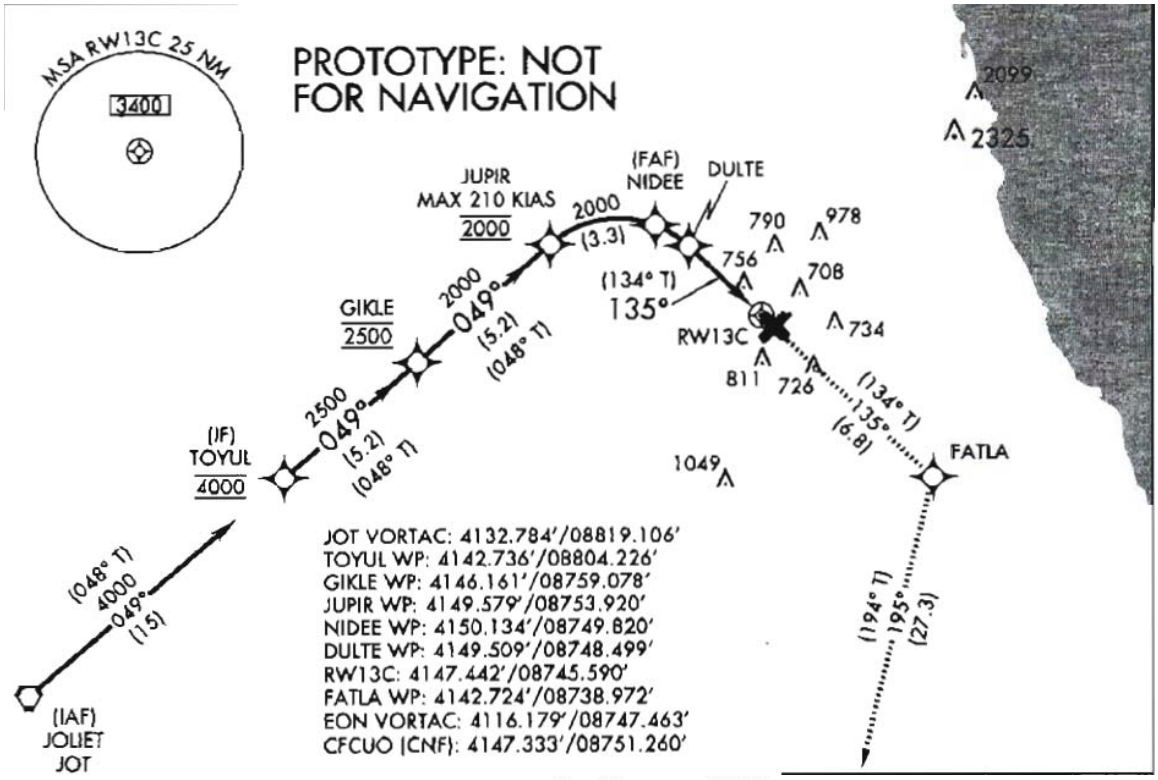


Figure 6: Current Prototype MDW RNAV (RNP) Y Runway 13C – April 2009

Figure 6 shows the latest changes that have been made to the prototype RNP approach to MDW Runway 13C. As shown, it includes the additional fix, GIKLE, at the midpoint between TOYUL and JUPIR. The locations of the fixes are identical to the first prototype approach produced in March 2008, but the altitudes are now defined. This prototype approach also defines the RNP requirement to be 1.00 (RNP 1.0) from JOLIET to the added fix, GIKLE; and 0.50 (RNP 0.5) from GIKLE to Runway 13C.

Additionally, there is a change to the departure procedure from ORD Runway 22L. The new procedure, O'Hare Three Departure (Appendix A), requires all DME aircraft to cross the 5 DME arc of ORD at or above 3,000 feet and the 8 DME arc of ORD at or above 4,000 feet and maintain 5,000 feet or an assigned altitude. Non-DME aircraft must cross DPA R-093 at or above 4,000 feet and then maintain 5,000 feet or an assigned altitude. The flyability and acceptability of this departure procedure has been demonstrated by its actual usage since being published in November 2008. The main difference from the previous departure procedure, O'Hare One, is the inclusion of the requirement to cross the 5 DME arc of ORD at or above 3,000 feet for all departure headings. This requirement provides an additional restriction for the minimum altitude of the departures and further facilitates separation from the MDW RNP (RNAV) Y Runway 13C IAP.

3.4 A Worst Case Scenario Analysis

A worst-case scenario was used in this evaluation:

> *A radar departure from ORD Runway 22L, climbing at the minimum rate required by the O'Hare Three Departure Procedure, on an assigned heading that intersects with the MDW RNP Runway 13C IAP. At the same time, an RNP arrival aircraft to MDW Runway 13C is off the RNP centerline laterally by two standard deviation (σ) values and is maintaining the maximum allowed altitudes between fixes until transitioning to the next fix's maximum altitude at the last possible moment using a maximum descent rate of 2,000 feet per minute and an indicated airspeed of 120 knots.*

In this scenario, if the arrival is between TOYUL and GIKLE, where the RNP requirement is defined as 0.5 (RNP 0.5), the aircraft would be displaced 1.0 NM from the RNP centerline (Figure 7). The lateral displacement puts the arrival aircraft closer to the climbing departure aircraft. Additionally, the velocities of the departure and arrival aircraft are such that their paths will intersect with only vertical separation remaining.

The analysis sought to determine whether proper separation would still be maintained during this worst-case scenario. The assumption being that separation would be maintained for all other scenarios where any of these conditions were changed to the operation's benefit; e.g., the arrival is on the RNP centerline or the departure's climbing rate is greater than the minimum required.

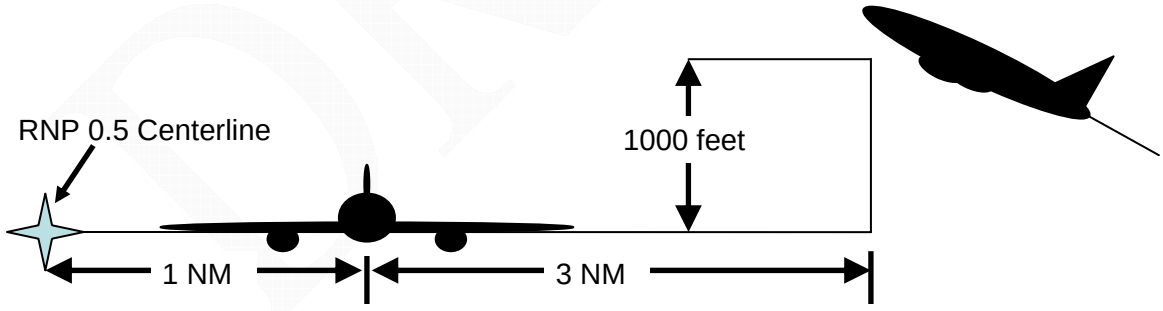


Figure 7: Worst Case Scenario (not to scale)

As shown in Figure 8, aircraft departing ORD Runway 22L using the O'Hare Three Departure procedure will have a minimum of 3.05 NM lateral separation when they reach 1,000 feet above an MDW Runway 13C arrival aircraft that is 1.0 NM left of the RNP centerline, which is the worst case tested in this analysis. The lateral separation is 3.80 NM lateral separation from an arrival aircraft that is on the RNP centerline.

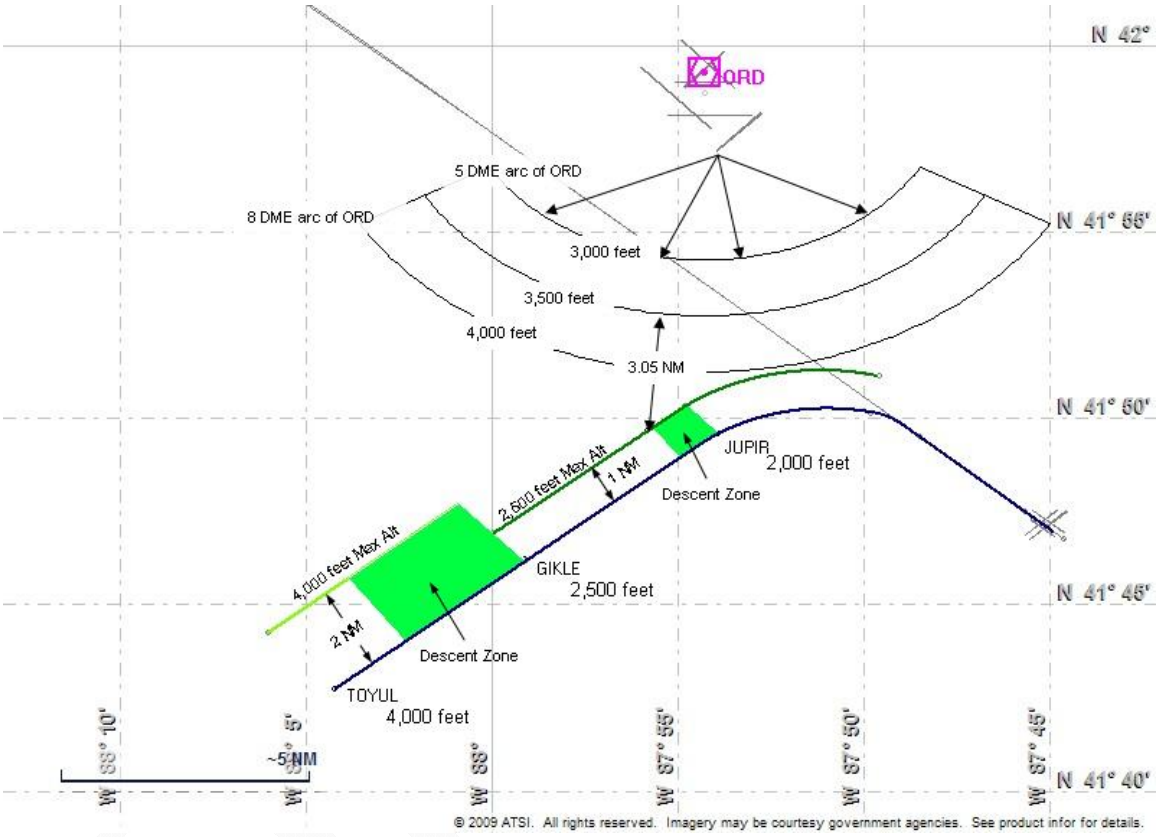


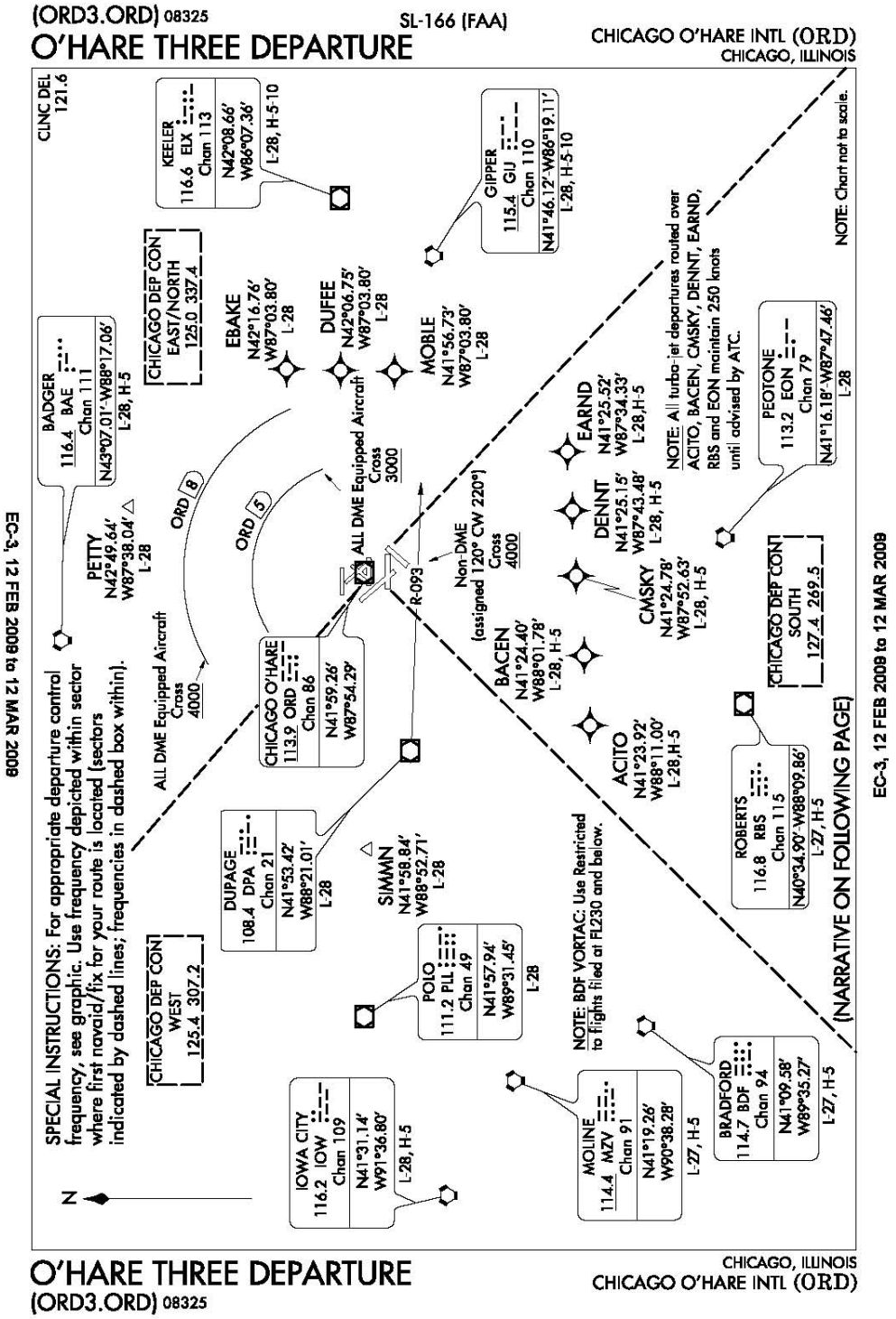
Figure 8: Separation Between O'Hare Three Departures from Runway 22L and Current Prototype MDW RNAV (RNP) Y Runway 13C IAP – April 2009

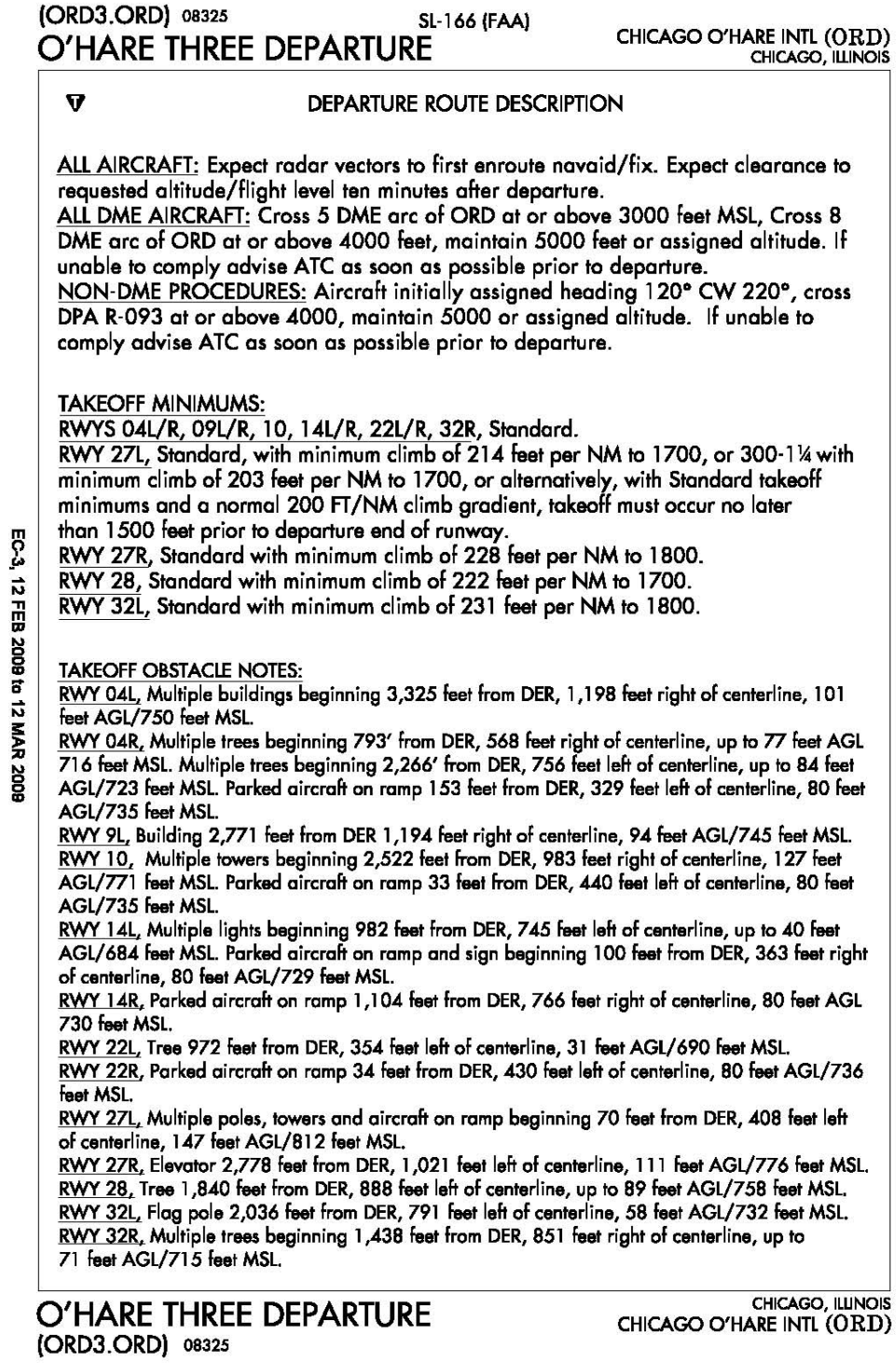
4.0 Results and Conclusions

The initial proposed operations in July 2007 did not provide for required separation, but later improvements to the departure and arrival procedures have been effective in assuring required separation is maintained procedurally. The latest prototype, MDW RNP (RNAV) Y Runway 13C IAP, restricts the altitude of the arrival aircraft such that the ORD Runway 22L Departure, flying the O'Hare Three departure procedure, can climb to an altitude of 1,000 feet above the arrival aircraft before reaching a lateral distance of 3.0 NM. Separation is still maintained when the arrival aircraft is 1.0 NM left of the RNP centerline and the departure aircraft is climbing at the minimum required rate to meet the O'Hare Three departure requirements.

Note: This operation, including the arrival procedure to MDW and the departure procedure from ORD, provides aircraft separation that meets or exceeds that required by current radar separation standards. Additionally, this operation will be observed on radar in real time by the controllers and monitored via Terminal Analysis Radar Program (TARP) by the Air Traffic Organization (ATO).

Appendix A: Operations Data





(ORD3.ORD) 08325 SL-166 (FAA)

O'HARE THREE DEPARTURE

CHICAGO O'HARE INTL (ORD)
CHICAGO, ILLINOIS

DEPARTURE ROUTE DESCRIPTION

ALL AIRCRAFT: Expect radar vectors to first enroute navaid/fix. Expect clearance to requested altitude/flight level ten minutes after departure.
ALL DME AIRCRAFT: Cross 5 DME arc of ORD at or above 3000 feet MSL, Cross 8 DME arc of ORD at or above 4000 feet, maintain 5000 feet or assigned altitude. If unable to comply advise ATC as soon as possible prior to departure.
NON-DME PROCEDURES: Aircraft initially assigned heading 120° CW 220°, cross DPA R-093 at or above 4000, maintain 5000 or assigned altitude. If unable to comply advise ATC as soon as possible prior to departure.

TAKEOFF MINIMUMS:
RWYS 04L/R, 09L/R, 10, 14L/R, 22L/R, 32R, Standard.
RWY 27L, Standard, with minimum climb of 214 feet per NM to 1700, or 300-1¼ with minimum climb of 203 feet per NM to 1700, or alternatively, with Standard takeoff minimums and a normal 200 FT/NM climb gradient, takeoff must occur no later than 1500 feet prior to departure end of runway.
RWY 27R, Standard with minimum climb of 228 feet per NM to 1800.
RWY 28, Standard with minimum climb of 222 feet per NM to 1700.
RWY 32L, Standard with minimum climb of 231 feet per NM to 1800.

TAKEOFF OBSTACLE NOTES:
RWY 04L, Multiple buildings beginning 3,325 feet from DER, 1,198 feet right of centerline, 101 feet AGL/750 feet MSL.
RWY 04R, Multiple trees beginning 793' from DER, 568 feet right of centerline, up to 77 feet AGL 716 feet MSL. Multiple trees beginning 2,266' from DER, 756 feet left of centerline, up to 84 feet AGL/723 feet MSL. Parked aircraft on ramp 153 feet from DER, 329 feet left of centerline, 80 feet AGL/735 feet MSL.
RWY 9L, Building 2,771 feet from DER 1,194 feet right of centerline, 94 feet AGL/745 feet MSL.
RWY 10, Multiple towers beginning 2,522 feet from DER, 983 feet right of centerline, 127 feet AGL/771 feet MSL. Parked aircraft on ramp 33 feet from DER, 440 feet left of centerline, 80 feet AGL/735 feet MSL.
RWY 14L, Multiple lights beginning 982 feet from DER, 745 feet left of centerline, up to 40 feet AGL/684 feet MSL. Parked aircraft on ramp and sign beginning 100 feet from DER, 363 feet right of centerline, 80 feet AGL/729 feet MSL.
RWY 14R, Parked aircraft on ramp 1,104 feet from DER, 766 feet right of centerline, 80 feet AGL 730 feet MSL.
RWY 22L, Tree 972 feet from DER, 354 feet left of centerline, 31 feet AGL/690 feet MSL.
RWY 22R, Parked aircraft on ramp 34 feet from DER, 430 feet left of centerline, 80 feet AGL/736 feet MSL.
RWY 27L, Multiple poles, towers and aircraft on ramp beginning 70 feet from DER, 408 feet left of centerline, 147 feet AGL/812 feet MSL.
RWY 27R, Elevator 2,778 feet from DER, 1,021 feet left of centerline, 111 feet AGL/776 feet MSL.
RWY 28, Tree 1,840 feet from DER, 888 feet left of centerline, up to 89 feet AGL/758 feet MSL.
RWY 32L, Flag pole 2,036 feet from DER, 791 feet left of centerline, 58 feet AGL/732 feet MSL.
RWY 32R, Multiple trees beginning 1,438 feet from DER, 851 feet right of centerline, up to 71 feet AGL/715 feet MSL.

EC-3, 12 FEB 2009 to 12 MAR 2009

EC-3, 12 FEB 2009 to 12 MAR 2009

O'HARE THREE DEPARTURE
(ORD3.ORD) 08325

CHICAGO, ILLINOIS
CHICAGO O'HARE INTL (ORD)

Figure A 1: O'Hare Three Departure

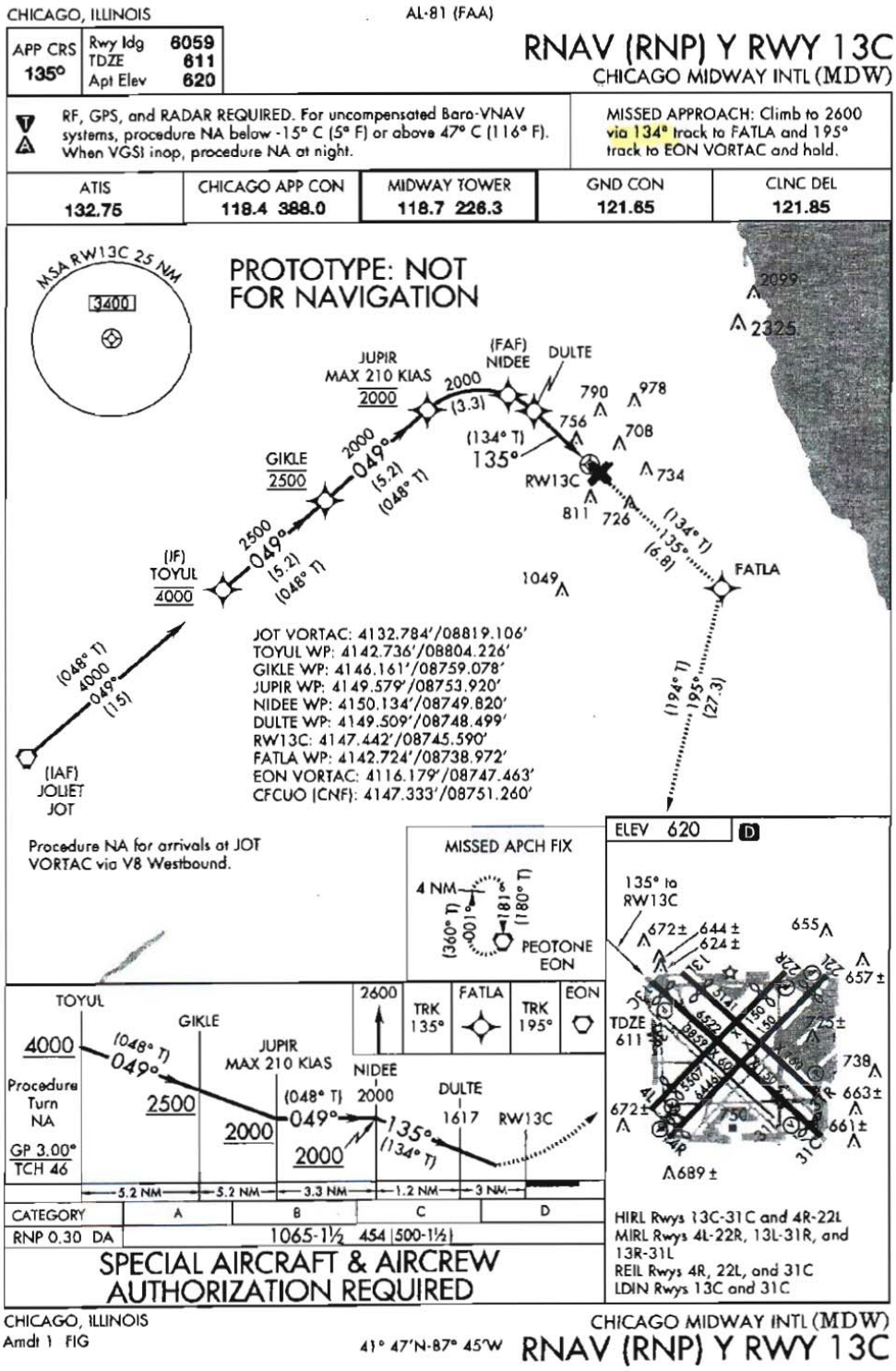


Figure A 2: Current Prototype MDW RNAV (RNP) Y Runway 13C – April 2009

References

[1.] FAA Order 7110.65S, *Air Traffic Control*. February 14, 2008.