Enclosure

(Reference Technical Letter H560-L18-060)

MITRE

Center for Advanced
Aviation System Development

Nuevo Aeropuerto Internacional de la Ciudad de México

Analysis of Runway Visual Range Data to Determine Occurrence of CAT II/III-Related Weather Conditions

Prepared for

Grupo Aeroportuario de la Ciudad de México

June 2018

Principal Acronyms and Abbreviations

AICM	Aeropuerto Internacional de la Ciudad de México
AWOS	Automated Weather Observing System
CAT	Category
FAA	(United States) Federal Aviation Administration
ft	Foot(feet)
GACM	Grupo Aeroportuario de la Ciudad de México
GPS	Global Positioning System
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
kt	Knot(s)
MITRE	The MITRE Corporation
NA	Not Available
NAICM	Nuevo Aeropuerto Internacional de la Ciudad de México
RNAV	Area Navigation
RVR	Runway Visual Range
sm	Statute mile(s)
U.S.	United States

1. Introduction

Through its work for Grupo Aeroportuario de la Ciudad de México (GACM), the MITRE Corporation (MITRE) is assisting the aviation authorities of Mexico in the development of a new airport for Mexico City. The new airport will replace the current Aeropuerto Internacional de la Ciudad de México (AICM) and is referred to in this report as Nuevo Aeropuerto Internacional de la Ciudad de México (NAICM). The final runway layout of NAICM will consist of three sets of closely-spaced parallel runways and will allow for triple independent arrival and departure operations. The NAICM runways will have an orientation of 002°/182° Tue North (i.e., approximately north/south).

GACM is considering the installation of Instrument Landing Systems (ILS) that would support Category (CAT) III approach procedures at NAICM. Overall, the desired outcome is to develop approach procedures to the lowest minima possible serving the needs of airport users in a safe and efficient environment. Therefore, one of the important considerations in determining the need for CAT III ILS-equipped runways is to estimate the frequency of low visibility conditions at the NAICM site. The examination of winds during such conditions is also important in order to determine the direction in which CAT III ILS approaches at NAICM are likely needed as well as whether crosswinds are a factor. Note that CAT III ILS approaches generally have crosswind component limitations of 10 knots (kt).[1]

MITRE previously conducted a detailed analysis of weather conditions at the NAICM site on the basis of over five years of data (1 May 2009 through 11 October 2014) from an Automated Weather Observing System (AWOS) located near the NAICM site just south of El Caracol. See Enclosure 1 to MITRE Technical Letter F500-L15-007, dated 12 January 2015, for the results of that analysis. MITRE's analysis of AWOS data showed that poor weather conditions that would require CAT III ILS approaches typically occurred during the winter months. (Note that poor weather conditions were also observed in other months as well.) However, AWOS-based analyses are not sufficient to appropriately determine the need for CAT III ILS approaches at NAICM due to limitations in the visibility sensors used in the AWOS. Therefore, MITRE recommended that a Runway Visual Range (RVR) sensing and recording device be installed so that the percentage of time that poor visibility conditions exist requiring CAT III ILS approaches, as well as what hours those approaches would likely need to be conducted, could be determined.

In late 2015, the Mexican aviation authorities installed an RVR sensing and recording device near the above-mentioned AWOS to collect visibility information.[2] In August 2016, MITRE conducted an initial analysis of the RVR data covering a period from January 2016 through March 2016. See MITRE document F500-L16-041, dated 12 August 2016. Since the initial

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[1] Autoland systems are commonly used for CAT III ILS approaches. These systems are often limited to 10 kt of crosswind.

[2] RVR sensors only collect visibility information (more precisely during low-visibility conditions than AWOS visibility sensors). AWOS sensors collect ceiling (cloud height), visibility, wind, and temperature information.

RVR-related results were based on only three months of data, MITRE recommended that additional data be analyzed, including essential winter months, to obtain more robust results.

MITRE then provided a summary of visibility conditions based on RVR data from 1 January 2016 through 13 March 2017. See Enclosure 1 to MITRE Technical Letter F500-L17-070, dated 28 June 2017. At that time, MITRE recommended that another analysis of RVR data considering the winter of 2017/2018 be conducted to further assist authorities in their decision-making process.

In late 2017, the RVR equipment and the AWOS were relocated within the NAICM perimeter fence and the sensors were recalibrated and synchronized. This delayed further obtaining timely data. Importantly, MITRE was informed that the AWOS and RVR systems were checked and calibrated on 17 and 23 November 2017, respectively. MITRE was also informed that the clocks of both the RVR and AWOS systems were synchronized.

This document summarizes the RVR visibility data obtained from 23 November 2017 through 31 March 2018. That represents much but not all the bad weather period (which starts around 1 November). As in the previous study, MITRE complemented the RVR visibility data analysis by examining wind data for the same period from the AWOS to better understand wind patterns and assess the operational implications during very low visibility conditions at the site. This report summarizes MITRE's review of the data for that period to assist authorities in determining the need for CAT III ILS-equipped runways.

Section 2 of this report details the visibility classification by categories used in the analysis. Section 3 provides a summary of the findings from the previous weather analyses. Section 4 presents the results of the analysis of the winter of 2017/2018. Section 5 presents MITRE's findings and discusses other important considerations.

2. Visibility Category Classification

MITRE used United States (U.S.) Federal Aviation Administration (FAA) criteria to classify weather conditions. Table 1 details the visibility categories applied in this analysis as well as the corresponding types of procedures typically required to land during those conditions. In the U.S., visibility is the controlling factor for instrument approaches. The visibility data categorization was based on the raw (nominal) RVR data, and no rounding of the nominal data was conducted by MITRE. The RVR data was collected for two approach light settings, and MITRE used the light setting that resulted in the lowest RVR. Thus, the conditions provided in this report may be slightly conservative.

MITRE has included one range of CAT II weather (i.e. < 1800 and ≥ 1200 feet [ft] RVR) and two ranges of CAT III weather (i.e., < 1200 and ≥ 700 ft RVR and < 700 and ≥ 300 ft RVR) in order to provide Mexico with data to assist in deciding what level of approach service is appropriate. Typically, aircraft, aircrew training, airport, and runway/equipment requirements increase when a CAT II capability is added to the runway. These requirements increase again when CAT III is added with RVR in the 1200-700 ft range, and requirements increase again when RVR is below 700 ft. CAT III approaches can be defined with as low as 0 (zero) ft RVR,

but no CAT III approaches are approved in the U.S. to below 300 ft RVR, so a lower limit of 300 ft RVR is used in this report.[3]

Note that analyzing the CAT I or better visibility conditions was outside the scope of this study, since they were addressed in the previously-mentioned 2015 AWOS data analysis.

Table 1. Visibility Categories Used in this Analysis

Visibility "Category"	RVR in ft	Notes
CAT I or better	≥ 1800	This category includes three possible scenarios: 1. Conditions during which visual approach procedures would likely be conducted[4] 2. Conditions during which instrument procedures may be conducted during the first portion of the approach and visual approach procedures during the final portion 3. Conditions during which the use of a CAT I ILS approach procedure is required
CAT II	< 1800 and ≥ 1200	Conditions that may require the use of a CAT II ILS approach procedure. Specialized aircraft and ground equipment, as well as pilot training, are required.
CAT III	< 1200 and ≥ 700	Conditions that may require the use of a CAT III ILS approach procedure. Specialized aircraft and ground equipment, airport infrastructure, as well as pilot training, are required.
	< 700 and ≥ 300	Conditions that may require the use of a CAT III ILS approach procedure (lowest approved in the U.S.). Additional specialized ground equipment, pilot training, and other airport services may be required.
Runway Closed	< 300	Runway closed for approaches

3. Previous Weather Data Analyses

In January 2015, MITRE submitted the results of its analysis of meteorological conditions at the NAICM site based on more than five years of AWOS data located near the site, just south of

[3] Takeoff visibility limits are also expressed in RVR during low-visibility conditions. Most airlines use takeoff limits that are consistent with landing limits, so classifications of takeoff limits are not discussed in this report.

[4] For the purposes of this analysis, ceiling (cloud height) requirements are not specified or discussed since RVR is the controlling value for the weather minima. However, for other instrument operations, the ceiling requirements can be an important consideration.

El Caracol. MITRE considered the overall weather and wind characteristics, their variability by time of day, and weather seasonality by months. That study found that periods of visibility at CAT II or below (based on AWOS visibility and ceiling data) occurred roughly 0.2 percent of the time. While most of such periods occurred between November and March, they could be found in other months of the year. During CAT II or below weather, winds were generally mild and from the north and were well aligned with the proposed runway orientation at NAICM. However, in one percent of those times, the winds were found to exceed 20 kt and to be from the west, resulting in an excessive crosswind component. Such winds during CAT II or below conditions would be sufficient to close the runways.

As noted earlier, MITRE submitted an analysis of RVR data covering the period from 1 January 2016 through 13 March 2017 in June 2017. Overall, MITRE concluded the following about CAT II and CAT III frequencies:

- CAT II: 474 minutes (0.08 percent) on 22 different days, mostly in the morning hours. The two longest periods were in July 2016 and November 2016.
- CAT III: 89 minutes (0.01 percent) on six different days, mostly in the early morning hours. The two longest periods were in July 2016 and March 2017.

Although the frequency of CAT II and CAT III visibility occurrences was low (less than 0.1 percent in total), **the important conclusion of the analysis was that low visibility does occur at NAICM for extended periods of time**. Additionally, the cross-comparison of the RVR and the AWOS data suggested that during the periods of poor visibility, and during the preceding and following hours, the winds were generally calm and aligned with the proposed NAICM runway orientation.

4. Latest Weather Data Analysis

The focus of this study is the analysis of CAT II and CAT III conditions from the period of 23 November 2017 through 31 March 2018 (i.e., the winter season), with a special emphasis on CAT III, as GACM (and SENEAM) are interest in CAT III. For this analysis, the north-flow direction is referred to as the Runway 002° True direction and the south flow as the Runway 182° True direction. Wind direction and speed were converted into the equivalent headwind and crosswind components. Local times are used throughout this section.

During the above-mentioned data period, the RVR system provided observations without any lapses in data. The majority of RVR recordings had available matching AWOS wind data within 30 minutes of the sample time point, and these provided consistent results.[5]

The RVR data analyzed by MITRE covered a period of 128.2 days, or 184,651 one-minute observations. During this time, there were 12 days with CAT II or below weather (i.e., or worse)

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[5] RVR data are provided every minute, and AWOS data are provided every 30 minutes with a time stamp of 5 minutes after the half-hour (e.g., at 7:05 and 7:35). RVR data were compared to the previous and next AWOS observations. For example, an RVR reading at 7:14 was compared with the winds from the 7:05 and 7:35 AWOS observations.

totaling 560 minutes (0.3 percent of the time). Table 2 gives a more detailed overview of each of those 12 days. Each row shows a different day with weather at CAT II or below with the "Start" and "End" times defining the period during that day where such weather was observed. The aggregate duration of CAT II and CAT III weather observed during this period is provided as well. Note that all the CAT II or below visibility occurred between 4:00 AM and 9:00 AM local time.

Table 2. NAICM RVR Data: Periods of CAT II <u>or Below</u> Weather Conditions (23 November 2017 through 31 March 2018)

Month/Year	Day	Start	End	Minutes		
				CAT II	CAT III (< 1200 ft and ≥ 700 ft)	CAT III (< 700 ft and ≥ 300 ft)
November 2017	28	4:33	8:35	172	17	-
December 2017	2	6:09	6:38	16	14	-
	3	4:44	4:47	4	-	-
	29	4:59	5:33	31	-	-
	30	4:49	8:11	35	96	5
January 2018	15	7:05	8:04	22	14	-
	23	8:15	8:16	2	-	-
	26	6:44	8:33	60	23	-
	27	5:57	6:01	5	-	-
February 2018	3	5:41	6:18	10	28	-
	10	7:15	7:19	2	3	-
March 2018	10	6:35	6:35	1	-	-
			Totals	360	195	5

In five of the 12 days, which are highlighted in yellow in Table 2, such conditions lasted only 5 minutes or less. Three of those five days (27 January 2018, 10 February 2018, and 10 March 2018), the AWOS winds were observed for the ½-hour before and after were zero. On 3 December 2017, winds were zero prior to the RVR low-visibility observations and showed a headwind of about 2 kt for the Runway 002° True direction after the RVR low-visibility observations. On 23 January 2018, data showed a headwind of less than 2 kt for the Runway 002° True direction prior to the RVR low-visibility observations, and winds were zero after the RVR low-visibility observations.

Results for the remaining seven days (i.e., not highlighted in yellow in Table 2) are summarized in Figures 1 through 7, which graph the RVR visibility by hour. Along the bottom

of each graph are shown the AWOS data for visibility and headwinds, computed as the headwind component for the Runway 002° True direction. When the wind or visibility data are unavailable, the missing value is indicated by "NA" for "Not Available". Note that during this period of study crosswind components were not a factor during CAT II and CAT III conditions, since no winds were observed that would result in crosswind components higher than 10 kt.

The threshold values for CAT II, CAT III, and Runway Closed conditions are shown as solid horizontal lines. Specifically, visibility observations between the green line at 1800 ft and the black line at 1200 ft represent CAT II weather conditions; visibility between the black line at 1200 ft and the red line at 300 ft represent CAT III weather conditions; and visibility conditions below the red line at 300 ft represent times when the airport would need to close even if a CAT III ILS were installed. Note that a purple line was also added at 700-ft RVR as a reference. Also, as shown in Table 2, weather conditions at CAT II or below were never observed outside of the hours 4:00 AM through 9:00 AM, so the figures below cover only those times.

For example, on 28 November 2017 (Figure 1), visibility dropped below CAT I at 4:33 AM local time and remained at CAT II or below for much of the time until finally rising above it at 8:36 AM. For some of that time, it was above CAT II (e.g., from 5:05 AM through 5:34 AM and later from 5:37 AM through 5:47 AM). Also, it was much worse, CAT III, during some of the period (i.e., from 7:19 AM through 7:35 AM). During this period of CAT II or below visibility, the corresponding AWOS visibility data have values ranging from ½ statute mile (sm) to less than ¼ sm (shown as "<1/4"), and headwinds favoring the Runway 002° True direction ranged from zero to 4.9 kt.

Note that on some days (e.g., 30 December 2017 – see Figure 4) with quickly changing visibility, there is a certain time lag between RVR visibility and AWOS visibility data. This occurred due to the difference in data collection frequencies in the two systems (1-minute vs. 30-minutes).

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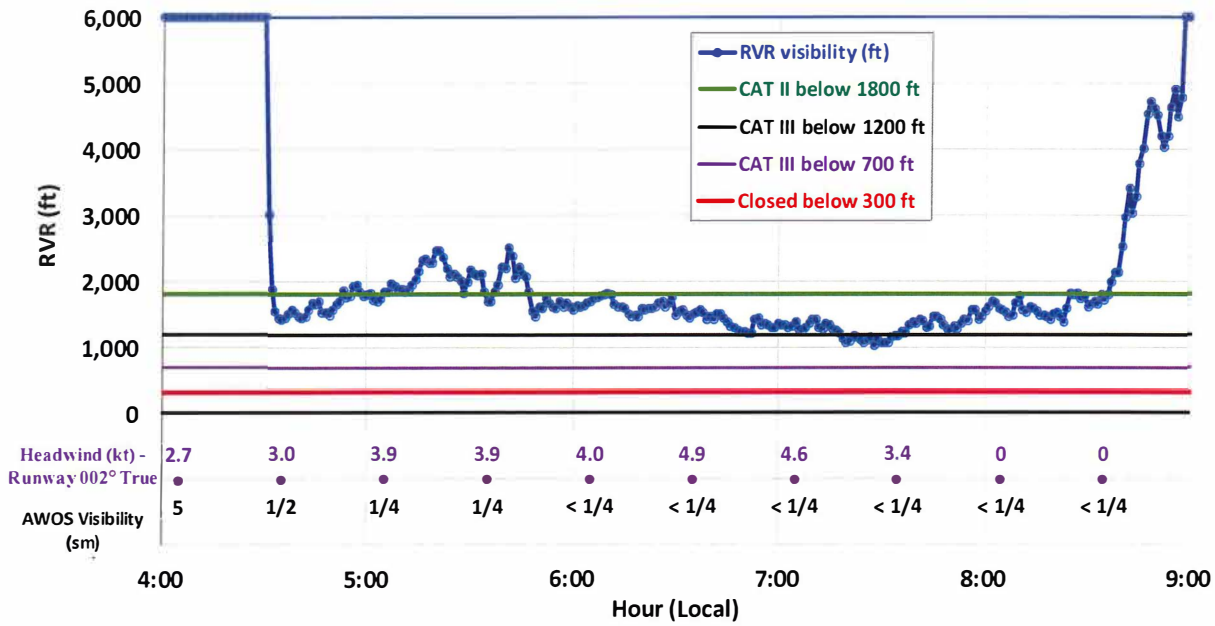

Figure 1. NAICM RVR Data, 28 November 2017

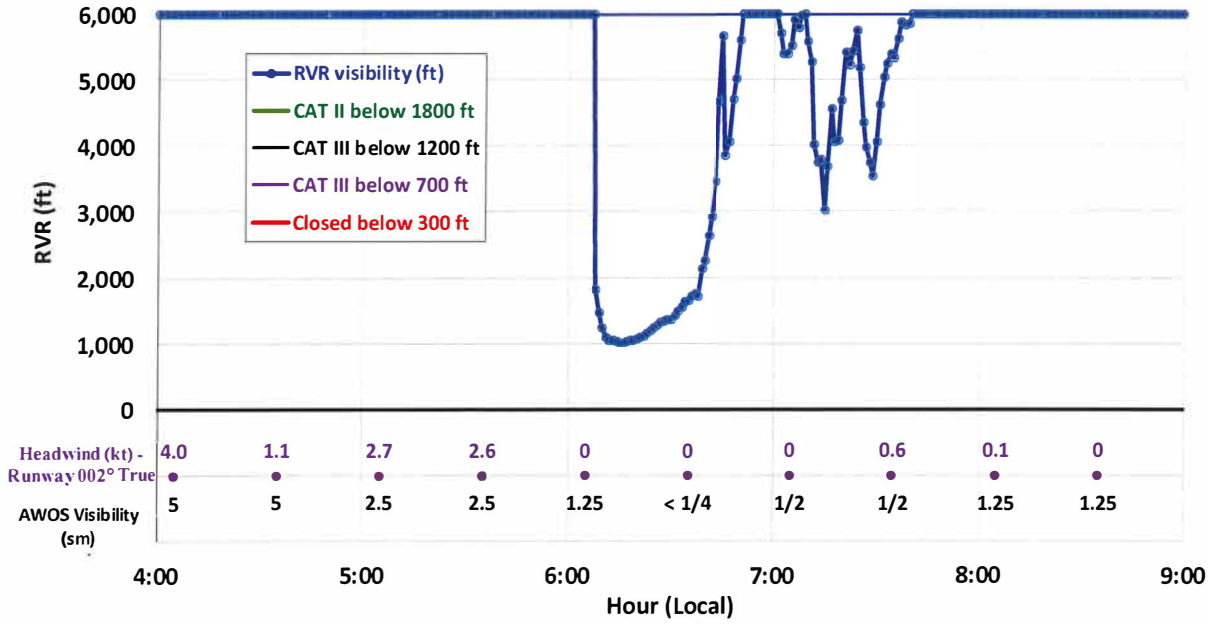

Figure 2. NAICM RVR Data, 2 December 2017

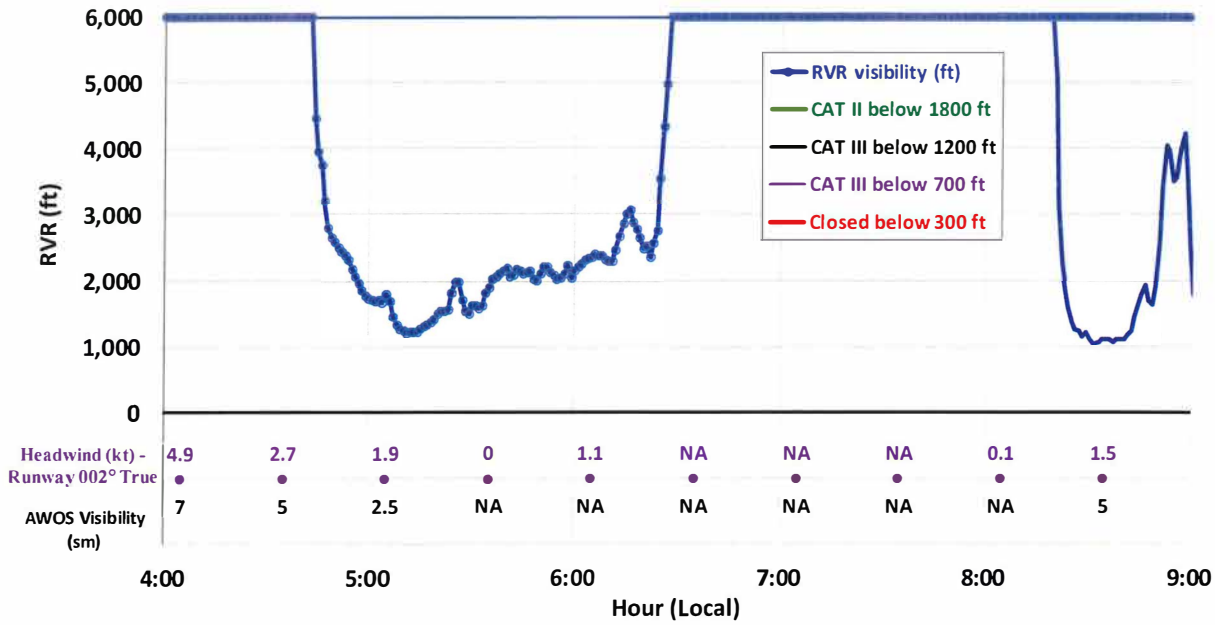

Figure 3. NAICM RVR Data, 29 December 2017

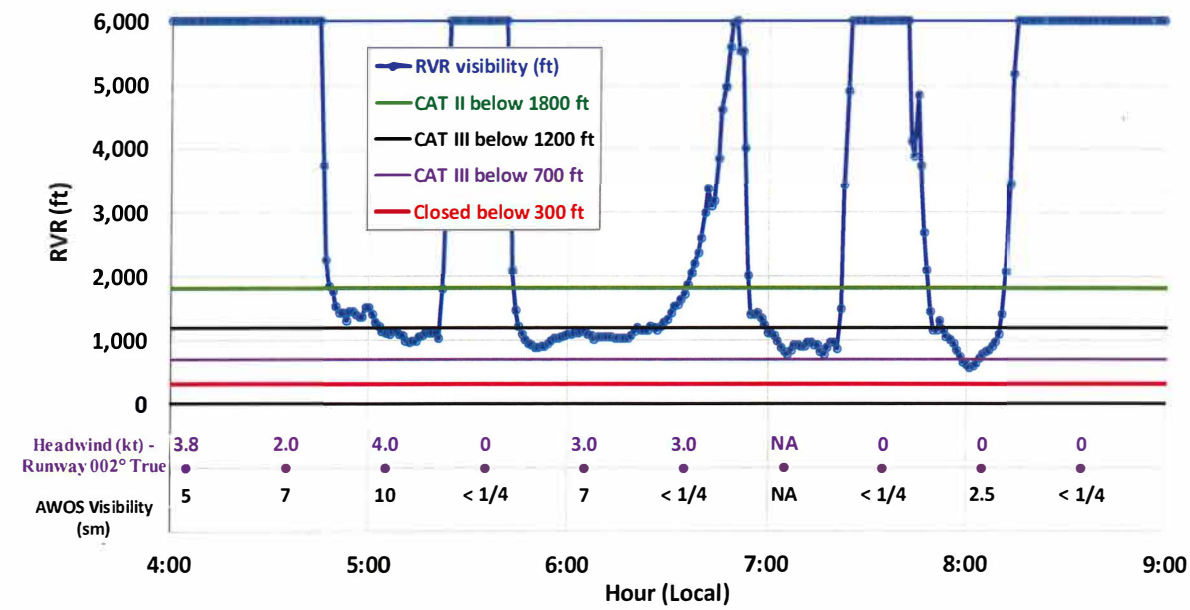

Figure 4. NAICM RVR Data, 30 December 2017

The morning of 30 December 2017 had the greatest duration of CAT III visibility, totaling 101 minutes over slightly more than three hours beginning at 5:04 AM and ending at 8:10 AM. As can be seen in Figure 4 above, visibility increased to above CAT II conditions at times but briefly (for about 5 minutes), dropped slightly below the limit of 700 ft (from 7:59 AM through 8:03 AM), but still above the CAT III lowest limit of 300 ft. Overall, the visibility conditions

were in CAT III for more than half of the time during that three-hour timespan. **In an important holiday travel season like this, without CAT III procedures available at NAICM, the airport would have needed to close for much of that time.**

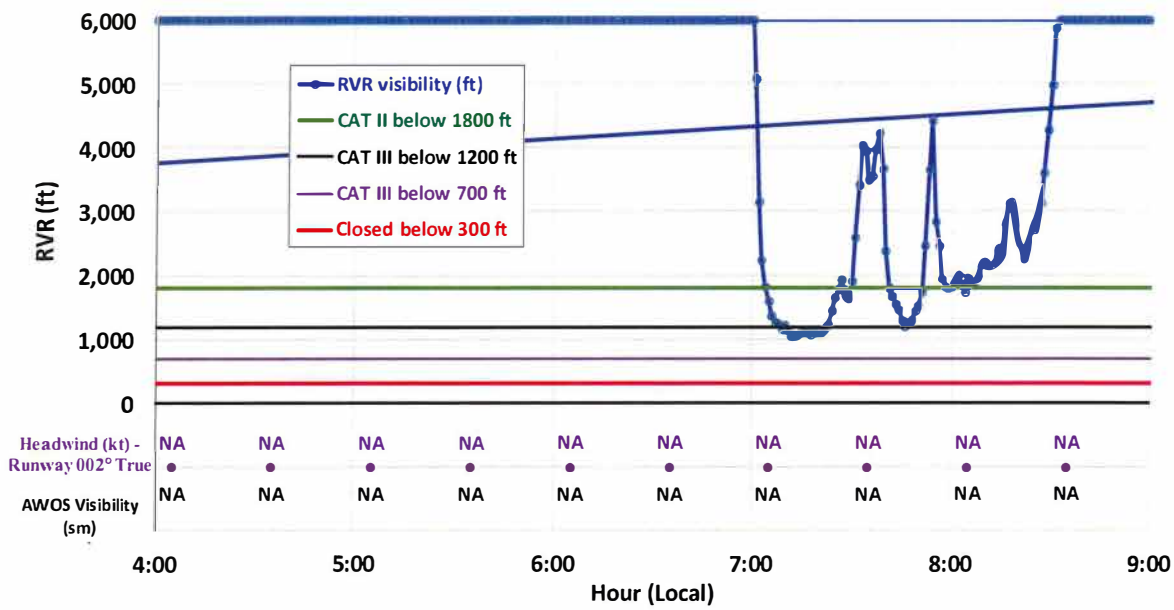

Figure 5. NAICM RVR Data, 15 January 2018

Note that neither AWOS winds nor AWOS visibility data were available on 15 January 2018 due to an overall system electricity outage of the AWOS, as shown in Figure 5 above.

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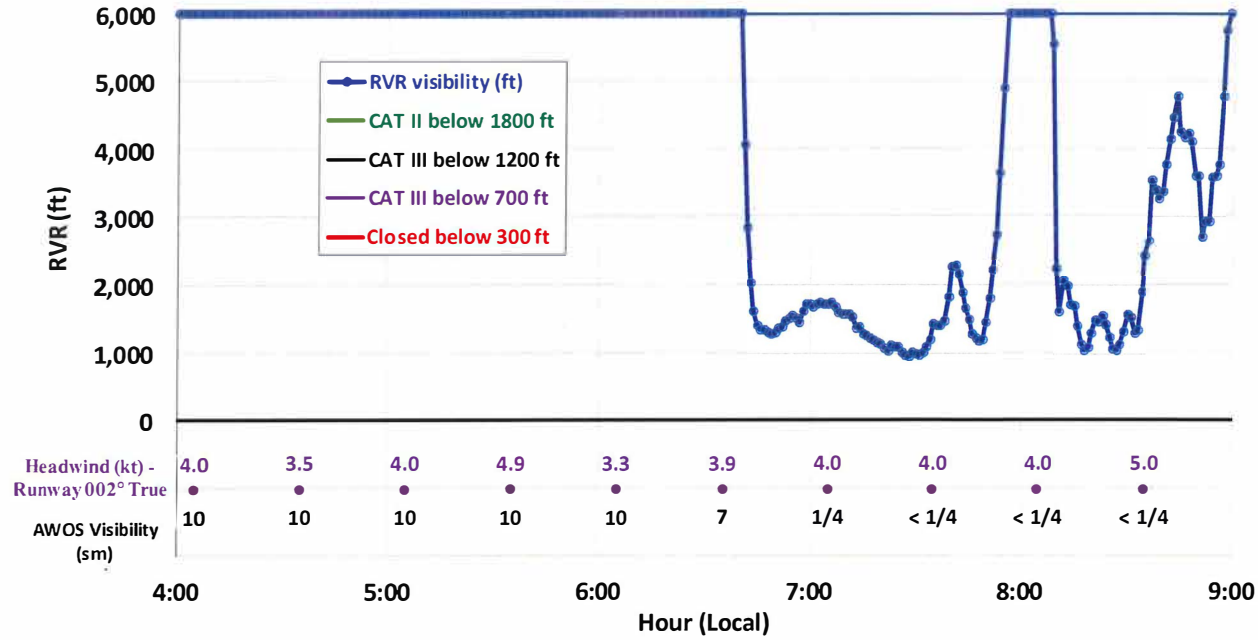

Figure 6. NAICM RVR Data, 26 January 2018

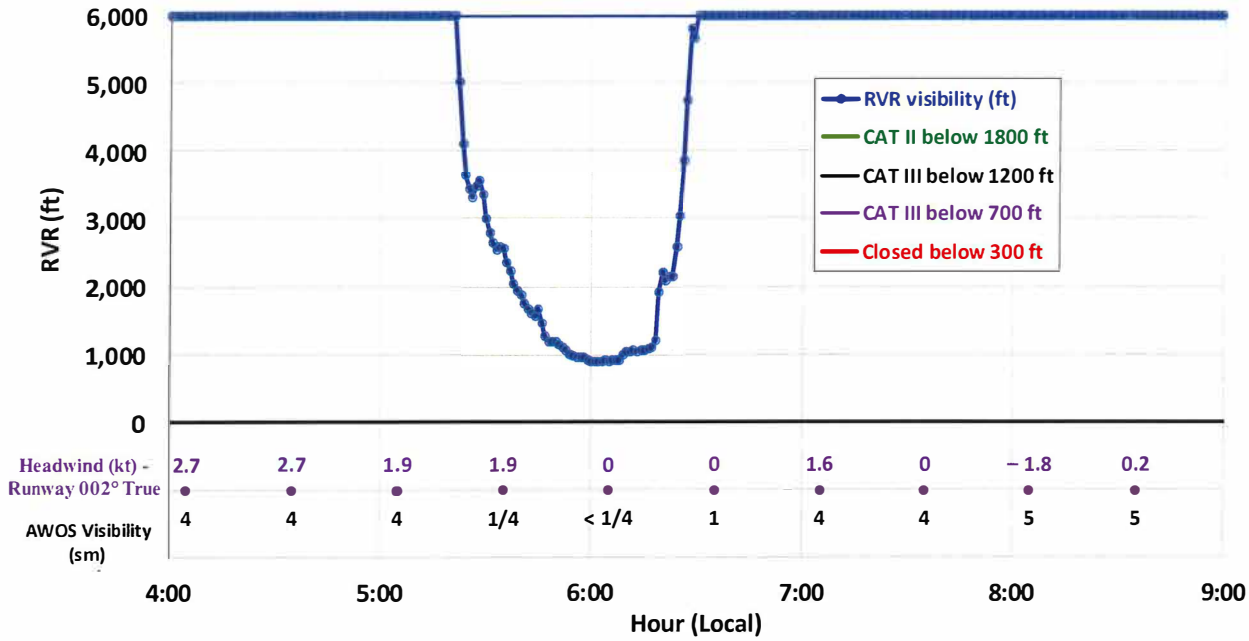

Figure 7. NAICM RVR Data, 3 February 2018

Note that on Figure 7, one data point of AWOS winds shows a negative value (-1.8 kt at 8:05 AM). This represents a headwind for the Runway 182° True direction (i.e., south flow) operations or a tailwind for the Runway 002° True direction (i.e., north flow) operations. However, this single AWOS observation fell outside the time range of low-visibility RVR weather occurrences, so it is not relevant to this analysis about winds during conditions at CAT II or below. Therefore, there were no occurrences of tailwinds for north-flow operations during any of the relevant (low-visibility) time periods for the study.

In summary, during the periods at CAT II or below weather, only mild winds were observed. For most of these times, winds were either calm (no winds) or came from the northerly direction. At some other times, winds were from east-northeast (between 40 and 70 degrees). All these types and directions of winds favored the Runway 002° True direction (i.e., north flow) operations.

5. Findings

The RVR and AWOS data from 23 November 2017 through 31 March 2018 suggest that at the NAICM site, good visibility conditions, for the purposes of this study, those equivalent to CAT I and better, occur the great majority of the time (when one truly includes all time, 24 hours per day). During this period, no periods of very poor visibility requiring runway closures (i.e., conditions below an RVR of 300 ft) were observed. A total of 200 minutes of CAT III visibility and 360 minutes of CAT II visibility were recorded on 12 different days. However, all periods of CAT II and III conditions occur between 4:00 AM and 9:00 AM, that is, hours during which the airport will be very busy.

Although the frequency of CAT II and CAT III visibility occurrences was low, the important conclusions of this analysis are that:

- **Low visibility does occur at NAICM for extended periods of time.**
- **There were seven days during the winter of 2017/2018 when the airport would have had to close runway operations during the important morning hours if CAT II and/or CAT III ILS approaches were not provided.**
    - **For example, on 30 December 2017, well within a high holiday period, a total of 101 minutes of CAT III visibility were recorded between 5:04 AM and 8:10 AM. During such times, any individual runway at NAICM without CAT III ILS approach capability would likely be closed.**
- **During the winter holiday season or other periods of high demand, any significant reduction in arrival capacity, even for a short amount of time, could result in major delays and operational disruptions, especially when triple independent approaches are needed.**

The cross-comparison of the RVR and the AWOS data suggested that during the periods of poor visibility and during the preceding and following hours, the winds were generally calm and/or favoring the Runway 002° True direction (i.e., north flow). Such conditions indicate that CAT II and CAT III infrastructure may mostly be necessary for the north flow, operational

direction (all three initial runways). At the same time, if the authorities would like to ensure practically no closings ever, they may want to install CAT III ILSs for part or all the south flow, a total of six CAT III ILSs.

Other important items that should be considered by the aviation authorities as part of their decision-making process regarding the number of CAT III-equipped runways at NAICM are as follows:

- The potential need for closing a CAT III-equipped runway for maintenance or for some other reason should be considered. For example, if only two runways at NAICM are equipped for CAT III operations and one of those runways were closed, the airport would be down to only a single CAT III-equipped runway, which could significantly impact capacity resulting in arrival delays and possible diversions to other airports.
- Departures were not discussed in this report but have similar requirements as approaches during low-visibility periods. This could affect the decision on the number of runways equipped for CAT III operations.

Recommendations

MITRE recommends that the decision-making process regarding the establishment of CAT III-equipped runways at NAICM be conducted in a collaborative manner with all stakeholders, especially the airlines and other airport users, and consider all appropriate factors.

Compared to the total cost of the airport, adding a few CAT III ILSs as opposed to CAT I may not be financially consequential and may result in an airport that, unlike AICM, may virtually never close or suffer delays due to visibility issues.

Notice in Appendix A, that it is easy to find a sampling of major airports that have ALL runways (both directions) equipped with CAT III ILSs: Chicago O'Hare, which operates triple independent approaches, Munich, and Frankfurt. Many others also have ALL approach runways equipped with CAT III ILSs, but not their departure-only runways. When NAICM grows further, some of its runways may be utilized almost always for departures only, but that is not the case today.

It appears justifiable and prudent to install initially at NAICM six CAT III ILSs.

Appendix A

Table A-1 shows examples of major international airports with ILS CAT I-, CAT II- and CAT III-equipped runways, by operational direction. The last column in the table specifies if that runway direction is authorized for dual- and/or triple-independent parallel approaches, as appropriate.

Table A-1. Examples of Major Airports with ILS CAT I, CAT II, and CAT III Runways

Airport	Runway	CAT I	CAT II	CAT III	Independent Parallel Approaches
Hartsfield–Jackson Atlanta International Airport - U.S. (Dual- and Triple-Independent Approaches)	8L	✓	✓	✓	✓
	8R	✓			✓
	9L	✓			✓
	9R	✓	✓	✓	✓
	10	✓	✓	✓	✓
	26L	✓			✓
	26R	✓			✓
	27L	✓	✓		✓
	27R	✓			✓
	28	✓	✓		✓
Chicago O'Hare International Airport - U.S. (Dual- and Triple-Independent Approaches)	4L				✓*
	4R	✓			✓
	9L	✓	✓	✓	✓
	9R	✓			✓
	10L	✓	✓	✓	✓
	10C	✓	✓	✓	✓
	10R	✓	✓	✓	✓
	22L	✓			✓
	22R	✓			✓
	27L	✓	✓	✓	✓
	27R	✓	✓	✓	✓
	28L	✓	✓	✓	✓
	28C	✓	✓	✓	✓
	28R	✓	✓	✓	✓

* Runway 04L at Chicago O'Hare International Airport uses an Air Navigation (RNAV) Global Positioning System (GPS) approach.

Table A-1. Examples of Major Airports with ILS CAT I, CAT II, and CAT III Runways (Continued)

Airport	Runway	CAT I	CAT II	CAT III	Independent Parallel Approaches
Dallas/Fort Worth International Airport - U.S. (Dual- and Triple-Independent Approaches)	13L				
	13R	✓			
	17L	✓	✓	✓	✓
	17C	✓	✓	✓	✓
	17R	✓			✓
	18L	✓			✓
	18R	✓	✓	✓	✓
	31L				✓*
	31R	✓			✓
	35L	✓			✓
	35C	✓	✓	✓	✓
	35R	✓	✓	✓	✓
	36L	✓			✓
	36R	✓			✓
Houston George Bush Intercontinental Airport - U.S. (Dual- and Triple-Independent Approaches)	8L	✓	✓	✓	✓
	8R	✓			✓
	9	✓			✓
	15L				
	15R	✓			
	26L	✓	✓	✓	✓
	26R	✓	✓	✓	✓
	27	✓	✓	✓	✓
	33L				
	33R	✓			
Washington Dulles International Airport - U.S. (Dual Independent Approaches)	1L	✓	✓	✓	✓
	1C	✓			✓
	1R	✓	✓	✓	✓
	12	✓			
	19L	✓			✓
	19C	✓	✓	✓	✓
	19R	✓	✓	✓	✓
	30				

* Runway 31L at Dallas/Fort Worth International Airport uses an RNAV GPS approach.

Table A-1. Examples of Major Airports with ILS CAT I, CAT II, and CAT III Runways (Concluded)

Airport	Runway	CAT I	CAT II	CAT III	Independent Parallel Approaches
Frankfurt Airport - Germany (Dual Independent Approaches)	7L	✓	✓	✓	✓
	7C	✓	✓	✓	✓
	7R	✓	✓	✓	✓
	18	Runway 18 not used for approaches; Runway 36 not available.			
	25L	✓	✓	✓	✓
	25C	✓	✓	✓	✓
	25R	✓	✓	✓	✓
Munich Airport – Germany (Dual Independent Approaches)	8L	✓	✓	✓	✓
	8R	✓	✓	✓	✓
	26L	✓	✓	✓	✓
	26R	✓	✓	✓	✓
Amsterdam Schiphol Airport - Netherlands (Dual Independent Approaches)	4				
	6	✓	✓	✓	
	9				
	18L				
	18C	✓	✓	✓	✓
	18R	✓	✓	✓	✓
	22	✓			
	24				
	27	✓	✓	✓	
	36L				
	36C	✓	✓	✓	✓
	36R	✓	✓	✓	✓