Multi-Mission Maritime Aircraft Airfield Analyses

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At the beginning of any study there is a call for information: What data exist? What has been done already? The genesis of this article is the direct result of the initial call for data concerning airfield environmental factors that could affect Multi-mission Maritime Aircraft (MMA) operations. Airfield data were found in various publications and reports, but not in a succinct form. The product of the analyses reported in this article was a compilation of data on the environments at 43 airfields that currently support P-3 maritime patrol aircraft operations and are projected to support the MMA. Data ranging from runway length and width to hazards on the runway were catalogued. We identified two aspects of the airfield environment that had the greatest impact on the MMA—crosswind landing conditions and runway weight-bearing capacity. Analysis of the former supported a relaxation of a crosswind landing requirement for the MMA, while analysis of the latter has resulted in an additional cost variable that must be factored into the decision to select the aircraft that becomes the MMA.

INTRODUCTION

The Multi-mission Maritime Aircraft (MMA) Initial Requirements Document (IRD), developed and published by the MMA Program Office, established preliminary basic aircraft performance requirements that candidate aircraft vying to become the Navy's next patrol aircraft must attain. These performance requirements included values for airspeed, endurance, altitude, and required runway length for takeoff and landing. The initial request from the MMA Program Office was for APL to perform an analysis of runway lengths for takeoff and landing because of the importance to the MMA worldwide deployability. In addition, the Office was concerned that environmental factors, such as wind conditions or runway construction characteristics, could restrict MMA performance.

To address the Program Office's concerns, an analysis of the potential airfield from which an MMA could operate was performed. A database on 43 airfields around the world that are currently used by U.S. maritime patrol aircraft was compiled (Fig. 1). Information was gathered on temperature, airfield communications, navigation systems, and airway length and width. Environmental hazards (e.g., deer and moose on the runways at two airfields in Alaska) were noted as well.

This article discusses two pieces of airfield information from the database that had the most significant impact

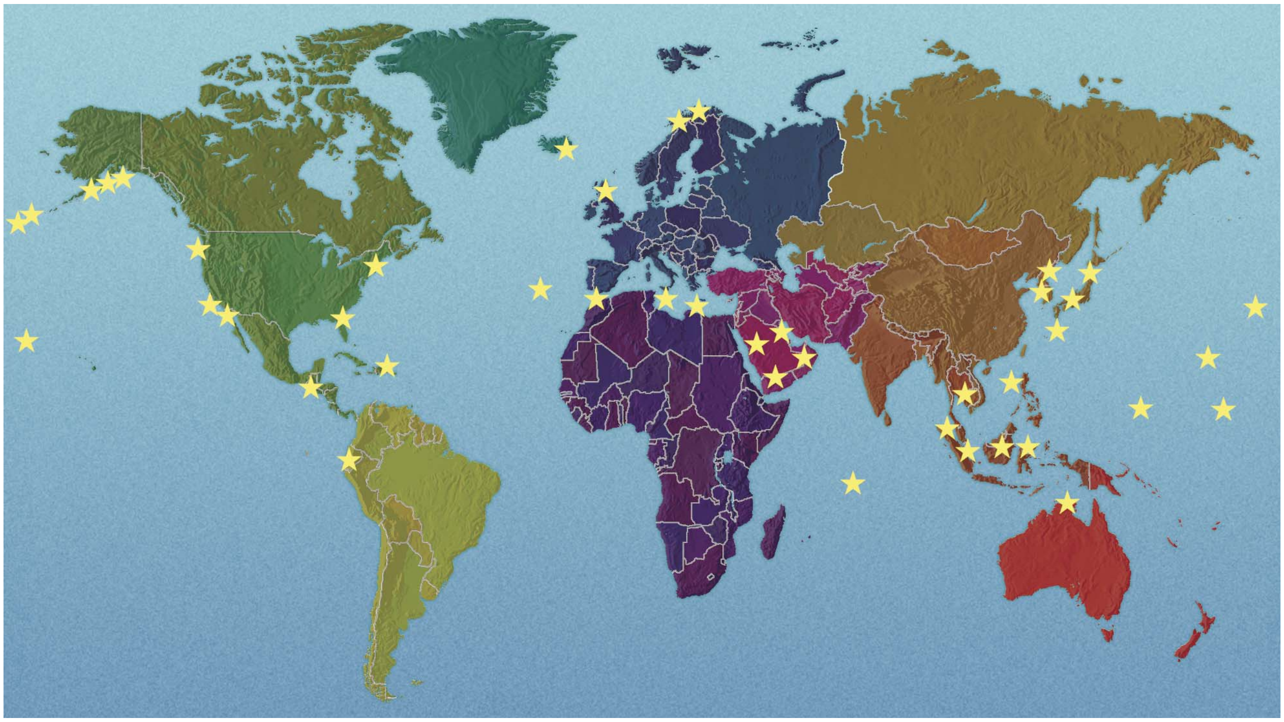

Figure 1. Worldwide locations of potential Multi-mission Maritime Aircraft airfields used in the analysis.

on the MMA Program: the occurrence and strength of crosswind conditions for landing[1] and the takeoff and weight-bearing capacities of the runways.[2]

MAJOR PERFORMANCE PARAMETERS

Crosswind

The first release of the MMA IRD had specified that the aircraft had to be able to land and take off in crosswinds of 30 to 35 kt under dry runway conditions and 20 to 25 kt under wet runway conditions. Weather data for evaluating crosswind conditions were obtained from the Federal Climate Complex, Asheville, North Carolina. Data consisted of hourly observations for wind direction and speed at the airfield over a 20- to 50-year period, binned by wind speeds of calm, 1–3, 4–6. . .22–27, 28–37. . . >56 kt using a 12- or 16-point point compass.

Crosswind analysis was performed by superimposing the wind observations at the airfields on the runway(s). Figure 2 illustrates the logic of the geographic positioning of the runway at Sigonella, Sicily, to account for its predominant westerly and easterly winds. Wind speeds at Sigonella are generally light during 99.9% of the year, at less than 27 kt. In this case, the marriage of the runway heading to the known wind conditions yielded no significant landing or takeoff crosswind conditions (0% chance of a 35-kt crosswind and only a 0.15% per day chance of a 30-kt crosswind).

Figure 3a illustrates the majority of crosswind landing conditions for MMA operations at Eareckson Air Station, 1200 miles southwest of Anchorage on Shemya Island, part of the Aleutian Chain. The geography of the island dictated the location and alignment of only a single runway, as building additional runways is considered fiscally prohibitive. Figure 3b illustrates the extreme winds at the same location that could place an aircraft in a precarious crosswind landing condition.

A detailed analysis of the potential for crosswind conditions was conducted for each airfield. Wind

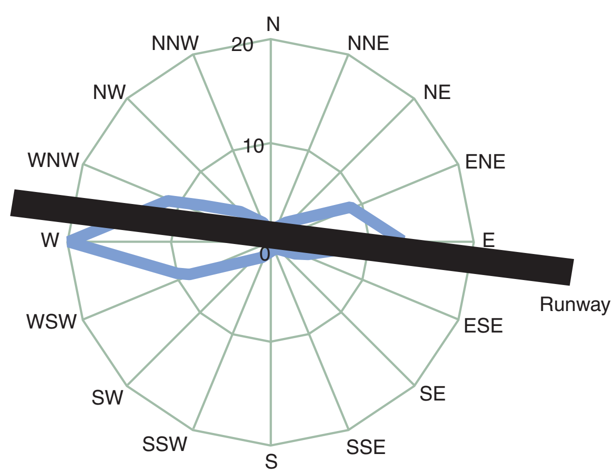

Figure 2. At the Sigonella, Sicily, airfield, winds were <27 kt (blue) for 99.9% of the year.

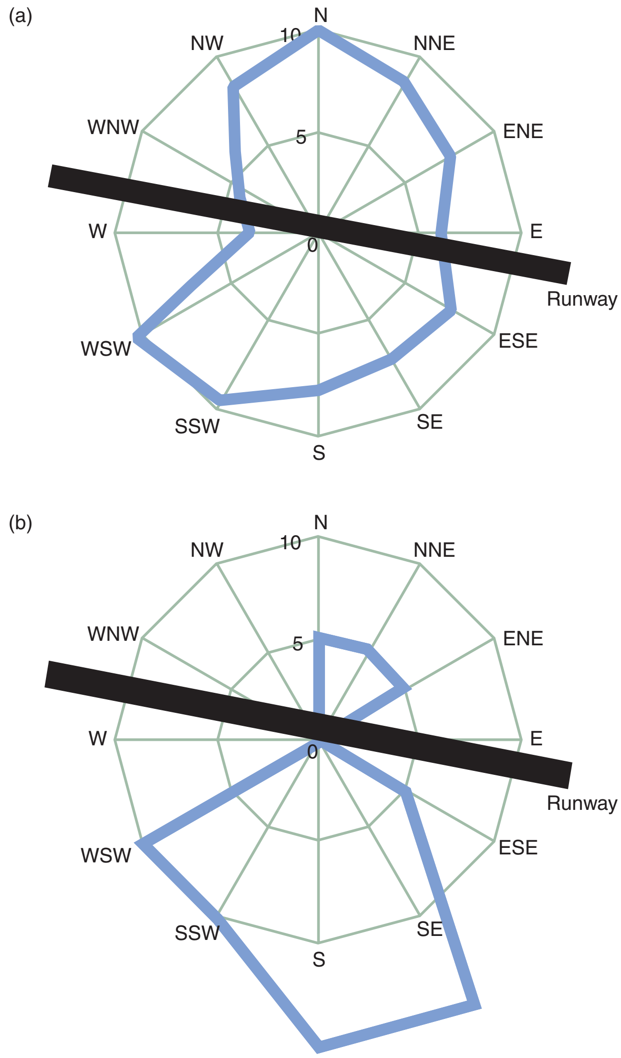

Figure 3. Conditions at the Eareckson, Alaska, airfield showing (a) winds at <29 kt (blue) for 91.4% of the year and (b) daily extreme crosswinds at 40 to 49 kt.

vectors (wind direction and speed) that generate crosswind component wind speeds of 20, 25, 30, and 35 kt were determined using crosswind wind templates. Crosswind conditions for airfields with more than one runway were derived by determining the crosswind component for each runway and then selecting the runway that minimized the crosswind component.

The results of this analysis indicated that 14 of the airfields had significant (for at least 15 min/day) 20-kt crosswind components, 6 had significant 25-kt components, 3 had 30-kt components, and 2 had significant 35-kt crosswinds. Table 1 identifies the four airfields that pose the most challenge regarding crosswind landing and takeoff conditions.

The finding of the crosswind component evaluation was that the 30-kt threshold and 35-kt objective value for the MMA crosswind capability requirement under dry runway conditions are appropriate for the anticipated airfield environments.

Table 1. Four worst airfields for crosswind components (% daily occurrence).

	Component			
Airfield	20 kt	25 kt	30 kt	35 kt
Keflavik	15.0	7.5	7.5	4.5
Eareckson	15.6	8.4	2.8	1.8
Kadena	1.9	1.4	1.1	0.3
Bodo	3.2	1.4	0.95	0.3

Analysis of the weather data indicated that there were seasonal effects associated with wet runway and crosswind conditions at the airfields. Only the airfield at Eareckson posed a significant challenge regarding a simultaneous wet runway and crosswind landing or takeoff condition. The month of March produced the most severe conditions for landing and takeoff, with 2.5 h of simultaneous 20- to 29-kt wind speeds and wet runway conditions per day, and close to 2 h of wet runway conditions in crosswinds $\geq$30 kt. However, Eareckson was the exception; the other MMA airfields do not have the high crosswind and wet runway conditions. Using this information, the MMA Program Office reduced the simultaneous wet runway and landing and takeoff crosswind component threshold requirement from 25 to 20 kt.

Runway Weight-Bearing Capacity

The capability of an airfield's runway to support aircraft operations depends on the type of pavement, the subgrade of the pavement, and the type of aircraft that operate from the runway. The impact of the aircraft on the pavement depends on the weight of the aircraft, number of wheels, separation of the wheels, and tire pressure. Reducing an aircraft's payload or fuel load can prevent structural damage to the runway on takeoff and landing; however, these loads can affect the operational performance of the aircraft, which was a concern of the MMA Program Office.

Airfield runways are not all constructed to the same weight-supporting ability. Factors of geography and economics are key determinants for how the runway is constructed. The natural soil composition underneath the runway and the thickness and density of selected materials above the soil determine the runway's ability to support a given load. Construction engineers make trade-offs in substrate and pavement materials based on available resources and the type of aircraft that are anticipated to use the airfield. These trade-offs are particularly important in airfields constructed on islands in the Pacific, where rock and gravel, used as the substrate for the runway, must be transported to the island. In addition, coral is used to cut cost. The abundantly available coral from the waters that surround the islands is mixed in with the paving material, but this produces a pavement of inferior quality.

Airfield runways also degrade over time from environmental damage and aircraft operations. Freeze/thaw cycles and water runoff affect the structural integrity of the pavement and the substrate. The cumulative effect of aircraft weight compressing the runway and the underlying substrate causes a runway to degrade over time. Airfields used by DoD are evaluated every 5 years. These assessments are employed to determine the airfield's suitability for conducting air operations and to plan for the need to repave the airfield's runway, taxiway, and ramp area.

Aircraft have several types of main landing gear (Table 2). Potential candidates for the MMA wheel types are twin (two wheels per main landing gear) or twin tandem (the main landing gear consists of an arrangement of four wheels). The use of multi-wheel landing gear generally allows the weight of the aircraft to be spread over a greater pavement surface area. For example, the multi-wheel configuration of a 700,000-lb C-5 cargo plane produces the same impact on a runway as a 130,000-lb P-3.

Table 2. Main landing gear classifications.

Wheel type (abbreviation)	Aircraft type
Single (S)	F-15
Twin (T)	P-3, 737, Gulfstream
Single tandem (ST)	C-130
Single belly twin tandem (SBTT)	KC-10
Twin tandem (TT)	757, Nimrod, 767, A320
Twin delta tandem (TDT)	C-5
Double dual tandem (DDT)	747
Triple tandem type (TRT)	C-17
Twin triple type (TTT)	777

Since 1981 an Aircraft Classification Number (ACN)/Pavement Condition Number (PCN) system established by the International Civil Aviation Organization (ICAO) has been used to provide a common worldwide method for determining whether the pavement of a runway can support an aircraft's weight. The ICAO defines these numbers as follows.[3]

> ACN: a number which expresses the relative structural effect of an aircraft on different pavement types for specified standard subgrade strengths in terms of a standard single wheel load
>
> PCN: a number which expresses the relative load-carrying capacity of a pavement in terms of a standard single wheel load

Under the ACN/PCN system, there are no weight restrictions for an aircraft that has an ACN value less than or equal to the pavement's PCN value (ACN/PCN $\leq$ 1).

The aircraft manufacturer determines the ACN, which, for most DoD aircraft, is published in the *Flight Information Handbook* (FIH). This handbook contains a table with the aircraft's ACN for two weight classes—empty and maximum takeoff weight—over two types of pavement. An ACN value for a weight between the empty and takeoff weight can be calculated by interpolation between the two weight limits found in the FIH table. An example of the ACN data found in the FIH for a P-3C is provided in Table 3.

The PCN for a runway is determined either by a technical report or an evaluation of the types of aircraft that have used the runway in the past without damaging the pavement. For technical evaluations, the frequency of operations on the runway and the allowable stress to the pavement are factors used to determine the PCN. The letter "T" for a technical report or "U" for an evaluation annotates the type of assessment used.

The PCN uses two pavement types: "R" for rigid runways that are normally made from concrete and "F" for flexible runways which are normally made from asphalt/concrete. Associated with each pavement type are four standard subgrades (Table 4).

An additional piece of information included with the runway PCN is the tire pressure that the runway can support. Tire pressure is a concern for flexible

Table 3. P-3C aircraft classification numbers (tire pressure = 180 psi).

Weight class	Weight (1000 lb)	Rigid pavement subgrades				Flexible pavement subgrades			
		High	Medium	Low	Ultra-low	High	Medium	Low	Ultra-low
Empty	61	16	17	18	19	14	14	16	18
Maximum	140	44	46	48	49	38	41	44	47

Table 4. Pavement subgrade classification.

Subgrade code	Type of pavement: Rigid (R) (lb/in.^{3})	Flexible (F) CBR*
A	>400	>13
B	201–400	8–13
C	100–200	4–8
D	<100	<4

*California Bearing Ratio.

pavements, but not for rigid pavements. The level of stress on a flexible surface is directly related to the inflation pressure of the wheels in contact with the pavement. There are four categories of tire pressure limits (Table 5).

The standardized format of a PCN is given in the following example:

38FBXT.

Here,

38 = PCN (normally between 0 and 100),
F = type of pavement (F or R),
B = type of subgrade (A, B, C, or D),
X = allowable tire pressure (W, X, Y, or Z),
T = how the PCN was determined (T or U).

A high PCN allows the operation of heavier aircraft. This is evident in the PCN for two airfields that support B-52 bombers, Anderson Air Force Base (PCN 85) and Diego Garcia (PCN 97).

The following is an example of how the ACN/PCN system is used to calculate the compatibility of an aircraft to an airway weight-bearing capacity using the P-3 PCN data from Table 3 and the above PCN values:

> Using a P-3 weight of 140,000 lb and the PCN values above (38FBXT), the P-3 ACN value for a flexible pavement with a medium subgrade is 41. The resulting ACN/PCN value is 41/38 = 1.08.

A ratio greater than 1 means that takeoff and landing operations for that aircraft's weight can potentially damage the runway. The Air Force advises engineers to use the ACN/PCN categories in Table 6[4] to rate the impact of aircraft operations at a given airfield. In the case above, a ratio of 1.08 means that this airfield's runway can adequately support P-3 aircraft operations.

Table 5. Tire pressure classification system.

Tire pressure code	Rating	Pressure limit (psi)
W	High	None
X	Medium	217
Y	Low	145
Z	Very Low	73

A set of MMA candidate aircraft were selected from the Analysis of Alternatives effort led by the Center for Naval Analyses, and each one was evaluated for its impact on the structural integrity of the runway of each airfield. For this assessment the maximum fuel and ordnance load was used. If an airfield had more than one main runway, the main runway that had the lowest weight-bearing capacity was used. For example, a Boeing 767 operating at its maximum weight would unsatisfactorily impact the runways at 4 airfields and marginally damage 8 others; therefore, all 12 airfields would require an upgrade to their runway subgrade and pavement.

The assessment of the runway impact of all the MMA candidate aircraft was provided to the MMA Program Office. Results are not published here because they are competition sensitive. However the impact on the runways at the airfields ranged from "no runway upgrades needed" for 1 candidate aircraft to 19 upgrades for another. As part of the aircraft selection process, the cost of upgrading runways to meet flight operations for each candidate aircraft is a factor in the total cost of the program.

The study recommended that the Naval Facilities Engineering Service Center, Port Hueneme, California, provide the engineering cost estimates to upgrade runways and other airfield facilities (e.g., ramps, parking areas) to meet MMA operational demands.

IMACT OF FINDINGS

The Airfield Analysis Document became a standard reference document for the MMA Program Office. It was used for requirements development and operations analysis that supported the IRD, MMA Performance Based Specification, and Cost Analysis Requirements Description. It has also been provided to the MMA prime contractors as a reference document.

The airfield analysis identified representative airfields from which MMA would be required to operate. These airfields were instrumental in verifying and developing the balanced field length and crosswind requirements for takeoff and landing in the IRD. Initially, the IRD

Table 6. Airfield rating system.

Rating	Structural adequacy
Adequate	ACN/PCN ≤ 1.25
Marginal	1.25 < ACN/PCN < 1.50
Unsatisfactory	ACN/PCN ≥ 1.50

identified higher wet runway crosswind takeoff and landing requirements for MMA. However, the airfield analysis did not support the higher crosswind requirements, resulting in a reduction to a lower level in subsequent documents.

The ACN/PCN runway compatibility assessment identified potential MMA program costs for funding runway upgrades that may affect the selection of a candidate aircraft as the MMA.

The airfields identified in the Airfield Analysis Document were also used in the Design Reference Mission Tactical Situations (TACSITs). Distances from this baseline set of airfields to operational areas defined in the TACSITs were fundamental in calculating the mission station radii for the MMA Performance Based Specification air vehicle flight profiles.

SUMMARY

Analyses of airfield and environmental data provided information that gave credence to the majority of the MMA IRD parameters as well as valuable insight into other parameters that must be considered as the MMA continues through its development. An evaluation of crosswind and wet runway conditions at the 43 airfields determined that a reduction in the MMA requirement to 20 kt for crosswind landing and takeoff during wet runway conditions was warranted. In addition, the compilation of the data from disparate sources has given the MMA Program a reference that continues to be used to support follow-on MMA efforts.

REFERENCES

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[3]*Standardized Method of Reporting Airport Pavement Strength—PCN*, Federal Aviation Administration Advisory Circular No. 150/5335-5 (Jun 1983).

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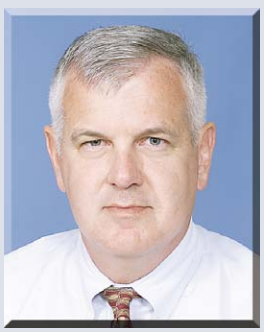

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