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Calculating Carrier Air Wing Readiness: An Additive Approach

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In "Operational Risk Rollup" published in September's issue of *Phalanx*, the authors proposed a probabilistic framework to support operational planners, staff, and commanders in readiness assessments at the tactical, operational, and strategic level (Doheney et al., 2019). The platform agnostic discipline of probability management represents uncertainty as arrays of auditable data called stochastic information packets (SIPs). Based on available system-level data, SIPs of the readiness of individual assets such as tanks or aircraft can be rolled up through array addition into readiness SIPs of platoons or squadrons, which can be further rolled up to calculate the readiness of companies or wings.

In this article, we discuss the development of a stochastic library that drives a decision dashboard for a hypothetical aircraft carrier air wing composed of all the aircraft on a single aircraft carrier (Figure 1). The dashboard allows a commander to input mission requirements in numbers of aircraft. Then it immediately estimates the chance that the air wing will be ready to successfully carry out that mission on short notice. It also displays the conditional probability that an aircraft type was deficient given a failure of mission capability. For example, Figure 1 displays a mission for which the air wing has an 82% chance of being ready on a given day. Furthermore, we see that, given that the wing was not mission capable, there is a 40% chance it was due to a deficiency in E/A-18G Growler availability. This conceptual Excel™ model runs 10,000 trials instantly each time the mission requirements are changed. It may be downloaded with other conceptual models at https://www.probabilitymanagement.org/readiness.

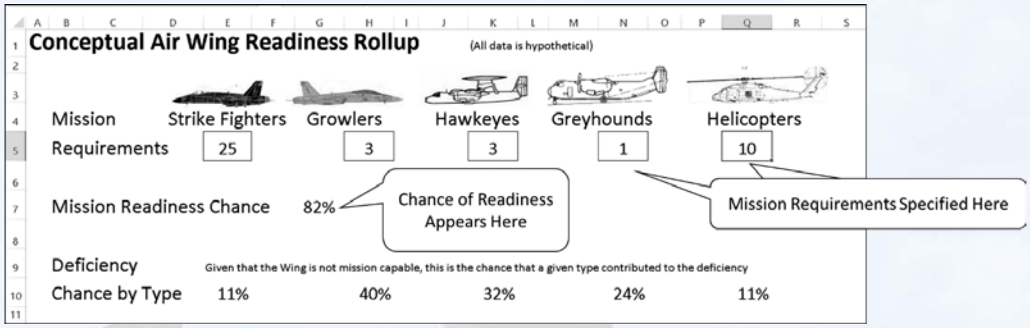

Figure 1. Readiness dashboard.

The Basic Principle of Probability Management

Probability management is based on representing uncertainties as coherent arrays of simulated outcomes and SIP's metadata. By coherent, we mean that global events that occur on a given trial for any aircraft will occur for all aircraft on that trial. For example, an oxygen system problem associated with a particular type of aircraft could ground all aircraft of that type simultaneously. This approach has been used for some time in financial engineering and insurance within large closed information systems. The Open SIPmath™ Standard (Kirmse and Savage, 2014) from nonprofit ProbabilityManagement.org has democratized this approach allowing for collaborative cross-platform networks of simulations (Savage and Thibault, 2015). Simulations in analytical platforms such as R or Python can create SIP libraries for use by dashboards like the one described here, which run in native Excel. Because these models do not require macros or add-ins, they provide nearly universal access to this sort of analysis.

Individual Aircraft Readiness

Although the data used in these examples are strictly notional, they are characteristic of aircraft system-level maintenance and supply data already meticulously documented by airframe mechanics and maintainers in all US military aircraft squadrons. Aircraft maintenance officers (AMOs) are required to maintain historical records and regularly report on each aircraft's status as either mission capable, partial mission capable, or non-mission capable. These AMOs know how many flight hours each aircraft has, to include the hours of operation of each major aircraft subsystem, such as the hours on each aircraft engine. With improvement and automation of aircraft inspection systems, AMOs can increase operational availability and mission capable rates through

MC SIP 101		
Scenario 1	1	
Scenario 2	0	<--- Flat Tire
Scenario 3	1	
:	:	
Scenario 342	1	
Scenario 343	0	<--- Fleet-Wide Grounding due to Oxygen System
Scenario 344	1	
:	:	
Scenario 6,344	1	
Scenario 6,345	0	<--- Faulty Gyro
Scenario 6,346	1	
:	:	
Scenario 9,999	0	<--- Bad Lubricant Squadron-Wide
Scenario 10,000	1	

Figure 2. A Hypothetical mission-capable SIP for F/A-18, Tail # 101 Aircraft.

dynamic maintenance programs that preemptively schedule maintenance based on operational history of specific aircraft. Such maintenance plans leverage near real-time predictive analytics, rather than reacting to unforeseen or unscheduled groundings due to system failures. Of course, there will always be some uncertainty in aircraft readiness, so a key aspect of dynamic maintenance planning is collecting accurate reliability and failure data, which can be used in simulations to create SIPs of readiness for an individual aircraft as shown in Figure 2.

This example SIP is based on 10,000 trials, in which 1 indicates that the aircraft is ready and 0 indicates not ready. Tail #101's mission capable (MC) rate is the average of its SIP elements, or the sum of its 10,000 elements divided by 10,000. Note that readiness is impacted by idiosyncratic factors such as flat tires or faulty gyros, squadron-wide factors such as bad lubricants, and fleet-wide issues such as oxygen system problems.

Squadron Readiness

The SIPs of individual aircraft readiness can be rolled up into a squadron readiness SIP through simple element-by-element array addition.

The SIP for one 10-aircraft F/A-18 Squadron equals the element-by-element sum of all 10 individual tail number SIPs, representing the distribution of the number of ready aircraft in the squadron (see Figure 3). Note that interrelationships such as fleet wide grounding are preserved across SIPs.

SIPs that preserve statistical relationships in this manner are said to be coherent and form a stochastic library unit with relationships preserved or a SLURP.

Strike Fighter Readiness

The strike-fighter mission capable SIP is then rolled up from four individual F/A-18 Squadron SIPs in the air wing (see Figure 4). The strike fighter SIP of 10,000 trials is now the summary of the 400,000 trials comprising the SIPs of the 40 individual aircraft.

The Air Wing SIP Library

The air wing mission capable SIP library has one SIP for each aircraft type, which is in turn rolled up across all aircraft of that type in the air wing (see Figure 5).

This coherent library may be used in readiness dashboards (see Figure 1) to determine how ready the air wing is for specified missions. Note that the Growlers, an F/A-18 variant, are grounded along with the entire F/A-18 fleet in scenario 343.

Additive Readiness

In theory, probability management provides an additive representation of readiness for a wide array of military units, which may be combined with one another to determine the readiness of the combined units. Readiness accounting has traditionally been in terms of a unit being either ready or not ready. This approach lets us ask how ready a combination of units will be for a specific mission and, if they are not ready, which elements are the most likely culprits.

	MC SIP 101	MC SIP 102	MC SIP 103	MC SIP 104	MC SIP 105	MC SIP 106	MC SIP 107	MC SIP 108	MC SIP 109	MC SIP 110	Squadron 1 SIP	
Scenario 1	1	1	1	1	1	1	1	1	0	1	9	
Scenario 2	0	1	1	1	1	1	1	1	1	1	9	
Scenario 3	1	0	1	1	1	0	1	1	0	1	7	
:	:	:	:	:	:	:	:	:	:	:	:	
Scenario 342	1	1	1	1	1	1	1	1	1	1	10	
Scenario 343	0	0	0	0	0	0	0	0	0	0	0	<--- Fleet-Wide Grounding
Scenario 344	1	1	0	1	1	1	1	1	1	1	9	
:	:	:	:	:	:	:	:	:	:	:	:	
Scenario 6,344	1	1	1	1	1	1	1	1	1	0	9	
Scenario 6,345	0	1	1	0	1	1	1	1	1	1	8	
Scenario 6,346	1	1	1	1	0	1	0	1	1	1	8	
:	:	:	:	:	:	:	:	:	:	:	:	
Scenario 9,999	0	0	0	0	0	0	0	0	0	0	0	<--- Squadron-Wide Grounding
Scenario 10,000	1	1	1	1	1	1	1	1	1	1	10	

Figure 3. A squadron mission-capable SIP is rolled up from 10 individual tail number SIPs.

	Squadron 1 SIP	Squadron 2 SIP	Squadron 3 SIP	Squadron 4 SIP	Strike Fighter SIP	
Scenario 1	9	8	10	9	36	
Scenario 2	9	8	7	10	34	
Scenario 3	7	10	10	10	37	
:	:	:	:	:	:	
Scenario 342	10	8	10	9	37	
Scenario 343	0	0	0	0	0	<--- Fleet-Wide Grounding
Scenario 344	9	8	10	7	34	
:	:	:	:	:	:	
Scenario 6,344	9	9	8	9	35	
Scenario 6,345	8	10	8	10	36	
Scenario 6,346	8	7	10	8	33	
:	:	:	:	:	:	
Scenario 9,999	0	8	10	9	27	<--- Squadron 1 Grounding
Scenario 10,000	10	8	9	8	35	

Figure 4. The strike-fighter mission-capable SIP.

	Strike Fighter SIP	Growler SIP	Hawkeye SIP	Greyhound SIP	Helicopter	
Scenario 1	36	4	4	2	14	
Scenario 2	34	5	5	2	12	
Scenario 3	37	4	5	1	17	
	:	:	:	:	:	
Scenario 342	37	5	4	2	13	
Scenario 343	0	0	5	2	12	<--- F/A 18 Grounding
Scenario 344	34	4	5	2	14	
	:	:	:	:	:	
Scenario 6,344	35	3	5	1	15	
Scenario 6,345	36	5	4	2	14	
Scenario 6,346	33	4	3	1	11	
	:	:	:	:	:	
Scenario 9,999	27	4	4	2	14	<--- Squadron 1 Grounding
Scenario 10,000	35	5	5	2	12	

Figure 5. The coherent air wing SIP library.

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About the Authors

Shaun Doheney is the chief analytics officer at JDSAT, a certified service-disabled veteran-owned small business specializing in operations research and data science. He is also the chair of Resources and Readiness Applications at ProbabilityManagement.org, a nonprofit devoted to the communication and calculation of uncertainty. He is a certified analytics professional credentialed through INFORMS and holds a BS in mathematics, an MS in operations analysis, and a graduate certificate in data analytics. As a Marine Corps Lieutenant Colonel (Retired) and Marine operations research analyst, he performed qualitative and quantitative analyses and evaluations across major Department of Defense decision support processes.

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Dr. Sam L. Savage is executive director of ProbabilityManagement.org, a 501(c)(3) nonprofit devoted to the communication and calculation of uncertainty. The organization has received funding from Chevron, Lockheed Martin, PG&E, and others, and he is joined on the board by Harry Markowitz, Nobel Laureate in Economics. Dr. Savage is author of *The Flaw of Averages: Why We Underestimate Risk in the Face of Uncertainty* (John WIley & Sons, 2009, 2012), and is an adjunct professor in civil and environmental engineering at Stanford University. He is the inventor of the stochastic information packet (SIP), an auditable data array for conveying uncertainty. He received his PhD in computational complexity from Yale University.