Readiness Modeling: Changing the Question from "Ready or Not?" to "How Ready for What?"

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ABOUT THE AUTHORS

Dr. Sam Savage

Executive Director

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 Ph.D. in computational complexity from Yale University.

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Mr. Shaun Doheney

Chair, Resources & Readiness Applications

Shaun Doheney is the Chair of Resources and Readiness Applications at ProbabilityManagement.org - a nonprofit devoted to the communication and calculation of uncertainty. He holds a B.S. in Mathematics, an M.S. in Operations Analysis, a Graduate Certificate in Data Analytics, is a Certified Data Analytics Professional (CAP®), and is a Project Management Professional (PMP ®). As a Marine Corps Lieutenant Colonel (Retired) and Marine Operations Research Analyst, he performed qualitative and quantitative analyses and evaluations across major DoD decision support processes. His past projects featured optimization, multiple-objective decision analysis, quantitative risk analysis, discrete event simulation, and survey design and analysis.

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Connor McLemore

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Connor McLemore is the Chair of National Security Applications at ProbabilityManagement.org and an E-2C naval flight officer with numerous operational deployments during 19 years of service in the U.S. Navy. He is a graduate of the United States Navy Fighter Weapons School (Topgun) and an operations analyst with Master's degrees from the Naval Postgraduate School in Monterey, California and the Naval War College in Newport, Rhode Island. In 2014, he returned to the Naval Postgraduate School as a Military Assistant Professor and the Operations Research Program Officer. He is currently with the Office of the Chief of Naval Operations Assessment Division (OPNAV N81) in Washington D.C.

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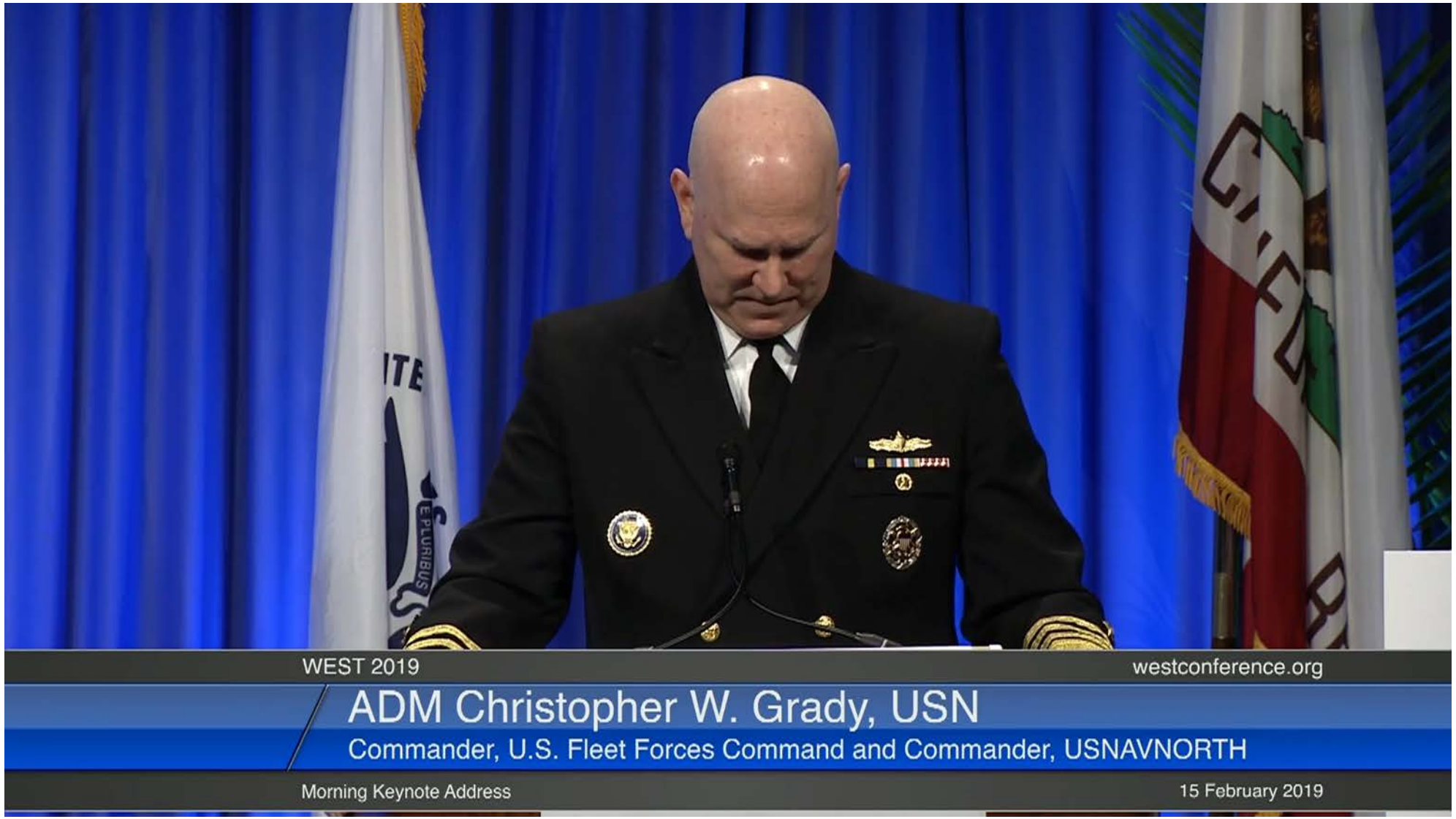
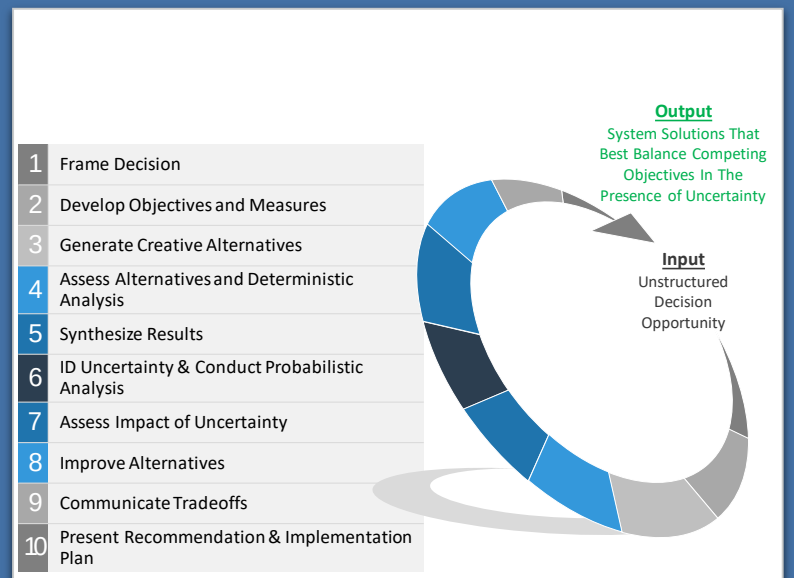
The Problem Defined by ADM Grady



Watch the full video here: https://www.youtube.com/watch?v=_9Jk-a-k6qQ&pbjreload=10

17:55 to 24:30 is the MUST WATCH on readiness



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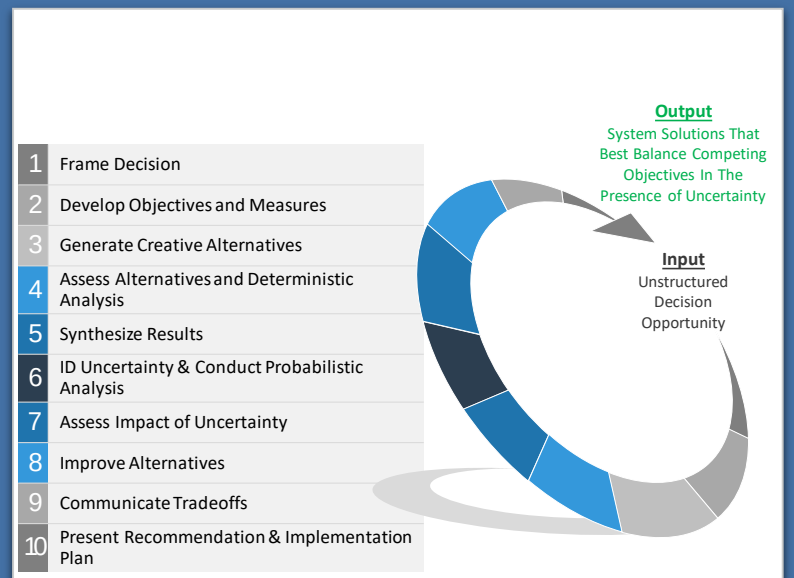
What We Heard Admiral Grady Say:

- "As Fleet Commander, **I am in the readiness business**."
- "I am not happy that **we lack analytically based integrated readiness assessment capability**, and I believe **that hampers our agility**."
- "We currently experience **too much friction** in both the force generation and resource allocation process supporting readiness"
- "**We need some fundamental changes in how we approach readiness**, how we generate it, analyze it, measure it, integrate it, articulate what we need, and predict what the return on our readiness investment might be."
- "Now I acknowledge that right now the word **readiness is somewhat ill defined**, but I am done letting that get in our way. We can't afford to wait around for someone else to tell us what that means."
- "Starting with a clean sheet, we will **derive a hierarchy of readiness** from the fleet level to the unit level."
- "**I want metrics** associated with every item on the mission essential task list."
- "This should help us answer the question: **Ready for What?**"



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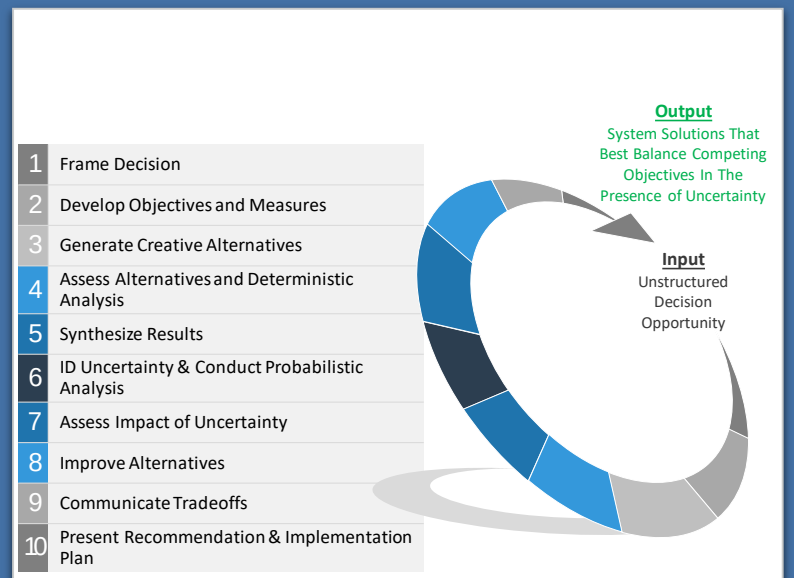
Key Features of a New Military Readiness Representation:

- **Open Standard Data:** The representation should use standard cross platform compatible data, and not require proprietary software to interpret. Additionally, the standard readiness data being reported must be stored in a common schema, allowing analysts to quickly wrangle the data for model development.
- **Actionable:** The representation should enable calculations involving the chance of readiness. Applications should be able to talk to each other, in that quantifiable results from one application can be easily incorporated into other analytical models, exercises, and war games.
- **Additive:** Using analytic tools, the arithmetic of chance becomes as simple as adding columns of data to get the readiness of combined units. Note that the columns capture the interdependencies between units. You probably can't do the required calculations in your head, or even with a calculator. They can, however, be done easily with a laptop and Excel, or Python, or R, or [insert your favorite computational platform here].
- **Auditable:** The representation should have an audit trail with provenance. Is the source of the data being used authoritative? If it isn't auditable, there may be no way to know.
- **Agnostic:** The representation should be available in numerous non-proprietary formats such as Excel, CSV, XML, etc. and be accessible across software platforms.



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Proposed Solution: Readiness Roll-Up

From Asset Readiness to Mission Readiness

- ***Column Representation of Readiness (CRR)***
  - ✓ ***Cures the Flaw of Averages (explained shortly)***
  - ✓ ***Enables Readiness Roll-Up***
  - ✓ ***Interactive***
- The discipline of probability management represents the readiness of a military asset as a vector of realizations. These vectors can be rolled up to model the readiness of multiple assets operating in an uncertain environment.
- The approach does not require specialized software. The Open SIPmath™ Standard from 501(c)(3) ProbabilityManagement.org allows simulations in any environment to be networked by communicating uncertainties as arrays of Monte Carlo realizations called Stochastic Information Packages (SIPs).
- The free SIPmath Modeler Tools create interactive simulations in native Excel which run 10,000 trials or more per keystroke. The models created by the tools do not require macros or add-ins to run so they can be shared with any Excel user.

The Flaw of Averages: Operation Eagle Claw

Situation: Iran, November 1979, the American Embassy was overrun by Iranian revolutionaries who took 52 Americans hostage. In April 1980 U.S. forces attempted a rescue codenamed OPERATION EAGLE CLAW. It ended in failure at Desert One due to helicopter failure.

Decision: How many helicopters to take on the mission knowing six were required to lift the rescue team and the hostages?

Objective: Take a sufficient number of helicopters to keep the risk of mission failure due to helicopter failure under given limit (e.g. 5%).

We need 6 helicopters.
Ao = 75%.
8*75% = 6
So send 8 just to be safe

The Good News: On Average you will have 6 helicopters

The Bad News: THERE IS ONLY A 68% CHANCE OF ACCOMPLISHING THE MISSION

Ready for Operation Eagle Claw

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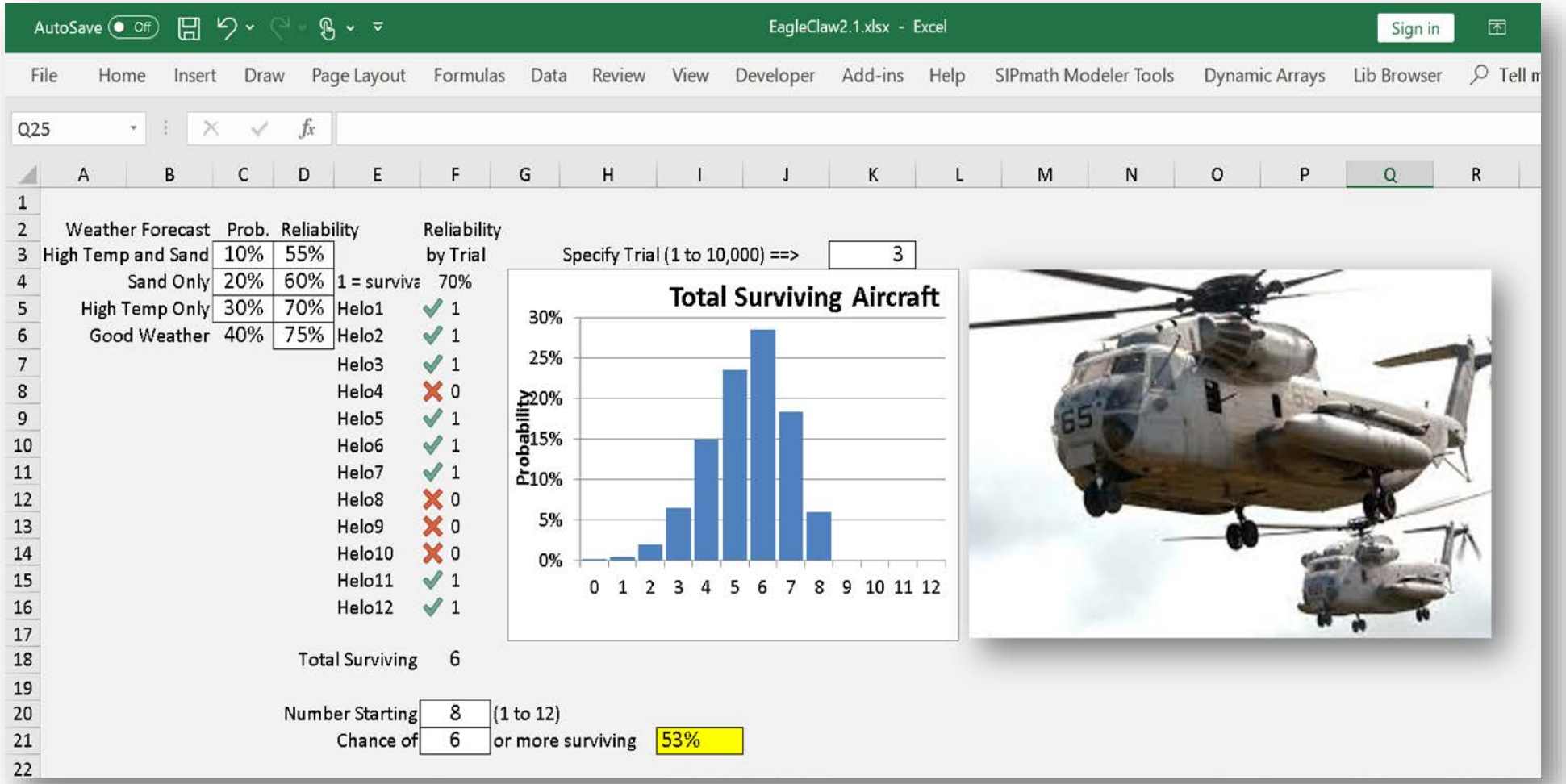

https://www.probabilitymanagement.org/s/EagleClawSimulation.xlsx

System-Level Readiness

SYSTEM-LEVEL DASHBOARD OF RELIABILITY, AVAILABILITY, AND MAINTAINABILITY

Sam Savage, Shaun Doheney & Connor McLemore

The data shown on this page is **FOR ILLUSTRATIVE PURPOSES ONLY**. This type of reliability, availability, maintainability, and cost data are available for many systems throughout the military. Access to data such as these enable robust modeling, simulation, and analysis associated with system-level readiness, which in turn can be used for myriad of tactical, operational, and even strategic-level readiness assessments. In this example, we use the current system operational availability (Ao) to generate a SIP library for tactical-level readiness assessments.

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Model created with the free SIPmath™ Tools from ProbabilityManagement.org

System ID: 123 **OBSERVED OPERATIONAL DATA**

Current System Operational Availability (Ao)	**65%**
Total Observed Time for System (in years)	**6.1**
Total Operating Distance of System (in miles)	**1095**

RELIABILITY

Time Between Failure (TBF) (in days)

MIN	AVG	MAX
13	**77**	186

Miles Between Failure (MBF) (in miles)

MIN	AVG	MAX
0	**73**	279

MAINTAINABILITY

Total Number of Corrective Maintenance (CM) Events	11
Total Down Time for CM (in days)	418

Down Time per CM Event (in days)

MIN	AVG	MAX
7	**38**	65

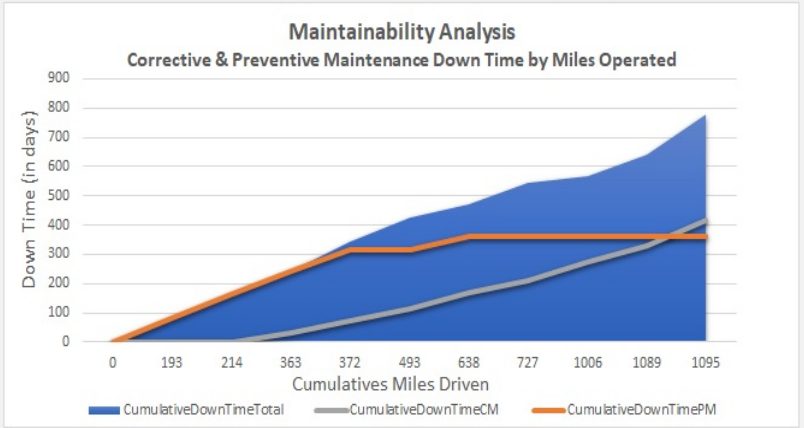
Total Number of Preventive Maintenance (PM) Events	11
Total Down Time for PM (in days)	360

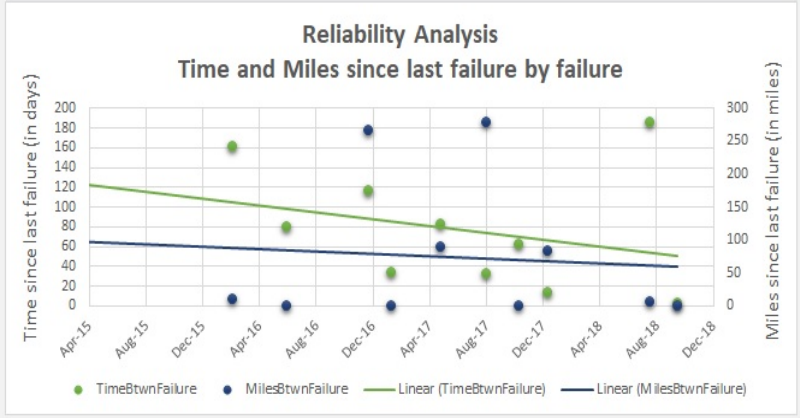
Down Time per PM Event (in days)

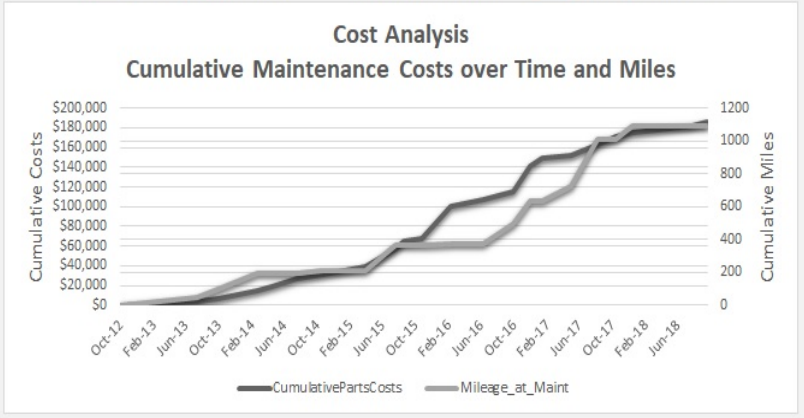
MIN	AVG	MAX
0	**33**	68

COSTS

Cumulative Cost of All Maintenance ($K)	$	187
Cumulative Cost of PM ($K)	$	59
Average Cost per PM Event ($K)	$	5.32
Cumulative Cost of CM ($K)	$	128
Average Cost per CM Event ($K)	$	12







Notional Data - For Illustrative Purposes Only

https://www.probabilitymanagement.org/s/Tank-Readiness-Model-1-21-19.xlsx

Column Readiness Representation (CRR)

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SIPmath Readiness Roll-up
Tank Model
Sam Savage, Shaun Doheney & Connor McLemore

The Tank Model makes use of the Stochastic Information Packet (SIP) Library representing each System's Operational Availability (Ao).

Given that system's Ao (based on notional, but realistic system-level data), we run 1,000 trials representing whether or not the system was available when it was needed and whether or not the system remained available throughout the mission it was needed for.

We can roll up this information for a set of systems (in this example, 14 Tank systems representing a Tank Company). The results of these 1,000 aggregated trials are run through the Data Table on the PMTable sheet. The first 25 trials are displayed in the interactive graphic on the right side of the screen.

This model allows users to calculate the chance of having a specific number of systems available for a mission and the chance of having a specific number of systems available throughout a mission.

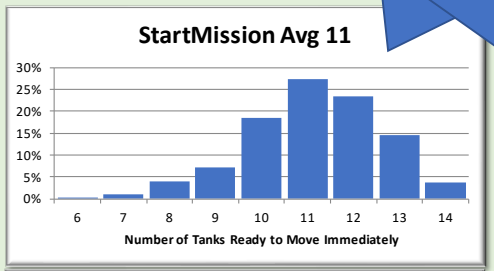
1. This model uses the system-level Operational Availability (Ao) data based on notional, but realistic system-level data captured for each specific system (see Background sheet).

2. Scroll through the 1,000 trials to see the number of systems that were available at the start of the mission and the number of systems that remained operational throughout the mission based on that system's Operational Availability (Ao).

4. See the histograms for the results of the 1,000 trials here. The first 25 trails are displayed in the interactive graphic on the right of the screen. The results of all 1,000 trials are listed on the PMTable sheet. These results can be further rolled up into the input SIP Library for other models.

ROLLED UP READINESS MODEL - TANK

Tank	Avg System Ao	Ready to Move Now	Remained Operational Throughout Mission
Tank123Ao	65%	0	0
Tank293Ao	75%	1	1
Tank357Ao	93%	1	1
Tank386Ao	85%	1	1
Tank417Ao	78%	1	0
Tank475Ao	90%	1	1
Tank529Ao	67%	0	0
Tank567Ao	82%	1	1
Tank661Ao	69%	1	1
Tank753Ao	92%	1	1
Tank765Ao	79%	1	1
Tank789Ao	89%	1	1
Tank873Ao	87%	1	1
Tank915Ao	63%	1	1
Total (for trial 180)	14	12	11
		86%	79%



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Generated with the SIPmath™ Modeler To

Index	StartMission	CompleteMission
Values	12	11
1	12	10
2	11	10
3	11	8
4	12	9
5	11	11
6	12	9
7	11	11
8	12	10
9	13	13
10	12	10
11	12	11
12	12	12
13	12	10
14	9	5
15	10	6
16	10	8
17	10	8
18	12	10
19	11	8
20	12	7
21	9	6
22	11	8
23	12	10
24	11	10
25	12	9

Scroll through Trial Numbers (1 to 1,000)	180		
Average number of Tanks available at start of mission	11	80%	(across all 1,000 trials)
Average number of Tanks remaining operational throughout mission	9	64%	(across all 1,000 trials)
The chance of	10		or more tanks ready to move now (ready at any moment)
The chance of	8		or more tanks remain operational throughout the mission

Model Created with the free SIPmath™ Modeler Tools
from www.ProbabilityManagement.org

87%
79%

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Notional Data - For Illustrative Purposes Only

3. Specify the minimum number of systems that are needed for the mission and see what the chance of those systems being available is and what the chance of those systems remaining available throughout the mission is (given the associated Operational Availability (Ao) of those systems).

https://www.probabilitymanagement.org/s/Tank-Readiness-Model-1-21-19.xlsx

Asset Readiness

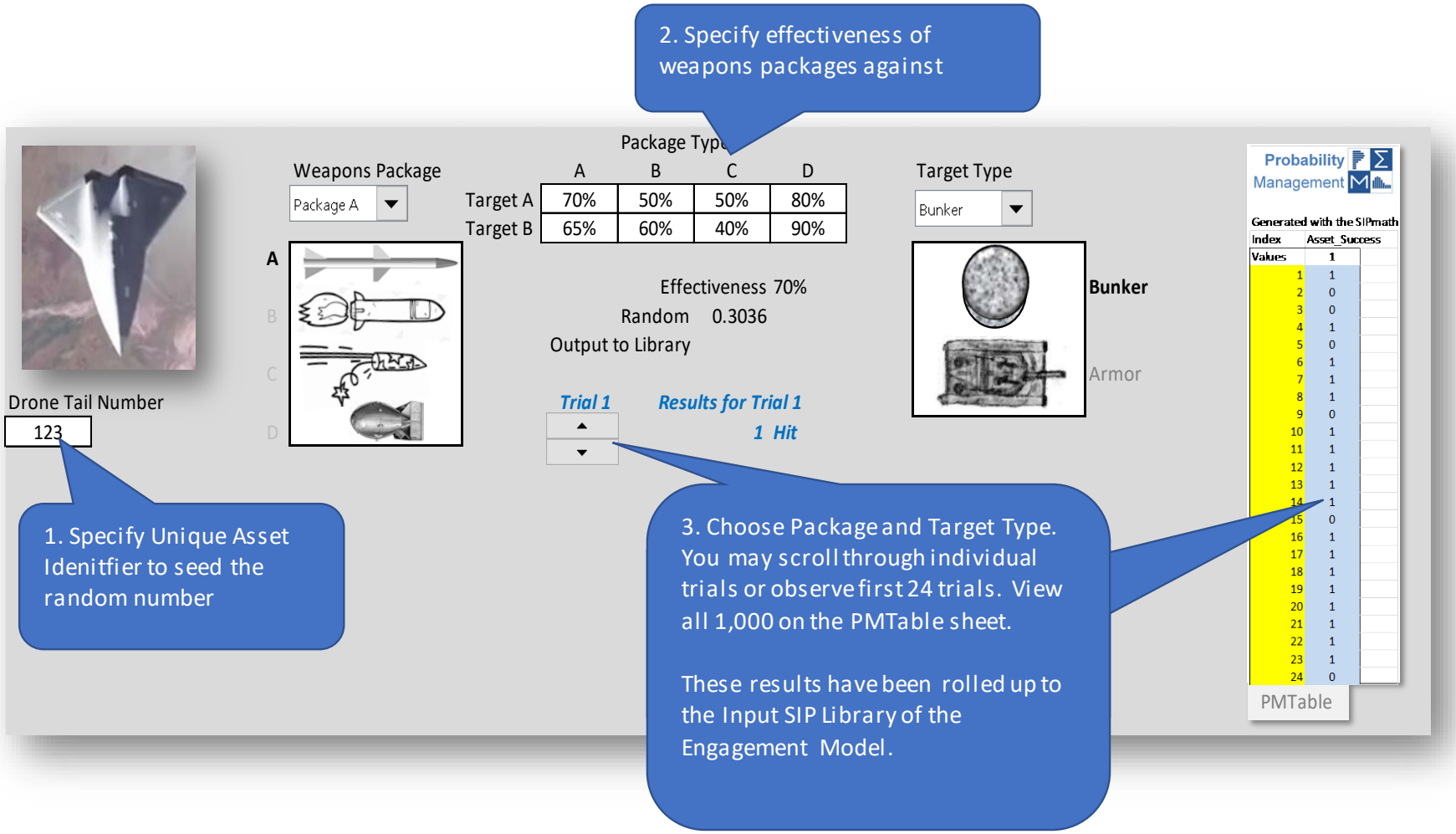
SIPmath Readiness Roll-up

Asset Model

Sam Savage, Shaun Doheney & Connor McLemore

The Asset Model lets you choose a Weapons Package and Target Type. It then runs 1,000 trials of Success or failure through the Data Table on the PMTable sheet. The first 24 trials are diplayed in the interactive graphic on right side of the screen.

This model has been run eight times, once for each Asset/Target combination. Each of the resulting SIPs has been rolled up to the Input SIP of



https://www.probabilitymanagement.org/s/Asset-Model-1-26-19.xlsx

Communication Network Readiness

2. Enter probability that Links will survive attack (assumes independence).

1. Specify network topology with connectivity matrix.

Link Survivability	All Drones Connected	Probability All Drones Connected
75%	No	48%

Com Links

FROM \ TO	A	B	C	D
F35	1	1	1	0
A		0	0	1
B			1	0
C				0

4. Scroll through 1,000 trials here

Trial 1

Drone	A	B	C	D
Connected	✗	✓	✓	✗
Chance	75%	88%	89%	57%

3. Read off chances that assets will be connected.

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Generated with the SIPmath™ Modeler Tools from

Index	All Connected	A Com	B Com	C
Values	0	0	1	1
1	0	0	1	1
2	1	1	1	1
3	1	1	1	1
4	0	0	0	0
5	0	0	1	1
6	1	1	1	1
7	1	1	1	1
8	1	1	1	1
9	1	1	1	1
10	1	1	1	1
11	0	0	1	1
12	0	0	1	1
13	1	1	1	1
14	1	1	1	1
15	1	1	1	1
16	1	1	1	1
17	0	1	1	1
18	1	1	1	1
19	0	1	0	0
20	0	1	0	0
21	0	0	1	1
22	1	1	1	1
23	0	1	1	1
24	0	1	0	1

PMTable

5. First 24 of 1,000 trials displayed here.

https://www.probabilitymanagement.org/s/Communications-Model-1-20-19.xlsx

Rolling Up Readiness from Multiple Models

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SIPmath Readiness Roll-up Suite

Sam Savage, Shaun Doheney
& Connor McLemore

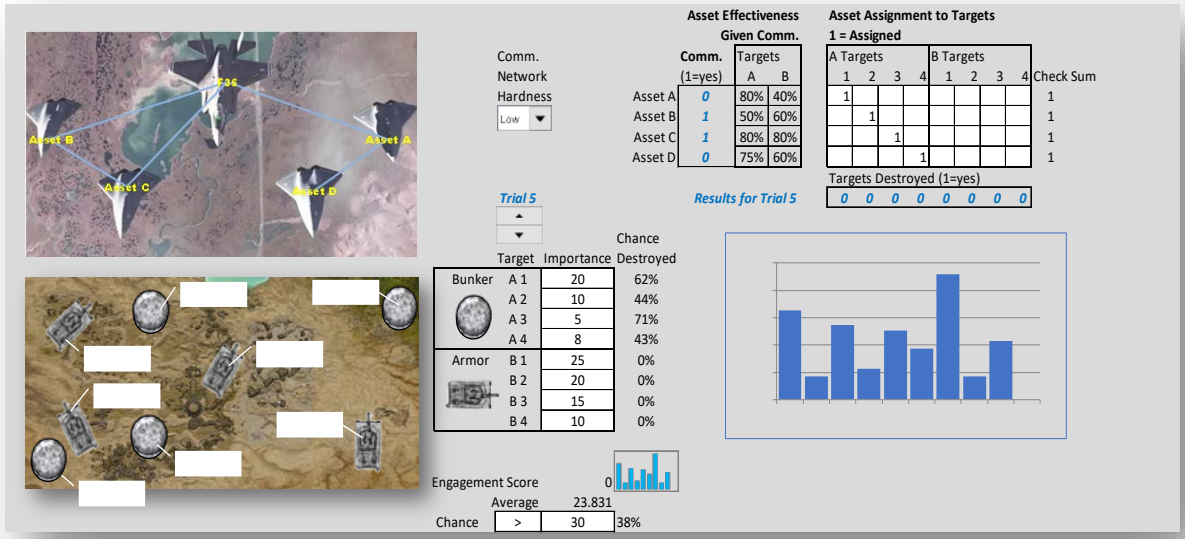
This suite of notional models demonstrates how SIP Libraries may roll up representations of readiness at multiple levels. Each model performs 1,000 Monte Carlo trials in native Excel using the Open SIPmath™ Standard.

At the lower level are an Asset model of effectiveness for individual assets, and a Communications model of the network that commands them from an escorting aircraft.

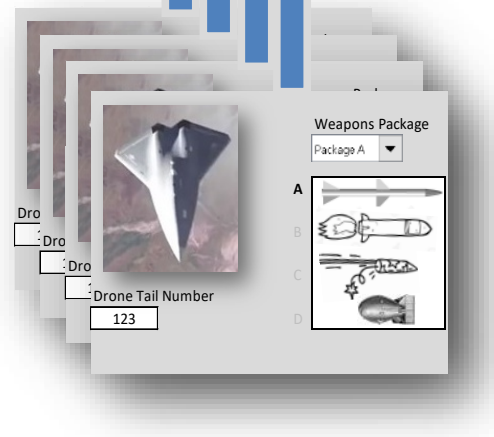
At the upper level, is an Engagement model based on a SIP Library of the outputs of the lower level models, which allows the user to make targeting decision` and immediately observe the chances of success.

The SIP (Stochastic Information Packet) represents uncertainties as arrays of realizations. The open SIPmath Standard from nonprofit ProbabilityManagement.org networks simulation results across platforms.

Engagement Model



Asset



Communication Network

https://www.probabilitymanagement.org/s/Engagement-Model-1-20-19.xlsx

Engagement Readiness

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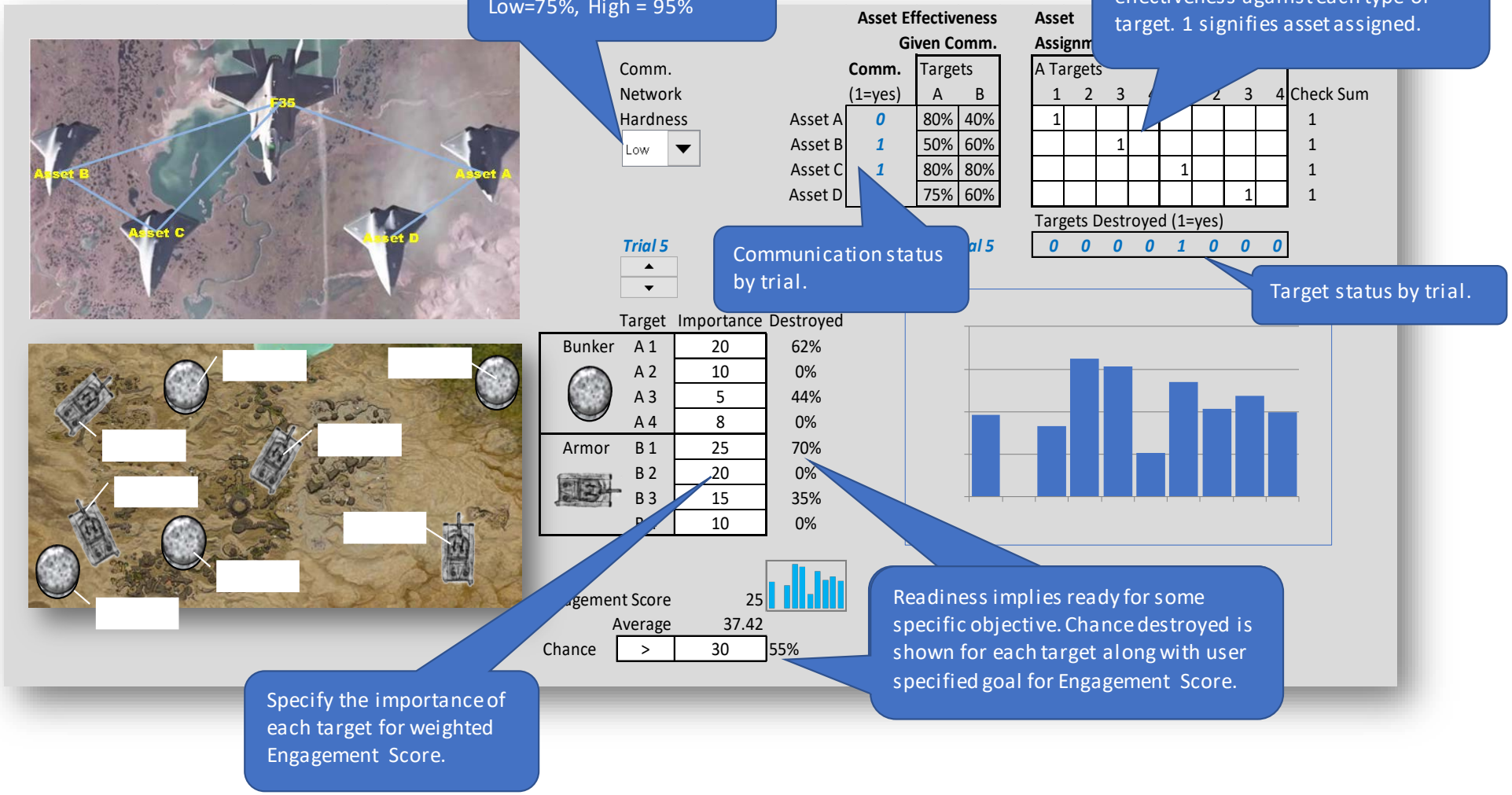
SIPmath Readiness Roll-up Engagement Model

Sam Savage, Shaun Doheney & Connor McLemore

This notional model demonstrates how SIP Libraries may be employed to roll up lower levels of operational readiness to higher levels for use by decision makers.

In this case, the operational readiness models of four assets are rolled up along with the operational readiness model of a communication network to the model of an engagement against specified targets.

The decision maker may assign assets to targets and immediately observe the results of a 1,000 trial simulation. In addition two levels of communication



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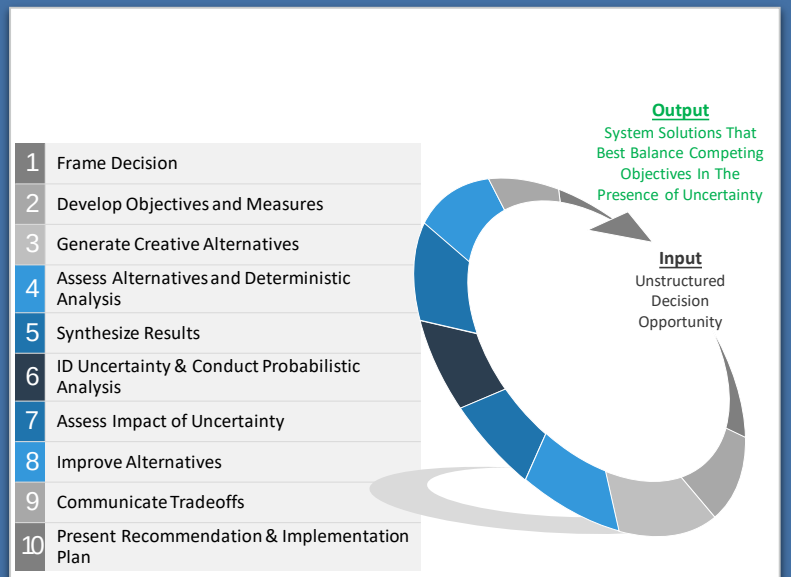

Column Representation of Readiness (CRR)

- ✓***Cures the Flaw of Averages***
- ✓***Enables Readiness Roll-Up***
- ✓***Interactive***

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Conclusion:

- Planners, commanders, and decision makers should speak the same language when describing “how ready for what” their units are.
- The readiness system should be able to aggregate the readiness of multiple units while accounting for chance.
- To do so, the military should consider adopting column representations of readiness that are additive, actionable, auditable, agnostic, and capable of accounting for chance.
- Column representations could provide the military a comprehensive understanding of readiness at all organizational levels, allowing for mathematically sound aggregation and true representation of how ready for each task units really are.
- By starting small and reinforcing success, adoption can grow organically at little cost.
- This approach would bring incremental value for measuring readiness in any military organization at which it was adopted.

We Encourage You to Download the Models To Discuss the Details

Please contact

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Probability Management

A nonprofit dedicated to rethinking uncertainty through education, best practices and our open SIPmath™ Standard and SIPmath Modeler Tools

For more information, visit www.ProbabilityManagement.org