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DATAWorks 2020:
A Validation Case Study:
The Environment Centric Weapons Analysis Facility (ECWAF)

Steven A. Rabinowitz, Project Leader

Elliot Bartis

February 2020

February 2020
Approved for Public Release.
IDA Document NS D-12081
Log: H 2020-000053

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4850 Mark Center Drive
Alexandria, Virginia 22311-1882

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About This Publication
This work was conducted by the Institute for Defense Analyses (IDA) under contract HQ0034-19-D-0001, Task No. BD-9-229932, "Undersea Warfare Systems (USW)," for the Office of the Director, Operational Test and Evaluation. The views, opinions, and findings should not be construed as representing the official position of either the Department of Defense or the sponsoring organization.

Acknowledgments
The IDA Technical Review Committee was chaired by Mr. Robert R. Soule and consisted of Robert Akins and Daniel Kim from the Operational Evaluation Division.

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Executive Summary

Reliable modeling and simulation (M&S) allows the undersea warfare community to understand torpedo performance in scenarios that could never be created in live testing, and do so for a fraction of the cost of an in-water test. The Navy hopes to use the Environment Centric Weapons Analysis Facility (ECWAF), a hardware-in-the-loop simulation, to predict torpedo effectiveness and supplement live operational testing.

In order to trust the model's results, the T&E community has applied rigorous statistical design of experiments techniques to both live and simulation testing. As part of ECWAF's two-phased validation approach, we ran the M&S experiment with the legacy torpedo and developed an empirical emulator of the ECWAF using logistic regression.

Comparing the emulator's predictions to actual outcomes from live test events supported the test design for the upgraded torpedo. This talk reviews the ECWAF's validation strategy, the decisions that have put the ECWAF on a promising path, and the metrics used to quantify uncertainty.

A Validation Case Study: The Environment Centric Weapons Analysis Facility (ECWAF)

Elliot A. J. Bartis

Steven A. Rabinowitz, *Project Leader*

8 April 2020

Institute for Defense Analyses

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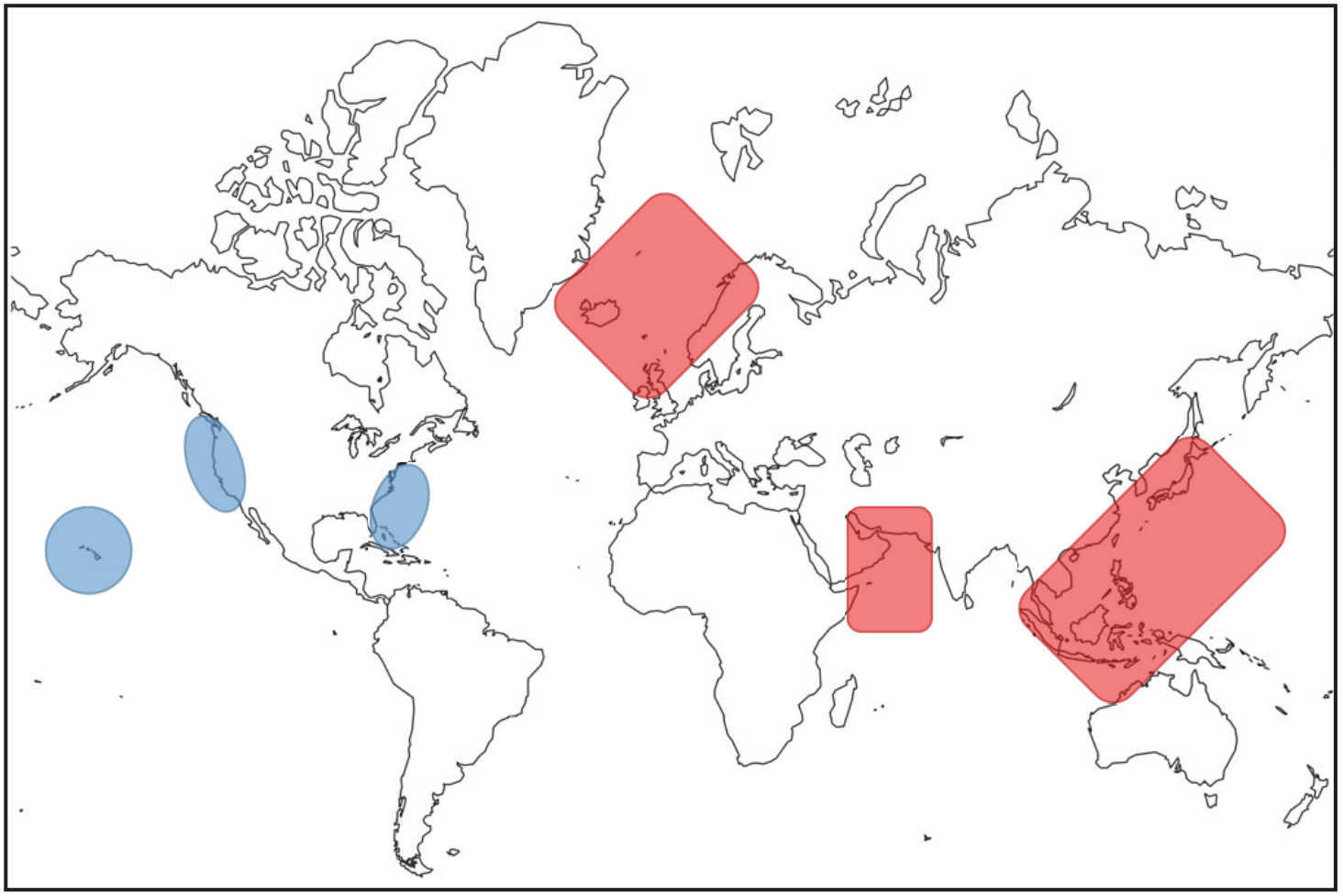
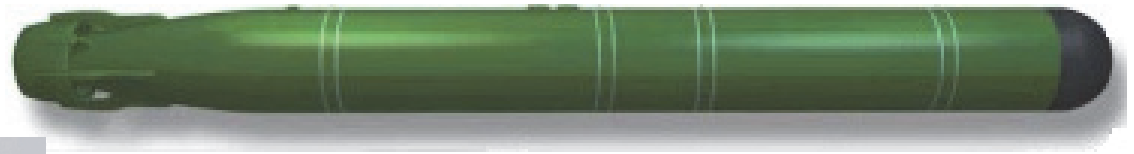
Reliable M&S can efficiently provide DoD with new insights into how to prepare for war.



In 2019, IDA published the “Handbook on Statistical Design and Analysis Techniques for Modeling & Simulation Validation

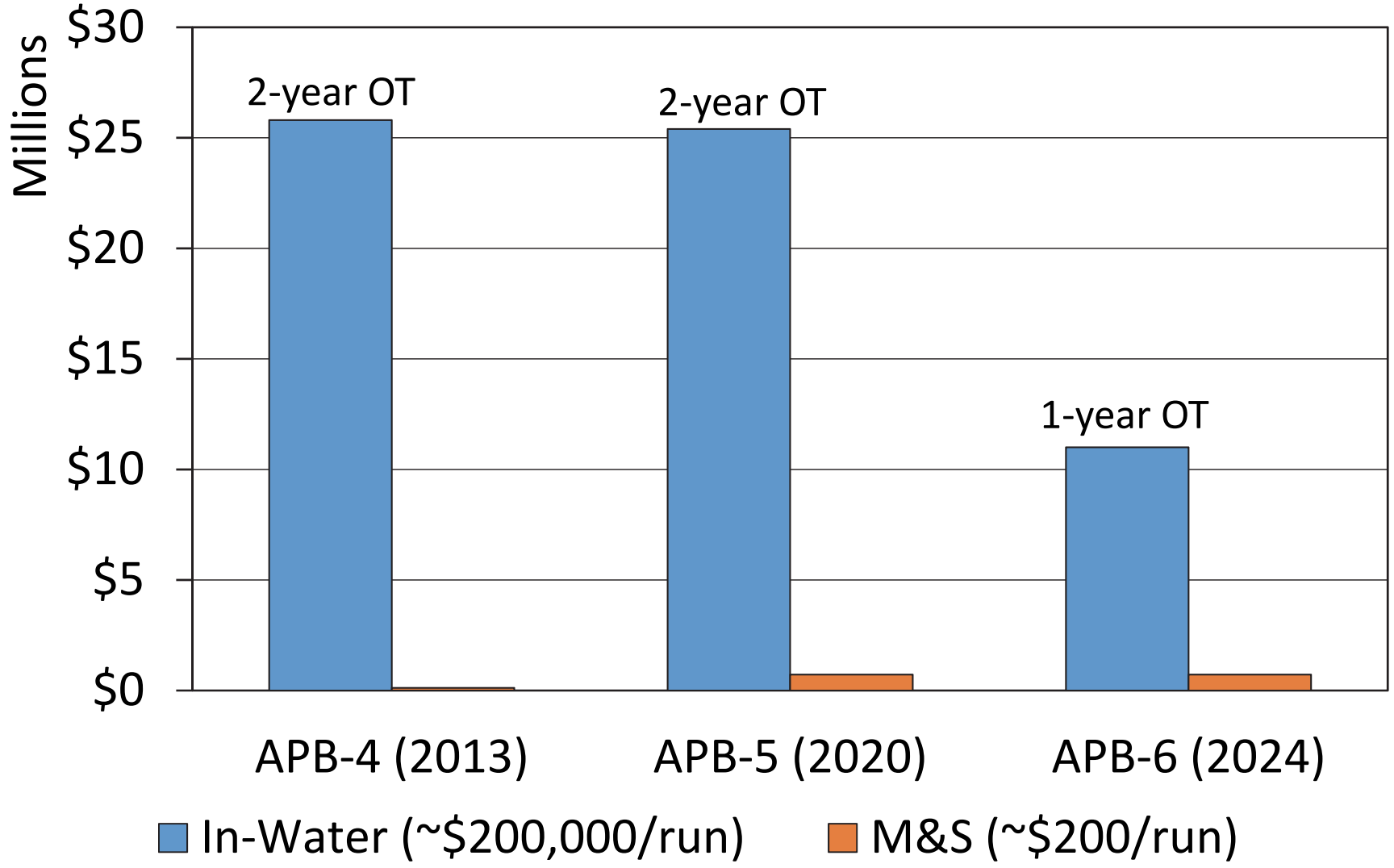


https://www.Raytheon.com

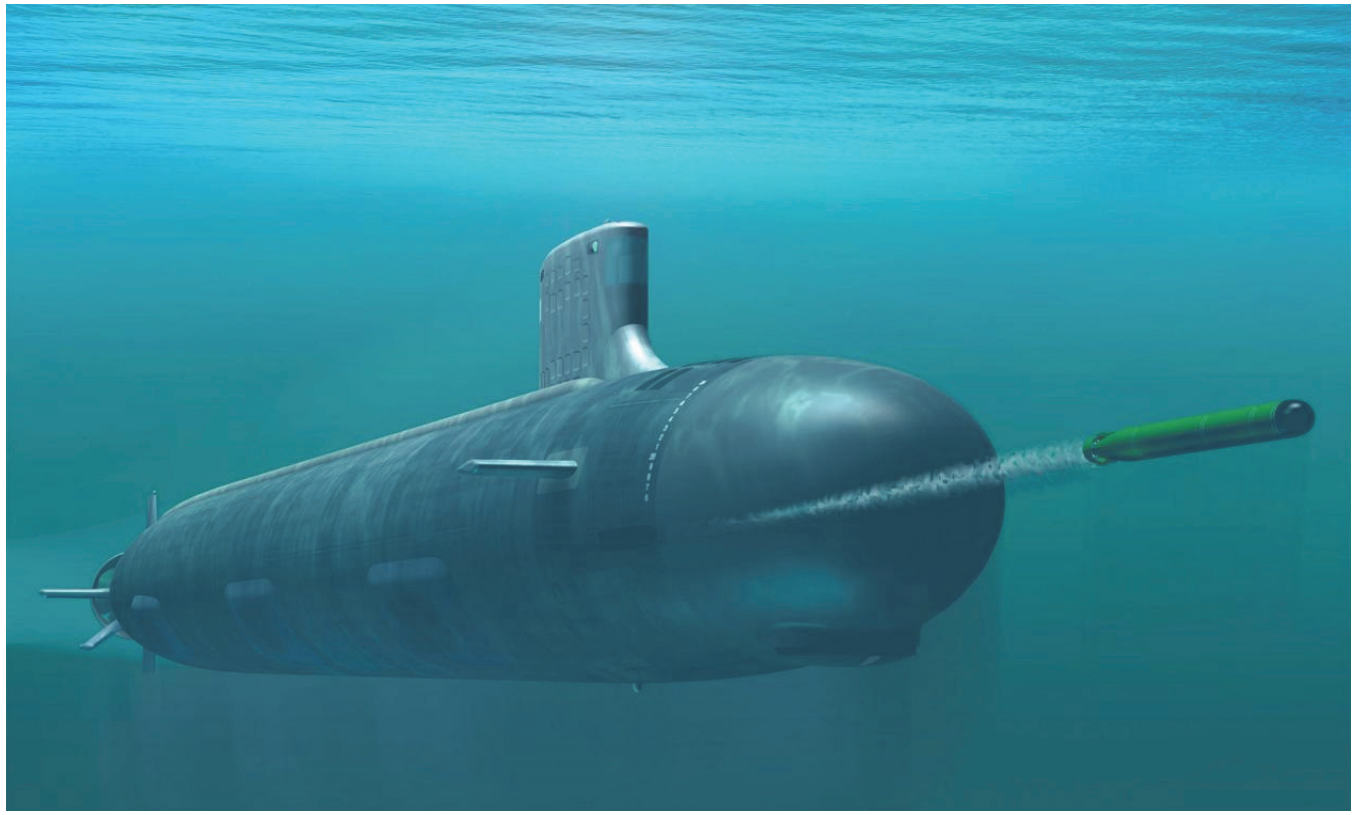
https://www.army.mil

https://news.usni.org

If we can validate the ECWAF, we can efficiently learn more about torpedo performance than ever before



The submarine's primary weapon is the torpedo, but testing torpedoes, like all weapons, is difficult

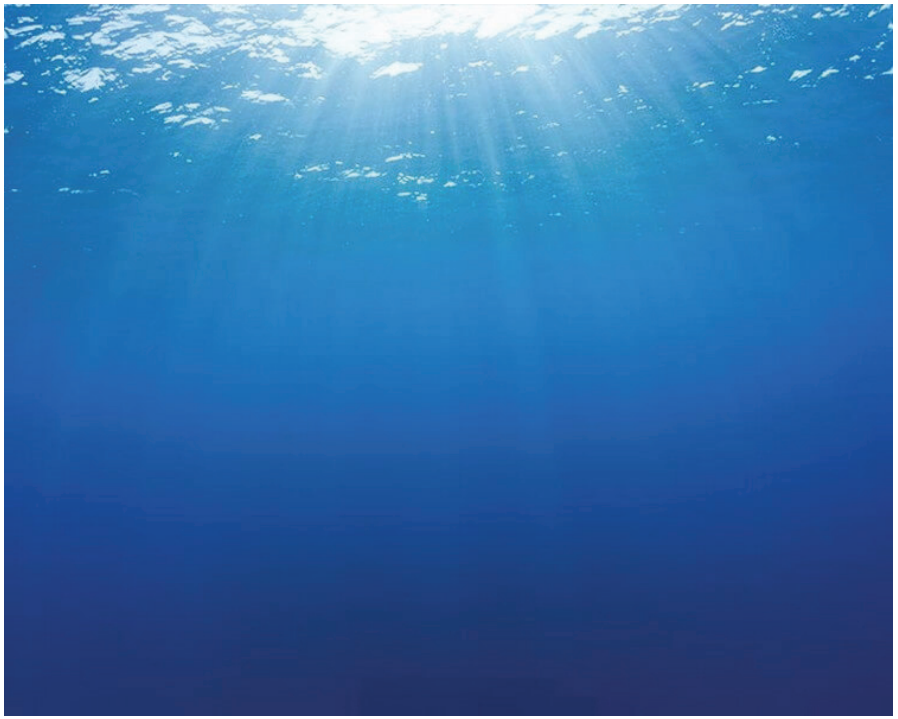


Actual torpedo hardware links to a computer-generated simulation that models undersea scenarios

Environmental factors impact torpedo performance and are hard to model

Rocky Littorals

Open Ocean



Why has the ECWAF Verification, Validation, & Accreditation (VV&A) process been successful?

1. Strong Navy and OSD investment in ECWAF development and VV&A
2. Early DOT&E/IDA involvement
3. Enough in-water data exists
4. Frequent working-level meetings and open lines of communication between stakeholders
5. ECWAF and torpedo developers work side-by-side at the Naval Undersea Warfare Center (NUWC)
6. Clear intended uses

The T&E community uses torpedo effectiveness (T_{EFF}) to describe performance.

T_{EFF} is a function, not a single number.

$$T_{EFF} = \beta_1(Target\ Type) + \beta_2(Evasion\ Tactic) + \ldots$$

Our goal is to develop the T_{EFF} function.

The five intended uses for the ECWAF take a crawl-walk-run approach.

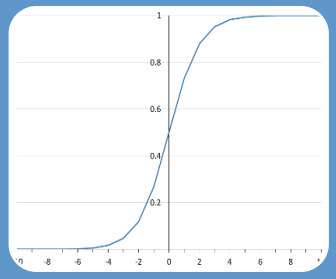
1. Use the ECWAF predictions to run side-by-side comparisons of torpedo variants.
2. Act as a “Super SME” to scope future torpedo testing.
3. Understand trends we see in-water.
4. Understand trends we cannot observe in-water (threat environments and targets, without safety rules).
5. Use the ECWAF to predict T_{EFF} and evaluate system performance.

A machine learning approach can validate the ECWAF in the general case, rather than only specific cases

ECWAF runs

Designed experiment

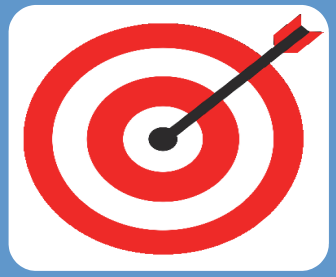
Results are hits and misses



Predictive emulator

Logistic regression

Result is a probability of hit

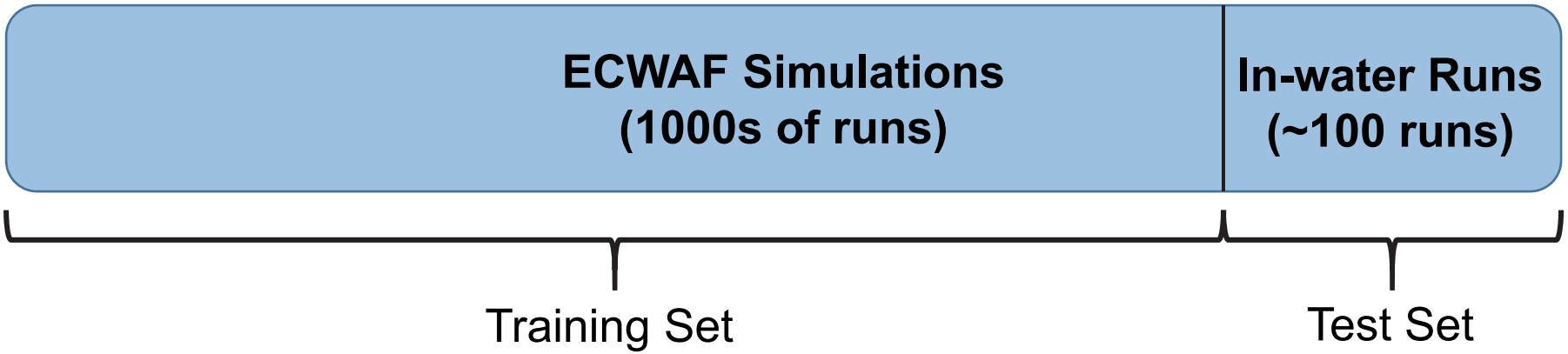


Live conditions as emulator inputs

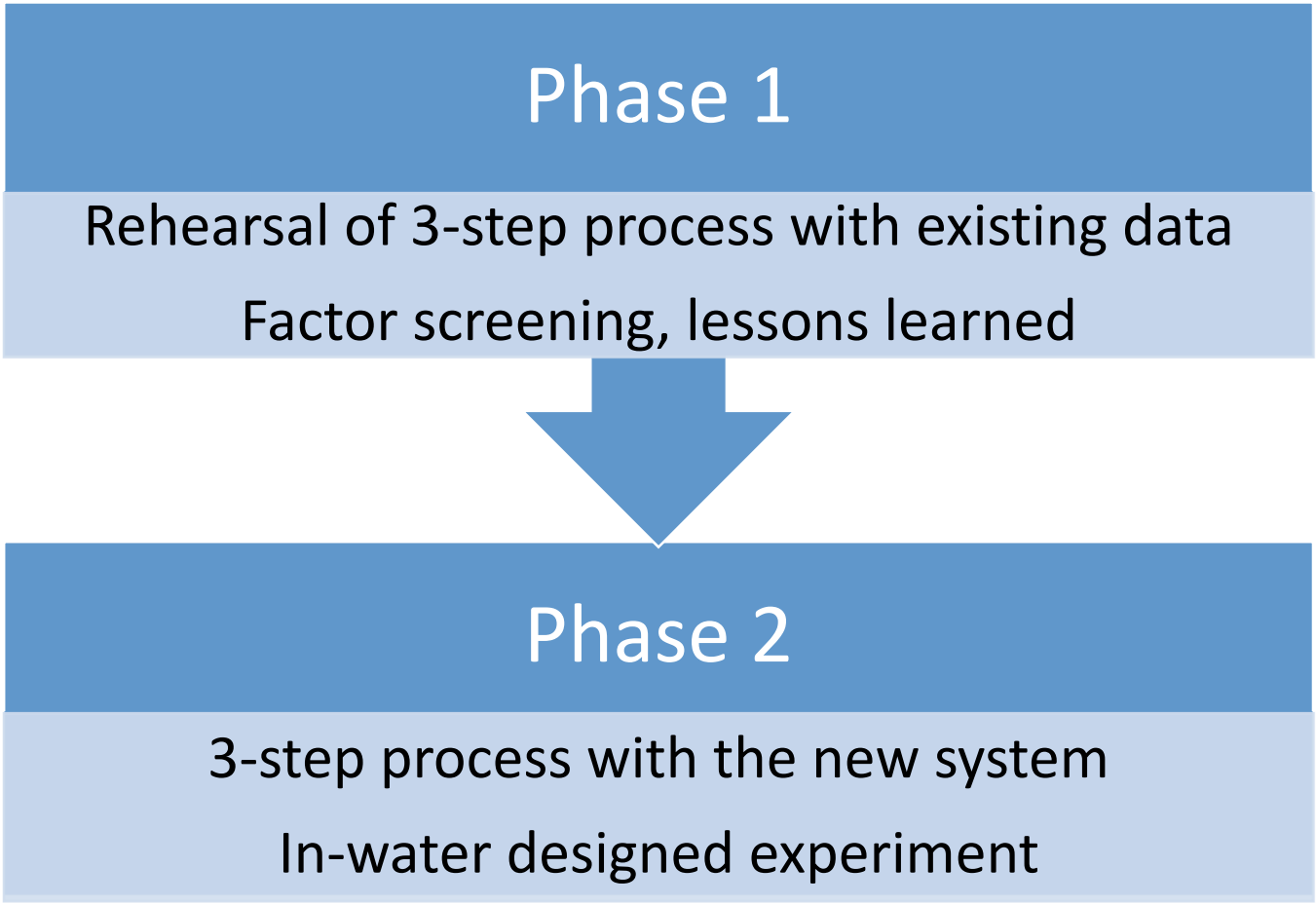
Compare predictions with actual results

Validation metrics and statistical tests

The metamodel is a statistical emulator of the ECWAF, which is tested on in-water data.



A two-phased VV&A reduces risk and allows for an opportunity to learn.



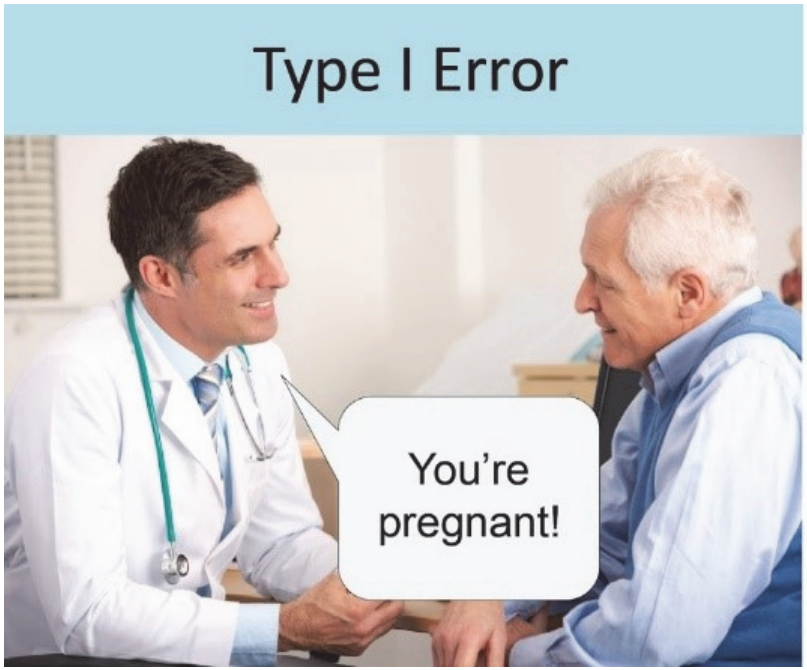
Important Outcomes	Important Factors
Hit/Miss	Evasion Tactic
False Alarm Rates	Target Type
Acquisition Range	Crew Targeting Errors
Detection Range	Environment
And many more…	Any many more…

Many metrics can quantify statistical risk

Accuracy: How often is a prediction correct?

Specificity: How often is a miss predicted correctly?

Sensitivity: How often is a hit predicted correctly?

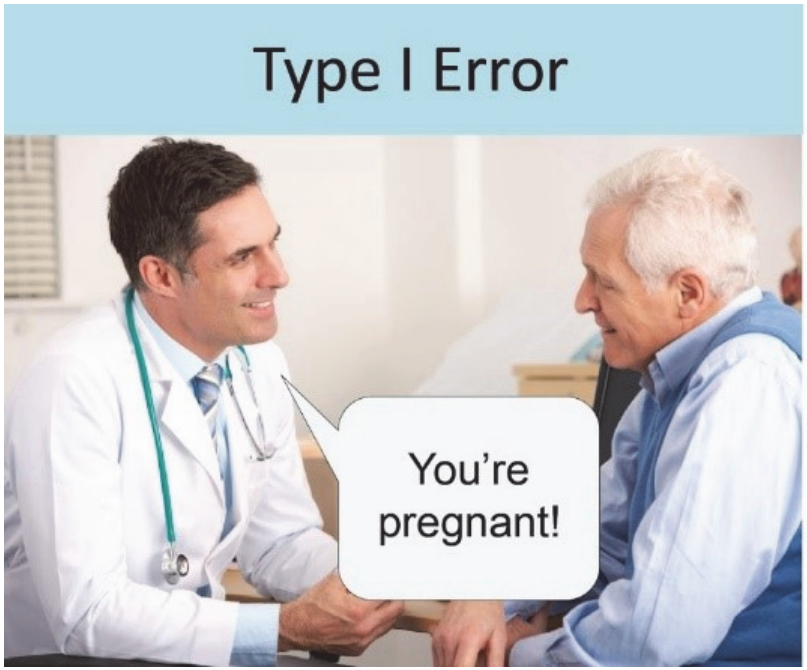


Phase 1 results were promising, with limitations

Accuracy: How often is a prediction correct? 71%

Specificity: How often is a miss predicted correctly? 32%

Sensitivity: How often is a hit predicted correctly? 83%



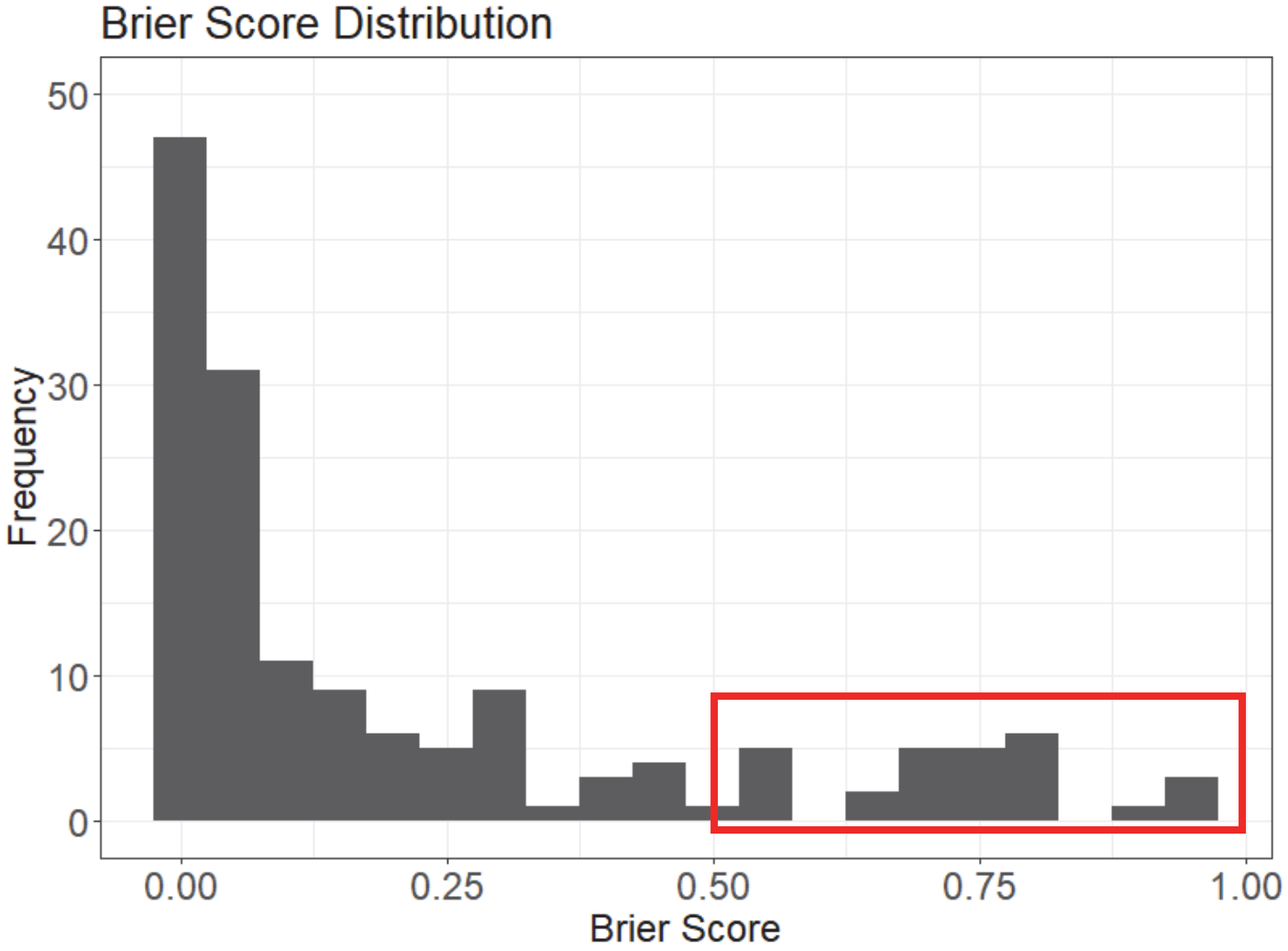
Which weather forecast do you trust?

The Brier Score measures the accuracy of probabilistic predictions and rewards closer predictions

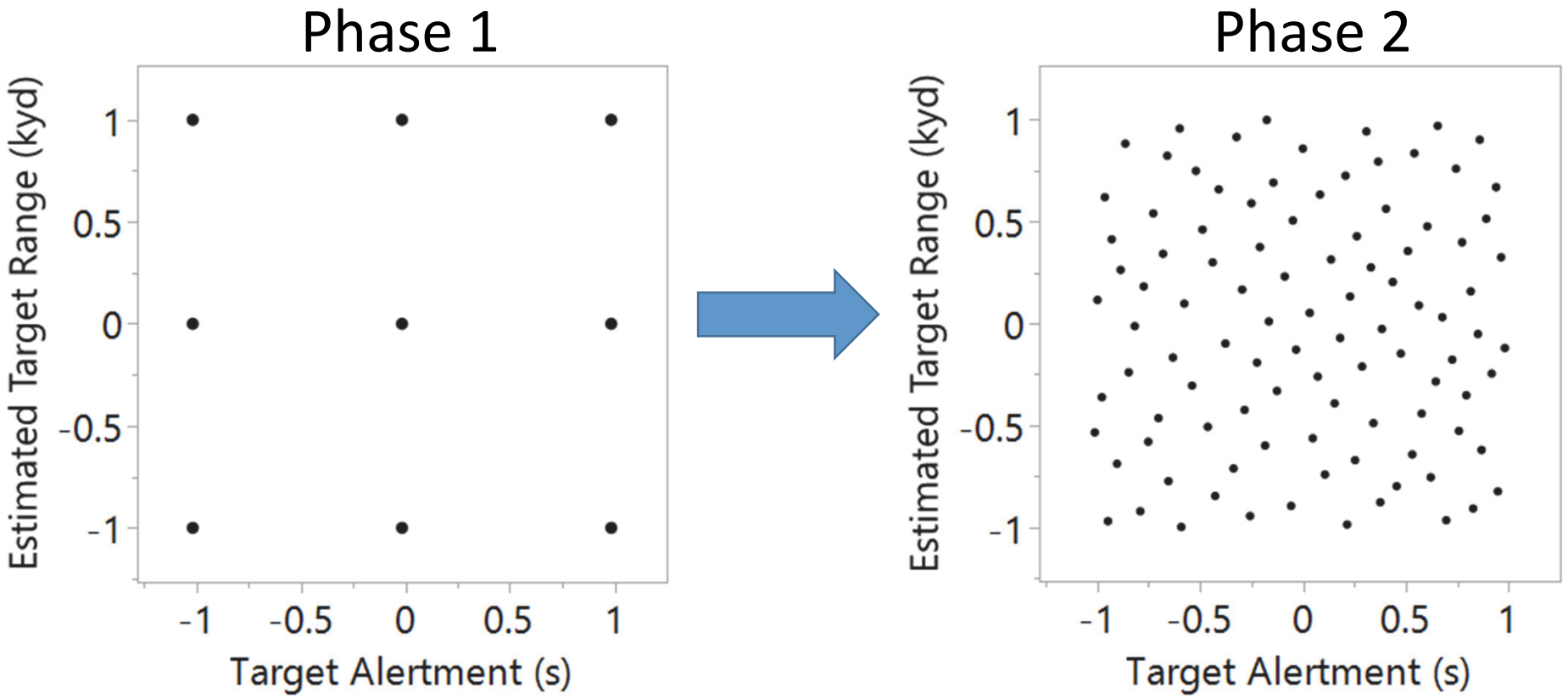
	ECWAF T_{EFF}	In-Water Outcome	Brier Score
Scenario A	0.5	1	$(0.5 - 1)^2 = 0.25$
Scenario B	0.9	1	$(0.9 - 1)^2 = 0.01$

The median Brier Score for Phase 1 was 0.07.

The ECWAF's incorrect predictions were not clustered in a particular area, supporting a data-driven decision to go to Phase 2



Factor screening in Phase 1 allowed us to shift to a space-filling design



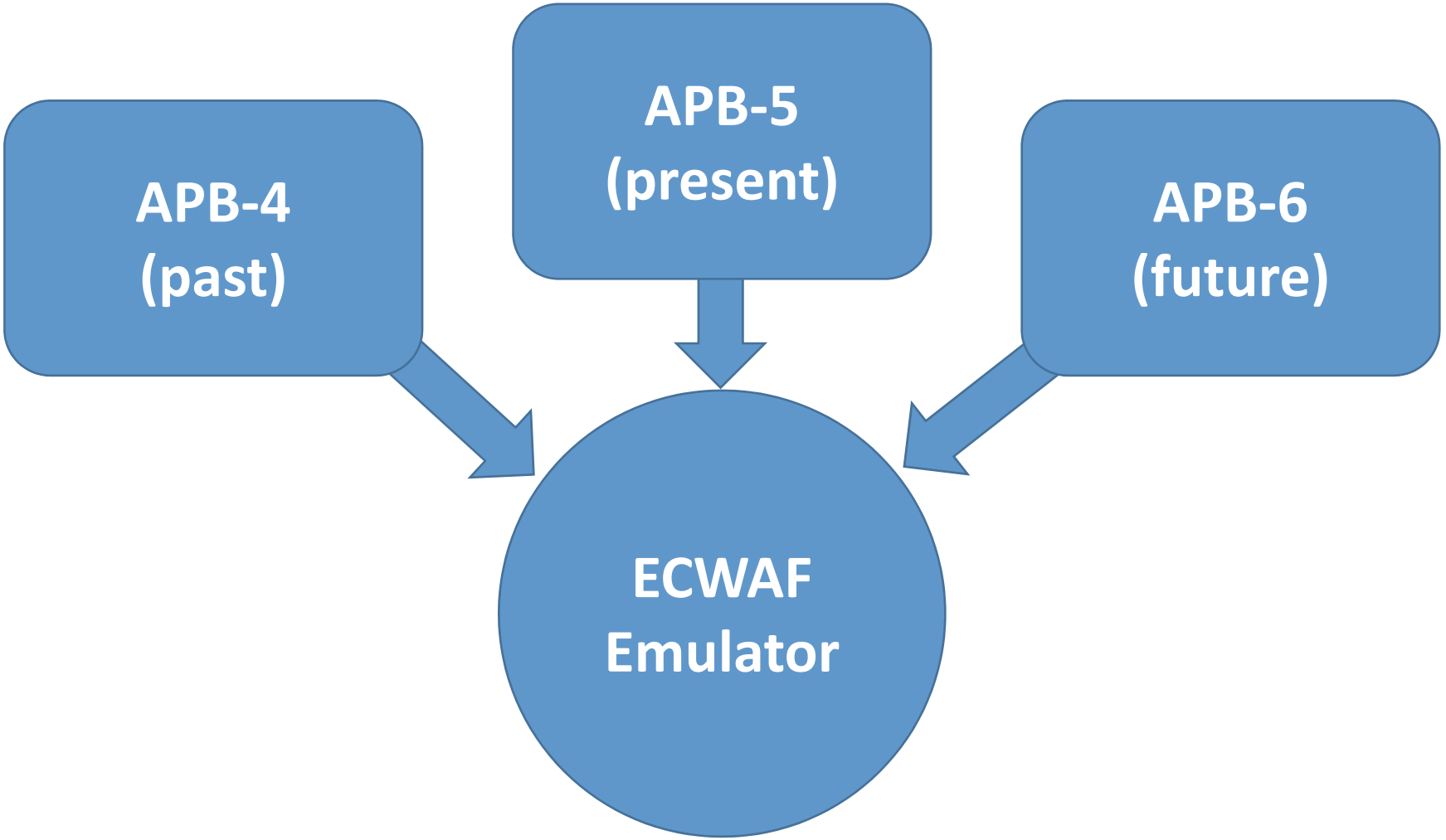
Phase 2 consists of three designs: one for deep water, one for shallow water, and one for threats.

400 deep water simulations

1,260 shallow water simulations

140 excursions with threat models in threat environments

The ECWAF emulator will evolve and constantly improve as more in-water and M&S data are available.



REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS**.

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
04-2020	IDA Publication	N/A

4. TITLE ANDSUBTITLE

DATAWorks 2020: A Validation Case Study: The Environment Centric Weapons Analysis Facility (ECWAF)

5a. CONTRACT NUMBER
HQ0034-19-D-0001

5b. GRANT NUMBER
____ ____ ____

5c. PROGRAM ELEMENT NUMBER
____ ____ ____

6. AUTHOR(S)

Elliot AJ. Bartis (OED); Steven A. Rabinowitz (OED);

5d. PROJECT NUMBER
BD-09-2299

5e. TASK NUMBER
2299(32)

5f. WORK UNIT NUMBER
____ ____ ____

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Institute for Defense Analyses
4850 Mark Center Drive
Alexandria, Virginia 22311-1882

8. PERFORMING ORGANIZATION REPORT NUMBER

NS D-12081
H 2020-000053

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Institute for Defense Analyses

4850 Mark Center Drive
Alexandria, VA 22311

10. SPONSOR/MONITOR'S ACRONYM(S)
IDA

11. SPONSOR/MONITOR'S REPORT NUMBER
____ ____ ____

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for Public Release. Distribution Unlimited.

13. SUPPLEMENTARY NOTES
Steven Rabinowitz, Project Leader

14. ABSTRACT

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15. SUBJECT TERMS
Modeling and Simulation (M&S) Validation; Torpedoes; and Undersea Warfare

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			Steven Rabinowitz (OED)
Unclassified	Unclassified	Unclassified	Unlimited	31	**19b. TELEPHONE NUMBER** *(include area code)* (703) 845-6971