

## Metrology and Calibration (METCAL) Overview



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"When you can measure what you are speaking about and express it in numbers, you know something about it; and when you cannot measure it, you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind. It may be the beginning of knowledge, but you are scarcely in your thought advanced to the stage of a science."

Lord Kelvin

# You don't know anything about anything unless you can measure it.



# **Overview**



- NSWC Corona Background
- Why Calibrate?
- Metrology and Calibration Program
- Measurement Reliability
- Measurement-Related Standards
- Conclusion



**NSWC Corona Mission** 



## To serve as the Navy's <u>independent assessment agent</u> throughout the lifecycle:

### "To gauge the warfighting capability of ships and aircraft, from unit to battlegroup level, by assessing the suitability of design, the performance of equipment and weapons, and the adequacy of training."

Ref: OPNAVNOTE 5450



#### <u>MISSION</u>

Operate the Navy's full spectrum research, development, test and evaluation, engineering and fleet support Center for ship hull, mechanical and electrical systems, surface ship combat systems, coastal warfare systems, and other offensive and defensive systems associated with surface warfare.

Reference: OPNAVNOTE 5450 Ser 09B22/1U510577 of 23 Dec 1991

**SHIPS AND** 

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Division

NAVSSES,

Philadelphia

# **Navy Organization**





### **NSWC Corona Division**







## **Measurement Science**



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Definitions



### *Metrology:* The Science of Measurement

### **Calibration:**

VIM: Set of operations that establish, under specified conditions, the relationship between values of quantities indicated by a measuring instrument or measuring system, or values represented by a material measure or a reference material, and the corresponding values realized by standards.

Navy: Calibration is the comparison of a measurement system or device of unverified accuracy, to a measurement system or device of known or greater accuracy, to detect and correct any variation from required performance specifications.



## **Measurement Possibilities**



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Not Precise/ Not Accurate

Precise / Not Accurate Precise / Accurate



- Ensure the readiness of test equipment to perform accurate measurements and provide valid data
- Limit the number of erroneous test decisions
- Maintain overall measurement integrity and traceability





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- How do we know the data is good?
  - Accurate? Precise? Stable?
  - Can you trust the person collecting the data?
  - Can you trust the measurement instrument?
  - What proof do you have that the numbers reflect reality?
- Can you trust the decision you are about to make using the collected data?
- What is the cost if you are wrong?





## **Uniform Measurement Accuracies**













## NSWC Corona serves as the

### Scientific and Technical Agent for the Navy Metrology and Calibration (METCAL) Program

per

OPNAVINST 3960.16A, Navy Test and Monitoring Systems (TAMS)

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METCAL Executive Director						
TAMS Executive Board						
NA	VSEA	NAVAIR		USMC		
TMDE		METC	AL			
SISCAL	NPSL					

#### Shore Calibration Laboratories

#### Afloat Calibration Laboratories



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METCAL Processes and Products





#### **Mission**

Ensure that TMDE used to make measurements on Navy Systems is accurate and traceable to National Standards to reduce or eliminate the safety and cost impacts of wrong test decisions.



# **METCAL Products and Services**















**TECH ASSISTS** 



PROCEDURES/ TECH PUBS

# Metrology Engineering Products and Services















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## **METCAL Program Scope**







## Measurement Traceability







# METCAL Acquisition Life Cycle



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$\mathbf{A}$	B		Â	7 I	ос		
Concept & Technology Development		System Develop & Demonstrati	ment ion	Production & Deploy	/ment	Operatio	nal Support
<ul> <li>Metrology Guidance/ Consideration</li> <li>International/ National Measurement Technology Assessment</li> </ul>	<ul> <li>Requirements Analyses</li> <li>ILSMT</li> <li>LSA</li> <li>Logistics Document Reviews</li> <li>CMRS Guidance</li> <li>Metrology R&amp;D</li> <li>Evaluation Criteria</li> </ul>	<ul> <li>Verify Contractor Traceability</li> <li>Technology Validation</li> <li>CMRS Development</li> <li>CSP Development</li> <li>TEMP Inputs</li> </ul>	<ul> <li>SERD</li> <li>CMRS Review, Approval</li> <li>Calibration Support Plan Approval</li> <li>Cal Standard Design Develop, Procurement</li> <li>Evaluation Criteria</li> <li>Cal Procedure Development, Approval (Contractor, DoD)</li> <li>Tech, Mgt, Pol. Docs</li> <li>Facility (Incl Environ Requirements</li> <li>Training Requirements</li> <li>Manpower, Workload Requirements</li> <li>Interval Analyses</li> </ul>	<ul> <li>Contractor's Calibration System Evaluation (Follow-on)</li> <li>Calibration Std ILS</li> <li>Deploy Calibration Support</li> <li>Establish Cal Support Level</li> </ul>	• TMDE • Feedl Respo • Techr Traini • Joint Supp • Modif Plann	E Calibration back onses hical/Engrg/ ing Assists Service ort fication/Rqmt ing	<ul> <li>Interval Reliability Analysis</li> <li>Measure Process Control</li> </ul>





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Provide Advanced Measurement Technology for Emerging Weapons Systems / Improve Effectiveness and Efficiency of Existing Measurement Systems





## Joint Service Metrology





#### Joint Chiefs – Joint Logistics Commanders



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# Industry/Professional Involvement

SCIENCE -

WARFARE CENTERS

#### **Represents the Navy in the Measurement Science Field**



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False Accept/False Reject





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 A Test Instrument is considered <u>In Tolerance</u> if it passes all the steps of an Instrument Calibration Procedure (ICP)



]	PROC. NO. NA 17-20AQ-356		MFR	MODEL		SER. NO.		
_	PROCEDURE			MEASURE	D VALUES	OUT		
	STEP	FUNCTION TESTED	NOMINAL	FIRST RUN	SECOND RUN	OF	CALIBRATION TOLERANCES	
	NO					TOL		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	
	4.1.7	TI Range (V)	(V)				(V)	
	× <sup>30</sup>	1 V	1.000000				0.999953 to 1.000047	
	70	10 V	10.00000				9.99960 to 10.00040	
	> 22	10 V	-10.00000				-9.99960 to -10.00040	





### A Unit Under Test (UUT) is truly in tolerance if:

### Lower Tolerance Limit < UUT Bias < Upper Tolerance Limit



#### The UUT Bias is unknown



**True Out Of Tolerance** 



### A Unit Under Test (UUT) is truly out of tolerance if:





#### The UUT Bias is unknown





### A Unit Under Test (UUT) is observed in tolerance if:

### Lower Tolerance Limit < Deviation < Upper Tolerance Limit



#### The Deviation is the observed difference between the UUT and the CAL



#### False Accept (FA):

- The Deviation is observed in tolerance [-L < Deviation < L]</li>
- The UUT Bias is out of tolerance [Bias > L or Bias < -L]</li>
- The decision to accept the UUT is incorrect



# Measurement Reliability



- <u>Measurement Reliability</u> is the probability of being in tolerance (the probability all the calibration procedure steps pass).
- Measurement Reliability decreases with time after calibration (which is why we calibrate periodically).



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Calibration Intervals And Test Decisions



- Good test decisions:
  - Detect bad items and repair or replace them
  - Verify good items and return them to the Fleet
- Good test decisions require accurate test equipment
- Accuracy in test equipment is maintained by periodic calibration
  - TMDE accuracy, or measurement uncertainty degrades with time
  - TMDE "Out of Tolerance" (OOT) not obvious to user *insidious error*
  - TMDE OOT can only be determined by calibration
  - Periodic calibration keeps measurement uncertainty at acceptable levels
- Accurate calibration intervals keep false accept risk (acceptance of bad test equipment) low



# **Calibration Intervals**



- To obtain a Calibration Interval, you need:
  - A Measurement Reliability Curve (Estimated using Calibration Results)
  - A Measurement Reliability Target







## 7.6 Control of monitoring and measuring devices

- Requires organization to assess/understand measurement needs
- Requires that measuring equipment
  - be accurate to ensure product conformity to specification
  - be calibrated or verified at specified intervals, or prior to use, against measurement standards traceable to international or national measurement standards



Z540-1 Withdrawal



### Test & Measurement Equipment/Cal Lab Accreditation



#### Z540.1 is replaced by Z540.3 and 17025



9001, 17025, & Z540.3 Relationship



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**Roles of New Standards** 

- Able to operate a management system
- Are technically competent
- Able to generate technically valid results

## • ANSI/NCSL Z540.3

**ANSI/ISO/IEC 17025**:

- Technical requirements for calibration of M&TE
- System for control of the accuracy of M&TE:
  - Calibration system performance requirements
  - Calibration laboratory performance requirements
  - Link to use of 17025 accredited cal labs
- ISO 17025 accredited cal lab "smart customer"

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Laboratory

Competence Requirements

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Program Requirements





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# **Calibration Program Functions**



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- **Calibration Requirements** 
  - Determination, Assessment
- Calibration Procedure ۲
  - Development, Review, Approval
- TMDE/Calibration Standards
  - **Inventory Control**
  - Reliability, Interval Assessment
  - Specification, Evaluation, and Management
- Calibration Laboratory ۲
  - Facility/Technical/Management Requirements
  - Assessment (Accreditation)
- **Calibration Data** •
  - Collection, Management, Assessment
- Training ۲
  - Development / Assessment
- **Technical Support** .
- **Professional Society Involvement** ۲



**Repair parts** 

Training

**Repair procedures** 

So, Why Calibrate?



#### Test, Measurement, and Diagnostic Equipment Must Be ... Must Be ... Compatible Supportable ICPs Standards Corron fit-function - Traceability

Prevent unauthorized substitution

Ensure adequate support

To operate and maintain safe and reliable systems

Repeatability

Allowances

Inventories

Documentation

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