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CENTER OF EXCELLENCE
for Aerospace and Advanced Manufacturing





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NIST GRANT FINAL REPORT

CENTER OF EXCELLENCE
for Aerospace and Advanced Manufacturing

Welcome to Washington State's Centers of Excellence

Our Mission: We serve as statewide liaisons to business, industry, and the educational system, providing support for economic development by representing the driver industries in the state.

Represented Industries:

- Aerospace and Advanced Manufacturing
- Agriculture
- Allied Health
- Construction
- Clean Energy
- Education
- Global Trade & Supply Chain Management
- Homeland Security – Emergency Management
- Information & Computing Technology
- Marine Manufacturing & Technology

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As one of 10 Centers of Excellence in Washington State, the ***Center of Excellence for Aerospace & Advanced Manufacturing*** serves as a honest, trusted broker of information within industry and education, focusing on the aerospace and advanced manufacturing industry sector.

The Center is responsible for:

- Engaging employer and labor representatives from strategic industries in identifying both industry needs and student needs.
- Identify industry skill standards and industry-based certifications.
- Facilitate the creation of model programs of study that prepare students for careers in strategic industries.
- Coordinate with industry assistance organizations to connect businesses with needed services.

Timeline: How We Got Where We Are Today

November , 2012

- Boeing approached the Center of Excellence (CoE) relating future workforce needs for entry level candidates with the knowledge, skills and abilities to do the work in measurement science.
- During our ACAT (Aerospace Curriculum Alignment Team) meeting in November, Jason Koehn made a presentation to representatives from Washington State Community and Technical Colleges, workforce development councils, labor, government and industry leaders relating this need and the KSA's involved.

January-March, 2013

- Working with Boeing, the CoE set up a tour of the Boeing Metrology Labs
- The CoE set up a tour of three community & technical college labs: North Seattle College, Olympic College and Lake Washington Institute of Technology

April 2013

- Working with Boeing, the CoE was able to identify and contact other industry partners in the Puget Sound region that were seeing needs in their workforce for future entry level candidates with the KSA's in measurement science

May 2013

- The CoE convened a Measurement Science Technician DACUM workshop with subject matter experts from local industry that included Boeing, Fluke Corporation, Puget Sound Naval Shipyard, Lockheed Martin, CimTech, Greysam Industries, and Northrup Grumman. Also, attending this DACUM as observers were faculty and deans from at least six colleges in the region that have manufacturing programs in place and have an interest in expanding their training capabilities

Winter, 2014

- The CoE was made aware of the NIST grant and , working with industry partners from the DACUM, submitted , what would become, a successful grant application in the spring of 2014.

August 2014

- The CoE was awarded the NIST grant; work began with faculty and deans along with our industry partners

Fall/Winter 2015/2016

- Article submitted to the Standards in Engineering Journal; copy included in our written final report.

The Preferred Demonstrated Skill Sets required of the typical Measurement Science Technician

****Tan indicates most critical skills**

Math specific to Measurement Science A	Basic Lab Skills B	Test Equipment Operations C	Technical Communications D
Apply math to interpret specifications & tolerance **A1**	Read Blue-prints and schematics B1	Operate digital multi-meters, oscillators etc C1	Career Readiness D1
Convert units **A2**	Recognize abnormal behavior of measurement B2	Apply appropriate standards C2	Social/Professional ethics D2
Calculate complex tolerances **A3**	Basic Soldering B3	Use electronic test equipment C3	Microsoft Office products D3
Make use of applied algebra and geometry **A4**	Conduct basic set-ups (cables, adaptors etc) B4	Use ancillary equipment appropriately C4	Written English (ATA Standard) D4
Apply basic math to problem solving **A5**	Use wide range of hand tools safely B5	Set-up process control operations C5	Communicating at appropriate level D5
Apply basic ratio formulas and statistical concepts **A6**		Operate frequency counters and signal generators C6	Conducting computer-based information search D6
		Set-up and perform automated measurements C7	Applying GDT symbols to data D7

The Preferred Knowledge Base for Measurement Science Technicians

(Tan items denote elements where a depth understanding is required)

The Expression of Units of Measurement A	Core Measurement Science Technology B	'Uncertainty' in Measurement Science C	Measurement Science Fundamentals D	Technical Communications E	Applied Mathematics for Measurement Science F	Data Integrity G
Measurement units & conversions A1	Basic Mechanics B1	Basics of Uncertainty Analysis C1	Measurement Theory & Techniques D1	Reading & Comprehending Technical Writing E1	Geometry & Algebra – basic functions F1	Basics of Data Integrity G1
	Simple and complex AC/DC Circuits B2	Error + Correction relationships C2	Why Calibrate? (Traceability, Repeatability, Reliability) D2	Writing Cogent Technical Reports E2	Statistical concepts and their applications in Measurement Science F2	
	Basics of Electrical, Mechanical, Optical & Chemical systems B3	Guardbanding Techniques C3	Vocabulary of Measurement Science D3	Basics of Technical Communications (Terms, glossary etc) E3		
		TAR/TUR/TR C4	Basics of Calibration Procedures D4	MS Office tools for data presentation E4		
SI and English units of Measurement			Basic Standards (NIST etc.,) D5	Assessing the knowledge level of customers (internal and external) E5	Concept of significant Digits as it applies to Measurement Science	Data Recording formats and norms in Measurement Science
	Basic Computer Operations	Role of Environmental Factors in the measurement process	Typical Laboratory Hazards D6			
			Quality Standards ISO, ASME etc D10	Communicating clearly at the customer's level		
A2	B4	C5	The History of Measurement D11	E6	F3	G2

The Work Profile of the typical Measurement Science Technician

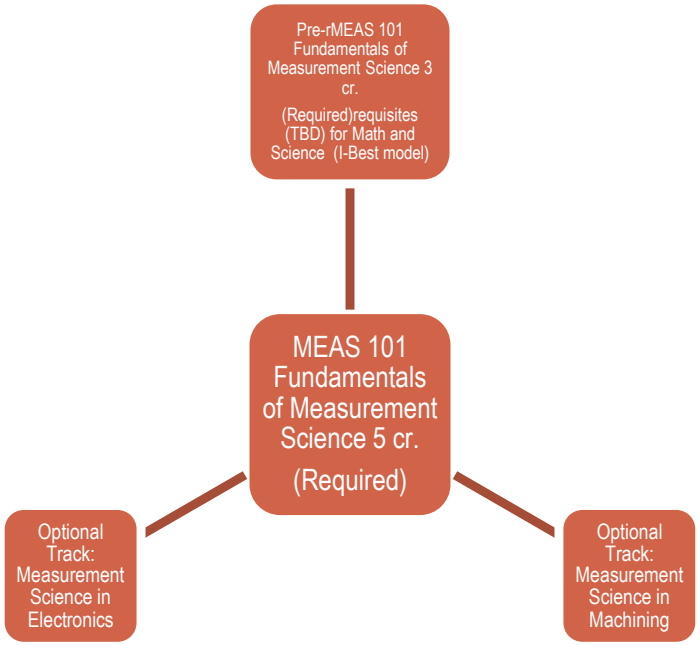
Main Duties	Primary Tasks (Purple = most challenging: Green = most commonly performed tasks: Tan = both common and challenging)					
Making Accurate & Repeatable Measurements **A**	Set up Measurement Processes A1	Work according to Safety SOPs in the lab A3	Read & understand technical procedures A5	Apply Measurement Science vocabulary in all work A7	Use MBD and other Measurement Science strategies A9	
	Read and Comprehend Performance Specs A2	Follow Calibration S.O.P.s A4	Calibrate equipment according to S.O.P.s A6	Care & Handle Lab Equipment safely A8		
Interpreting, Documenting & Communicating Test Results **B**	Communicate test results accurately B1	Communicate effectively with customers B3	Gather data from measurements B5	Document results (O.O.T. Conditions etc) B7	Analyze non-conforming data B9	Assess measurement results (OOT, SOOT, Limited use) B11
	Apply Measurement Units accurately B2	Educate customers on process and results interpretation B4	Certify or reject test instruments based on results B6	Report data results in various formats (text, graphs, charts, numbers) B8	Communicate results to customer's declared need B10	Use Excel to calculate Measurement Results B12
Researching & Applying Measurement Science Knowledge **C**	Calculate Basic Test Accuracy Ratios C1	Choose Standard Base UUT Specifications (T.A.R./T.U.R.) C2	Apply the Basic Principles of Traceability in the Measurement Process C3	Identify Potential Sources of Measurement Error C4	Use G.D.T. to interpret Blue Prints C5	Research Specifications and Measurement Issues C6
Trouble Shooting, Adjustment & Repair **D**	T.S. and Repair a range of instruments D1	Adjusting test instruments to perform within manufacturer's specs D2	Applying Basic T.S. approaches to Measurement & Test Equipment D3	Apply Basic I.T. knowledge to problem solving D4		
Incorporating Quality Systems **E**	Follow Standard Quality Assurance S.O.P.s of the company on all work E1					

OUR GOALS

- Develop course curriculum with industry subject matter experts' input that can be embedded into advanced manufacturing/aerospace programs
- Develop a series of courses that can be included in a short term certificate that can be adopted at any of the state's community and technical colleges
- Create curriculum that will be easily recognizable (common certificate with course titles/objectives) so that industry hiring managers are able to clearly identify the training when it appears on resumes
- Increase the number of community and technical college students that are qualified to fill job openings in measurement science/precision measurement/metrology within local companies
- Provide professional development opportunities for Design Team faculty to attend industry-led conferences and seminars for exposure to workplace best practices

Short Stackable Certificate in Measurement Science

MEAS 101, entitled Fundamentals of Measurement Science, is a 5-credit common course designed to measure core competencies. Students then have an option for an additional 5-credit course (including lab credits) in either machining or electronics.



Sample of Course Overview for Fundamentals of Measurement Science

MEAS& 101	TOPIC: Fund of Measurement Sci	CREDIT/HRS: 5CR 30/40(Lec/Lab)
PURPOSE:	Provide an introduction to the foundation knowledge and skills in measurement science that are required to prepare for an entry level position in Manufacturing and/or related fields.	
OUTCOMES:	Upon successful completion of this course, students should reliably/correctly be able to: 1. Demonstrate safe practices and situational awareness typical of a manufacturing environment. 2. Successfully apply and/or use fundamental concepts, tools, equipment and basic principles of measurement science to include: 2.1 Recall or recognize terms, definitions, facts, ideas, materials, patterns, sequences, methods, and principles, as applied to metrology and measurement science. 2.2 Comprehend descriptions, communications, reports, tables, diagrams, directions, regulations, standards, etc. as applied to metrology and measurement science. 2.3 Use applied math to solve measurement related problems. 2.4 Correctly interpret technical illustrations and documents for specifications, measurements, tolerances, etc. (“Specmanship”) 2.5 Select and use precision measuring and test equipment to inspect parts and devices to confirm they conform to specifications; inspect parts and devise to confirm they conform to specifications. 2.6 Demonstrate familiarity with applicable standards, including the concept of traceability as it applies to materials, calibration, and finished products. 2.7 Use Excel for data collection, analysis and presentation of information. 2.8 Identify non-conforming materials, tools, etc. and initiate resolution. 2.9 Identify and describe a measurement problem. 2.10 Translate a measurement problem to measureable quantities. 2.11 Estimate whether a quantity is measureable under certain conditions. 3. Demonstrate attention to detail, personal integrity, interpersonal skills, and effective communication in a classroom and laboratory environment.	

Sample of Course Overview for Electronics Measurement

MEAS& 102	TOPIC: Electronics Measurement	CREDIT/HRS: 5 (30/50 Lec/Lab)
PURPOSE:	Provide application of the foundational knowledge and skills in measurement science, with a focus on Electronics, that are required to prepare for an entry level position in Manufacturing and/or related field.	
OUTCOMES:	Upon successful completion of this course, students should reliably/correctly be able to: 1. Demonstrate safe practices and situational awareness typical of a manufacturing environment. 2.Successfully apply the appropriate concepts and principles related to electronics measurement theory and practice to include: 1. The selection, use and operating principles of the applicable test equipment. 2. Communications, reports, tables, diagrams, directions, regulations, standards, etc. 3. Applied math and statistics to document measurement. 4. Interpretation of technical illustrations and documents for specifications, measurements, and tolerances, etc. (“Specmanship”) 5. Select and use precision measuring and test equipment to inspect parts and devices to confirm they conform to specifications. 6. Inspect circuitry to confirm they conform to specifications. 7. Show familiarity with applicable standards, including the concept of traceability. 8. Compose reports using Excel and other industrial software for data collection, analysis and presentation of information. 9. Identify and document out of tolerance results. 10. Judge whether a quantity is measureable under situational conditions. 3. Demonstrate attention to detail, personal integrity, interpersonal skills, and effective communication.	

Sample of Course Overview for Mechanical Measurement

MEAS& 103	TOPIC: Mechanical Measurement	CREDIT/HRS: 5 CR (20/60) Lec/Lab
PURPOSE:	Provides an application of the foundational knowledge and skills in measurement science, with a focus on Mechanical Measurement, to prepare for an entry level position in Manufacturing and/or related fields.	
OUTCOMES:	Upon successful completion of this course students should reliably/correctly be able to: 1. Demonstrate safe practices and situational awareness typical of a manufacturing environment. 2. Successfully apply the appropriate concepts and principles related to mechanical measurement theory and practice in a classroom/laboratory environment to include: 2.1 Interpret technical drawings and apply inspection tools and techniques to verify the acceptability of machined parts. 2.2 The use of surface plate layouts and the coordinate measuring machine (CMM). 2.3 Familiarity with standards applicable to manufactured parts. 2.4 Familiarity with the concepts of traceability as applied to calibration. 2.5 Proper use of computer software used in quality management. 2.6 Non-conforming instruments, finished parts and assemblies, and initiate resolution. 2.7 The selection, use and operating principles of mechanical measurement tools and test equipment. 2.8 Communications, reports, tables, diagrams, directions, regulations, standards. 2.9 Use applied math and statistics to document measurement. 2.10 Interpretation of technical illustrations and documents for specifications, measurements, tolerances, etc. (“Specmanship”) 2.11 Inspect parts and assemblies to confirm they conform to specifications. 2.12 Apply appropriate standards, including the concept of traceability as it applies to mechanical measurement. 2.13 Compose reports using Excel and other industrial software for data collection, analysis and presentation of information. 2.14 Identify and document out of tolerance results. 2.15 Judge whether a quantity is measureable under situational conditions. 3. Demonstrate attention to detail, personal integrity, interpersonal skills, and effective communication.	

Communication Outcomes

- A grant webpage has been created on the COE website; our NIST grant plays a pivotal part on that webpage. http://www.coeaerospace.com/grants
- The curriculum that has been developed will also be put on the COE website on the Curriculum Resources page ; this curriculum page is essentially open source, so anyone within a educational system can request an account password and log-on.
- We have been approached by Standards Engineering to submit an article about our grant and its outcomes. That article has been submitted and we are awaiting final notice of a publication date.
- Our industry representative from Boeing recently attended an exploratory meeting in Cleveland on the topic of a national certification standard for measurement science. After reviewing the more basic "fundamentals of measurement science" approach taken with our CTC's in a presentation submitted by the COE, the group thought it best to follow a similar course and begin looking at a measurement science certification that could be stacked on (or a prerequisite for) other existing certifications. Included reps from NIMS and Association for Manufacturing Technology.

Future Project Expansion Ideas

- Further expansion of the course overviews that includes an in-depth syllabi for each course; separate certificate in Measurement Science earned through the participating colleges; a listing of pre-requisites for each of the courses that were developed
- Provide a pathway to incumbent workers who have experience in Measurement Science; such a pathway would allow them to earn a certificate or degree to validate that work experience;
- Develop two to three stackable certificates leading to a 2-year AAS or AAS-T degree to be implemented at Washington Community or Technical Colleges
- Work with industry partners and certification bodies to create a nationally industry recognized certification available through training
- Provide training for community and technical college faculty, led by industry leaders, that continues to help them enhance their knowledge, skills, and abilities towards curriculum enhancement and teaching techniques in measurement science

EXTERNAL EVALUATION PROCESS

Surveys were designed by the external evaluator; all data were collected and analyzed by the external evaluator and data were aggregated to protect confidentiality

Surveys were sent to all project participants to obtain their input on:

- Quality of the process for curriculum design
- Quality of the curriculum developed by the project
- Suggestions for improvement of the curriculum
- Potential impact on students





Quality of the Curriculum Design Process

Please rate the quality of the curriculum development	
Excellent	40.0%
Good	60.0%
Fair	0.0%
Poor	0.0%

"A strong team of faculty from diverse measurement science related fields was gathered, facilitation was made available, the time-frame was challenging but reasonable, and the goals were reasonably clear."

Curriculum Design Team Member

"I came away with great respect for all my colleagues involved ... both for what they added to this project, and for what they do every day in their profession."

Curriculum Design Team Member





Quality of the Curriculum

Please indicate the degree to which the curriculum developed by the project meets the following criteria:				
Criteria	Completely meets the criteria	Somewhat meets the criteria	Does not meet the criteria very well	Does not meet the criteria at all
Includes knowledge of the principles and concepts of measurement science, including various levels of measurement science terminology, definitions of common metrology terms and units of measure.	80%	20%	0%	0%
Includes basic knowledge of measurement and uncertainty concepts.	80%	20%	0%	0%
Provides students with the ability to make accurate, precise and repeatable measurements with general purpose electrical test and measurement equipment.	80%	20%	0%	0%
Contains appropriate hands-on projects for each level of training.	40%	60%	0%	0%





Impact on Colleges, Students, Workforce from the Educators perspective

"Assuming schools can move forward with providing instruction to the curriculum generated, the grant will have come a long way to providing industry with a better skilled workforce, and with providing workers with skills to get better jobs."

"Manufacturing programs students will have a better idea of how crucial measurement science is to all of these disciplines. Additionally, the measurement science courses might well serve as a "Intro to Manufacturing" career exploration opportunity for high school students."





Impact on Colleges, Students, Workforce from Industry perspective

"Measurement science is the fabric of manufacturing and technology. Without a pipeline of qualified entry-level candidates to fill positions in industry, we are at risk of reduced quality products, lower efficiencies, and increased safety risks. By providing our future technical workforce with the necessary skills related to measurement science, we are arming them with the tools they need to be successful."

"This grant will give students a practical knowledge that can be used by any manufacturing, engineering or construction trade."

"The primary impact to the workforce will be an immediate improvement of the measurement skills of associates seeking employment."





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A SPECIAL THANK YOU TO OUR DESIGN TEAM:

David Cunningham, Education Consultant/Workshop Facilitator

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Jeff Purdy/Faculty, Shoreline College

Stan Jirak/Faculty, Everett Community College

Peter Welty & Dennis Candelaria/Faculty, Lake Washington Institute of Technology





A VERY SPECIAL THANK YOU TO OUR INDUSTRY PARTNERS; THEIR CONTRIBUTION WAS INVALUABLE

Jason Koehn, The Boeing Company

Jeff Gust, Fluke Corporation

Kelly Anderson, Lockheed Martin

Andrew Balasa, Puget Sound Naval Shipyard

Mark Foxworth, Greysam Industrial Services

Steve Kidd, CimTech

Kristina Hayek & AJ Schuehle, Hexcel Corporation





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ADDITIONAL INFORMATION

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