# Virginia Tech Manufacturing

## Advanced Manufacturing Capabilities

**Dr. Jaime Camelio**
Commonwealth Professor for
Advance Manufacturing

# Motivation – Current Needs in Mfg

# What is needed in manufacturing today

- **NNMI Latest Report [2013]**

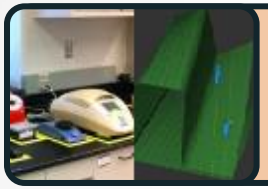
  "National Network for Manufacturing Innovation—an initiative to accelerate U.S. advanced manufacturing by catalyzing the development of **new technologies**, **educational competencies**, **production processes**, and products via shared contributions from the public and private sectors and academia… designed to serve as regional hubs of world-leading technologies and services. …provide shared facilities to **local start-ups and small manufacturers** to help them **scale up** new technologies, **accelerate technology transfer** to the marketplace, and facilitate the adoption of innovative developments across supply chains. … act as '**teaching factories**' to build workforce skills at multiple levels and to strengthen business capabilities in large and small companies.

  John Holdren, Director, Office of Science and Technology Policy [NNMI Report, 2013]

# Center for Innovation Based Manufacturing

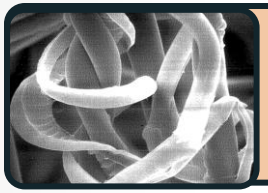
CENTER FOR INNOVATION-BASED MANUFACTURING

an ICTAS CENTER at VIRGINIA TECH



## Manufacturing Innovation

- Improved Efficiency in DNA Fabrication (NSF)
- Self-healing Assembly Test-bed



## Manufacturing Scale-up

- Melt-blown Nanofibers
- DC-DC Solar Inverter

## Local Industry Applied Research

- Value/Asset Recovery & Capacity Improv. – Volvo
- Facility Adaptation for New Product Lines – Metalsa

## Student-Driven Initiative Support

- GreenStar Smart-grid Technologies
- PureAir Asthma Inhaler

## Continuing Education & Functional Problem Solving

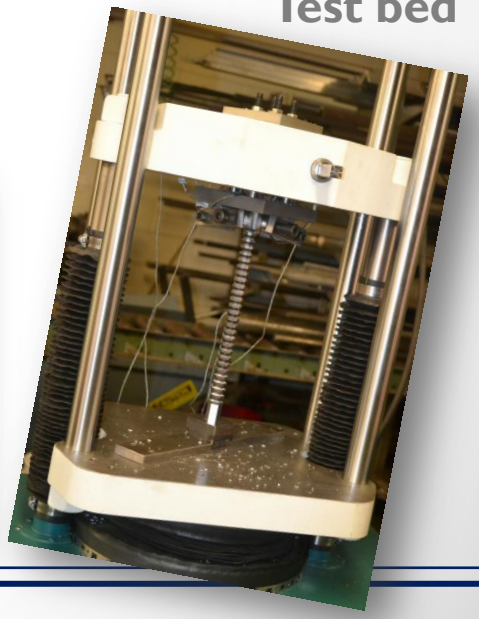
- Research Experience for Teachers
- "Deep Dive" Activities

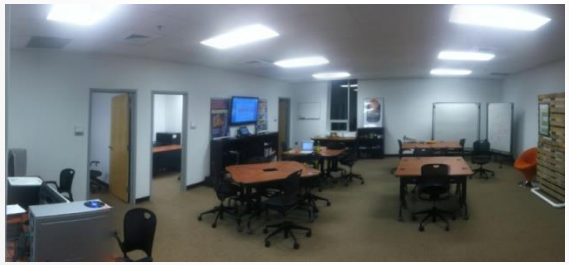
# From the blackboard to manufacturing demonstration facilities

Deep Dives

Inspection

Broaching Test bed





CIBM

CENTER FOR INNOVATION-BASED MANUFACTURING
an ICTAS CENTER at VIRGINIA TECH

ICTAS
INSTITUTE for CRITICAL TECHNOLOGY and APPLIED SCIENCE at Virginia Tech

VirginiaTech
Invent the Future

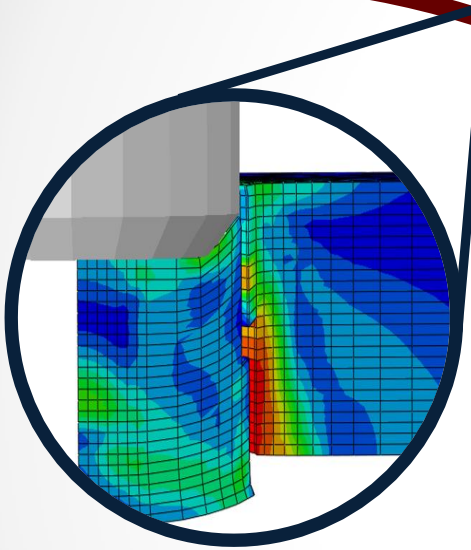
# Industry Supported Research

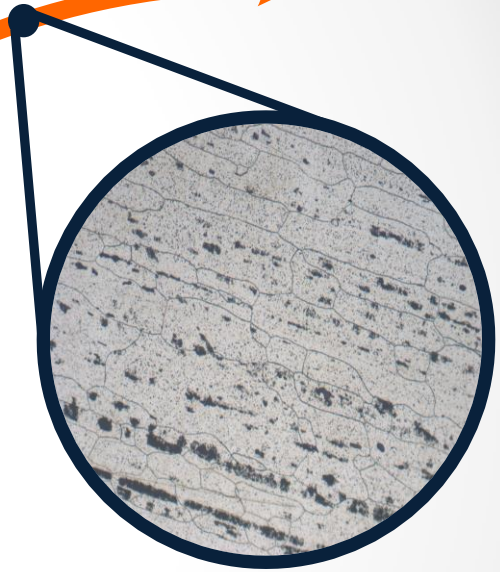
General Applicability

Technology Readiness

Metalsa

Quality as a way of life





Fundamental Research

Applied Research

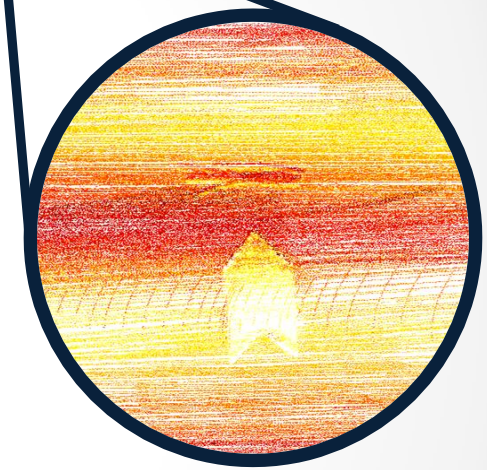
# Industry Supported Research

**General Applicability**

**Technology Readiness**

NSF

$$R_{m,s} = \begin{cases} \max\limits_{0 \le \tau < s,k} \dfrac{n_k(s-\tau)}{2\sigma_k^2}\left(\hat{\mu}_{1,\tau,s}(k) - \mu_{0,k}\right)^2 \\ s = 1,2,\dots,m \\ \max\limits_{s-m \le \tau < s,k} \dfrac{n_k(s-\tau)}{2\sigma_k^2}\left(\hat{\mu}_{1,\tau,s}(k) - \mu_{0,k}\right)^2 \\ s = m+1, m+2, \dots \end{cases}$$



**Fundamental Research** ⟷ **Applied Research**

# Center for High Performance Manufacturing

## VT Manufacturing Outreach

# CHPM Mission

## Mission

To provide Leadership to solve the challenges of manufacturing firms; Sponsorship to swiftly and appropriately respond to industry inquiries and proposal requests; and Stewardship to direct and coordinate resources for the support and development of interdisciplinary manufacturing education, research, and services.

## CHPM Objectives

- To assist Center manufacturing firms in becoming high performance producers by providing a "one-stop source" of manufacturing research in strategy, design, and analysis for launching new products and facilities, or re-engineering existing manufacturing systems.
- To enhance the manufacturing research competitiveness of Virginia universities in the federal marketplace by building the above expertise.

# CHPM Beginning

- The CHPM has been operational since 2001
- CTRF in the amount of $4.6 Million
- Original partners: Virginia Tech, William and Mary, James Madison University, and Virginia State University.
- Four VT departments: Mechanical Engineering, Materials Science Engineering, Engineering Science and Mechanics and Industrial & Systems Engineering.
- Conceived on a membership basis, but later relaxed that restriction.
- Each member had a seat on the Industrial Advisory Board that was charged with project selection.

# CHPM Functions

- As a single point of contact to the full capabilities of the Virginia Tech College of Engineering.
- As an entity through which manufactures can seek assistance in process improvement and instruction in a vast array of topics.
- As the locus for grant funding proposals to state, federal and industrial organizations from VT and industry.
- As a repository for critical knowledge and information on advanced manufacturing topics.
- Center Capabilities
    - Manufacturing Engineering
    - Planning, Design and Control
    - Supply Chain Management and Logistics
    - Manufacturing Process Analysis and Improvement
    - Manufacturing Organizational Analysis

# CHPM Numbers

| | FY02-FY06 7/01-6/06 | FY07 7/06-6/07 | FY08 7/07-6/08 | FY09 7/08-6/09 | FY10 7/09-6/10 | FY11 7/10-6/11 | FY12 7/11-6/12 | FY13 7/12-6/13 |
|---|---|---|---|---|---|---|---|---|
| Total Revenue $ | $4,340k | $262k | $406k | $728k | $466k | $724k | $619k | $1,100k |
| Private Sponsored Research $ | | | | $10k | $46k | $34k | $243k | $342k |
| Public Sponsored Research $ | | | | $644k | $385k | $504k | $76k | $253k |
| Grant Sponsored Research $ | $4,340k | | | $80k | | $1,100k | | |
| Grant Source/Name | CTRF Grant | SBA - NPDCC | | SBA - NPDCC | | EDA - TEMCI | | |
| Customers Served | 29 | 4 | | 4 | | 23 | | |
| Degrees Awarded (Research Center) | | | | | | | | |
| GRAs Supported | 90 (aprox) | 6 | | 7 | 11 | 7 | 14 | 12 |

# Who do we work with?



























# Virginia Tech Manufacturing

**University-wide community of researchers and leaders with the common objective of creating a solid knowledge base for high-value manufacturing while educating the future manufacturing leaders.**


From Manufacturing Process to Manufacturing Systems

# Intelligent Manufacturing Group

Dr. Jaime Camelio
Dr. Ran Jin
Dr. James Kong
Dr. Bob Sturges

# Intelligent Manufacturing

## From data collection to decision making combining process modeling, statistical learning and uncertainty management

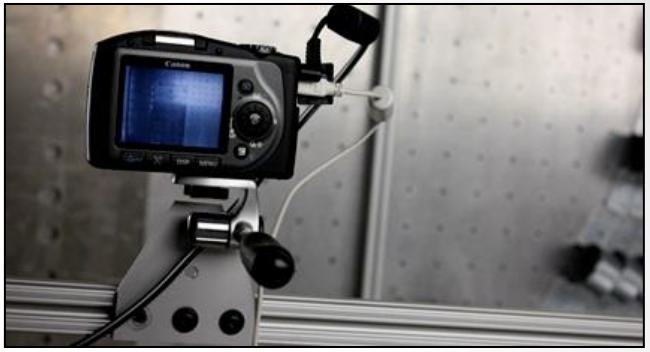
**Data → Information → Knowledge**

| Observed | Measured Variable | Processing | Diagnosis/Decision |
|---|---|---|---|
| Sheet metal | Surface Data | Multivariate SPC f(x) | System Knowledge |
| PZT sensor, Locating fixtures | Voltage signals | Data Compression g(x) | Action, decision making, diagnosis formulation |
| Formed pans | Images | Image Recognition h(x) | Process malfunction, Damaged fixture, Cracked pan |

Project Highlight

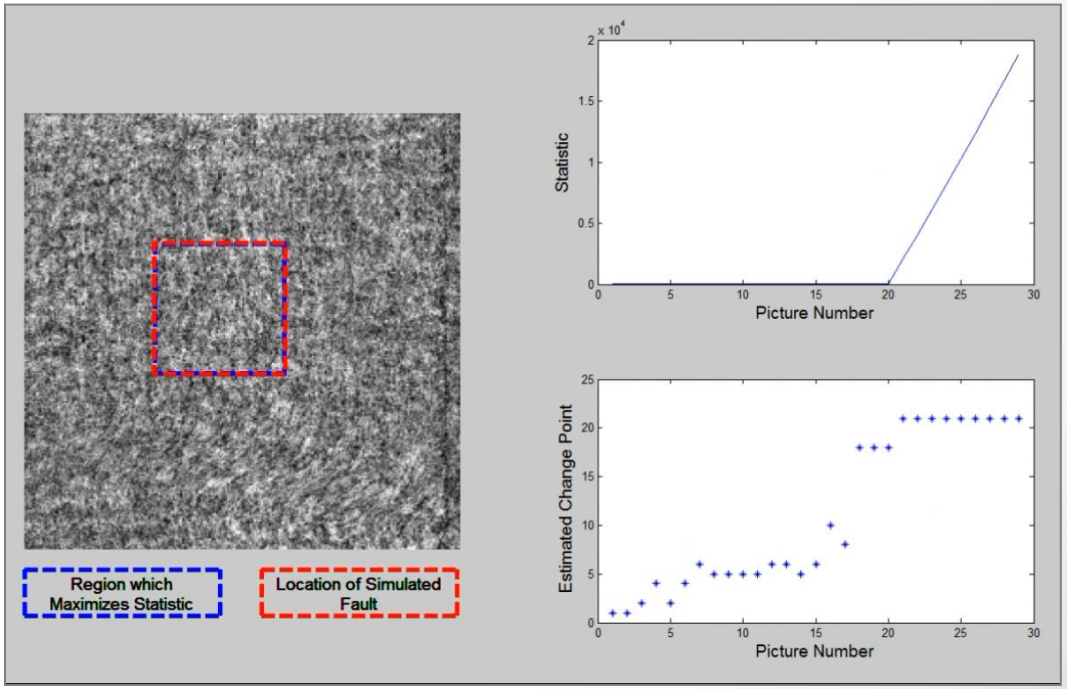
# Spatiotemporal Monitoring Methodology

## Visual Quality Inspection to Monitor the Potential Fault Locations and Sizes



Through one image (i.e. one measurement), the following inferences about the product and the process can be made:

- » Dimensional measurements
  - Width
  - Height
  - Diameter
- » Surface finish



Project Highlight

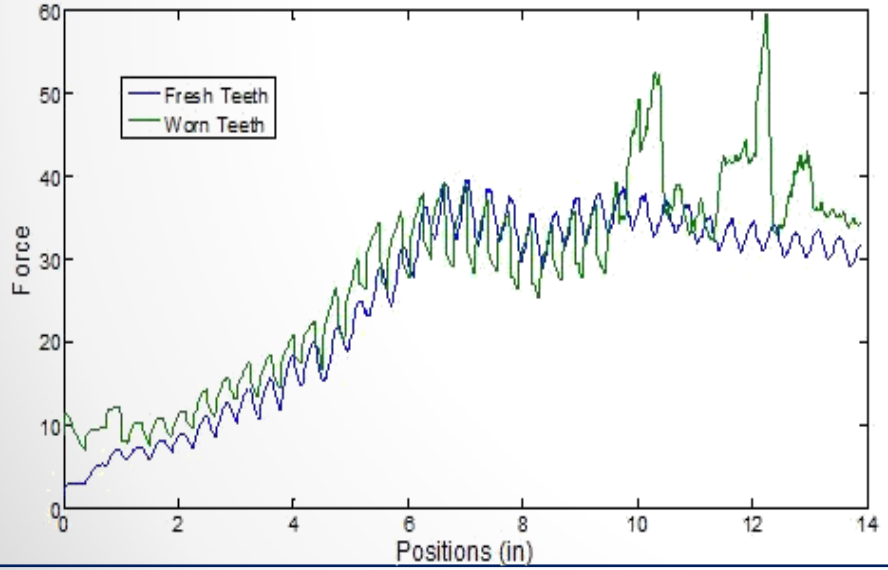
# Multi-Channel Profile Monitoring

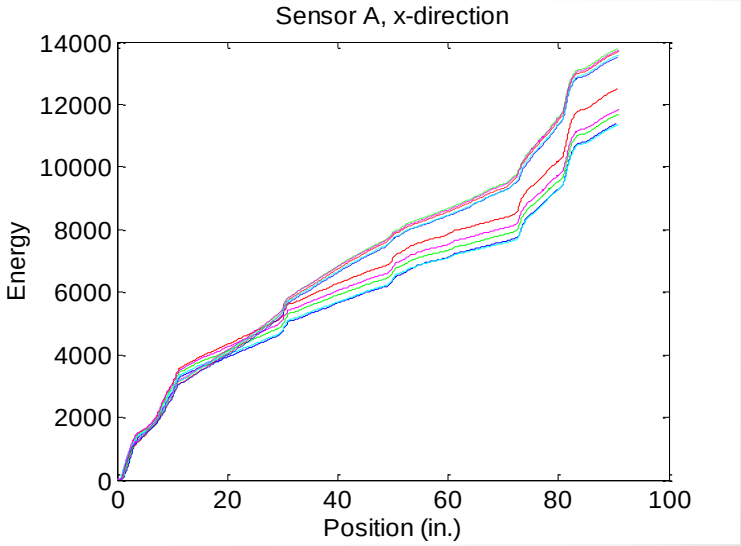
Broaching Process

- Requires High Accuracy
- Currently a Bottleneck

Monitor Wear to Optimize Maintenance

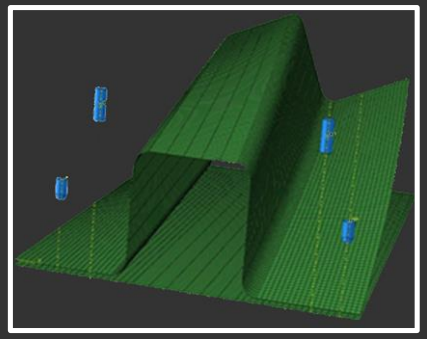
- Collect Force Data
  - Four Locations
  - Three Directions



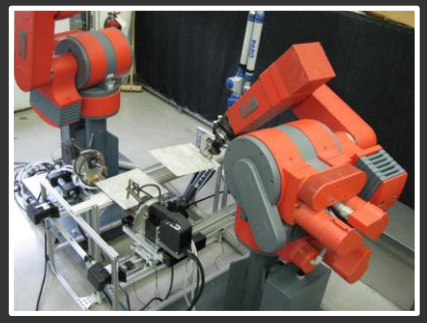
Project Highlight

# Self-Correcting Assembly Systems



FEM Assembly Simulations

Assembly System Test-Bed



**Modeling of Nonlinear Hierarchical Manufacturing Systems**

Multi-Station Variation Propagation

Statistical Learning

***Objective:*** *Predictive assembly variation models*

Human Knowledge

Statistical Learning

**Abnormal Condition Monitoring, Detection, and Isolation**

***Objective: Monitoring-detection-diagnosis synthesis***

**Abnormal Condition Correction and Adjustment**

Decision-Making Under Uncertainty

***Objective: Self-Healing assembly system mathematical framework***

Dimensional Assembly Data

Project Highlight

# Real Time Monitoring of Wafer Surface Topography in Chemical Mechanical Planarization (CMP) Operations

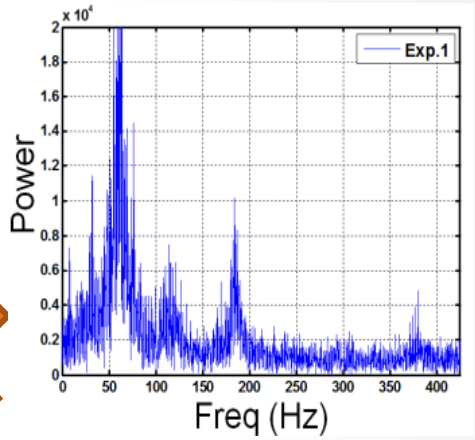
## Approach

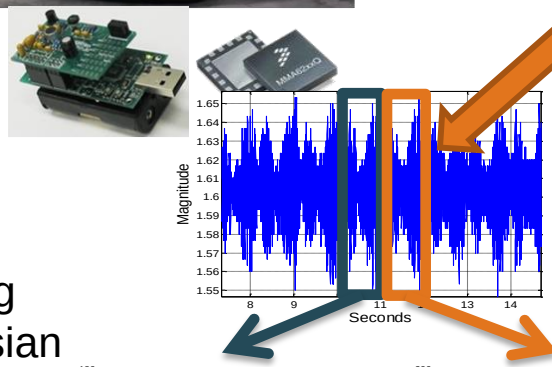
- MEMS (vibration, AE, etc.) Sensor based CMP apparatus
- Signal processing and feature extraction
- Recurrent nested Bayesian method for detection of process changes

Experimentation (wireless sensors)

*Defect Pattern Generation*

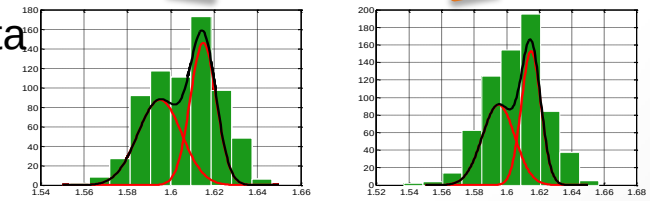
Signal Processing




*Sensor Feature Extraction*

Modeling using mixture of Gaussian for non-Gaussian data caused by process nonlinearity



Detection of process changes based on extracted features from process nonlinearity

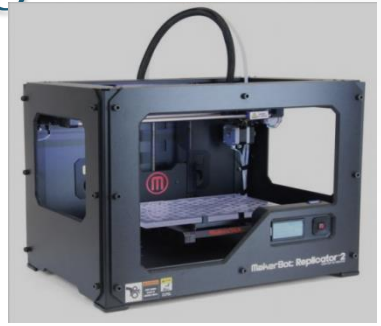
Project Highlight

# Online In-Situ Process Monitoring for Additive Manufacturing

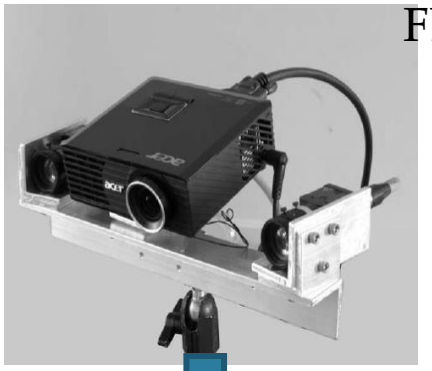
Process

Sensing

Analytics



SLS FDM



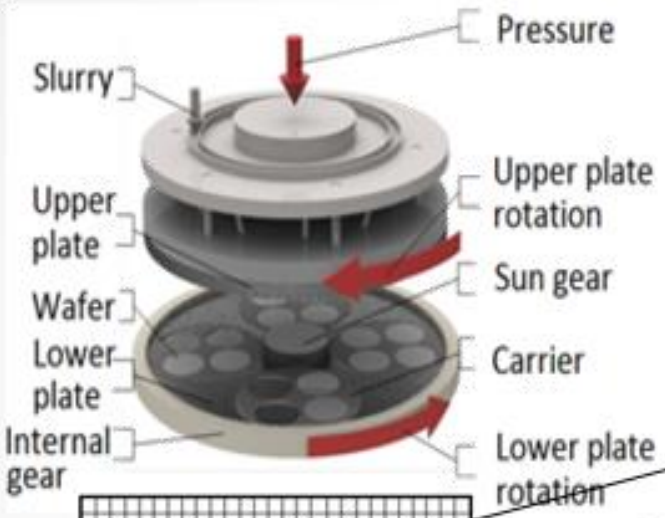
Real Time 3D Scanner

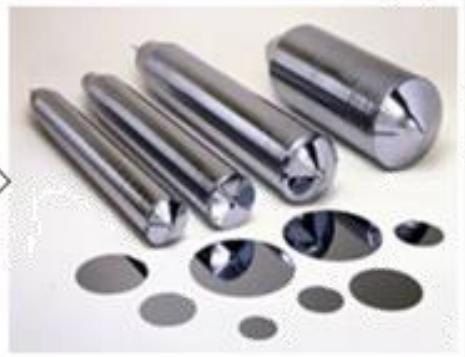
**Online Process Control for Spatial/High Dim Data**

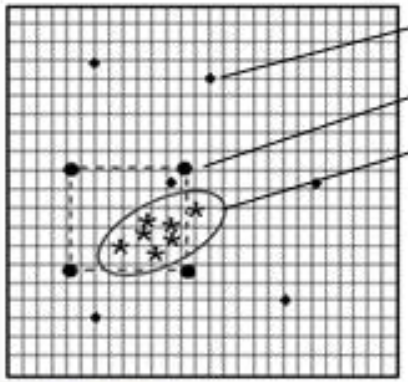
- **Spectral Graph Theory based Surface Characterization**
- **Gaussian Process Modeling for Spatial Data**
- **High dimensional data analysis using Reproducing Kernel Hilbert Space**

Project Highlight

# Data Fusion in Manufacturing Scale-up





Simulation data (engineering models, FEA)

Experimental data (design of experiments)

Observational data

Data Fusion

| | Sim. | Exp. | Obs. |
|---|---|---|---|
| Size | M | L | H |
| Accuracy | L | H | M |
| Range | H | M | L |

*Jin, R. and Deng, X., 2012, Ensemble Modeling for Experimental and Observational Data Fusion in Manufacturing scale-up, submitted to *IIE Transactions*.

*Deng, X. and **Jin, R.**, 2013, QQ Models: Joint Modeling for Quantitative and Qualitative Quality Responses in Manufacturing Systems", submitted to *Technometrics*.

# Dr. Jaime Camelio

Associate Professor
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Dr. Jaime Camelio is currently an Associate Professor in the Grado Department of Industrial and Systems Engineering at Virginia Tech. Dr. Camelio obtained his B.S. and M.S. in Mechanical Engineering from the Catholic University of Chile in 1994 and 1995, respectively. In 2002, he received his Ph.D. from the University of Michigan. His professional experience includes working as a consultant in the Automotive/Operations Practice at A.T. Kearney and as a Assistant Professor in the Department of Mechanical Engineering at Michigan Tech.

Dr. Camelio's research interests are in intelligent manufacturing. In the context of his work, he defines intelligent manufacturing systems as a structure that learns, understands, and adapts as needed through the combined efforts of physical modeling, human knowledge, data analysis, and advanced sensors systems. His current efforts towards intelligent manufacturing can be divided into three main domains: 1) Assembly Systems, 2) High Density Data Usage, and 3) Occupational Safety. Dr. Camelio director of the VT Center for Innovation Based Manufacturing. He is also the Virginia Tech Manufacturing Systems Director for the Commonwealth Center for Advanced Manufacturing and a board member for Virginia Manufacturing Advisory Council. Currently, he serves as Associate Editor for the SME Journal of Manufacturing Systems and the ASME Journal of Manufacturing Science and Engineering. He has received multiple awards including, 2010 Outstanding Assistant Professor at Virginia Tech, 2007 SME Outstanding Young Manufacturing Engineer Award, and 2001 Best Paper Award from the ASME Design Engineering Technical Conference.

# Dr. James Kong

Associate Professor
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Zhenyu "James" Kong joined the department of industrial and system engineering at Virginia Tech as an associate professor in August 2013. He started his academic career at Oklahoma State University's School of Industrial Engineering and Management in August 2006. He was promoted to associate professor with tenure in 2012. Prior to his stint at Oklahoma, he spent two years as a senior research engineer at Dimensional Control Systems, Inc., of Troy, Mich. His research interests are in the monitoring and control of micro/nano manufacturing operations via MEMS sensor based predictive modeling. He also focuses on compressive sensing based modeling, synthesis, and diagnosis for large and complex manufacturing systems. He conducts online structural health monitoring of nonlinear/nonstationary data. His research has been sponsored by the National Science Foundation, the Department of Transportation, and the National Institute of Standards and Technology. He has a broad range of teaching experience, offering courses in: manufacturing process/systems modeling; facility planning; and quality/reliability engineering. He was awarded the Halliburton Outstanding Faculty Award from the College of Engineering, Architecture and Technology at Oklahoma State University in 2013. He received his bachelor's and master's degrees in mechanical engineering from the Harbin Institute of Technology in China in 1993 and in 1995, respectively. He earned his Ph.D. in industrial and systems engineering from the University of Wisconsin-Madison in 2004.

# Dr. Ran Jin

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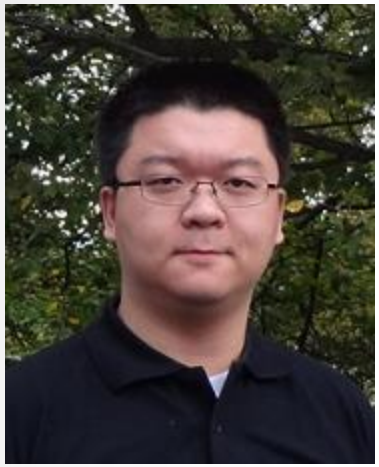

- **Education**
  - B.Eng.: Electronics Information Engineering, Tsinghua Univ.
  - M.S.: Industrial Engineering, Univ. of Michigan
  - M.A.: Statistics, Univ. of Michigan
  - Ph.D.: Industrial Engineering, Georgia Tech.
- **Research Interests**
  - Quality engineering through engineering driven data fusion
  - Sensing, modeling and optimization for surface and 3D cloud data
  - Quality engineering for manufacturing scale-up

# Dr. Bob Sturges

Professor
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**Robert H. Sturges, Jr.**, is a Professor of Industrial and Systems Engineering at Virginia Polytechnic Institute & State University. He received his B.S.M.E. and M.S.M.E. from MIT in 1969. He began his career at Charles Stark Draper Laboratories and he spent over ten years at Westinghouse in various product design and manufacturing departments before returning to academia. In 1986 he received his Ph.D. in Mechanical Engineering from Carnegie Mellon University and then taught there for eight years before coming to Virginia Tech. His 40 years of research experience in industry and academia have included the development and teaching of integrated design-manufacturing methods, and the design and development of advanced automation equipment and robotics. Dr. Sturges holds 16 US patents, has published over 175 papers in various international technical journals and conference proceedings, and drives a 1975 Morris Mini. Among his many inventions is his Wire Harness Flexible Manufacturing System; one of the industry's first CAD driven systems producing finished wiring assemblies from raw materials. Early in his career, he pioneered the development master/slave remote robot systems for the nuclear service industry. He invented a Design for Assembly calculator and developed a quantification of Dexterity. Dr. Sturges's current research interests include energy-efficient design-manufacturing systems for machining, assembly, and advanced robotics. At Virginia Tech, he has advised the SAE Formula Racing Team, and chaired the EFO Executive Committee. He is a Professional Engineer, and member of ASME.

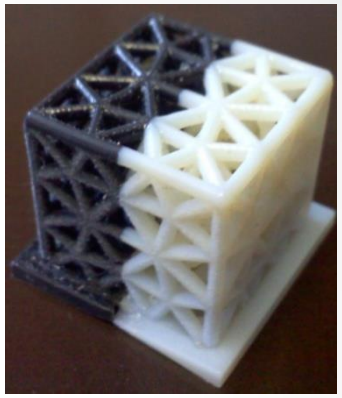
# Additive Manufacturing

**Dr. Christopher Williams**

# DREAMS Lab: Research Foci

## Design for Additive Manufacturing

- DfAM decision support methodologies
- Cellular material topology design & optimization

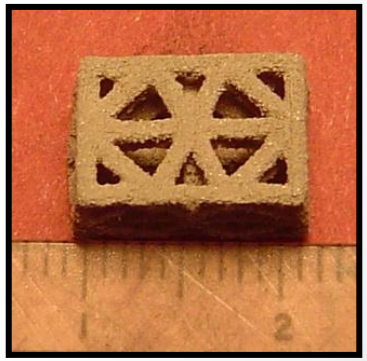


*Multi-Material Optimization*

## Process and Materials Research

- 3D Printing of metals and ceramics
- 3D Printing with nanocomposites
- Embedded electrical and actuation systems

*Metal Oxide 3D Printing*

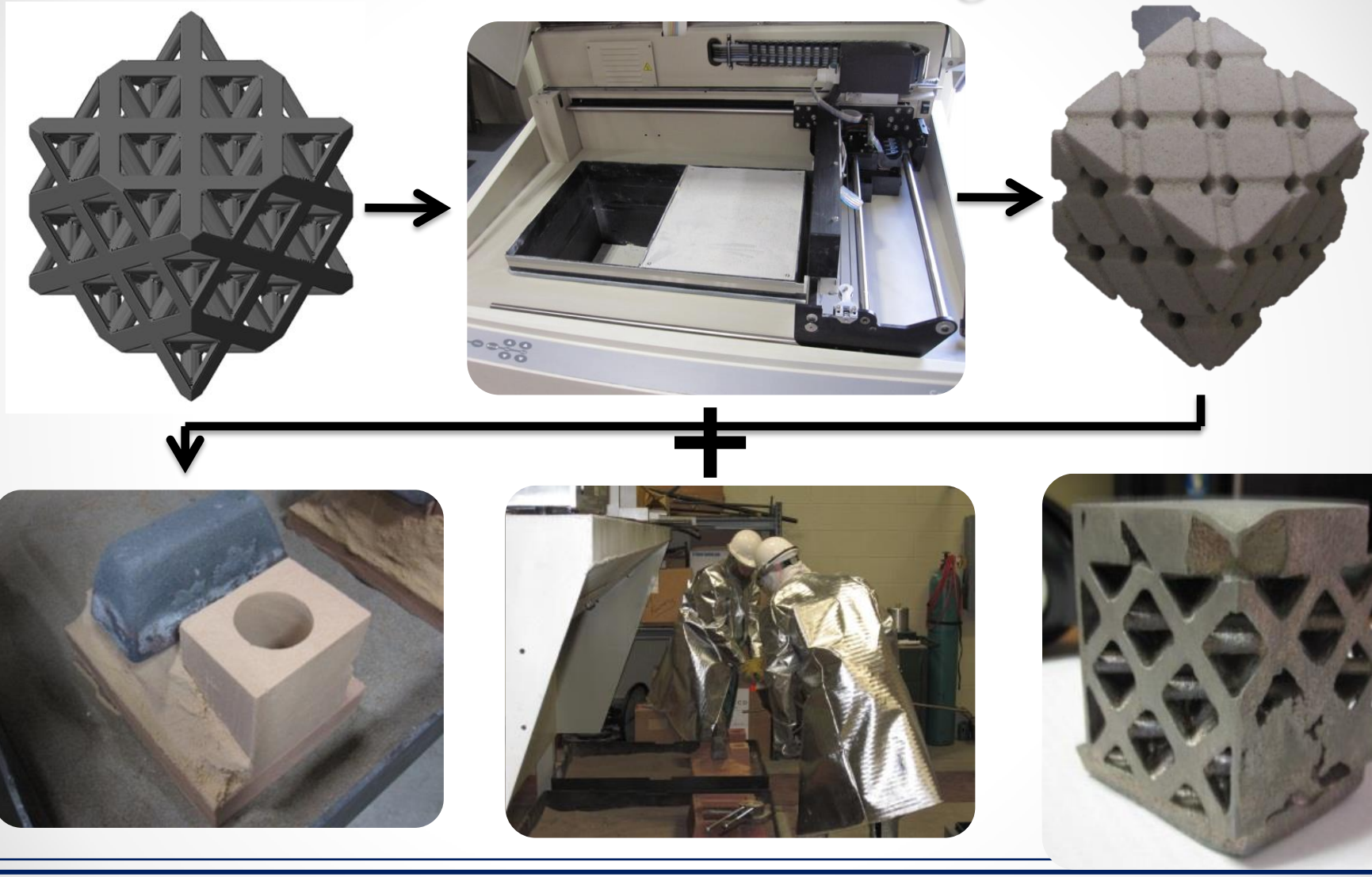


## Education

- Undergraduate and graduate courses
- Continuing education
- K-12 STEM Outreach

Project Highlight

# 3DP Cellular Castings



Project Highlight

# 3DP Cellular Castings

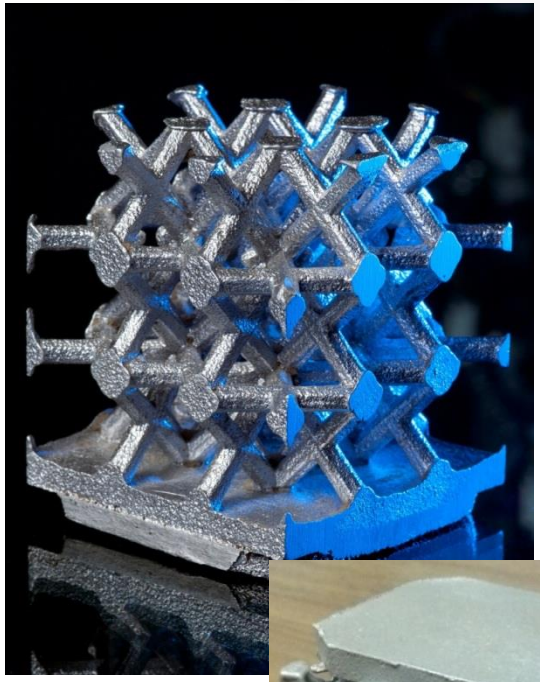
Scalable process

- 2D patterning inkjet technology
- Can print molds as large as 70x39x27”
- Can assemble printed “bricks”

Large material selection

Known material properties

Homogeneous sandwich panels



# Dr. Christopher B. Williams

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Professor Chris Williams is an Assistant Professor with a joint appointment in the Department of Mechanical Engineering and the Department of Engineering Education at Virginia Tech. He is the Director of the Design, Research, and Education for Additive Manufacturing Systems (DREAMS) Laboratory (http://www.dreams.me.vt.edu) and the co-director of Virginia Tech's Center for Innovation-based Manufacturing (http://www.cibm.ise.vt.edu).

In the realm of Additive Manufacturing (AM), Chris's expertise is focused in both process and materials improvements and in creating a suite of design tools to guide the use of AM to create functional, end-use artifacts (*i.e.*, "Design for Additive Manufacturing").

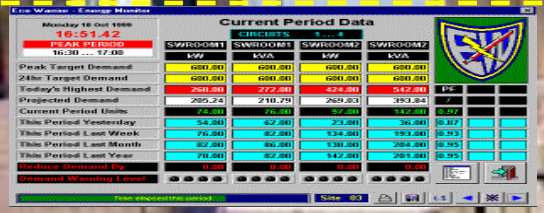
Dr. Williams was awarded a National Science Foundation CAREER Award in 2013. For his AM research contributions, he was presented the 2012 International Outstanding Young Researcher in Freeform and Additive Manufacturing Award and the 2010 Emerald Engineering Outstanding Doctoral Research Award. He was selected as co-chair of the AM session at the 2013 National Academy of Engineers German-American Frontiers of Engineering Symposium.

For his contributions in the classroom, he was awarded Virginia Tech's 2012 XCaliber Award, the 2011 White Award for Innovation in Engineering Education, and the 2011 Outstanding Engineering Education Faculty Member Award.

Chris holds a Ph.D. and M.S. in Mechanical Engineering from the Georgia Institute of Technology (Atlanta, Georgia) and a B.S. with High Honors in Mechanical Engineering from the University of Florida (Gainesville, Florida).

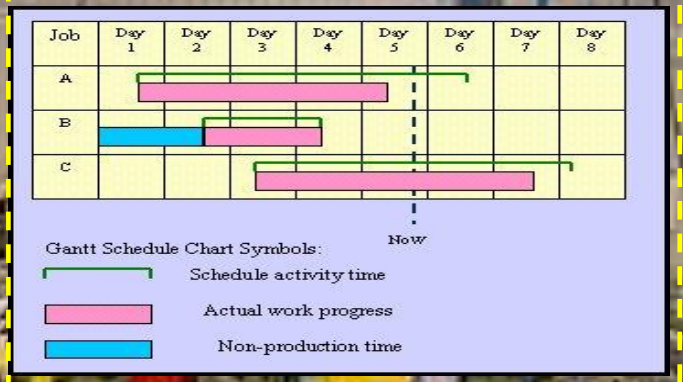
# Production Control Group

Dr. Subhash Sarin
Dr. John P. Shewchuk




**Production Planning**
(Aggregate Planning, MRP,MRP II, ERP, APS)

**Inventory Control**
(Lot Sizing, Deterministic & Stochastic Models, MTS, MTO, JIT)




**Production Scheduling** (MPS, Dynamic Scheduling, Project Scheduling, Flow shop, Job shop and Reentrant shops, FMS, Agile Manufacturing)

**Assembly System Design and Line Balancing**

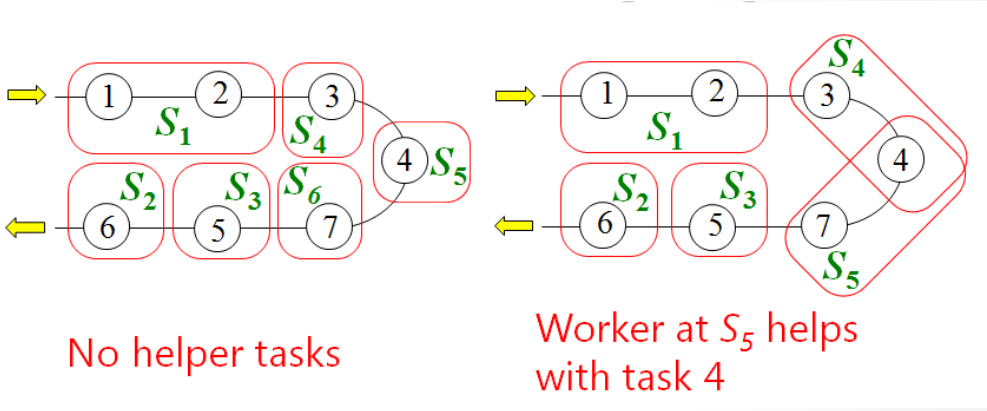
**Production System**

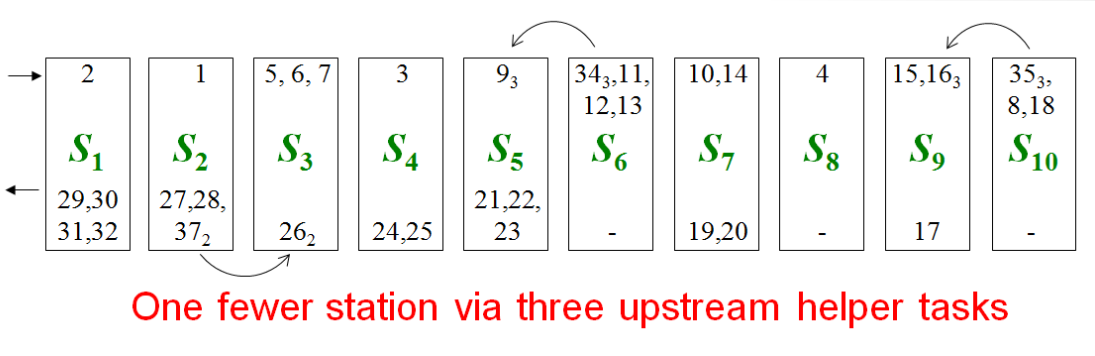
**Lean Manufacturing**


**Material Flow Control**
(Kanban, CONWIP)

# U-line Design and Operation with Helper Tasks

- U-shaped assembly lines common in lean manufacturing firms.
  - basic assumption: each task performed by single worker.
- Improve line operation via incorporating mutual relief in the design process.
- Mathematical model (MILP) and heuristic: RPW-H.
- Result when used:
  - Fewer workers needed.
  - Improved product flow.
  - Reduced line stops.



# Lean and Simulation-Based Design of Panelized Residential Construction

- Panelized construction in residential housing industry.
  - Panels made in factory, sent to site, workers assemble (install).
  - Considerable worker stress, injuries: panels big, cumbersome, heavy.
- Analyze entire process (panel design through worker assembly), improve via lean manufacturing, OR, simulation, and ergonomic analysis.
  - Vast improvement in worker health and safety, construction efficiency and overall lead time.
- Unique conjunction of heuristic problem solving via discrete simulation and lab-based (ergonomic) data.
- Approach applicable to manufacturing as well: assembly lines, MH, etc.

# Lab Infrastructure

- **Simulation**
  - AutoSched AP 10.1
  - Auto Mod 12.2
  - Promodel 4.2
- **Optimization**
  - CPLEX 12.2
  - AMPL
  - MINOS 5.5
  - SNOPT 7
  - Excel Premium Solver
- **Tools**
  - Microsoft Visual Studio 12
  - Microsoft Visual Studio.Net
  - AutoCAD 2013
  - Matlab
  - Mathematica
- **Statistical Analysis**
  - Design Expert 6.0
  - JMP

# Dr. Subhash Sarin

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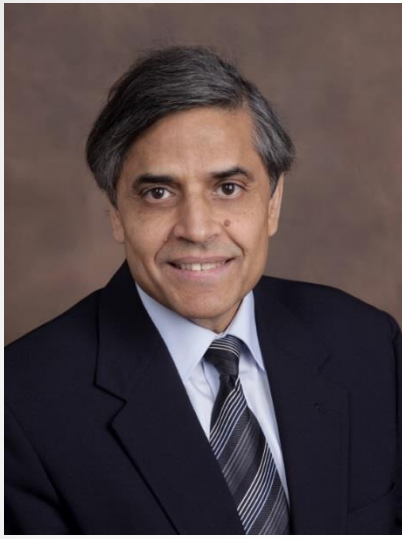

**Subhash C. Sarin** is the Paul T. Norton Endowed Professor in the Grado Department of Industrial and Systems Engineering at Virginia Polytechnic Institute and State University, Blacksburg, Virginia. His research interests are in the areas of production planning and scheduling, applied mathematical programming, and design and analysis of manufacturing systems. He joined the department in 1983 as an Assistant professor, and was promoted to Associate Professor in 1987 and to Full Professor in 1991. He has also taught at The Ohio State University. He became the Paul T. Norton Endowed Professor in 2002. He has advised 52 M.S. and 23 Ph.D. students. He is the author of two books, over 80 refereed publications, and numerous conference proceedings papers. He is a Fellow of the Institute of Industrial Engineers (IIE) and a Full member of the Institute for Operations Research and Management Science. He is a recipient of: IIE Holzman Award as an Outstanding Educator in the Nation (for outstanding contributions in research, teaching and service), Alumni Award for Excellence in Graduate Advising, Dean's Award for Excellence in Teaching, Pletta Award as Virginia's Outstanding Educator of the Year, and Sporn Award for Excellence in Teaching, College of Engineering. Five of his M.S. and Ph.D. students have won IIE Outstanding Thesis and Dissertation Awards in national competitions. He received his B.Sc. in Mechanical Engineering from University of Delhi, M.S. in Industrial Engineering from Kansas State University, and Ph.D. in Operations Research and Industrial Engineering from North Carolina State University.

# Dr. John P. Shewchuk

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Dr. John P. Shewchuk is an Associate Professor in the Grado Department of Industrial and Systems Engineering at Virginia Tech. He received his Ph.D. in Industrial Engineering from Purdue University in 1995: he also holds an M.S. in Industrial Engineering from Purdue and a B.Sc. in Mechanical Engineering from the University of Manitoba, Canada (1984).

Dr. Shewchuk's research interests include lean manufacturing, advanced production planning and control, discrete simulation modeling and analysis, and flexible and agile manufacturing. He is particularly interested in manufacturing and production problems facing the aeroengine/aerospace/aircraft industries. Dr. Shewchuk spent several years employed as a materials and processes engineer, test engineer, and NDT specialist with Bristol Aerospace Ltd. (Winnipeg, Canada). He worked with a variety of advanced manufacturing processes including superplastic forming, diffusion bonding, and electron beam welding. Additionally, he performed ultrasonic, eddy current, and radiographic inspection and evaluation of aeroengine, aircraft, weapons systems, and nuclear reactor components. Dr. Shewchuk has also worked as a simulation analyst with Carrier Corporation (Indianapolis, IN) and as a technical consultant with Purdue University's Technical Assistance Program (TAP).

Dr. Shewchuk's recent awards include the Best Paper Award (Lean Systems Track) at the 19th Industrial Engineering Research Conference (2012) and the Lean Teaching Award from the Institute of Industrial Engineers (2011). He is a member of IIE and a registered professional engineer of the Province of Manitoba.

# Engineering Logistics

Dr. Kimberly Ellis
Dr. Don Taylor

# Center for Excellence in Logistics and Distribution (CELDi)

**CELDi is a university-based enterprise providing innovative solutions for logistics and distribution excellence with our member organizations.**

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- **Six major research universities**
- **More than 20 member organizations from commercial, military, and government sectors of the economy**

# Center for Excellence in Logistics and Distribution (CELDi)

**CELDi has the mission of enabling member organizations to achieve logistics and distribution excellence by developing meaningful, innovative and implementable solutions that provide a return on investment.**

## Through in-context projects, CELDi

- **Solves real problems that achieve bottom-line impact**
- **Graduates students with real-world project experience**
- **Shares research results amongst member organizations to leverage intellectual and monetary capital**
- **Produces generalized, cutting-edge research that is published in leading journals**

Project Highlight

# Asset Allocation Project with Air Liquide

## Project Goal: Reduce Logistics Ratio

(cost-based metric proportional to miles/ton)

**Project Summary:** With the use of mixed-integer programming techniques, the VT team developed a model of Air Liquide operations to determine the right balance between investment in tanks and distribution costs.

**Project Outcomes:**

- Substantial savings realized in distribution costs
- International deployment of software after packaging
- Students: 1 Ph.D. and 1 undergraduate

# Dr. Kimberly Ellis

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Dr. Kimberly Ellis is an Associate Professor in the Grado Department of Industrial and Systems Engineering at Virginia Tech. Dr. Ellis obtained her B.S. and M.S. in Industrial Engineering from the University of Tennessee and her Ph.D. in Industrial and Systems Engineering from Georgia Tech. She has professional experience in production planning and control, systems engineering, and project planning.

Dr. Ellis conducts research in production planning, logistics and distribution planning, and applied operations research. She currently serves as the Site Director of the Center for Excellence in Logistics and Distribution (CELDi) at Virignia Tech. She has conducted collaborated research with Air Liquide, Eastman, LMI, Kollmorgen, Averitt Express, and Ericsson. She is also serving as the President of the College-Industry Council on Material Handling Education.

# Augmented & Virtual Reality

Dr. Joseph L. Gabbard

Project Highlight

# Usability Engineering for AR/VR

- Poor usability in many 3D environments; very little user-centered design and evaluation of AR/VR systems
- Existing usability engineering methods have not been adequately adapted for AR design and evaluation


- How can we effectively design and develop a quality interfaces?
- How can we modify/extend existing usability engineering methods to address difficult AR design activities?

- Developing usability engineering methods for AR for mobile environments
- Conducted a series of user-based studies to help understand user interface design space, parameters and tradeoffs in human-performance

# Dr. Joseph L. Gabbard

Associate Professor
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Dr. Joseph L. Gabbard is currently an Associate Professor in the Grado Department of Industrial and Systems Engineering (ISE) at Virginia Tech. Dr. Gabbard obtained his M.S. and Ph.D. in Computer Science from Virginia Tech in 1997 and 2008, respectively. His professional experience includes working as a consultant in HCI, UX and usability engineering for virtual reality, mobile and life science interfaces.

Dr. Gabbard's work centers on human-computer interaction; specifically usability engineering for novel user interfaces including (but not limited to), 3D environments (augmented and virtual reality), mobile interfaces, visualizations for life sciences using big data, and multimodal interactive systems. Gabbard has been a pioneer in usability engineering with respect to applying, and creating methods for augmented and virtual reality systems for more than 15 years. During this time, he has received funding from the NSF, NIH, the Office of Naval Research, the US Army, the US Navy, and several private companies and foundations.

Dr. Gabbard is the director of the Director of the COGnitive Engineering for Novel Technologies (COGENT) Lab. He is also Director of the ISE Human-Computer Interaction Lab. Currently, he serves on the Program Committee for the forthcoming IEEE Virtual Reality 2014 conference. He has recently authored a book chapter on usability engineering of virtual environments, and has co-authored a second book chapter addressing human factors issues in optical see-through AR displays. He has received multiple awards including the 2004 Alan Berman Publication Award, and the 1999 IEEE VR Conference Best Paper Award.

# Decision Making under Uncertainty

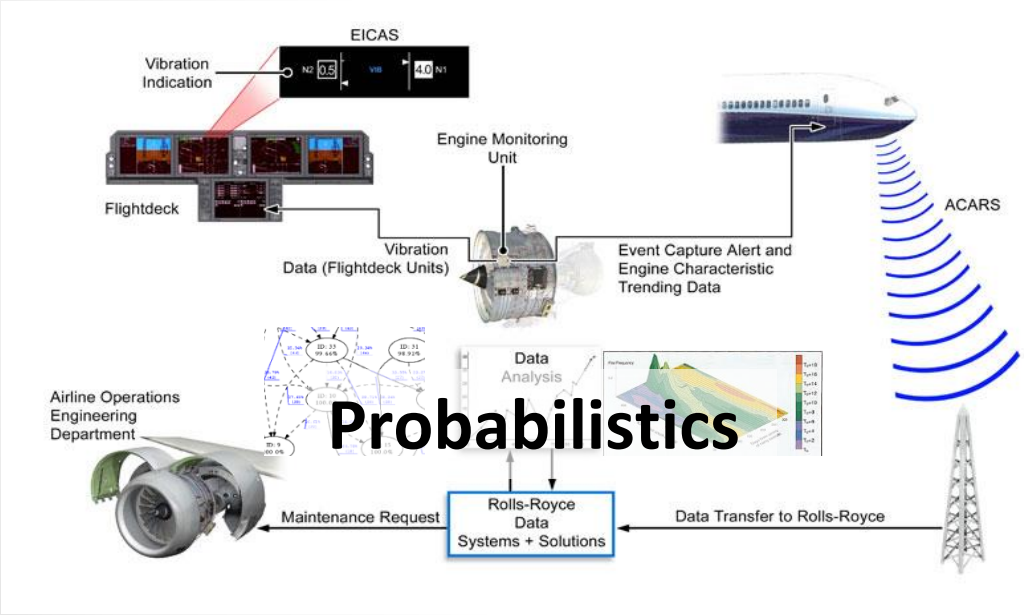
**Dr. Christian Wernz**

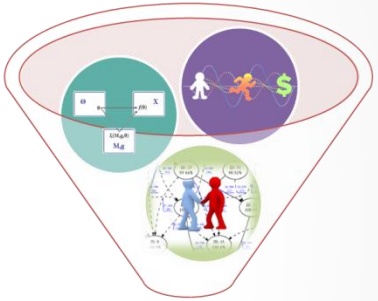
Project Highlight

# Design of Future Maintenance Contracts to Improve Safety and Economics

**1. Opportunity: Advances in Gas Turbine Monitoring and Maintenance**

**2. Using Decision Theory to Analyze and Design Maintenance Contracts**



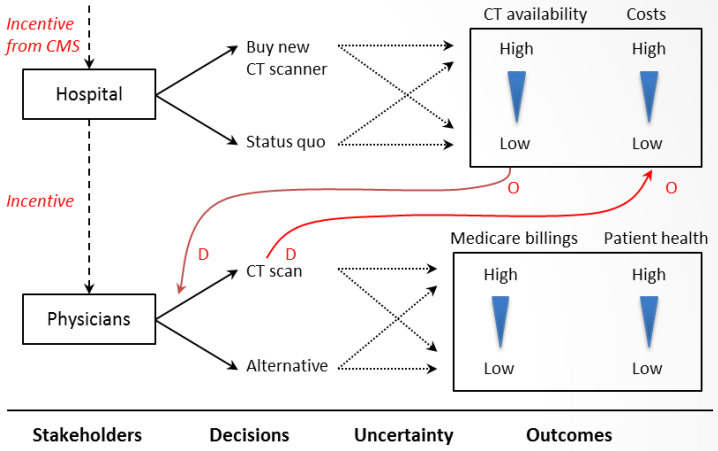



**3. Result: New Contracts with Win-Win**

Project Highlight

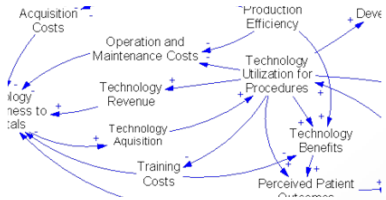
# Other Projects on Advances in Decision-Making and Systems Design

1. **Decision-Making across multiple organizational levels and time scales under uncertainty (National Science Foundation, NSF)**




2. **Project/Investment Prioritization for complex, multi-objective decision problems, e.g. medical technology investments by hospitals (Agency for Healthcare Research and Quality, AHRQ)**


Data-to-Information method: System Dynamics (SD)




Information-to-Decision method: Decision Analysis (DA), SMARTS

| Objective Category | Financials | Quality | Capac Acce |
|---|---|---|---|
| Evaluation Criteria | Investment… is profitable | …enhances quality of patient care | …crea capacit future g |
| Evaluation Measures | Net present value (NPV), return on investment (ROI) | Health outcomes, patient satisfaction | Increase patients market |

# Dr. Christian Wernz

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Dr. Christian Wernz is currently an Assistant Professor in the Grado Department of Industrial and Systems Engineering at Virginia Tech. He received his doctorate in Industrial Engineering and Operations Research from the University of Massachusetts Amherst in 2008. He obtained his bachelor's and master's degree in Industrial Engineering and Business Administration from the Karlsruhe Institute of Technology, Germany, in 1999 and 2003, respectively.

Dr. Wernz's research focuses on complex system analysis, decision-making and multiscale system analysis. In a recent research project, he analyzed maintenance contracts in the gas turbine industry and developed solutions for new contract design. Other research on complex systems includes health care systems analysis. Through advanced decision-making tools, stakeholders – including physicians, hospitals, insurance companies – are supported in improving organizational design and decision strategies. In general, research methods include decision analysis, game theory, agency theory, mechanism design theory, Markov decision processes and multiscale decision theory.

Among his awards and scholarships, he received the 2006-07 Graduate School Fellowship for Outstanding Doctoral Students, the 2004-05 Eugene M. Isenberg Award for Entrepreneurship and Technology Management, Germany's 2003-04 Research Scholarship for Post Graduate Research, and he was a German National Academic Foundation Fellow from 2000-04. In recent years, he was a finalist for two best paper awards from the Institute of Operations Research and Management Science (INFORMS).

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