Robotic Technology Development in Sewing and Textile Handling
SPESA 2019 Executive Meeting
New Orleans, October 29, 2019
Arnold Kravitz, CTO, Advanced Robotics for Manufacturing (ARM)
ARM FORMATION

- Established: Jan 13, 2017 by Carnegie Mellon University (now separate entity)

- Located at Mill 19, Hazelwood Green, Pittsburgh, PA, USA

- Approximately 90,000 sq feet occupied by ARM, CMU and MEP Catalyst Connection
ADVANCED ROBOTICS FOR MANUFACTURING

- Chosen by the Department of Defense to allocate the investment of $80 million to grow U.S. manufacturing
- Consists of dedicated staff and resources focused on spurring innovations in robotics technologies and workforce development
- Guided by a consortium of members in industry, government agencies, economic development, academia and technology who are experts in advanced robotics and education
ARM Nature, Mission, and Method

Nature
- Diversified public-private partnership

Mission
- Increase U.S. global manufacturing competitiveness

Method
- Develop a strategy to invest in the most urgent and important Key enabling technologies for Robotic Manufacturing acceptance and adoption

A Diverse and Influential Membership

Investing $10M of consortium funding on 7 textile handling or sewing projects ($7M consortium funding, 3.5M OSD funding)
**ARM Approach to Invigorate US Manufacturing**

**Strategic thrusts**

1. **Assert leadership** in advanced robotics manufacturing thru achievement
2. **Lower** the technical, operational, economic and regulatory barriers hindering companies from adopting robotics technologies
3. **Deploy workers** in a way that is cost-competitive with low-wage workers abroad
4. **Aid in the creation**, sustenance and societal understanding of the **value** of manufacturing jobs

**Tactics**

1. Identify and invest in Key Enabling Technologies with large market lift
2. Educate, train and develop a workforce to use the robotic technology
3. Nurture and sustain a robotic manufacturing infrastructure and ecosystem
WHAT ARM DOES

- Provide funding to further develop advanced robotics technology
- Provide funding to further develop innovative robotics training
- Provide access to a nationwide ecosystem of innovators and industry insights
- Transition new technology to the factory floor
NATION’S STRONGEST MANUFACTURING + ROBOTIC ECOSYSTEM

SEWING INDUSTRY
Hickey Freeman
Bluewater Defense
Sewbo
Vibram

COMPOSITE FIBER APPLICATION MANUFACTURERS
Lockheed Martin
Boeing
Raytheon
Northrup Grumman
Airbus
Fiat Chrysler
GE
Siemens
United Technologies
Qinetiq

ROBOT SUPPLIERS
ABB
FANUC
YASKAWA
ATI
IAM
RE2
Harmonic
Force Robots
iCobotics
Orangewood Labs
Picknik
Ubiros
Motus
Hebi

RESEARCH INSITUTES
CMU
MIT
USC
Purdue
Texas A&M
Princeton
UC Berkeley
Textile Membership

3M  Yaskawa  WPI
bluewater defense

Wichita State University  SEBOW  Hickey Freeman Eyewear

Fanuc  Siemens  University of Southern California
R&D AND TESTING FACILITY IN PITTSBURGH, PA

- Mill 19
- Prototyping and testing
- Center of Pittsburgh’s manufacturing and robotics districts
- 30K sf high bay
- 30K sf low bay
THOUGHTS ON THE FUTURE OF MANUFACTURING

- Automating tasks, not jobs
- Robots should perform
  - Tasks that people can’t do well
  - Tasks that humans shouldn’t be doing at all
- Humans and robots working with and around each other will take our manufacturing productivity to new heights.
- Increasing our manufacturing productivity will attract and create thousands of manufacturing jobs, revitalizing the middle class.
THOUGHTS ON THE FUTURE OF TEXTILE MANUFACTURING

- Point of service manufacturing
  - Reduced supply chain timeline
  - Nimble customer service
  - Reduced inventory waste
  - Less guess work predicting market demand

- Reshoring jobs
  - Manufacturing more product per person
  - Up-skilling the textile workforce

- Robots should perform
  - Tasks that people can’t do well
  - Tasks that humans shouldn’t be doing

- Humans and robots working co-operably and collaboratively improve productivity

- Increased productivity will attract investment creating new middle-class manufacturing jobs

- Scanners and robots have the potential to democratize custom-made clothing
  - Scanners scan customer’s body
  - Advanced processors can custom design the patterns for clothes that fit as desired
  - Digital twin software with improved user interfaces can allow the consumer to visualizes themselves in the desired garments in the scenarios they desire
  - Onsite manufacturing has the potential to produce the garments while the customer is having lunch, a few drinks, spa treatment, or other revenue generating activities

Agile, flexible, and reconfigurable sewing robots enabling distributed manufacturing by both large and small manufacturers
ARM TECHNOLOGY FOCUS
INVESTMENT FOCUS

Manufacturing Process
- Metal Finishing
- Textile handling (includes Composites)
- Logistics
- QA / inspection

Market Segments
- Aero Space
- Automotive
- Food Inspection
- Sewing
- Heavy equipment
SEVERAL AREAS OF ARM’S TECHNOLOGY INVESTMENT STRATEGY SUPPORT ROBOTIC SEWING AND TEXTILE HANDLING

FA-1 RISK REDUCTION FOR TRANSITION TO THE FACTORY FLOOR

1.1 Methods and tools for successful robotics adoption and expansion
1.2 Methods and tools for streamlining integration
1.3 Methods and tools for assessing industrial readiness of new technology
1.4 Virtual modeling and testing of robotics systems
1.5 Improving design and standards for robot safety

FA-2 HUMAN-ROBOT INTERACTION

2.1 User-friendly interfaces for programming, operation, and maintenance
2.2 Bi-directional communication on the shop floor
2.3 Human-robot trust and safety

FA-3 INTER-OPERATABILITY

3.1 “Plug-and-play” software and standards (System Level)
3.2 Plug-and -hardware and standards (System Level)
3.3 Open source and open architecture software, methods, and environments
3.4 Master Integration Platform
3.5 Metrics of Interoperability

FA-4 RECONFIGURABLE, AGILE, AND FLEXIBLE ROBOTICS SYSTEMS

4.1 Agile and reconfigurable robotic design
4.2 Modular robotic design
4.3 Smart, flexible tooling and end-effectors
4.4 Smart, flexible sensors and integration
4.5 Automated path planning and robot instruction generation
4.6 Virtual Modeling for Reconfigurable, Agile, and Flexible Robot

FA-5 INTELLIGENT ROBOTIC SYSTEMS

5.1 Self-aware and adaptive systems
5.2 Machine learning and Artificial Intelligence
5.3 Distributed, edge, and cloud computing
5.4 Advisor Robot: Observation, identification, fault detection, and training.

Note the Bolded sub focuses areas were rated by the Membership to be the most Urgent and Important At last years membership meeting and are the basis of our calls.
Projects span many market segments developing robotic manufacturing solutions across a wide spectrum of manufacturing applications

### Manufacturing Process
- **14 Underway**
  - 3 Fabrication
  - 4 Metal Finishing
  - 2 Textile handling (includes Composites)
  - 3 Logistics
  - 2 QA / inspection
- **6 Selected**
  - 1 Metal Finishing
  - 3 Textile handling (1 of which is sewing)
  - 1 QA / inspection
  - 1 User interface improvement
- **3 Special topics**
  - 1 Metal Finishing
  - 1 Textile handling
  - 1 Chemical Fabrication
- **2 Special projects**
  - 2 Wiring harness fab

### Market Segments
- **Calls**
  - Space
  - Automotive
  - Food Inspection
  - Textile / garment fabrication and composites
  - Heavy equipment
- **Cross Institute Special topics**
  - Heavy equipment (MXD)
  - Textile garment fabrication (AFOA)
  - Biomedical pharmacology (NIIMBL)
  - Proposal for a new institute (CESMII)
- **Special projects**
  - Automotive, Marine, Electrical switch gear and controls, large electronics
MEMBERSHIP PROVIDES AN ELITE TEAM OF EXPERTS FOR ADVICE AND COUNCIL

- TAC
  1. Regularly scheduled Monthly Meeting
  2. Serving as pools of expertise
     - SMEs to supporting technical design reviews to the Programs
     - SMES are supporting process the Metrics Evaluation working group.
  3. Serving as volunteers for proposal reviews
TEXTILE HANDLING AND SEWING PROJECTS
$10m CONSORTIUM INVESTMENT IN 7 PROJECTS (2 COMPLETED 2 UNDERWAY 3 CONTRACT)

<table>
<thead>
<tr>
<th>Status</th>
<th>Year</th>
<th>Compiled Title</th>
<th>Lead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comp.</td>
<td>2017</td>
<td>ARM-17-QS-F-01: Robot Assistant for Composites Manufacturing</td>
<td>RPI</td>
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<tr>
<td>Comp.</td>
<td>2017</td>
<td>ARM-17-01-F-20: Robotic Assistants for Composite Layup</td>
<td>USC</td>
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<td>underway</td>
<td>2018</td>
<td>ARM-TEC-18-01-F-21: Robotic Assembly of Garments</td>
<td>Siemens</td>
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<tr>
<td>contracts</td>
<td>2019</td>
<td>ARM-TEC-19-01-F-12: Collaborative Composite Sheet Layups for Complex Geometry of Small Plies</td>
<td>UTRC</td>
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<tr>
<td>contracts</td>
<td>2019</td>
<td>ARM-TEC-19-01-F-14: Development of a Cost Effective Robotic Sewing System</td>
<td>RPI</td>
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<tr>
<td>contracts</td>
<td>2019</td>
<td>ARM-TEC-19-01-F-18: Handling &amp; Direct 3D Draping of Limp Materials</td>
<td>GE R&amp;D</td>
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2 assembly and sewing garments and uniforms
5 Manipulating handling and bonding woven fabrics
<table>
<thead>
<tr>
<th>Title</th>
<th>Process description</th>
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<tbody>
<tr>
<td>Robotic Assembly of Garments (Siemens SEWBO Berkley, Blue water def.)</td>
<td><strong>Robotic Assembly of Garments</strong> - Develop technology to demo the sewing of a uniform.</td>
</tr>
<tr>
<td>Rensselaer CATS, Interface Technologies, DAP America, Hickey Freeman, National Safety Apparel, Yaskawa America</td>
<td><strong>Development of a Cost Effective Robotic Sewing System</strong> - develop a robotic system that can manipulate a subset of fabric types and sew a pair of Men's Trousers</td>
</tr>
<tr>
<td>University of Southern California, UTRC, and Lockheed Martin</td>
<td><strong>Robotic Assistants for Composite Layup</strong> - Robotic system to drape and layup multiple layers of carbon fiber sheets over a saddle point with out wrinkles or bubbles</td>
</tr>
<tr>
<td>The Boeing Company; University of Southern California, Rensselaer Polytechnic Institute</td>
<td><strong>Large Composite sheet handling robot</strong> - layup mandrel, large woven composite sheet, manipulated by human-robot team</td>
</tr>
<tr>
<td>Rensselaer CATS, Interface Technologies, DAP America, Hickey Freeman, National Safety Apparel, Yaskawa America</td>
<td><strong>Development of a Cost-Effective Robotic Sewing System</strong> - Develop a robotic system that can manipulate a subset of fabric types and sew a pair of Men's Trousers</td>
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Robotic Assembly of Garments

Technical Approach
- Stiffened but compliant textiles are manipulated, molded, welded, and sewed
- Simulation-based; trajectory planning, pose/shape estimation, grasping and visual servo to flexibly manipulate, position and sew fabric sheets

Value Proposition
- Point of service garment manufacture anywhere
- Scalable from boutique to factory
- Clothing made to order while you wait
- Reduce repetitive motion injury positions
- Reduce cost and improved throughput

Demo will include the sewing of a Military uniform

Siemens Corporate Technology, University of California at Berkeley, Sewbo, Bluewater Defense

ARM Cost: $486,652
Cost Share: $626,465
Total Budget: $1,113,117
**Development of a Cost-Effective Robotic Sewing System**

**Need**

- **U.S. domestic Apparel Manufacturing lost 316,000 jobs, a 62.7% job force reduction, from Jan 2000 - December 2018 to foreign suppliers with lower labor costs.**
  
  - Problem: Human operators must touch every piece of fabric
  - Lack of reliable commercially available robotic solutions that can obtain a single layer of fabric, called a ply, from a bundle containing many plies
  - Designing custom end effectors for products that undergo changing styles and fabrics requires a significant amount of integration and design effort
  - Target sizeable market sub-segment (Men’s Trousers) to create cost effective robotic solutions

**Benefit**

- **Significantly reduced human touch points -1 operator loads entire bundles into 4 machines instead of separate pieces into 1 machine.**
  
  - Improved Productivity: Current state; one operator 700 units per machine per 8 hr shift. The target state is 2,800 trousers per work group in an 8 hrs shift (480 minutes). A work group consists of 1 operator per 4 serging machines, and two robots
  - 300% productivity increase per serging operator
  - Defect rate target no greater than 14/2800 trousers or 0.05%
  - Efficiency: 90% efficiency target as compared to an industry standard of 80% for manual sew operations
  - Investment Prudency: Predict 540 days to breakeven or 66.7% annual ROI. @ $134,000 system cost payback is 18 months Robotic system for work group. (2 Robots, Control Systems)

**Approach**

**Robotic Feed of Automated Serger Sewing Systems**

1. Create cost effective robotic solutions
2. Develop End Effector that can load single ply work pieces from a bundle into two serge sewing systems
3. “Plug and Play” Open Source software modules for existing MES system:
   - a. Work Group Controller that obtains piece and ply data from CAD
   - b. Operator Interface to safely load fabric bundles instead of individual fabric pieces
   - c. Maintenance I/F for plant technicians to configure, deploy and maintain the system

**Business Case**

**Over 2 billion Men’s and Boy’s trousers produced annually, 21% can be sewn on serging systems1.**

- Men’s Trousers are a sizeable market sub-segment
- New product category: robotic feeders for serging systems
- Initial $6.3M potential market, growth to $126.75 M1 within 5 years.
- First affordable robotic implementation for medium sized Apparel Manufacturers. Robotic Feeder system designed for 18-month payback @ $134K acquisition and deployment cost.
- Initial 100% “first-mover” market status. Future development to automate other sewing workstations will yield similar market size for each new robotic workstation feeder system and maintain status
- Low cost labor countries (ie: Bangladesh, Indonesia, Nicaragua) will remain primary competitors, followed by copycats

**Rensselaer Polytechnic Institute, Interface Technologies LLC, Bluewater Defense**

Topic Area 5 (TA5), Modular Robotic Designs and Topic Area 2 (TA2), User Friendly Interfaces for Programming, Operation and maintenance.
ROBOTIC ASSISTANTS FOR COMPOSITE LAYUP

University of Southern California, Lockheed Martin, United Technologies Research Center

Technical Approach & Methodology
- Demonstrate technical feasibility of automating composite layup process through robotic assistants
- Make advances in perception, planning and control areas to enable use of robotic cells in composite layup process
- Evaluate the quality of robotic layup process and compare it with manual process
- Perform business case evaluation and develop technology transition plan

Description
- Advanced composites are critical to US aerospace and defense industries
- Layup of prepreg sheets is one of the main processes for realizing composite parts with complex geometries
- Sheet layup process requires significant manual labor
- Sheet layup automation reduces ergonomic challenges and increase throughput

Technology Transition & Deliverables
- Software for Perception, Planning, and Control for performing composite sheet layup
- Cell design for performing composite sheet layup
- Robot end-effector designs used for composite sheet layup
- Operation parameters for performing automated composite layup on two industry use-cases provided by the Lockheed and United Technologies
Human-Robot Teaming for Composite Ply Lay-up and Conforming

Technical Approach & Methodology
- A large woven composite sheet part, a layup mandrel, is manipulated by a human and a robot working collaboratively.
- AI is used for Robotic motion planning and dynamic scheduling of tasks.
- AI Force feedback, gesture control, and exception replanning are used to enhance the Human robot interface.

Value Proposition
- Manipulation and handling of bulky, semi-stiff, heavy textile and composite materials is prone to cause worker injury and involve multiple workers in a team.
- Frequent breaks are necessary to prevent injury and fatigue induced errors.
- Dynamic Cobots aiding human workers prevent these injuries and exhaustion induced errors from occurring.
- Force controllers, motion planning, and task planning algorithms and methodologies are key to the efficient handling of the materials while avoiding inertias and forces that will exhaust or injure the human coworker.

The Boeing Company, University of Southern California, Rensselaer Polytechnic Institute
Motivation & Background
- Wind turbine blade manufacturing a time-consuming, labor-intensive process
- Manufacturing of segmented structure based on fixtures for alignment
- Drive to improve ergonomics, product quality, process efficiency
- Challenges: Large, heavy, curved loads, structural flexibility, high precision alignment requirement

Objectives
- Demonstrate safe, robust, efficient robotically assisted fixtureless precision blade assembly
- Develop sensor-based robot control software for manipulation of large, heavy, flexible loads.

Key Metrics:
- Cycle Time
- Alignment Tolerance
- Damage avoidance (vibration, placement)

Tasks & Milestones
- Testbed hardware setup (3/18)
- Testbed software setup (3/18)
- User Interface (5/18)
- Panel pickup (7/18)
- Panel transport (8/18)
- Panel alignment/placement (11/18)

Evaluation (2/19)
- Data management (2/19)
- Education workforce development (2/19)
- Final report and demonstration (4/19)

Conclusion & Applicability
- Development of sensor-based robotics technology to automate composites manufacturing with faster cycle time, increased precision, and process repeatability.
- Demonstration of sensor-based robot manipulation and assembly of large structures using open source tools to allow adoption in other industries with needs for robotic manipulation of large payloads, e.g., aerospace.

Anticipated Results
- Vision and force guided industrial robot manipulation of composites panels (pickup, transport, and placement) in ROS architecture with integrated simulation.
- Fast and robust robotic composite panel assembly with precise alignment and gentle panel pickup and placement.
- Multi-mode user interface: teleoperation, shared control, supervised autonomy
- Competency matrix for robotics in composites manufacturing
- Knowledge capture and database for robotics in composites manufacturing

Intellectual Property
- Integrated robot motion planner and controller with sensor (vision, force, vacuum pressure) and user inputs through robot external guided motion
- User directed path planning
- Learning-based robot dynamics compensation using robot dynamic simulator
- Robot motion control with payload vibration suppression
- Multi-RGBD based safety system
ARM Education and Workforce Development Focus
MAJOR CHALLENGES

Six major challenges to prepare US workforce for the future of advanced manufacturing

In response to these challenges, ARM is working with our Member organizations to address the overall education and workforce development goal of expanding the size, diversity, and skill set of the United States robotics workforce.

1. U.S. education insufficient for advanced mfg. careers
2. Negative perceptions of robotics and manufacturing
3. SMEs have limited resources to prepare talent
4. Manufacturing workforce not prepared for continual re-skilling
5. Little coordination between initiatives in advanced mfg.
6. Regional skill gaps in manufacturing skills
Evolution of Workforce Investment Strategy (WIS) Framework & Calls

- Stakeholder feedback
- Research
- Focused Topic Summits

Roadmapping Sessions

1st EWD Project Call
- Develop apprenticeship programs for small and medium manufacturers (SMMs) in robotics and automation

2nd EWD Project Call
- Work and Learn
- Micro-Credentialing
- Talent Attraction
**Next Key Challenges to Address**

1. U.S. education insufficient for advanced mfg. careers
2. Negative perceptions of robotics and manufacturing
3. SMEs have limited resources to prepare talent
4. Manufacturing workforce not prepared for continual re-skilling
5. Little coordination between initiatives in advanced mfg.
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**Skills Gap**

**Re-Skilling**
Why Do We Have To Continuously Learn and Adapt?
**EXPECT INDUSTRY 4.0 TO IMPACT MANUFACTURING JOBS**

Industry 4.0 technologies drive link between workers, equipment, software, and machines... 
...increasing the need for certain jobs and creating new jobs altogether

- IT solutions architects
- Robot coordinators
- Industrial data scientists
- Sales and marketing agents
- Digitally assisted field service engineers

**Industry 4.0**

- Big Data and analytics
- Augmented reality
- Additive manufacturing, e.g. 3D printing
- Cloud
- Autonomous robots
- Simulation
- Industrial Internet (network of hardware-integrated sensors)
- Horizontal/vertical software integration
- Cyber-security
DRIVING GROWTH AND DIRECTLY CREATING 900K NEW INDUSTRY JOBS

Estimated # jobs directly created by Industry 4.0 through 2025

Jobs along all functions will be affected by Advanced Robotics

Refer only to functional roles directly related to managing robotics
ACCELERATING THE MANUFACTURING RENAISSANCE WITH PEOPLE & ROBOTS. TOGETHER.

- Working to instill an enthusiasm for active, lifelong learning.
- Showing that robots are collaborative and can help human workers and attain more rewarding, in-demand, safer manufacturing careers.
- Creating a robust workforce pipeline that keeps students engaged in STEM and promotes careers in manufacturing.