Sustainable Manufacturing

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Third Wave Systems Inc.

Georgia Institute of Technology, Purdue, Pennsylvania State University, University of California Santa Barbara

2012-2015

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Third Wave Systems Inc.

THIRD WAVE SYSTEMS Georgia Tech PURDUE UNIVERSITY UCSB UNIVERSITY OF CALIFORNIA SANTA BARBARA PENNSTATE

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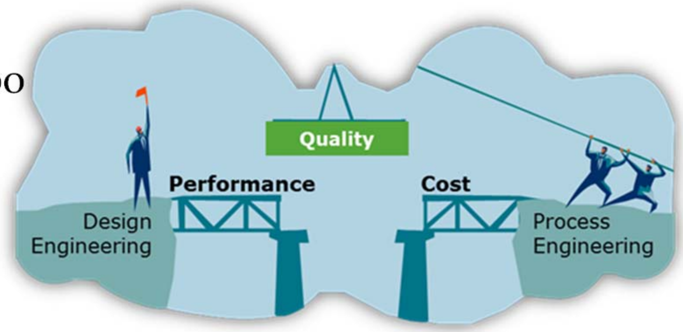
Project Objective

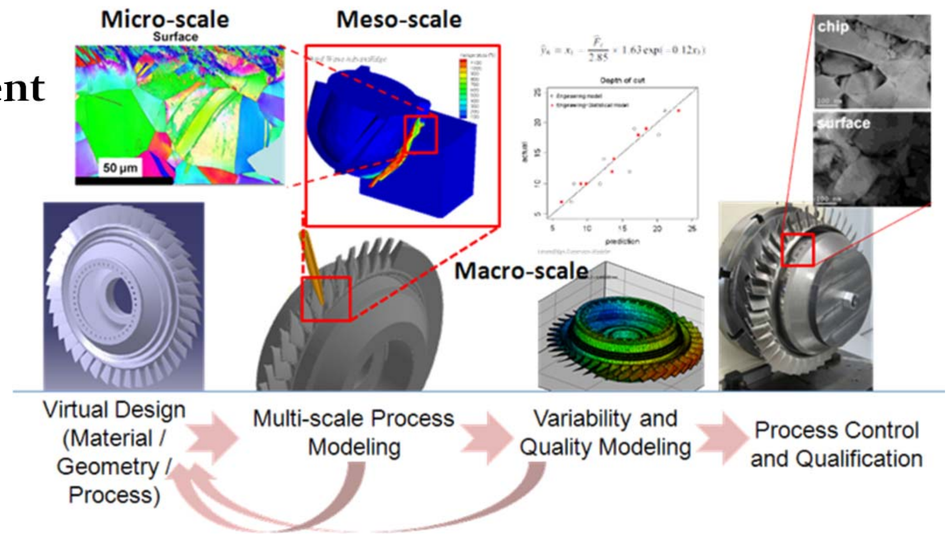
- What are you trying to do?
  - Develop and demonstrate a new **manufacturing-informed design paradigm** to dramatically improve manufacturing productivity, quality, and costs of machined components
- What is the problem?
  - Current machining processes and cutting tool designs are slow and too conservative, leading to high costs and significant waste
  - Currently, design teams are "*manufacturing-aware*," not necessarily "*manufacturing-informed*"
  - Performance, Cost and Quality problems are found too late in the Product Development Process



- Challenges
  - Lack of sufficient fundamental understanding of process physics
  - Lack of physics-based process design and optimization tools for finish and semi-finish operations
  - High computational costs of modeling at multiple length and time scales for process optimization
  - Statistical variability of tooling, equipment, and materials

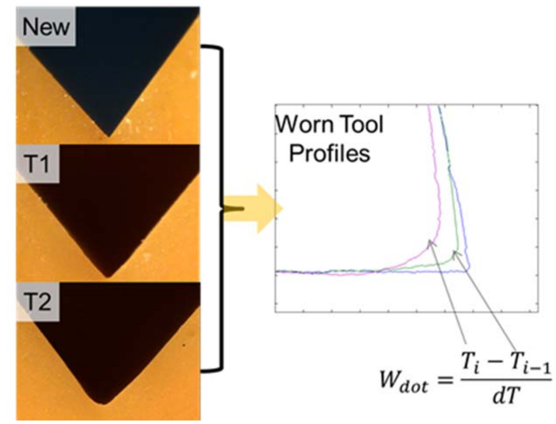
Technical Approach

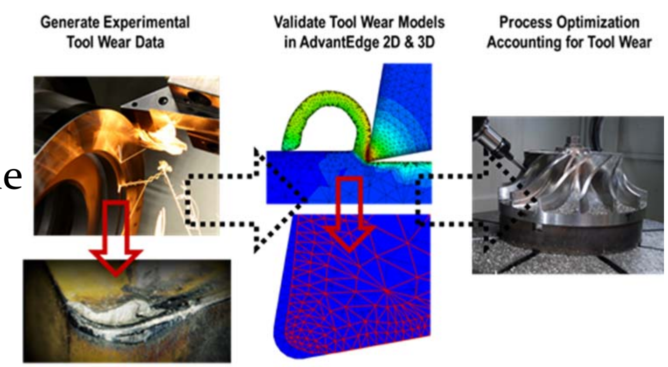
- **State-of-the-art**
  - “*Manufacturing aware*” part and process design – No knowledge of process outcomes (cost, quality, performance) until manufacturing trials
  - Long and slow trial-and-error design of machining processes and cutting tools
  - Resulting manufacturing processes and cutting tool designs are conservative – unnecessarily slow, sub-optimal and expensive
- **Innovation**
  - **Multi-scale Physics-based Modeling** can provide detailed knowledge of process outcomes before manufacturing trials
  - **Physics-based Optimization** can squeeze significant productivity from state-of-the-art machining processes
  - **Reduce** (rough and finish) **machining costs and cycle times**, while **extending tool life** and maintaining **component performance**



Technical Approach

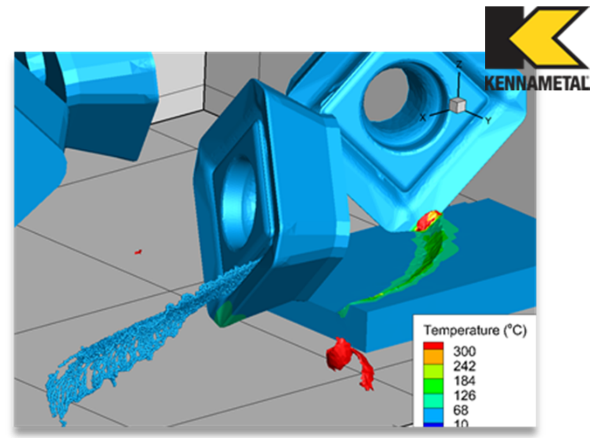
- Third Wave Systems is a market leader in physics-based process modeling in Machining
  - 100% SBIR Commercialization Score
  - Consistently achieved 25-35% reduction in cycle times for roughing operations
  - Customers include all major component and tool manufacturers
- Partnering with premier universities focused on experimental and computational methods in machining and materials science
- Utilize or develop advanced tools and techniques to achieve goals
  - **Experimental measurement** - SEM for microstructure, new cost-effective tool wear measurement techniques, etc.
  - **Computational techniques** - SPH for coolant jet modeling, parallel FEM, massively parallel programming, etc.
  - **Verification** and **validation** of every new model and process
- Technical exchange with existing and new commercial customers every Quarter
  - Applying new technology to solve customer problems
  - Verification and validation enables high accuracy
  - Technology incorporated into commercial versions of the software



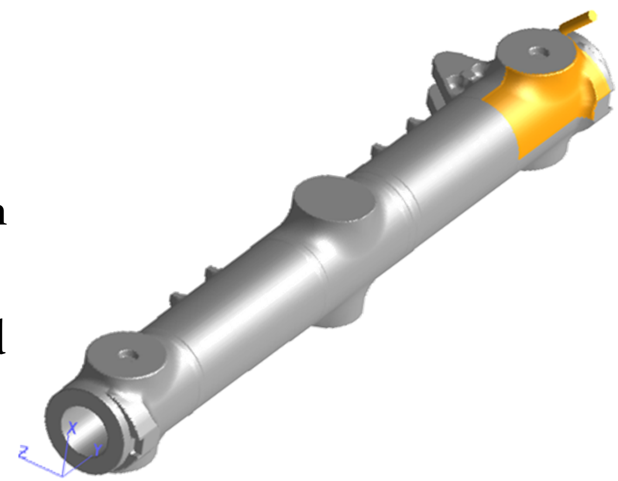


Transition and Deployment

- All modeling components will be verified, validated and incorporated into TWS commercial software – *Civilian and Defense*
- Cutting Tool Manufacturers
  - **Who**: Kennametal, Ceratizit, Ingersoll, ATI Stellram, Allied Tools
  - **Why**: Improve cutting tool designs - specifically coolant delivery and tool life–related improvements, faster tool design iterations
- Aerospace Manufacturers
  - **Who**
    - Jet Engine: GE, Pratt & Whitney
    - Airframe: Boeing, GKN Aerospace, NexTech, Raytheon
    - Landing Gears: UTC Goodrich
  - **Why**: Higher tool life, reduced cycle times, reduced costs, reduced energy consumption, effective coolant usage, improved final microstructure properties and performance, accelerated insertion of new materials



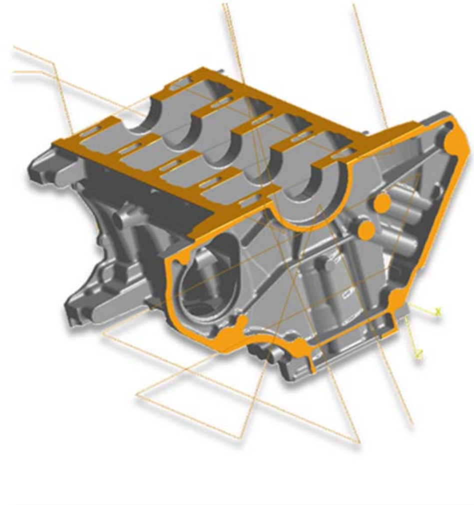
Cutting Tool Manufacturers



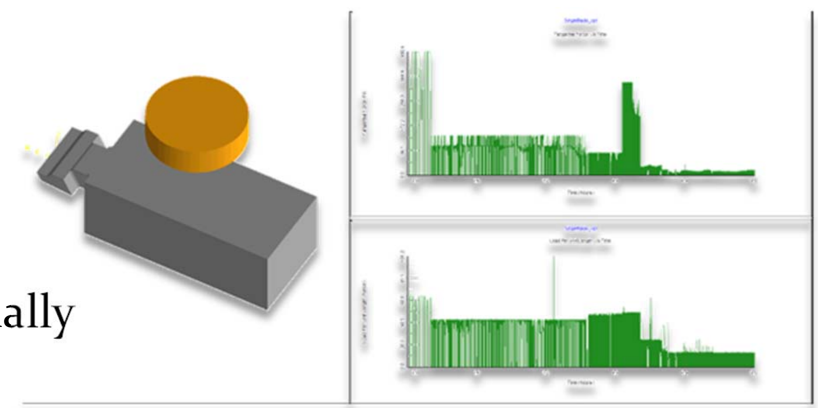
Aerospace Component

Transition and Deployment

- Others
  - Automotive and Heavy Equipment
  - Medical Implants (e.g. DePuy Synthes)
  - Oil &Gas and Power Systems
  - **Why**: Longer tool life, reduced cycle times, reduced costs, reduced energy consumption, effective coolant usage, improved final microstructure properties & performance, and accelerated insertion of new materials
- Technology Sustainment Strategy
  - Early technology adoption of component technologies by partners
  - Incorporation of technology into commercially available software and services



Automotive



Power Systems

TWS Customers

Measure of Success

- **Impact and Metrics**
  - Demonstrate a **manufacturing-informed design framework** in a machining context.
    - **Metrics**: Correlation (error %) with experimental data for Forces, Torque, & Microstructure
  - Advanced optimization algorithms that take into account final component characteristics to **reduce machining cycle times by 50 percent**, while maintaining or improving cutting tool life.
    - **Metrics**: Achievement of 50% reduction in machining cycle time on representative components
- **Energy and Economic Impact**
  - Achieve **50 percent reduction in machine tool *tare* energy and water consumption** in machining via reduced cycle times, coolant and tooling consumption.
  - Achieve a **50 percent reduction in cycle times and energy consumption** for machining.
  - Save over **4.1 trillion BTUs per year** and **7.2 million metric tons of CO2-equivalent per year** for machining processes.
  - Estimated savings of **$1.14 billion in tooling** costs, reduction of **$24 billion in cutting fluid** costs

	Carbon equivalent (CO_2 eq)	Lifecycle Energy Consumption
Lifecycle consumption of a single CNC machine tool	782 tons CO_2-eq [2]	444 million BTUs
Yearly consumption of a single CNC machine tool	65.16 tons CO_2-eq /year	37 million BTUs
Yearly consumption of U.S. installed base	14.48 million tons CO_2-eq/year	8.22 Trillion BTUs/year
Total Savings (estimated)	**7.24 million tons CO_2-eq/year**	**4.12 trillion BTUs/year**
	Coolant Usage	**Water Usage**
Yearly consumption of U.S. installed base	100 million gallons	500 million gallons
Total Savings (estimated)	**50 million gallons/year**	**250 million gallons /year**

Project Management & Budget

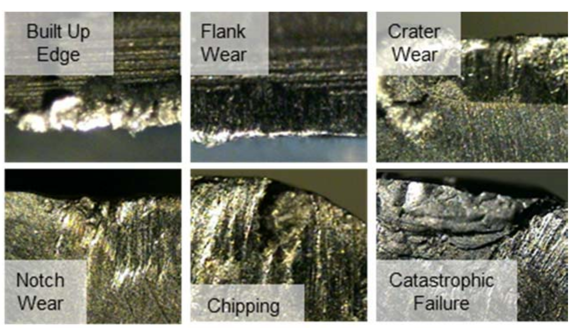
- Project Duration : 36 months
- Project task and key milestone schedule
- Measure of Progress and Success
  - Project Plan has Qualitative and Quantitative Milestones
  - Comparison against experiments (validation metrics)

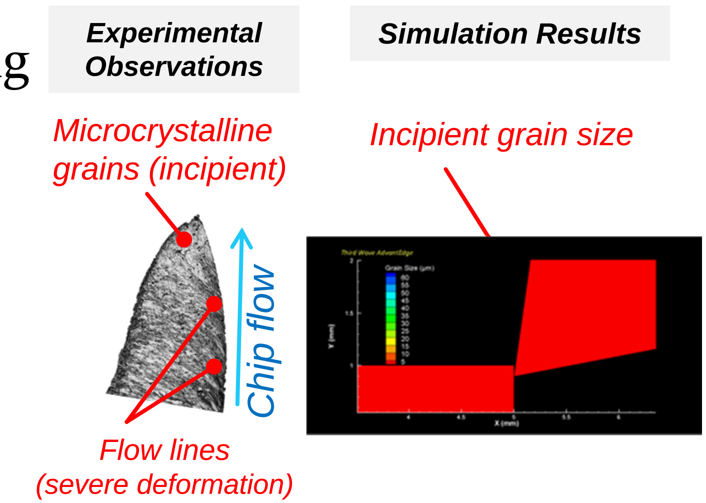
Number	Go / No-go Description	Verification Method	Planned Completion Date
1	Coolant model implementation	Simulate 27 turning cases, achieve 90% completion success rate	End of Budget Year 1
2	Tool wear model prediction	Simulate 18 conditions, achieve 90% success rate of completion	End of Budget Year 2
3	Cutting force prediction	Predicted and measured forces within 30% agreement	End of Budget Year 2

Total Project Budget	
DOE Investment	$4,069,880
Cost Share	$964,719
Project Total	$5,034,599

Results and Accomplishments

- Advanced machining microstructure modeling
  - Force prediction within
- Coolant Model Developed
  - Verification Complete (Thermo-mechanical effects)
  - Validation is on-going
- Tool Wear Model Development
  - New methods of wear quantification and calibration completed
- Statistical Variability Modeling
  - Developed and verified methodologies for variability modeling for cutting forces given variations in hardness and tool geometry





Good qualitative correlation between simulation and experiments for incipient grain size.