Integration of AVM iFAB Tools for Industrial Use
DMDII-14-01-09
Penn State Applied Research Laboratory

April 12, 2016
Prepared for: Model-Based Enterprise Summit 2016

Primary Point of Contact: Chris Ligetti
Principal Investigator
Email: cxl300@arl.psu.edu
Agenda

1. Project Background
2. Problem Statement
3. Proposed Solution
4. Scope of Work / Manufacturing Analysis
   System Components
5. Assisting Organizations
6. Success Criteria
Background

• DARPA Adaptive Vehicle Make (AVM)
  • Portfolio of programs aimed at reducing development time of complex
    weapon systems

• iFAB Foundry – **manufacturing** component of AVM
  • Manufacturability Assessment
    • Provide automated feedback to designer
    • Cad-embedded Design Assist Tools to support manufacturable designs
    • Primary metrics: Cost and Lead Time

• Foundry Configuration
  • Pareto front of build plan alternatives
  • Schedule development and decision-maker analysis

• Manufacturing Execution
  • Generate and maintain machine code, work instructions, and tech data
  • Handle work plan exceptions and problem reports
  • Provide build status/As-built TDP
Background

Design (for Manufacturability) Assist Tools - DATs

• AVM Challenges/Discoveries
  1. Design (for manufacturing) environment must be in CAD software
  2. Designs must contain enough “manufacturing data” for analysis
  3. Guiding/Constraining designers increases likelihood of manufacturable design (or within cost/lead time targets)

• ARL Penn State developed Design Assist Tools to be used by designers within the Creo environment
  • Guide: offering valid options for materials, part classes, welds, etc. that results in data specification used in manufacturability analysis
  • Constrain: limit options to what is supported in component and manufacturing model libraries; rejecting non-iFAB-able designs

• HuDAT – Hull Design for Manufacturability Assist Tool
• MAAT – Manufacturing Analysis Augmentation Tool
Problem Statement

• Problem Statement Overview
  • Current ability to conduct detailed manufacturability assessments and cost roll-ups throughout the design process requires human-in-the-loop interaction
  • Early detection of manufacturability issues or expected excessive costs prior to manufacturing release will reduce product cost and total development time

• Current State Baseline

<table>
<thead>
<tr>
<th>Process</th>
<th>Industry Standard</th>
<th>Current State of Research (AVM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturing Data Specification</td>
<td>Manual; lacking in concept/early design; insufficient for analysis</td>
<td>CAD-embedded Design Assist Tools (DATs)</td>
</tr>
<tr>
<td>Manufacturability Analysis; Product Cost Estimating</td>
<td>Manual; post-design; time consuming; lack of cost roll-ups</td>
<td>Automated manufacturability assessment / cost estimating</td>
</tr>
</tbody>
</table>
Problem Statement

Current State Design / Manufacturing Interaction
(human-in-the-loop manufacturing analysis after design release)
Proposed Solution & Outcomes

• Future State of Technology
  • *Design Assist Tools* for efficient manufacturing data specification *during* design
  • *Automated* manufacturability feedback *during* the design process
    • Confirmed *manufacturable* design prior to manufacturing release
  • Cost roll-ups at *different levels of detail* (component, sub-system, system)
  • Matured Manufacturability Analysis System demonstrated on an existing product line to validate implementation benefits in Industry and DoD/Government
  • System specification ready for implementation at design/manufacturing organizations with validated results/benefits from Use Case
Proposed Solution & Outcomes

Proposed Design / Manufacturing interaction
(automated manufacturing analysis throughout design using iFAB tool chain)
Proposed Solution & Outcomes

• Goals and Objectives:
  • Reduce product development time (DARPA AVM goal)
    • Less manual labor in manufacturing data specification and developing product cost roll-ups
  • Reduce Engineering Change Requests
    • Lower risk of non-manufacturable designs being released to production
  • Provide accurate product cost roll-ups at multiple levels of detail
    • Component – Assembly – Sub-System – Total Product

• Benefits realized after full-scale implementation of the Manufacturability Analysis System architecture
  • Oshkosh – 2017
  • Industry and DoD/Govt - 2018
Scope of Work

• Task 1 – Evaluate Current State iFAB Tools (mo 1-3, Oshkosh lead)
  • Includes Design Assist Tools and manufacturability analysis/feedback tools

• Task 2 – Modify iFAB Manufacturability Analysis System (mo 3-7, ARL lead)
  • Establish requirements for tool extension
  • Modify software to meet requirements

• Task 3 – Configure Manufacturing Models (mo 2-7, aPriori lead)
  • Enable cost estimation for fabricated parts (machined, plate/sheet, casting, bar/tube)
  • Configure aPriori Virtual Production Environments for bulk load use in MAS

• Task 4 – Integrate iFAB Tools with Internal Oshkosh Component Model Library (mo 5-7, ARL lead)
  • Mechanism for retrieval of cost/lead time of non-fabricated components
Scope of Work

• Task 5 – Integrate iFAB Tools with PLM System (mo 5-8 – ARL lead)
  • Enable data management of product design, manufacturing data specification, and manufacturability analyses
  • Lead – ARL Penn State

• Task 6 – Evaluate Modified iFAB MAS (mo 7-8, Oshkosh lead)
  • Confirm tool modification requirements (Task 2) have been achieved

• Task 7 – Execute Use Case for Existing Product Line (mo 7-12, ARL/Oshkosh lead)
  • Using existing Oshkosh product line (e.g., JLG access lift), conduct design and manufacturability analysis exercise
  • Document product development process and compare to traditional methods

• Task 8 – Implementation Support (mo 12, ARL Lead)
  • Define software requirements and hardware recommendations for industry implementation
  • Includes summary of potential commercialization
Manufacturing Analysis System

PTC Creo\(^1\)

Custom Creo Plugins\(^2\)

- **HuDAT\(^2a\)**
  - Solid Weld Generation and Data Specification

- **MAAT\(^2b\)**
  - Manufacturing Data Specification
  - Design Submission for Analysis

Manufacturability Analysis System (MAS)\(^3\)

- **Submission**
  - CAD (STEP) Manufacturing Data (XML)

- **Feedback**
  - Cost
  - Lead Time

Manufacturing Analysis Website\(^4\)

- Design Submission Management
- Manufacturing Analysis Feedback
- System Statistics

https://oshkosh-mas.arl.psu.edu

Analysis Server\(^5\)

- **aPirori\(^5a\)**
  - Piece Part Analysis
  - Part Class Manufacturing Models

- **Assembly Analysis\(^5b\)**
  - Assembly Planning
  - Assembly Cost Models

- **Foundry Configuration\(^5c\)**
  - Manufacturing Plan Alternatives
  - Build Schedule
Manufacturing Analysis System
1. PTC Creo

• Creo was required CAD system for AVM tool chain
• Software evaluation activities will assume the use of Creo
  • Creo designs either designed natively or imported from STEP (parts and assemblies)
  • Version 2.0 well tested
    • Need to consider upgrade plans to 3.0
• Note: MAS does not use native Creo input (STEP)
Custom plugin (Java-based)

Allows designers to specify manufacturing data for analysis in the MAS

Piece part specification (Machined, Plate/Sheet, Casting, Pipe/Bar/Tube)

Assembly specification (Mechanical, Welded, Bonded)
  - Automated assembly seam identification based on part-to-part interferences

Direct submission to MAS

Receipt and display of manufacturability feedback
MAAT Interface in Creo 2.0 (example: assembly seam specification)
Manufacturing Analysis System
2b. MAAT

Manufacturability Feedback in MAAT
Manufacturing Analysis System

2a. HuDAT

- Custom plugin originally developed to support the detailed design of ground vehicle hull structures
  - Ballistic qualifiable weld joints
- Automated feature generation for edge preparation and solid weld geometry
  - Storage of weld details as parameters on weld part
- Development of as-cut plates in addition to final geometry
- Manual generation of solid welds and data required in MAS

Automated Hull Generation

Joint Creation
Solid Weld Generation in HuDAT
Manufacturing Analysis System

3. MAS

• Primary software architecture developed in DARPA AVM/iFAB

• Includes:
  • Manufacturing Analysis Website (4)
  • Analysis Server (5)

• Currently hosted on a server at ARL Penn State
  • No client installation required

• System specification will include details on how industrial partner can stand up MAS internally
• Originally developed for management of design submissions from many users during AVM program
• Receives design submission data from MAAT and passes the information to the analysis server
• User accounts are created for MAAT users to allow them to access the site from a web browser to review their design submissions
• Also currently maintains MAS statistics including submission counts, analysis times, and user details
Manufacturability Analysis System
4. Manufacturing Analysis Website

Manufacturability Analysis Results/Feedback in Manufacturing Analysis Website
Manufacturing Analysis System
5. Analysis Server

• Manufacturability analysis is conducted by various modules depending on the design component type (e.g., machined part, welded assembly)
• Mix of custom software developed in the AVM program as well as commercial software
• Individual analysis modules are not required to be installed on each user’s machine
• Server-based analysis allows for more efficient distribution of the computation requirements
Manufacturing Analysis System
5. Analysis Server

a. aPriori
   • Commercial software package that estimates cost and manufacturing time for piece parts
   • Inputs include the CAD model and process options that are extracted from the manufacturing data specified MAAT
   • Predicts process plans and costs based on manufacturing models (VPEs) stored on the analysis server

b. Assembly Analysis
   • Collection of custom-developed software applications that process assembly data specifications obtained from MAAT
   • Analyzes sequence alternatives, and predicts assembly cost and time based on the attachment mechanisms and the masses of the assembled parts

c. Foundry Configuration
   • Enumeration of all manufacturing build plans for a given product (e.g., process, machine, sequence, etc.)
   • Analyzes alternatives, seeking to generate the cost vs. lead time pareto front
Assisting Organizations

<table>
<thead>
<tr>
<th>Organization</th>
<th>Role</th>
<th>Partner Contributions &amp; Responsible Tasks</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARL Penn State</td>
<td>Project Lead</td>
<td>Program management, Transition of the iFAB Manufacturability Assessment System to the Oshkosh Environment, Analysis Support, and Training and Documentation</td>
</tr>
<tr>
<td>Oshkosh</td>
<td>Subcontractor; Industry Implementation</td>
<td>Industrial partner for use case, technology transition, validation, and commercialization.</td>
</tr>
<tr>
<td>aPriori</td>
<td>Services and Cost Share</td>
<td>Software partner for commercialization and analysis support</td>
</tr>
<tr>
<td>PTC</td>
<td>Cost Share</td>
<td>Software partner for post-project commercialization evaluation</td>
</tr>
</tbody>
</table>
## Success Criteria & KPIs

<table>
<thead>
<tr>
<th>Deliverable</th>
<th>Success Criteria / KPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manufacturability Analysis System, to include the following software</td>
<td>• Manufacturability feedback is rapid and accurate</td>
</tr>
<tr>
<td>interfaces: (MAAT, PTC Windchill, aPriori, Manufacturability Analysis</td>
<td>• Interfaces to Component Model database and PLM system are complete</td>
</tr>
<tr>
<td>Website)</td>
<td>• Use case exercise demonstrates quantifiable savings in product development time</td>
</tr>
<tr>
<td></td>
<td>with added analysis capability</td>
</tr>
<tr>
<td>Design Assist Tools (Creo Plug-ins, HuDAT and MAAT)</td>
<td>• DATs enable sufficient manufacturing data specification for manufacturing analysis and cost estimation</td>
</tr>
<tr>
<td>System Specification Document</td>
<td>• System specification adequately supports full-scale deployment of MAS to Oshkosh and other industrial organizations</td>
</tr>
<tr>
<td>Transition Plan</td>
<td>• Technology developer support not required for post-project industry implementation and end-use support</td>
</tr>
<tr>
<td>Software User Guides</td>
<td>• Transition Plan</td>
</tr>
</tbody>
</table>