PENNSTATE iMAST
Applied Research Laboratory
Institute for Manufacturing and Sustainment Technologies

NAVY MANTECH
Manufacturing Technology Program

Design for Production Process Improvement

Bill Sabol, ARL- PSU /iMAST

NSRP
Product Design & Materials Technologies Panel meeting
11 February 2009

Outline

- Project objectives & coordination of research efforts
- ARL role in support of overall Navy MANTECH DfP initiative
- Report of efforts in three task areas
- Summarize lessons learned
- Final report availability & further information resources

DfP Objective

Lower VCS costs by;

- Incorporating manufacturing best practices and capabilities in design
- Establish design standards and rules that when Implemented and/or executed on the shop floor reduce manufacturing, assembly, and testing costs.
- Provide manufacturing cost estimates as decision support tool

Navy MANTECH DFP

Coordination of related DFP Research:

- DFP0 -> General Technology Best Practices Survey
- DFP1 -> Design for Production Knowledge Tools
- DFP2 -> DfP Seamless Delivery
- DFP3 -> Design Alternatives that Reduce Manufacturing Cost

ARL Tasking (DFP0)

Supporting Investigation:

- Industry Best Practices Survey
- Survey of Seamless Delivery Technologies
- Investigation of Underlying Cost Integration

Industry Survey

State of the Art:

- Classical view of DfP, What is it and how does EB effort relate? [1]

- (Classic) “Design-for-production methodologies have proven to be an effective tool to reduce excess design complexity …”, NSRP report [2]

- (Modern view) Conveying Design Intent across the enterprise is crucial, On-going NSRP research [3]

- (Future view) Intelligent CAD models are required [4]

Industry Survey (cont.)

State of the Art:

CAD vendors that support imbedded GD&T (ASME Y14.41-2003) within CAD model environment

- No - CATIA V4
- Yes - CATIA V5
- Yes - Pro/ENGINEER Wildfire 2.0 (release of 4.0)
- Yes - UGS (formerly Unigraphics) NX 4

Potential Problem - is this level of detail available to complimentary software systems (MRP, MES)? Does STEP carry these attributes along?

Industry Survey (cont.)

State of the Art:

http://www.steptools.com/library/standard/step_3.html

- A model of GD&T information is being added to STEP as part of an upgrade to AP-203 called Edition 2
- Currently being tested with leading CAD vendors
- No set timetable – market driven

Industry Survey (cont.)

Plant Tours:

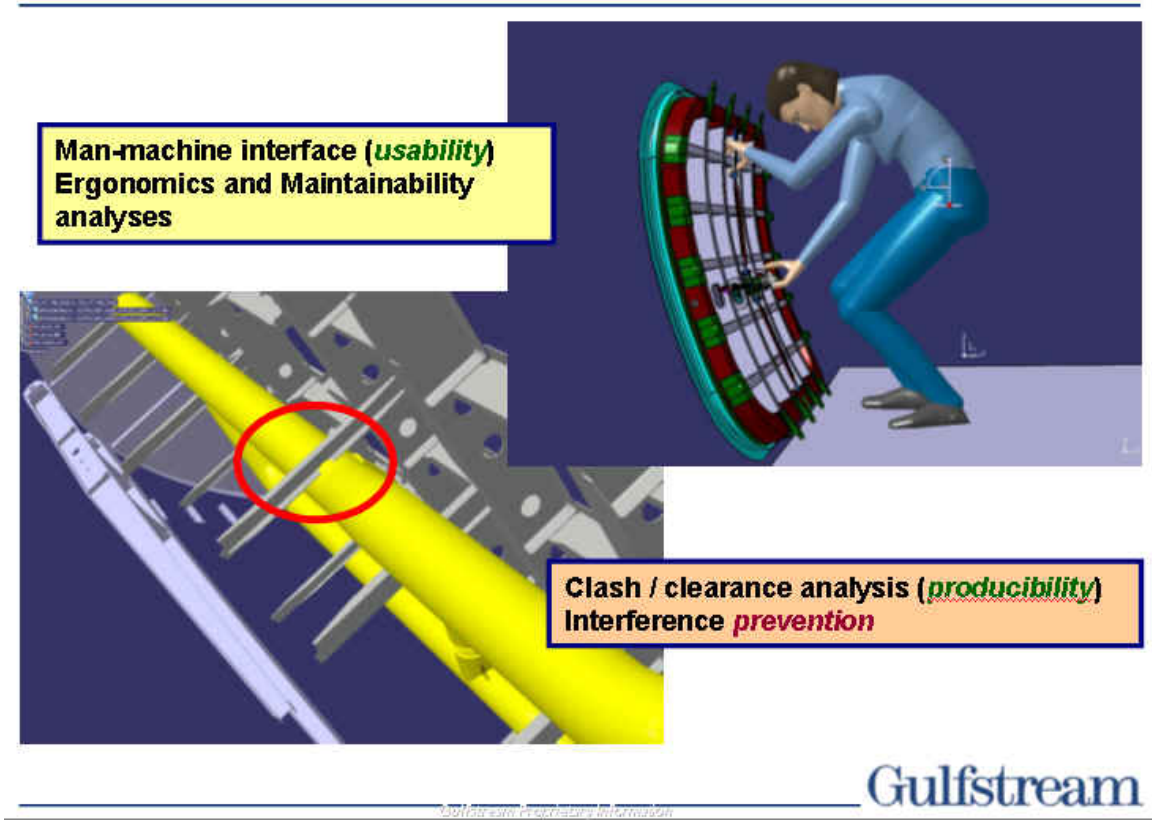
visit sites that are implementing/planning DfP best practices

1. **Sikorsky Helicopter** (Hartford, CT)
    - Work Instructions (paper) contain some 3D model views
    - DfP mostly manifested as classic approach:
        - reduce part count
        - design for ease of assembly
        - design for efficient joining and fastening
2. **Gulfstream Aerospace** (Savannah, GA)
    - Design Review Support for 3D Model Release
    - Multidisciplinary teams include engineering, manufacturing, quality & supply chain

Industry Survey (cont.)

Gulfstream Aerospace (Savannah, GA)

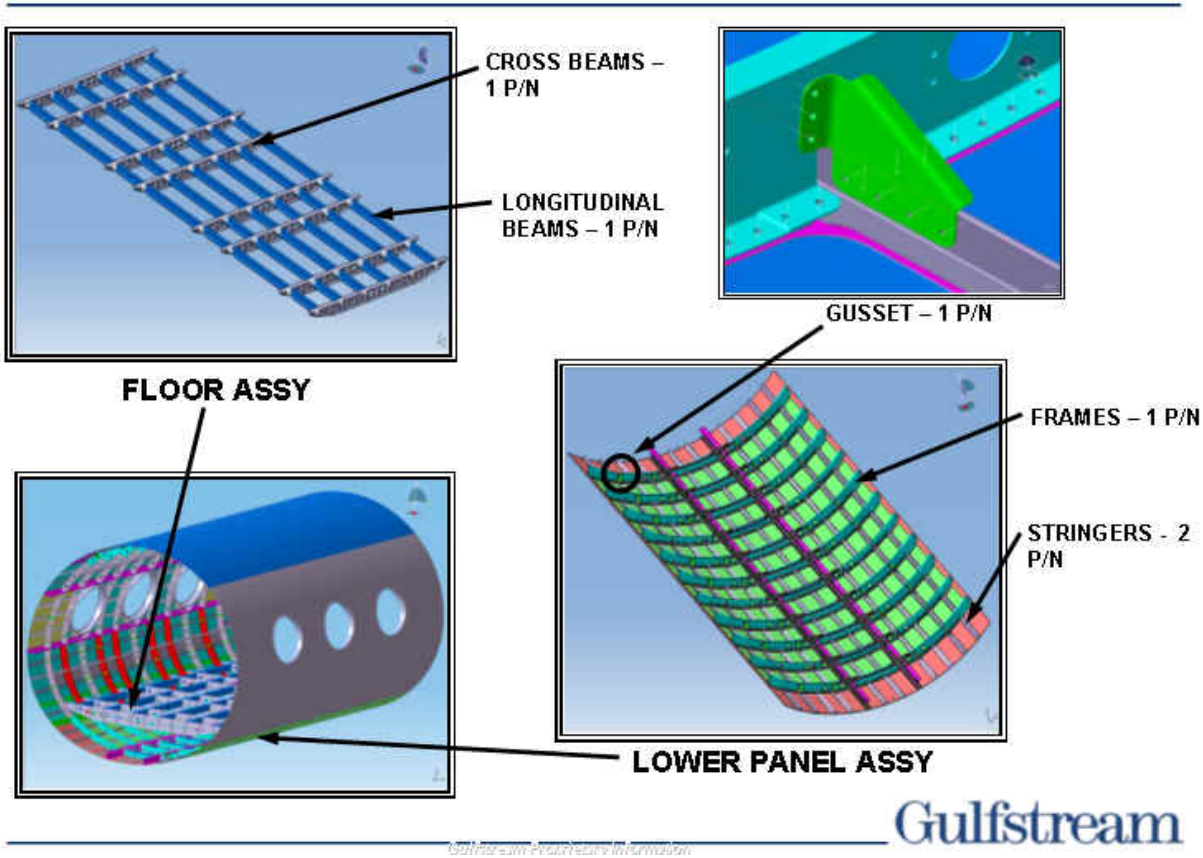
- Integrated 3-D Solids-Based Design



Industry Survey (cont.)

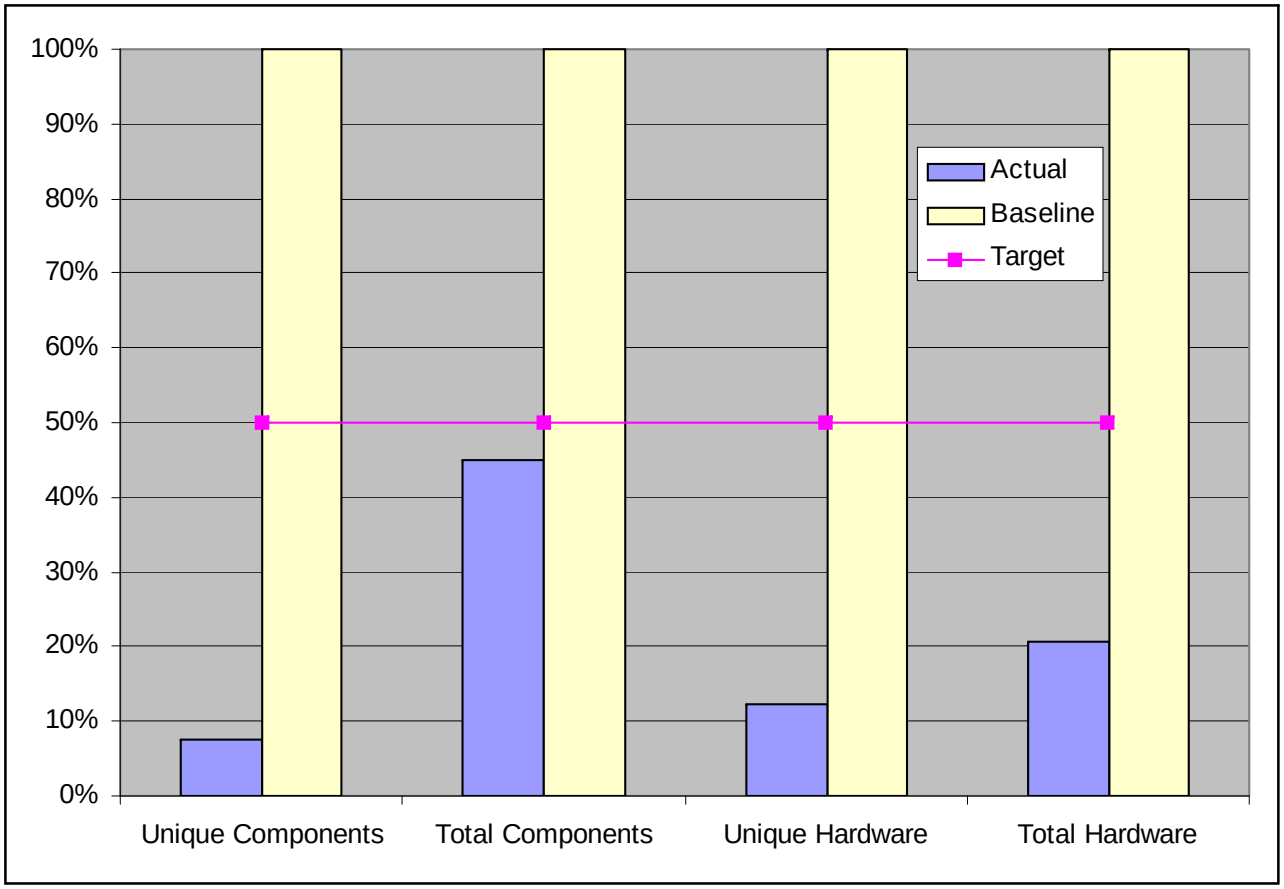
Gulfstream Aerospace (Savannah, GA)

- Design for Assembly, Increase use of Standard Parts, Reduce Part Count



Industry Survey (cont.)

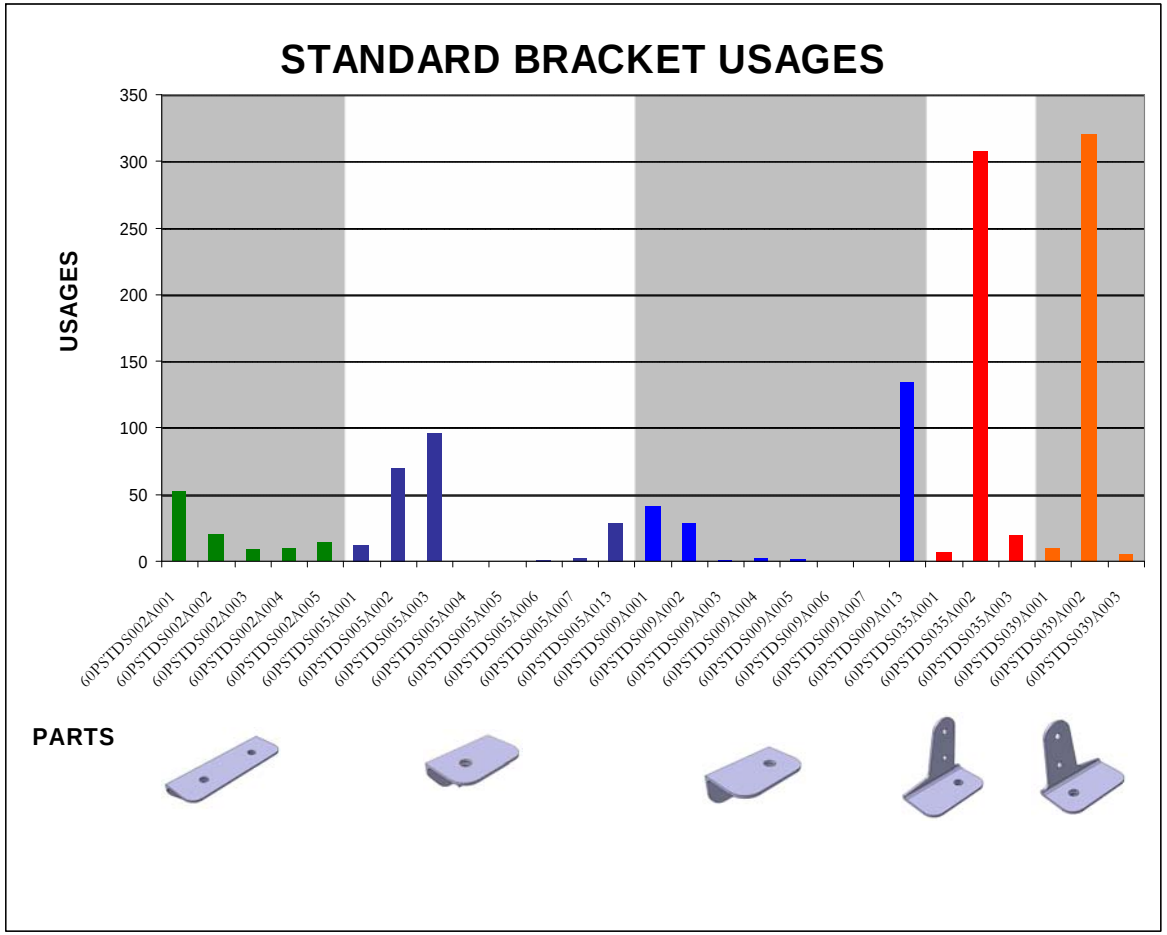
Component/Hardware Reduction efforts



Gulfstream

Industry Survey (cont.)

Maximize use of standard parts – track progress



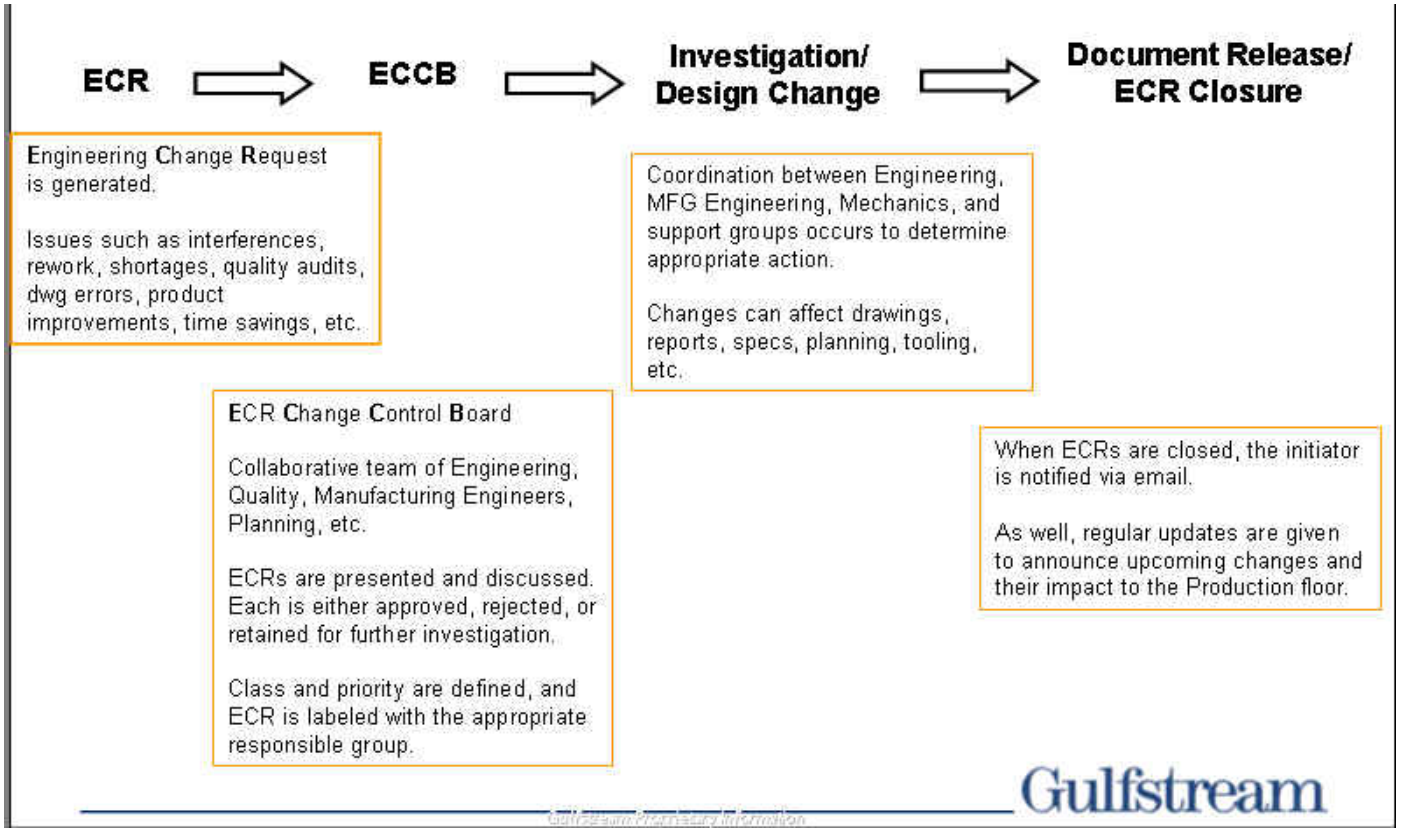
Totals
28-Sept
734
17-Oct
1231

Gulfstream

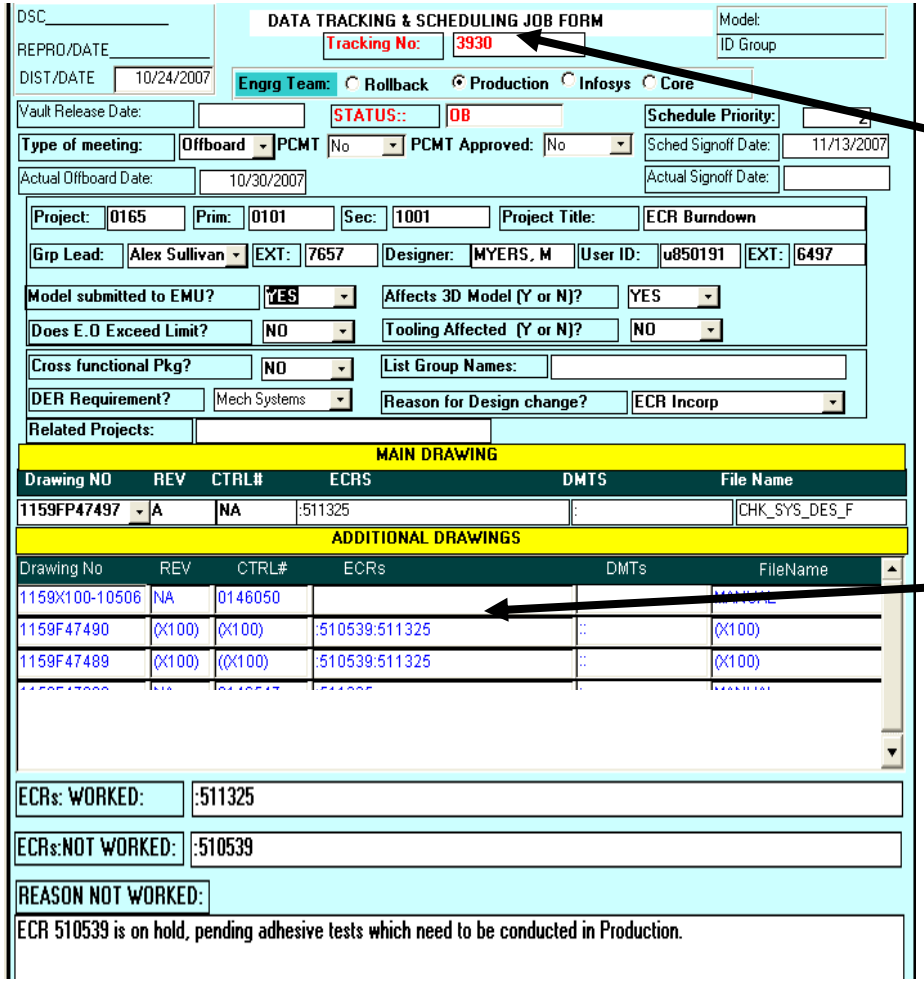
Industry Survey (cont.)

Gulfstream Aerospace (Savannah, GA)

- Production Engineering Process Flow



Industry Survey (cont.)



Electronic Job Tracking

All packages are identified by an EJTF number.

Basic information and requirements are displayed.

All DMTs, ECRs, and associated documents are populated automatically from the various database systems.

This allows for accurate and timely closure of ECRs by the Vault.

Gulfstream

Industry Survey (conclusion)

•Gulfstream is a world class organization in its implementation of design for production techniques.

•Although the fabrication technologies and product definitions are markedly different than that typical found in the shipbuilding industry, their engineering approaches and production techniques are very similar to the challenges that face Electric Boat.

•By pursuing similar technologies and integration of these approaches into the overall DfP initiatives Electric Boat would greatly reduce the technical risk and enhance their chances of success.

Seamless Delivery

Areas of Investigation:

Examine use of Paperless environments: [5]. From this study we learn;

- Technical challenges remain
- Recommend multi-phase multi-year implementation
- Management support critical
- Educational and Culture changes not insignificant

Examine benefit of using a Manufacturing Execution System [6] [7] [7a]

- Both Gulfstream and Sikorsky are customers of COTS MES solution Solumina

Cost Metrics

Areas of Investigation:

- Operation Based Costing (OBC) [8]

  Knowledge-based models can be created to associate design variables with cost elements. Providing basis on which optimization can be applied in search of the product design that leads to the minimum production costs.

- Cost as a critical design parameter

  Imbedded utilities within CAD environments can provide designers upfront parametric assessments of cost impact before design is finalized. This allows consideration and evaluation of cost effective design and manufacturing scenarios. A COTS solution that can work in the CATIA V5 environment that provides such a utility is called aPriori, www.apriori.com

Summary

ARL investigated technology to support EB's goal of establishing "***An Enhanced Design-Build Process*"**

Produce work-packages that better convey design intent to production workforce, by;

- Incorporating both the design of product and the design of manufacturing fixtures within the same CAD system. Produce detailed electronic work orders that include graphics of both that provide shop floor technicians sufficient manufacturing process instructions.
- Migrating to V5 CATIA to support ability to extract information from design model, and support the use of GD&T into work-packages.
- Consider purchase of Manufacturing Execution System (MES) software as way to produce these content rich work-packages.

Evaluate cost impact during the design, considering impact of design alternatives.

- Consider purchase of COTS cost estimation software as way to generate these cost evaluations. ARL-Penn State has identified aPriori as an industry leader that markets a product that integrates within the CATIA V5 environment that is designed specifically to generate this information.

Emulate the corporate commitment to DfP demonstrated by Gulfstream Aerospace.

- Establish VCS design metrics for and collect data on ECRs. Track and categorize by type ECRs and assess their impact on cost during manufacturing. Expend resources on those categories that will result in greatest savings.

Additional Information

- Final Report
  - ***Technology Development to Support Shipbuilders' Design for Production Initiatives***, W. J. Sabol, Technical Memorandum, File No. 08-041, 10 November 2008
- Program Office
  - Program Executive Office, Subs, PMS 450 – VCS
  - POC: Mr. Larry Becker, PMS 450C1
- Contractor Organizations
  - General Dynamics Electric Boat, POC: Rick Nelson & Brad Colschen
- COE(s)
  - CNST POC: Kevin Carpentier
    - Project Technical Representative: Vickie Dlugokecki
  - iMAST POC: Tim Bair
    - ARL Penn State POC: Bill Sabol, wjs4@psu.edu

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Thank you

Reference Tags

[1] Design for Manufacturability / Assembly Guidelines, Kenneth Crow
http://www.npd-solutions.com/dfmguidelines.html

- **Simplify the design and reduce the number of parts**
- **Standardize and use common parts and materials**
- **Design for ease of fabrication**
  - For higher volume parts, consider castings or stampings to reduce machining
  - Use near net shapes for molded and forged parts to minimize machining and processing effort.
  - Design for ease of fixturing by providing large solid mounting surface & parallel clamping surfaces
  - Avoid designs requiring sharp corners or points in cutting tools - they break easier
  - Avoid thin walls, thin webs, deep pockets or deep holes to withstand clamping & machining without distortion
  - Avoid tapers & contours as much as possible in favor of rectangular shapes
  - Avoid undercuts which require special operations & tools
  - Avoid hardened or difficult machined materials unless essential to requirements
  - Put machined surfaces on same plane or with same diameter to minimize number of operations
  - Design workpieces to use standard cutters, drill bit sizes or other tools
  - Avoid small holes (drill bit breakage greater) & length to diameter ratio > 3 (chip clearance & straightness deviation)
- **Design within process capabilities and avoid unneeded surface finish requirements.**
- **Mistake-proof product design and assembly** (poka-yoke)
- **Design for parts orientation and handling**
- **Minimize flexible parts and interconnections**.
- **Design for ease of assembly**
- **Design for efficient joining and fastening**
- **Design modular products**
- **Design for automated production**

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Reference Tags (cont.)

[2] NSRP 0538, N4-95-1,"Design for Production Manual", July 1999, 2nd edition
Excerpts of Note describing the attributes desired of a CAD model well suited to support DfP

- "This data can consist of detailed production related information that can be used by the designer to **construct design models that are production friendly**."
- And "**requires design information** to be represented in a Product Model that **may be shared throughout the design, manufacturing, build and operational phases of the product**."
- This model "fully describes the product specification and 3-D multi-discipline CAD geometry that defines the location, **orientation and relationship between the component parts** of the product".

Other pertinent NSRP sponsored reports:

[NSRP-0006] Design for Production
[NSRP-0236] Design for Production Manual (3 Vols.)
[NSRP-0310] Design for Steelwork Production During the Concept Design Phase
[NSRP-0310] Design Through Manufacture: A Computer Aided Advisor for the Manufacture of Submarine Hulls
[NSRP-0148] Design/Production Integration
[NSRP-0408] Design/Production Integration
[NSRP-0383] Design/Production Integration and the Industrial Structure
[NSRP-0310] Designing the Future U.S. Naval Surface Fleet for Effectiveness and Producibility

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Reference Tags (cont.)

[3] Design for Producibility for Mid-Tiered Shipyards, NSRP

The design-for-production work will be formalized through DFP Manuals that provide designers, design agents, and customers with the design rules associated with the constraints and preferences of each shipyard.

- Steel
- Piping
- Machinery
- Electrical
- HVAC
- Joiner
- Paint
- Steel Outfit

Facility Capabilities

Design Rules

Material Schedules

Design Details

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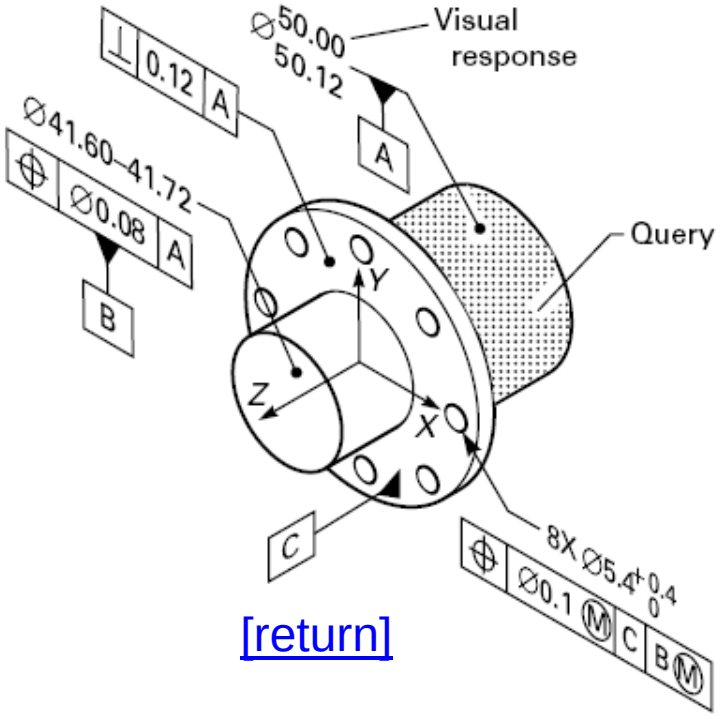
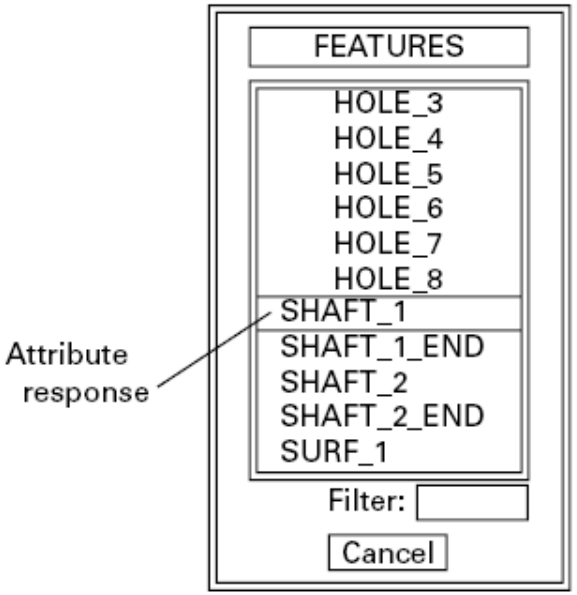
Reference Tags (cont.)

[4] Digital Product Definition Data Practices, ASME Y14.41-2003



(a) Individual feature.



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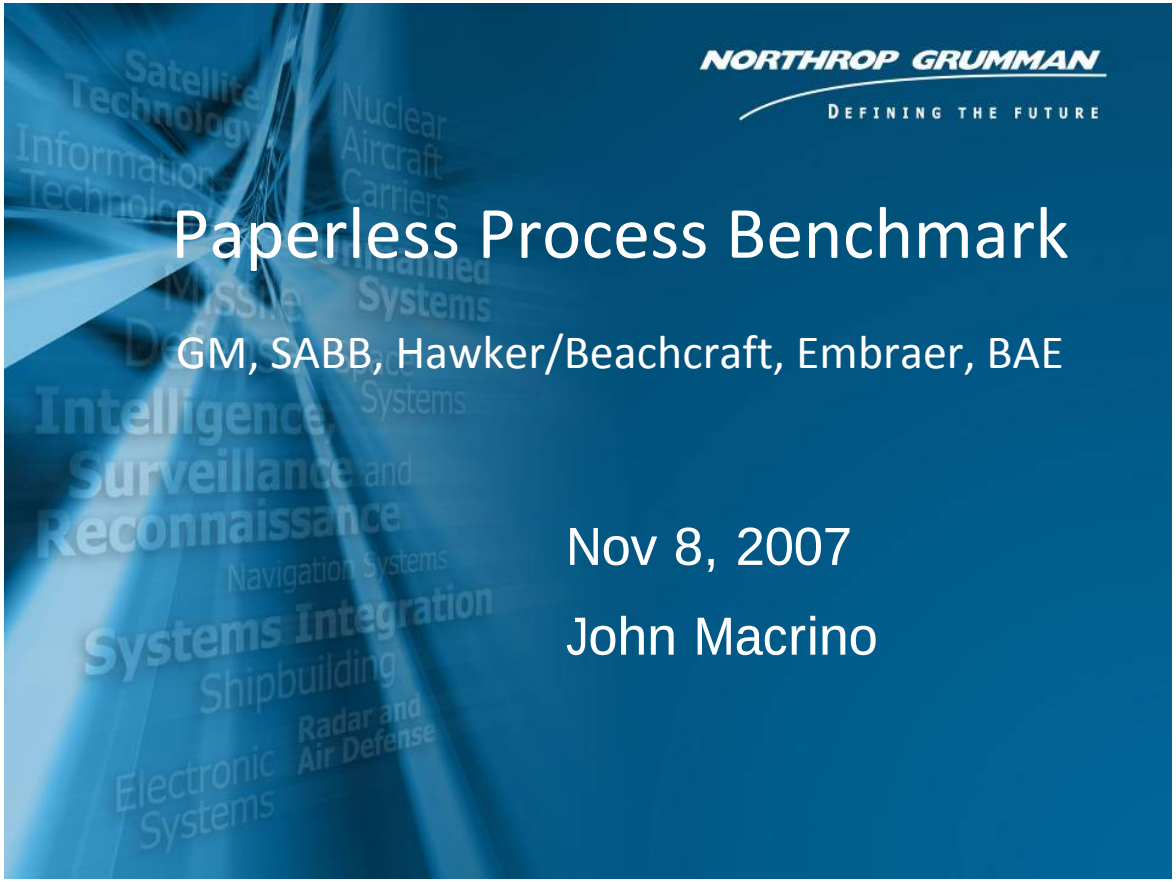
Reference Tags (cont.)

[5] Northrop Grumman presentation



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Reference Tags (cont.)

[6] Gulfstream presentation to EB, Solumina Summary, Jim Calevich

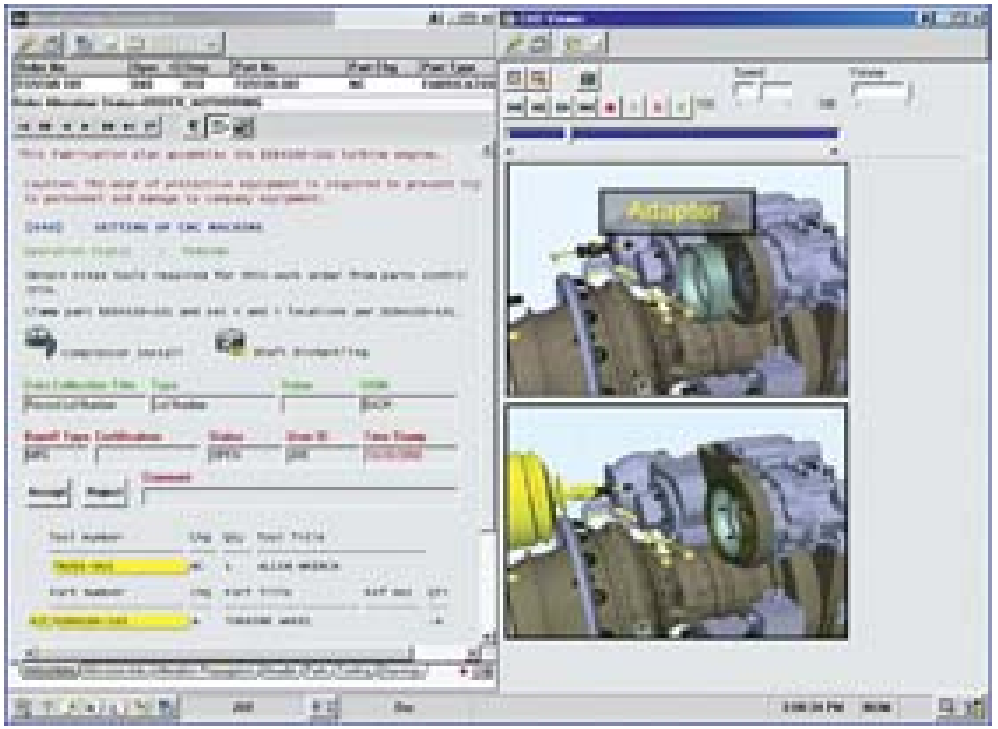
- SOLUMINA is a Manufacturing Execution System (MES) software application from iBASEt of Foothill Ranch, California.
- At Gulfstream SOLUMINA has been interfaced with the CAS Legacy MRP software application.
  - SOLUMINA Item Master, Manufacturing Bill of Material (MBOM) and Work Plans are passed to CAS electronically.
  - CAS Manufacturing Orders continue to be released in CAS allowing the legacy Material Issue Process to coexist with SOLUMINA. The interface with CAS creates Electronic SOLUMIA Manufacturing Orders.
  - CAS Jobs (CAS's shop Floor paperwork) are eliminated when SOLUMINA Manufacturing Orders are turned on for specific Initial Phase and Mexicali Department Numbers.

Reference Tags (cont.)

[7] iBASEt *http://www.solumina.com*

The transition to a complete paperless system will yield the following immediate benefits:

- Elimination of clerical work needed to update, distribute and replace documents
- Fast deployment of Engineering changes to the shop
- Consistent job performance using the correct and latest versions of drawings, instructions, and parts



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"Enhanced Work Instructions - Solumina provides the operator with easy to follow instructions that reduce the learning curve and errors. Instructions for simpler jobs can be text descriptions complemented with links to illustrations and bookmarked drawings; instructions for more difficult jobs can be intricate animated slide shows that incorporate marked-up drawings, 3D models or videos, and prompt the user for data collection when required." [4]

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Reference Tags (cont.)

[8] *A New Design for Production (DFP) Methodology with Two Case Studies,* Lee Ming Wong, G. Gary Wang and Doug Strong, Department of Mechanical & Manufacturing Engineering, The University of Manitoba, Winnipeg, MB, Canada, http://cer.sagepub.com/cgi/content/abstract/12/4/263

For each operation in a manufacturing process, OBC breaks down the cost into eight major elements. The sum of the eight element costs gives the total cost. These 8 elements are:

1. Machinery – Infrastructure costs
2. Fixture – cost to design and manufacture
3. Operator – human costs
4. Space – costs incurred to host workstation
5. Contract– with outside entities for needed support services
6. Incentive – cost to control quality and obtain timely delivery
7. Material– raw material inputs
8. Tied Cost– cost of inventories

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