3-D Model System

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SELP 695 INTEGRATIVE PROJECT
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3-D Model System Agenda

- 1. Introduction
- 2. Background
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  - Cost Analysis
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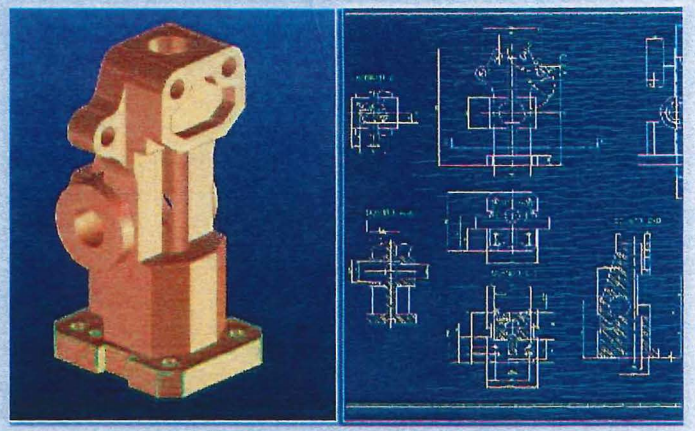
  - Lessons Learned
- 5. Conclusion



Picture Courtesy of http://www.designworldonline.com

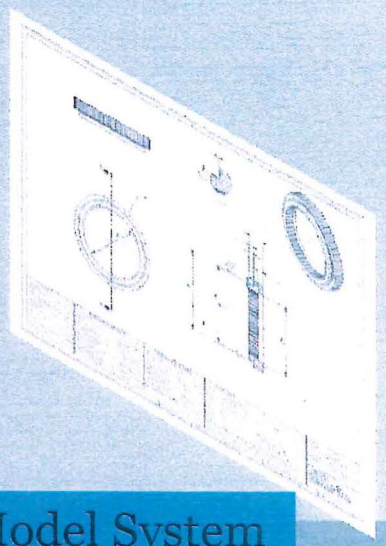
1. Introduction

- Objective:
  - To analyze the process of using a 3-D Model System to convey the Mechanical Design of Spacecraft Hardware
- Project Activities
  - Illustrate how the 3-D Model System Integrates within the Spacecraft Systems Engineering (SE) Process
  - Assess Quality Enhancements and Cost Savings
  - Recognize and Record Risks
  - Review Lessons Learned

Picture Courtesy of http://www.nasa.gov

2. Background

- Currently, 2-D Drawings are used to illustrate Spacecraft (S/C) Mechanical Design
- How is the 2-D Drawing Created?
  - In the Past, the 2-D Drawing derived from a Full-Scale Physical Mock-Up
  - Today, Drawings derive from a 3-D Computer Aided Design (CAD) Digital Mock-Up.
- Aircraft Systems
  - Before Employed 2-D Drawings
  - Now Employ the 3-D Model System
  - Boeing and Airbus use the 3-D Model System



Aircraft Industry has **Greatly** Benefited from the 3-D Model System

2. Background

- Integrative Project Approach
  - Establish Requirements
    - Mission Requirements
    - Top Level Requirements
  - Perform Trade Study Analysis
  - Review Lean Principles and Quality Methods
  - Record Ethical Issues
  - Risk Assessment
  - Software Technology Assessment
  - Cost Analysis
  - Requirements Verification Matrix
  - Lessons Learned

3. Requirements

Requirement ID	Mission Requirements
3.2.1.1	The method used to illustrate the Spacecraft Mechanical System Design shall represent the Mechanical System Design as it is depicted in the 3-D Computer Aided Design (CAD) Mock-Up Model.
3.2.1.2	The method used to illustrate the Spacecraft Mechanical System Design shall be capable of being configuration controlled.
3.2.1.3	The method used to illustrate the Spacecraft Mechanical System Design shall be capable of producing a manufactured product.
3.2.1.4	The method used to illustrate the Spacecraft Mechanical System Design shall be capable of illustrating design changes.
3.2.1.5	The User(s) shall be capable of accessing the product(s) produced by the method chosen, without incident.
3.2.1.6	The method used to illustrate the Spacecraft Mechanical System Design shall be capable of integrating within the Spacecraft System Engineering Process.

Six Mission Requirements are Defined

3. Requirements

Requirement ID	Top Level System Requirements
3.2.2.1	The 3-D Model System shall be capable of exactly conveying the information currently represented in 2-D Drawings.
3.2.2.2	The 3-D Model System shall not hinder the User(s) from manufacturing the Mechanical System.
3.2.2.3	Training on how to use the 3-D Model System software products shall be equal to or less than 40 hours per User.
3.2.2.4	The 3-D Model System shall generate a cost savings to the Company which owns the Spacecraft Mechanical System Design.
3.2.2.5	The 3-D Model System shall be a Lean alternative to 2-D Drawings.
3.2.2.6	The Computer-Aided Design (CAD) software tools used in the 3-D Model System shall have a Technology Readiness Level of 9.

Six Top Level Requirements are Defined

4. Project Results – Trade Study Analysis

- Performed a Comparison Analysis on the 3-D Model System and 2-D Drawing System
  - Compared and Analyzed how each System satisfies the 6 Mission Requirements
  - Assigned a Grade, A = Exceeds Requirement, B = Meets Requirement, C= Does Not Meet Requirement
- Reviewed INCOSE SE Handbook Version 3.1
  - Verified Requirement 3.2.1.6
  - Eleven Systems Engineering Processes applied Throughout System Life Cycle
  - Evaluated how 2-D Drawing System and 3-D Model System Integrate within each Process
- Trade Study Results
  - 3-D Model System Scores Higher in 3 out of 6 Mission Requirements
  - 3-D Model System provides **Infinite** viewpoints, **Eliminates** errors associated drawings, Assists in Concurrent Engineering, **Improves** Quality and Schedule
  - Design Recommendation: Satellite System shall implement the 3-D Model System

3D Model **Superior** over 2-D Drawing

4. Project Results – Trade Study Analysis

Mission Requirement	2-D Grade	3-D Grade	Grade Explanation
3.2.1.1 The method used to illustrate the Spacecraft Mechanical System Design shall represent the Mechanical System Design as it is depicted in the 3-D Computer Aided Design (CAD) Mock-Up Model.	B	A+	The Drawing System meets the Requirement; however, the system has an error factor. An error in translating from 3-D to 2-D can result. The 3-D Model System exceeds the requirement. It uses the actual model to illustrate the design. Thus, zero discrepancies are associated with this method.
3.2.1.2 The method used to illustrate the Spacecraft Mechanical System Design shall be capable of being configuration controlled.	B	B	Both systems meet the Requirement. 2-D Drawings and the 3-D Models are controlled thru the PDM system. The CDMO owns the 2-D drawings and the 3-D Models.
3.2.1.3 The method used to illustrate the Spacecraft Mechanical System Design shall be capable of producing a manufactured product.	A	A+	Both systems exceed the requirement. A manufacturer is more than capable of producing a part using a drawing or the 3-D Model System. The 3-D Model System provides infinite number of viewpoints which help illustrate design intent, interfaces, and accessibility points.

4. Project Results – Trade Study Analysis

Mission Requirement	2-D Grade	3-D Grade	Grade Explanation
3.2.1.4 The method used to illustrate the Spacecraft Mechanical System Design shall be capable of illustrating design changes.	B	B	Both Systems meet the Requirement. Design changes are illustrated by Revisions in the 2-D drawing System and the 3-D Model System. The revisions are controlled by CDMO.
3.2.1.5 The User(s) shall be capable of accessing the product(s) produced by the method chosen, without incident.	B	B	Both Systems meet the Requirement. A user is capable of accessing a 2-D drawing by downloading it from the PDM system or printing a hard copy from the PDM system. A user is capable of accessing the 3-D model by downloading and viewing it from the PDM system or viewing it from software such as Product View or 3D Live.
3.2.1.6 The method used to illustrate the Spacecraft Mechanical System Design shall be capable of integrating within the Spacecraft Systems Engineering Process.	B	A+	Both systems integrate well within the Systems Engineering Process. The 3-D Model System surpasses 2-Drawing System during the Requirements Definition, Architecture Design , Implementation, and Integration Processes.

4. Project Results Lean Principles

- Value
  - Manufacturing Team: Meet or Exceed Quality Standards
  - 3-D Model System Value
    - Provides Infinite Viewpoints
    - Assists in Determining Interferences and Accessibility Limitations
    - Reduces Rework
  - SE Team: Meet or Exceed Stakeholder Requirements
  - 3-D Model Value
    - Assists in Concurrent Engineering
    - Promotes Quality
    - Allows Problems to be Solved Early in SE Life Cycle
- Flow
  - 3-D Model System Eliminates Waiting
    - No Waiting for Drawing Check or Drawing Approval
  - Flows information to SE Team Members early in the SE Life Cycle
  - Eliminates Unnecessary Rework

4. Project Results – Lean Principles Current State Value Mapping

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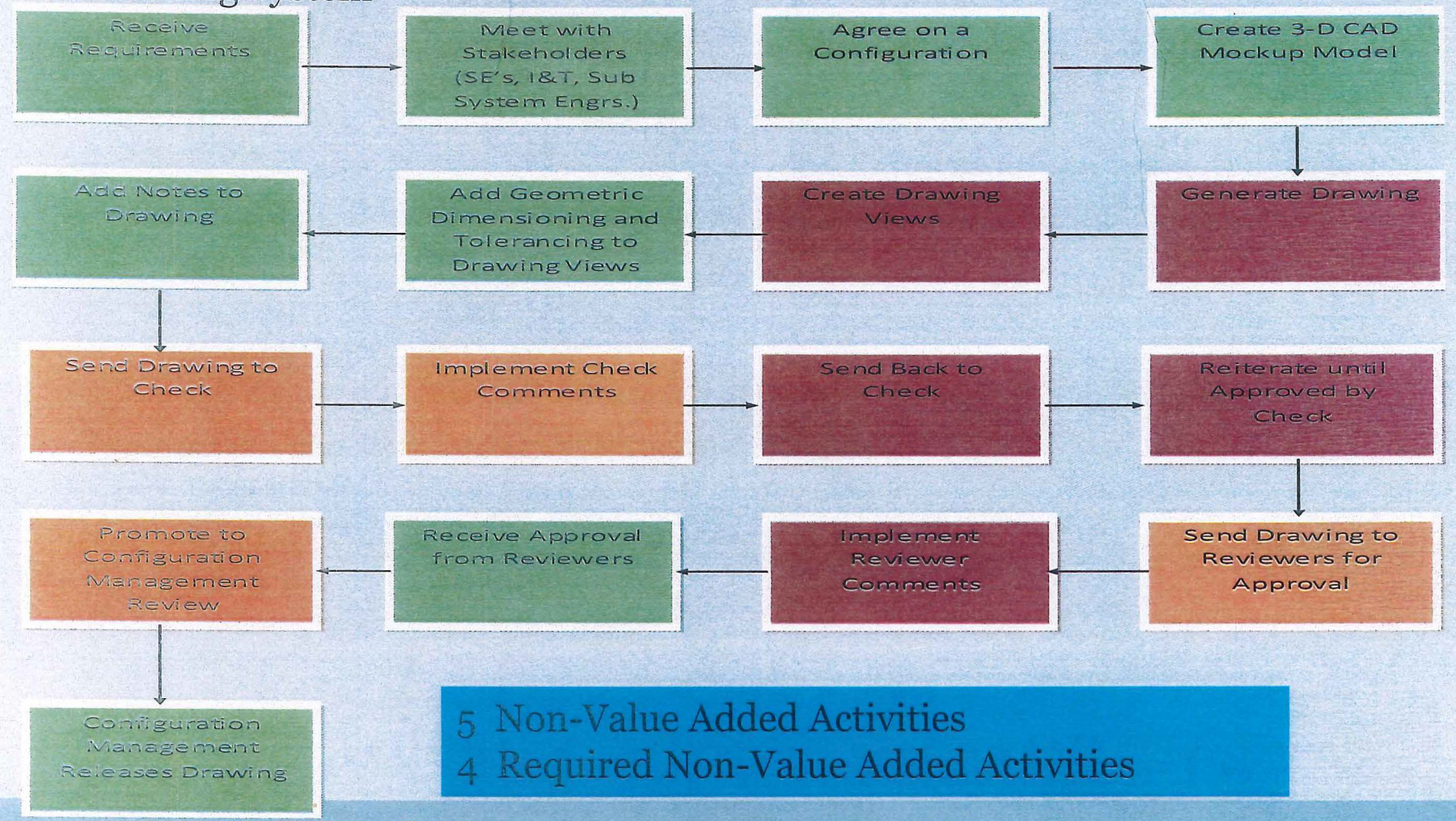
2-D Drawing System



5 Non-Value Added Activities
4 Required Non-Value Added Activities

4. Project Results – Lean Principles Future State Value Mapping

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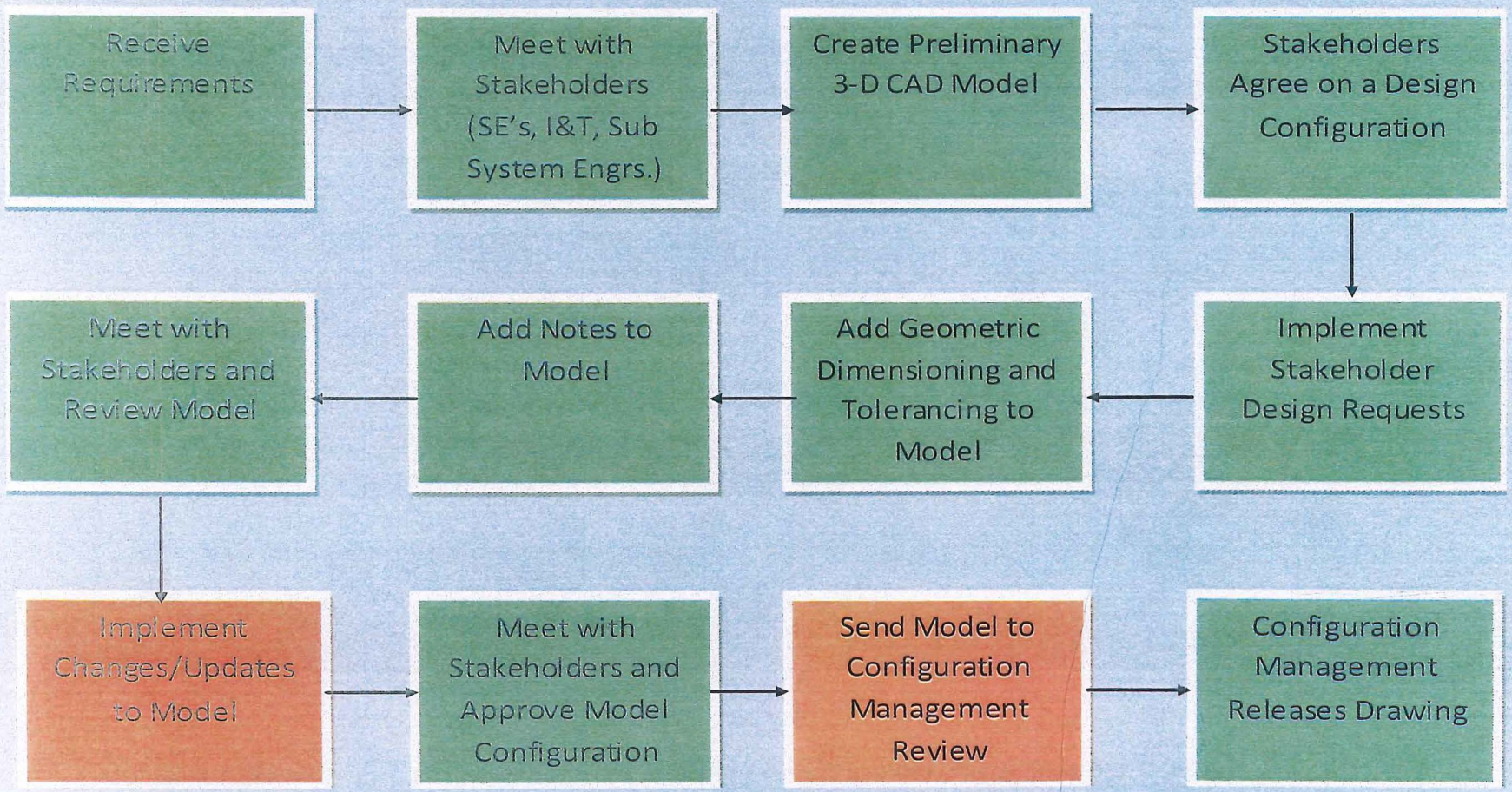
3-D Model System



0 Non-Value Added Activities, 2 Required Non-Value Added Activities

4. Project Results – Technology Readiness Assessment

- Parametric Technology Corporation (PTC)
  - Pro-Engineer
    - 3-D CAD Software
  - Windchill
    - Product Data Management (PDM) Software
  - Product View
    - Visual Collaboration Software
- Dassault Systemes
  - Catia
    - 3-D CAD Software
  - Enovia
    - PDM Software
  - 3D Live
    - Visual Collaboration Software

TRL 9: Technology is Operational and Proven

4. Project Results – Ethics

- Honesty
  - Migrating to 3-D Model System will be a Huge Paradigm Shift
  - Engineers Might Perform Dishonest Practices
    - Untruthful about 2-D Drawing Limitations
    - Purposely Dismissing 3-D Model System Benefits
    - Self-Deception – Allowing one's Judgment to be Biased
    - Sabotage
  - To Prevent Dishonest Practices from occurring, System shall receive Senior Leadership support prior to workforce introduction
- Computer Ethics
  - Hardware/Software Malfunctions
  - Utilize a Trial Run Program to Minimize effects
  - Health and Safety: Ergonomics
  - Occupational Safety and Health Assessment

4. Project Results – Risk Management

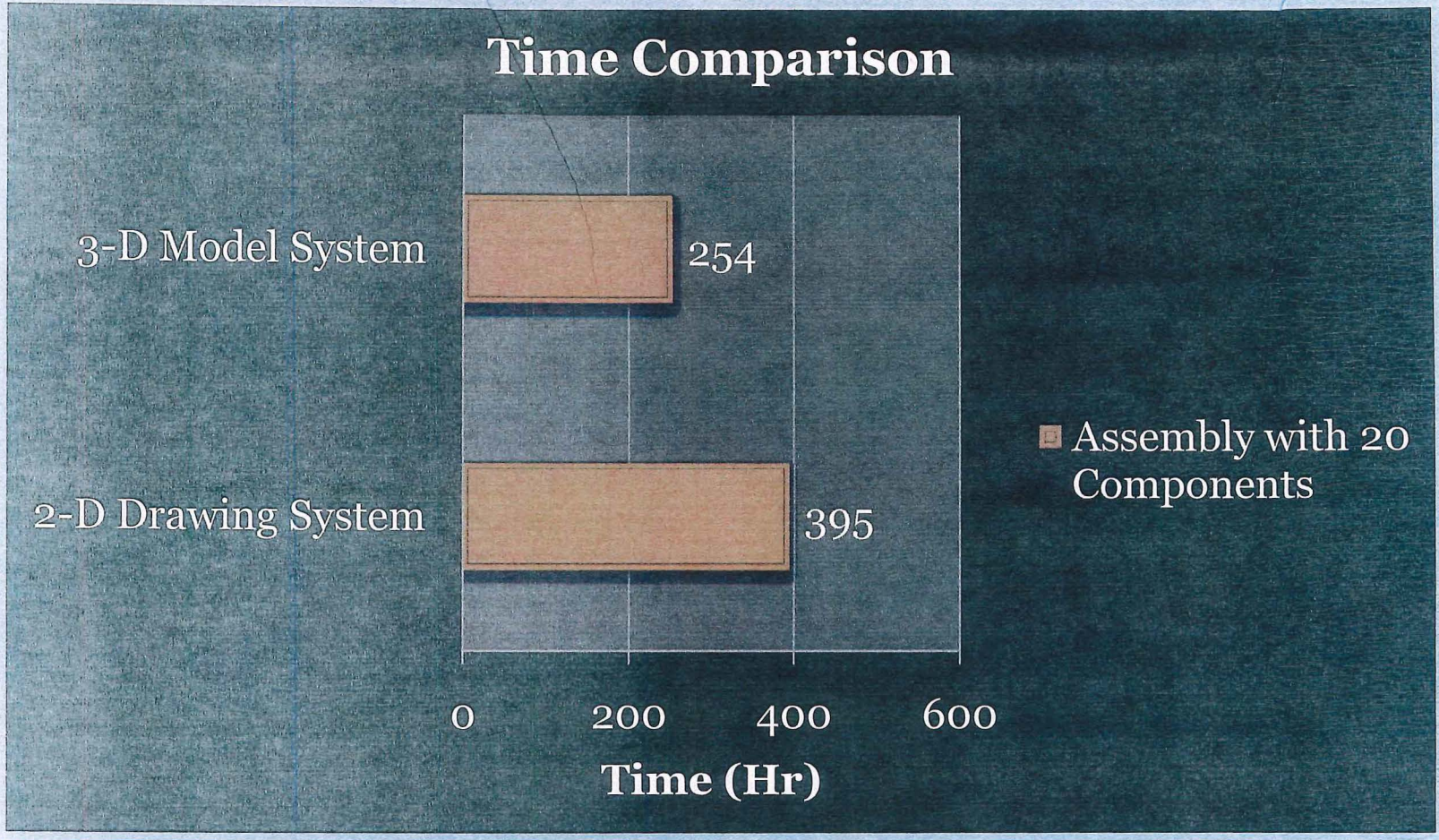
Risk	Risk Level	Risk Handling Activities
1. If the Manufacturer is unable to download the 3-D model, due to a computer network malfunction, then the mechanical system delivery may be delayed.	Moderate	Build a Robust Computer Support Team
2. If the 3-D model is incorrect, due to an error in the mechanical design, then the mechanical system may be built incorrectly.	High	Hold Meticulous Peer Reviews, and Configuration Review Meetings. Practice Concurrent Engineering and Install Training Programs for Mechanical Designers
3. If the 3-D Model System implementation process is poor, due to inefficient training, then the mechanical system delivery may be delayed.	High	Invest in a strong training program. Utilize Software Vendor Trainers
4. If the Manufacturer is unable to view the 3-D Model due to a lack of computer resources, then the mechanical system delivery may be delayed.	Moderate	SE Team shall verify Manufacturers contain the necessary resources to complete the job. Create a resource management plan.

4. Project Results – Cost Analysis

- Boeing
  - Saved over 50% in Labor Cost Reductions
  - Reduced Costs Associated with 2-D Drawings, Design Errors, Rework, and Revisions
- Implementation Costs

Software Products	Costs ($)
CAD Software License	15,000
PDM Software License	2,500
3-D Visualization Software	1,000

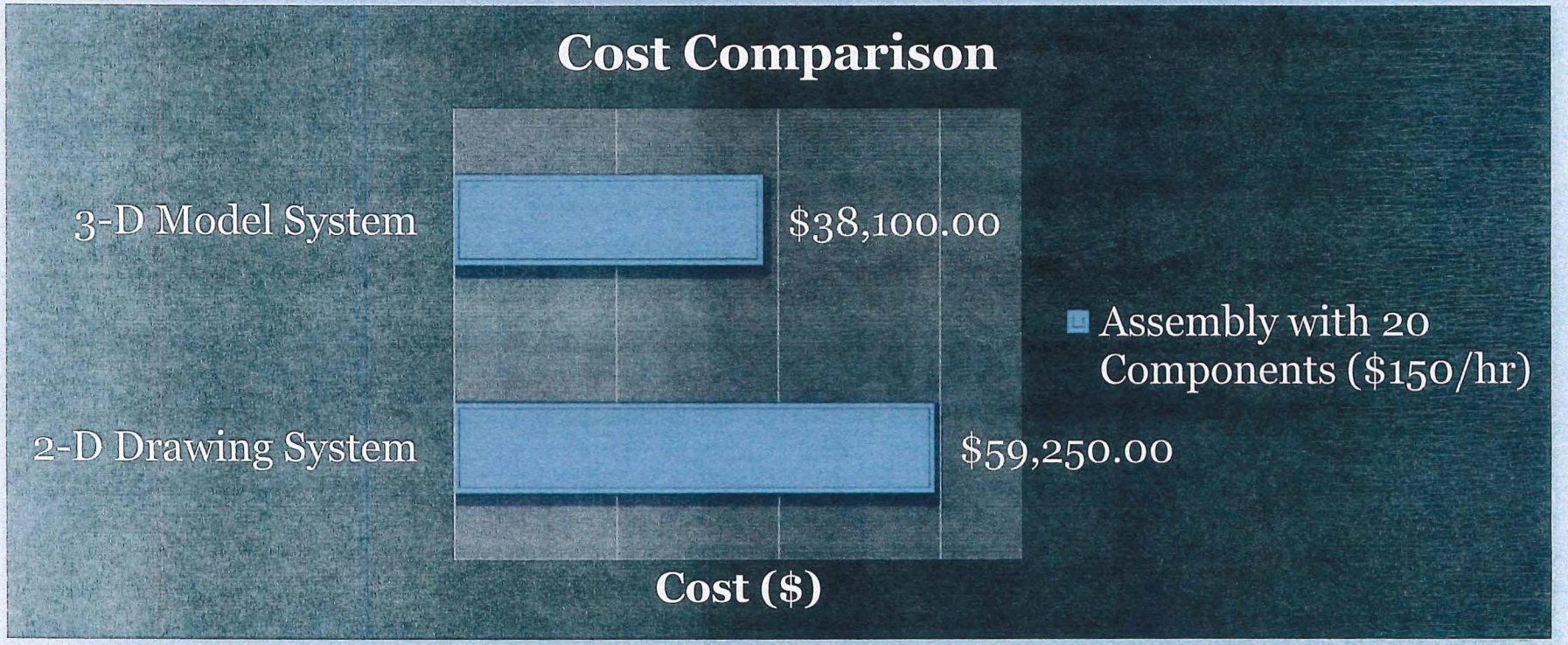
4. Project Results – Cost Analysis



3-D Model System Produces a Superior Product in 141 less Hrs.

4. Project Results – Cost Analysis

- Cost Savings of $21,150 is achieved
- Medium Satellite System has approximately 375 Drawings
- Multiply 375 x Cost savings/1 Drawing = $7, 931, 250



Medium Satellite System will save over $7.9 Million

4. Project Results – Requirements Verification

Requirement	Verification Method	Design Capability	Verified	Supporting Documents
3.2.1.1 The method used to illustrate the Spacecraft Mechanical System Design shall represent the Mechanical System Design as it is depicted in the 3-D Computer Aided Design (CAD) Mock-Up Model.	Analysis	The actual 3-D CAD Mock-up model is used to convey the design. The System accurately represents the Mechanical Design as it is depicted in the CAD Model.	Yes	Technology Readiness Assessment Report, Trade Study Report
3.2.1.2 The method used to illustrate the Spacecraft Mechanical System Design shall be capable of being configuration controlled.	Analysis	The 3-D Models are controlled by the Configuration Data Management Office (CDMO). The model is uploaded to the Parts Data Management System (PDM) in an electronic format. Once approved and signed by the reviewers, CDMO marks the model with the release date and revision level. The model is then controlled and released.	Yes	Technology Readiness Assessment Report, Trade Study Report
3.2.1.3 The method used to illustrate the Spacecraft Mechanical System Design shall be capable of producing a manufactured product.	Analysis	3-D Model System conveys the form, fit, and function of the manufactured item.	Yes	Technology Readiness Assessment Report, Trade Study Report

4. Project Results – Requirements Verification

Requirement	Verification Method	Design Capability	Verified	Supporting Documents
3.2.1.4 The method used to illustrate the Spacecraft Mechanical System Design shall be capable of illustrating design changes.	Analysis	The 3-D Model System is capable of being revised and extensively revised if necessary. A new revision of the model is created. The model revision is approved. Once approved the model is stored and controlled by CDMO.	Yes	Technology Readiness Assessment Report, Trade Study Report
3.2.1.5 The User(s) shall be capable of accessing the product(s) produced by the method chosen, without incident.	Analysis	The 3-D models are stored electronically in the PDM database system. The model can be downloaded and viewed directly from the PDM database. It can also be viewed from other products such as Product View and 3DLive.	Yes	Technology Readiness Assessment Report, Trade Study Report
3.2.1.6 The method used to illustrate the Spacecraft Mechanical System Design shall be capable of integrating within the Spacecraft System Engineering Process.	Analysis	The 3-D Model System integrates within the Spacecraft System Engineering Process	Yes	Trade Study Report

4. Project Results – Requirements Verification

Requirement	Verification Method	Design Capability	Verified	Supporting Documents
3.2.2.1 The 3-D Model System shall be capable of exactly conveying the information currently represented in 2-D Drawings.	Analysis	The 3-D CAD Model contains all information conveyed in a 2-D drawing. Geometric Dimensioning and Tolerancing, notes and Special Instructions are conveyed in the Model. A complete digital mockup of the manufactured item is represented in the Model.	Yes	Technology Readiness Assessment Report, Trade Study Report
3.2.2.2 The 3-D Model System shall not hinder the User(s) from manufacturing the Mechanical System.	Analysis	The 3-D Model System does not hinder the manufacturer. Safety issues such as Ergonomics will be taken into account when the system is implemented.	Yes	Ethics Review
3.2.2.3 Training on how to use the 3-D model System software products shall be equal to or less than 40 hours per User.	Analysis	Training on how to use the 3-D Model System software is completed within 5 working days.	Yes	Technology Readiness Assessment Report
3.2.2.4 The 3-D Model System shall generate a cost savings to the Company which owns the Spacecraft Mechanical System Design.		The 3-D Model System does generate a Cost Savings to the Organization which employs the System.		Cost Assumptions and Estimates Review

4. Project Results – Requirements Verification

Requirement	Verification Method	Design Capability	Verified	Supporting Documents
3.2.2.5 The 3-D Model System shall be a Lean alternative to 2-D Drawings.	Analysis	The 3-D Model System is a lean alternative to the 2-D Drawing System	Yes	Lean Principles Review
3.2.2.6 The Computer-Aided Design (CAD) software tools used in the 3-D Model System shall have a Technology Readiness Level of 9.	Analysis	The CAD software tools used are at a Technology Readiness Level 9. They are currently used in aerospace and other industries	Yes	Technology Readiness Assessment Report

All Requirements are Verified

4. Project Results – Lessons Learned

- Company A
  - Performed Six Sigma Project on Model Based Definition System vs. Installation Drawings
  - Conducted R&D Project using Six Sigma Recommendations
  - System has not been Implemented on a Production Program
  - Lesson: Consider implementing on an Engineering Development Program
- Company B
  - Built Risk Reduction Satellite System
  - Used Minimally Dimensioned Drawings and Step Files
  - Used Windchill System for PDM
  - Saved Money and Time not using traditional drawing release program
  - Very Pleased with Results
  - Lesson: Success can now be translated to larger projects
- Company C
  - Interested in implementing 3-D Model System but Customer requires 2-D Drawings
  - Lesson: Sell 3-D Model Success to your Customer

Project Results – Lessons Learned

- Northrop Grumman Joint Strike Fighter (JSF)
  - Uses 3-D Model System
  - Sends 3 Documents to Vendors: Model, PowerPoint File, and Instruction Notes
  - Small number of Drawings used to communicate with Prime Contractor
  - Employees Very Pleased with 3-D System
- Boeing
  - Uses Dassault Product Lifecycle Management (PLM) Suite to build 787 *Dreamliner*
  - 3-D Models have saved over 50% in Labor Costs
  - Created Strict Requirements for PLM implementation
- Airbus
  - Uses Dassault PLM for Airbus A380
  - Had Major Lesson Learned regarding using same CAD versions
  - Lost $6 Billion in rework Costs

5. Conclusion

- Summary
  - Project Objectives Have Been Met
  - Complete Review of 3-D Model System was Conducted
  - Results Illustrate how 3-D Model System Integrates within S/C System Engineering Process
  - 3-D Model System Enhances Quality, Reduces Costs and is a Lean Alternative to 2-D Drawings
- Conclusion
  - Satellite Industry shall Implement 3-D Model System

Questions?

Back-Up Slides

4. Project Results – Trade Study Analysis

Mission Requirement	2-D Drawing System Compliance	2-D Grade	3-D Model System Compliance	3-D Grade	Grade Explanation
3.2.1.1 The method used to illustrate the Spacecraft Mechanical System Design shall represent the Mechanical System Design as it is depicted in the 3-D Computer Aided Design (CAD) Mock-Up Model.	2-D Drawings are created from the 3-D CAD Model. The Drawing is a 2-D representation of the 3-D CAD Model.	B	The 3-D Model System uses the actual 3-D CAD model to convey the design. Thus, the System accurately represents the Mechanical Design as it is depicted in the CAD Model.	A+	The Drawing System meets the Requirement; however, the system has an error factor. An error in translating from 3-D to 2-D can result. The 3-D Model System exceeds the requirement. It uses the actual model to illustrate the design. Thus, zero discrepancies are associated with this method.

4. Project Results – Trade Study Analysis

Mission Requirement	2-D Drawing System Compliance	2-D Grade	3-D Model System Compliance	3-D Grade	Grade Explanation
3.2.1.2 The method used to illustrate the Spacecraft Mechanical System Design shall be capable of being configuration controlled.	Drawings are controlled through the Configuration Data Management Office (CDMO). The drawing is delivered to the Parts Data Management (PDM) System in an electronic or hard copy format. Once approved and signed by the reviewers, CDMO places a meta data stamp on the drawing which states the release date and revision level. The drawing is then controlled and released.	B	The 3-D Model System Models are controlled by the Configuration Data Management Office (CDMO). The model is uploaded to the Parts Data Management System (PDM) in an electronic format. Once approved and signed by the reviewers, CDMO marks the model with the release date and revision level. The model is then controlled and released.	B	Both systems meet the Requirement. 2-D Drawings and the 3-D Models are controlled thru the PDM system. The CDMO owns the -2D drawings and the 3-D Models.

4. Project Results – Trade Study Analysis

Mission Requirement	2-D Drawing System Compliance	2-D Grade	3-D Model System Compliance	3-D Grade	Grade Explanation
3.2.1.3 The method used to illustrate the Spacecraft Mechanical System Design shall be capable of producing a manufactured product.	Drawings are blue prints for mechanical assembly design. Drawings convey the form, fit, and function of the manufactured item to the manufacturer.	A	3-D Model System conveys the form, fit, and function of the manufactured item. In addition, it provides infinite number of viewpoints which help illustrate design intent, interfaces, and accessibility points.	A+	Both systems exceed the requirement. A manufacturer is more than capable of producing a part using a drawing or the 3-D Model Based System. The 3-D Model Based System provides additional information to the manufacturer.
3.2.1.4 The method used to illustrate the Spacecraft Mechanical System Design shall be capable of illustrating design changes.	Drawings are capable of being revised and extensively revised if necessary. A new revision is created to revise a drawing. Once the revision is approved it is controlled and stored by CDMO.	B	The 3-D Model System is capable of being revised and extensively revised if necessary. A new revision of the model is created. The model revision is approved. Once approved the model is stored and controlled by CDMO.	B	Both Systems meet the Requirement. Design changes are illustrated by Revisions in the 2-D drawing System and the 3-D Model System. The revisions are controlled by CDMO.

4. Project Results – Trade Study Analysis

Mission Requirement	2-D Drawing System Compliance	2-D Grade	3-D Model System Compliance	3-D Grade	Grade Explanation
3.2.1.5 The User(s) shall be capable of accessing the product(s) produced by the method chosen, without incident.	Drawings are stored in the PDMO database system. Drawings are stored electronically or via hard copy. Drawings can be retrieved by downloading and electronic copy or by printing a hard copy from the PDMO database.	B	The 3-D Model System models are stored electronically in the PDMO database system. The model can be downloaded and viewed directly from the PDMO database. It can also be viewed from other products such as Product View and DELMIA.	B	Both Systems meet the Requirement. A user is capable of accessing a 2-D drawing by downloading it from the PDM system or printing a hard copy from the PDM system. A user is capable of accessing the 3-D model by downloading and viewing it from the PDM system or viewing it from software such as Product View or DELMIA.
3.2.1.6 The method used to illustrate the Spacecraft Mechanical System Design shall be capable of integrating within the Spacecraft Systems Engineering Process.	See Appendix A of Final Report	B	See Appendix A of Final Report	A	Both systems integrate well within the Systems Engineering Process. The 3-D Model System exceeds the standard 2-Drawing System during the Requirements Definition and Architecture Design Processes.

4. Project Results Lean Principles

- Flow
  - 3-D Model System is comprised of 83% Value Added Activities
  - 2-D Drawing System is comprised of 47% Value Added Activities
- Pull
  - Design Process initiated at Customer's Request
  - 3-D Models Generated when Requested by Systems Engineering
- Perfection
  - 3-D Model System provides Visibility of Mechanical Design Imperfections early in the Design Life Cycle
- Respect of People
  - Configuration Meetings Involve Direct Communication

4. Quality Methods

- Continuous Improvement
  - 3- D Model System is an Continuous Improvement Activity for the Satellite Industry
- Bottom Up Suggestions shall Strengthen 3-D Model System
- Standard Practices shall be implemented
  - Guidelines for developing 3-D Models and loading Models in to PDM System
- Training
  - How to Create a 3-D Model
  - How to Use PDM System
- Path Forward
  - Eliminate all Non-Valued Added Activities and further Streamline the Process