Track Preference: Systems Engineering

Presentation Title: Re-engineering complex legacy systems at NASA

Synopsis:

This presentation will discuss the Lean Project Management and Model Based Systems Engineering approach applied to re-engineer the NASA Johnson Space Center, Mission Operations Directorate's flight production process for future space flight products. The talk will deliberate on how the approach helped to overcome key obstacles and challenges.

Abstract:

The Flight Production Process (FPP) Re-engineering project has established a Model-Based Systems Engineering (MBSE) methodology and the technological infrastructure for the design and development of a reference, product-line architecture as well as an integrated workflow model for the Mission Operations System (MOS) for human space exploration missions at NASA Johnson Space Center. The design and architectural artifacts have been developed based on the expertise and knowledge of numerous Subject Matter Experts (SMEs). The technological infrastructure developed by the FPP Re-engineering project has enabled the structured collection and integration of this knowledge and further provides simulation and analysis capabilities for optimization purposes. A key strength of this strategy has been the judicious combination of COTS products with custom coding.

The lean management approach that has led to the success of this project is based on having a strong vision for the whole lifecycle of the project and its progress over time, a goal-based design and development approach, a small team of highly specialized people in areas that are critical to the project, and an interactive approach for infusing new technologies into existing processes. This project, which has had a relatively small amount of funding, is on the cutting edge with respect to the utilization of model-based design and systems engineering.

An overarching challenge that was overcome by this project was to convince upper management of the needs and merits of giving up more conventional design methodologies (such as paper-based documents and unwieldy and unstructured flow diagrams and schedules) in favor of advanced model-based systems engineering approaches.

Speakers Biographies

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Jim Ruszkowski is currently the Deputy Office Chief for the Mission Operations Directorate (MOD) Technical Integration and Production Control Office located at the Johnson Space Center (JSC) in Houston Texas. He is also the Project Manager for the MOD Flight Production Process Re-engineering Project whose focus is putting in place the next generation flight production process that the MOD will use to support all future space vehicle missions.

Jim is a graduate of the University of Texas at Austin with a Bachelor of Science degree in Chemical Engineering. For the last 25 years he has worked in the Mission Operations Directorate (MOD) at the Johnson Space Center. For the first 13 years he worked in the Training Division where he obtained roles with increasing responsibility first as Shuttle Systems instructor, then a Shuttle Team Lead and finally as a Shuttle Simulation Supervisor training Astronauts and Flight Controllers. From 1998 to May, 2001 Jim served as the Chief of the JSC Emergency Operations Center Office where he focused on making JSC emergency response have the same disciplined approach to training and on console operations that are found in MOD. Since June 2001 Jim has worked in the MOD's Technical Integration and Production Control Office first as a Flight Production Manager, then as the Deputy Office Chief. Since 2005 Jim has also served MOD as the Mission Operations Project Integrated Master Schedule Lead and as the Project Manager for the Flight Production Process Re-engineering Project.

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Dr. Leila Meshkat is a Senior Engineer in the Systems & Software Division at the Jet Propulsion Laboratory (JPL) and a part time faculty member at the University of Southern California (USC) School of Engineering. During the course of her career at JPL she has conducted and led numerous Risk and Systems engineering tasks. She created the Risk Chair in JPL's Concurrent Engineering team and led the design and development of an associated distributed software system. She conducted the post-anomaly quantitative risk modeling for the MRO and ODY missions and built models for the assessment of the reliability of the Mars relay network. She has created new processes and rules for software development at JPL.

She is currently the Principal Investigator for the JPL Command Process Modeling & Risk Analysis task and one of the Lead Systems Engineers in the Special Analysis Team (Flight Production Process Re-engineering Project). Prior to joining JPL, she was a postdoctoral researcher at the USC Information Sciences Institute. She holds a Ph.D. in Systems Engineering from the University of Virginia, an M.S. in Operations Research from the George Washington University and a B.S. in Applied Mathematics from the Sharif University of Technology.

Re-engineering Complex Legacy Systems at NASA

2011 Project Management Challenge

JSC MOD/Technical Integration and Production Control Office

JSC MOD/Jim Ruszkowski
JPL/Dr. Leila Meshkat
February 13, 2011

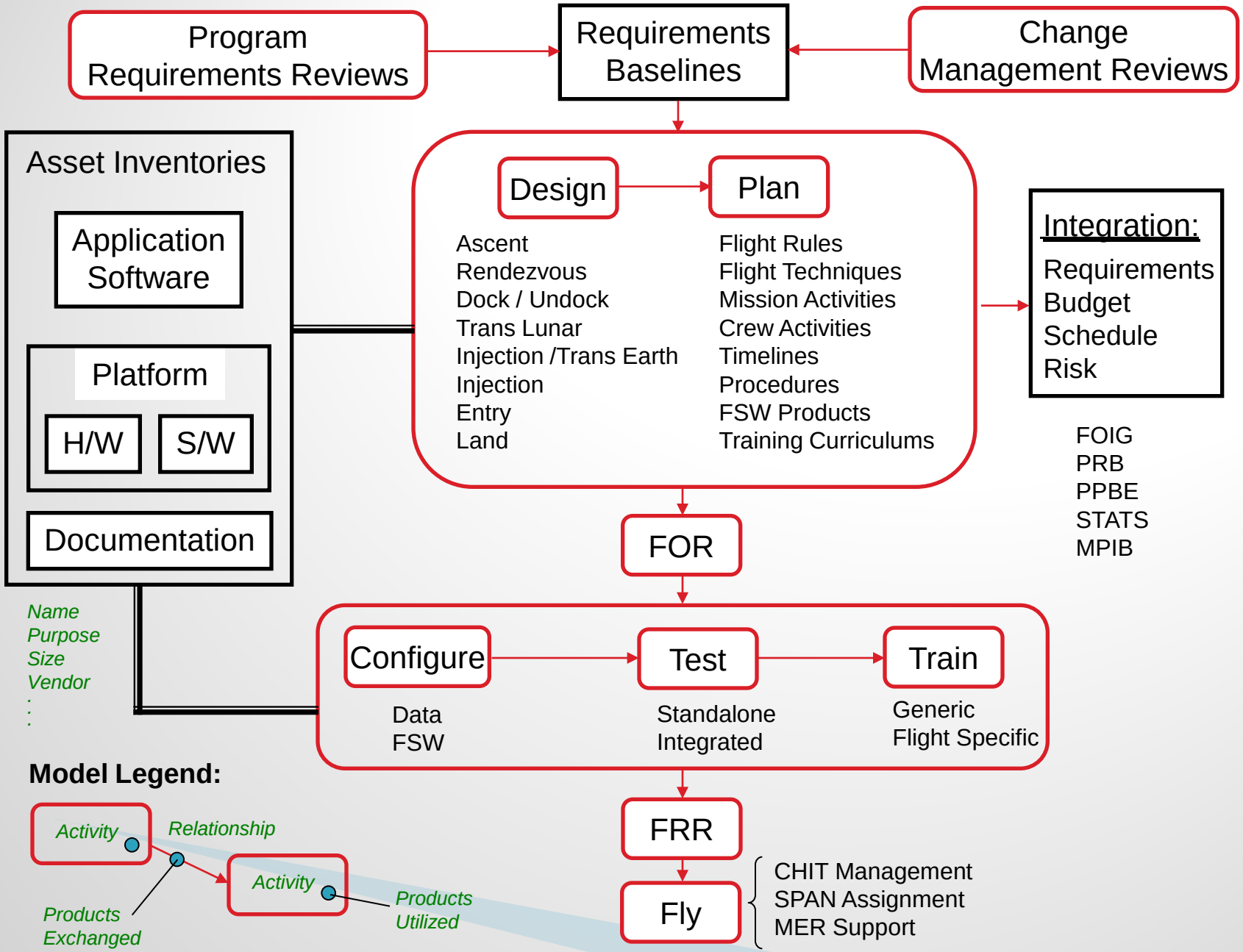
Outline

A. Project Description
B. Problem Definition
C. Challenges
    1. Building Project Support
    2. Acceptance of Model Based Systems Engineering (MBSE) and Enterprise Architecture (EA) as the correct methodologies
    3. Resource Limitations
    4. Maintaining Management Support
    5. Establishing a tool set for MBSE and EA development

Project Description – What is the FPP?

- The Mission Operations Directorate (MOD) supports the crew and flight controller training, pre-launch/launch operations, and flight operations through a methodology known as the Flight Production Process (FPP)
- This process is a compilation of work tasks conducted by a number of technical disciplines within MOD and its operations contractor(s)
- The FPP provides:
  - The products required to reconfigure the mission control center with its associated training facilities
  - The flight software and associated data products required for reconfiguring the flight vehicles
  - Trained and certified flight personnel, including crew, flight controllers and analysts
- The FPP is the set of business processes within the overall Mission Operations System (MOS) that are executed for each Space Mission

MOD Flight Production Process



What Problem are we trying to solve?

- The MOD Space Shuttle Program (SSP) and International Space Station Program (ISSP) FPP's were not built as one integrated system; instead the separate and distinct production processes used for these two programs were built a piece at a time by each of the six large functional areas within MOD:
  - Flight Dynamics Division
  - Operations Division
  - Space Transportation Vehicle Division
  - Expedition Vehicle Division
  - EVA, Robotics and Crew System Division
  - Mission Operations Facility Division
- Systems Integration was not the basis for the design of the Systems established by these Divisions
- A new FPP is needed for the future and it must be efficient if we are to remain competitive

Challenge # 1- Building Project Support

- Establishing that re-engineering our business processes was necessary
  - MOD management set a clear goal to cut operations costs by 50% over FY10 Shuttle Program costs by 2014
  - The FPP Re-engineering Projects primary objective is to support this goal but our vision and corresponding approach was not widely understood
- Building the case that analysis of MODs business processes in the context of the FPP will enable the development of an MOS that more effectively meets user needs
  - MODs focus and expertise is on providing world class Mission Control Center Operations
  - MODs Shuttle and Station Flight Production Processes were not established through detailed business process development
  - "Systems Engineering" was done on the back end when the individual system component designs where fairly mature

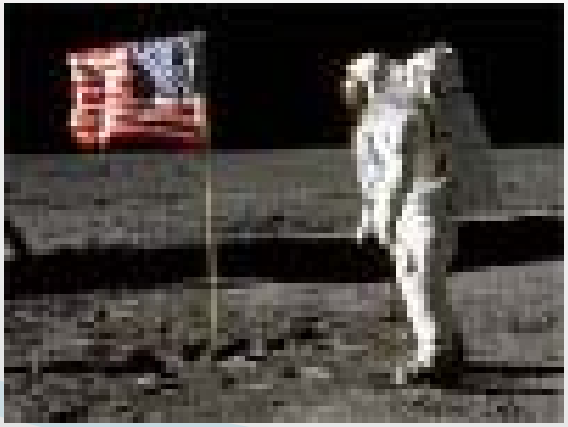
Obstacle # 1

Convincing our stakeholders that "An understanding of the concept of a business process and the need to conduct integrated business process analysis is a prerequisite for systems integration" (1)

Key Term – Systems Integration is an important element in Systems Engineering. It involves the integration of hardware, software, products, services, processes and humans. The ever increasing scale of complexity of systems and its impact on the business requires that we revisit the processes involved in the development and integration of a system" (1)

What is the scope of MODs System Integration problem?

- The MOD Mission Operations System (MOS) performs over 150 functions for the Space Shuttle and International Space Station Programs
  - These functions are required to Plan, Train and Fly all current and future human space flight programs
- These functions result in the production of over 600 products



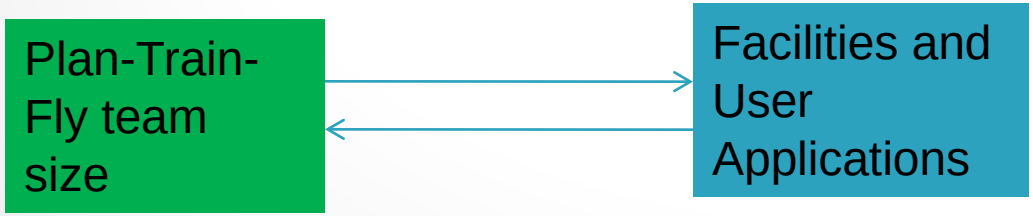
What is the scope of MODs System Integration problem?

- Limitations with the Systems Engineering and Integration (SE&I) discipline in the 70's and 80's resulting in the usual problems in MODs FPP:
  - Duplication of functions and associated activities
  - Manual data conversion and entry from one tool to the next in the process
  - Hundreds of configuration management steps to ensure data integrity
  - Overtime work to get products produced in the available time period
  - Interoperability was not addressed in the initial design of these systems and had to be addressed after the systems had been developed
  - We had to use a series of process improvement/Lean activities to fix problems and streamline the overall process

- Key term – Interoperability is the ability of systems to provide services to and accept services from other systems, and to use the services so exchanged to enable them to operate effectively together (1)

What Problem are we trying to solve? (Con't)

- Because of limited SE capabilities in the past MOD has not been able to effectively develop our P-T-F team business processes and then perform analysis of those processes up-front in order to perform systems integration

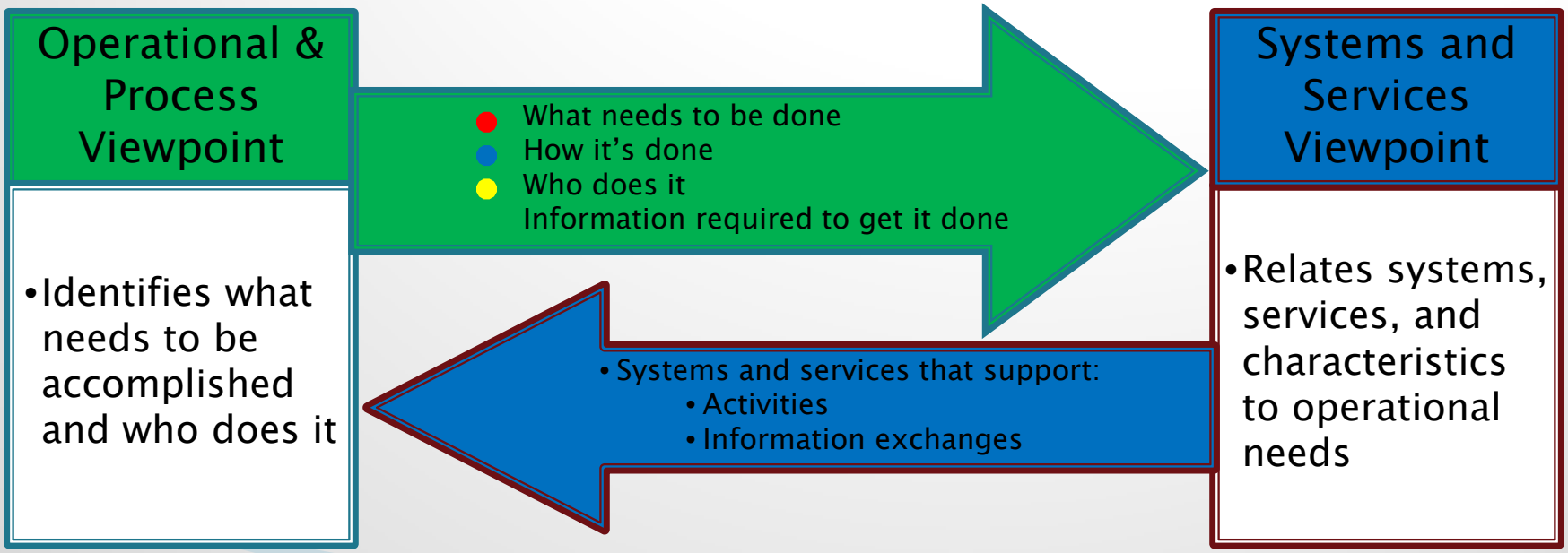


These two items must be integrated to optimize the cost profile

- If Facility and User Applications (UA) costs are too low then the P-T-F team will need to do extra work to off-set limits in tool functionality
- If P-T-F team needs are not understood up front then Facility and UA costs will go up as new functionality requirements are better understood

Another View of the Problem

- Mission Operations Flight Controllers have system requirements that are needed to Plan, Train and Fly Missions
- Facility developers focus is to develop systems/services that meet program and security requirements
- Optimally these two viewpoints must be addressed and integrated before system design



Solving MODs Systems Integration Problem

- MOD'S business processes (P-T-F team requirements) have been captured in a large architecture description document
- Integrating all of them "up front" using this document makes it extremely hard to:
  - Understand and integrate the division-to-division processes
  - Develop requirements for facility and system design
- You can do integration "on the back end" with multiple iterations of Lean type activities to make process improvements but this extremely expensive
- **MOD needs to develop a more efficient way to develop, integrate, analyze and continuously improve a very complex architecture**

Challenge # 2 – Acceptance of MBSE and EA

- Establish that the approach to develop MOD's 21st century Mission Operations System is to use Model Based Systems Engineering technologies to establish an Enterprise Architecture

- Overcome the issues associated with implementing a MBSE in an organization with a long history and legacy of performing systems integration by hiring the right Project Managers

Obstable # 2

"There are groups where MBSE is practiced (both within and outside of NASA), but it is not widely understood outside of those groups" (2)

Why MBSE?

- MOD has traditionally used paper based methods for developing requirements and designing new systems
- MOD needs a methodology that focuses on addressing integration issues up-front in order to minimize integration related complexities and challenges later on in the system engineering process

What is MBSE?

- "Model-based systems engineering (MBSE) is the formalized application of modeling to support system requirements, design, analysis, verification and validation activities beginning in the conceptual design phase and continuing throughout development and later life cycle phases" (7)
- MBSE enables the systems engineer to precisely capture, analyze, and specify the system and its components and ensure consistency among various system views.
- For many organizations, AS IS THE CASE FOR MOD this is a paradigm shift from traditional document-based and acquisition lifecycle model approaches (4)

- Key Terms: A **model** is an approximation, representation, or idealization of selected aspects of the structure, behavior, operation, or other characteristics of a real-world process, concept, or system (IEEE 610.12-1990), i.e. an abstraction. A model usually offers different views in order to serve different purposes. A **view** is a representation of a system from the perspective of related concerns or issues (IEEE 1471-2000).

Why use MBSE to establish an Enterprise Architecture?

- MOD needs to transform into an agile organization to be able to quickly meet needs and opportunities that arise in the next decade
- Currently, most information about how we conduct business is housed in different documents, spreadsheets, systems and other repositories
- An EA will allow us to gain a comprehensive, integrated, common view of the way we conduct business
- The modeling artifacts being developed can easily be refined and reused in other applications to support product line and evolutionary development approaches

Why use MBSE to establish an Enterprise Architecture ? (Con't)

- An enterprise architecture will allow us to:
  - Define, develop, validate and execute our missions with a common understanding of how our people, processes and systems will interact with one another
  - Run models and simulations of our business processes to validate our processes and systems and find areas where efficiencies can be achieved
    - Improving net-readiness and interoperability
    - Eliminating gaps and overlaps between our operations needs and system capabilities
    - Reducing the sustaining costs and
    - Increasing system reliability, robustness and maintainability
- The result will be an organization that can quickly assess the impact of external events and quickly adapt to changes

Challenge # 3 – Resource Limitations

- The MOD at the JSC is currently providing operations for two active programs, the Shuttle and Station Programs, with a constant focus on flying these missions safely in a cost constrained environment
- With this primary focus it has been challenging to find the resources required to re-engineer our Business Processes and to develop new Systems for future programs

Obstacle # 3 A & B

Because the goals and benefits of our Project, and how it supported MODs strategic goals, were not broadly understood resources were limited

When choosing the right mix of Process, Methods, Tools, and Environment elements, one must consider the knowledge, skills and abilities (KSA) of the people involved (5)

Dealing with Limited Resources

MBSE can be done with a lean team

- MBSE and EA were not widely understood methodologies within MOD at the initiation of this Project
- As a result the request for support to build a 21st MOS using this approach was not readily embraced
- Without the support of one high level MOD manager we would not have stepped into the world of MBSE in 2008
- Because of this lack of overall management acceptance of the merits of our Project (remember MBSE is relatively new) we had to do this work with a lean team

Establishing a Lean Team

We looked for resources that were already moving in the right direction

- MOD had already established a team of SMEs across the Divisions who had started the process of performing systems integration, in support of the CxP, using traditional document based methodologies
- Melding this effort into one that utilized our MBSE approach was the first step in the process of establishing our team
  - Fortunately the leadership for the team attempting to perform the paper based SI quickly realized the benefits of the MBSE approach

Establishing a Lean Team (con't)

We limited the number of employees reporting directly to Project Management

- Only the minimum number of direct reports were co-located with the PM
- A matrix approach was used to establish the rest of the team
  - Kept SME's in their home Divisions to allowing them to infuse information from a broader group of system experts
  - This provided some amount of management support as matrix'ed personnel interacted with their own management

Establishing a Lean Team (con't)

We consolidated our Key personnel into a core team, called the Special Analysis Team (SAT)

- Representatives from all Divisions (relevant disciplines) were included on this team
- Experienced former flight director led this team
- Experts in modeling, simulation, design process engineering, and systems engineering were also included
- This team developed and established the approach for modeling the processes, establishing the required tool set and performing analysis
- Subject Matter Experts on this team were instrumental in getting buy-in from broader MOD team

Establishing a Lean Team (con't)

We took advantage of the "NASA Inter-center community of practice model" to build the SAT

- Allowed us to use available talent across multiple centers to reach better technical solutions
- The team was distributed across several different organizations and centers
  - Tietronix – a Houston based contractor
  - Johnson Space Center
  - Jet Propulsion Laboratory
  - Ames Research Center
- Because the SAT was able to quickly embrace and understand the MBSE concept teamwork was very effective and efficient

Challenge # 4 – Maintaining Management Support

- The overarching challenge was to convince management that what we were doing was necessary and that our cutting edge systems engineering methodologies were the right approach

Obstacle # 4

Knowledge of integrated flight production processes is not widely understood within the organization

Management Support Issues

- Key people in MOD management positions were not convinced of the merits of model based systems engineering
- The Constellation Program that was funding this Project was not using a MBSE approach to establish the program-wide FPP
  - As a result they were more interested in the final products required from the process than the structured design of the process itself
- Each of the project elements (DODAF views, DES model, Process Flow Diagrams, etc.) was foreign to MOD management

Steps Taken to Obtain Management Support

We used a Value-Focused Design & Development approach

- We strived to clearly identify the Project stakeholders
  - Enterprise Level, Flight Projects, System Developers, End-Users
- We then identified what quality attributes were of value to each of them?
  - Maintainability, Reliability, Re-usability, Cost-Reduction, Performance, Ease of Verification and Validation, Analyzability with respect to requirements
    - Mapping table between quality attributes and stakeholders
- We then targeted the work to deliver these quality attributes as effectively as possible
  - DODAF viewpoint development, Discrete Event Simulation (DES), Management Level Network Executive (MLNE)

Value-Focused Design & Development (Con't)

Quality Attributes of Value for the Project Stakeholders:

	Maintainability	Reusability	Risk Reduction	Cost Reduction/Affordability	Performance	Analyzability with respect to requriements	Ease of Verification and Validation	Reliability
Enterprise Stakeholder								
NASA HQ's		x	x	x	x	x		x
Cx Program		x	x	x	x	x	x	x
JSC MOD	x	x	x	x	x	x	x	x
KSC MOD		x	x	x	x			x
Flight Project Stakeholders								
Orion					x	x	x	x
Ares					x	x	x	x
System Development Stakeholders								
Designers	x	x			x	x		
Implementers	x	x			x	x	x	
Testers	x	x	x		x	x	x	x
End-User Stakeholders								
Flight Controller/Mission Analysts	x	x	x		x	x	x	x
Flight Directors	x	x	x	x	x	x	x	x
Ground Operations	x	x	x	x	x	x	x	x
Logistics/Maintenance/Recovery and Refurbishment	x				x			

The FPP project uses DODAF architectural artifacts (Operations and Systems views), Discrete Event Simulation, and the Management Level Network Executive to deliver these values to the stakeholders.

We mapped Quality Attributes to our Modeling Techniques

Modeling Technique	Information Flow Spanning Organizational Boundaries (OV-5, OV-2, OV-3)	System Capabilities to support information flow (SV-2,SV-3,SV-6)	Discrete Event Simulation	Management Level Network Executive
Quality Attribute				
Cost Reduction	x	x	x	x
Risk Reduction	x	x	x	x
Maintainability	x	x		
Reusability	x			
Performance		x		x
Analyzability			x	
Ease of Use	x	x	x	x

Steps Taken to Obtain Management Support (Con't)

Project Management established a clear vision for the mid and long term state of the project

- Each of the elements of the project are assessed and decisions are made with consideration of the expected end state
- A continuous theme is to always be looking for better ways to explain MBSE, DoDAF, etc., in terms that non System Engineers can understand
- Our focus was on understanding Customer needs and providing products that meet those needs
  - Develop products that meet customer needs as soon as possible – go for quick victories
  - Provide value to management throughout the project

Challenge # 5 – Establishing a tool set to support MBSE and EA

- Since MBSE and EA were new to MOD we did not have a tool set that would support these activities
- As we found out there were many tools that would do aspects of what we wanted but nothing that would support the end to end process integration that we were seeking to do
- We also had a goal of not getting locked into a single COTS tool that would prohibit the use of other tools

Obstacle # 5

"It will take time before a robust set of tools are able to fully support it (MBSE) and it becomes a capability of most systems engineers " (2)

"The capabilities and limitations of technology must be considered when developing a systems engineering development environment" (6)

Approach – corresponding tree next chart

- Consider the fundamental objectives of the project.
- Decompose it into the means objective
- Determine what technique is used for achieving each means objective.
- Determine what class of tools/applications are required for the implementation of that technique.
- Determine their corresponding operations concept within the context of the modeling and development team.
- Develop requirements for each class of tool.
- Conduct trade studies to pick the right option within that class.
- Take into consideration the Object Management Group (OMG) recommendations. (http://www.omg.org/) throughout the selection process.

Objective Hierarchy – FPP Re-engineering

Fundamental Objectives:

Reengineer the MOD MOS with goal of reducing sustaining costs

Means Objective:

Build an Enterprise Architecture

Design and Optimize Processes

Optimize Operations

Organizational Structure (OV-s)

System Structure (SV-s)

Interface Control Documents

DES Model Completeness; Validity; Sensitivity Analysis;

Connect with program models

Risk/Margin Management

Workflow Execution

Uncertainty Management by Re-planning

Design Optimization:
schedule optimization; queuing systems
Phased mission systems,
Trade studies, risk analysis, etc.

General Tool Requirements

- Ease of Data Elicitation from SME's
  - A focus of Project Management was to provide tools that would allow the SMEs to develop and maintain ownership of their Division's processes
- Maintainability
  - After achieving the primary goal of developing all the Business Processes to perform Systems Integration the secondary goal is to put in place a tool set that allows the Divisions to maintain and easily update their Business Processes
- Extensibility to a plethora of COTS products.
  - We did not want to be locked into any single COTS tool or EA framework since the technology is moving so fast and there's significant vendor turnover

We had many tools to select from

Workflow Execution

Savvion

Drawing Tools

Graphviz

Visio

Microsoft Add-On

Visio

ProModel

@Risk

General Purpose Simulation

Mathematica

Simulink

Matlab

What tool do we use???

Discrete Event Simulation

Arena

SIMPROCESS

SIMUL8

CORESIM

Witness

Rhapsody

GPSS/H

Minitab

Galileo

ASSAP

Hugin Expert

Saphire

Statistical/ Reliability Analysis

CORE

Magic Draw

Rational Rose

System Architect

Enterprise Architect

Architecture Development BPMN

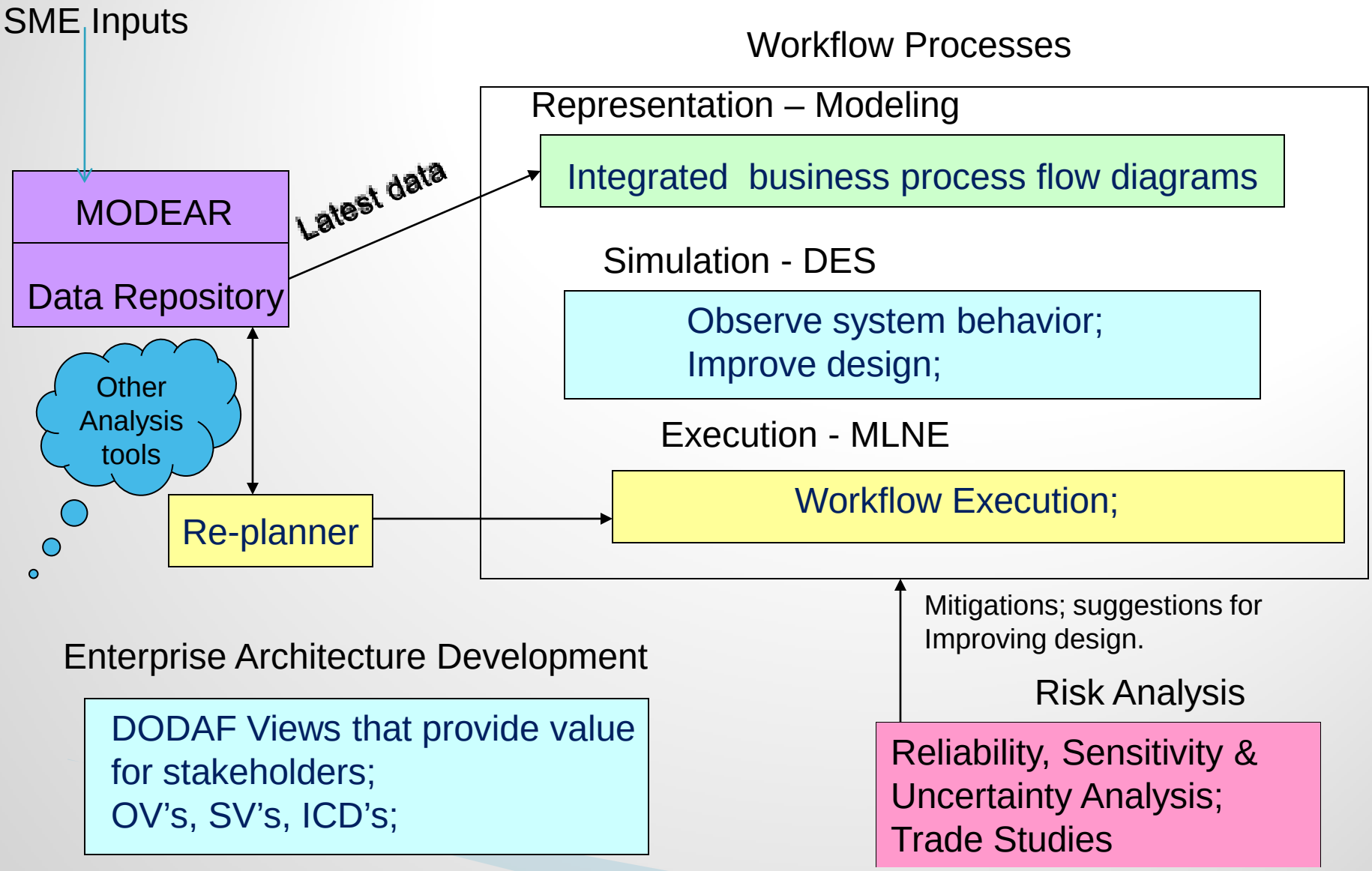
Process for Model Development

- This process starts with data elicitation from the Subject Matter Experts.
  - In order to standardize the data representation, an ontology was developed based on the Business Process Modeling Notation (BPMN) and a glossary of terms and notations for the MOD was agreed upon with participation of the SME's.
  - This ontology was then the basis of the data schema underlying a customized repository that was developed.
- In order to facilitate the data elicitation process, standardized templates were built that allowed SME's to develop the Process Flow Diagrams (PFD's) for each of the main functions that they perform.
- The data in the repository is then transferred into other applications for processing.
  - Each applications provides a unique type of analysis and processing.

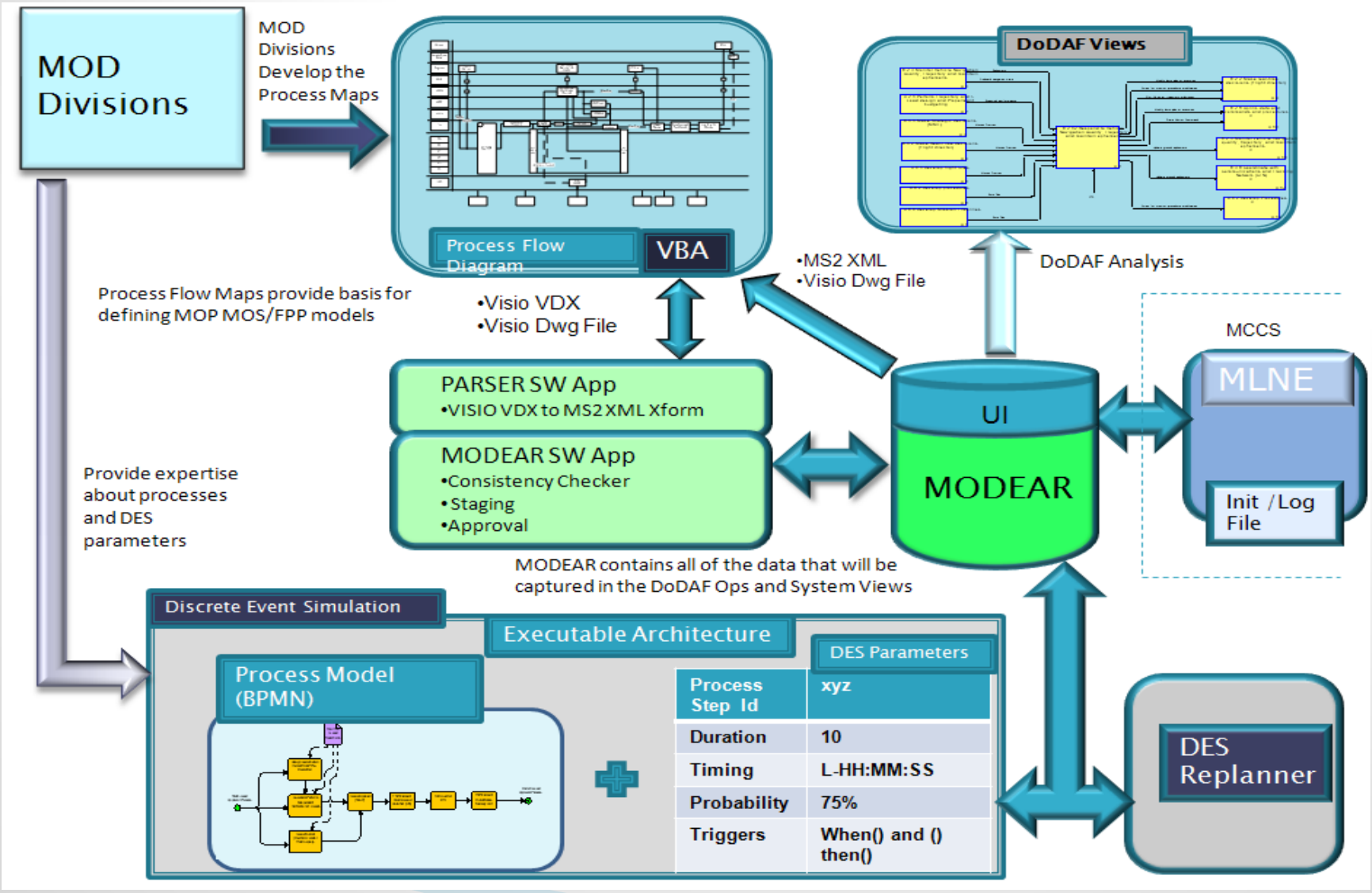
Process for Model Development

- A Visio Add-On has been developed to provide a standardized structure for data elicitation from the SME's.
  - The latest data from the repository is available to the SME's automatically in the form of pull-down menus.
- Data from this Add-on is then automatically ingested into the repository.
- The repository serves to store and integrate all relevant data.
- The Architecture Views are produced in an Enterprise Architecture Application (Currently IBM's System Architect).
- The Discrete Event Simulation (DES) is performed by a specialized DES tool (currently IBM's Witness). The objective of the DES is to simulate, verify and further analyze the workflow model.
- The Uncertainty & Risk Analysis is conducted in Galileo ASAP and Saphire (NASA PRA tools).

How did we do the Modeling?



How did the data flow between applications?



Why a customized repository?

- MODEAR (Mission Operations Directorate Enterprise Architecture Repository) is a repository for the data pertaining to the design of the Mission Operations System.
  - Workflow Operations Processes
  - System Architecture

- The totality of the data in MODEAR is available as an XML output and hence MODEAR data can be transformed to any arbitrary applications/COTS tools for further analysis/processing/development of architectural graphs, etc.

- MODEAR Schema is consistent with the BPMN and DODAF framework and provides a reference architecture for Mission Operations System design.

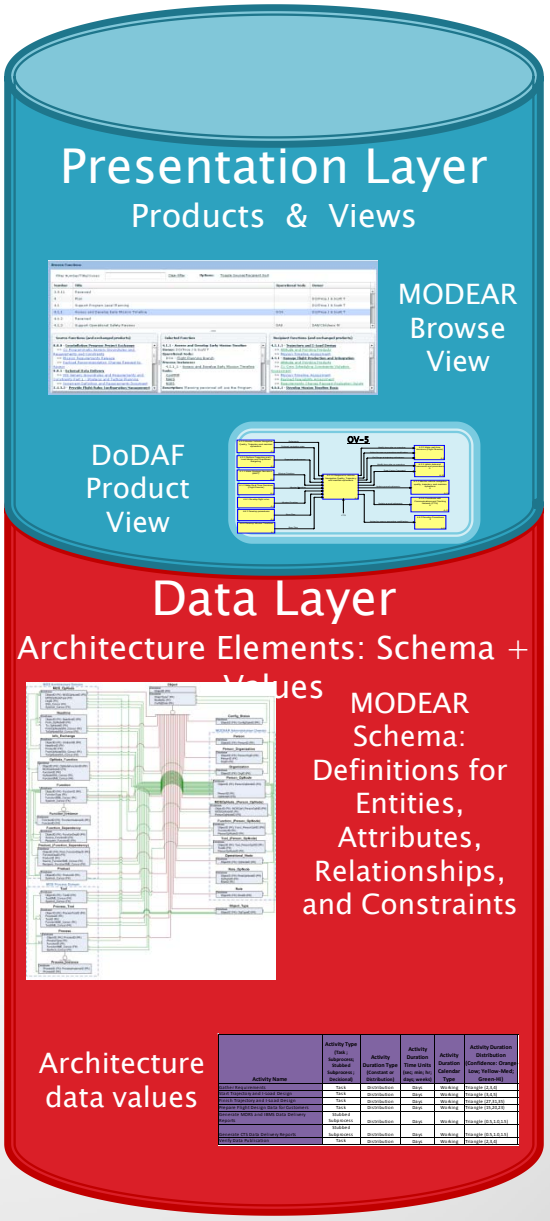
- MODEAR Schema is extensible to additional artifacts for:
  - Capturing relevant design information for the system components (Facilities, hw, sw).
  - Serving as a database/repository of the performance data during the execution of the workflow processes.

- MODEAR has only 70-90k lines of code. This is very insignificant in comparison with applications which deal with thousands of kslocs. Building the necessary code to use any of the applications for our current purposes would require coding in the same order that MODEAR has today.

Why did we structure MODEAR the way we did?

- In the Data Layer:
  - Architecture data elements and their defining attributes, relationships, and values
    - Object-oriented data model
    - Relational database schema
  - Data retained in MODEAR
    - MySQL

- In the Presentation Layer:
  - Products and views that support a visual means to communicate and understand the architecture
    - Its purpose
    - Its description
    - The analyses it is expected to support
  - Virtual Layer; physically distributed
    - XML is MODEAR's medium for data exchange among the layer's distributed applications
      - Including client-server messaging
  - Currently MODEAR's Presentation Layer includes:
    - MODEAR User Interface (UI)
    - System Architect
      - DoDAF Products (OV-2, OV-3, OV-5)
      - Discrete Event Simulations with Witness Plug-in (BPMN)



Take-Away's

- Competent Systems Engineers are typically knowledgeable about the various subsystems of the space system, are able to see the interfaces, and effectively communicate and collaborate with the Subsystem Engineers.
- Expertise in the formal discipline of Systems Engineering, which encompasses modeling and simulation technology and uncertainty management is not a requirement for Systems Engineers.
  - Both these types of expertise are valuable and necessary in today's market.
- Modeling & Simulation technology is used successfully for subsystems (such as rover prototypes and simulations), but not at the higher systems level.

Take-Aways

- In a large organization where there are relationships back to the home Divisions, with the technical knowledge, we found success using a matrixed approach to establish the systems Integration team.
- Take advantage of the NASA Inter-center community of practice model that allowed us to use available talent across multiple centers to reach better technical solutions
- Build your team around a few "top guns" to ensure that you stay on the leading edge
- To put in place an MBSE team you need to find people who can embrace new ideas quickly (you will need to weed out detractors)
- Never stop trying to explain MBSE and its benefits (don't make the mistake of thinking others understand what you are talking about)

Take Away's (Con't)

- Education in and leadership of Model-Based Systems Engineering and Information Systems at the Agency and, in fact, all levels of management is critical to the affordability and sustainment of large, complex systems (3)

- Avoided using a specific COTS tool set to store all your data.
  - If all your data is in a COTS tool you will be limited to that vendors tool suite for Discrete Event Simulations, developing architecture view, etc.
  - We developed a custom database designed to provide the ability to operate with any XML compatible tool
- Develop products that meet customer needs as soon as possible - go for quick victories

Take Away's (Con't)

- Following are the key steps to our success:
  - Clear goals and our ability to stay on target
  - Ability to put together an extremely skilled core team
  - Motivated working level personnel who understood the Project goals and provided enthusiastic support
  - Project structure and organization
  - The establishment of a powerful tool set that facilitated working level personnel support
  - A business atmosphere that mandated cost reductions

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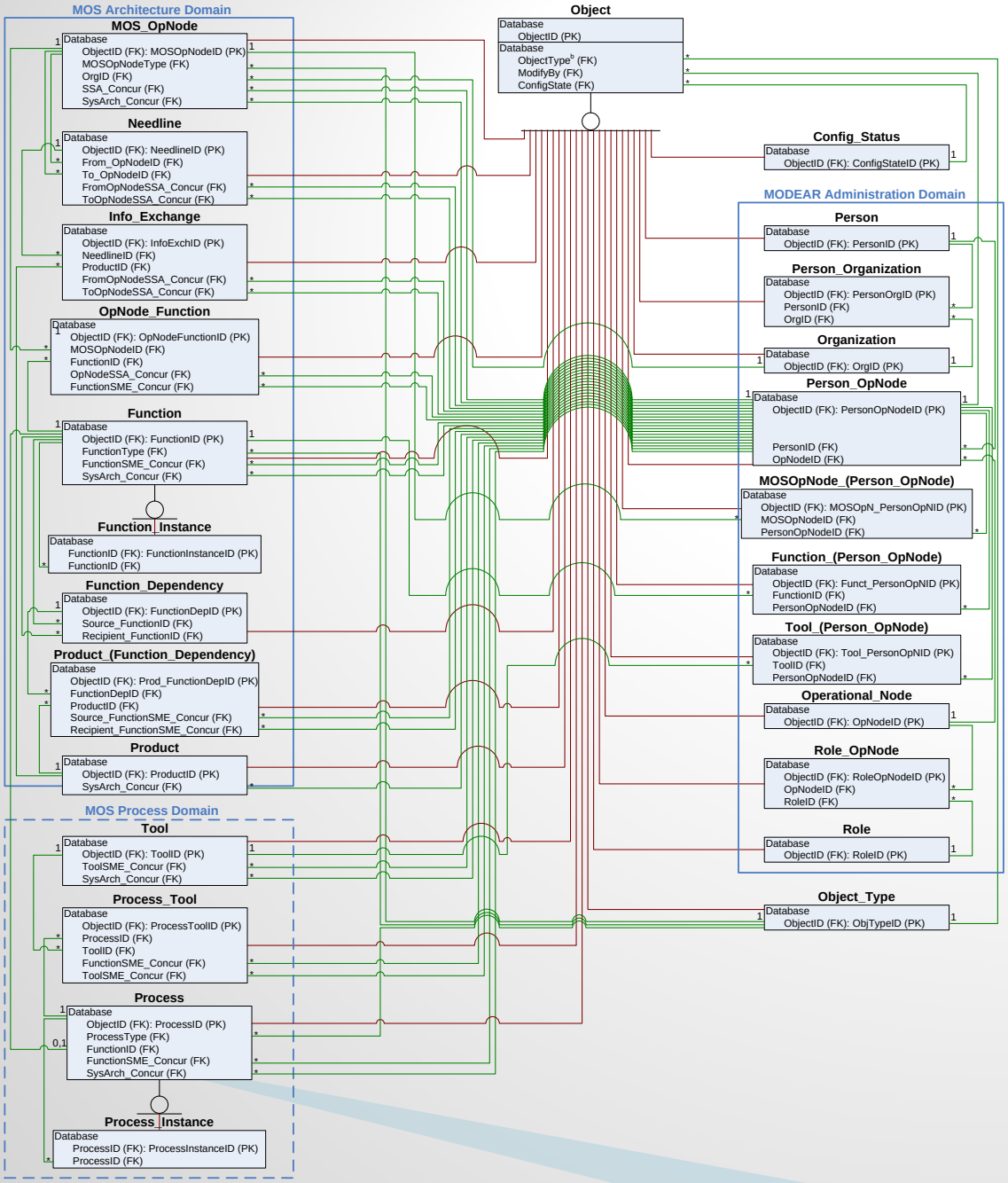
- (4) Jeff A. Estefan, Jet Propulsion Laboratory, California Institute of Technology Pasadena, California, U.S.A., "Survey of Model-Based Systems Engineering (MBSE) Methodologies," 05/27/2007
- (5) Boehm, Barry W., "A Spiral Model of Software Development and Enhancement," Computer, pp. 61-72, May 1988.
- (6) Martin, James N., Systems Engineering Guidebook: A Process for Developing Systems and Products, CRC Press, Inc.: Boca Raton, FL, 1996.
- (7) INCOSE-TP-2004-004-02, Version 2.03, September 2007

Backup

Data Model (ERD) for MODEAR (notional)

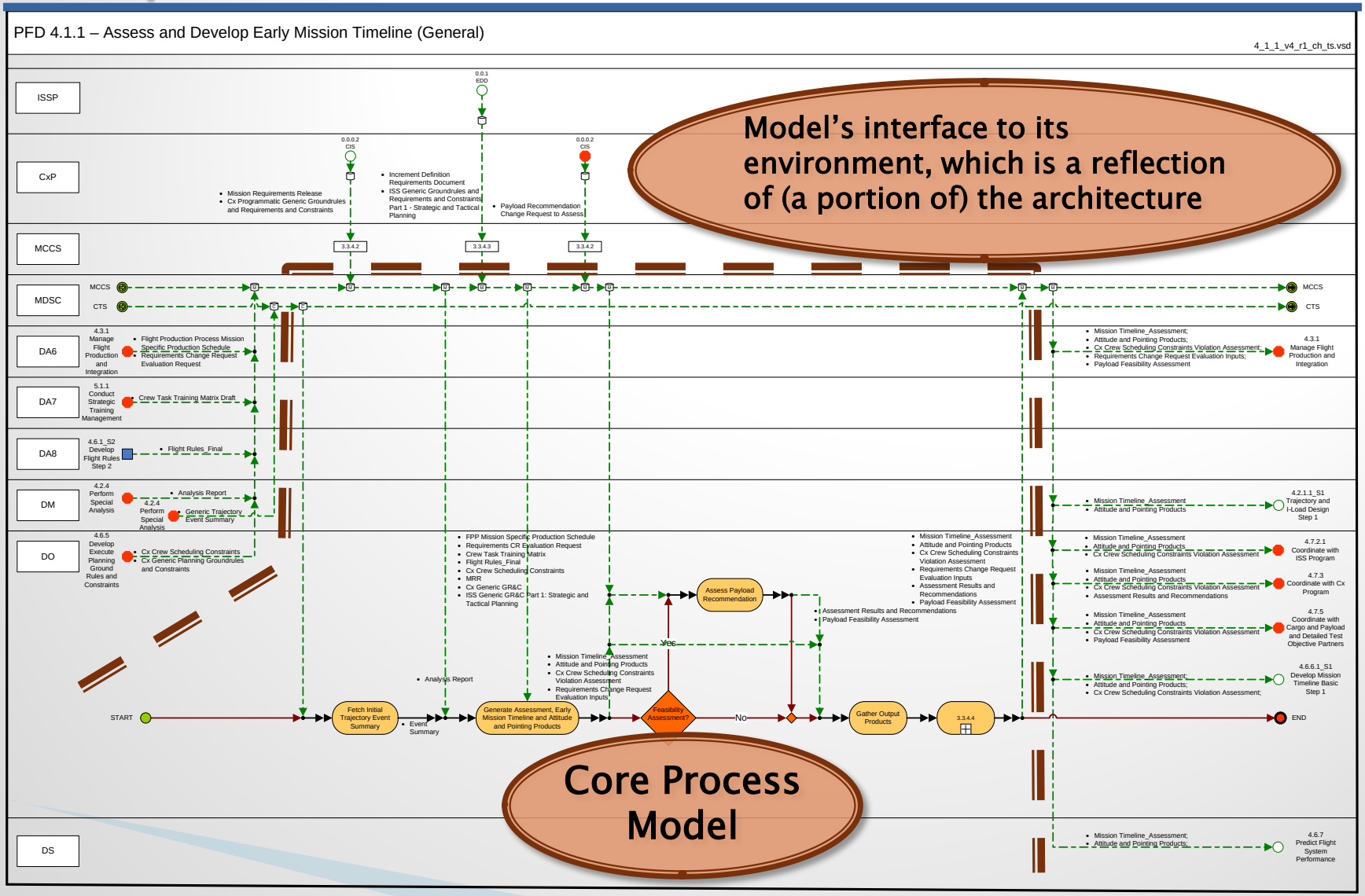


MODEAR

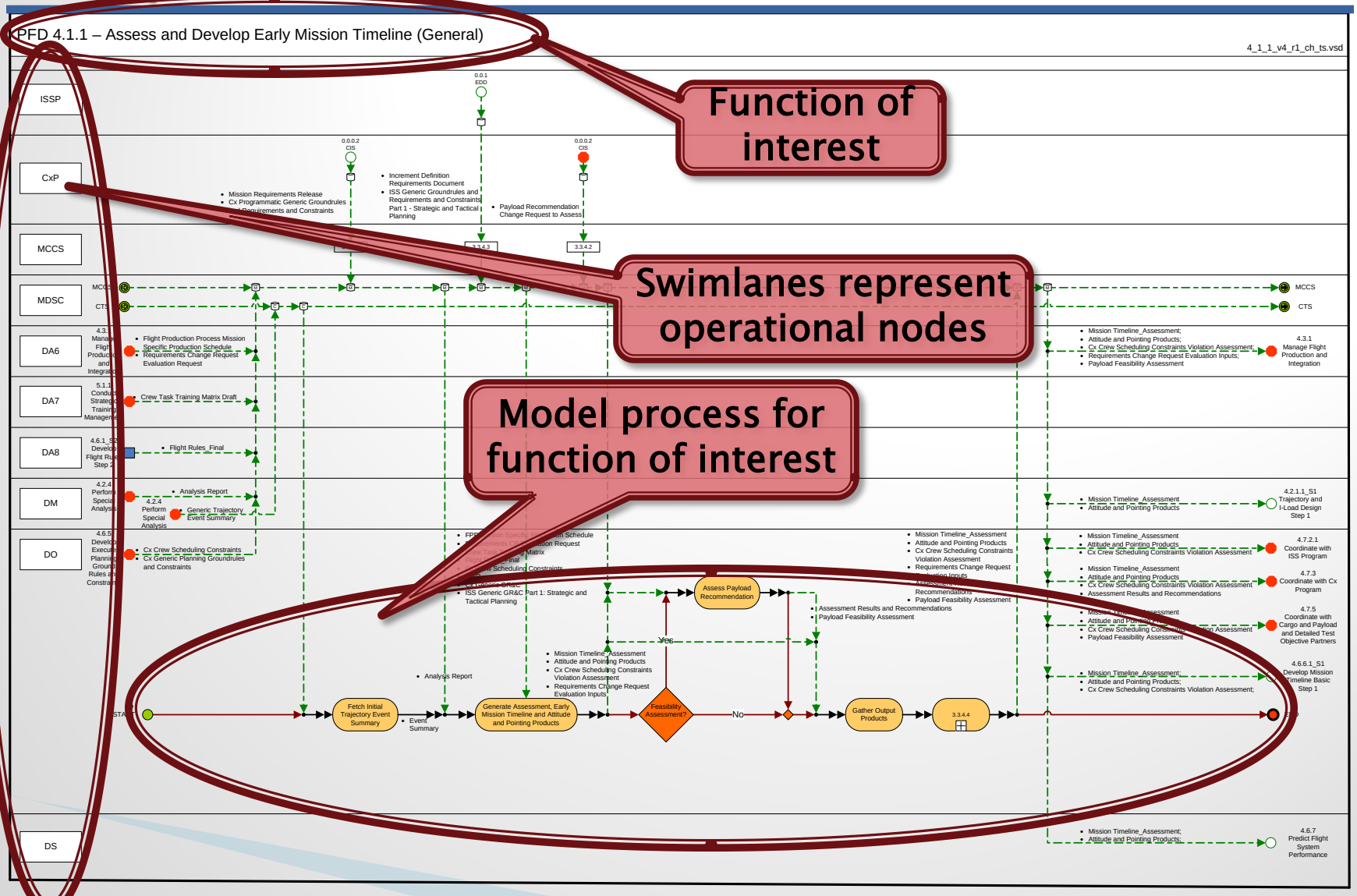
Entities and Relationships

- MODEAR Data Model is object-oriented
  - Entities reflect classes
    - Object entity is the abstraction
    - Some primary; most associative
    - Object_Type maps classes to entities
- Values are seen through the lens of the MODEAR UI

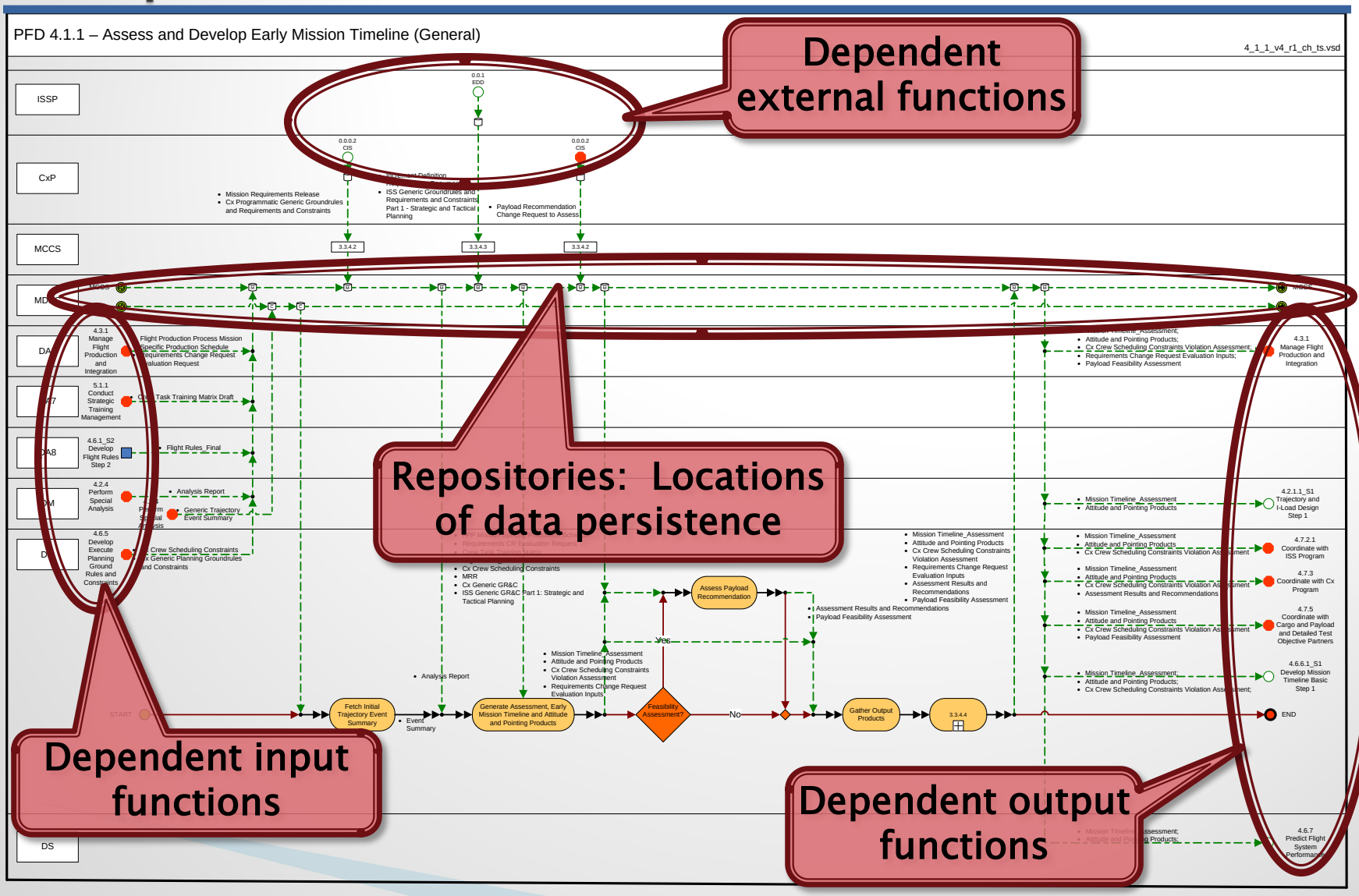
PFD
Sample PFD



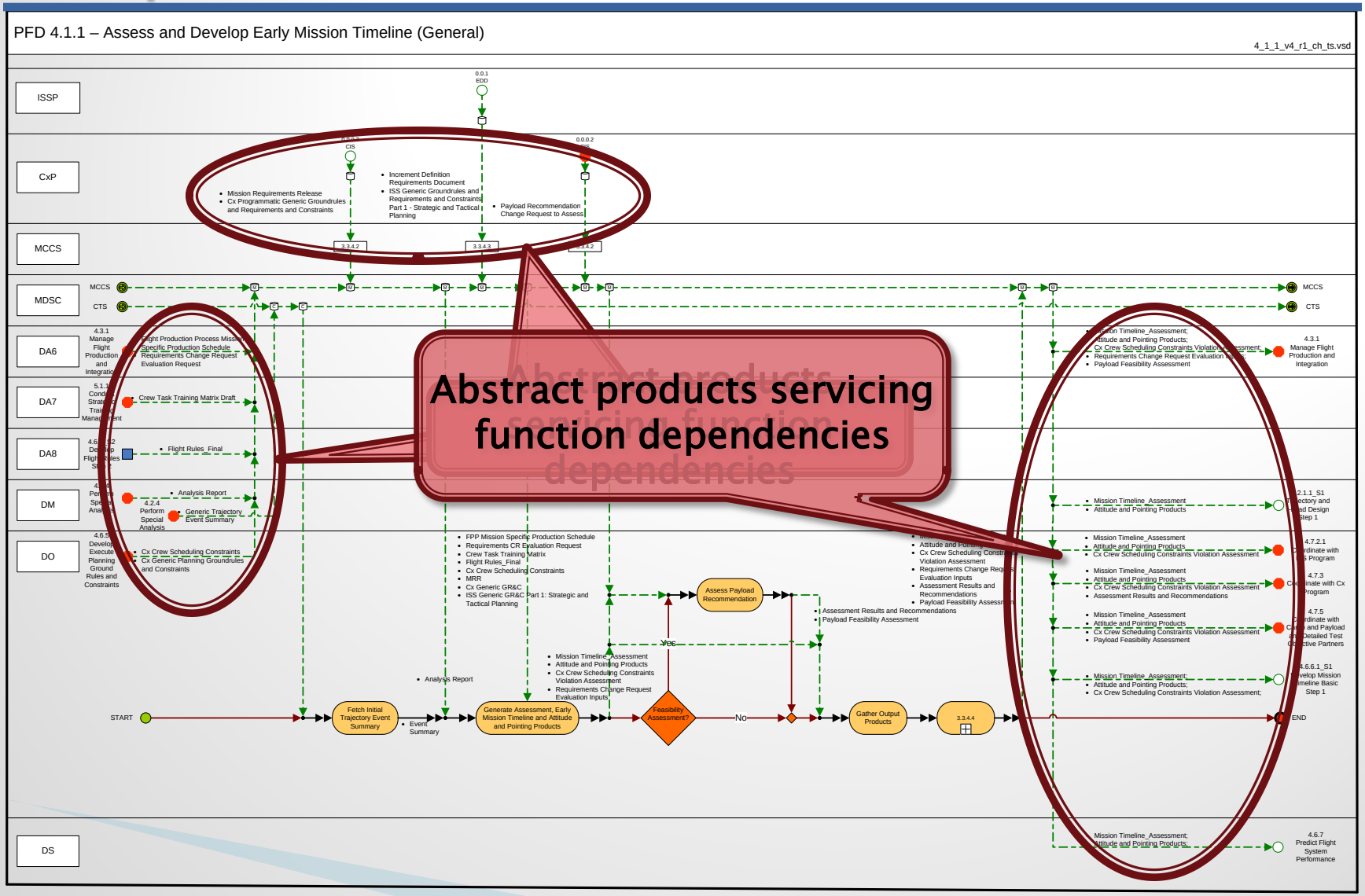
PFD
Sample PFD



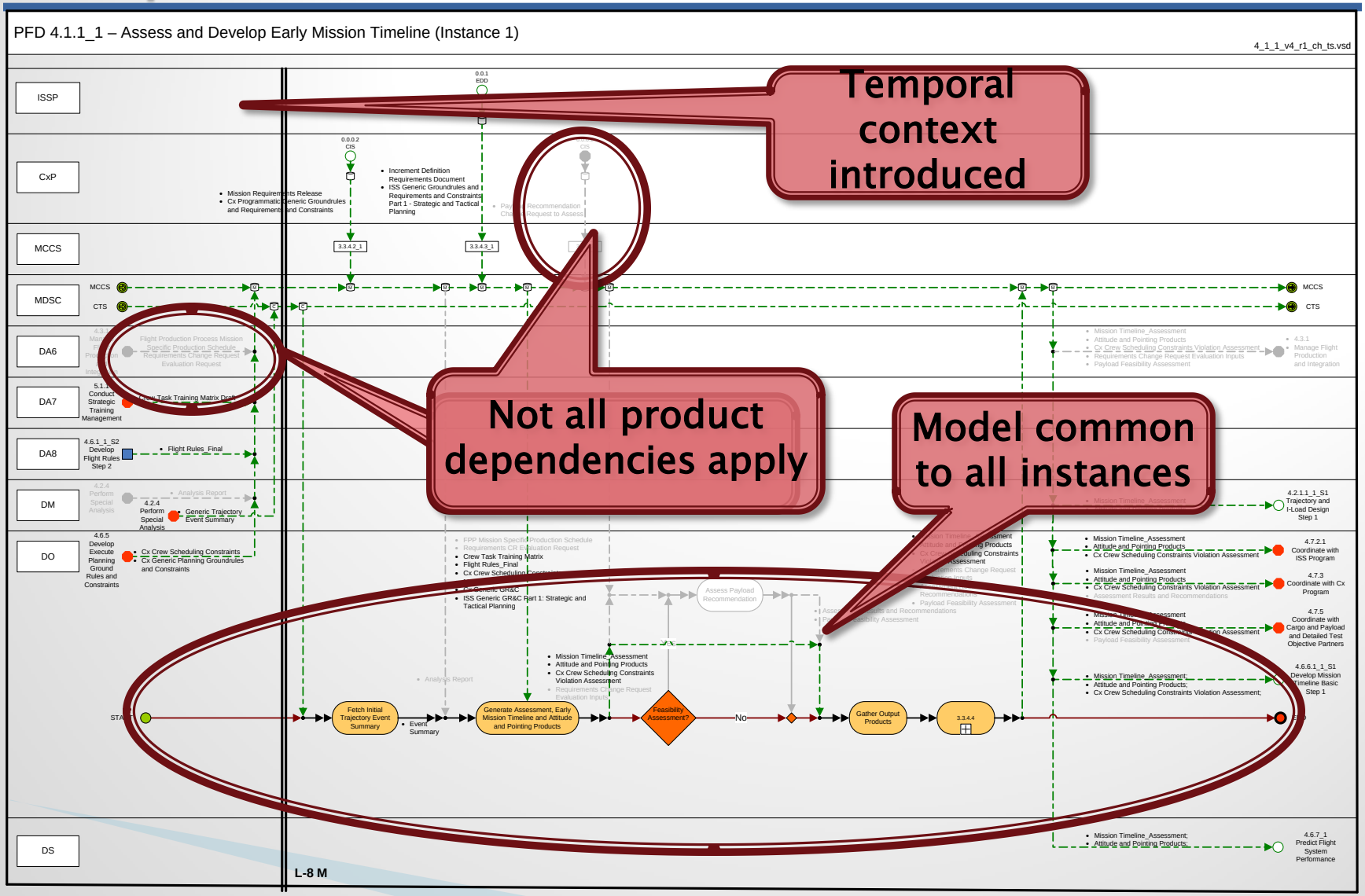
PFD
Sample PFD



PFD
Sample PFD



PFD
Sample PFD -- Instance



More Key Terms (4)

The word methodology is often erroneously considered synonymous with the word process. For purposes of this study, the following definitions from Martin [1] are used to distinguish methodology from process, methods, and tools:

- A Process (P) is a logical sequence of tasks performed to achieve a particular objective. A process defines "WHAT" is to be done, without specifying "HOW" each task is performed. The structure of a process provides several levels of aggregation to allow analysis and definition to be done at various levels of detail to support different decision-making needs.
- A Method (M) consists of techniques for performing a task, in other words, it defines the "HOW" of each task. (In this context, the words "method," "technique," "practice," and "procedure" are often used interchangeably.) At any level, process tasks are performed using methods. However, each method is also a process itself, with a sequence of tasks to be performed for that particular method. In other words, the "HOW" at one level of abstraction becomes the "WHAT" at the next lower level.
- A Tool (T) is an instrument that, when applied to a particular method, can enhance the efficiency of the task; provided it is applied properly and by somebody with proper skills and training. The purpose of a tool should be to facilitate the accomplishment of the "HOWs." In a broader sense, a tool enhances the "WHAT" and the "HOW." Most tools used to support systems engineering are computer- or software-based, which also known as Computer Aided Engineering (CAE) tools.

More Key Terms (con't) (4)

- A methodology can be defined as a collection of related processes, methods, and tools. A methodology is essentially a “recipe” and can be thought of as the application of related processes, methods, and tools to a class of problems that all have something in common.
- Associated with the above definitions for process, methods (and methodology), and tools is environment. An Environment (E) consists of the surroundings, the external objects, conditions, or factors that influence the actions of an object, individual person or group. These conditions can be social, cultural, personal, physical, organizational, or functional. The purpose of a project environment should be to integrate and support the use of the tools and methods used on that project. An environment thus enables (or disables) the “WHAT” and the “HOW.”

MOS Architecture & DES Development Approach

- Integrated with the on-going effort to develop the overall MOP Mission Operations Architecture Description Document (MO ADD).
  - The Baseline Operations Plan (BOP) and Flight Preparation Process (FPP) development efforts have combined with a common focus of creating a MO ADD
  - MO ADD data is being used by the Special Analysis Team (SAT) to create the MOS Model
- Use Department of Defense Architecture Framework (DoDAF 1.5) as the standard for identification all the activities and associated processes. Selected DoDAF views utilized are based on project objectives.
- MOS Model Maturation Process is tied to the MOP Development Lifecycle:
  - Recursive Decomposition Process: The highly related nature of the products necessitate that they be developed in an iterative manner, as greater understanding is achieved of work processes.
  - Today MODEAR produces:
    - Functional Flow Block Diagrams (DoDAF Activity Model, OV-5)
    - Process maps (PFDs, precursor of DoDAF Operational Event/Trace, OV-6c)
    - Needlines (DoDAF Operational Node Connectivity, OV-2)
    - Product Exchange – Functional Dependency (precursor of DoDAF Operational Information Exchange, OV-3)
- Build Discrete Event Simulations (DES's) in alignment with the development lifecycle:
  - Prototype DES (Completed)
  - Functional DES (Completed)
  - Operational View DES (On-going)
  - System View DES (Future)

Note: Process modeling per Business Process Modeling Notation (BPMN)

Summary – Model Based Systems Engineering

- **Why you don't want to model (common objections)**
  - Modeling is hard
  - Modeling tools are difficult
  - Modeling will likely require cultural changes
- **Why you do want to model**
  - It increases the rate of communications
  - It increases the precision of communications
  - It promotes a common understanding of your Processes and the Systems that support those Processes
  - It enables validation of the design.
  - It enables simulation, optimization and execution of design.