Project Quicklook Final Presentation

Tactical Satellite – 3 System Design

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Project type: SE

Agenda

- Overview
- Project Purpose
- Results Overview
- Project Methodology
- Design Project Overview
- Trade Study Overview
- SysML Evaluation and Lessons Learned
- Conclusion

Project Purpose

- Evaluate SysML as a Modeling Language
  - Understand capabilities and limitations of SysML
  - Assess learning curve involved for using SysML
  - Document capabilities of software tool
    - Chose IBM Rational Systems Developer
- Evaluate SysML's contribution to more efficient and effective performance analysis
  - Conduct behavior analysis
  - Perform a trade study of system design alternatives

Results Overview

Q: Can SysML perform as advertised?

- Yes. SysML allowed traceability between requirements and design model
- Yes. It allowed us to conduct a trade study on design alternatives
- Yes. It allowed behavior analysis of the designed system

Q: Would we use SysML in future projects?

- Yes. SysML has proven valuable in designing a small system
- The TSS team believes that SysML would be effective in designing large scale systems as well

SysML is an adequate modeling language and the software tool allowed us to effectively utilize SysML's capabilities

Project Methodology

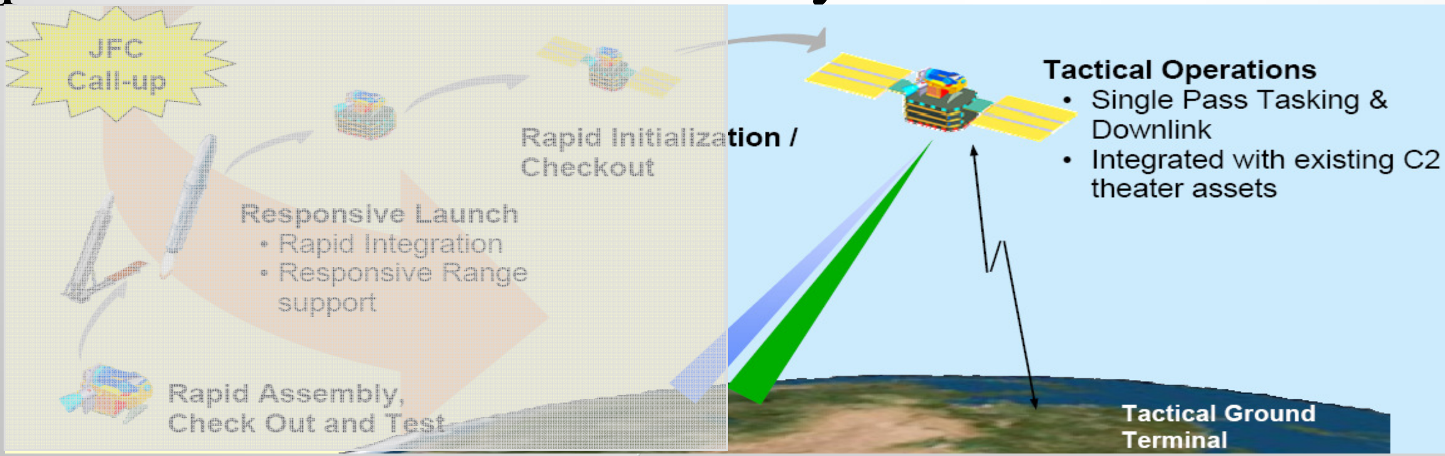
- Performed initial project planning and scoping
- Elicited and analyzed requirements
- Designed a satellite system
- Learned Systems Modeling Language (SysML)
- Learned relevant software packages
  - IBM Rational Systems Developer
  - Embedded Plus SysML toolkit
- Conducted behavior analysis on the satellite design
- Documented results and findings

Project Scope

- Design efforts consist of:
  - Relatively small satellite system
  - Scoped the design efforts to provide enough content for our trade study
- Team training analysis focuses on:
  - Studying team members' training and engineering hours
  - Assessing the learning curve involved with using SysML

Design Definition

- Tactical Satellite 3 (TacSat-3) is a low cost, small, and rapidly deployable satellite system
  - Receiving collection tasks
  - Gathering imagery information
  - Processing imagery and communication data
  - Communicating information to the warfighter in < 10 minutes
- Focus is on the imagery and communication operations of the TacSat-3 System



*Picture from Air Force Research Laboratory Presentation: TacSat-3: Requirements Development for Responsive Space Missions by Capt Stan Straight

Major Project Accomplishments

- Monitored training and engineering hours
- Completed the TacSat-3 design using SysML
- Explored the behavior analysis capabilities of SysML
- Documented lessons learned

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Design Overview

- SysML diagrams provide views of the design model and promote communication
- The Quicklook design contains over 630 elements and is organized into 26 packages with 45 diagrams
- This portion of the presentation will explain our development process and provide diagram examples that highlight key findings

SysML Hierarchical Design Model

Take Component from Higher Abstraction Level

Conduct Requirement, Input/Output, and Higher Level Activity Analysis

Conduct Logical Decomposition of Current Level Block Definition Diagram(BDD) and Internal Block Diagrams(IBD)

Conduct Activity Decomposition of Current Level Based on BDD/IBD

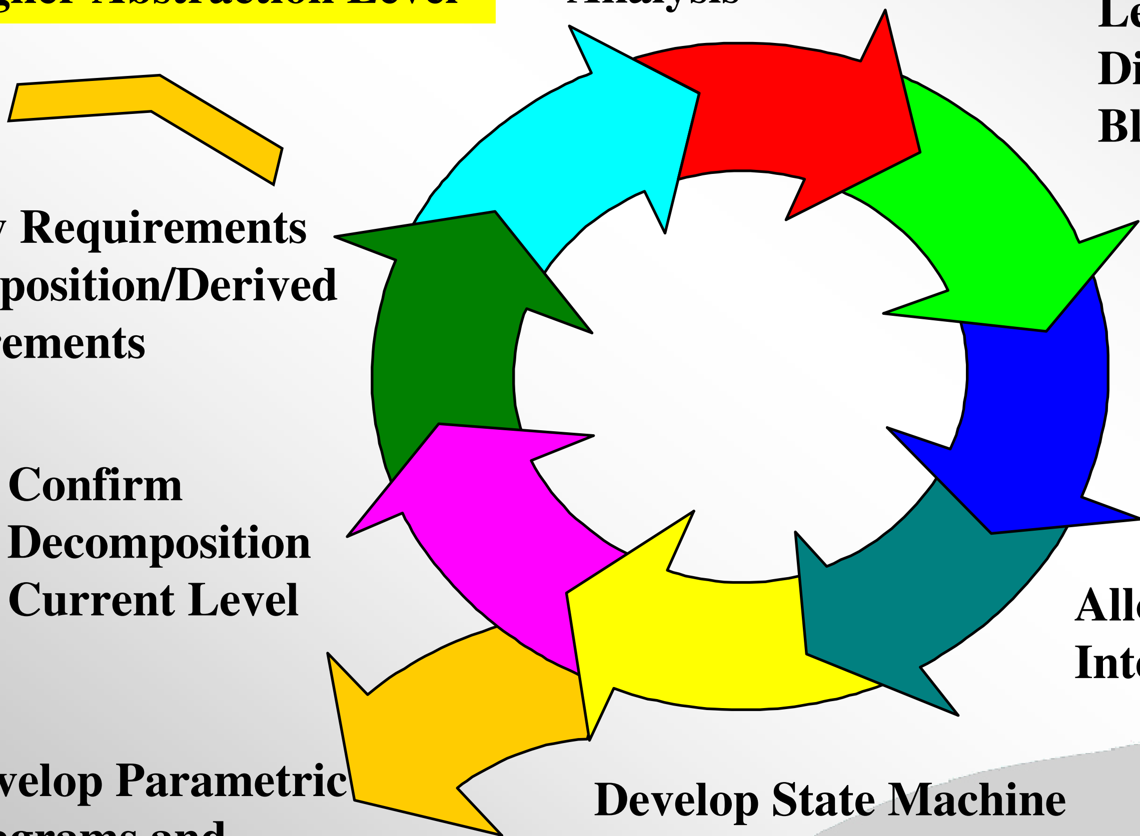
Allocate Operations and Interfaces

Develop State Machine Diagrams and Attributes

Develop Parametric Diagrams and Executable Models

Confirm Decomposition Current Level

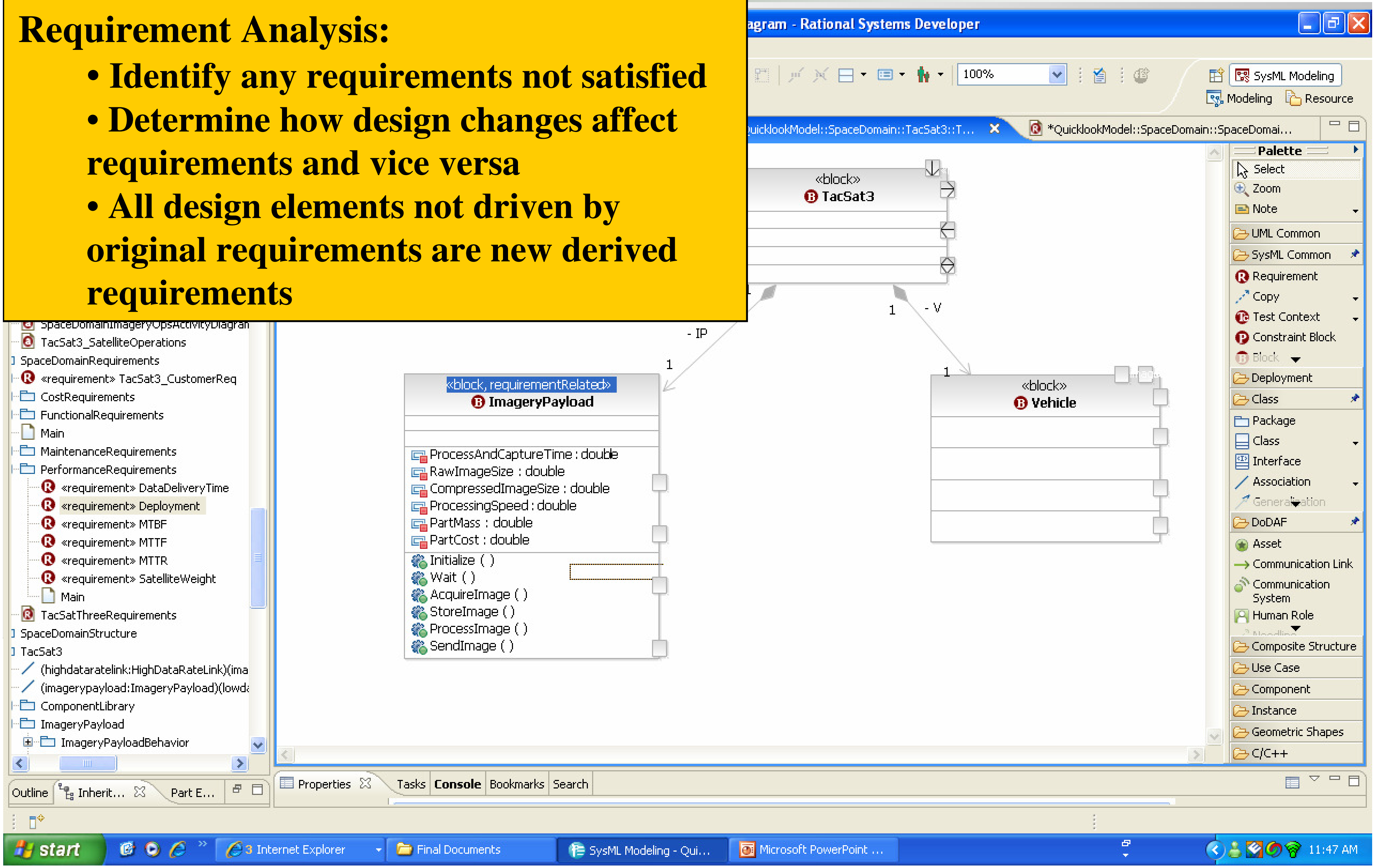
Review Requirements Decomposition/Derived Requirements



Requirements

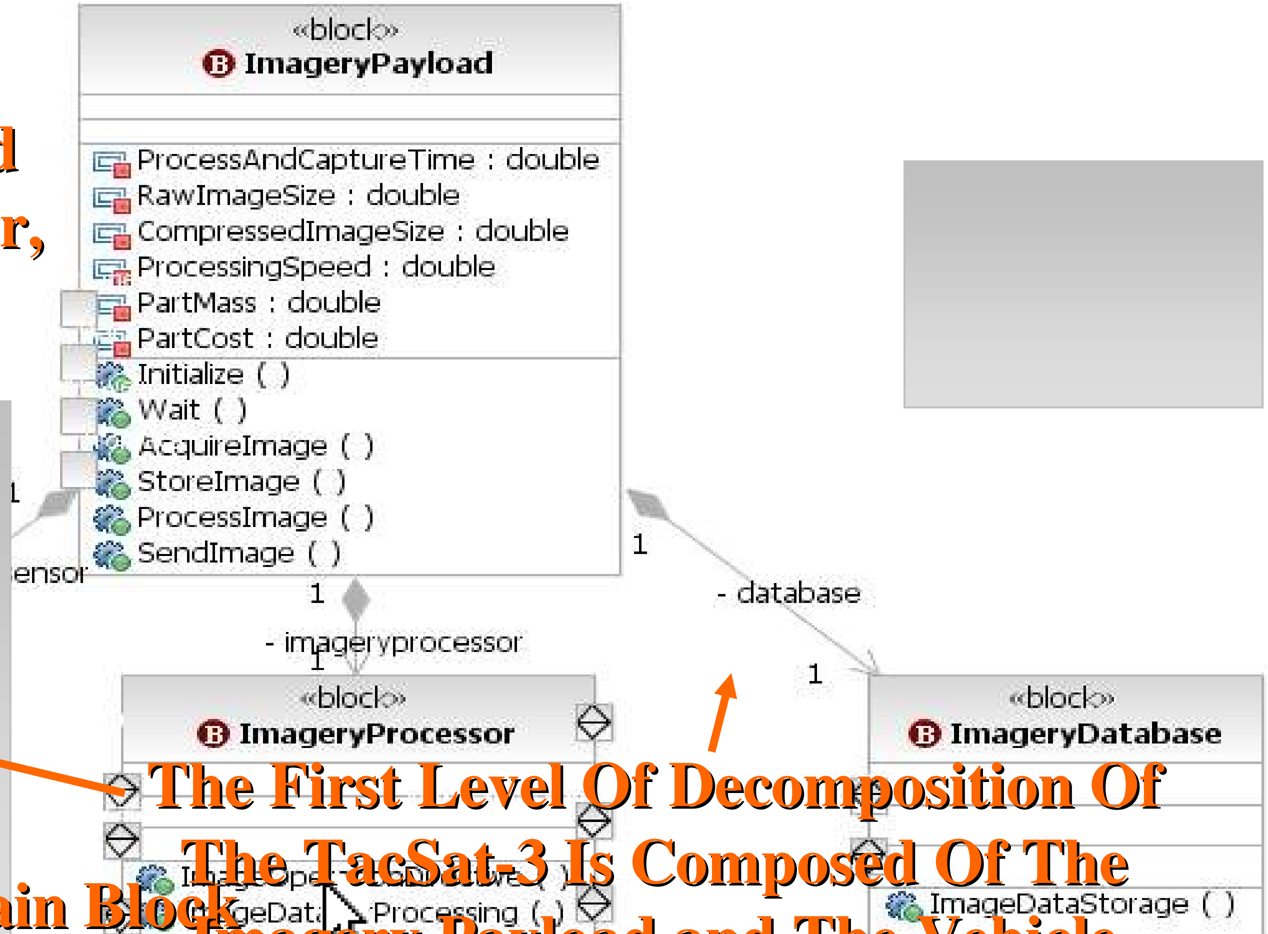
Requirement Analysis:

- **Identify any requirements not satisfied**
- **Determine how design changes affect requirements and vice versa**
- **All design elements not driven by original requirements are new derived requirements**



Space Domain and TacSat-3

Imagery Payload Is Further Decomposed Into Sensor, Processor, and Database



The First Level Of Decomposition Of The TacSat-3 Is Composed Of The Imagery Payload and The Vehicle

The Space Domain Block Definition Diagram Serves As The Context For The TacSat-3

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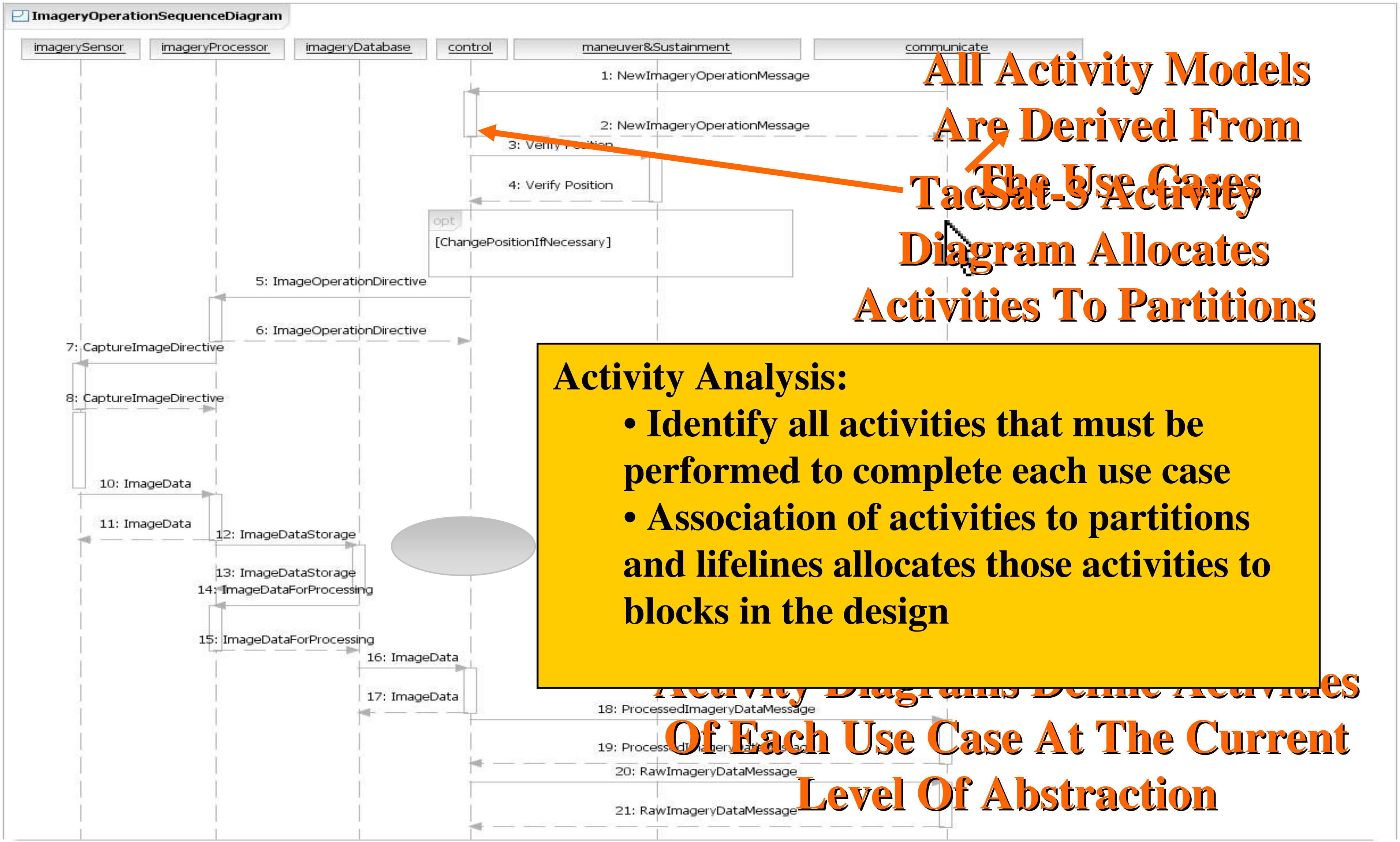
Activity Diagram/Use Cases



All Activity Models Are Derived From The Use Cases

TacSat-3 Activity Diagram Allocates Activities To Partitions

Activity Analysis:

- **Identify all activities that must be performed to complete each use case**
- **Association of activities to partitions and lifelines allocates those activities to blocks in the design**

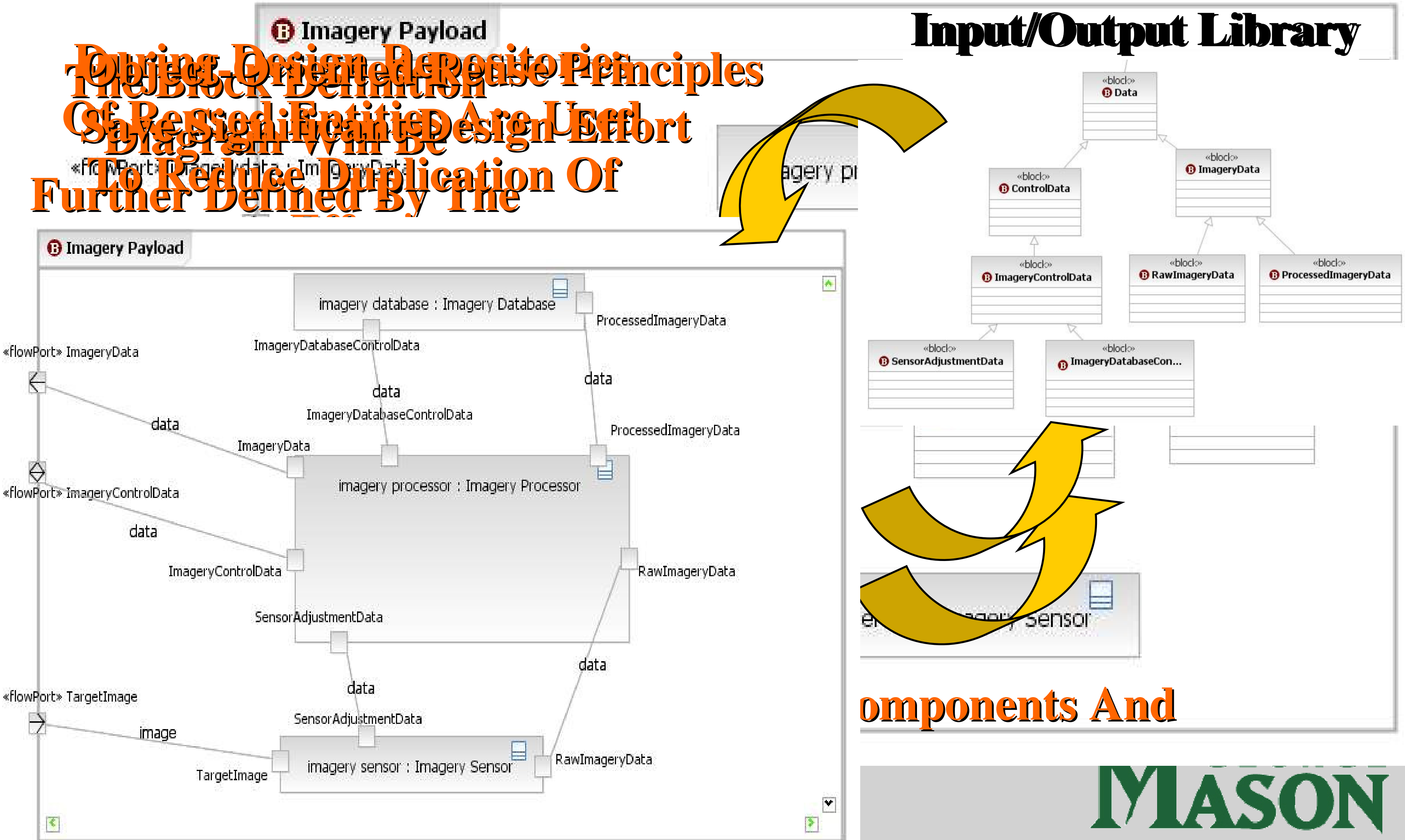
Activity Diagrams Define Activities Of Each Use Case At The Current Level Of Abstraction

Structure

During Design Repositories
Of Reused Entities Are Used
To Reduce Duplication Of

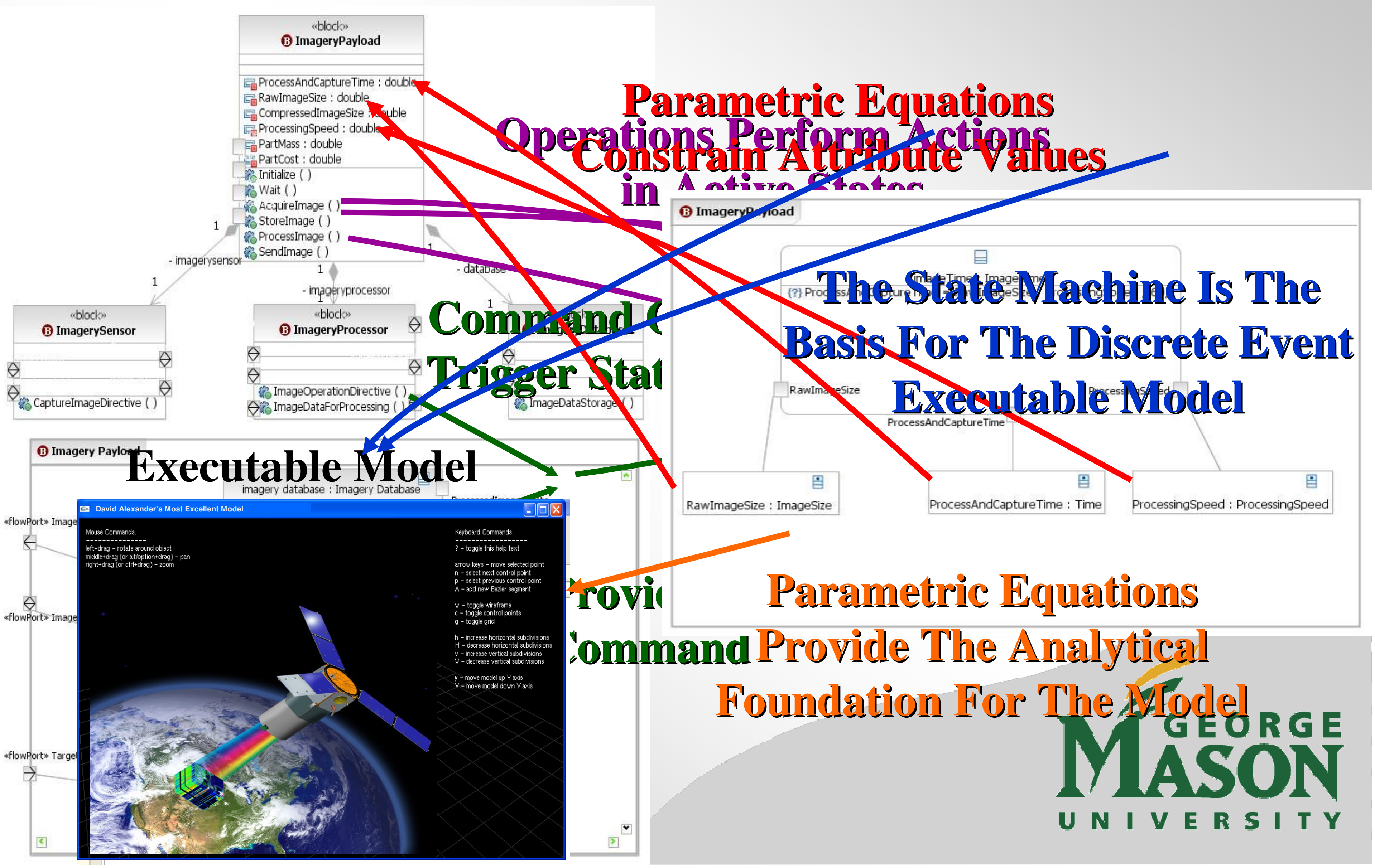
Object-Oriented Reuse Principles
Save Significant Design Effort

The Block Definition
Diagram Will Be
Further Defined By The



omponents And

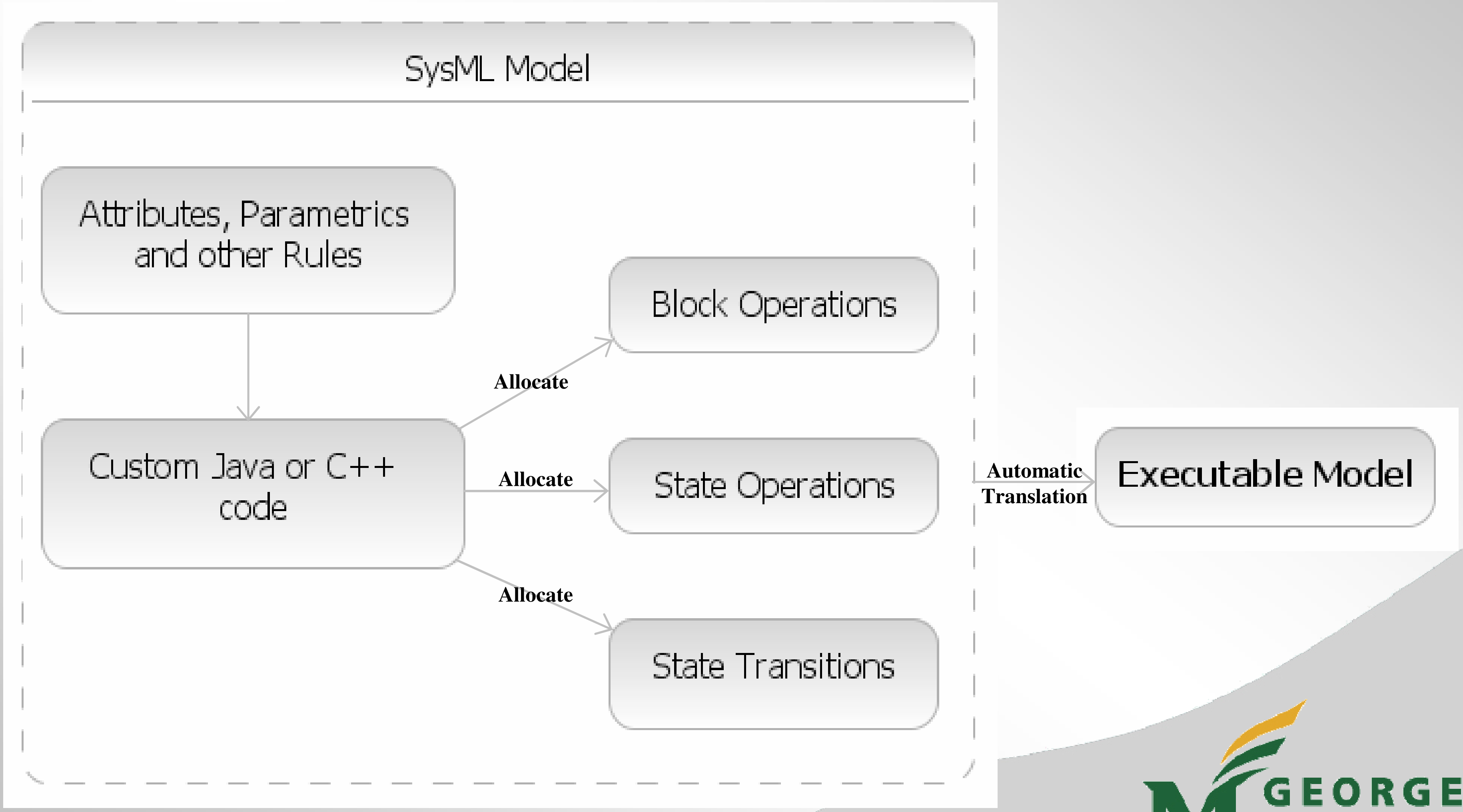
Behavior and Parametric Diagrams



Executable Model Overview

- The executable model allows us to conduct:
  - Behavior analysis
  - Performance analysis
  - State space analysis
  - Trade study
- The executable model provides traceability back to static SysML model
- The executable model is tool dependent

Executable Model



Trade Study Overview

- We used the executable model to determine the following:
  - Given a captured image size and communications bandwidth, what type of system components are required to meet the system requirements?
  - What is the best achievable performance within mass and cost constraints?

Morphological Box/Trade-off components

Raw Image Size = 1,250 MB
Compressed Image Size = 250 MB

Initial Conditions

Intermediate Calculations

Final Results

Performance Options

(yellow) = Fails to Meet Requirements

	Cost and Performance Results → / Design Alternative ↓	Image Capture and Processing Time (min)	Raw Image High Data Rate Transfer Time (min)	Compressed Image High Data Rate Transfer Time (min)	Compressed Image Low Data Rate Transfer Time (min)	Total High Data Rate Transfer Time (min)	Total Low Data Rate Transfer Time (min)	Total Mass (kg)	Total Cost (millions $)
Option 1	IPS = 10 LDRB = 1.5 HDRB = 45	16.7	3.7	0.7	22.2	21.1	38.9	30.0	1.5
Option 2	IPS = 50 LDRB = 3 HDRB = 137	3.3	1.2	0.2	11.1	4.8	14.4	40.0	3.0
Option 3	IPS = 100 LDRB = 10 HDRB = 234	1.7	0.7	0.1	3.3	2.5	5.0	50.0	4.5

IPS = Image Processing Speed
LDRB = Low Data Rate Bandwidth
HDRB = High Data Rate Bandwidth

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SysML Evaluation

Evaluation Methodology

Studied SysML and learned about relevant software tools

- Available SysML literature
- SysML training provided by Mr. Sanford Friedenthal*

Hands on experience using IBM Rational

- Used SysML to design TacSat-3 artifacts
- Documented tool's modeling capabilities and limitations

Evaluated SysML capabilities and limitations

- Conducted trade study on TacSat-3 communication and imagery components' design alternatives

Assessed learning curve involved

- Monitored individual training level-of-effort

*** Mr. Friedenthal chairs the OMG Systems Engineering Domain Special Interest Group (SE DSIG)**

Lessons Learned

- SysML adequately addresses systems engineers' needs through:
  - Providing notations to establish traceability and relationship between requirements and the design model
  - Constraining the design model using mathematical equations that serve as executable specifications
  - Supporting verification and analysis of various systems

Overall SysML Comments and Findings 1 of 2

- Knowledge of Unified Modeling Language (UML) makes SysML easier to learn
- Takes advantage of Object-Oriented design
- Provides bi-directional traceability between design and requirements
  - Reduces efforts involved with verification of requirements and validation of system behavior

Overall SysML Comments and Findings 2 of 2

- Modeling in SysML could be improved by:
  - Using well-developed modeling tools that allow
    - Creation of a unified data dictionary, which makes it easy to translate the design model to executable models
    - Automation of updating the model based on modifications realized after performing design trade-off
  - Applying a hierarchical design process to define systems at the right level of abstraction

Acknowledgements

Questions and Answers

Backup Slides

Quicklook SysML Diagram Usage

SysML Diagram	Space Domain	TacSat-3 Satellite	Unit Level (Payload/Vehicle)	Subsystem Level	Component Level	Design Team Purpose	User/Stakeholder/Sponsor Purpose	Stakeholder Interest
Package diagram	X	X				Organization of model elements	Views can be organized to focus on specific aspects of interest such as security or software	All
Block definition	X	X	X	X	X	Organize the logical and physical design of the system hierarchy	Show system design to the appropriate level of detail	All at high levels, Domain Engineers at lower levels
Internal Block diagram	X	X	X	X	X	Identify the interfaces between subcomponents required to satisfied component activities	Show system design to the appropriate level of detail with interaction of lower level of components	All at high levels, Domain Engineers at lower levels
Requirements	X	X				Ensure every requirement is satisfied, Develop derived requirements	Demonstrate the designs satisfaction of requirements	PM, SE
Use Case	X	X				Organize the system activities, Identify reusable activities, identify system context	Communicate the major system activities	All
Activity	X	X	X			Defines the flow of activities, used to develop controls and input/outputs which verifies the structure of the next level of decomposition	Communicate the major system activities in more detail and show their relationships	SE, Software Engineers, Domain Engineers
Sequence				X	X	Use to explore the logic of the next level of decomposition of the model	Shows the logic of control and sequence between components	SE, Software Engineers, Domain Engineers
Statemachine		X				Define states, Shows how attributes affect state transition, Use to identify fault states	Demostrate the state space of the system, show how design minimizes deadlocks	SE, Software Engineers
Parametric diagram		X	X	X	X	Constraints from Parametric Diagram used for design decisions, Allows engineering analysis and bridge to executable models	Results of analysis used for trade-off decisions	SE, Domain Engineers

Level of Effort

- Weekly hours collected as an indicator of individual's level-of-effort
- Engineering and training hours were monitored separately
- Total engineering hours could provide basis for future planning
- Training hours give a hint at expected learning curve

Project Hours			
Scheduled	Actual	Engineering	Training
442	520	292	228

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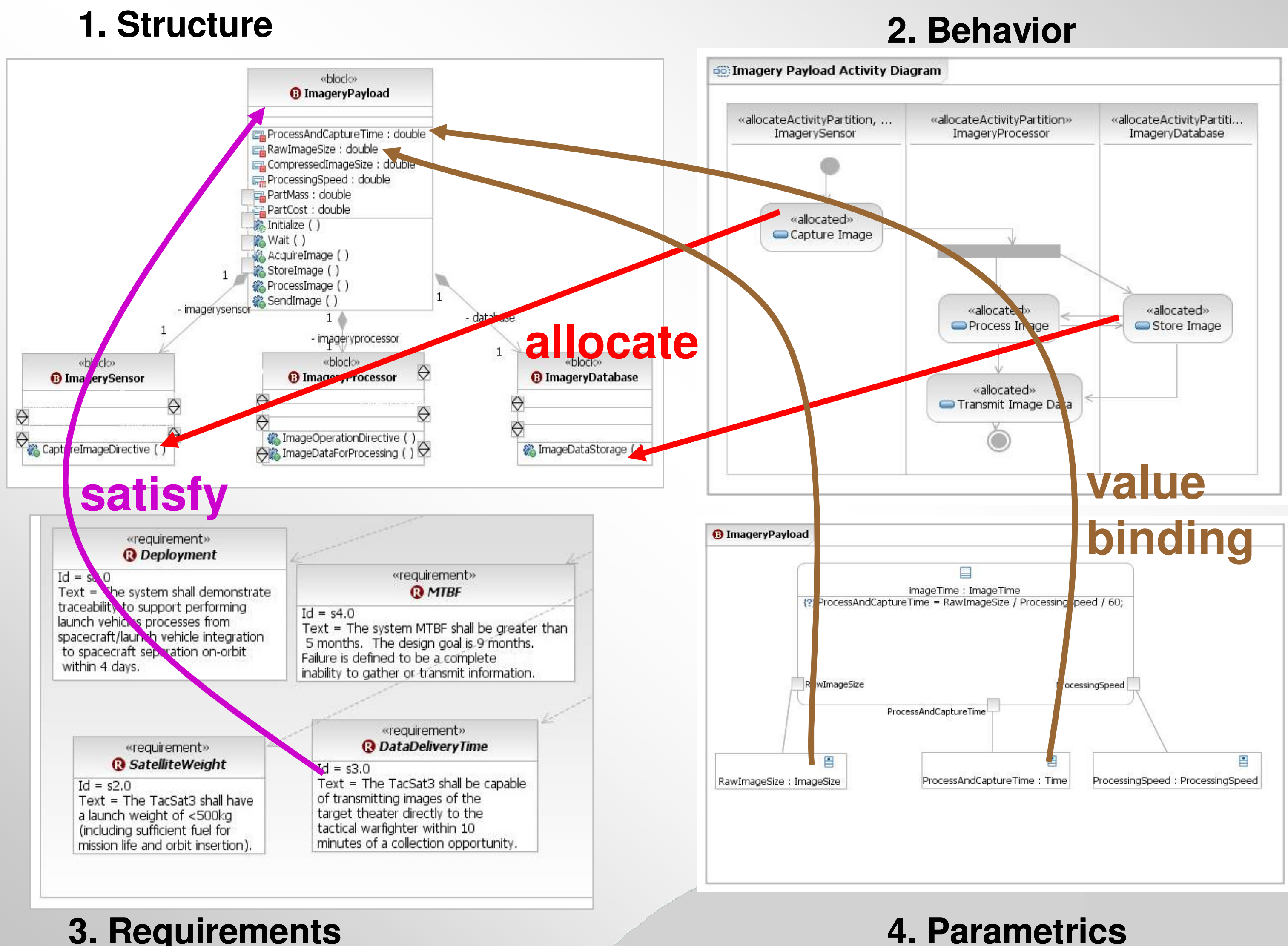
DoDAF-SysML

- Different methodologies prevent a true mapping schema
  - DoDAF is driven by functional decomposition
  - SysML takes advantage of OO methodology
  - SysML can be used to implement minimum required set of DoDAF views

Future Efforts

- Design elements converted into DoDAF
- Cover additional aspect of the satellite design
- User interface added executable model

SysML Concordance



* The concept of this graphic is based on slide 65 of the OMG Systems Modeling Language (OMG SysML) Tutorial, 11 July 2006

Project Deliverables

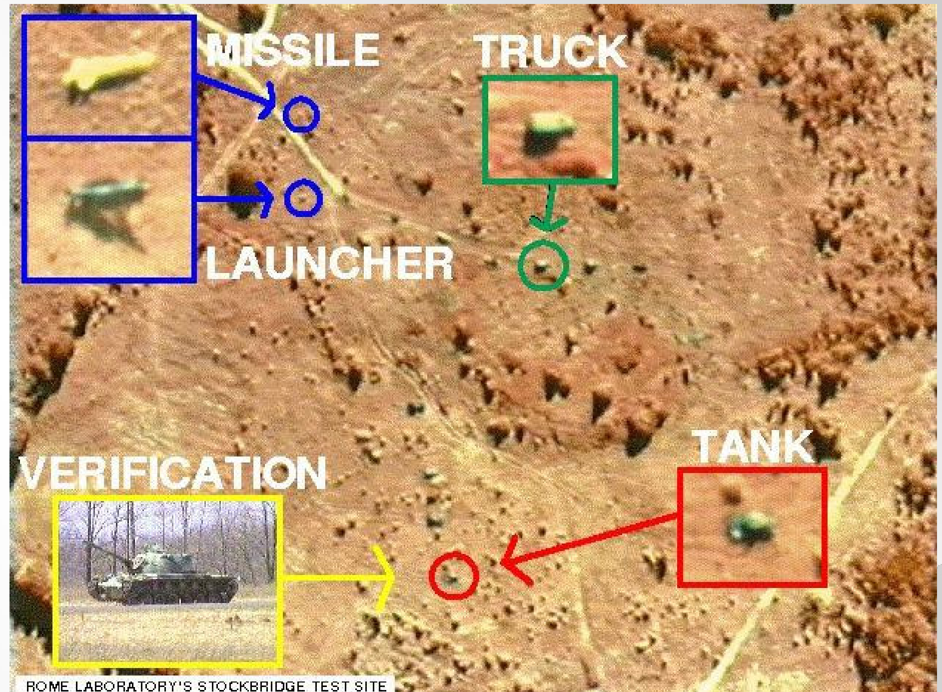
- Final Report
- System Design
- Requirements Document
- Proposal
- Concept of Operations and Use Cases
- Program Management Plan
- Risk Management Plan
- Configuration Management Plan
- Engineering Effort Analysis
- Evaluation Plan
- TSS Website

Executable Model Recommendations

- Have plans for the executable model before the SysML model begins
- Understand the limitations of the tool used to create the executable model
- Some programming experience is required for the executable model
- Understand that each tool handles executable models differently

Hyperspectral Imagery

- Creates a large number of images from contiguous regions of light spectrum (UV, visible, IR)
- Can detect many militarily important items such as camouflage, thermal emissions and hazardous wastes
- Useful for detection of chemical or biological weapons, bomb damage assessment of underground structures, and foliage penetration to detect troops and vehicles



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* Information from Federation of American Scientists (http://www.fas.org/irp/imint/hyper.htm)