

# **Systems Modeling Language (SysML): In a Book and In a Project**

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\* OMG SysML Background

\* Feature 1:

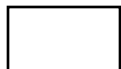
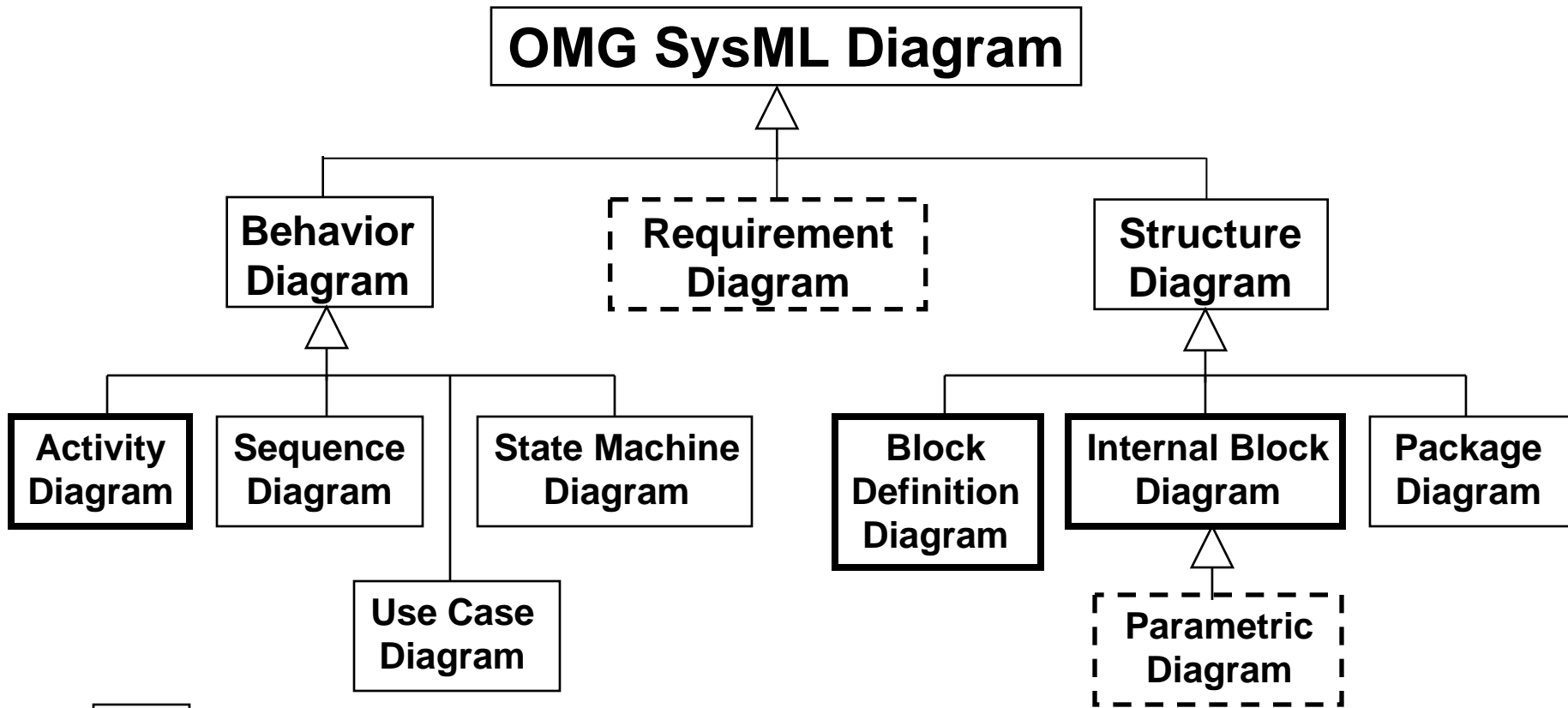
Systems Engineering By the Book series for 2008

Book review of “Systems Engineering with SysML/UML”  
by Tim Weilkiens

\* Feature 2:

Using SysML to Develop a Spacecraft Specification and Design  
Model, Part 2

- OMG SysML is a modeling standard created by the Object Management Group (OMG) as an extension of their Unified Modeling Language™ (UML®)
  - OMG has been an international, open membership, not-for-profit computer industry consortium since 1989.
- Recognized a need/benefit to apply a modeling language similar to UML to be used by systems engineering organizations for systems consisting of both hardware and software
- OMG and INCOSE jointly developed the UML for Systems Engineering (SE) Request For Proposals (RFP) to solicit feedback concerning the requirements for extending UML to support the needs of the SE community
- OMG released the RFP in March 2003
- SysML Specification was developed in response to these requirements by tool vendors, end users, academia, and government representatives
  - SysML Specification 1.0 was released in May 2006
  - OMG trademarked SysML
- OMG SysML reuses a subset of UML 2.0 and provides additional extensions needed to address the requirements in the UML for SE RFP
- Modeling tool companies are developing their SysML tools
- SysML Revision Task Force currently working on SysML Version 1.1 (2008)



Same as UML 2



Modified from UML 2



New diagram type

Source: OMG SysML Tutorial, 11 July 2006, pg 18

# **Systems Engineering with SysML/UML: Modeling, Analysis, Design**

**By Tim Weilkiens**

**Morgan Kaufmann OMG Press, 2008**

**English edition, 320 pages**

**ISBN: 978-0-12-374274-2 (softcover)**

- Provide enough information for the attendees to answer question: “Would I be interested in obtaining and reading this book?”
- For all attendees, regardless of whether they decide to obtain the book or not, provide some information from the books that they may find useful



## Tim Weilkiens

- Coach and advisor at oose Innovative Informatik GmbH, a leading German consultancy devoted to information technology for business
- Head of systems engineering
- Been involved with object-oriented software development since 1991
- Member of OMG working groups about SysML and UML
- Wrote sections of the SysML specification
- Considered to be one of the top ten UML experts in the world
- Other books: UML 2 Certification Guide, other titles only in German
- More information at his website: [www.system-modeling.com](http://www.system-modeling.com)
  - Can download his SysML reference card
- E-mail: [twe@system-modeling.com](mailto:twe@system-modeling.com)



Forward (by Richard M. Soley, Chairman and CEO of the OMG)  
Author Biography

Chapter 1: Introduction

Chapter 2: The Pragmatic SYSMOD Approach

Chapter 3: UML – Unified Modeling Language

Chapter 4: SysML – The Systems Modeling Language

Chapter 5: Systems Engineering Profile – SYSMOD

Glossary

References

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## Chapter 1: Introduction

\* Addresses the following:

### 1) Why was the book written?

- Need for a modeling language to address complex and distributed systems
- As a result of his involvement in developing SysML specification
- To communicate his SYSMOD toolbox for system modeling

### 2) What is systems engineering?

- Explains the SIMILAR process (State the problem, Incinvestigate alternatives, Model system, Integrate, Launch the system, Assess performance, Re-evaluate)
- Systems engineer is the connecting link between the project disciplines
- Systems engineering has evolved due to lack of oversight by only one person

### 3) How do SysML and UML relate to each other?

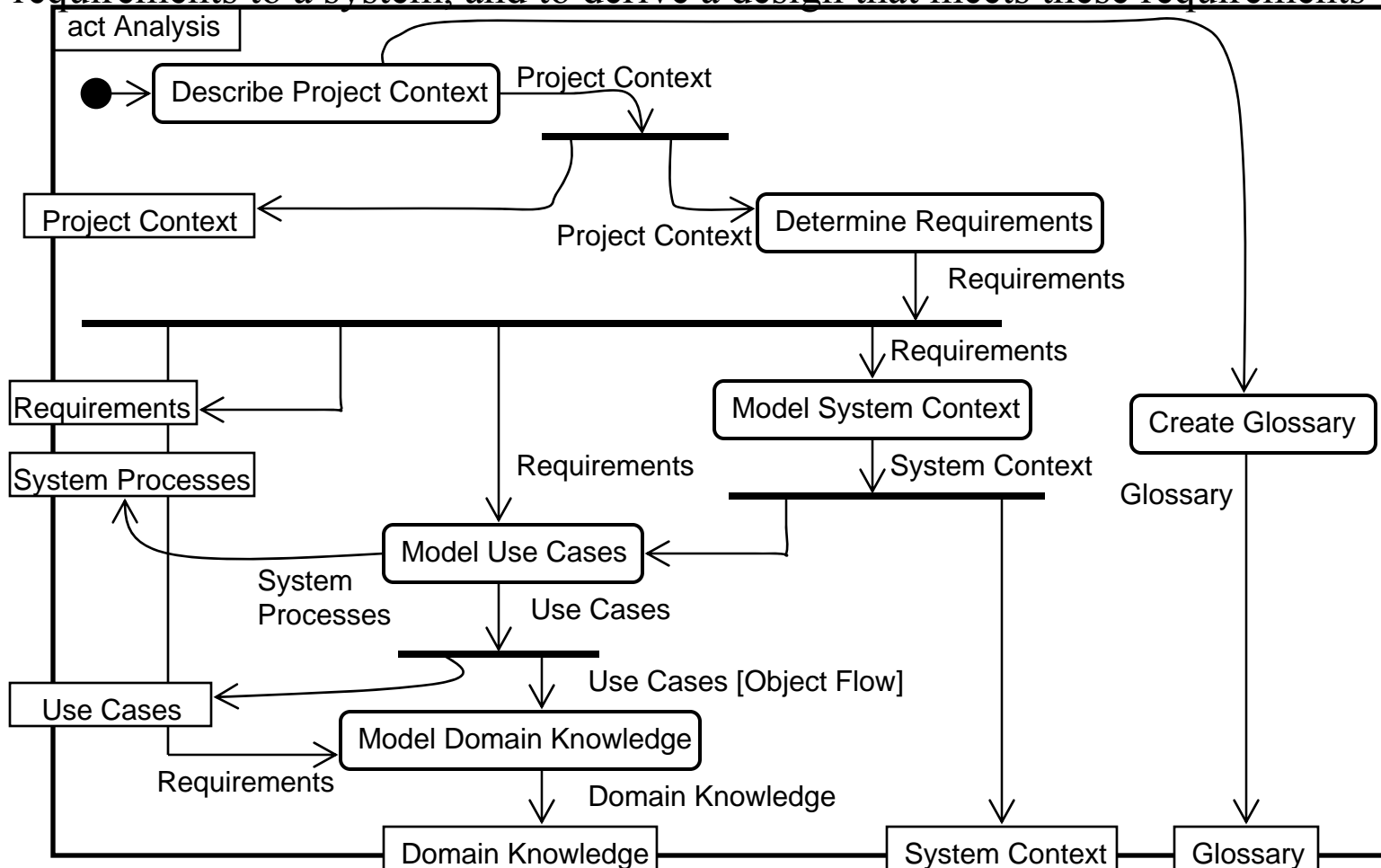
- Explains the differences between the two languages (e.g., modified, new diagrams)
- SysML needed to address multidisciplinary developments, beyond UML's utility

### 4) How does the content of the book relate to CMMI, V model, and AUTOSAR?

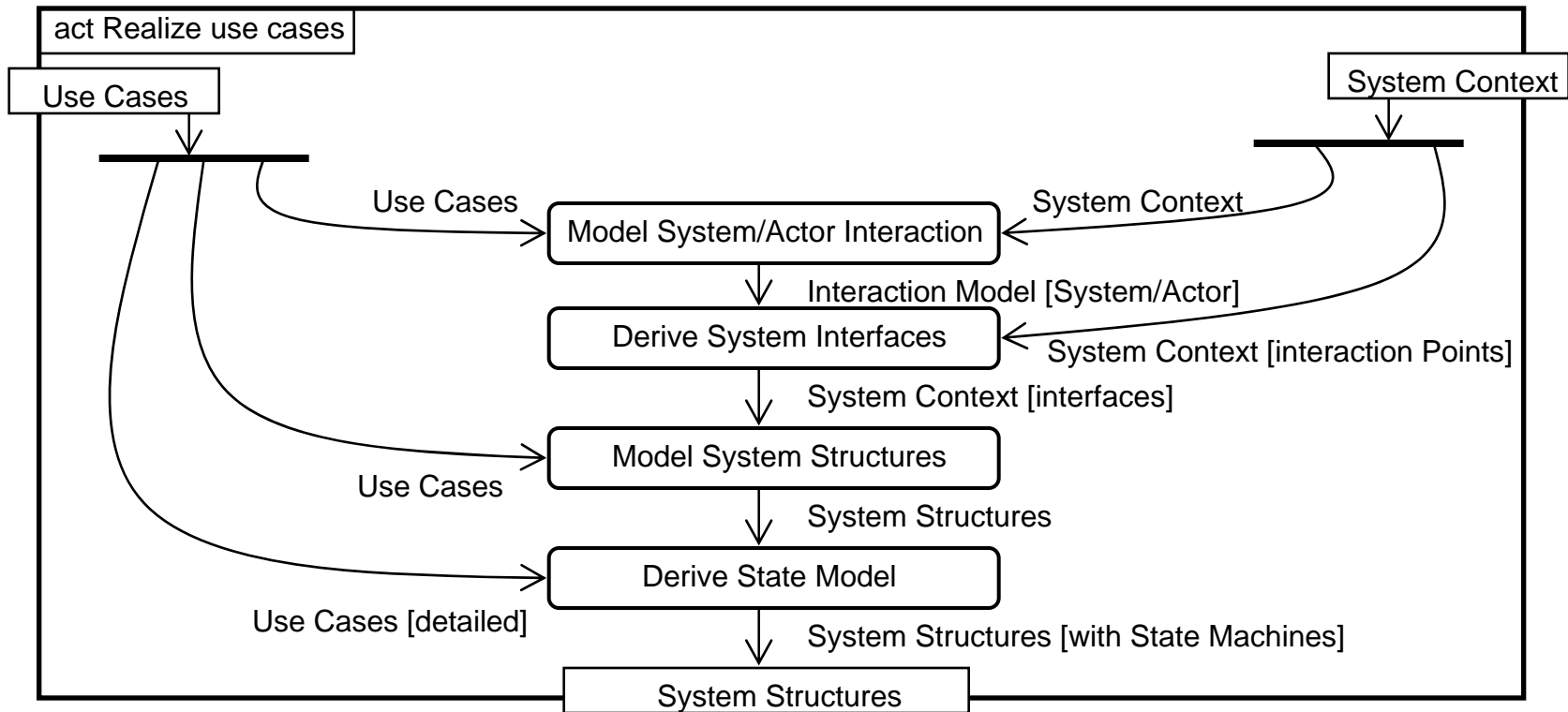
- Good SysML models and the processes that create them help to meet the CMMI quality criteria
- V model provides instructions not provided in SysML that can be used in projects
- SysML can be used to model a system according to the Automotive Open System Architecture (AUTOSAR) architecture

## Chapter 2: The Pragmatic SYSMOD Approach

\* Describes the System Modeling (SYSMOD) approach used to collect and model the requirements to a system, and to derive a design that meets these requirements



## Chapter 2: The Pragmatic SYSMOD Approach (Cont'd)



- Each activity is decomposed into sub-activities in a figure
- Each activity is explained in a reference card provided in a table
  - Identifies incoming and outgoing data
  - Provides motivation/description (Why? What? How? Where?)
  - Asks guiding questions
  - Lists the minimum set of SysML elements needed

## Chapter 3: UML – Unified Modeling Language

- \* Discusses only those UML elements and their contents that are also used in SysML
  - Uses UML terminology (reader has to convert to SysML terminology)
- \* Recommends “The Unified Modeling Language Reference Manual”, 2<sup>nd</sup> ed. by Rumbaugh, Jacobson, and Booch for a full description of UML
- \* Provides history behind Unified Modeling Language (UML)
  - Evolved from the rise of object-oriented programming languages
- \* Distinguishes between model (the full description of the system) and diagram (visualization of the model with regard to a certain aspect)
- \* Addresses the following diagram types and their contents:
  - Class diagram (→ SysML Block Definition diagram)
  - Composite Structure diagram (→ SysML Internal Block diagram)
    - # Added in UML 2
  - Use Case Diagram
  - Activity diagram
  - State Machine diagram
  - Interaction diagrams (→ SysML only uses Sequence diagram type)
  - Package diagram

## Chapter 4: SysML – The Systems Modeling Language

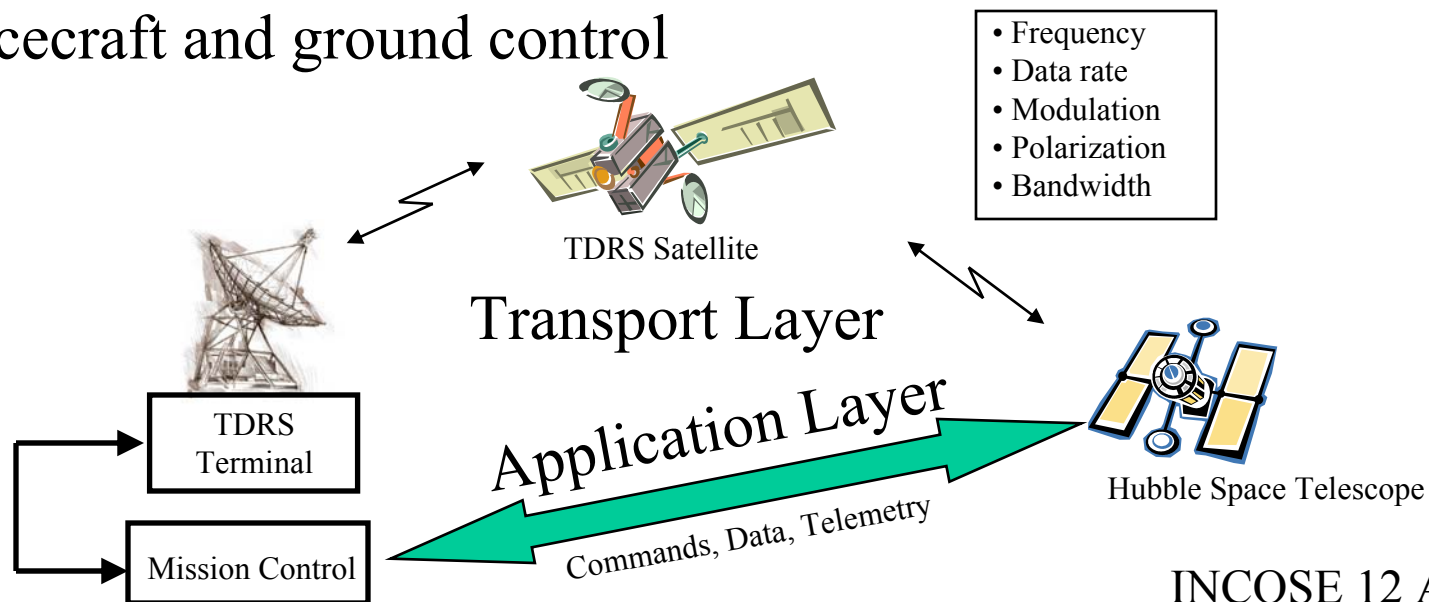
- \* Explains that SysML came about because Systems Engineering did not have a uniform modeling language that was independent of specific disciplines like software, hardware, or mechanics
- \* SysML grew out of UML; UML well established and extensible; not all of UML included
- \* Describes SysML elements that extend UML
- \* Addresses the following diagram types:
  - Requirement Diagram (relate to other requirements, blocks, use cases, test cases)
  - Block diagrams (Classes → Blocks)
    - # Block definition for black box; Internal block for white box views
  - Parametric Diagram (defines parametric relationships between block properties)
  - Use Case Diagram (unchanged)
  - Activity Diagram (supports continuous object flow)
  - State Machine Diagram (unchanged)
  - Sequence Diagram
  - General Modeling Elements
    - # Rationale
    - # Model View and Viewpoint



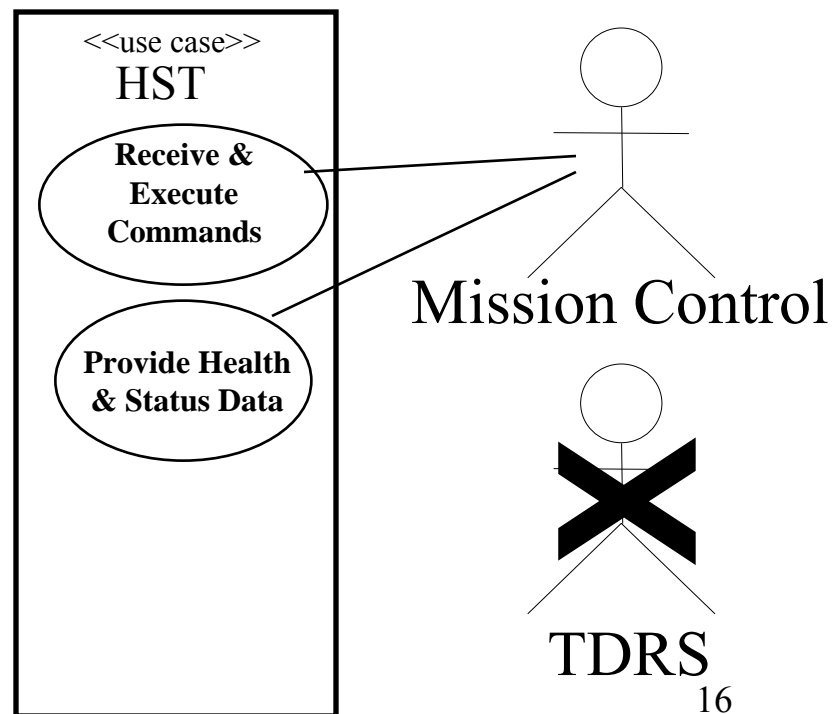
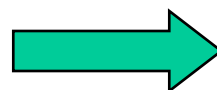
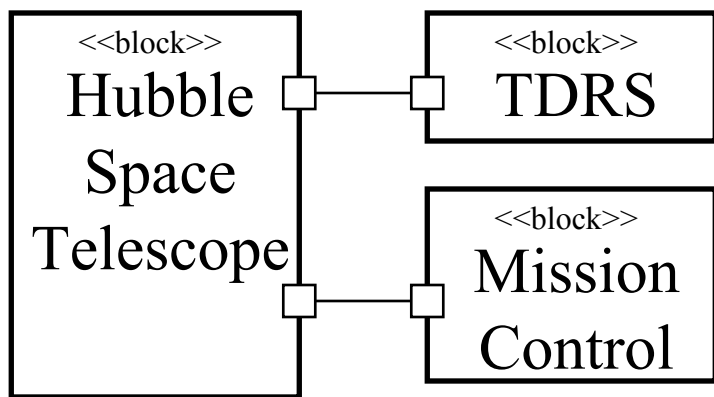
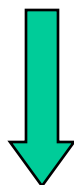
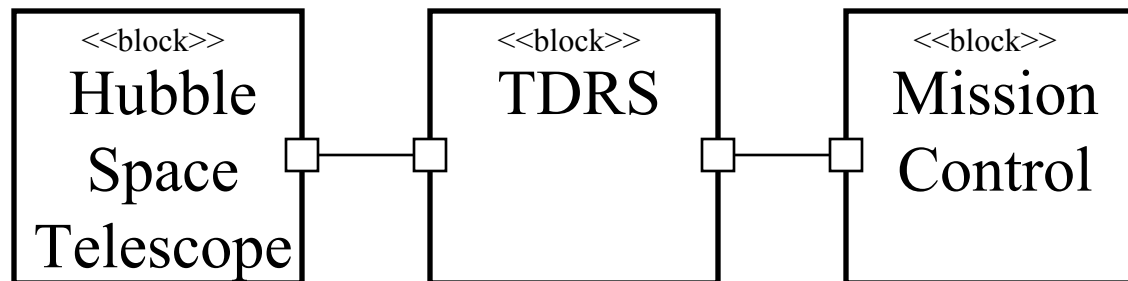
## Chapter 5: Systems Engineering Profile - SYSMOD

- \* Discusses the language extensions (stereotypes) that together make up the SYSMOD Profile needed in the SYSMOD approach discussed in Chapter 2
  - SYSMOD Profile extends the SysML language
  - Extensions that do not belong to either SysML or UML language standards
- \* Extends UML “actor” categories to include: “environmental effect”, “external systems”, and “stakeholder”
- \* Extends “external systems” to include: “user system”, “boundary system”, “actuator”, “sensor”, and “mechanical system”
- \* Extends SysML “requirement” to include: “extended requirement”; adds properties – priority, obligation, stability, type, risks
- \* Extends UML “activity” to include: “essential activity” to ensure essential activities are directly visible in the diagram
- \* Extends SysML “block” to include: “domain block” for object, concept, location, or person from real-world domain; “system”; “subsystem”; “system context element”
- \* Extends UML “use case” and “activity” to include: “continuous use case”, “secondary use case”, and “system process”

- External interfaces may need to be separated into behavioral and structural components.
  - Structure component is transport layer, the already designed medium for the interface (i.e., a design constraint)
  - Behavioral component is application layer, to be designed
- \* Potential actors in behavioral diagrams
- Example: TDRS satellite for relay communications between spacecraft and ground control



# What I Learned (2)



## Summary:

- Introduced his SYSMOD approach
- Discussed UML elements that apply to SysML
- Discussed SysML elements and UML extensions
- Explained the SYSMOD extensions to SysML

## Assessment:

- Overall, well-written book; some possible translation issues
- Written more as a toolbox and not strong on how to put the tools together

## Recommendation:

- Add this book to your SysML library but don't have it as your only SysML book/reference



Where to obtain “Systems Engineering with SysML/UML” as reviewed here:

- [www.amazon.com](http://www.amazon.com)
  - New list price - \$44.96
  - 30 copies used (as of 06 August 08)
  - Price for used copies start at \$40.63
  
- [www.barnesandnoble.com](http://www.barnesandnoble.com)
  - New list price - \$49.45 (Member price - \$44.95)
  - 2 copies used (as of 06 August 08)
  - Price for used copies start at \$48.45



- The official OMG SysML web site (<http://www.omgsysml.org>)
  - SysML specifications
    - \* OMG SysML Specification v1.0, dated September 2007
  - Publications
    - \* Tutorials
      - OMG SysML Tutorial June 2008 (INCOSE Symposium 2008)
    - \* Papers
    - \* Presentations
    - \* Articles
    - \* Books (see next chart)
  - Vendors
  - Related Links
  
- Other SysML-related papers can be found by web search
- Number of SysML related papers in the INCOSE Symposium proceedings
- SysML-related papers are also available in INSIGHT and SE Journal

- Other SysML Books Now Available

- “A Practical Guide to SysML: The Systems Modeling Language”
  - \* Authors: Sanford Friedenthal, Alan Moore, and Rick Steiner
  - \* Available from Amazon.com for \$53.96
  - \* Published by Morgan Kaufmann/OMG Press (July 25, 2008)
- “Sysml for Systems Engineering: The Emperor’s New Modelling Language”
  - \* Authors: John Holt and Simon Perry
  - \* Available from Amazon.com for \$98.77
  - \* Published by Inspec/lee (May 30, 2008)



# Using SysML to Develop a Spacecraft Specification and Design Model, Part 2



- Project Background
- Project Report Outline
- Project Scope
- Project Process Flow
- Requirements Matrix Example
- Model Worksheet Example
- Project Results
- Sample Diagrams
- Flight Software Subsystem Shared Associations
- Personal Accomplishments
- Lessons Learned

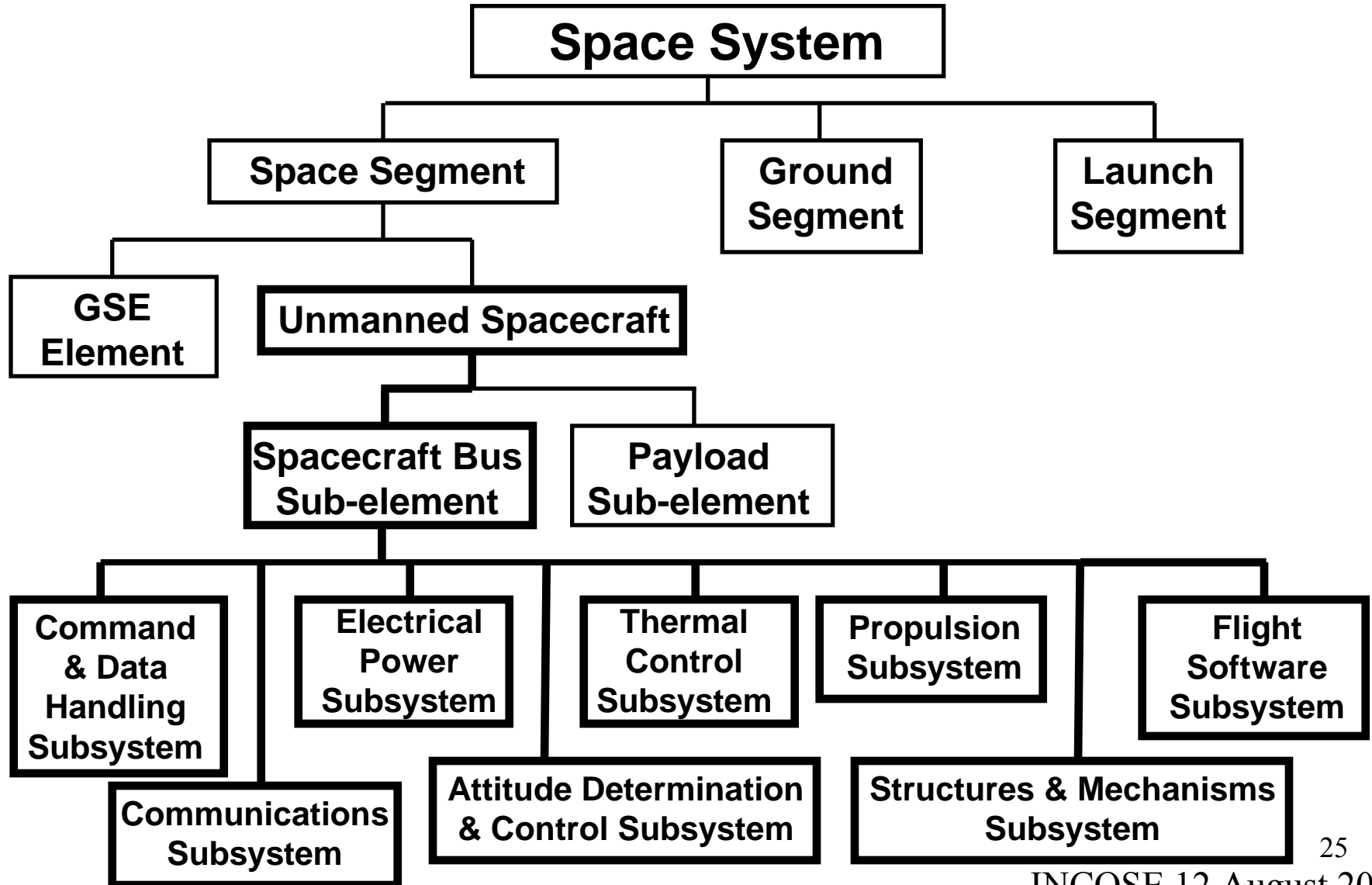


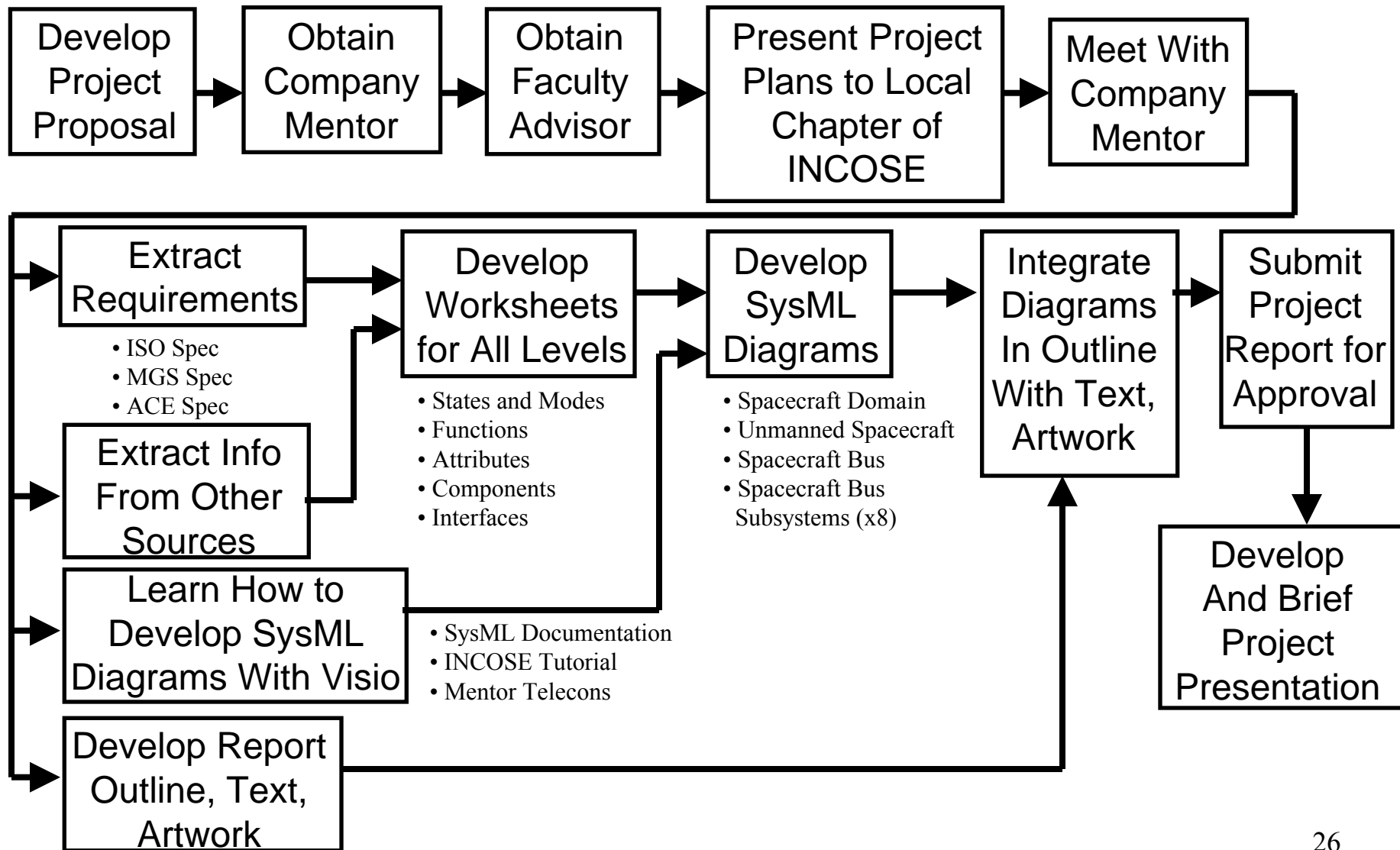
- Graduated in 2007 from Lockheed Martin/Cal Poly – San Luis Obispo distance-learning graduate program for Aerospace Engineering
  - Specialized in Space Systems Engineering
- Graduate degree required completion of a final project
  - Choose a topic of interest to us and work-focused/practical
  - Find a mentor within Lockheed Martin to oversee the work
  - Arrange for a faculty advisor who would be involved to help with project administration and to give a grade for the project
  - Provide project presentation to faculty review committee
  - Submit project report for review and final submission to Cal Poly library
  - Had to clear the report for release from Lockheed Martin
- Presented my project concept and plans in September 2006
- Presenting project results in August 2008



- Title Page
- Authorization for Reproduction
- Approval Page
- Abstract
- Acknowledgments
- Revisions Page
- Table of Contents
- List of Tables
- List of Figures
- Chapter 1 – Introduction
- Chapter 2 – Project Background
- Chapter 3 – Spacecraft Model
- Chapter 4 – Findings and Interpretation
- List of References
- Appendix A – Infrared Space Observatory (ISO) Requirements
- Appendix B – Mars Global Surveyor (MGS) Requirements
- Appendix C – Advanced Composition Explorer (ACE) Requirements
- Appendix D – Spacecraft SysML Model Worksheets

# Space System Hierarchy for Project Scope





## A.3 ISO Spacecraft Bus Level Requirements

Source: ISO System Specification, ISO AS 1400 SP 0090, Issue 04, Rev. B

Name	Role	Requirements	Section No.	Used ?
ISO Service Module (SVM)	Spacecraft Bus Sub-Element	<p><b>Functional Requirements:</b> The Service Module shall provide the following functions:</p> <ul style="list-style-type: none"> <li>- <u>structural support and SVM thermal control</u></li> <li>- <u>control and measurement of satellite attitude and orbit control</u></li> <li>- <u>electrical power generation, conditioning, storage and distribution</u></li> <li>- <u>shadowing of the PLM from direct sun light</u></li> <li>- <u>radio frequency transmission/reception with the ground</u></li> <li>- <u>data handling for distribution of ground and onboard commands and sampling/formatting of telemetry data</u></li> <li>- <u>interfaces with the launcher and support of the PLM</u></li> <li>- <u>distribution of all electrical signals through an SVM harness.</u></li> </ul>	Sec 3.3.2	X
		<p><b>Service Module Requirements:</b> The Service Module (SVM) consists of a load carrying primary structure, of a secondary structure and of the equipments and parts of the subsystems necessary for the ISO mission.</p>	Sec 3.10	

## D.3.3.1 ADCS States and Modes Worksheet

ADCS States and Modes	References								
	A	B	C	D	E	F	G	H	I
Off State									
On State									
Star Acquisition Mode	X								
Fine Pointing Mode	X								
Calibration Mode	X								
AOCS programmable pointing mode	X								
Survival mode	X								
Launch Mode		X							
Prepare to Control Mode		X							
Detumble Mode		X							
Sun Search Mode		X							
Sun Hold Mode		X							
Home Base Mode (Control Submode)		X							
Home Base Mode (Knowledge Submode)		X							
Attitude Control Disabled Mode		X							

Ref A: ISO System Specification

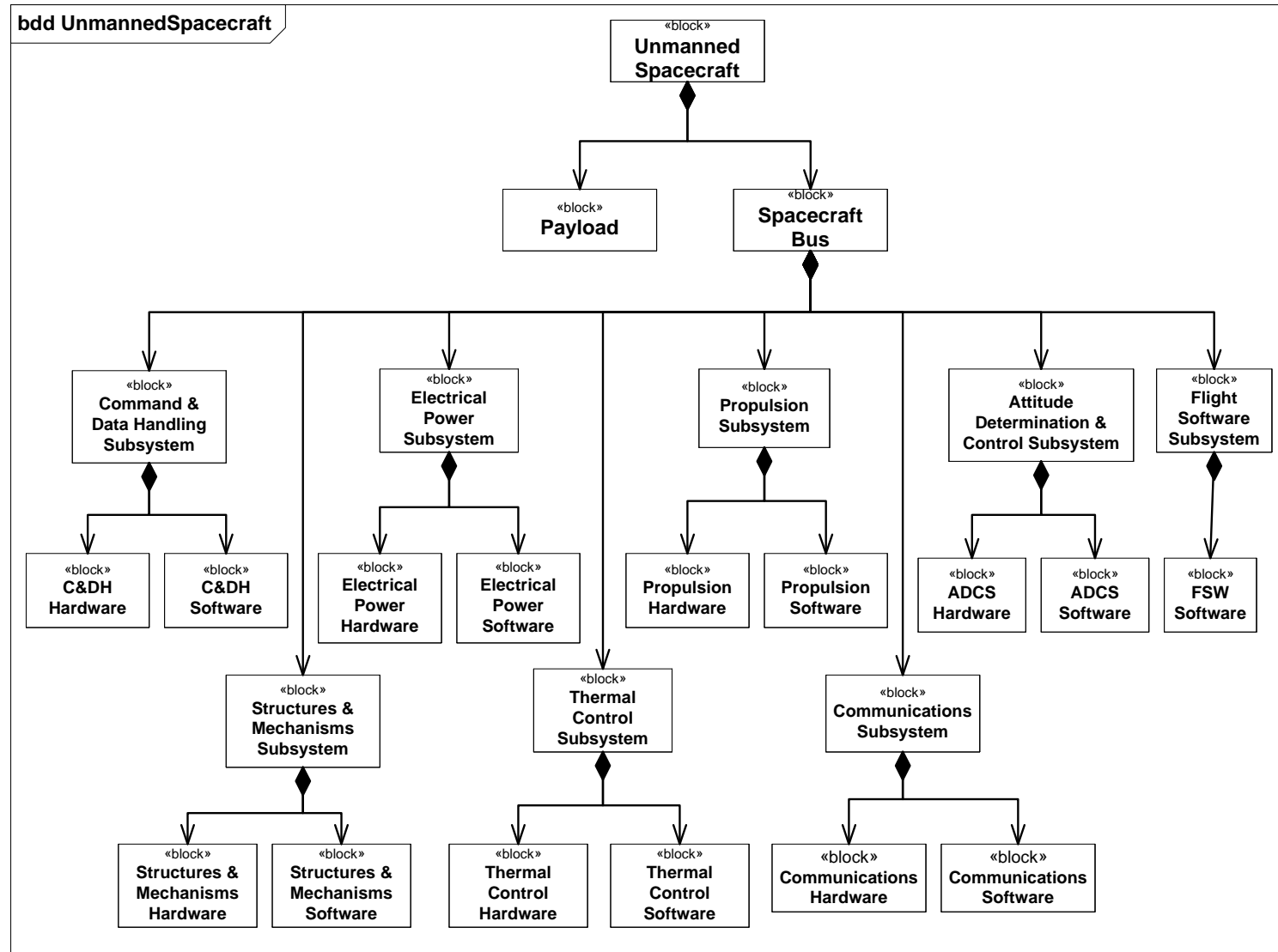
Ref B: Hackney, John C., Douglas E. Bernard, and Robert D. Rasmussen, "The Cassini Spacecraft: Object Oriented Flight Control Software," Jet Propulsion Laboratory, AAS 93-033, 1993.

# Project Results

Spacecraft Model Levels	OMG SysML Diagrams								
	Activity	Sequence	Use Case	State Machine	Requirement	Block Definition	Internal Block	Parametric	Package
Spacecraft Domain					8	1		2	
Unmanned Spacecraft		4	1		2	1		1	
Spacecraft Bus			1		1	1		2	
Spacecraft Bus Subsystems								1	
Command & Data Handling					1			1	
Electrical Power					1			1	
Attitude Control					1			1	
Communications					1			1	
Propulsion					1			1	
Thermal Control	1				1			1	
Structures & Mechanisms					2			1	
Flight Software			1		1			1	

# Block Definition Diagram (bdd)

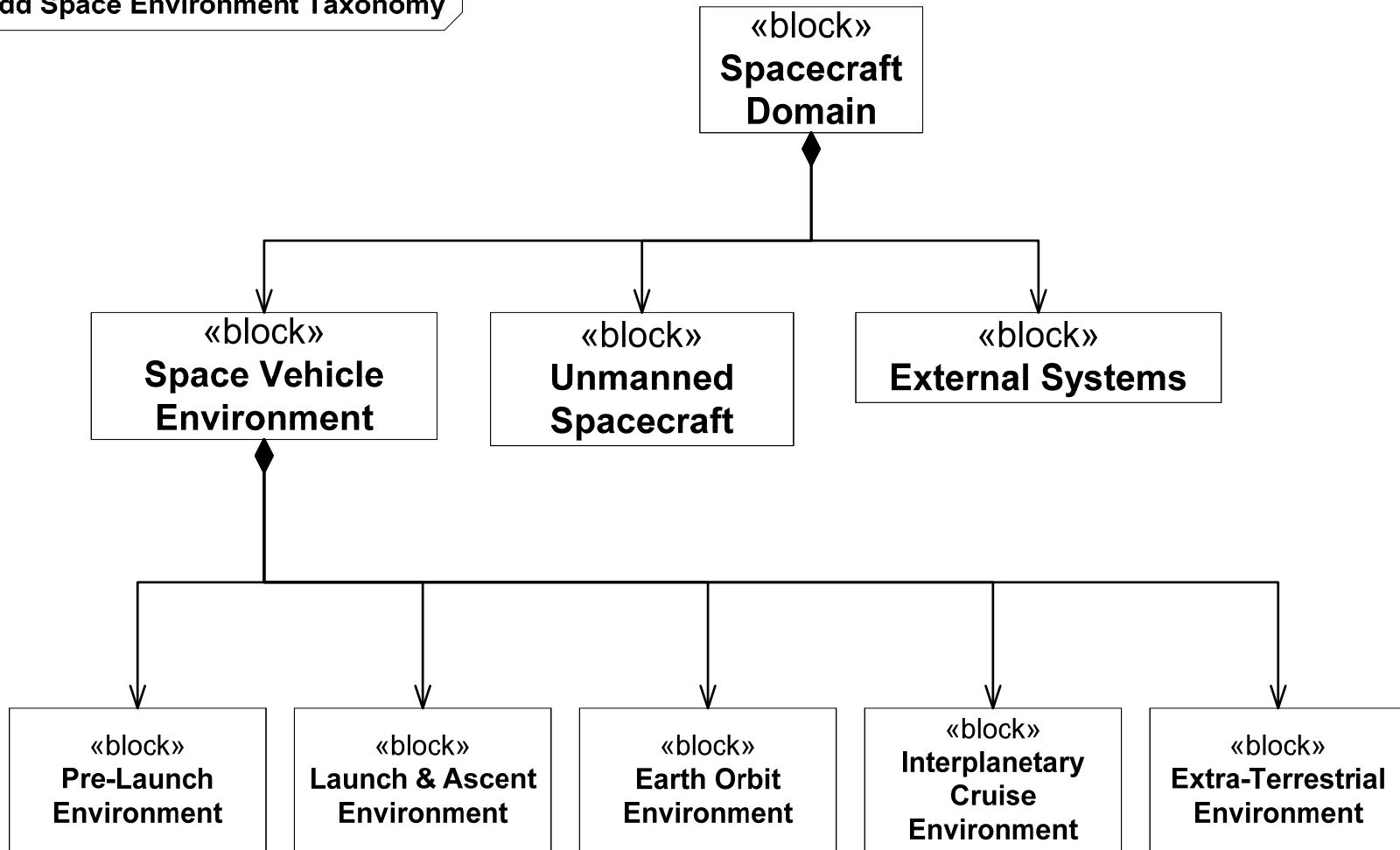
## System Hierarchy Example



# Block Definition Diagram (bdd)

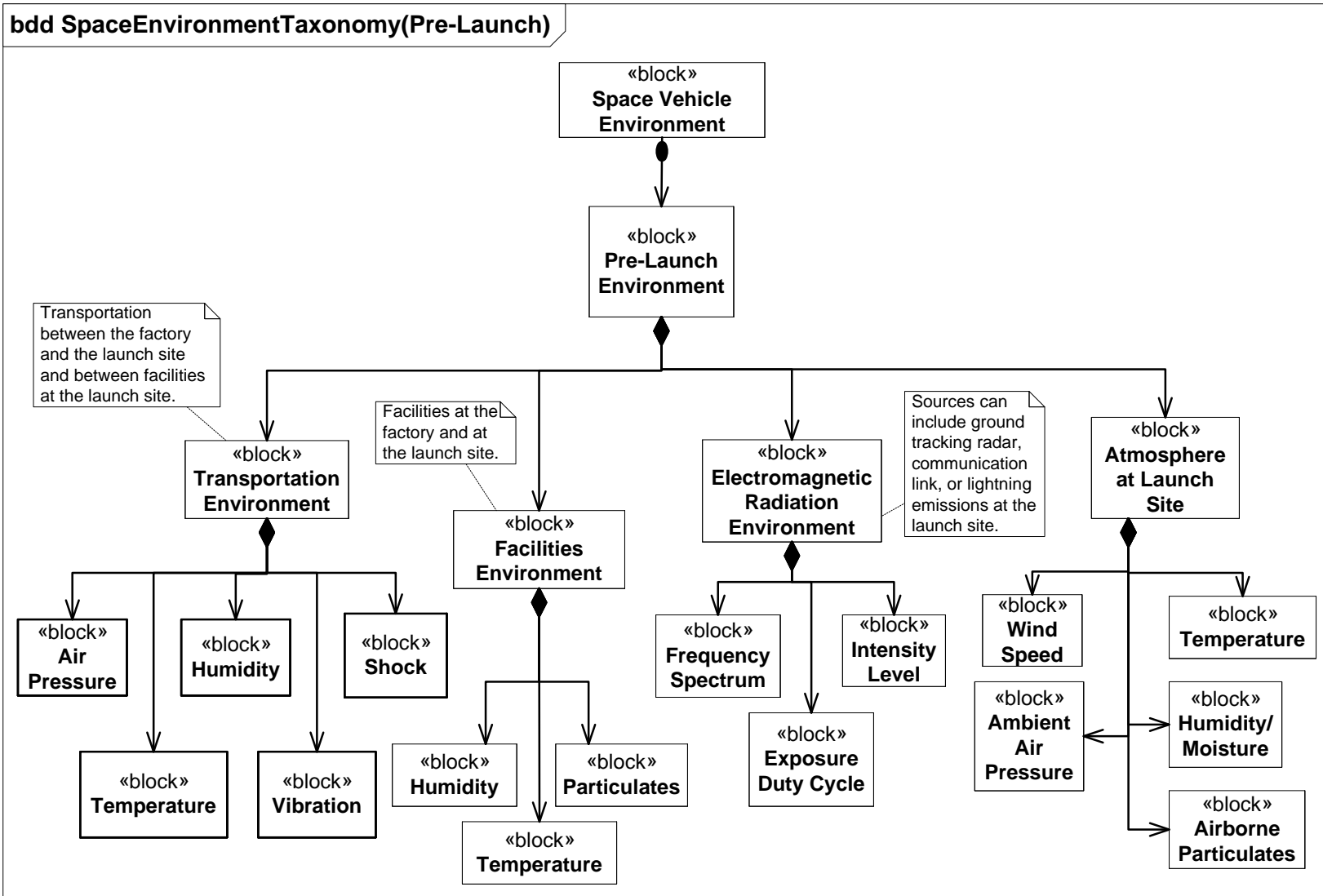
## Environment Example

**bdd Space Environment Taxonomy**



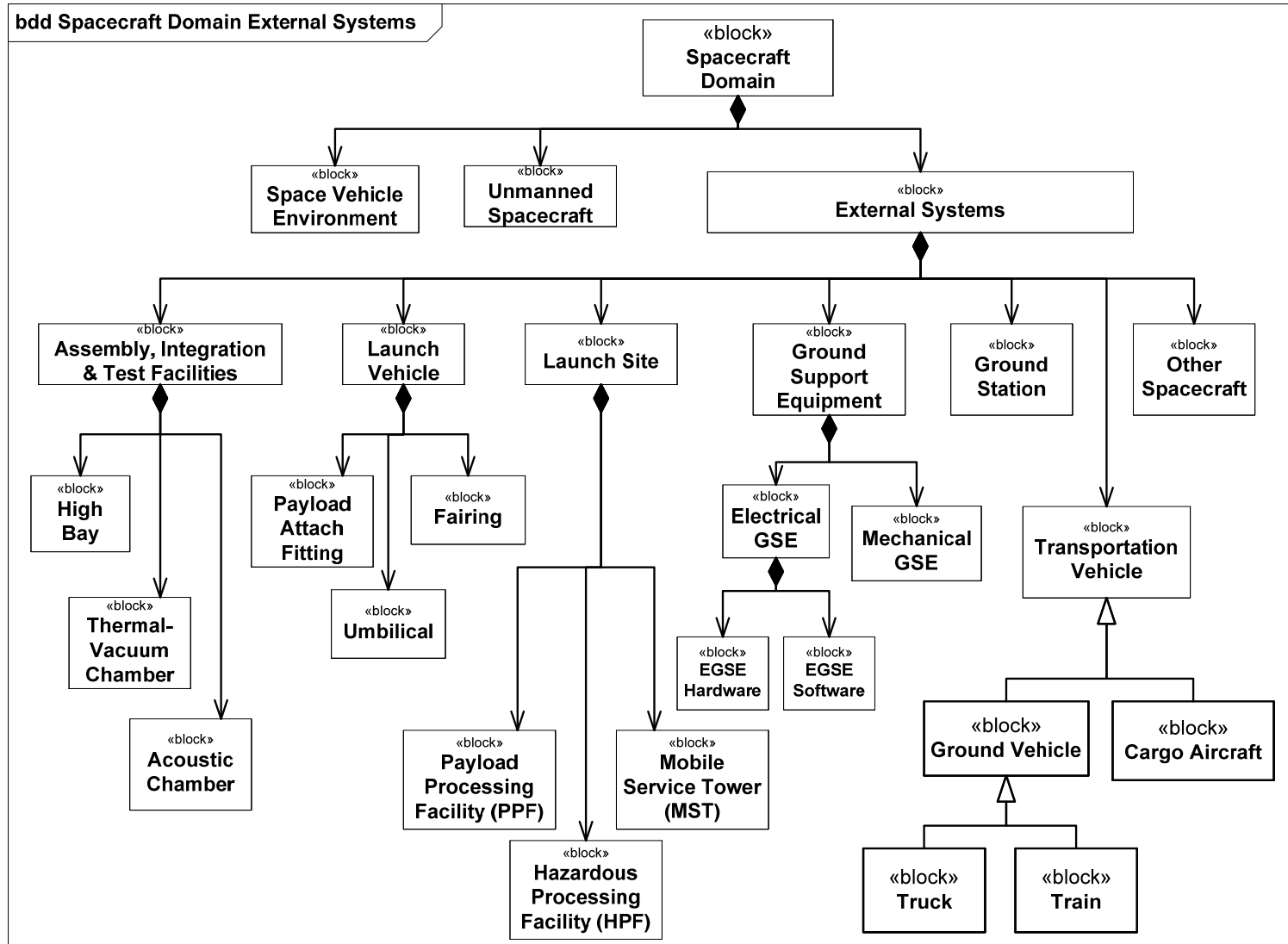
# Block Definition Diagram (bdd)

## Environment Example (2)



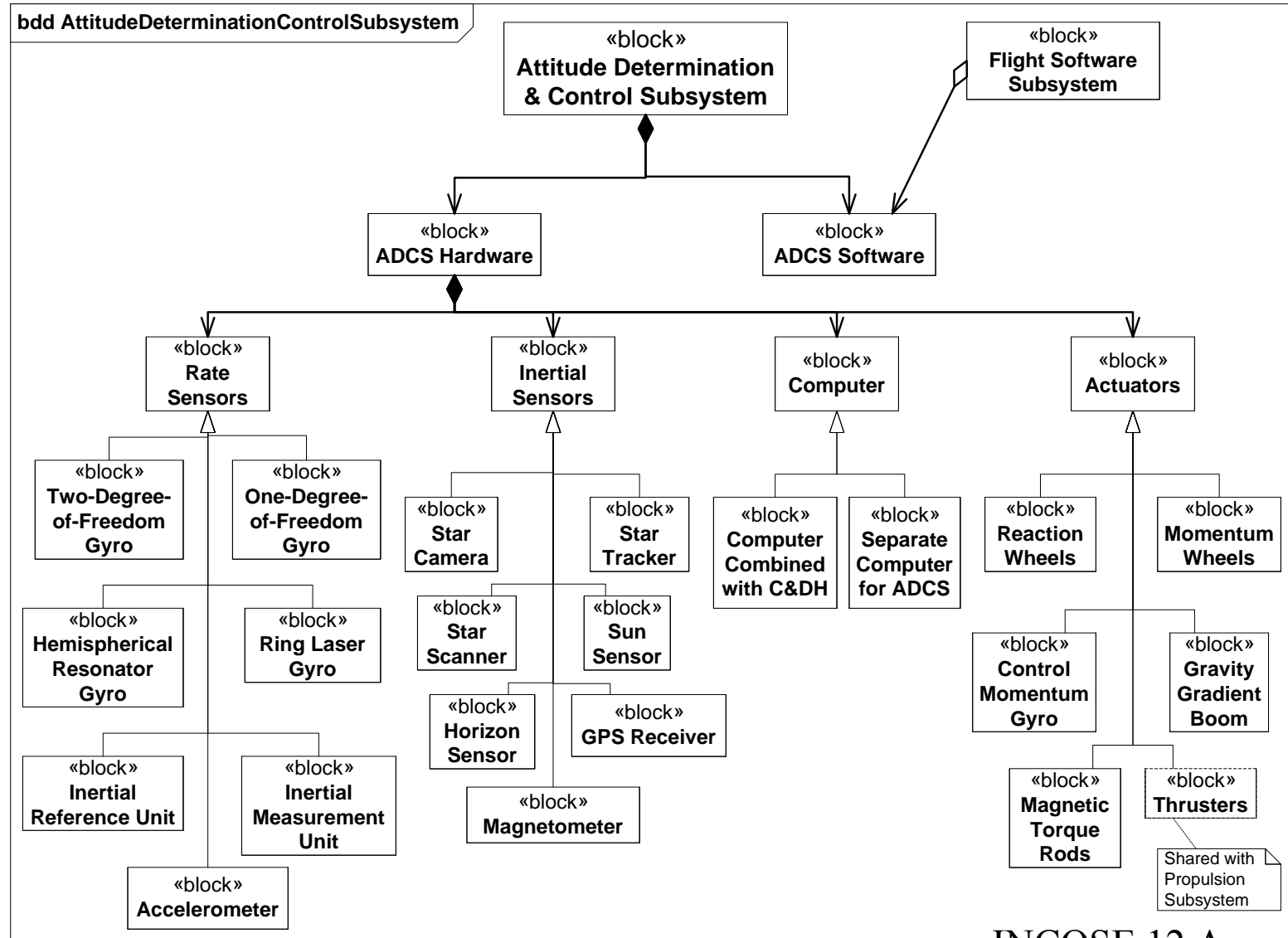
# Block Definition Diagram (bdd)

## External Interface Example

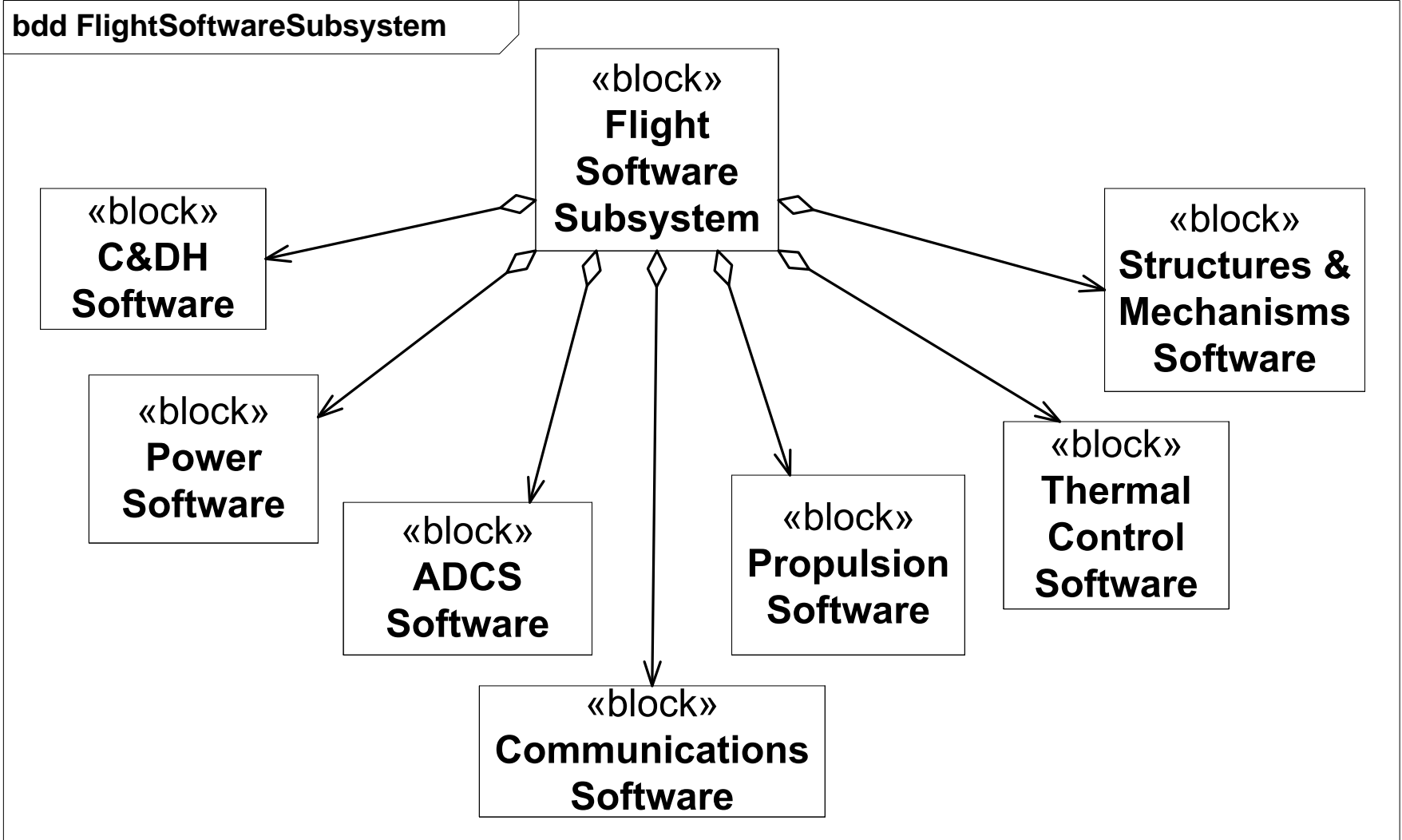


# Block Definition Diagram (bdd)

## Subsystem Example



# FSW Subsystem Shared Associations





Over the course of this project, I accomplished a number of different activities:

- Developed a set of SysML diagrams to form the foundation for a SysML-based model for generic spacecraft
- Learned how to use Microsoft Visio (Visio Standard 2003)
- Learned how to download and employ the SysML stencils for Visio 2003
- Learned to develop a variety of SysML diagrams.
- Learned how to use pdf conversion software (ScanSoft PDF Converter Professional 4)
  - To convert Visio diagrams to pdf format
  - To convert Word version of this report to pdf format
  - To convert ACE Spacecraft Specification from pdf format to Microsoft Word
- Developed my own process to document extracted information from the various specifications and other references and correlate the information with their source in the Appendix D format.
- Read a number of sources on information (e.g., specs, papers, articles, standards) previously unread
- Learned to apply “Form & Style” format guidelines



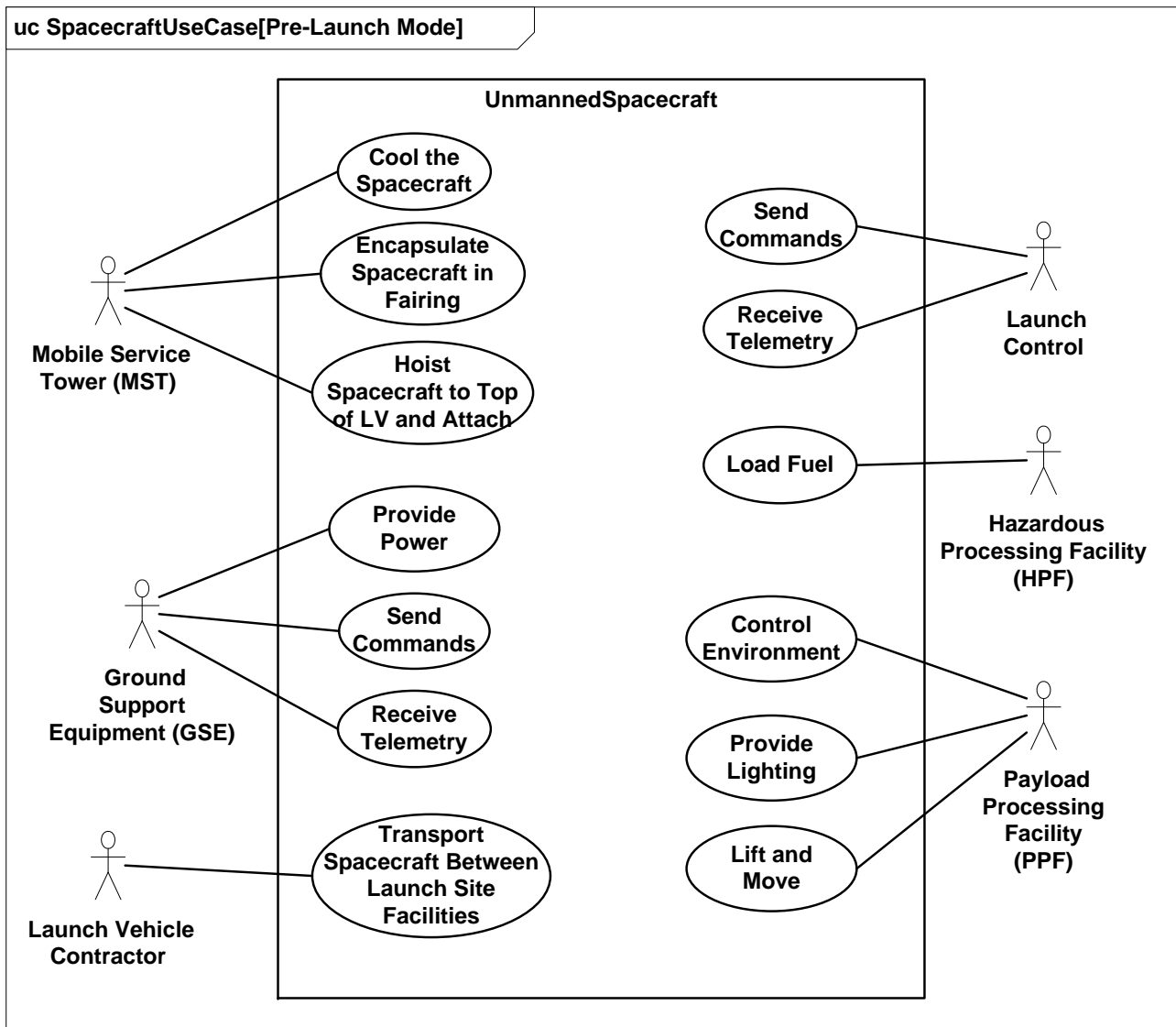


# Backup Charts

For successful model development, four types of knowledge/  
experience is needed:

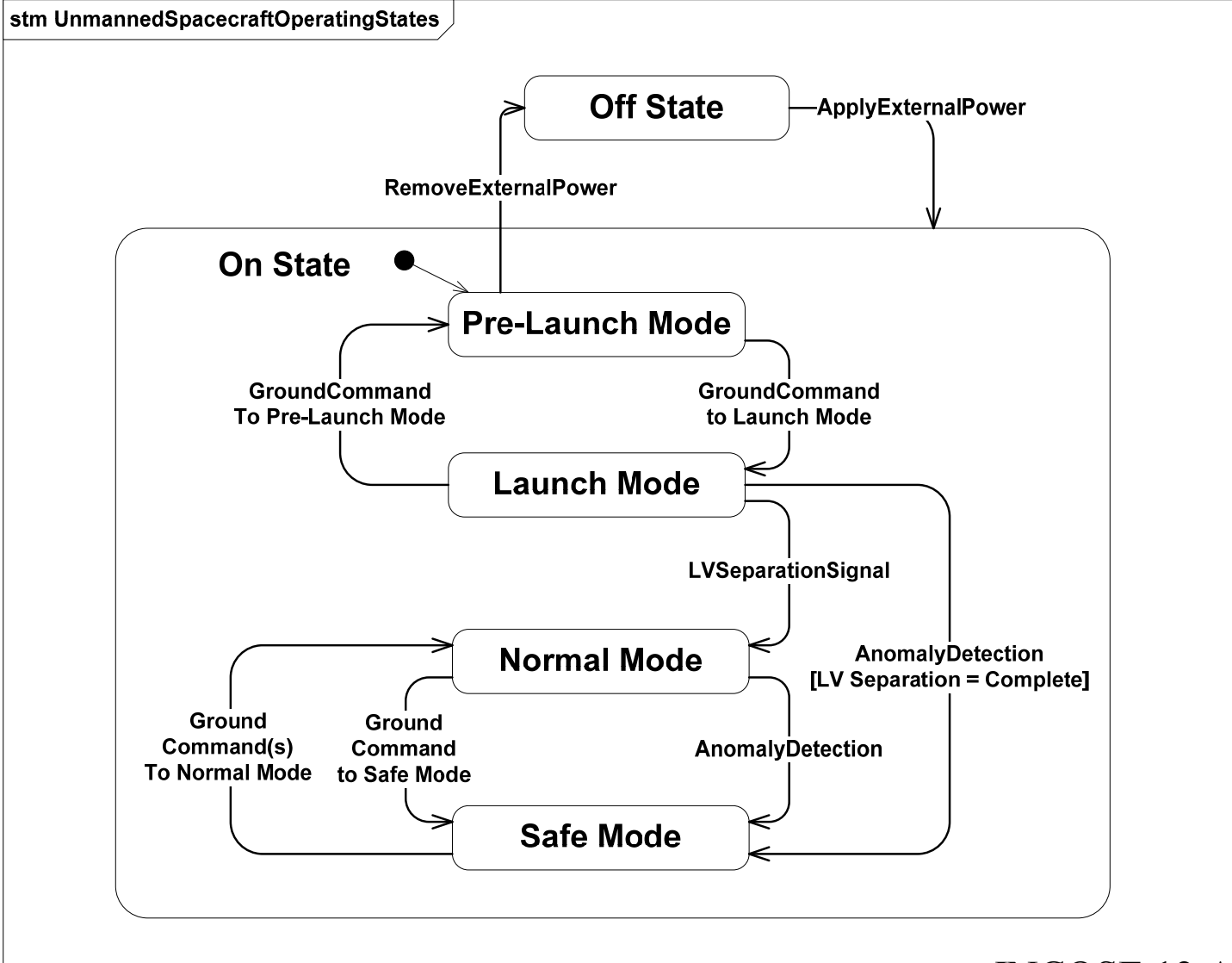
- Language (diagrams, symbology)
- Process
- Modeling Tool (Visio, Rhapsody)
- Domain knowledge (spacecraft, aircraft, ship, IT, etc.)

# Use Case (uc) Example





# State Machine (stm) Example

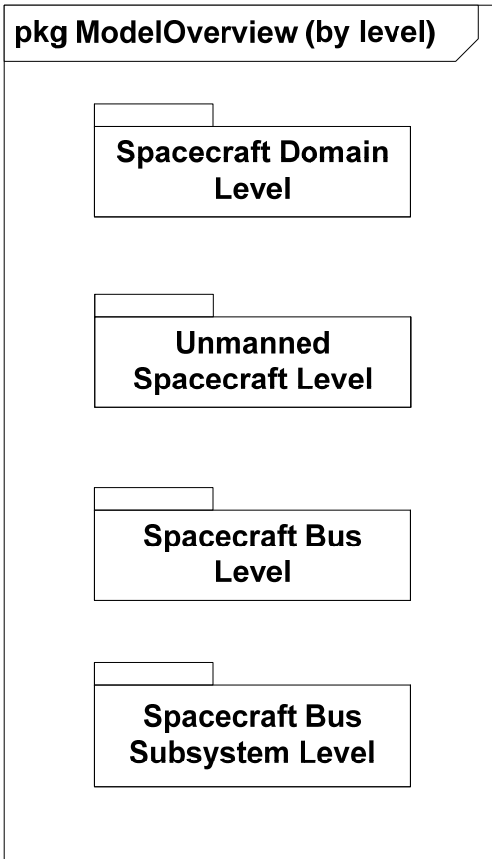




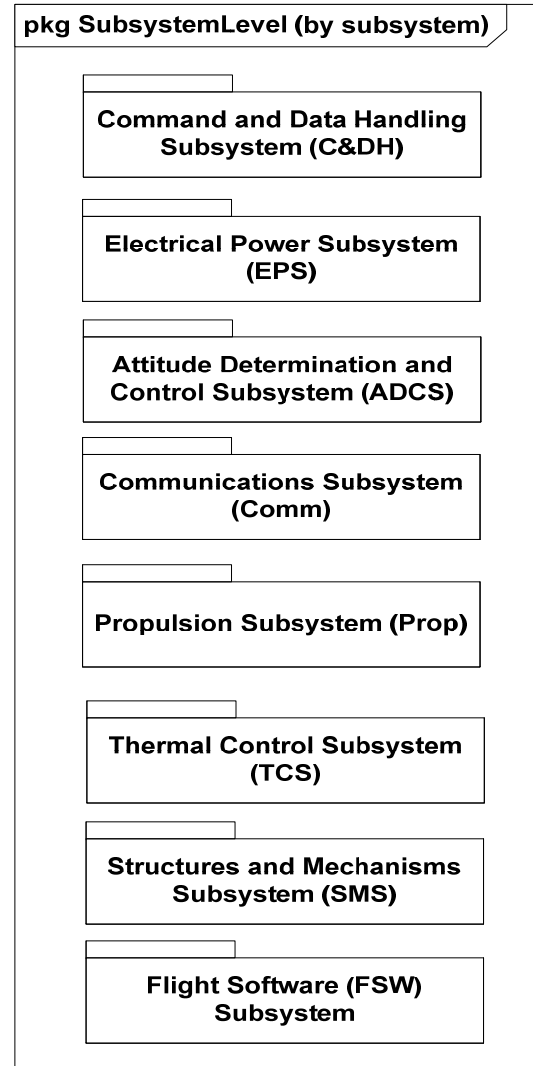
- Helps prevent starting from scratch - no more reinventing the wheel when starting a new project
- Guidelines for design development to help ensure completeness
- Description document outline and content completeness
- Help to ensure specification development completeness
- Red Team review guide for both developers and reviewers – completeness of proposal/proposed design
- Program knowledge base not entirely dependent on just the knowledge of personnel working on the program

# Package Diagram (pkg) Examples *SFBAC*

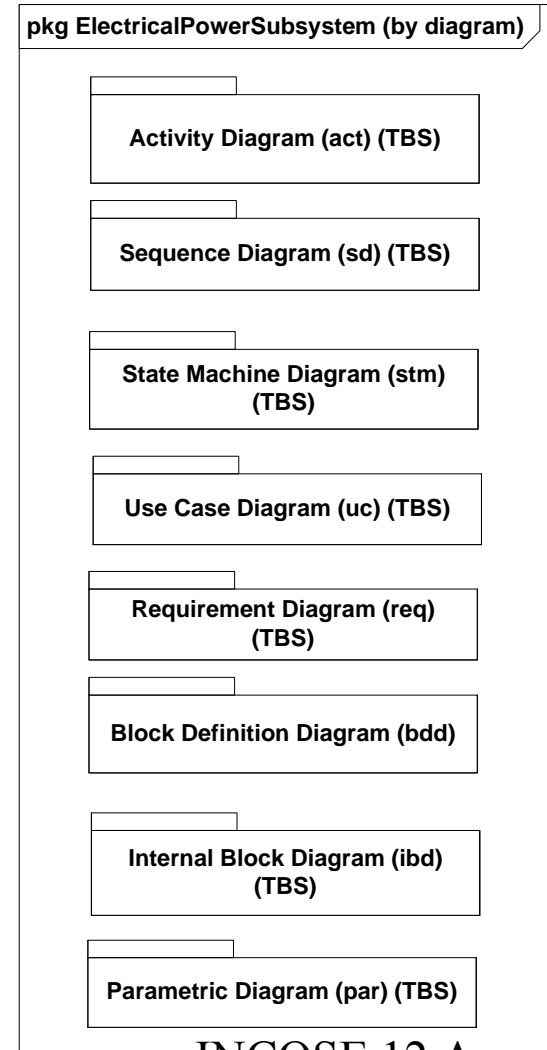
## By Level



## By Subsystem

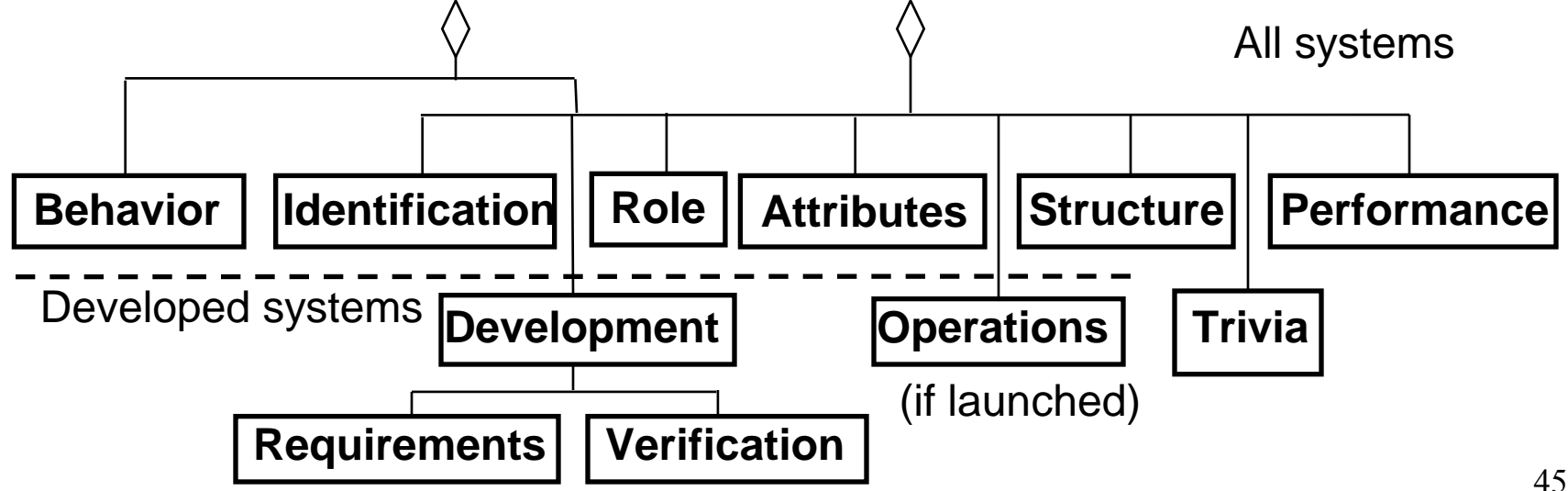
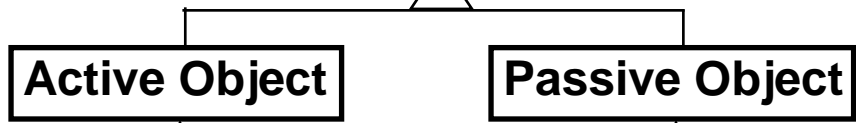
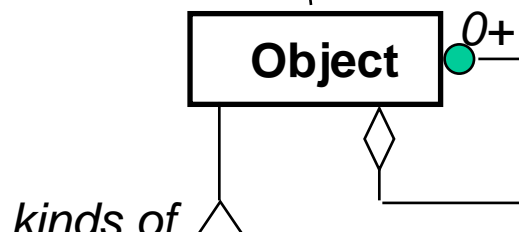
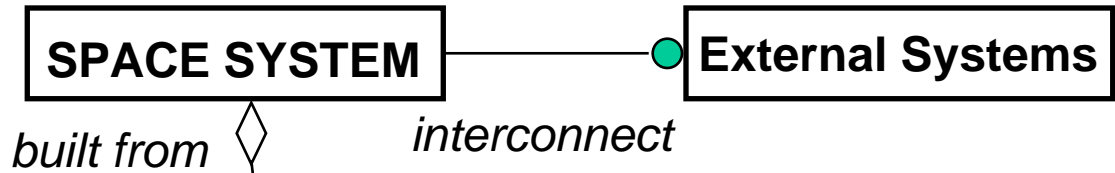


## By Diagram

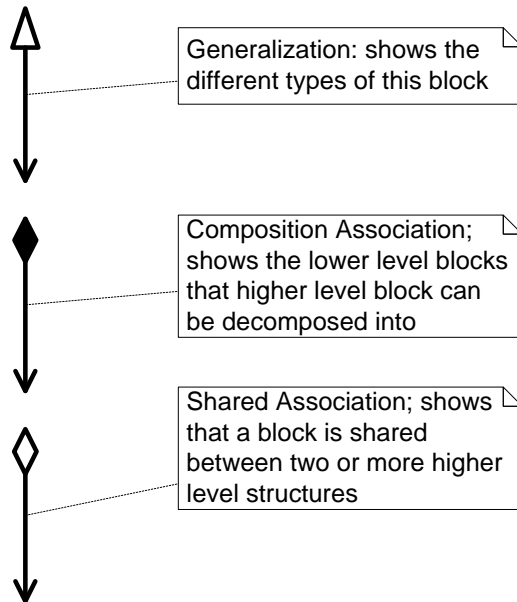
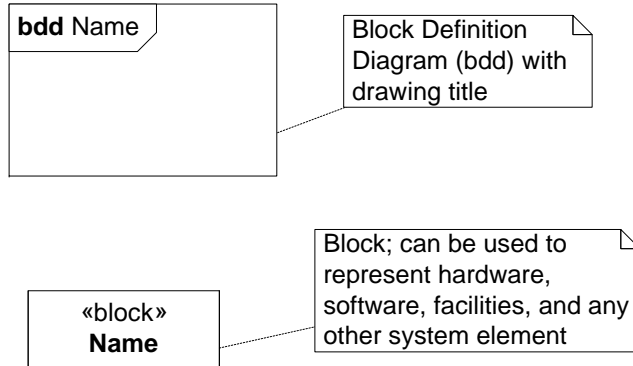


## Context

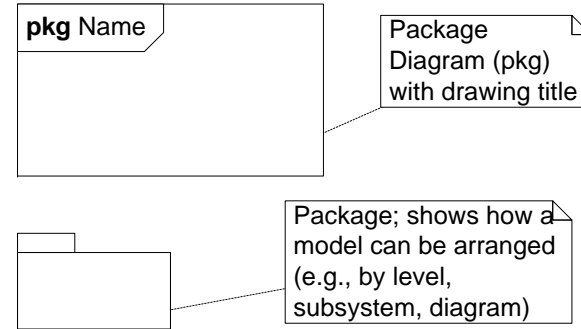
- Mission objectives
- Mission profile
- External Interfaces
- Environments
- Customer expectations/benefits
- Other constraints



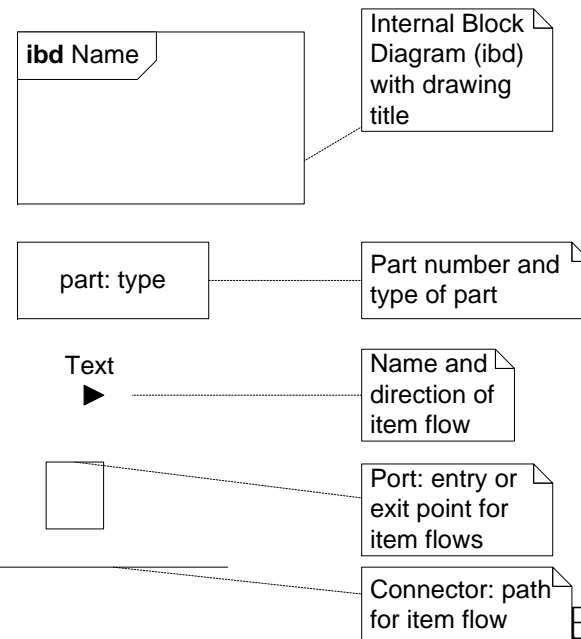
## Block Definition



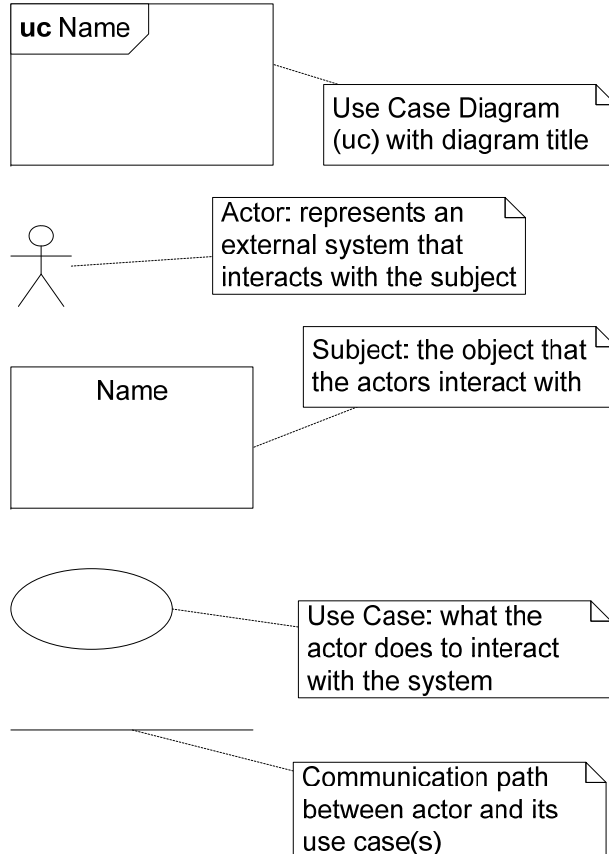
## Package



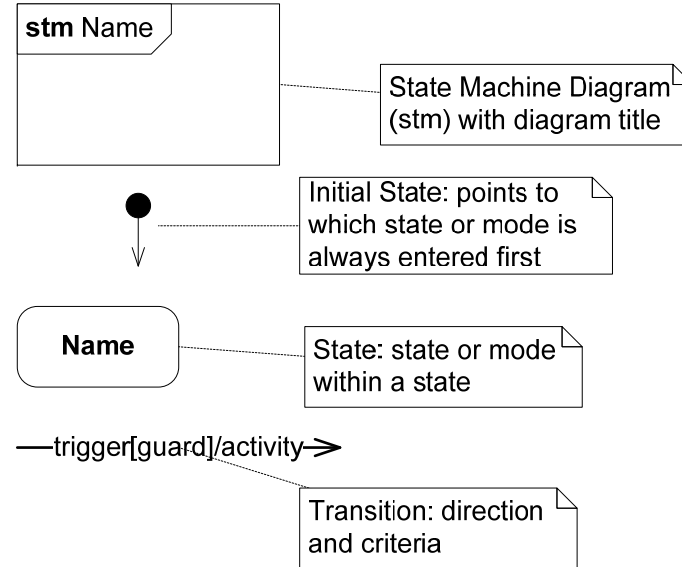
## Internal Block



## Use Case



## State Machine



## Activity

