Systems Engineering a Model Based Systems Engineering Tool Suite: The Boeing Approach

Brittany Friedland, Robert Malone, and John Herrold

The Boeing Company

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Agenda

1. Model Based Systems Engineering at Boeing
2. MBSE Tool Suite Development Process
3. Systems Engineering Skills Required to Develop an MBSE Tool Suite
4. MBSE Tool Suite Configuration Management
5. Conclusion

Boeing at a Glance

- Customers and customer support in 150 countries

    - Total revenue in 2012: $81.7 billion

    - 70 percent of commercial airplane revenue from customers outside the United States

- Manufacturing, service & technology partnerships with companies around the world

    - Contracts with 22,000 suppliers and partners globally

- Research, design & technology-development centers & programs in multiple countries

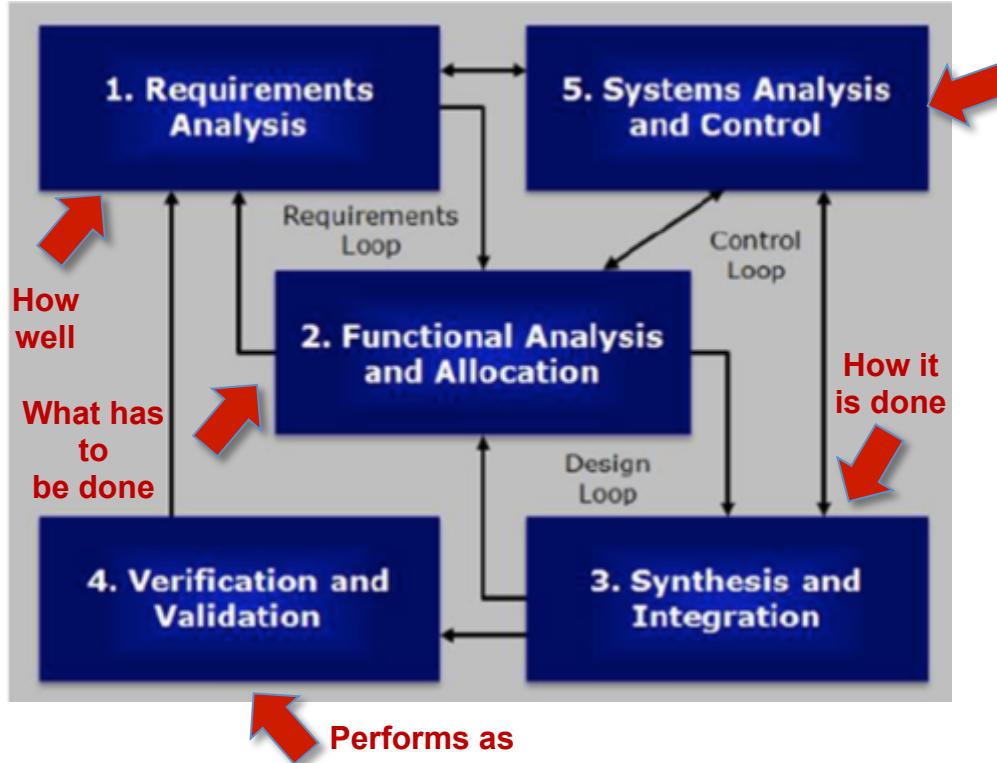- More than 170,000 Boeing employees in 50 states and 70 countries

A Sample of Diverse Boeing Products

Model Based Systems Engineering at Boeing

Model Based Systems Engineering at Boeing

Completeness and accuracy

How well

What has to be done

How it is done

Performs as desired

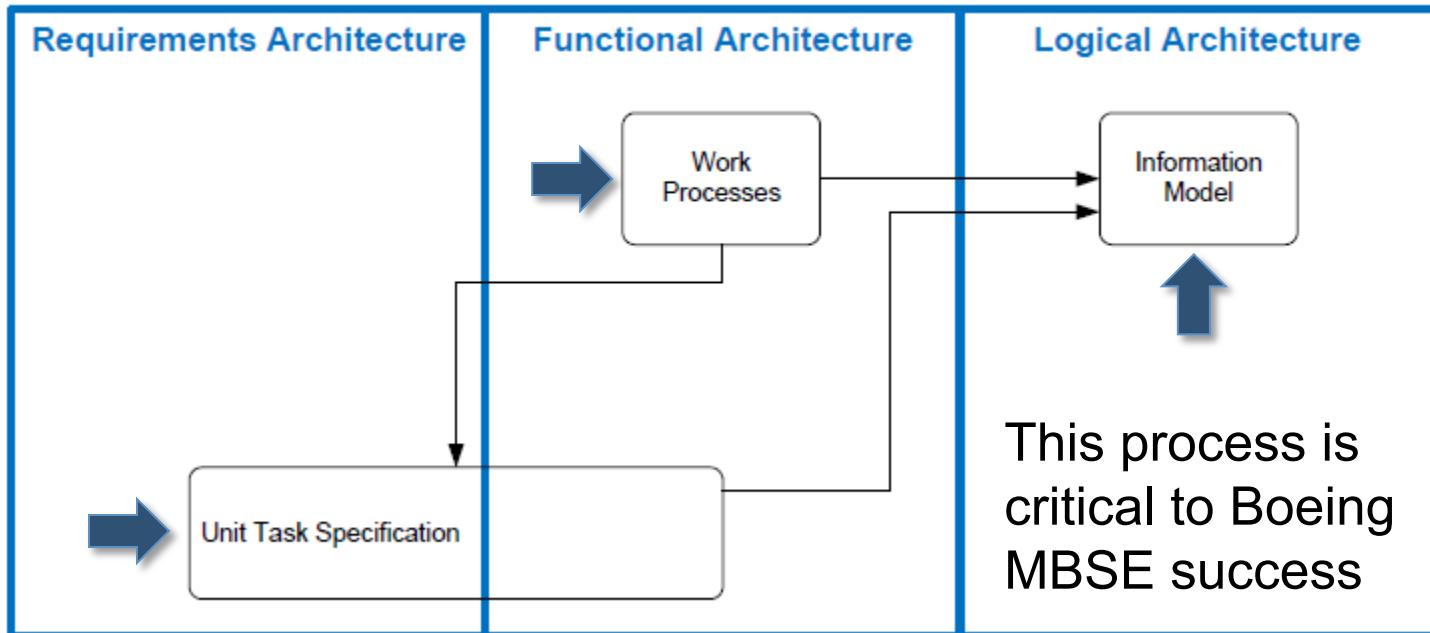- Core Elements of Boeing Systems Architecture Models

MBSE Tool Suite Development Process

MBSE Tool Suite Development Process

Relationship between tool suite specification deliverables and classic SE architectures

Modified IT development processes

This process is critical to Boeing MBSE success

Work Processes

Work Process Deliverable Outline

Introduction	
•	Purpose
•	Assumptions
•	References
•	Background
Requirements	
•	Use Case Title
○	Overview
○	Data Model
○	Process Flow
○	Functional Requirements
▪	Sub-Use Case
•	Overview
•	Unit Task Enumeration

Work processes should be derived from well defined business processes
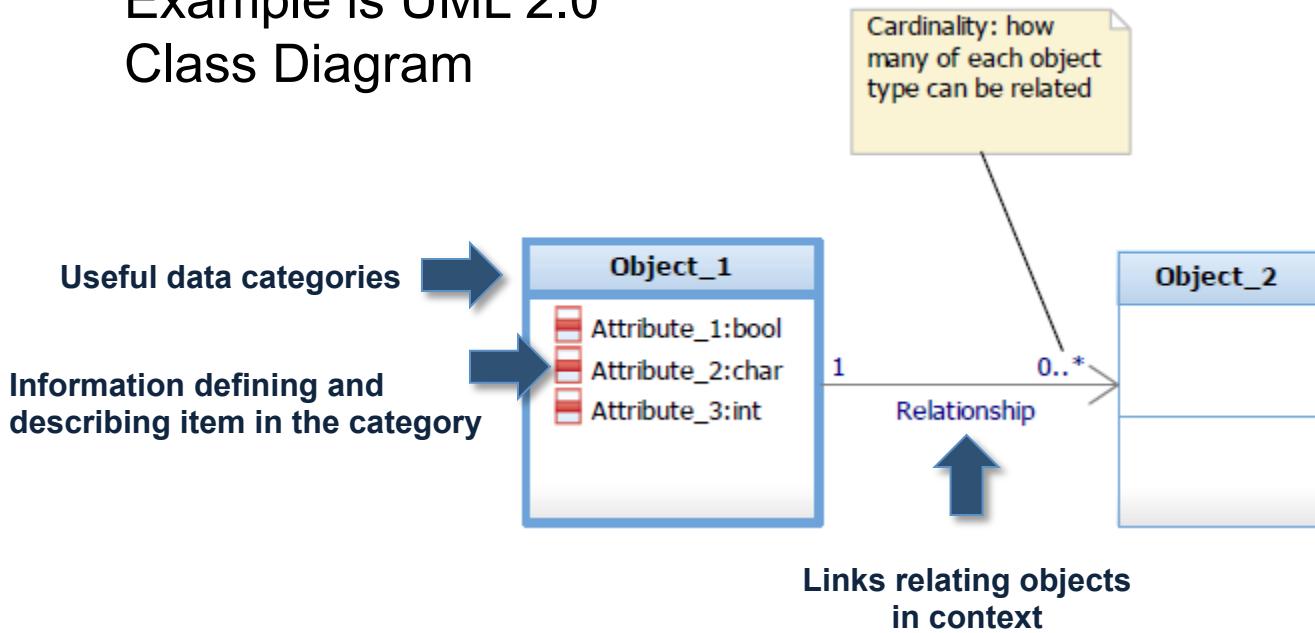
Unit Task Specification

Unit tasks decomposed from process steps

Unit Task Specification Outline
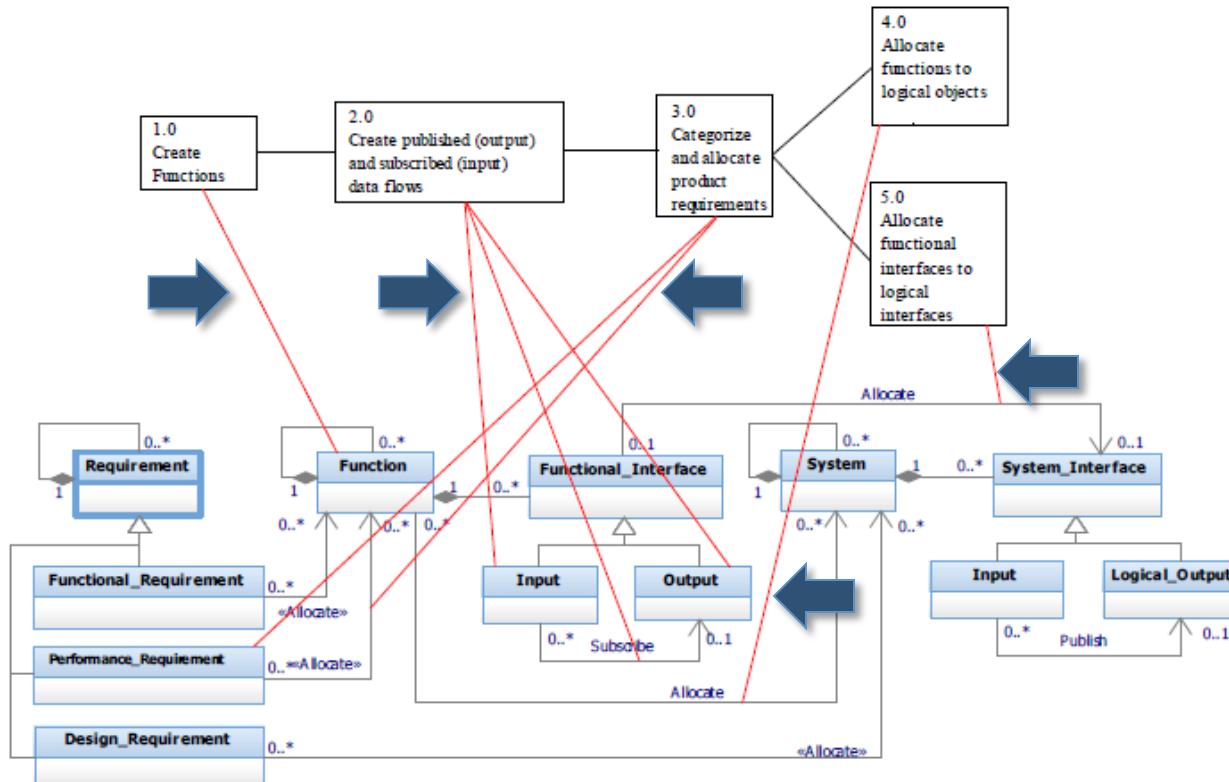
Unit Task
• Roles
• Pre-Conditions
• Post-Conditions/Expected Results
• Exceptions
• Quality Criteria
• Level of Automation
• Business Requirements

Information Model

Example is UML 2.0
Class Diagram

Cardinality: how
many of each object
type can be related

Object_1

Useful data categories

Attribute_1:bool
Attribute_2:char
Attribute_3:int

Information defining and
describing item in the category

1   0..*
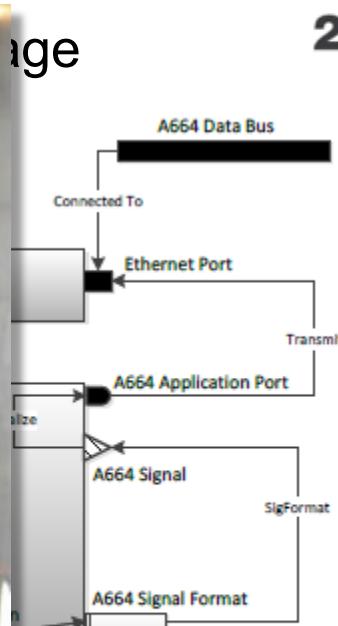
Relationship

Object_2

Links relating objects
in context

Transforming Work Processes & Unit Tasks Into Information Models

Transforming Work Processes & Unit Tasks Into Information Models

- Specializ... ...age between ...

A664 Data Bus

Connected To

Ethernet Port

Transmit

A664 Application Port

A664 Signal

SigFormat

A664 Signal Format

LRU 1

Acrony...
A429 –
A664 –
LRU –

Using an MBSE Tool Suite to Architect an MBSE Tool Suite

- MBSE tool suite is a software system, with many interrelated components and its specification, therefore, benefits from application of MBSE techniques

- Boeing MBSE tool suite developers use an MBSE tool suite to capture tool suite specification data

- Use of an MBSE tool suite to specify an MBSE tool suite demonstrates the value of MBSE

- MBSE tool suite architects enhance their modeling and tool suite skills by using an MBSE tool suite for tool suite modeling

Sample MBSE Tool Suite Specification Information Model
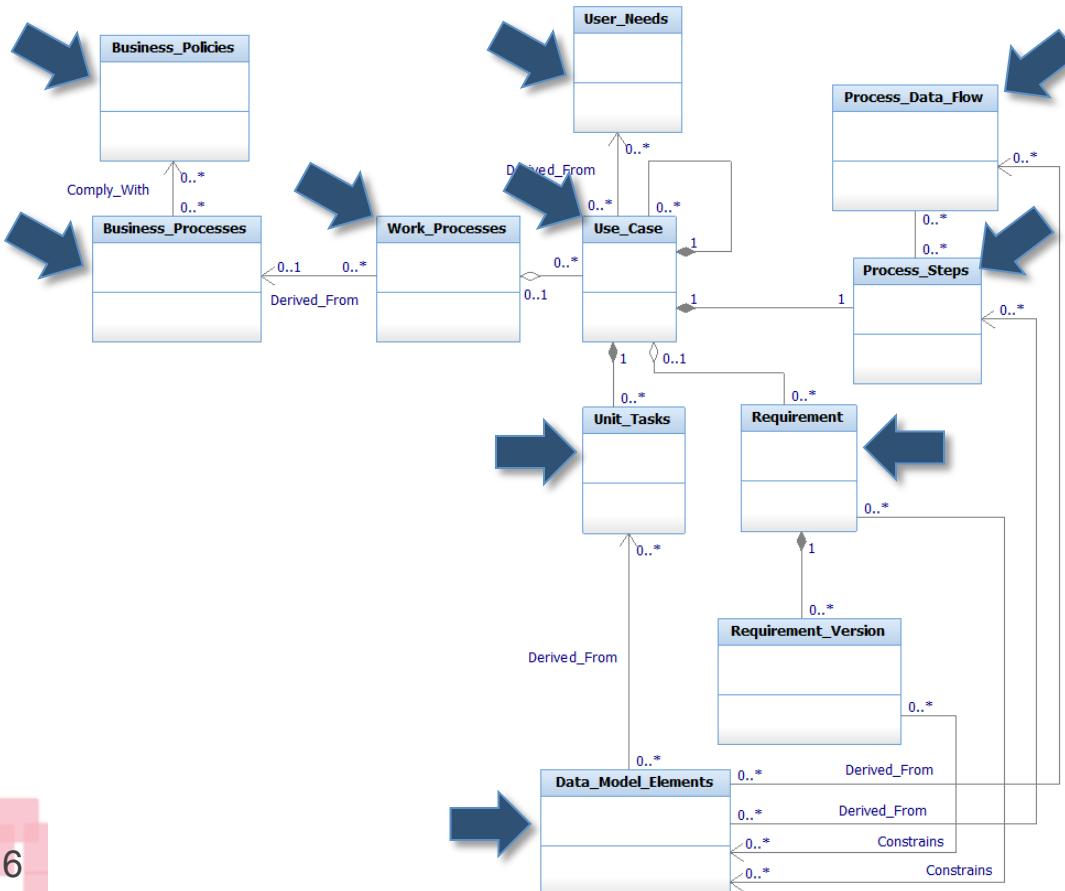
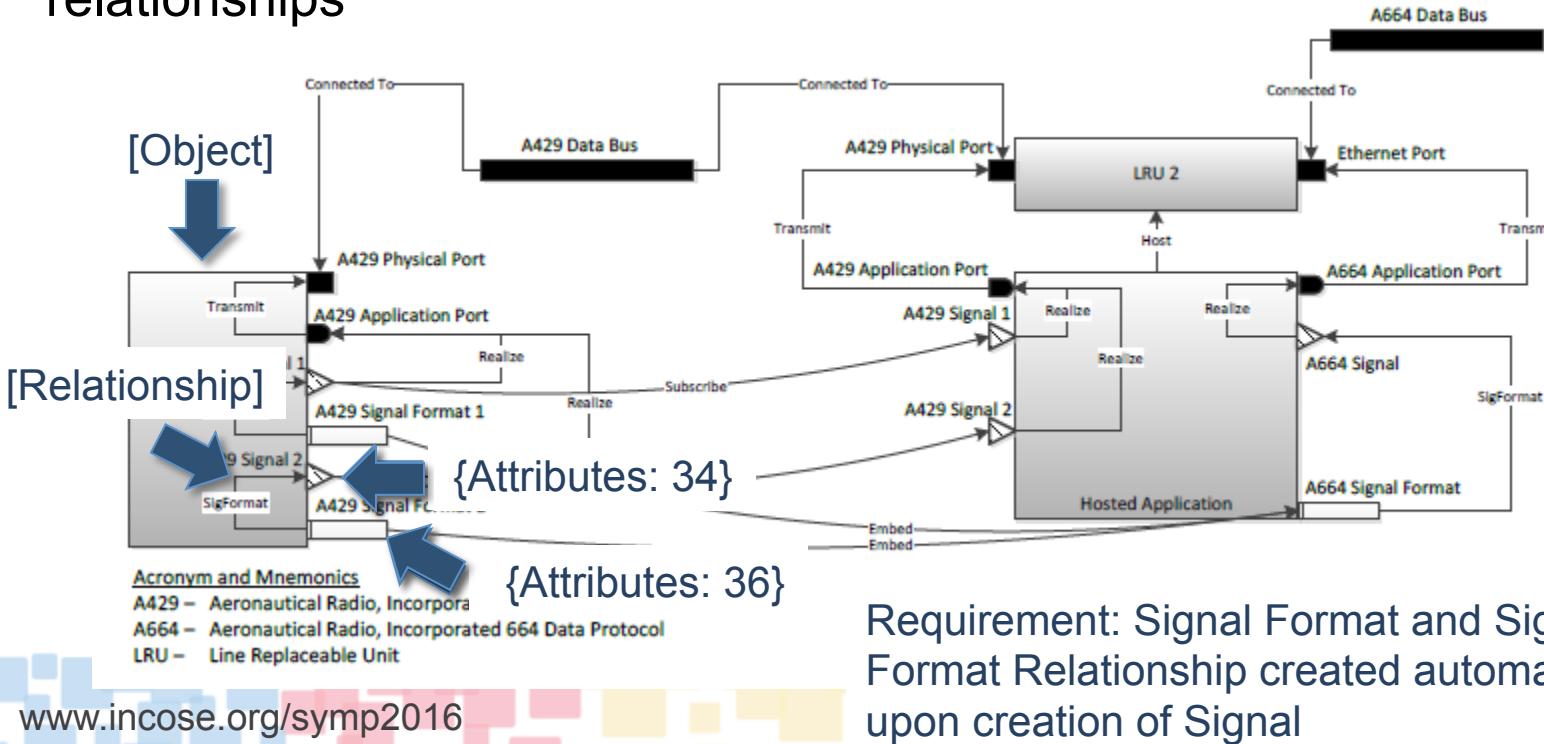# Typical MBSE Tool Suite Specification Model Data Volume

Large, detailed system architecture models are specified by large, detailed information models

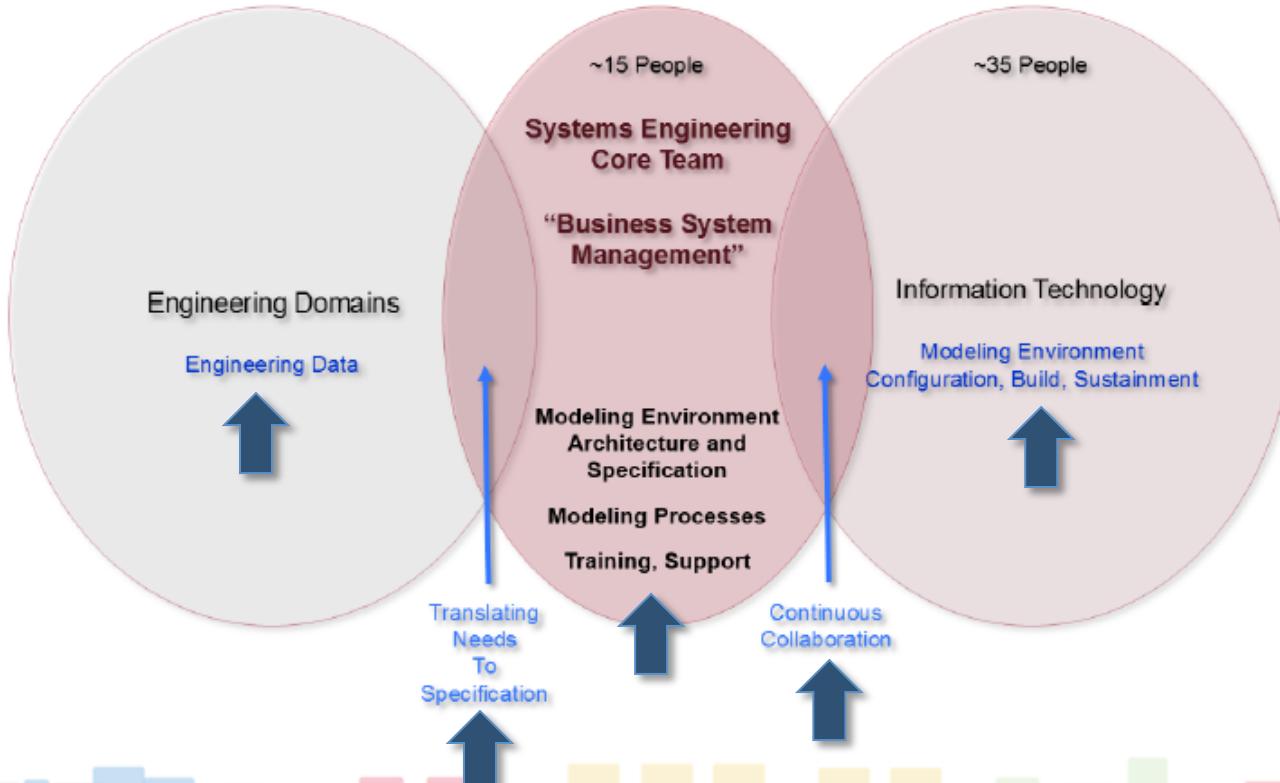| Tool Suite Data Model Elements	# of Each Element in Boeing Data Model
Use Cases	~1K
Business Requirements	~25K
Data Object Subtypes	~300
Data Relationship Subtypes	~75
Data Attributes	~2K

Specification Model Data Volume – Why So Large?

• Depiction of instances of information model objects and relationships

[Object]

[Relationship]

{Attributes: 34}

{Attributes: 36}

A664 Data Bus

Connected To

A429 Data Bus

A429 Physical Port

LRU 2

Ethernet Port

Connected To

Transmit

Host

Transmit

A429 Physical Port

A429 Application Port

A429 Application Port

A664 Application Port

Transmit

Realize

Realize

A429 Signal 1

A664 Signal

A429 Signal Format 1

Realize

Realize

Subscribe

A429 Signal 2

SigFormat

A429 Signal 2

A664 Signal

SigFormat

A429 Signal Format

A664 Signal Format

Embed
Embed

Hosted Application

Acronym and Mnemonics
A429 – Aeronautical Radio, Incorpora
A664 – Aeronautical Radio, Incorporated 664 Data Protocol
LRU – Line Replaceable Unit

Requirement: Signal Format and Signal Format Relationship created automatically upon creation of Signal

Systems Engineering Skills Required to Develop an MBSE Tool Suite

Systems Engineer Skills Required to Develop an MBSE Tool Suite

~15 People

Systems Engineering Core Team

"Business System Management"

~35 People

Engineering Domains

Engineering Data

Information Technology

Modeling Environment Configuration, Build, Sustainment

Modeling Environment Architecture and Specification

Modeling Processes

Training, Support

Translating Needs To Specification

Continuous Collaboration

BSM skills were critical to the successful customization of the COTS platform

Business System Manager Key Skills

- Collecting processes, data and modeling needs from users
- Producing usable tool suite specification deliverables
  - Use case development
  - Information Modeling
  - Ancillary utilities and automation features
- Development of model queries
- Verification and validation of delivered tool suite
- Defining tool suite updates
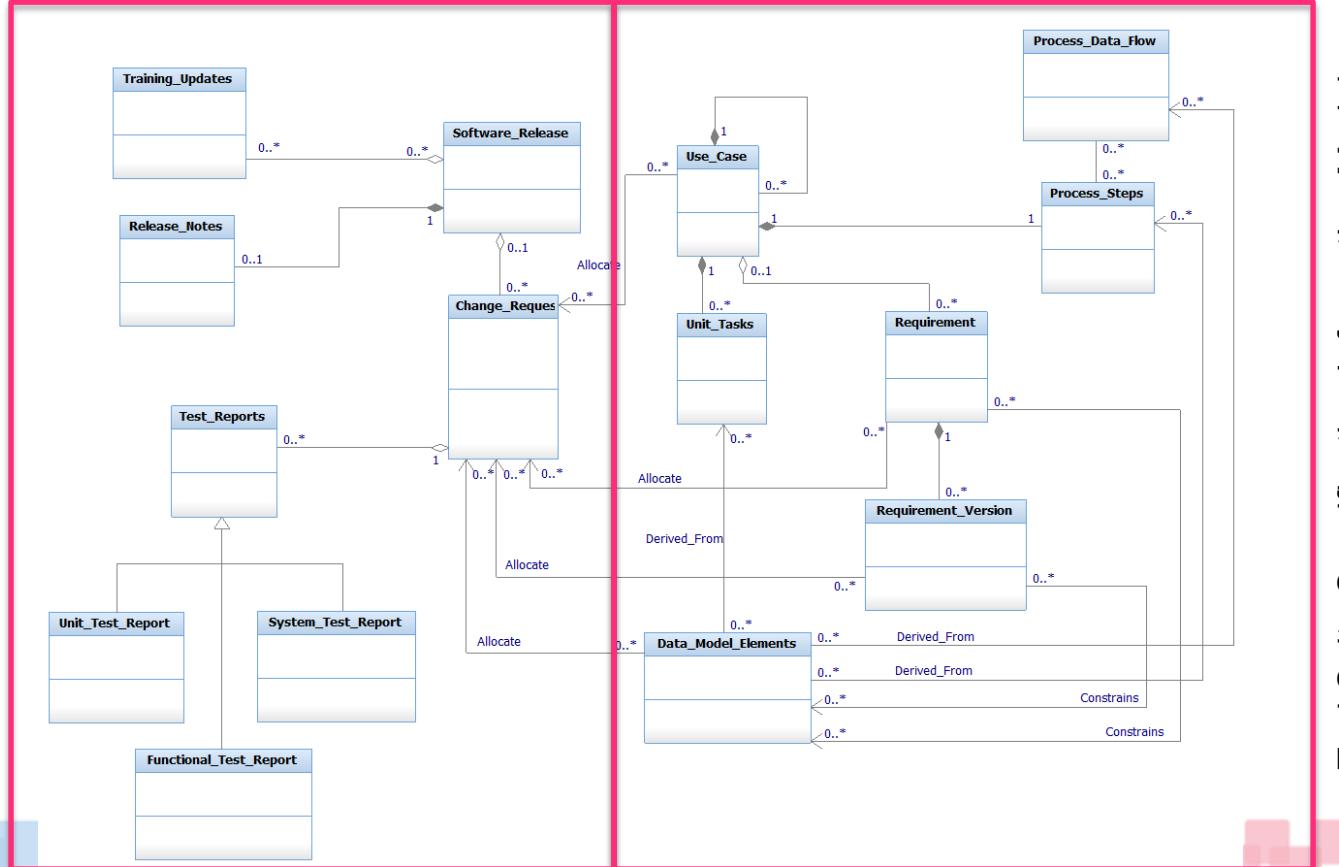- Change and configuration management of the tool suite

MBSE Tool Suite Configuration Management

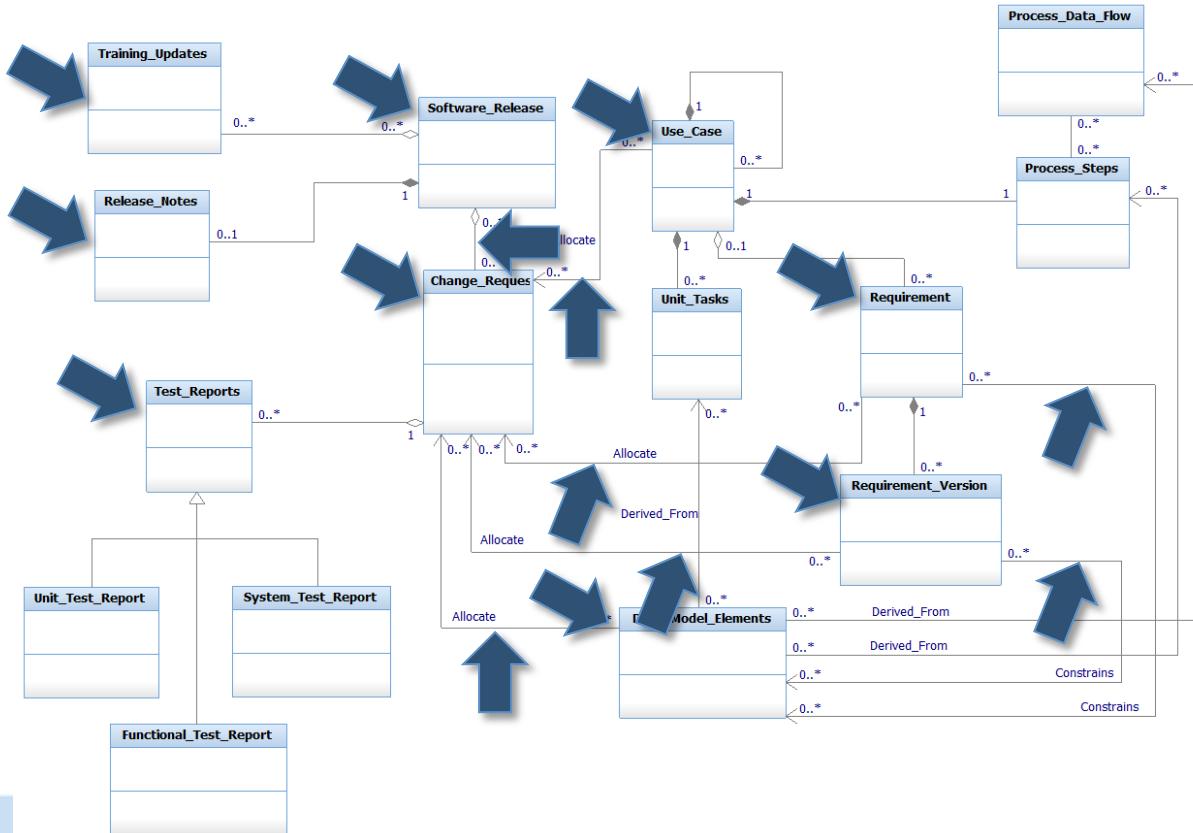# MBSE Tool Suite Configuration Management

MBSE Tool Suite Configuration Management

Conclusion

Conclusion

- Finely detailed large scale systems architecture tool suites need to be deliberately architected and rigorously specified
- In order to be successful at developing and deploying large scale systems architecture tool suites, the following are required:
  - A team of skilled architects and developers (Business System Managers) who form a bridge between the engineering and user community;
  - Rigorous tools suite specification, test and deployment processes; and,
  - A detailed, tightly integrated, configuration managed, tool suite specification model housed in an MBSE modeling environment
- Effective configuration management of the MBSE tool suite specification model is vital to obtaining tool accreditation

Tutorial ?

Questions?

References

Evans, E. 2004. *Domain-Driven Design: Tackling Complexity in the Heart of Software.*
Indianapolis, US-IN: Addison-Wesley Professional.

Object Management Group. 2005. Unified Modeling Language Version 2.0. Needham,
US-MA. Object Management Group.

Malone, R., Friedland, B., Herrold, J., & Fogarty, D. 2016." Insights from Large Scale Model
Based Systems Engineering at Boeing." Paper presented at the International
Symposium of INCOSE, Edinburgh, UK, 18-21 July.

Author Biographies

Brittany Friedland spent the beginning of her career in the Oil and Gas Industry before making a career change to work in the Aerospace Industry. She currently works for Boeing developing and deploying Model Based Systems Engineering tools and processes with the Boeing Enterprise (Commercial and Defense).

Robert Malone has spent his entire thirty-five year career as an aerospace engineer and has specialized in systems engineering for the past twenty-six years. He has held positions in aircraft maintenance operations, aviation security system integration, human factors, reliability, maintainability and testability. His current focus is on developing computer-based tools and processes supporting systems engineering, large scale system integration, and system integration modeling.

John Herrold is currently the System Architect for the Integrated Product Architecture enterprise systems engineering program that provides a service ready model based systems engineering solution (process, tool and training) for systems and design engineers. John has been a Boeing employee for 35 years and has worked mostly in the engineering analysis domain, supporting many of the Boeing Commercial and Military Airplane products. John is a designated Boeing Technical Lead Engineer and a member of the International Council on Systems Engineering (INCOSE). John has a BSEE from the University of Washington.