Adopting MBSE at Kongsberg Defence & Aerospace – Joint Strike Missile project

June 9th 2015

Svein-Erik Soegaard
Kongsberg Defence & Aerospace

MBSE using SysML

Adopting MBSE in the Joint Strike Missile (JSM)

Svein-Erik Soegaard

Kongsberg Defence and Aerospace

KONGSBERG

About Presenter

- Svein Erik Søgård, MSc
  - Principal Engineer, Missile Systems

- Engaged since 1995 at the Missile Division in Kongsberg Defence & Aerospace (KDA)
- Background from SW development, system integration and test in NSM (Naval Strike Missile)
- Current work (since 2010) : System Architect in JSM and responsible for adopting MBSE using SysML

Joint Strike Missile (JSM)

- Next Generation Cruise Missile from Kongsberg Defence and Aerospace
  - Based on technology from current generation Naval Strike Missile (NSM)
- To be integrated on the F-35 Joint Strike Fighter (block 4)
- Contracts with the Royal Norwegian Air Force (development) and Lockheed Martin (aircraft integration)

2009 start of development

2015 first test F-16 platform

2018 verified

2020 deployed

JSM – some key characteristics

- Many different technologies to be integrated (multi disciplinary):
  - Passive Infrared Imaging Target Seeker
  - multi-sensor Navigation System
  - Jet Engine and bank-to-turn flight control
  - In-flight radio communication (Weapon Data Link)
  - on-board Flight Route Planning based on situation awareness
  - programmable Fuze/Warhead
  - Multicore Computing Platform
  - ……
- SW intensive
  - >60% of the system requirements affects SW
- >30 years product lifecycle, mid life updates

How do we manage this?

Continuing going document based?

MBSE in the JSM Project – Initial objectives

KONGSBERG

- Establish System Architecture Model (SAM) – “The Big Picture”
  - Consistent model ensuring successful functional/logical integration of discipline components
  - fulfil system requirements by tracing
  - Navigation ONLY through diagrams to READ information
    - Both structural drill-down and between views
  - Information available outside tool -> publishing to web and some type of docs (Requirement Specs)
  - Linking related/detailed information (docs, other models etc) scoped by the nodes in the system architecture
- Life cycle focus – System Architecture understandable for maintenance, mid-life update, new product variants

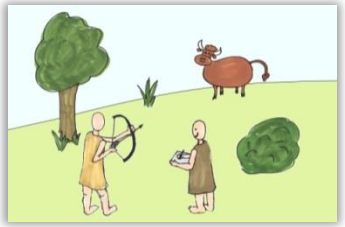
JSM Modeling scope

KONGSBERG

Define customer needs

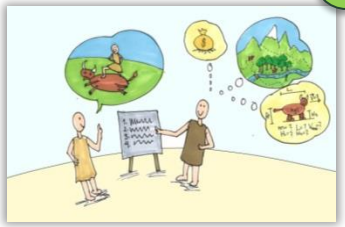
Validation

Validate system



Customer requirements, operational concepts and JSM System Requirements in DOORS

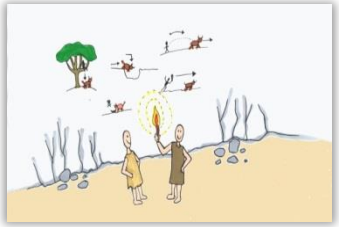
Analyse requirements



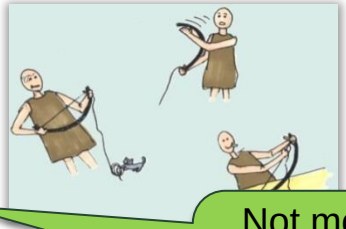
Verification

Verify system

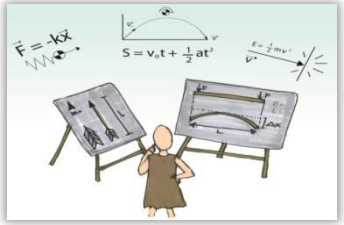
Define concept & behaviour



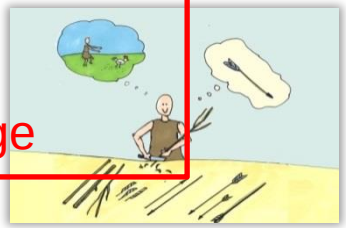
Integrate



Identify sub functions



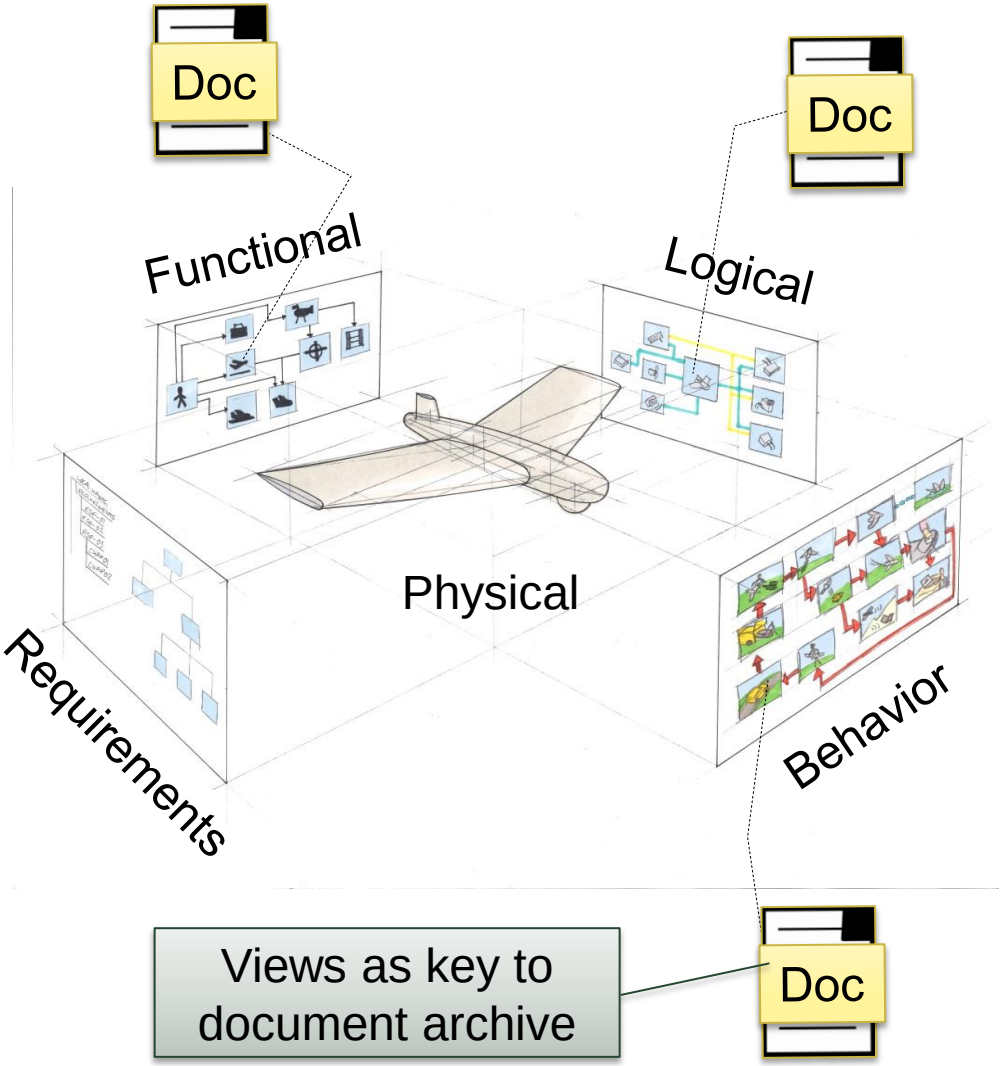
Implement



Not modeling alternative concepts and analysis in SysML, done in separate tools

Establish SAM - Focus in first stage

System Architecture Framework - Views



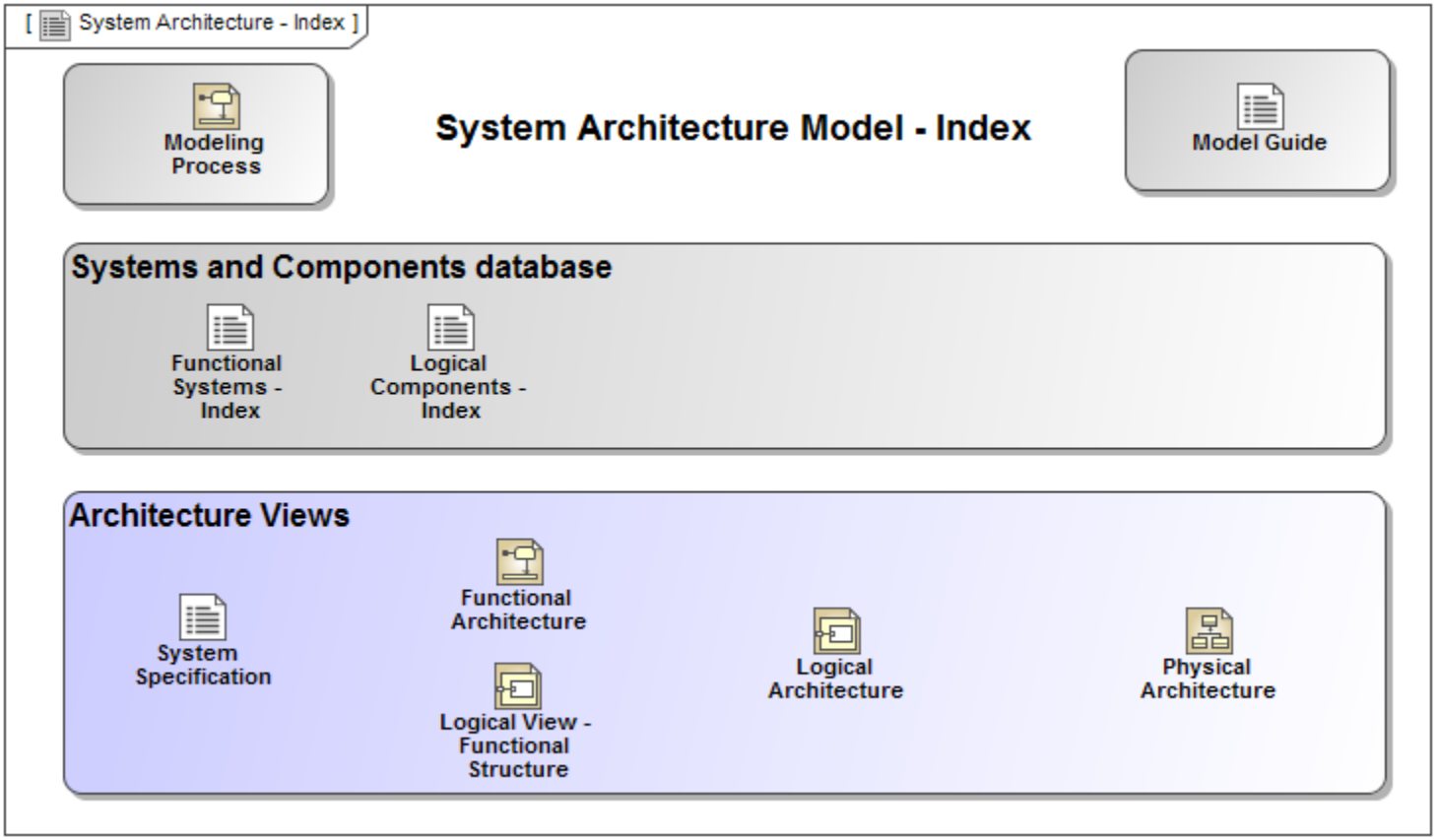
Specification
- WHAT shall the system do?
- Context/interfaces
- Requirements and Behavior

Design
- Functional
  - Given concept, HOW shall the system work?
  - Activity Diagrams with dataflow
- Logical
  - Given functional design, HOW shall the system be constructed?
  - Interfaces
  - Block Diagrams
  - Sequence Diagrams
- Physical
  - Mechanical design, 3D DMU in Catia®
  - HOW is the product assembled (MBOM)?

KDA Missile Reference Model

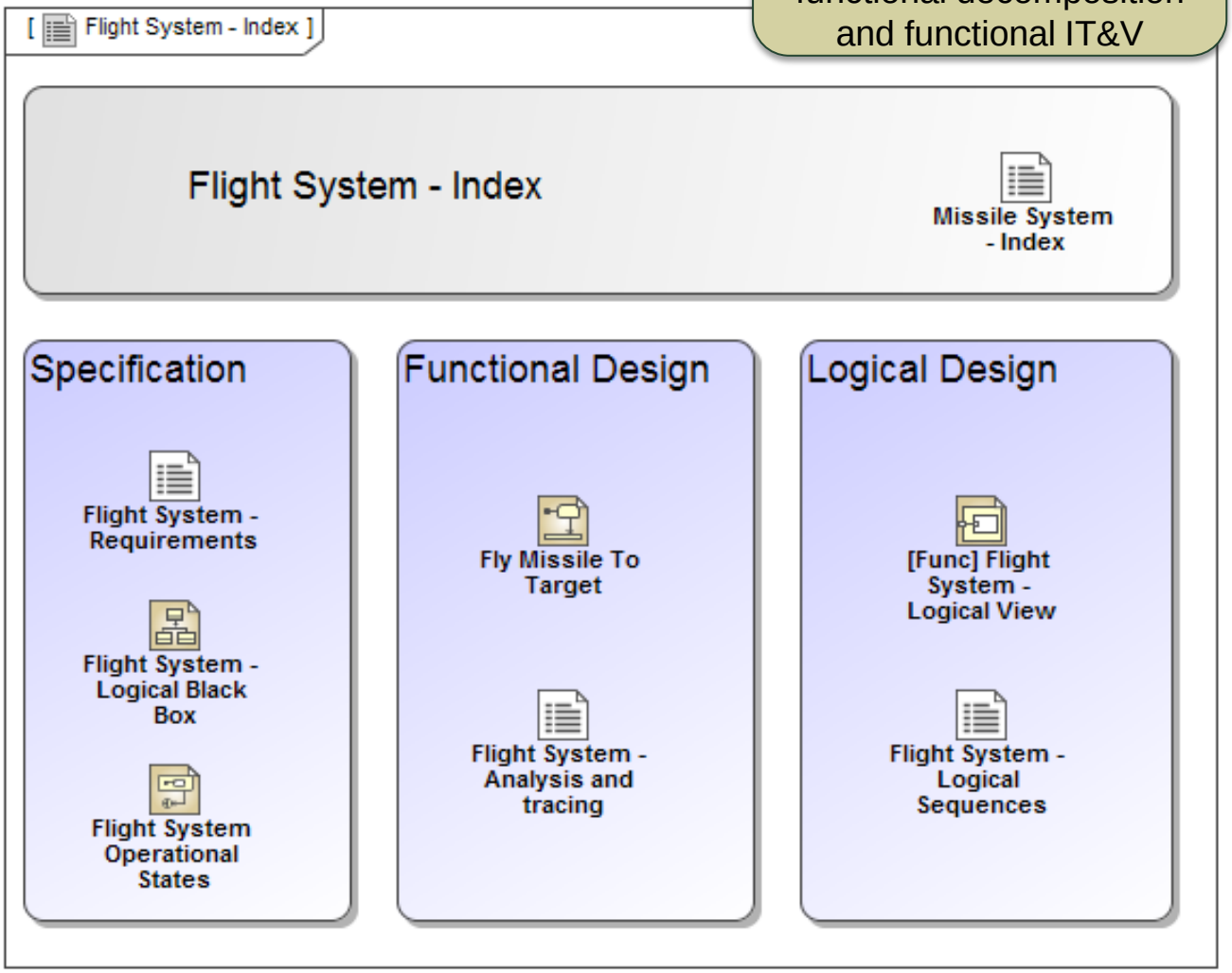
- Developed reference model – «KDA Missile Reference Model»
  - Stripped down unclassified version of JSM product
- Purposes
  - Define how we shall organize the model, define the Architecture Framework
  - Define which subset of SysML that should be used for which view
  - Cover all modeling aspects/principles in the real product
  - Basis for training and presentations
  - Basis for developing customizations (validation rules, plugins etc)
- Evolved in parallel with product development

Navigable model: Top –level index

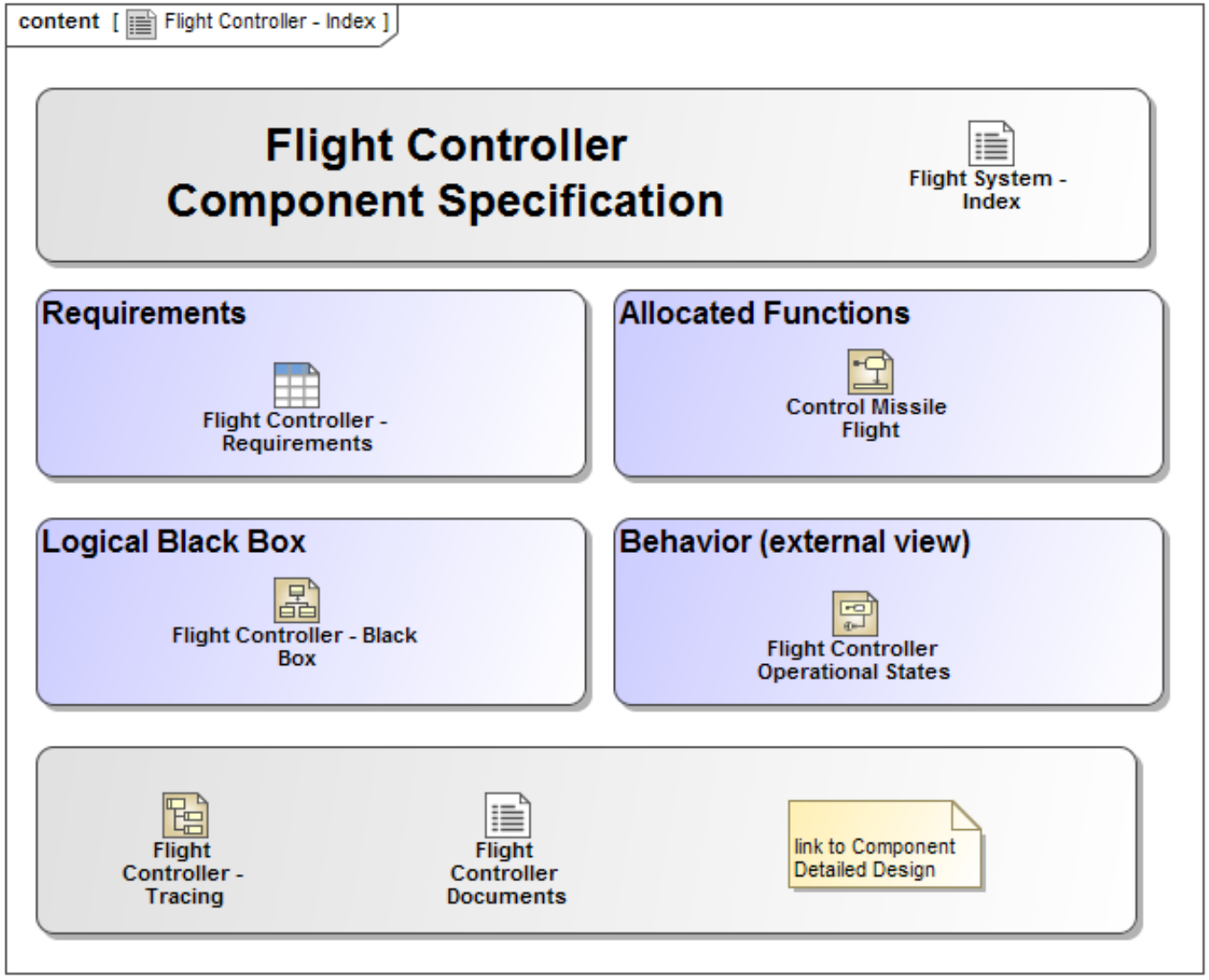


Functional System - index

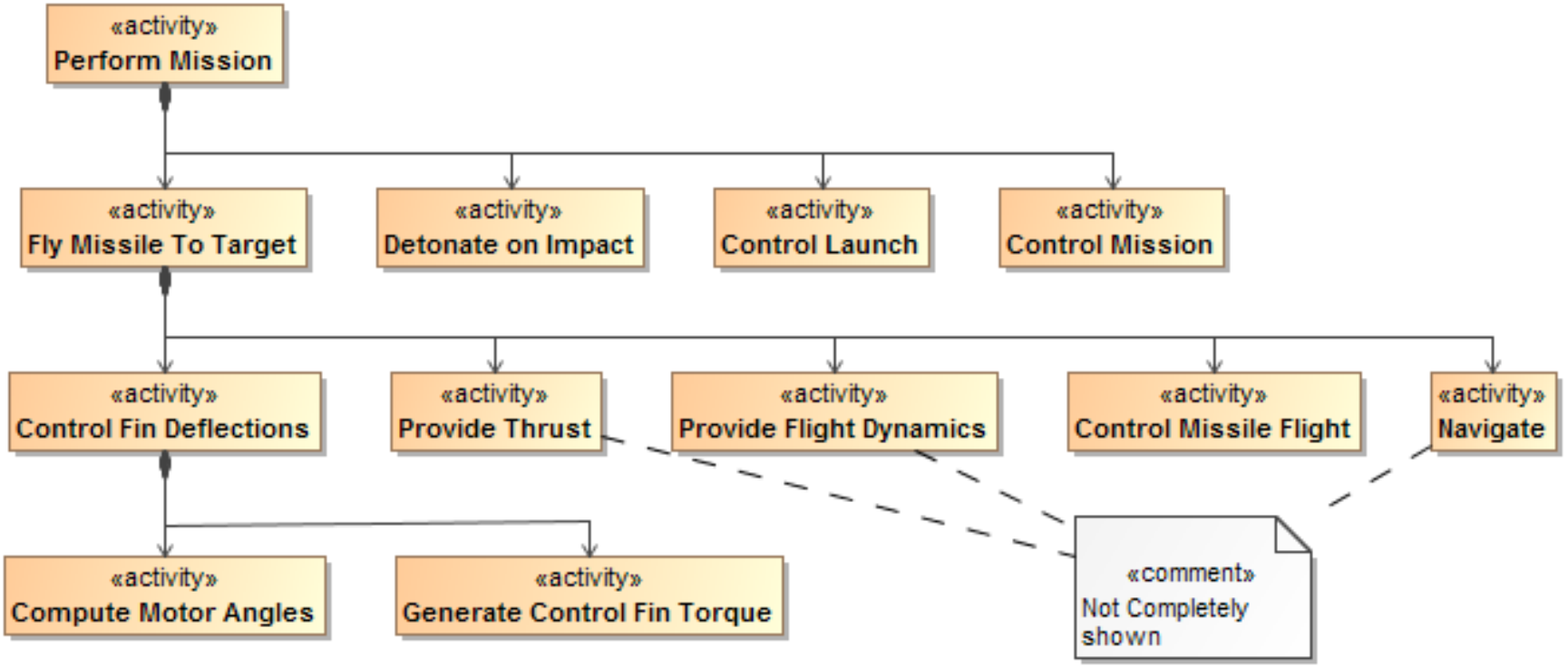
Functional System:
Manage complexity,
context for further
functional decomposition
and functional IT&V



Component Index

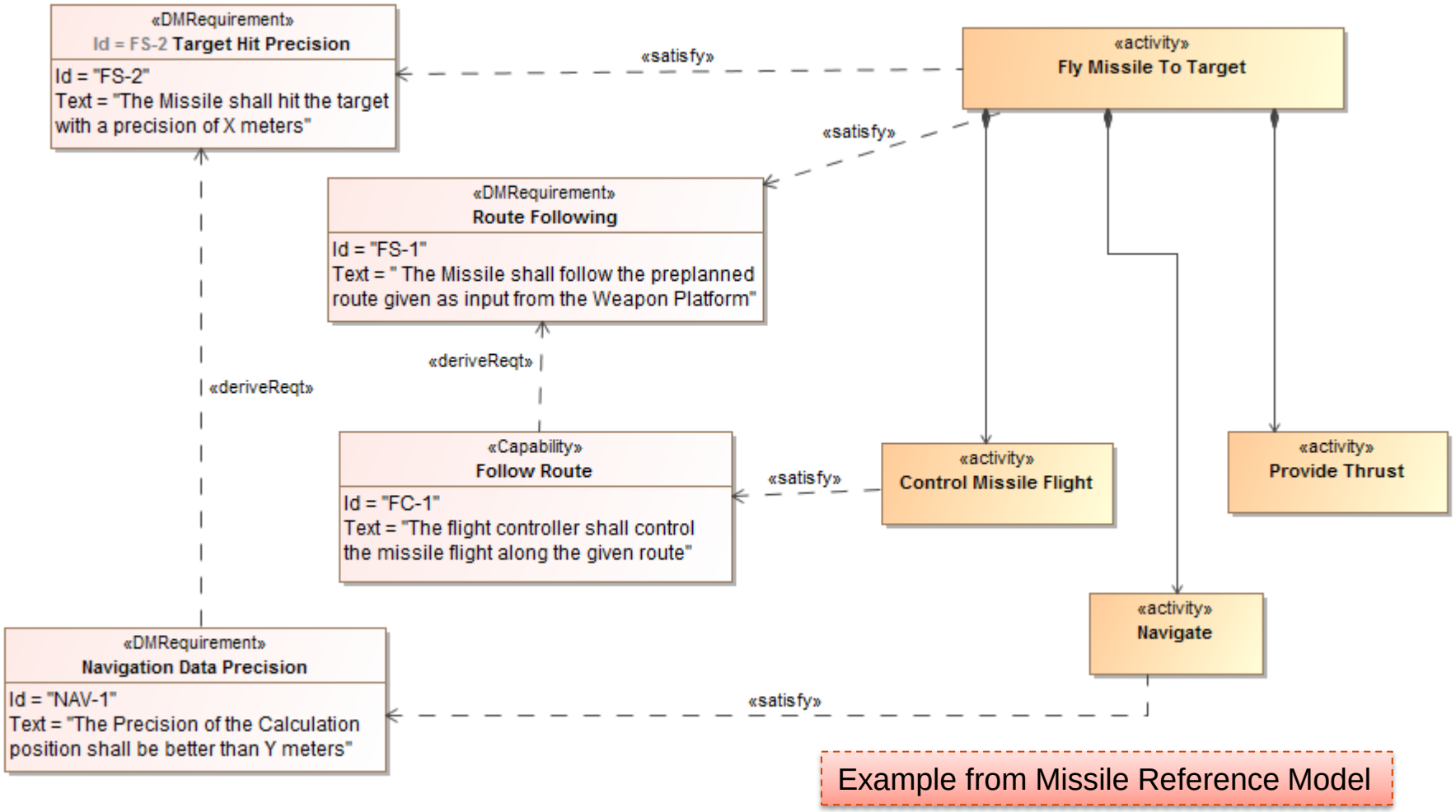


Functional Architecture



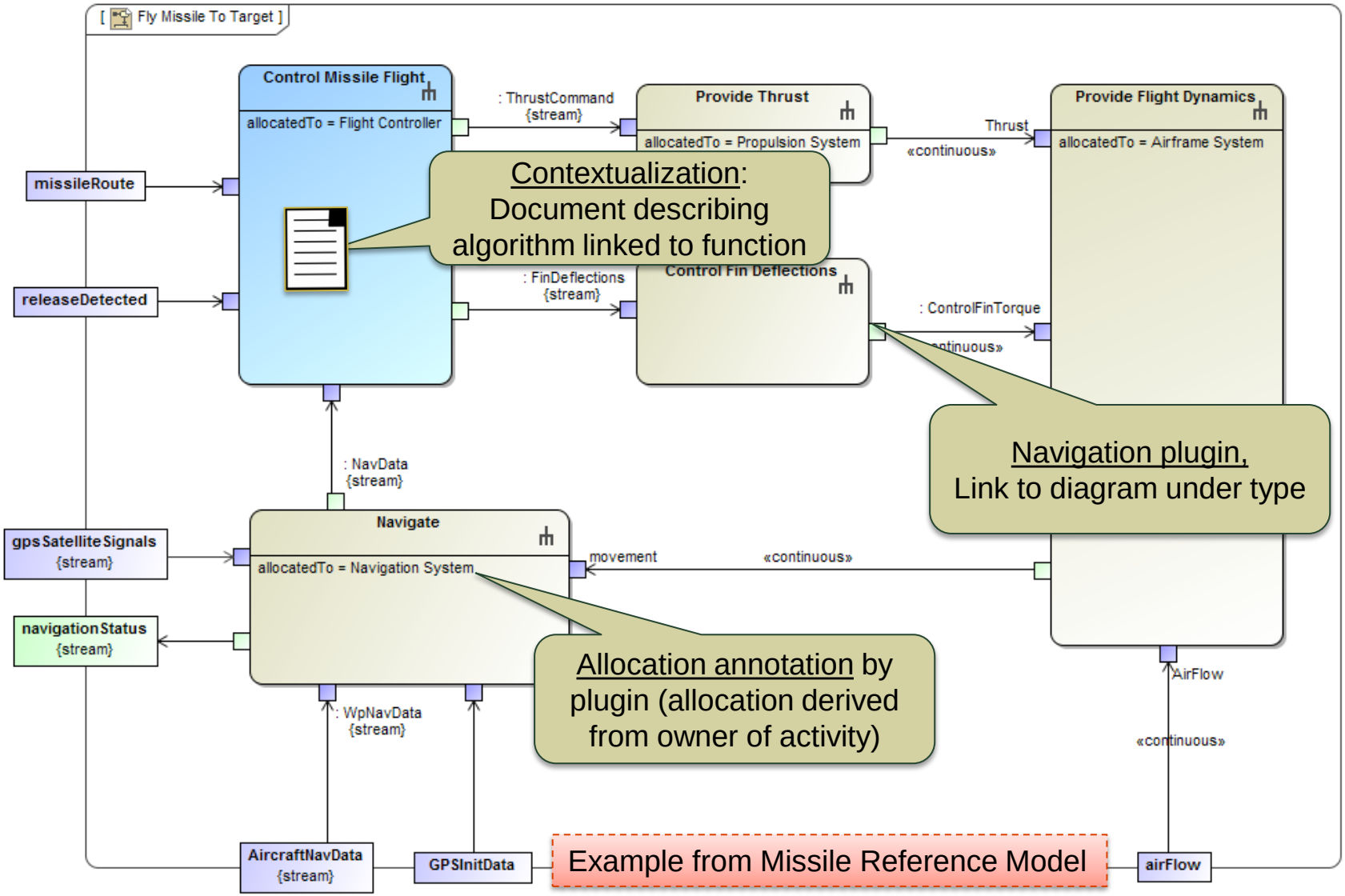
Example from Missile Reference Model

Requirements

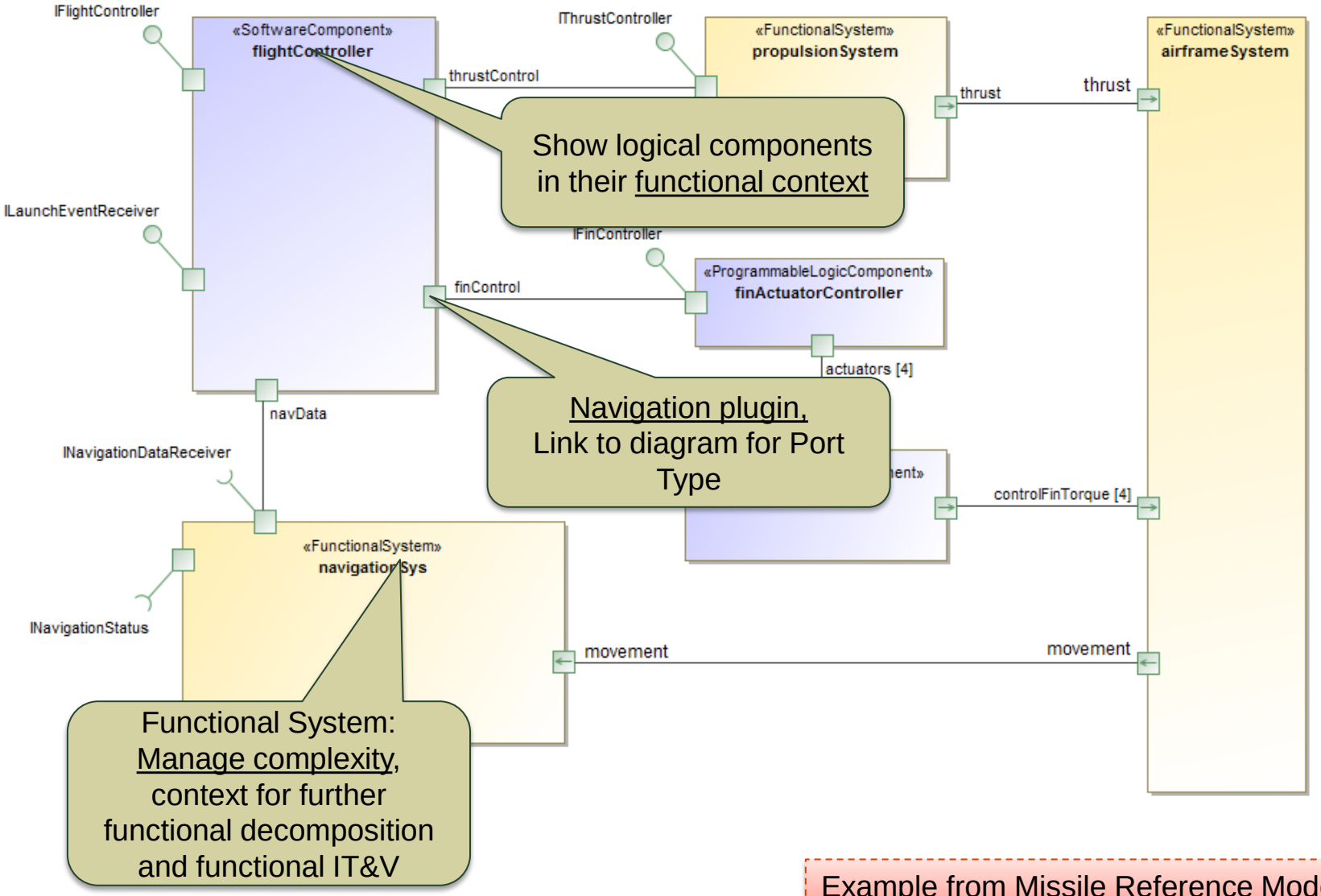


Example from Missile Reference Model

Functional view

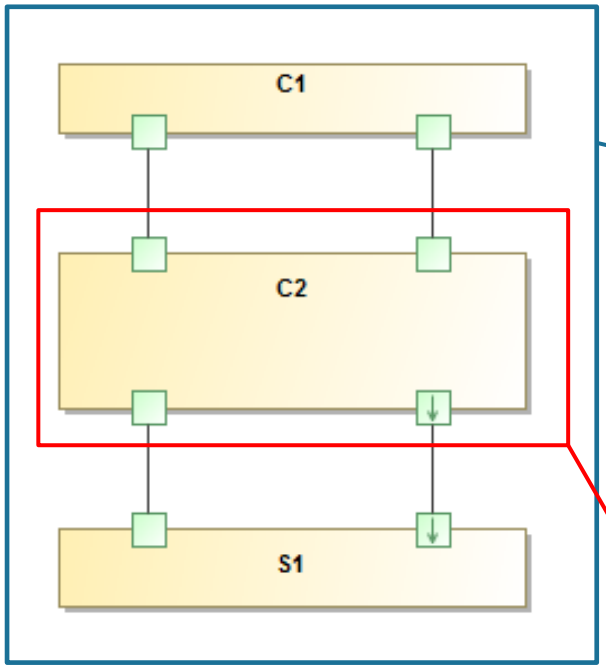


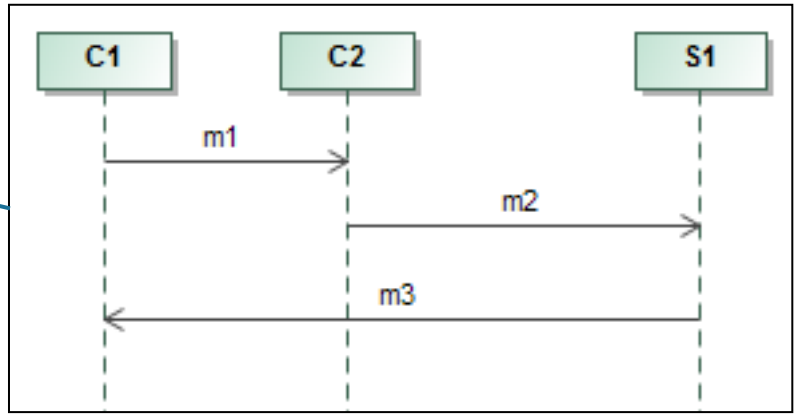
Logical design view - Functional Structure

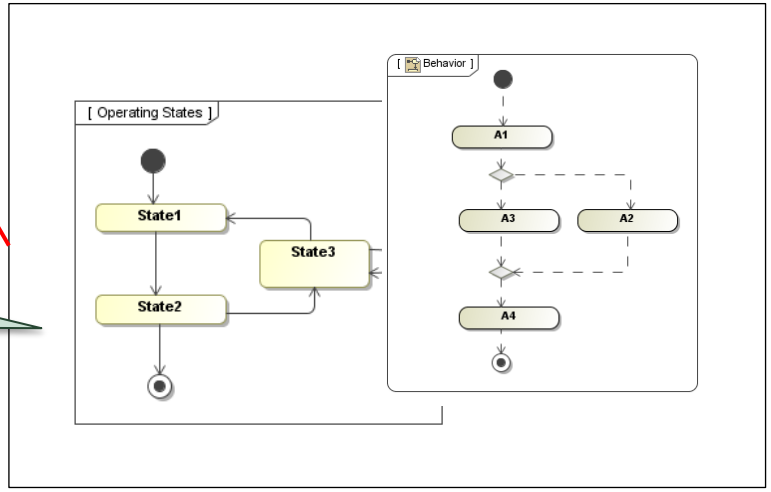


Example from Missile Reference Model.

Defining Behavior

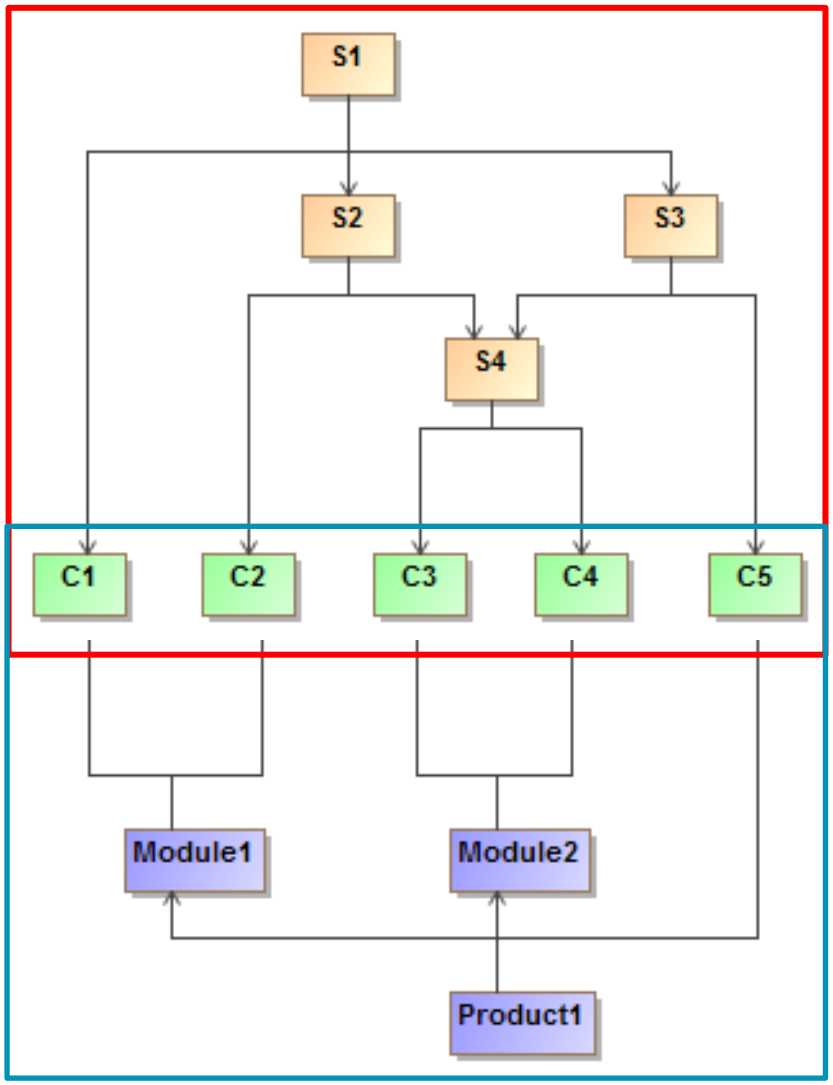






State and Activity Diagrams shows external visible behavior for System and Components

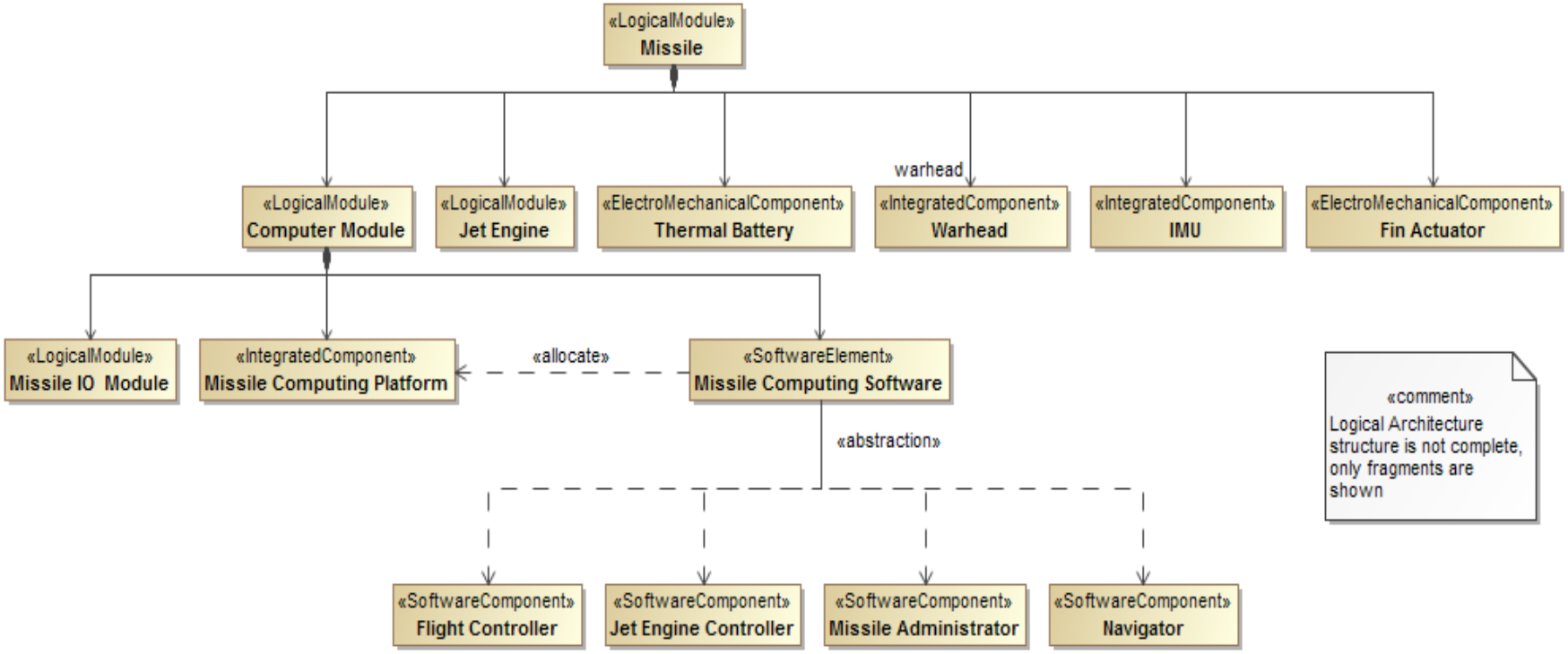
Logical Architecture



- Functional Systems
  - Functional breakdown
  - Requirement development and tracing
  - Logical view
- Component Specifications
  - Information interfaces
  - Allocated Requirements
  - Allocated Functions
  - Behavior

- Logical Architecture
  - Realization oriented
  - Modules integrating components to a product
  - Modules have block diagrams for different layers: information, protocol, electrical, cabling
  - Design constraints and Physical Requirements

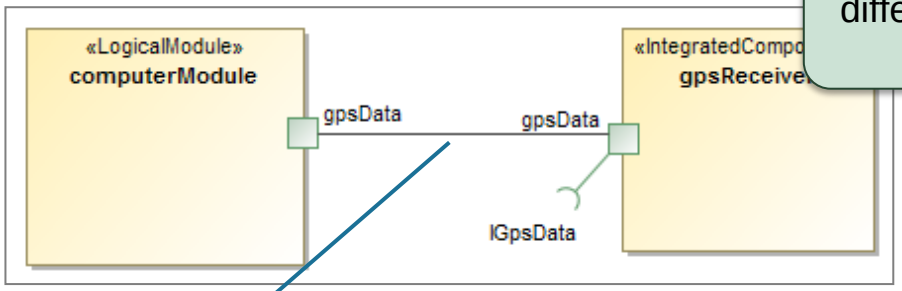
Missile – Logical architecture structure



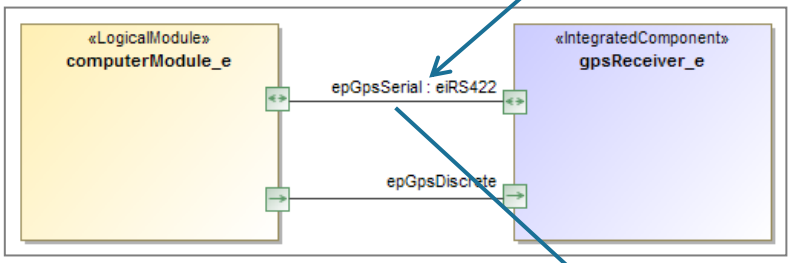
Example from Missile Reference Model.

Logical Architecture – layers

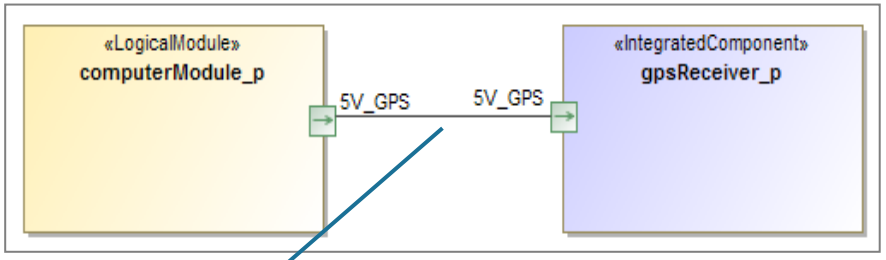
Logical modules may have different layers depending on technology



Information view

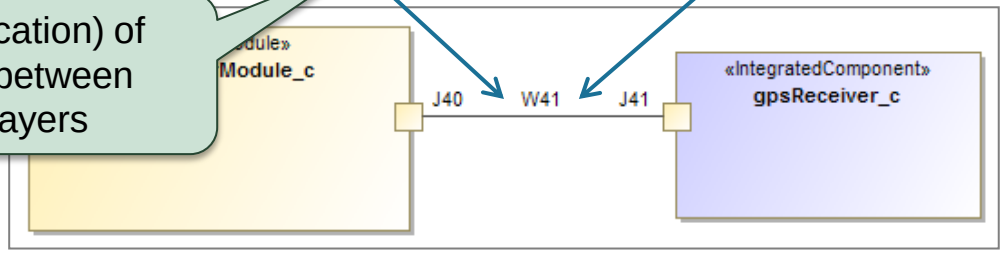


Electrical Signal view



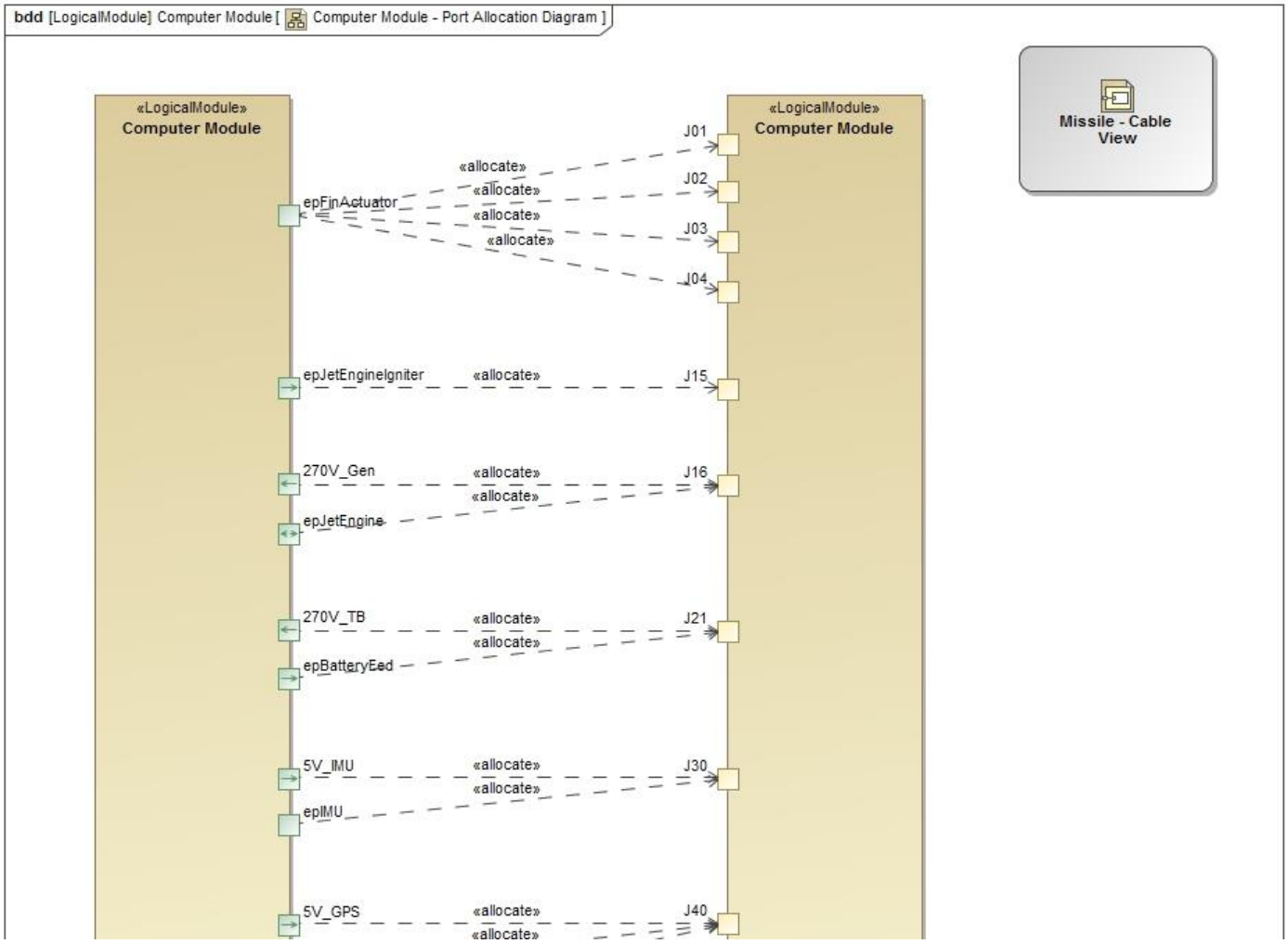
Power distribution view

Tracing (allocation) of connectors between different layers



Cabling view

Logical Architecture (Realization)
Port Allocation



Example from Missile Reference Model

From System Design to Software Design

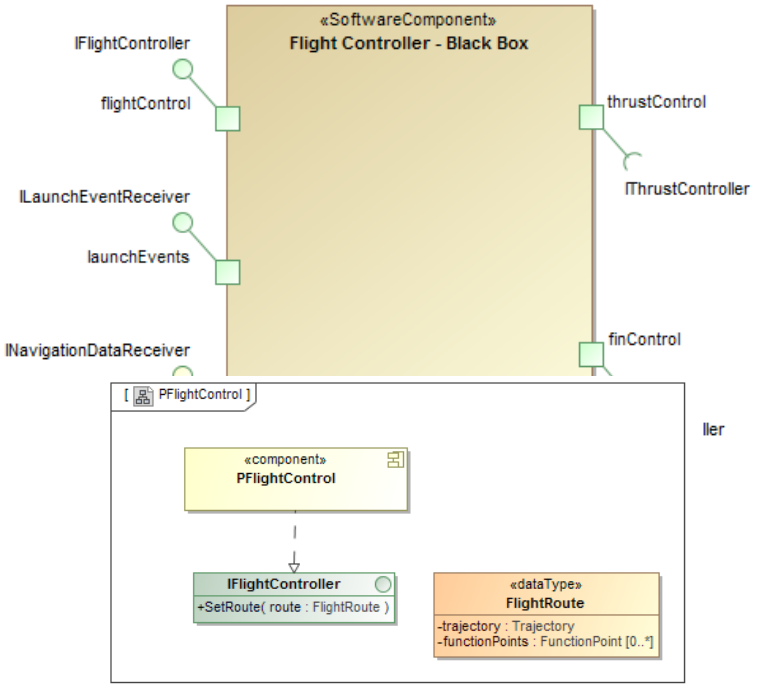
KONGSBERG

SW Component Specification – Flight Controller

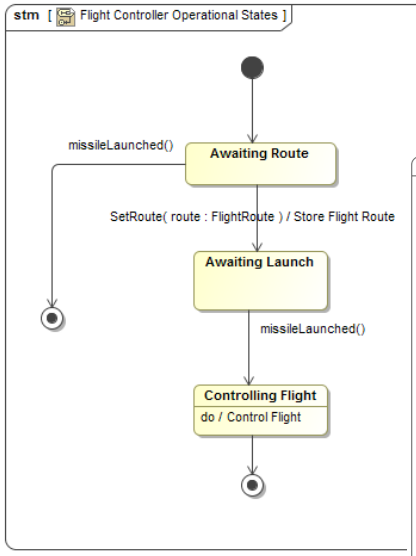
Requirements

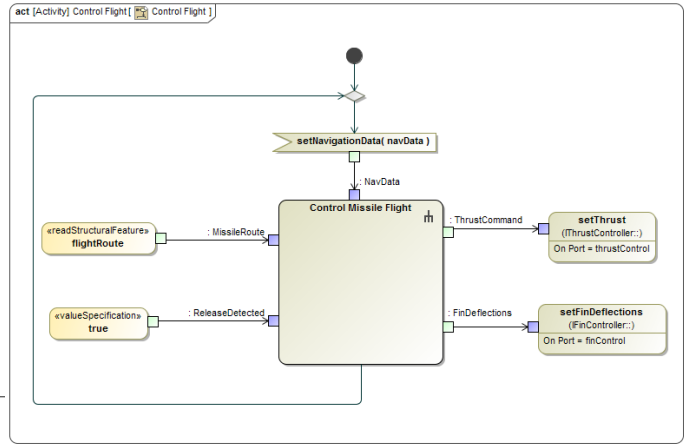
#	Id	Name	Text	Derived From
1	FC-1	Follow Route	The flight controller shall control the missile flight along the given route	Route Following
2	FC-1.1	Route Following Precision	The Precision of the Route following shall be better than Z meters	Target Hit Precision

Black – Box (Ports/Interfaces)



Behavior (states, activitites)



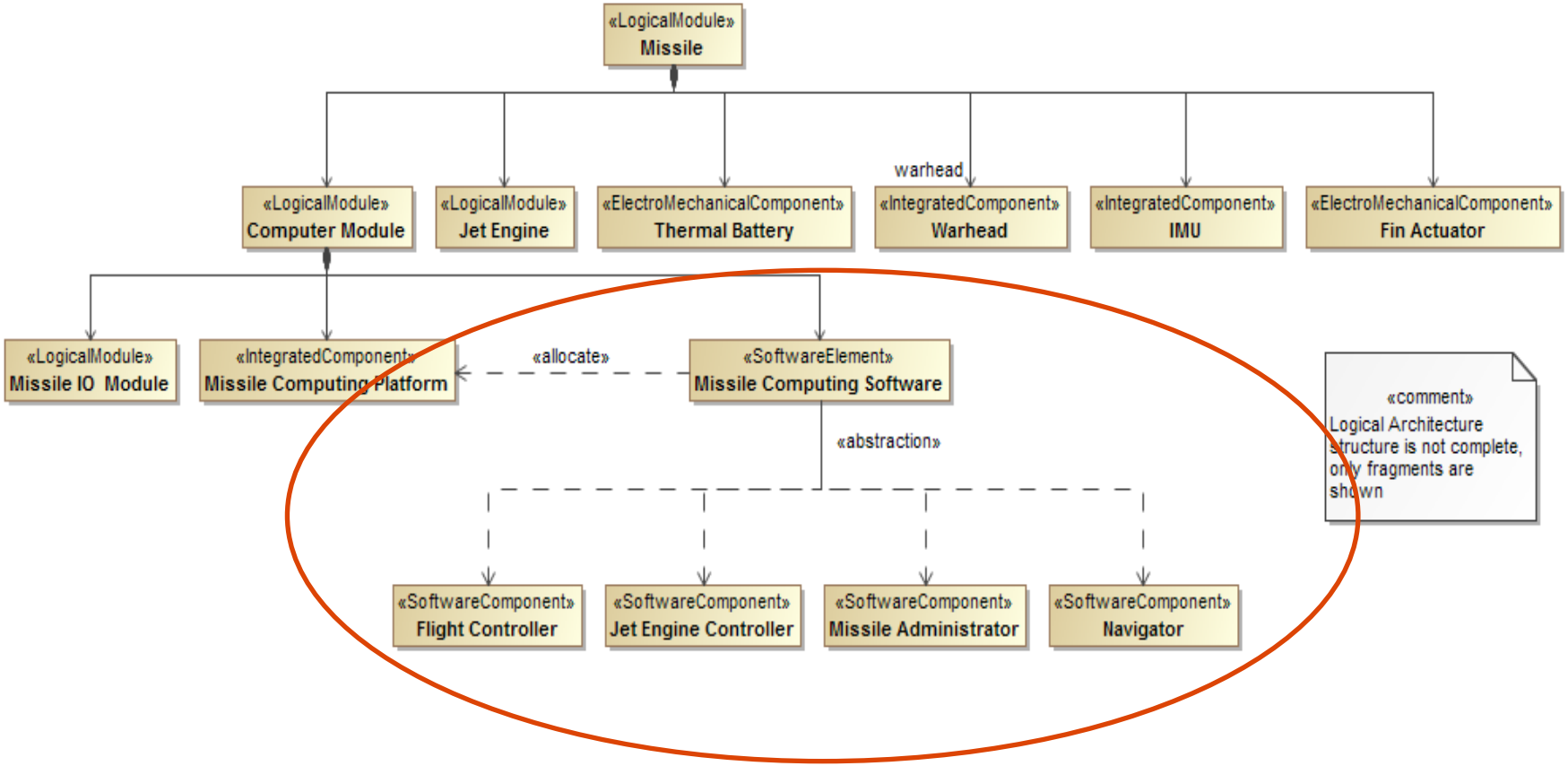


Documents (A3s, algoritms, models etc..)

Linked Non-SysML Information

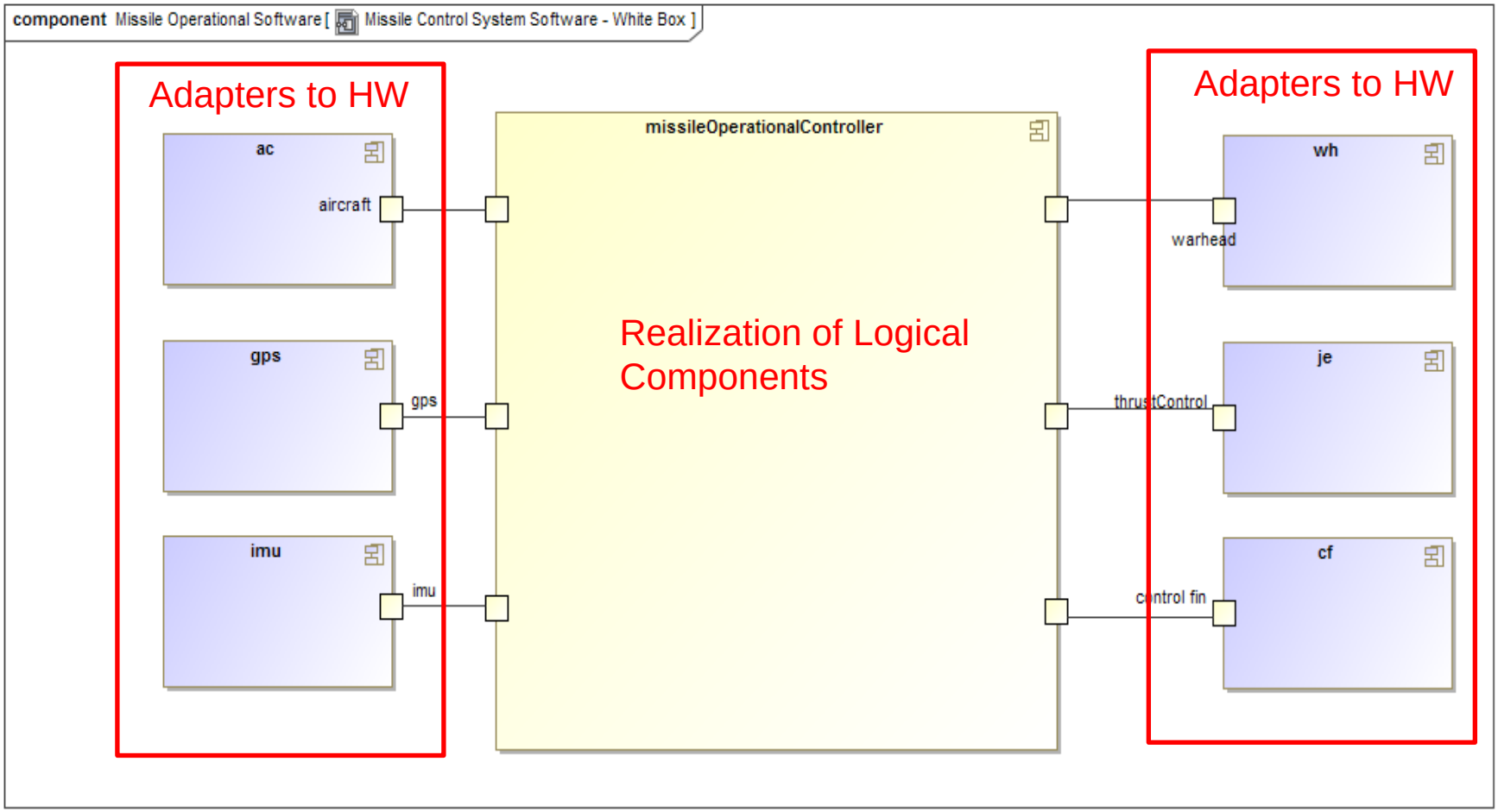
Example from Missile Reference Model

Missile – Logical architecture structure



Example from Missile Reference Model

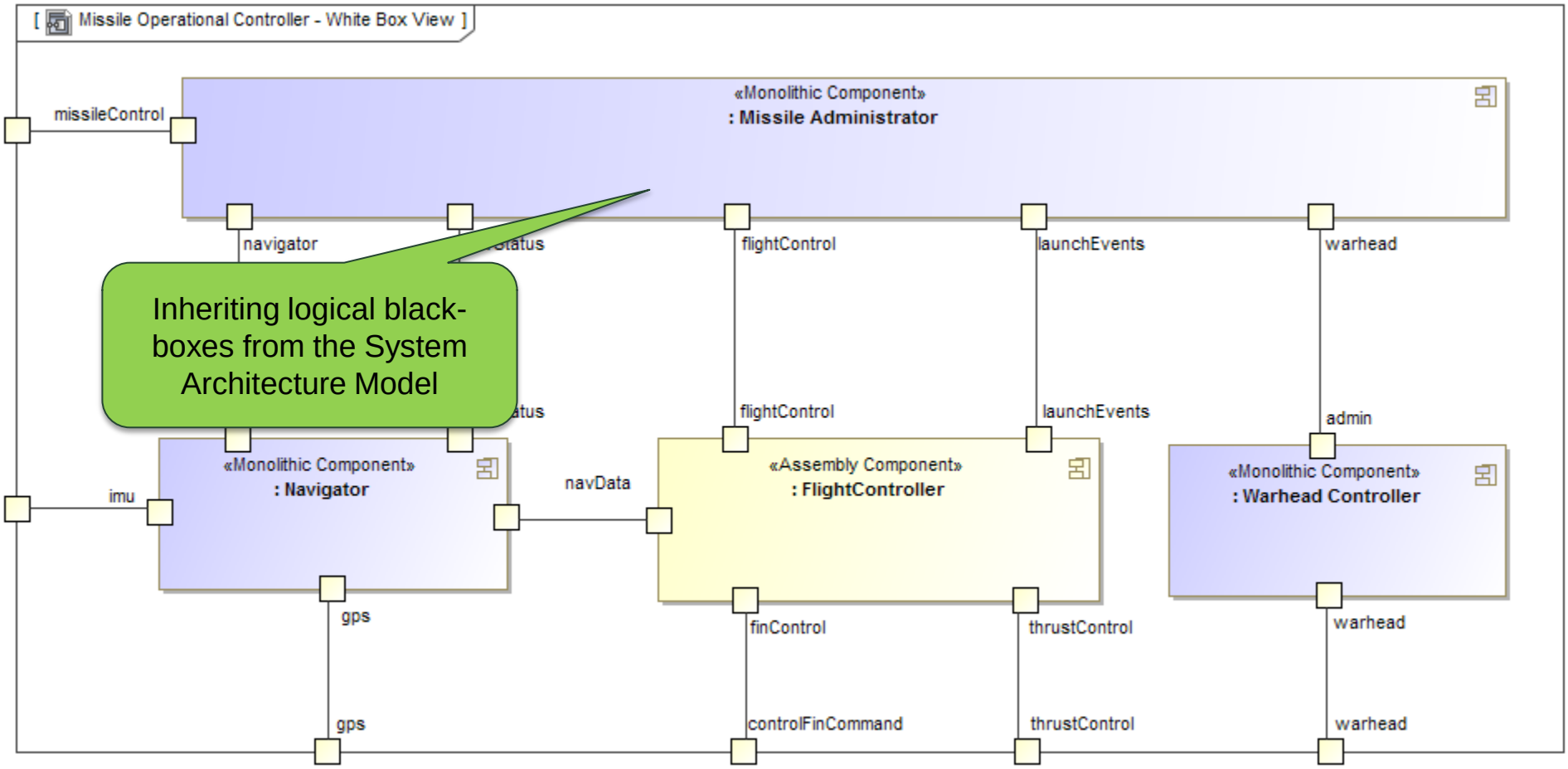
Software Logical Architecture



Example from Missile Reference Model

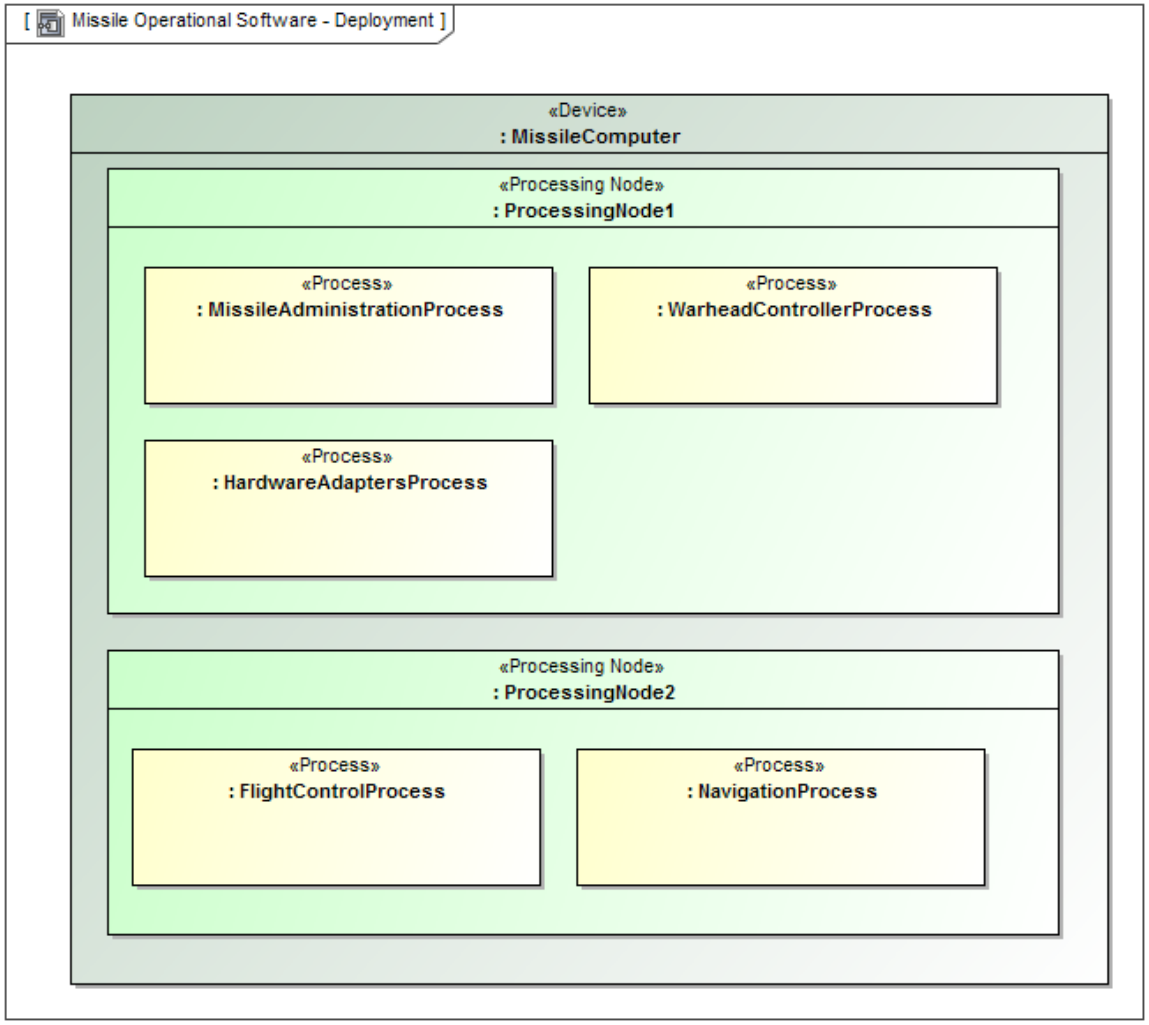
Software Logical Architecture

KONGSBERG



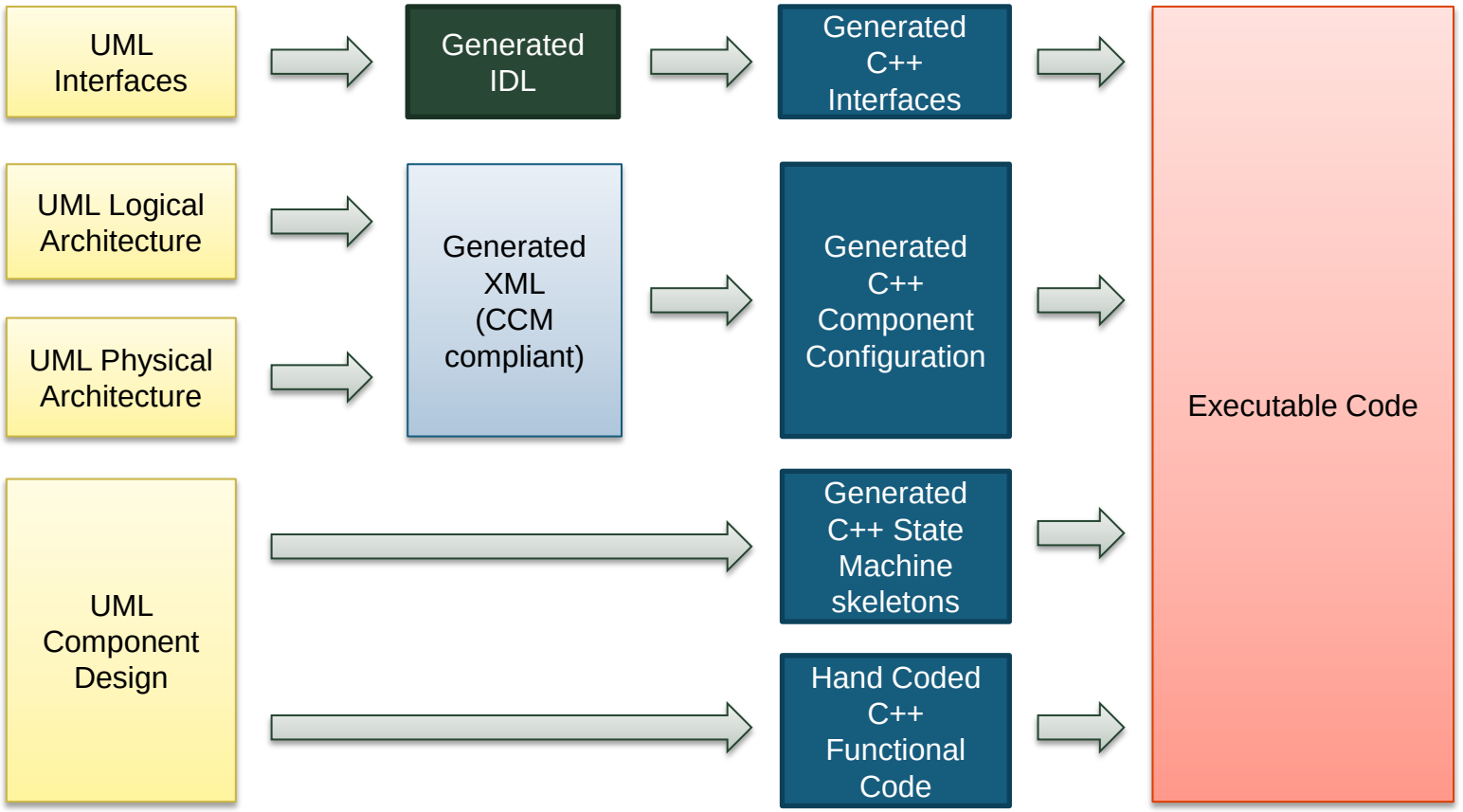
Example from Missile Reference Model

Software Physical Architecture



Example from Missile Reference Model

Software: Code generation from model



Summary (System to SW)

KONGSBERG

- Smooth and consistent transition to SW design
  - Inheriting Component black boxes with ports/Interface
    - Chosen UML interfaces for information interfaces at sysML
  - Tracing to other model elements (requirements, state machines, activities)
- Challenges
  - Requires frequent iterations between system and SW
  - Where is the border between System and SW?
    - Ground rule: Define course grained SW components at system level, one component for a function that plays a role in its functional system

Lessons learned

Experiences and recommendations

KONGSBERG

Experiences and Recommendations #1

KONGSBERG

- Adopting a MBSE solution is a long journey
  - It's about learning new methodology, new architecture framework and a new language/tool in parallel
    - In JSM it took several years to get the Architecture Framework mature
      - 10 Workshops and trainings (2-3 days), extensive mentoring
      - MBSE test bed – tested in student project
    - Many people are in general not motivated to spend much time on learning tools, MagicDraw is not a tool for everyone
  - Invest in training and mentoring, Establish core team(s) and mentor(s)
- Keeping the model update and consistent is mandatory
  - Do not put too much details into the model
  - Throw away duplicated/obsoleted information
  - (sub)Model ownership mandatory
- SysML very expressive and powerful, but complex
  - Define a language subset and a strict guideline to develop large models -> Establish a reference model expressing which subset of sysML to use for which purpose

Experiences and Recommendations #2

KONGSBERG

- Systems Engineering terminology is overloaded
  - Functional versus logical versus physical? What is a system?
  - Clear terminology is essential in communicating the model -> define!
  - Communicate terminology with examples
- Complex System Models require well managed abstractions
  - abstractions are not popular at the first glance for many
    - «abstractions hiding the details that is important»
    - «the information become fragmented by applying separate views»
  - Framework and abstractions need to be teached frequently
- It is a challenge to develop methodology and guidelines in parallel with product development
  - Start small: Establish methodology and Architecture Framework on pilot projects or small products/small parts of a product
  - Documenting existing products components – good way to learn and establish methodology & framework, «sandwich» process – meet in the middle
  - Roll out stuff that works!

The recipe for success [1)]

think **BIG**

start **SMALL**

and **EVOLVE**

1) From presentation by Darius Silingas, No Magic

Is MBSE in JSM a success story?

KONGSBERG

We have made a good foundation

- Established SAM expressing R,F, L and P of the JSM
  - > 25 systems, > 80 components, > 4000 diagrams
  - 20-30 persons contributed to modeling the SAM (R,F,L)
- Precise specifications for component development, especially for SW
  - Smooth transition to SW component design
  - Generating code for interfaces defined in SAM
- Commitment from Management

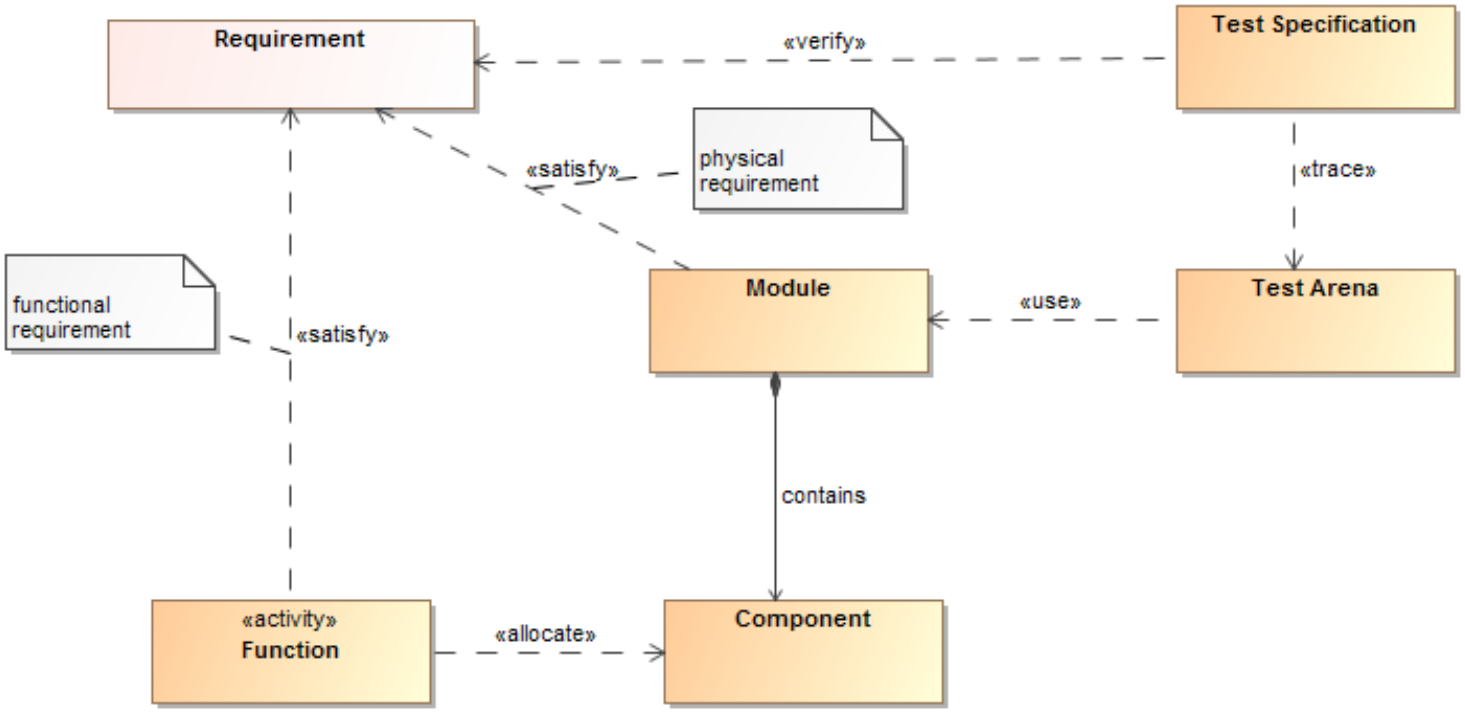
Success so far! But we still need to improve and evolve…..

- Integration, test and verification of the next JSM product increments must be successful
- «everyone» has to understand the model
- new employees should efficiently maintain the product
- model (elements) should be reused from JSM in other product variants
- the modeling culture must be sustainable

Next steps for KDA

KONGSBERG

Test and verification



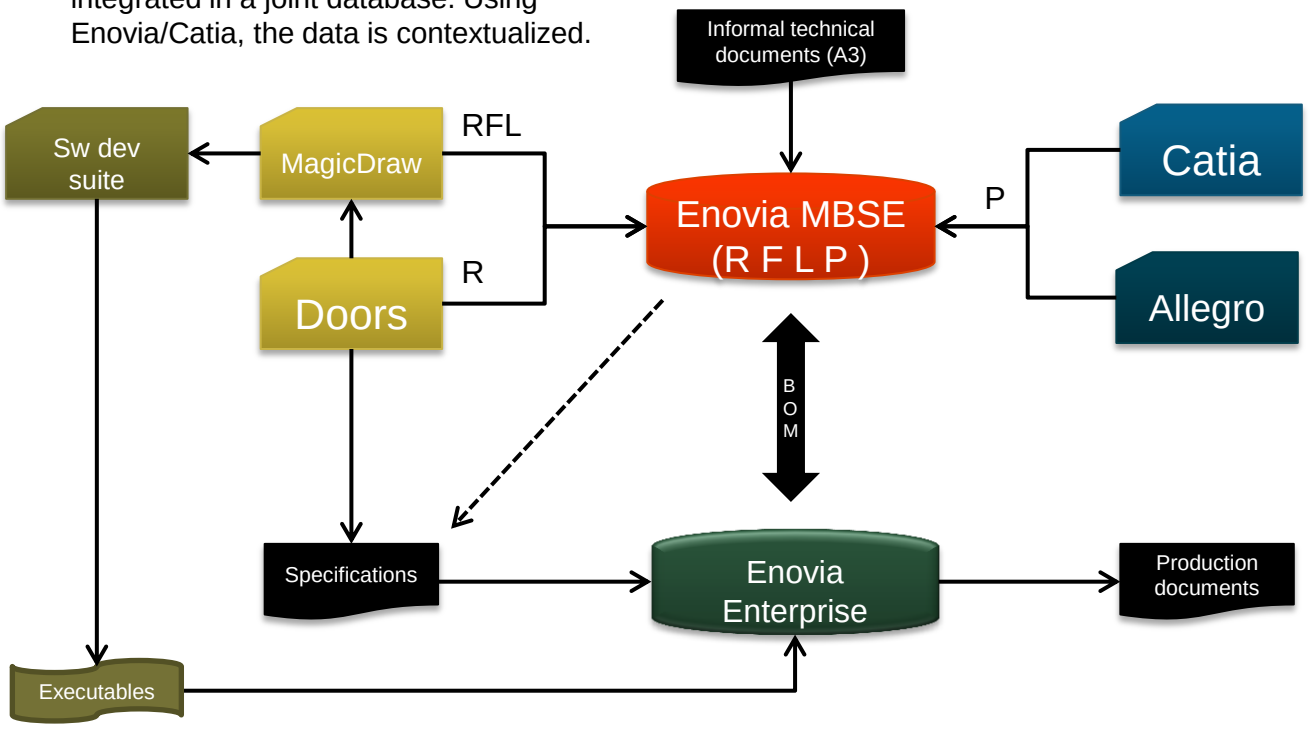
- Add more requirements/capabilities for test and verification
  - «extracted» from functional design and behavior
  - Hooks for test and verification
- Define Test Specifications/Test Cases

Future state of KDA Integrated Development Platform:

- Multi-disciplinary process
- Cross-disciplinary platform
- Model-based knowledge management

Data originating from multiple sources are integrated in a joint database. Using Enovia/Catia, the data is contextualized.

Knowledge is related to the system element(s) to which it refers



R = Requirements
F = Functional
L = Logical
P = Physical

Questions?

- What is the best way to communcate the SysML models?
  - Easy navigable model?
    - Structural drill down, navigation between views
  - Generating viewpoints/documents?
    - Internal/external users
  - Other?