

Model-Based Systems Engineering #1

ENSTA
CSC_5R008_TA
2024-2025

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Chiffres clés 2023



81 000
collaborateurs



68 pays
Une présence
mondiale



4 Mds €*

*Dont 1,1 Md € de
R&D autofinancée



18,4 Mds €
de chiffre
d'affaires

Aérospatial



2 millions

de passagers utilisent chaque jour les systèmes de multimédia de bord de Thales.

Thales Alenia Space fournit

50% du volume pressurisé de la **Station Spatiale Internationale**.



2/3 des avions

dans le monde décollent et atterrissent grâce à des équipements Thales.



Grâce à des projets tels que **FlyIX**, Thales développe des **solutions d'optimisation des trajectoires de vol** afin de **réduire de 10 % les émissions de CO₂** des avions.





+800 000
radios tactiques
Thales sont en
service dans **plus de**
50 pays.

+50 pays
protègent leur
population et leur
territoire grâce
aux équipements
Thales.



Les systèmes et
équipements Thales
représentent près de
25% de la valeur
totale de l'avion de
combat **Rafale**.



Thales déploie des solutions pour le **combat**
collaboratif permettant d'augmenter l'efficacité des
soldats, des véhicules et des capteurs en temps réel.

Cyber et Digital



+30 000

organisations utilisent nos technologies de gestion des identités et de protection des données.

5 milliards

de dollars de transferts de fonds interbancaires sécurisés par jour.



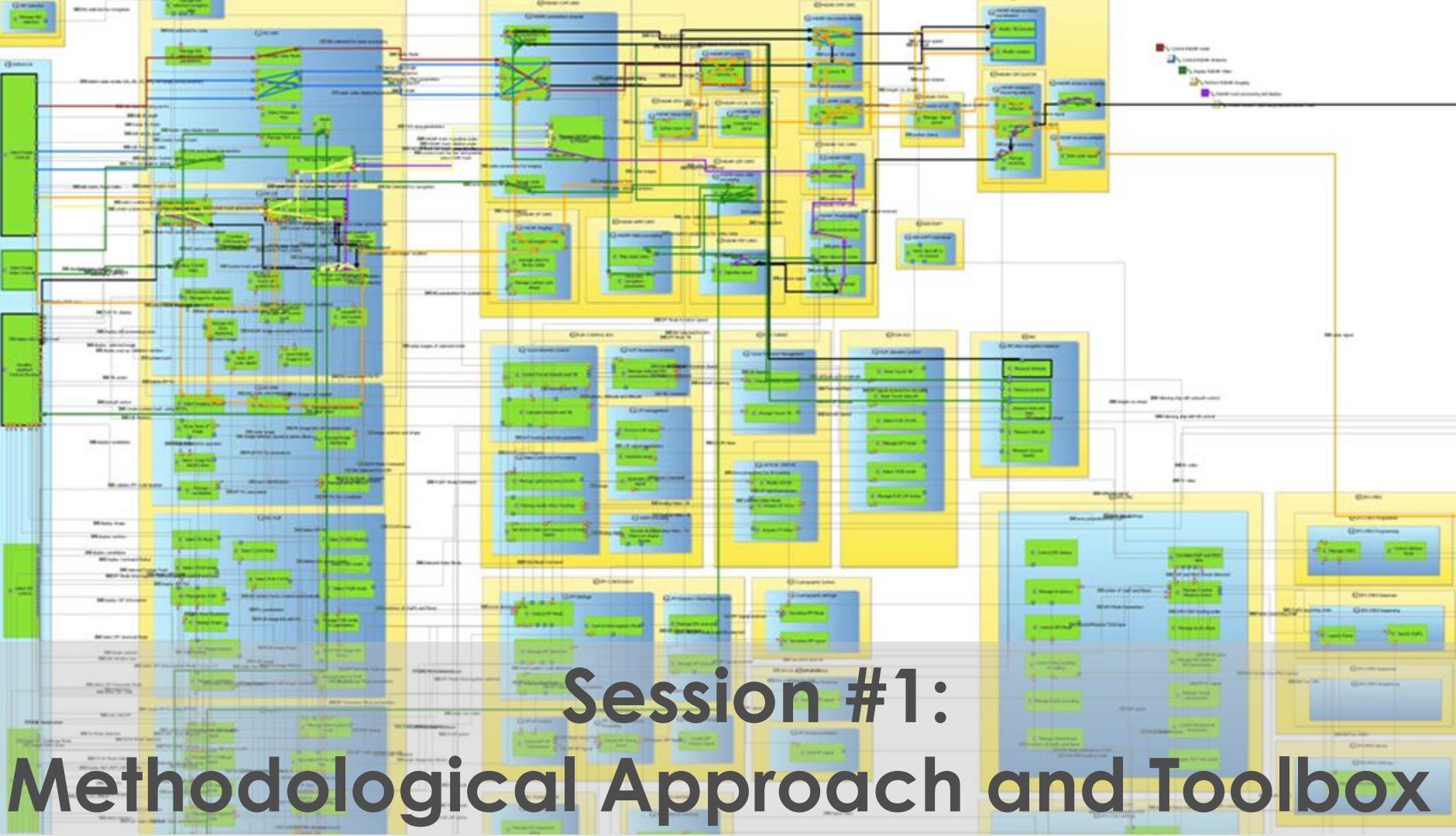
+300

programmes gouvernementaux déployés pour l'identité régaliennes, la biométrie et les forces de l'ordre.

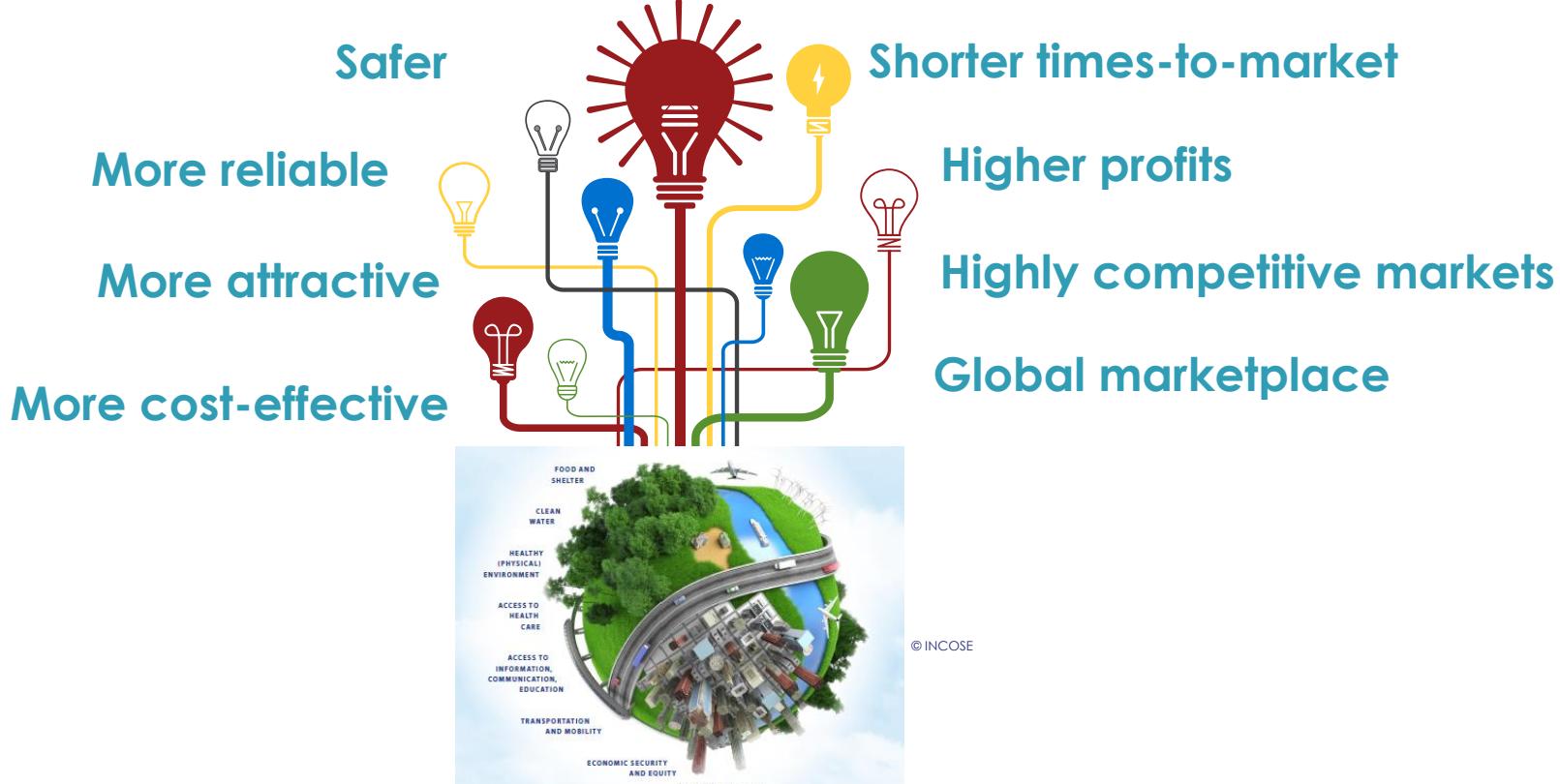


Avec l'**acquisition d'Imperva**, Thales entre dans le **top 5 mondial** des acteurs de la **cybersécurité** et confirme son ambition de devenir un **leader** dans ce domaine.





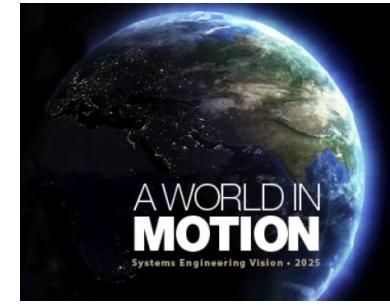
System Engineering Challenges



A too familiar picture in all sectors...

A changing world...full of opportunities

- > New players – customers, providers, competitors
- > Market growth spread world-wide
- > Emerging societal needs & constraints
- > Accelerated evolution of technology



Key challenge: How to deliver the **appropriate systems** or services in this context, with ever **shorter times-to-market** and at **competitive costs**?

Model-based System & Architecture Engineering:

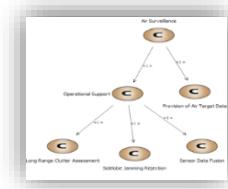
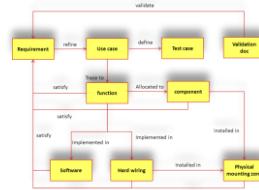
- Arcadia Method
- Capella Workbench

Model-Based System Engineering

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| Formalized application of modelling techniques to support the engineering activities, using a combination of static, dynamic and executable models

- Develop consistent operational, functional and physical architectures
- Perform analysis and support optimization, trade-off studies, and then Integration, Verification and Validation (IVV)



| A shift in the nature of representation of systems

- Prose forms ➔ Explicit, theoretically unambiguous (if not formal) data structures and representations



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| Improvements in quality and communication, costless traceability, increase of productivity...

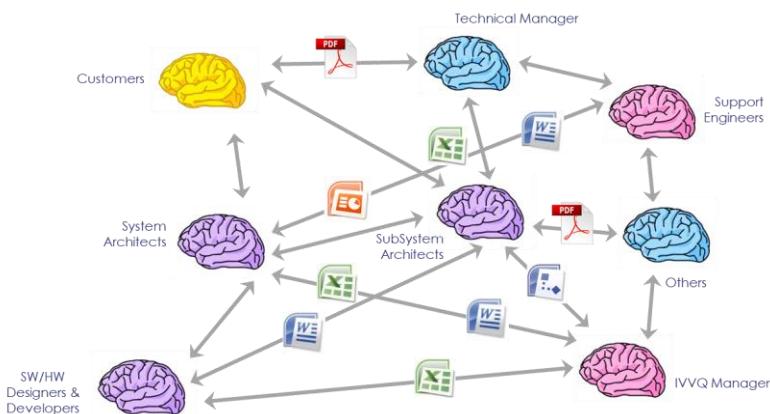
Model Based Systems Engineering

Standard practices

Standalone documents and models

Incoherent reference and decisions

Poor continuity between engineering levels

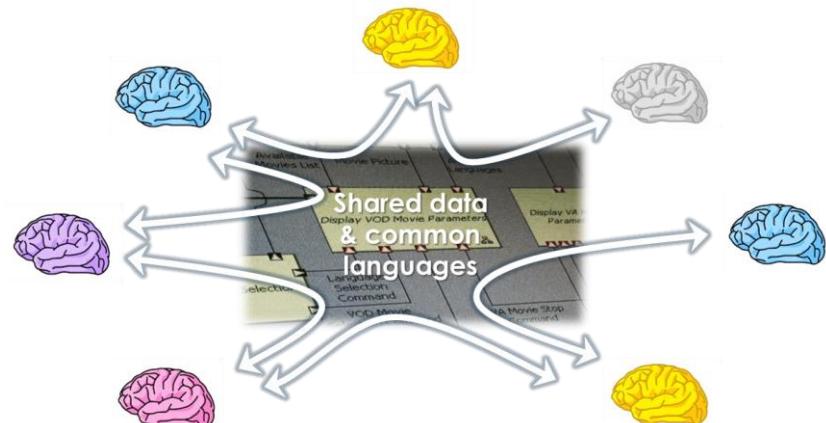


MBSE

Shared models with multiple views

Collaborative workflow and unique reference

Common unified language/concepts



Tight coupling between method and tool

Methodology and
high level concepts
and viewpoints



Purpose-built to
provide the
notation and
diagrams fitting the
Arcadia approach

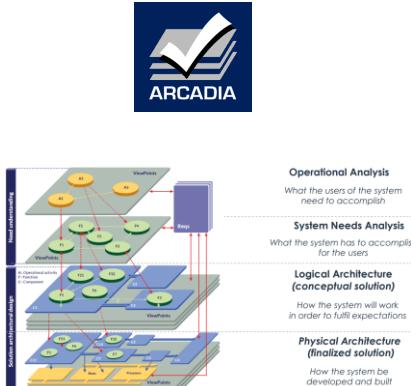


ARCADIA/CAPELLA Pillars

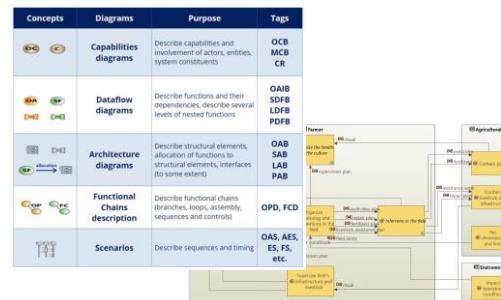
ARCADIA/CAPELLA



Method

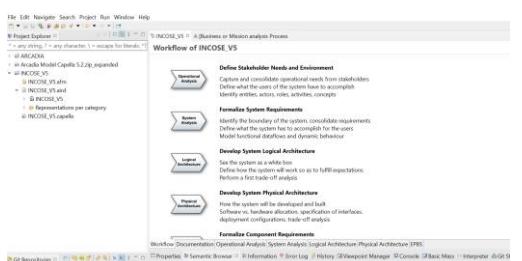


Language



{OPEN}

Tool



ARCADIA at a Glance

ARCADIA(**AR**chitecture **A**nalysis & **D**esign **I**ntegrated **A**pproach) is a model-based engineering method for systems, hardware and software architectural design, helping you to:



Understand the real needs and context



Define and share the solution among stakeholders



Early evaluate and justify architectural design



Secure Sub-System/SW/HW engineering, prepare subcontracting



Prepare and master Verification & Validation



Case Study

Case study



PYTHAGORE The Drone Company

Entrust us with your tedious tasks

| The privileged company strategy is to

- Target professional markets rather than mass consumers
- Sell products to consumers and third-party service providers, rather than provide services
- Leverage on features supported on data intelligence

| Marketing has identified 5 target market segments



Agriculture



Photography



Environment



Security



Inspection

| Our mission is to design a Product Line addressing the needs of these markets

Tight coupling between method and tool

Methodology and
high level concepts
and viewpoints



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Major Perspectives of the Method



Arcadia Perspective #1

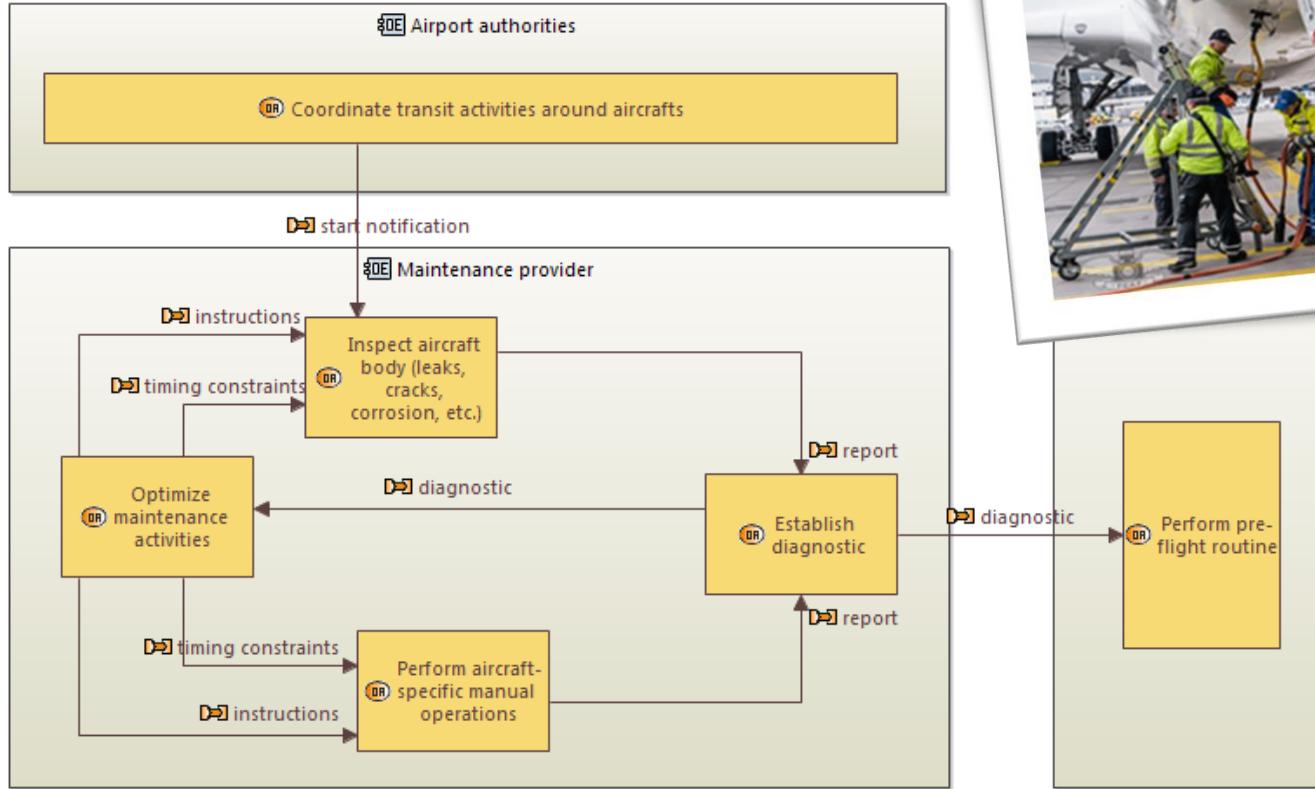


DEFINE WHAT THE USERS/STAKEHOLDERS NEED TO ACCOMPLISH

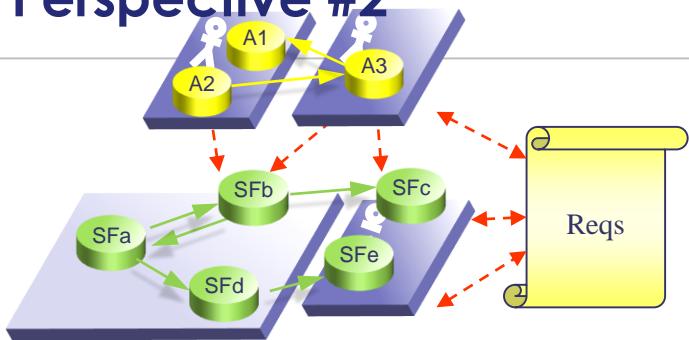
Support of discussions
with the customer,
capabilities, scenarios
and processes,
stakeholders activities

Operational Analysis

Arcadia Perspective #1 : Operational Analysis



Arcadia Perspective #2

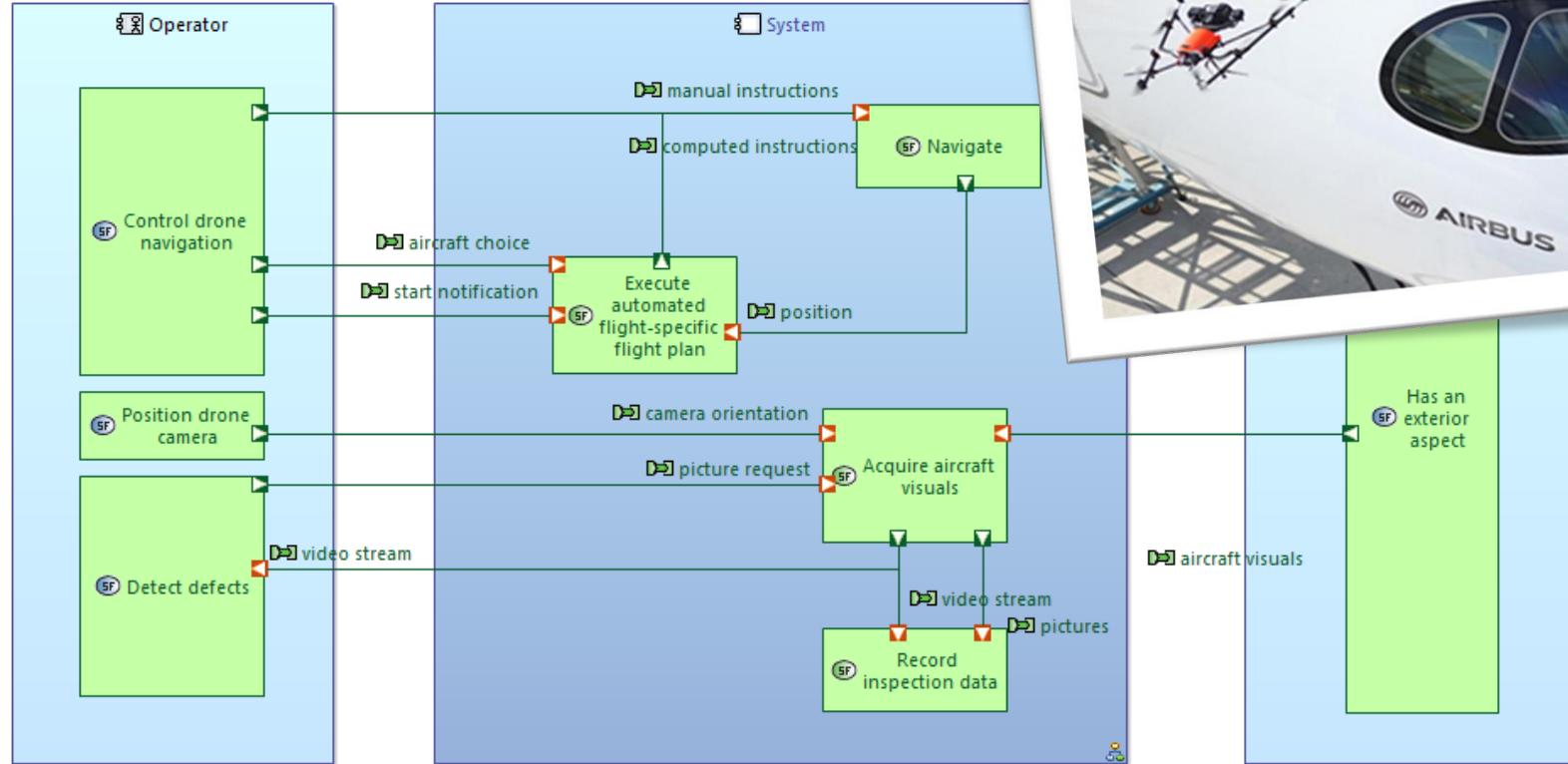


SPECIFY WHAT THE SYSTEM HAS TO ACCOMPLISH FOR THE USERS

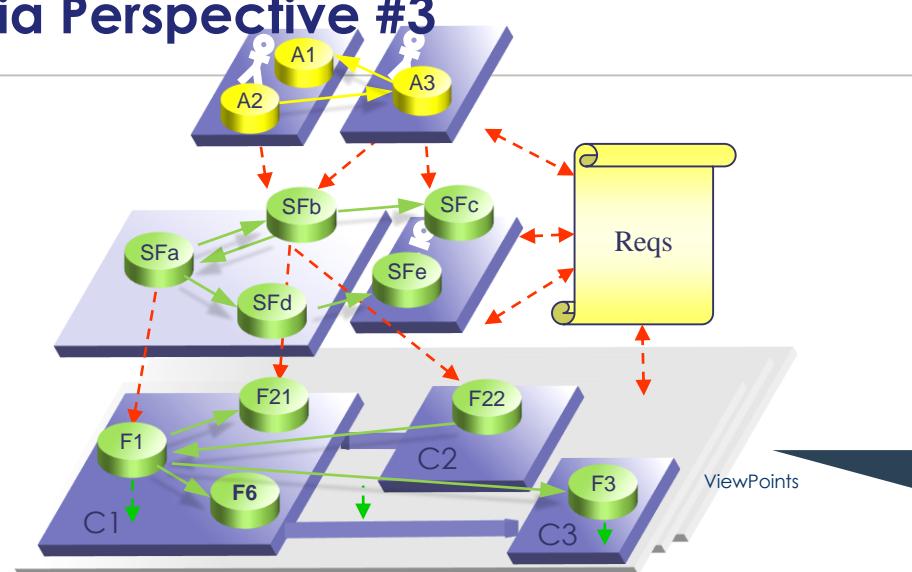
Boundaries,
expected services, external
interfaces, specification,
V&V procedures,
feasibility of requirements

System Need Analysis

Arcadia Perspective #2 : System Need Analysis



Arcadia Perspective #3



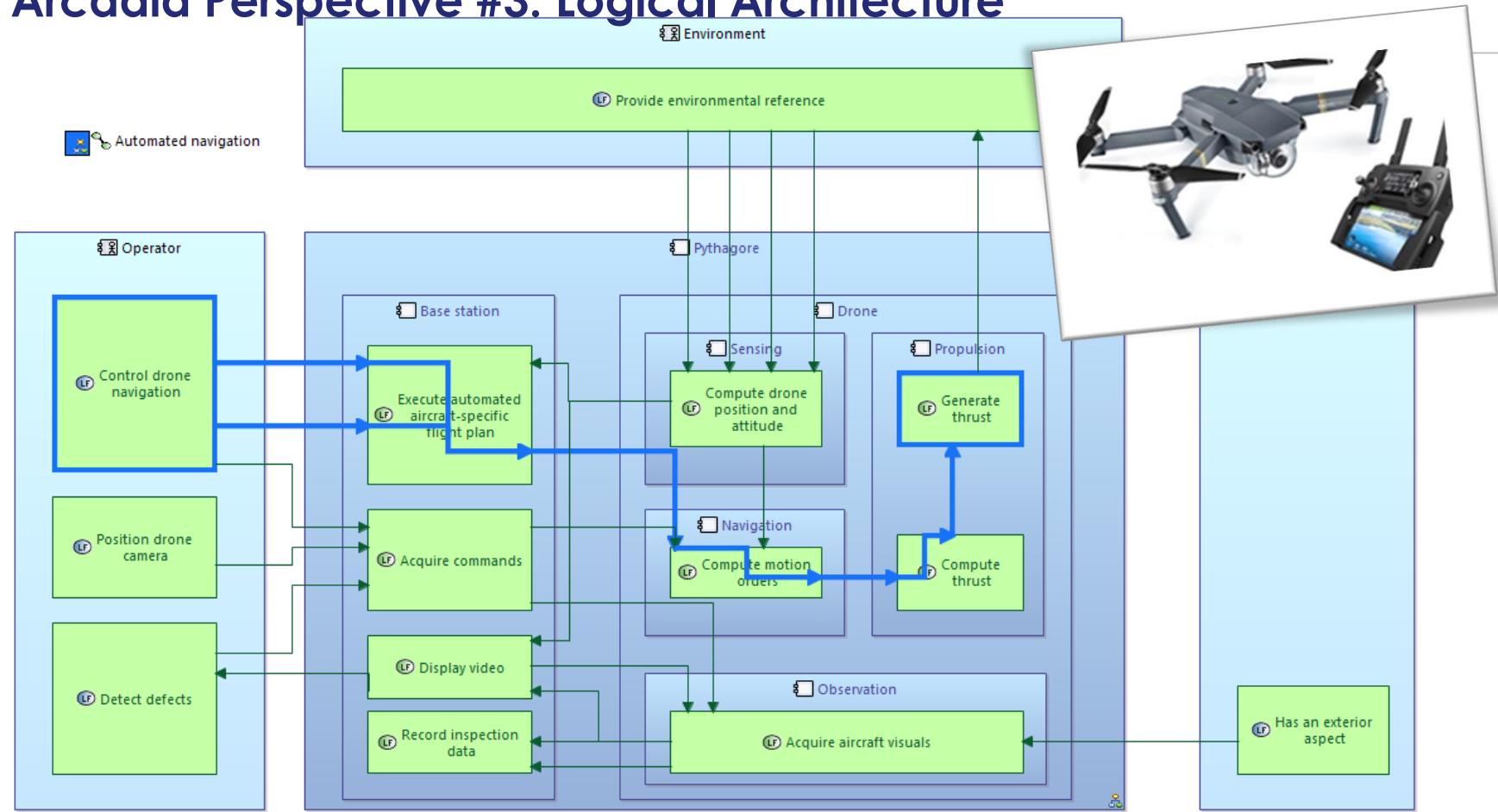
**DEFINE HOW THE SYSTEM
WILL WORK SO AS TO FULFIL
EXPECTATIONS**

High-level architecture description, functional behaviour, architectural drivers, functional allocation to components, first trade-offs, modes and states analysis

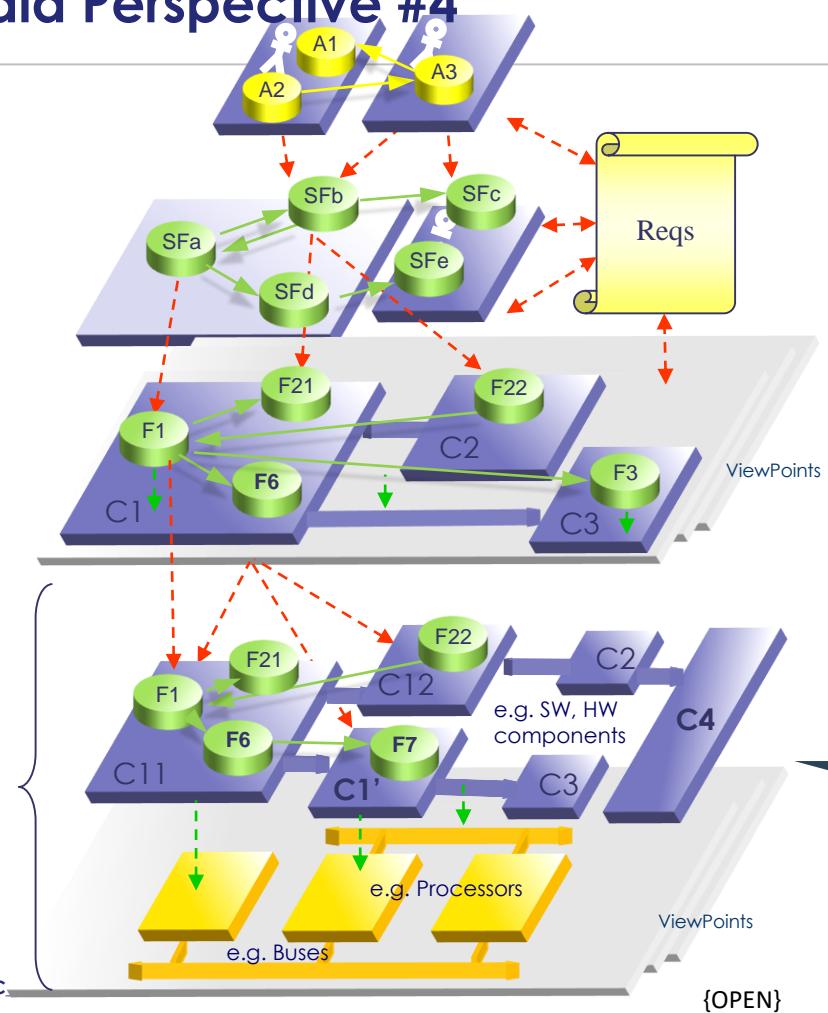
Logical Architecture

Arcadia Perspective #3: Logical Architecture

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Arcadia Perspective #4

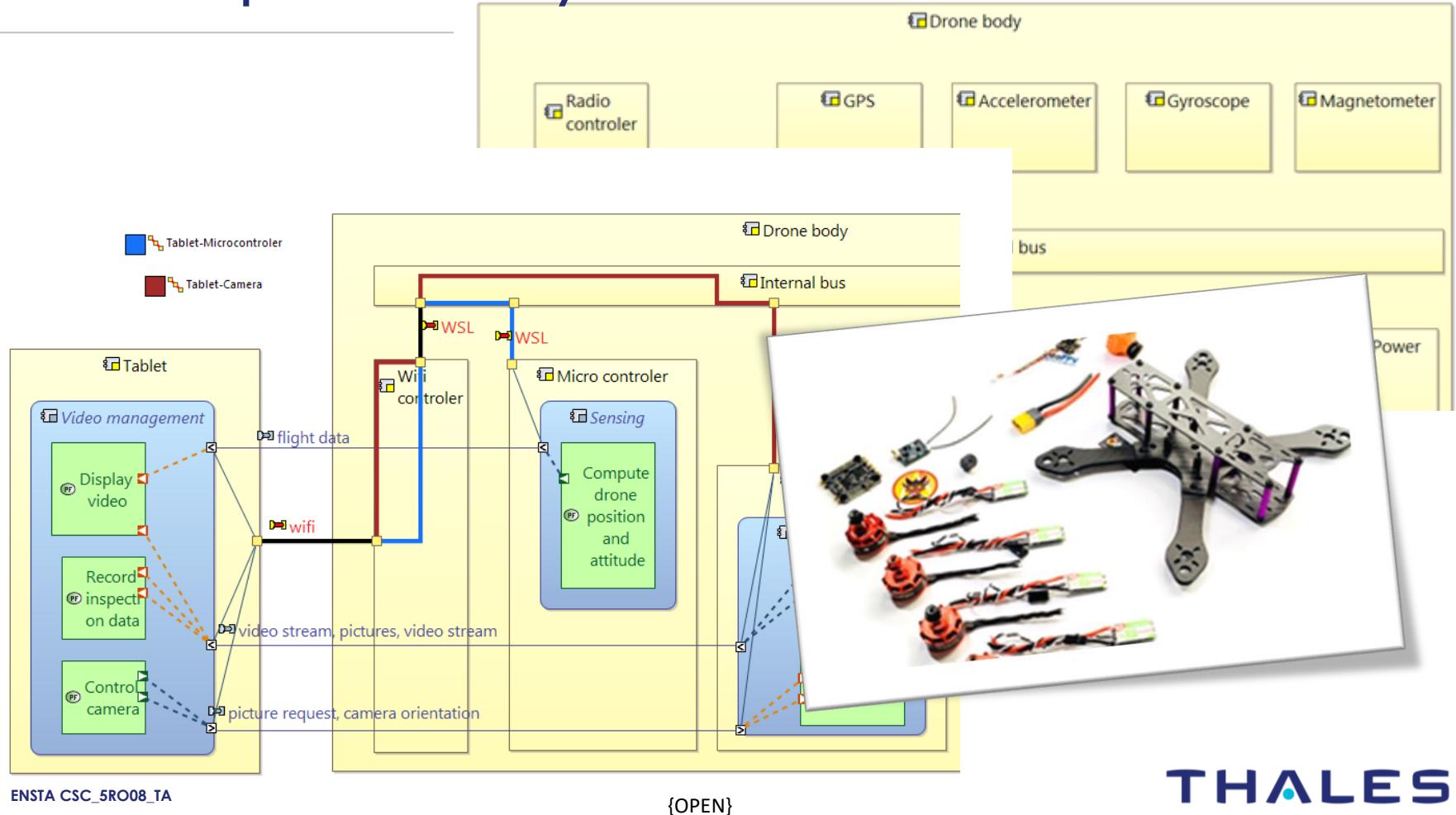


**FINALISE HOW THE SYSTEM
WILL BE DESIGNED,
DEVELOPED AND BUILT**

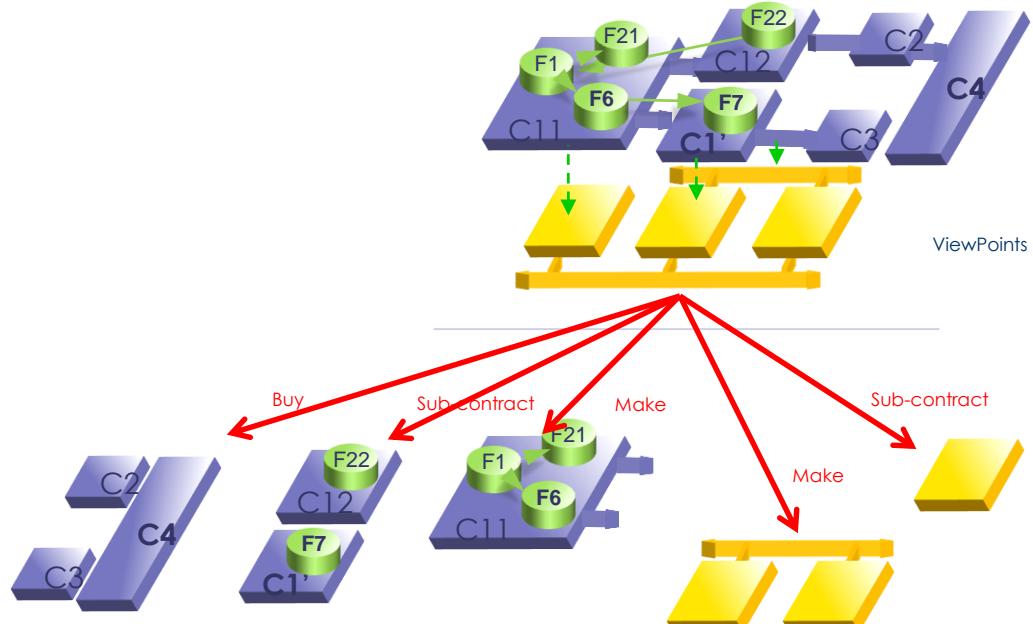
Implementation constraints,
reuse, refined trade-offs,
M/T/B strategy,
finalized detailed interfaces

Physical Architecture

Arcadia Perspective #4 : Physical Architecture



Arcadia Perspective #5 : Building Strategy

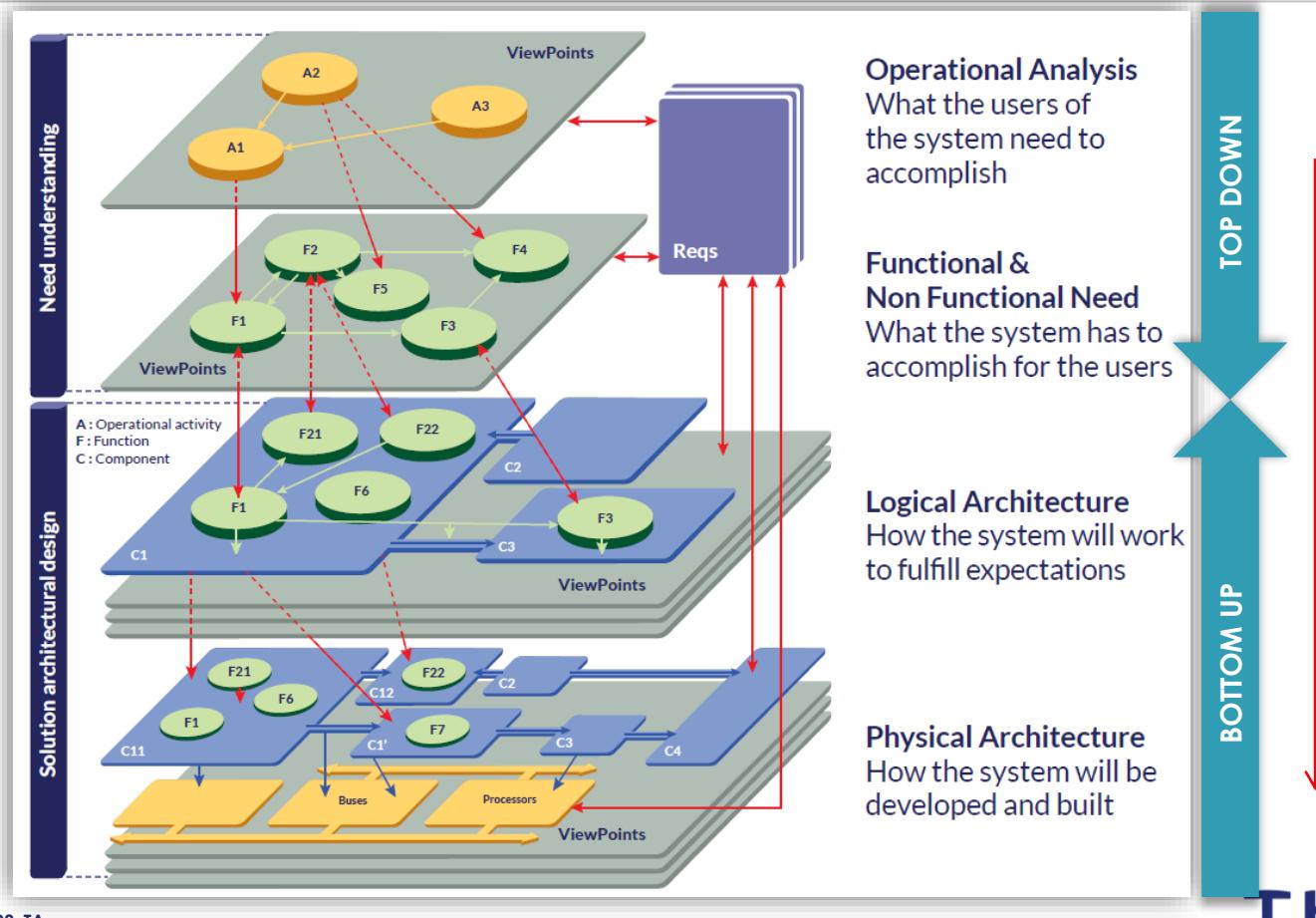


**SPECIFY WHAT IS EXPECTED
FROM EACH DESIGNER /
SUB-CONTRACTOR,
HOW TO INTEGRATE**

Definition of Configuration Items, definition of development strategy (make, buy, sub-contract), and of Integration verification validation strategy

Building Strategy

Arcadia Perspectives summarised: Need Vs Solution Consistency

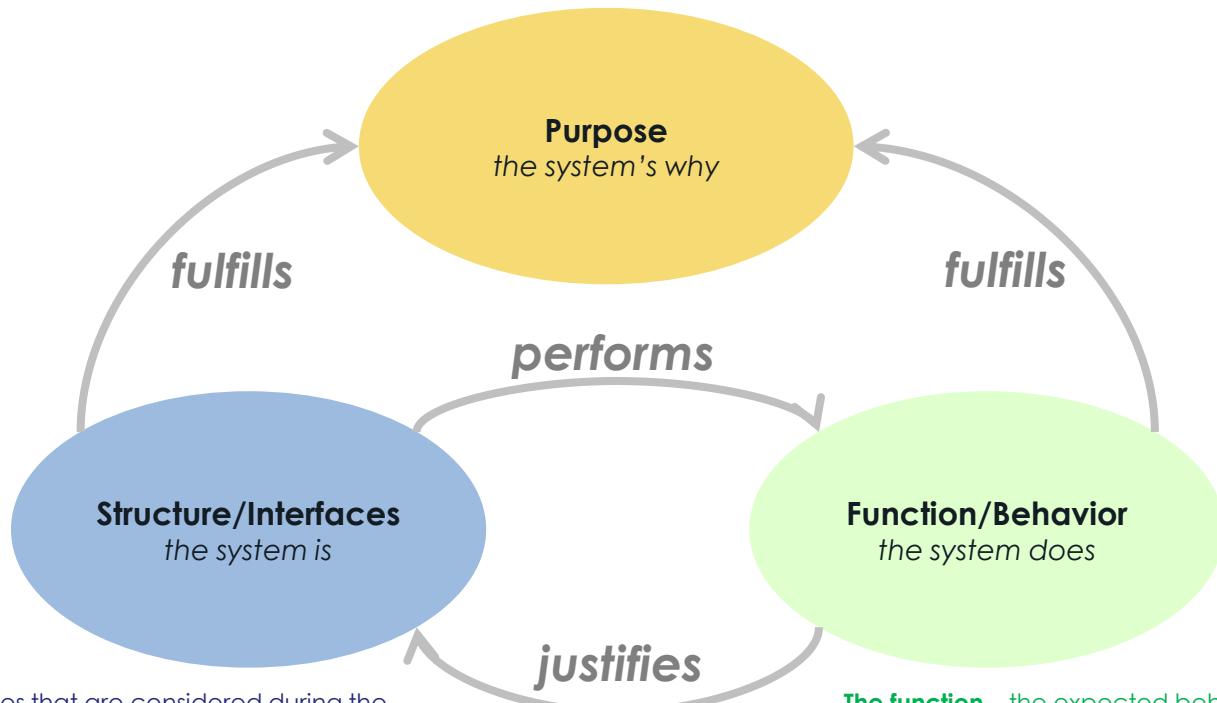


METHOD STEPS	TASKS	SAMPLE MODEL	CONCEPTS	DESCRIPTION MEANS
NEED	Customer Operational Need Analysis What the users of the system need to accomplish	<ul style="list-style-type: none"> ✓ Define operational capabilities ✓ Perform an operational need analysis 	<ul style="list-style-type: none"> - Operational capabilities - Actors, operational entities - Actor activities - Interactions between activities & actors - Information used in activities & interactions - Operational processes chaining activities - Scenarios for dynamic behaviour 	<p>Dataflow: functions, op. activities interactions & exchanges</p>
	System/ SW/HW Need Analysis What the system has to accomplish for the Users	<ul style="list-style-type: none"> ✓ Perform a capability trade-off analysis ✓ Perform a functional and non-functional analysis ✓ Formalise and consolidate requirements 	<ul style="list-style-type: none"> - Actors and system, capabilities - Functions of system & actors - Dataflow exchanges between functions - Functional chains traversing dataflow - Information used in functions & exchanges, data model - Scenarios for dynamic behaviour - Modes & states 	<p>Scenarios: actors, system, components interactions & exchanges</p>
SOLUTIONS	Logical Architecture Design How the system will work so as to fulfil expectations	<ul style="list-style-type: none"> ✓ Define architecture drivers and viewpoints ✓ Build candidate architectural breakdowns in components ✓ Select best compromise architecture 	<p>SAME CONCEPTS, PLUS :</p> <ul style="list-style-type: none"> - Components - Component ports and interfaces - Exchanges between components - Function allocation to components - Component Interface justification by functional exchanges allocation 	<p>Functional chains, operational processes through functions & op. activities</p>
	Physical Architecture Design How the system will be developed & built	<ul style="list-style-type: none"> ✓ Define architectural patterns ✓ Consider reuse of existing assets design a physical ✓ Design a physical reference architecture ✓ Validate and check it 	<p>SAME CONCEPTS, PLUS :</p> <ul style="list-style-type: none"> - Behavioural components refining logical ones, and implementing functional behaviour - Implementation components supplying resources for behavioural components - Physical links between implementation components 	<p>Breakdown of functions & components</p>
	Development Contracts What is expected from each designer/ sub-contractor	<ul style="list-style-type: none"> ✓ Define a components I&V&Q strategy ✓ Define & enforce a PBS and component integration contract 	<ul style="list-style-type: none"> - Configuration items tree - Parts numbers, quantities - Development contract (expected behaviour, interfaces, scenarios, resource consumption, non-functional properties) 	<p>Data model: dataflow & scenario contents, definition & justification of interfaces</p>
				<p>Allocation of op.activities to actors, of functions to components, of behav.components to impl.components, of dataflows to interfaces, of elements to configuration items</p>

The Language

ARCADIA Aspects

The Purpose - The reason to exist of the system: the services it provides in different contexts of usage, so to fulfill stakeholders expectations



The form – the entities that are considered during the different contexts of usage of the system, as well as the constituents of the system

The function – the expected behavior of the entities in the context of usage, of the system, and of its constituents

Arcadia Language major Concepts Definition

Mission

A major goal to which the system is expected to contribute

Capability

The ability of an operational entity or of the system, to provide a service that supports the achievement of a mission

Operational Activity

An action, an operation or a service fulfilled by an operational entity, contributing to a mission

Operational Entity

A real world entity or stakeholder, involved in a mission

Operational Actor

A [usually human] non decomposable operational Entity

Operational Interaction

An interaction from an operational entity delivering exchange items to another entity (information, signal, material, torque...)

Operational Process

A logical organization of Interactions and Activities to fulfil an Operational Capability

Operational Scenario

A time-ordered set of interactions between operational activities performed by operational entities to fulfil an Operational Capability

System

An organized set of elements functioning as a unit to achieve a given purpose, subject of the engineering

System Actor

An external entity, organisation, system, or human, interacting with the system via its interfaces

Function

An action, an operation or a service fulfilled by the system, by a behavioural component or by an actor interacting with the system

Functional Port

An interaction point of a function with others, either for input or output

Functional Exchange

An interaction from a source function likely to deliver exchange items to another function (information, signal, material, torque...) through functional ports

Functional Chain

A logical organization of functions and functional exchanges to fulfil a Capability

Functional Scenario

A time-ordered set of functional exchanges between functions, to fulfil a Capability

Mode

A behaviour expected from the system or from a component or an actor in chosen conditions

State

A context undergone by the system or a component or an actor in specific circumstances

Transition

A move from one mode or state to another under some conditions

Component

A constituent of the system contributing to its behaviour and properties, by interacting with other components

Behavioural Component

A component in charge of realising some functions that are allocated to it

Behavioural Port

An interaction point of a component with others

Behavioural exchange

An interaction between two components likely to exchange some items (information, signal, material, torque...) through behavioural ports

Logical Component

A behavioural component in Logical Architecture

Implementation Component

A component hosting behavioural components, delivering them required resources

Physical Port

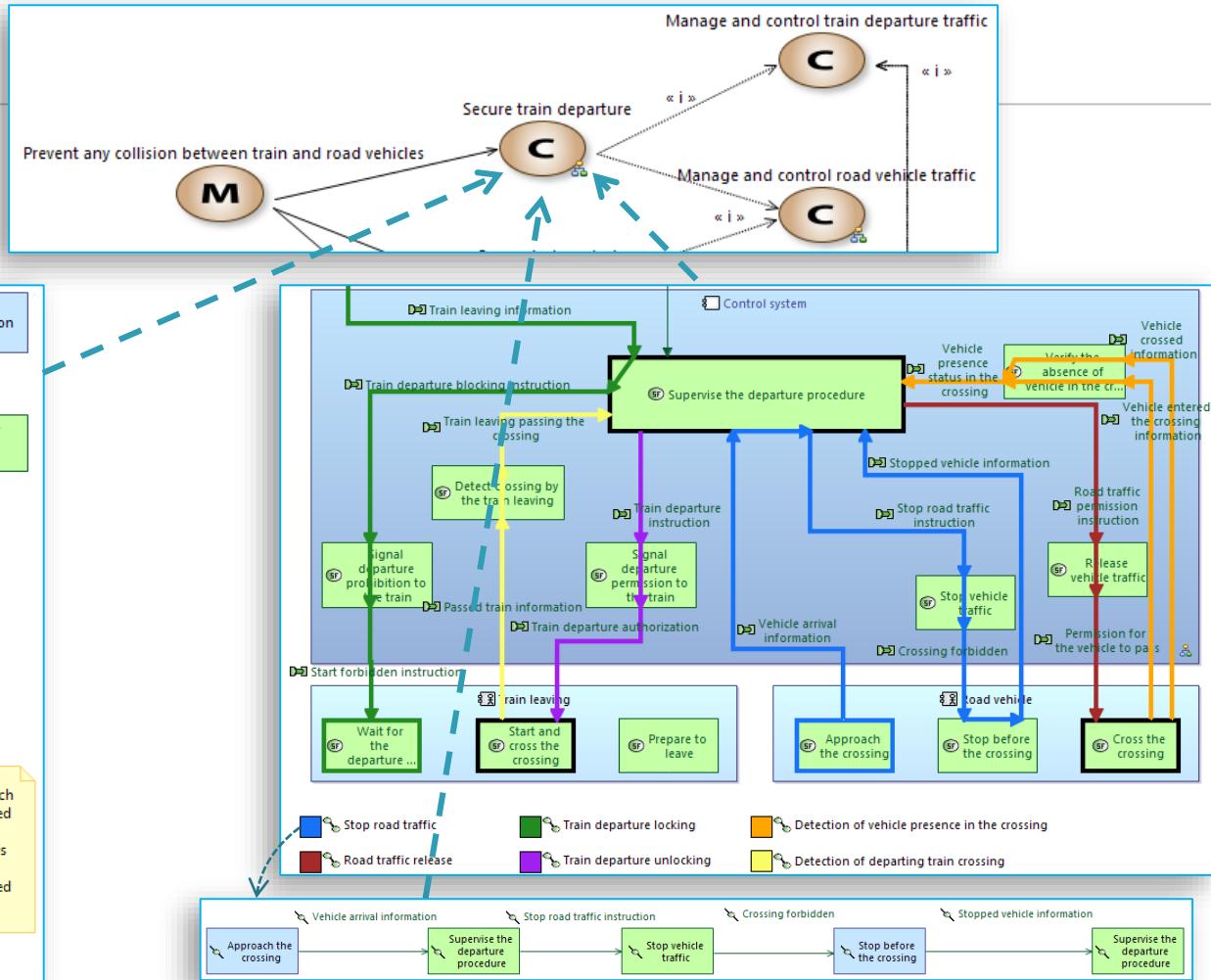
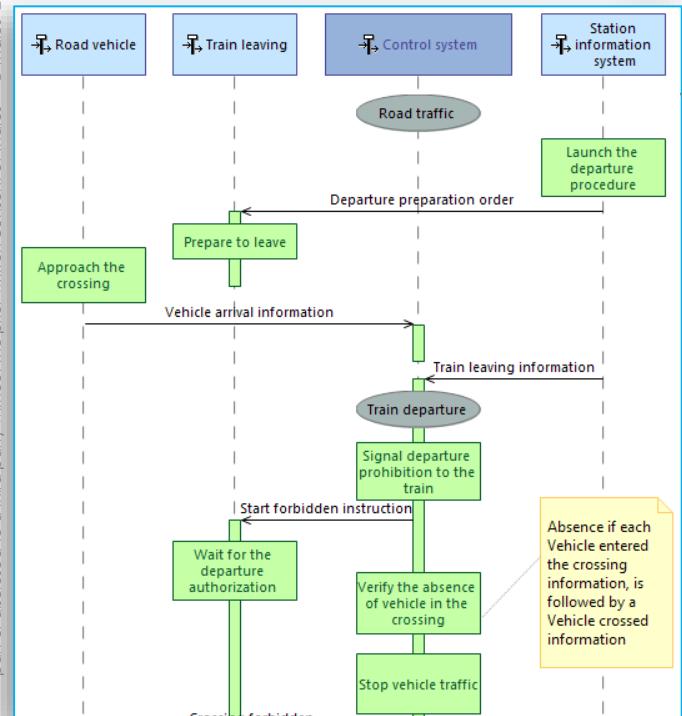
A connection point of an implementation component with others

Physical Link

A communication means between two implementation components through their physical ports

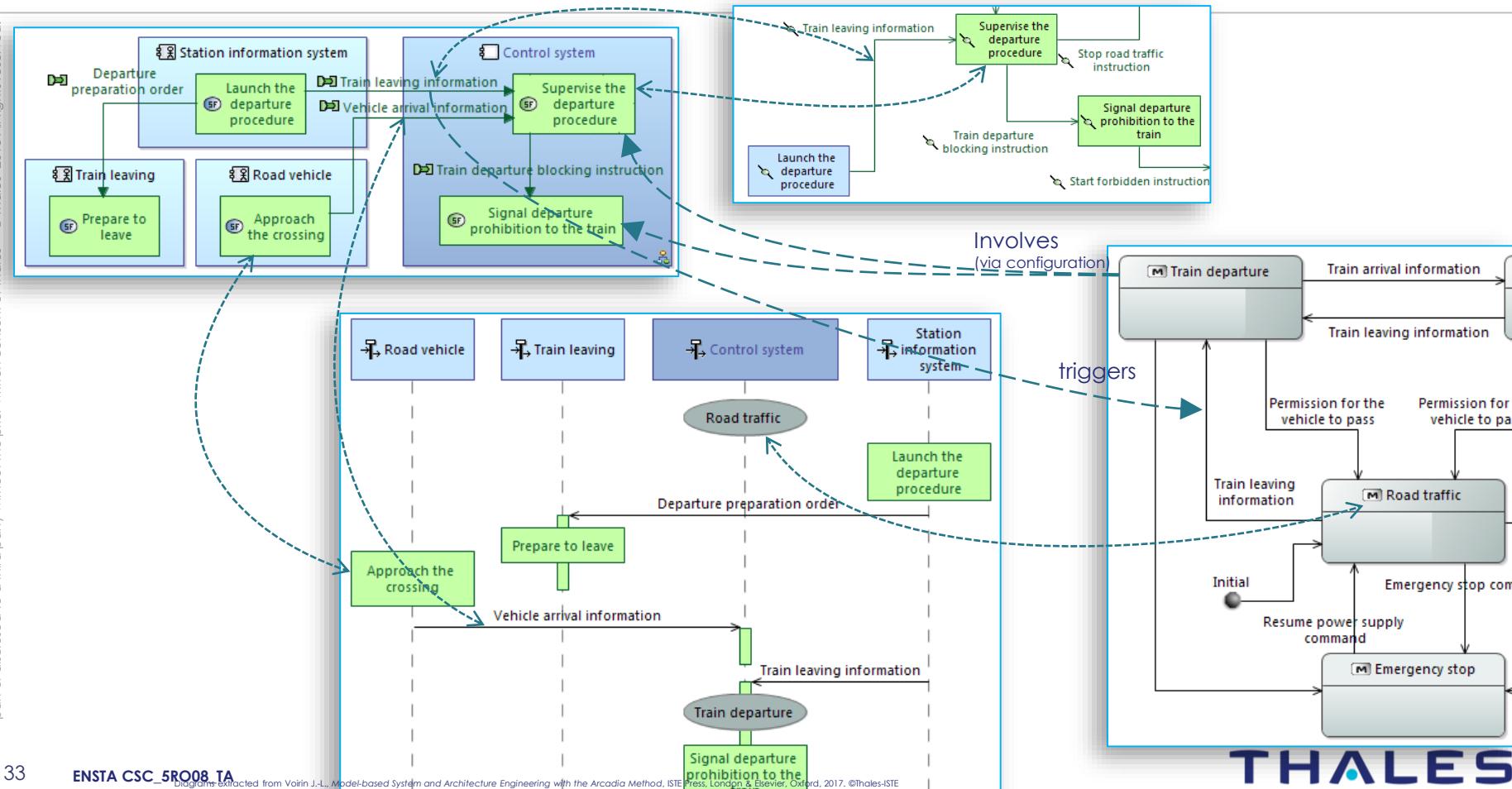
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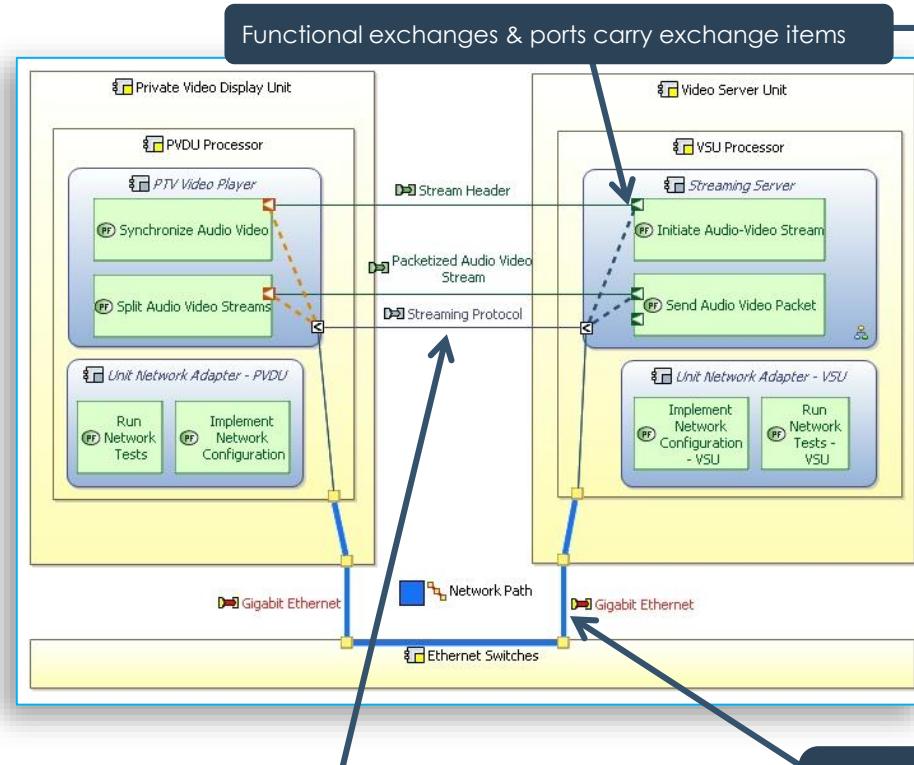
Dataflow / Scenarios & F. Chains / Modes & States Consistency

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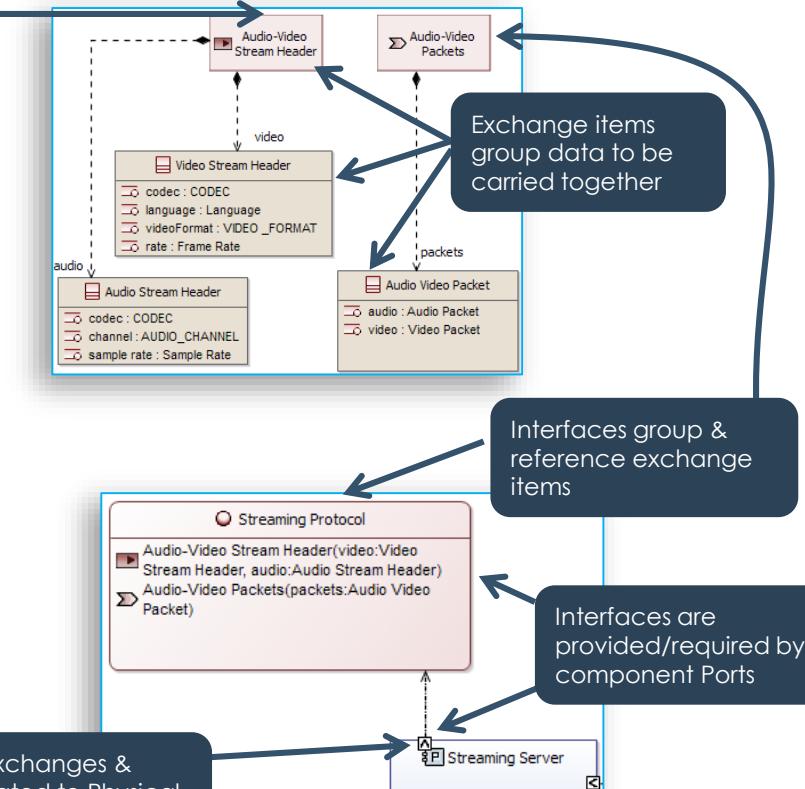


Functional analysis / Structure / Interfaces Definition Consistency

Functions are allocated to behavioral components, who use implementation components as resources



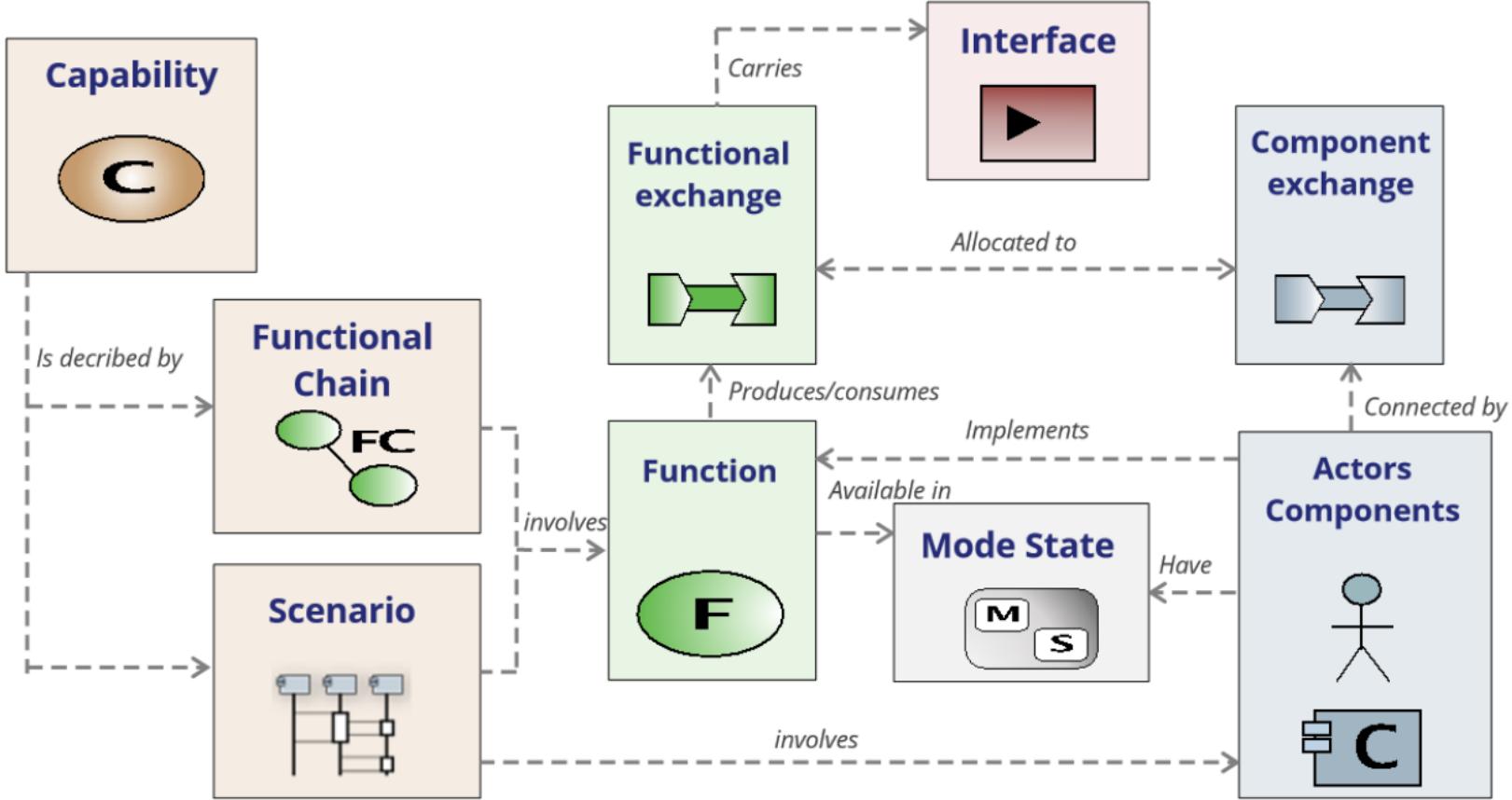
Functional exchanges & ports carry exchange items



Functional exchanges & ports are allocated to component exchanges & ports

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Concept summary



ARCADIA Typical questions to be raised

		ASPECTS				
		Purpose	Function	Behavior	Structure	Interfaces
NEED PERSPECTIVES	Operational Analysis					
	What the stakeholders need to accomplish					
SOLUTION PERSPECTIVES	System Analysis					
	What the system has to accomplish for the stakeholders					
SOLUTION PERSPECTIVES	Logical Architecture					
	How the system will work to fulfill expectations					
SOLUTION PERSPECTIVES	Physical Architecture					
	How the system will be developed and built					

Each of these boxes refer to questions that are relevant when defining the architecture of a system

ARCADIA Typical questions to be raised

NEED PERSPECTIVES	ASPECTS				
	Purpose	Function	Behavior	Structure	Interfaces
Operational Analysis What the stakeholders need to accomplish	What are actors/entities expecting ?	How and when interactions between actors/entities occur ?	What are the operational modes ?	Who interact with whom ?	What information is exchanged between actors/entities
System Analysis What the system has to accomplish for the stakeholders	What services shall my system provide?	What actions are expected from the system? What are expected from an external entity?	What are the operational modes of my system?	Who will my system interact with?	What are the external interfaces of my system?
Logical Architecture How the system will work to fulfill expectations	What is the contribution of a conceptual component to the services my solution shall provide?	What actions are expected from a conceptual component?	What are the operational modes of a conceptual component ? Are they consistent with system modes?	What is the high-level, conceptual decomposition of my system?	What are the interfaces between the system conceptual component?
Physical Architecture How the system will be developed and built	What is the contribution of the HW and SW components to the services my solution shall provide?	What actions are expected to be implemented by the SW team in the next increment?	How to ensure that the SW and HW constituents are available in a given mode?	What are the SW and HW components of the system ?	What are the connections between the components? What data is conveyed?

Tight coupling between method and tool

Methodology and
high level concepts
and viewpoints

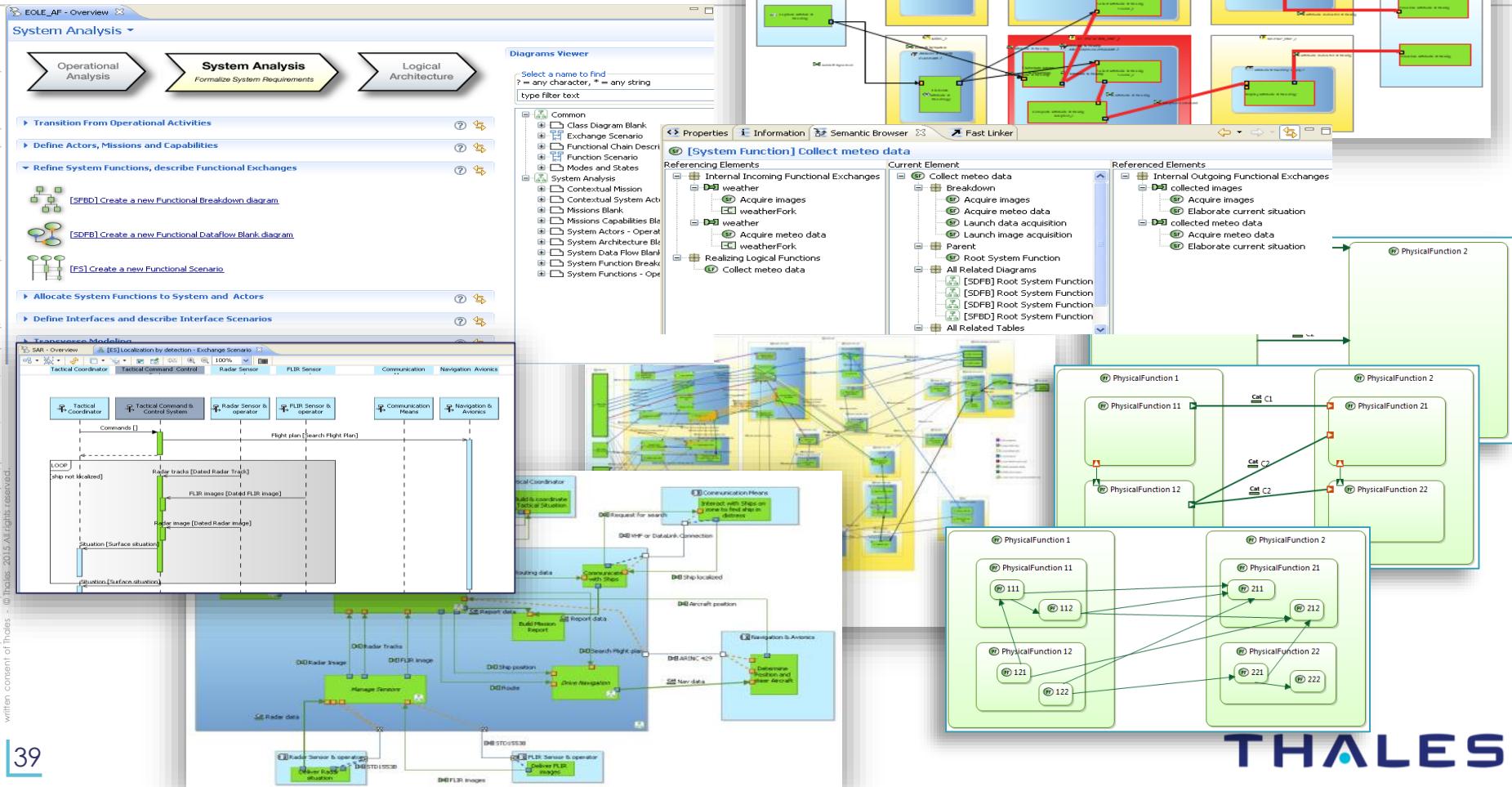


Purpose-built to
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Demonstration

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Methodological Overview

