MBSE within an Enterprise Digital Environment

Phoenix Integration
2018 International Users‘ Conference
April 17-19, 2018
Annapolis, Maryland, USA

DEFENCE AND SPACE

Ralf Hartmann

AIRBUS

Airbus is at the forefront of the aviation industry.

We build the most innovative commercial aircraft and consistently capture about half of all commercial airliner orders. Thanks to its deep understanding of changing market needs, customer focus and technological innovation, Airbus helps airlines grow and people connect.

Commercial Aircraft

Employees
54,000

2016 Revenues
€49.24 bn

Aircraft delivered
10,200

Order Backlog 2016
6,874 aircraft

Net Orders in 2016
731 aircraft

Deliveries in 2016
688

Meet the Airbus family from 100 to 600+ seats

A320 Family

The most successful aircraft family ever

A330 Family

Powering into the future

A350 XWB

Shaping the future of air travel

A380

Unique passenger experience

AIRBUS

The world’s No.1 helicopter manufacturer.

We provide the most efficient civil and military helicopter solutions to our customers who serve, protect, save lives and safely carry passengers in highly demanding environments.

AIRBUS

Helicopters

No.1 helicopter manufacturer in the world

Largest civil and military helicopter range in the world

Employees

22,500

2016 Revenues

€6.7 bn

Helicopters in operation worldwide

Around **12,000** helicopters in **154** countries

2016 Order Book

€11.3 bn

Leadership in the civil market

47%

(based on deliveries)

AIRBUS

Civil Range

Light Single

H120

H125

H130

Light Twin

H135

EC145

H145

Medium

AS365 N3+

H155

H160

H175

Heavy

H215

H225

Military Range

Light

H125M

H135M

H145M

Medium

AS565

Heavy

H215M

H225M

Specialised

Tiger

NH90

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DEFENCE AND SPACE

Airbus is Europe’s largest and most innovative defence and space company.

We develop and manufacture world-class aerospace products. Our exceptional platforms and services allow our customers to address even their most challenging operational needs.

Defence and Space

No.1 European defence and space company

Employees
34,400

2016 Revenues
€11.9bn

2016 Order Book
€41.5bn

Military Aircraft, total orders by 2016
1,928 aircraft

1,400 accumulated years in orbit since 1965 by our satellites

18 armed forces worldwide served by our satellite communications

AIRBUS

Strong, innovative and customer focused – Our portfolio.

Military Aircraft

- A400M
- A330 Multi-Role Tanker Transport
- Special Mission Aircraft
- Combat Aircraft
- Full In-Service Support

Space Systems

- Telecommunication Satellites
- Earth Observation Satellites
- Navigation Satellites
- Orbital and Space Exploration Infrastructure
- Science Missions
- ArianeGroup (Launchers)

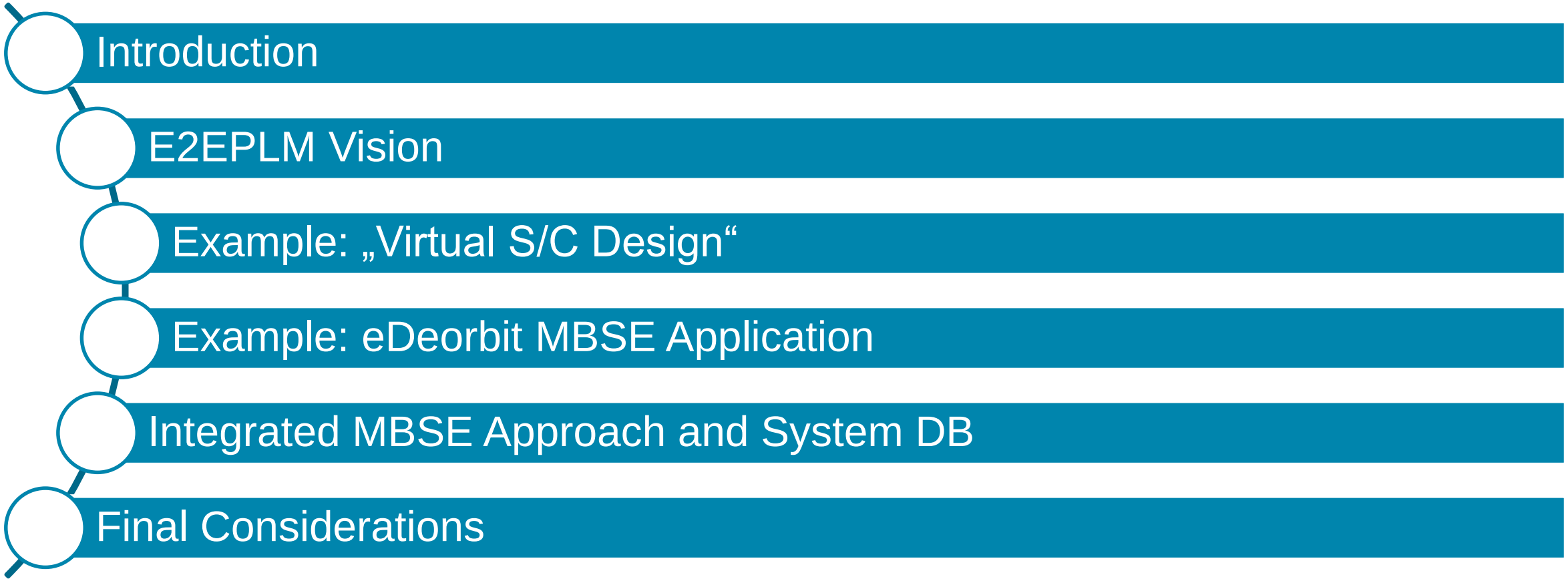
Communications, Intelligence and Security

- Earth Observation Satellite-based Geo-Intelligence Services
- Command & Control (C5ISR) Systems
- Secure Communications
- Cybersecurity Solutions and Services
- Security Solutions

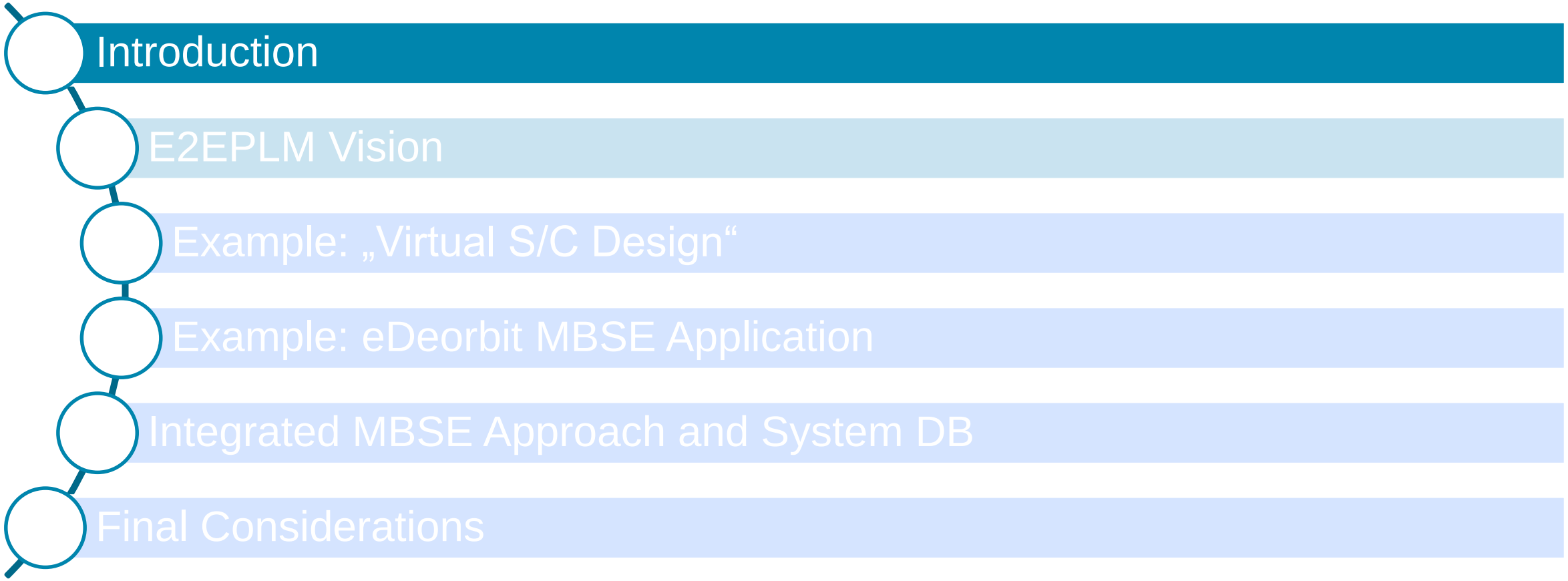
Unmanned Aerial Systems

- UAS and UAV solutions for airborne intelligence, surveillance and reconnaissance, and combat missions

Overview



Overview



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Product Line Business Challenges

Military Aircraft

A400M

Aircraft customisation & services improvement
(Design For Manu/Quality/Customer services)

Eurofigher (legacy)

Improved customer support
(Design for Customer Services)

MRTT. C295

Improved Customer Support
(Design For Manu/Quality/Customer services)

UAV / NGWS

Rapid Product Development
(collaborative engineering, links to partnerships)

Space Systems

Telecom / Space Equipments

Time To Market & Cost Reduction
(Integrated Eng/collaborative operating environment)

Satellite Systems (OneWeb)

Joint Venture co-working – industrialise solution
(Supplier cohesion/Recurring production environment)

ENS / Space Equipments

Time To Market & Cost Reduction
(collaborative platform/KPIs/industrialisation)

Orbital

New Markets Rapid Development/ Product stabilisation
(end to end common space operating environment)

Comms Intel. Security

Governmental / Cyber Security

Grow market share, create future ecosystem
(Product development, partnership liaison)

GEO Intelligence / Mobile Solutions

Grow market share, extend product to market
(modernise end to end operating environment)

Secure Comms / Security Solutions

Extend field utilisation / Grow customer base
(modernise end to end operating environment)

Similar challenges in the different PL, requiring transversal, scalable & flexible solution

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The Changing Environment

Switch from a **transactional selling model** to **product as a service model.** Customer do not buy final products but SLAs. E.g: Rolls-Royce "power by the hour" model

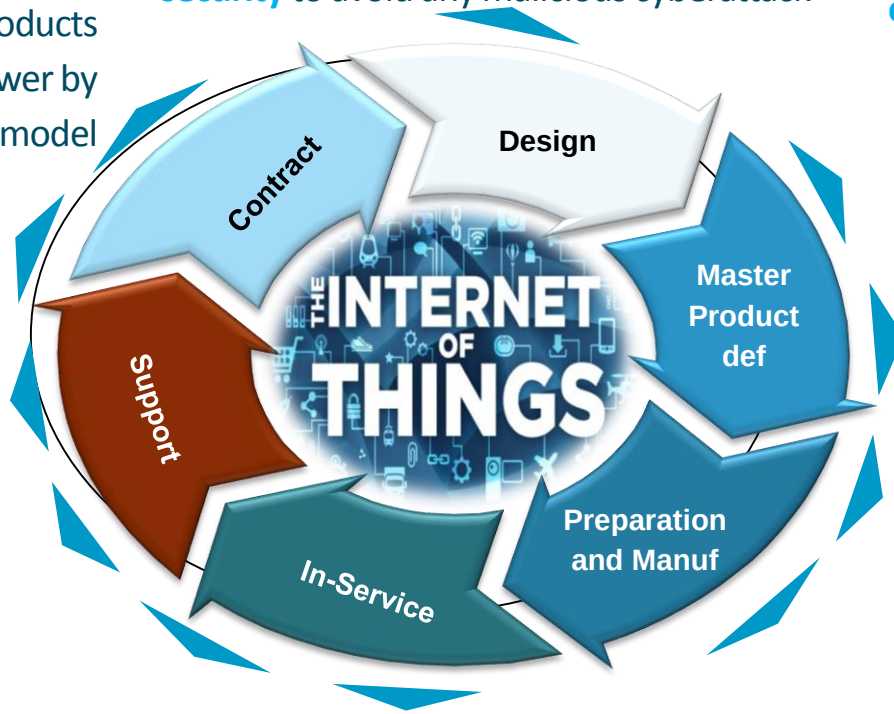
Manufacturer **remains connected to customers** via the product

Predictive maintenance: through analysis of BigData generated by the product itself

Product variability: thanks to software, the key features of the products can be easily modified

Improved performance: products Big Data analytics can drastically improved their performance. E.g.: Schindler's PORT technology reduces elevator wait times by 50% by predicting elevator demand patterns

The design of the product has to be overhauled: **more software** and **connectors embedded** along with a **drastically improved security** to avoid any malicious cyberattack



Remote upgrading: products that can be remotely upgraded, through simple software update. For instance, many Tesla automobiles are connected to a single manufacturer system that monitors performance and accomplishes remote services and upgrades

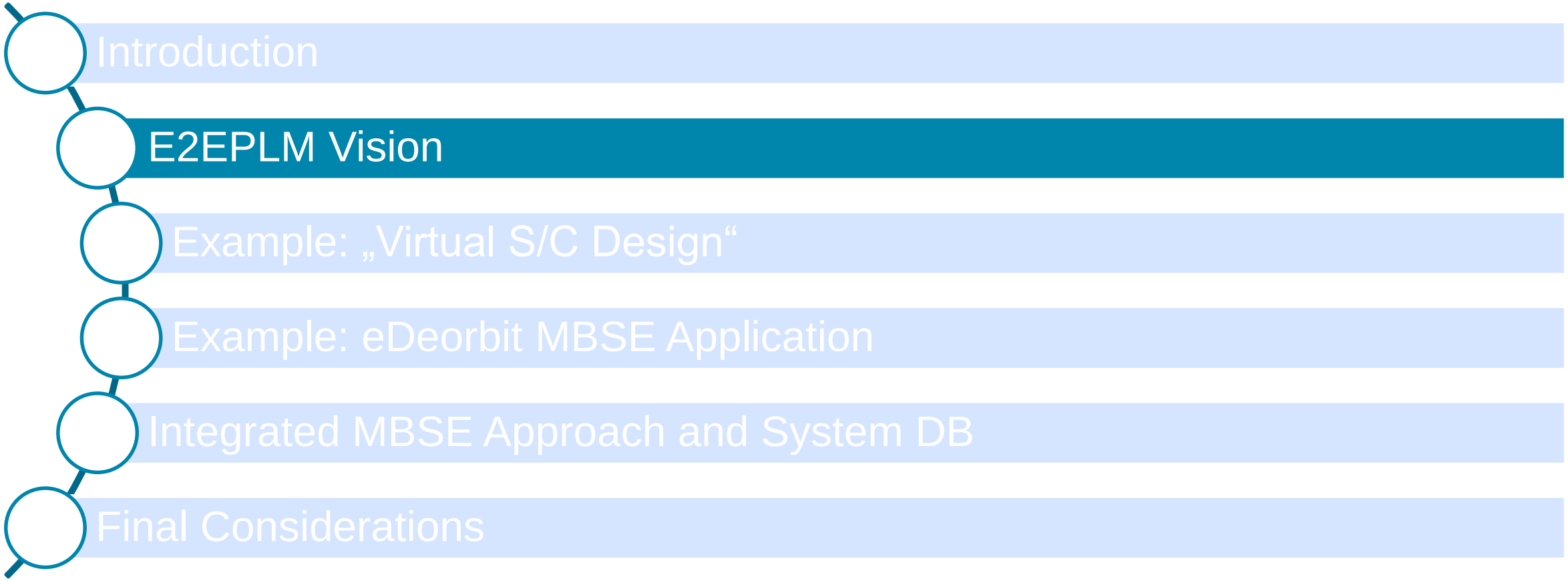
Taking into account the BigData generated by the product, it is now possible to **continuously upgrade the specifications** of the product/product warranty and the procedures to use the product

PLM system that **bridges the digital world and the physical world** : Latest version of PDM integrates data from physical world. It is informed by real world usage and quality data from smart connected products

Workers empowerment: Smart connected tools used by blue-collars can be parameterized to ensure that the operations are performed in line with the specifications

Machine automation: a production machine can detect a potentially dangerous malfunction, shut down other equipment that could be damaged etc.

Overview



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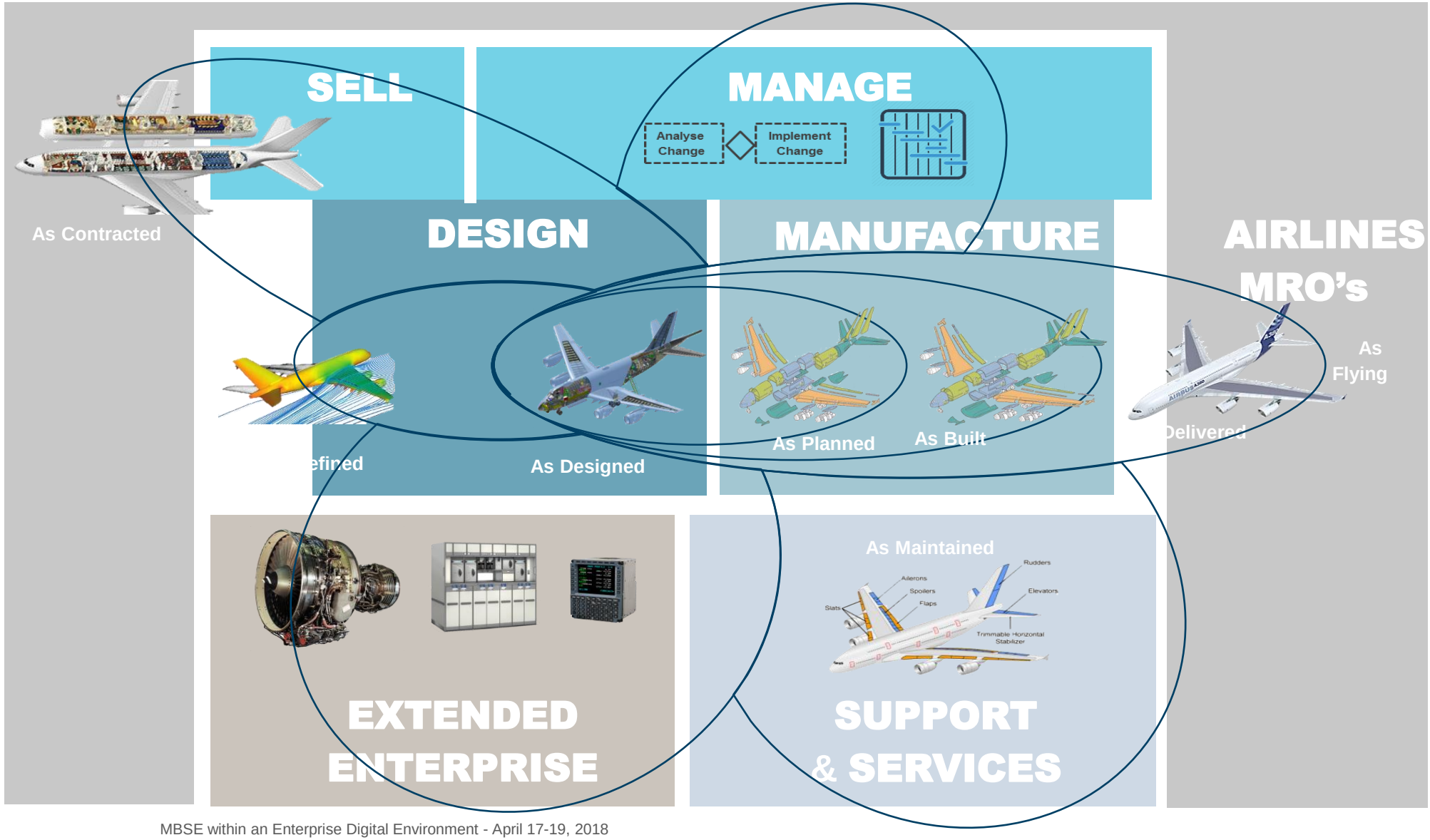
Digital Aim: Be more efficient in our business execution

Opportunities within domain linkages…



Target Model: A federated end to end operational landscape

Product Data Reference

Central Digital Service
(Analytics. Data Exposure. Streaming between functional domains. Data Aggregation. Visualisation)

Functional Product Authoring
through the industrial process (Master data & Operational data management)

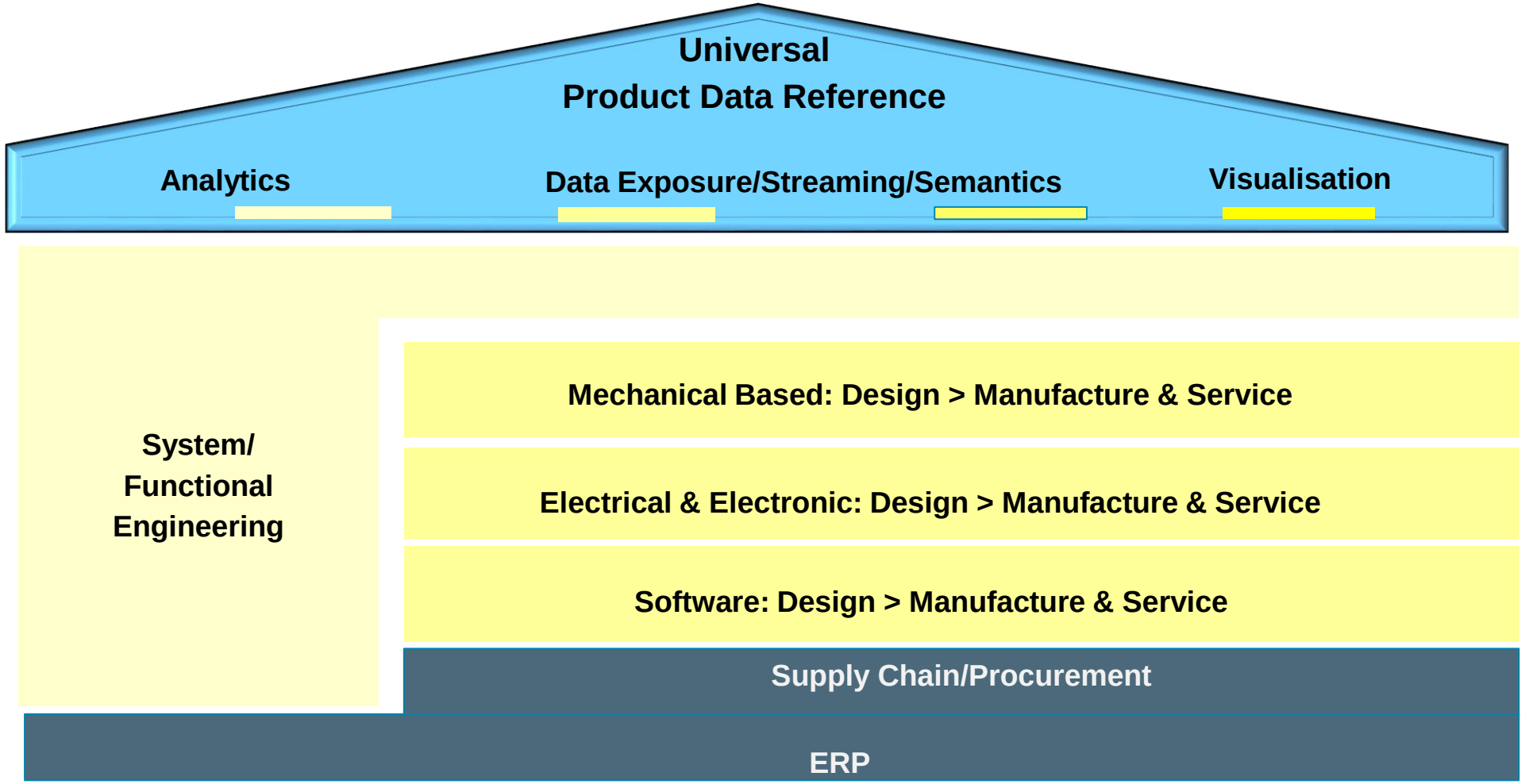






Customer Bid → Systems Eng → Product Design → Procurement → Manufacturing → Customer Services → Customer Operations

Target Model: A federated set of digital threads



Complementary & interconnected layering of product data solution providers provisioning 6 interconnected domains

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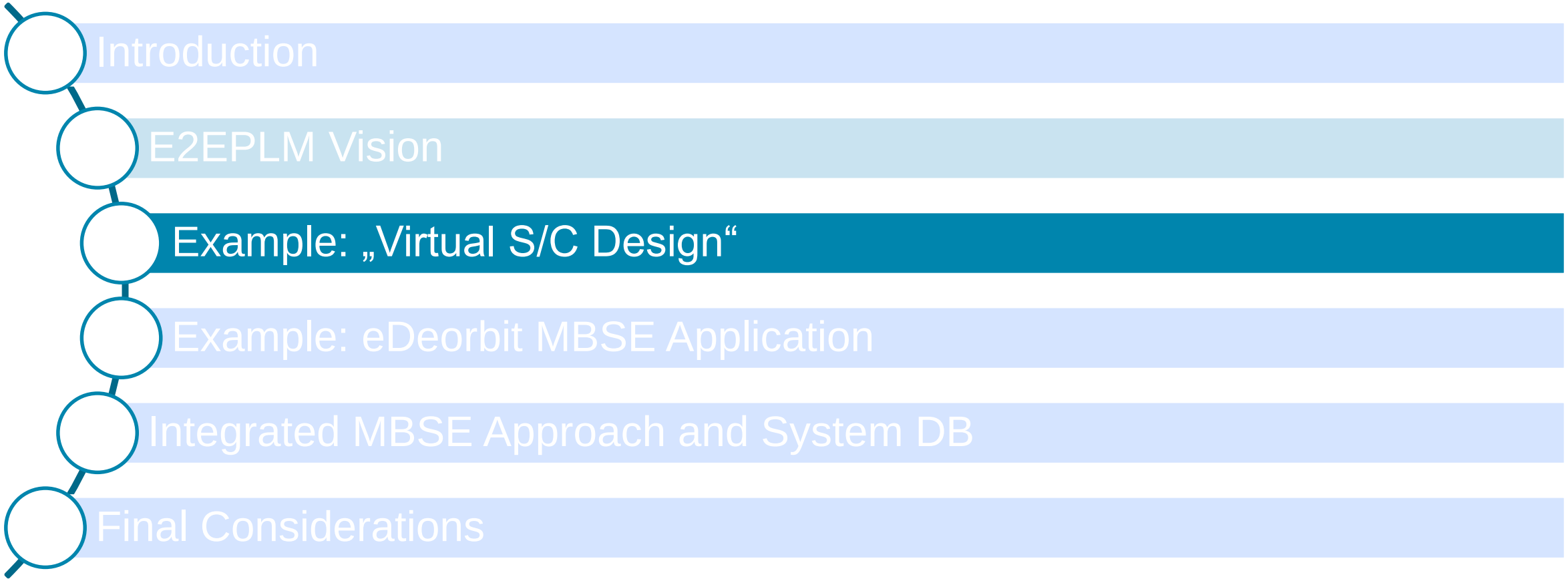
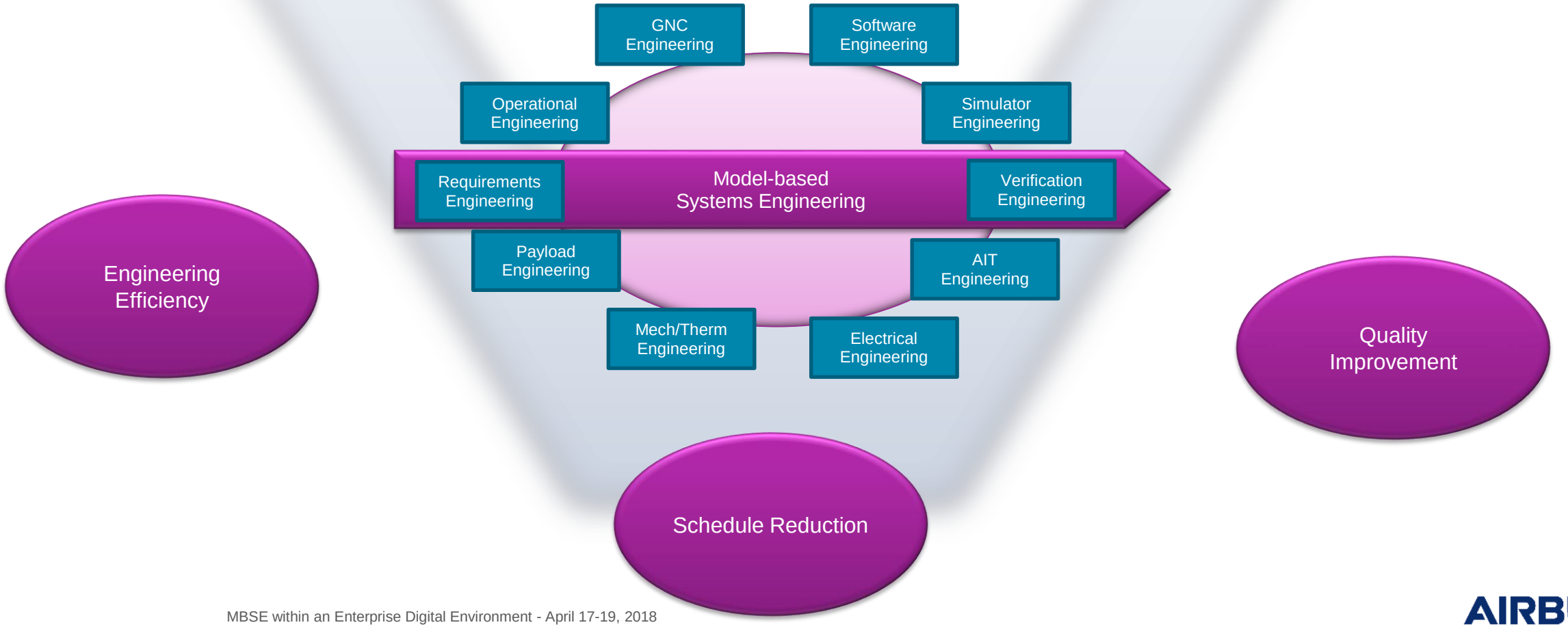
Overview

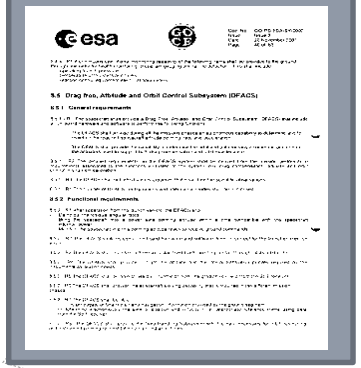


ESA Virtual Spacecraft Design to demonstrate the value of MBSE for space – relying on the concepts of ECSS-E-TM-23 (2008-2011)



Starting point for the VSD developments were key processes – not supported by existing modeling tools or databases

Requirements



Operational Modes

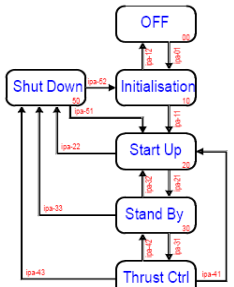
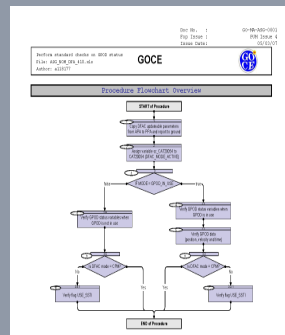


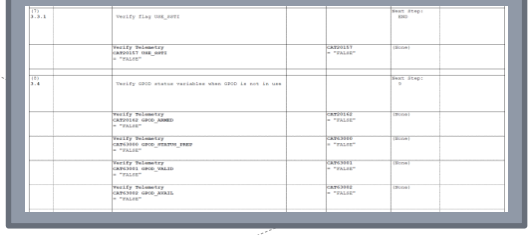
Figure 4-10: IPA Operational Modes and Transitions

Operational Proc



Configuration

Integration Procedure



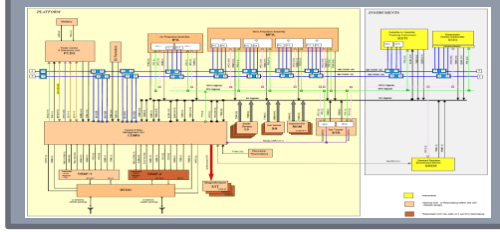
Verification Matrix

7.1.1 Platform SM Verification Matrix

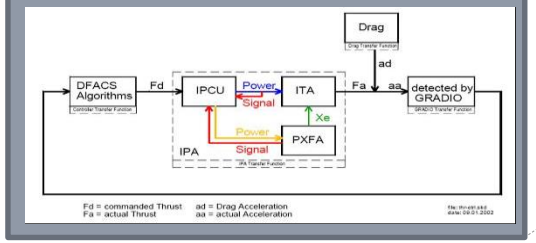
The following table summarises the key requirements and verification method versus the SM configuration:

Requirement Category	Equipment- Level	Platform- Level	Spacecraft- Level
Function	-	-	-
Performance	-	-	-
Leakage	-	-	-
Alignment	-	T	T
Thermo Elastic Stability	-	A	T
Interfaces	T, I	T, I	-
Physical Properties (mass, CoG)	T [1]	-	T
Quasi Static Load	-	-	T
Vibration	-	-	T
Acoustic	-	-	T
Separation Shock	-	-	T
Thermal Verification (TV/TB Test)	-	-	-
EMC- R & C	-	-	-
ESD	-	-	-
Magn. Moment	-	-	-
Radiation environment	-	-	-
Oxygen	-	-	-

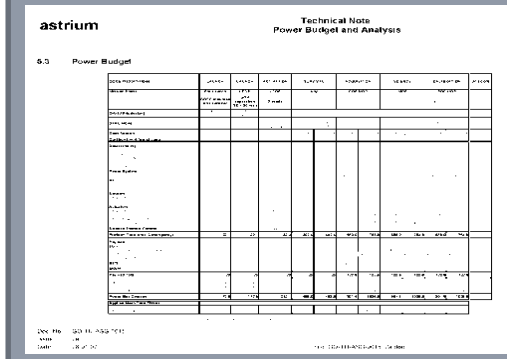
Electrical Interfaces



Functional Architecture



Budgets



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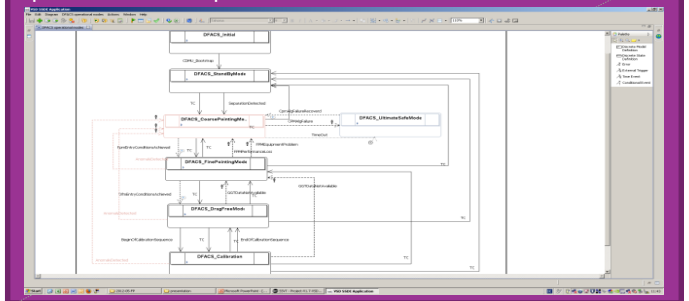
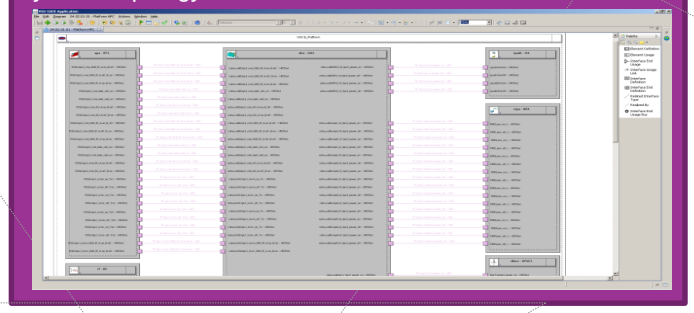
Re-hosting (→ digitalised) of models and views into a system relying on the semantics defined by the CDM of 10-23

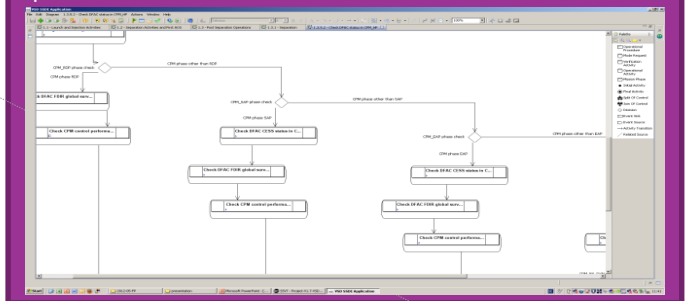
Operational Concept



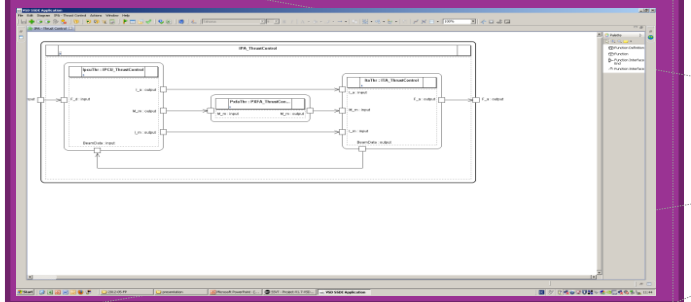
System Topology



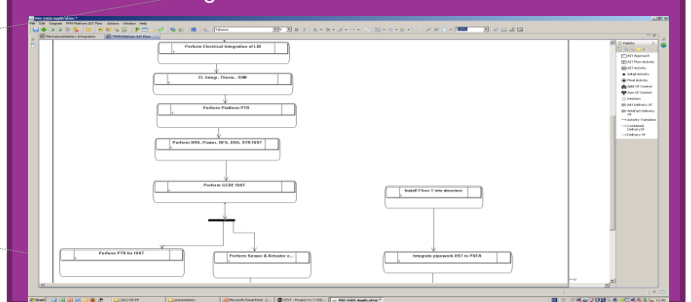
Operational Procedures



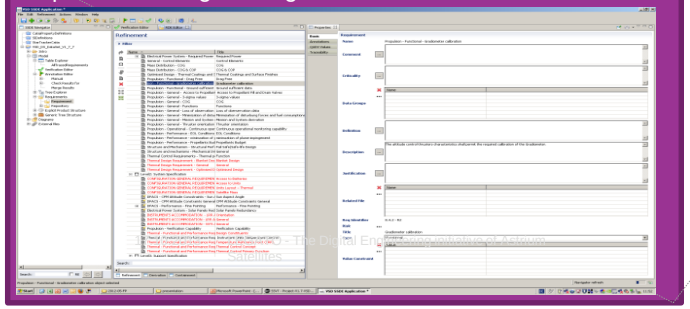
Functional Architecture



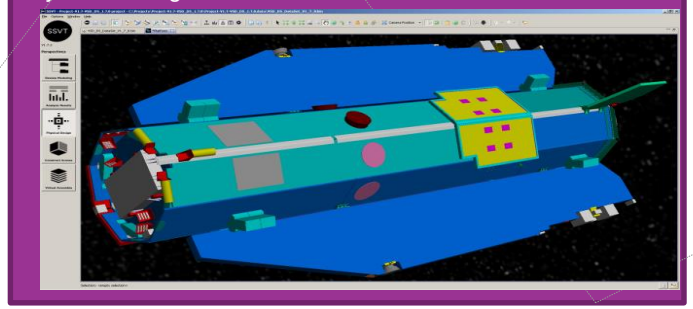
AIT Flow and Integration Procedures



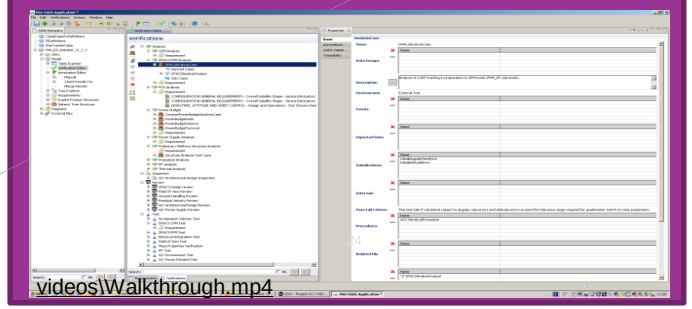
Requirements Engineering



Physical Configuration



Verfication Definitions



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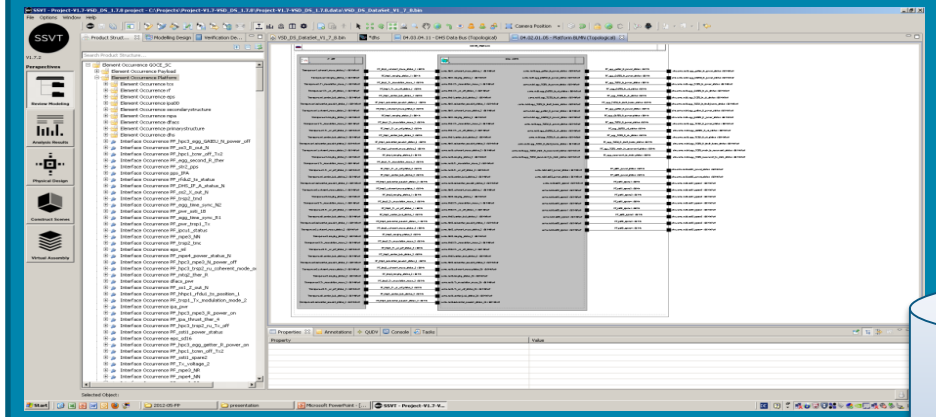
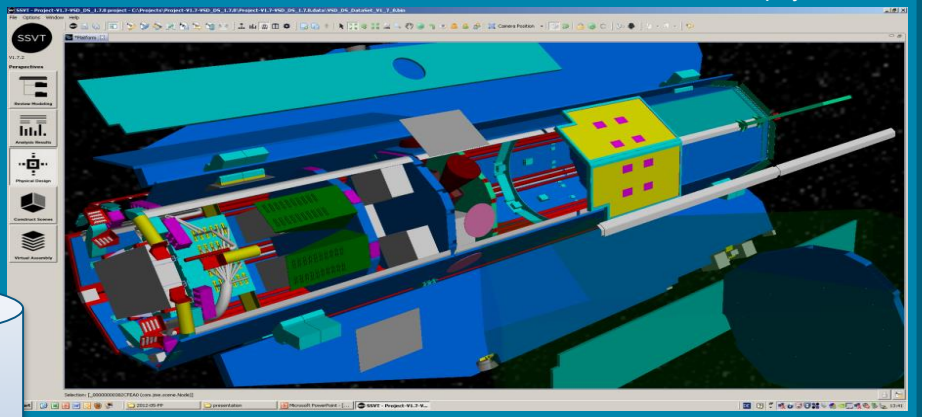
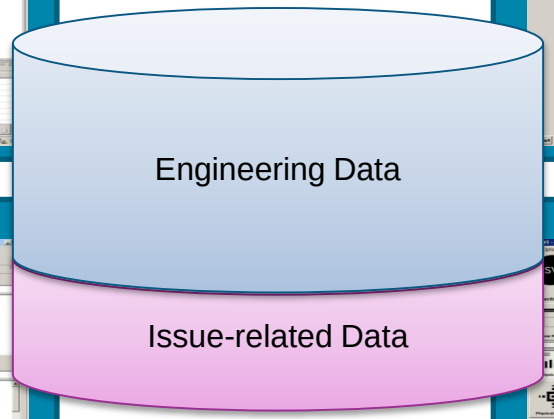
Digitalizing the review use case: provide “data packages” with all data and views – and get “issue-related” data in return

Visualization of all “functional” views and data

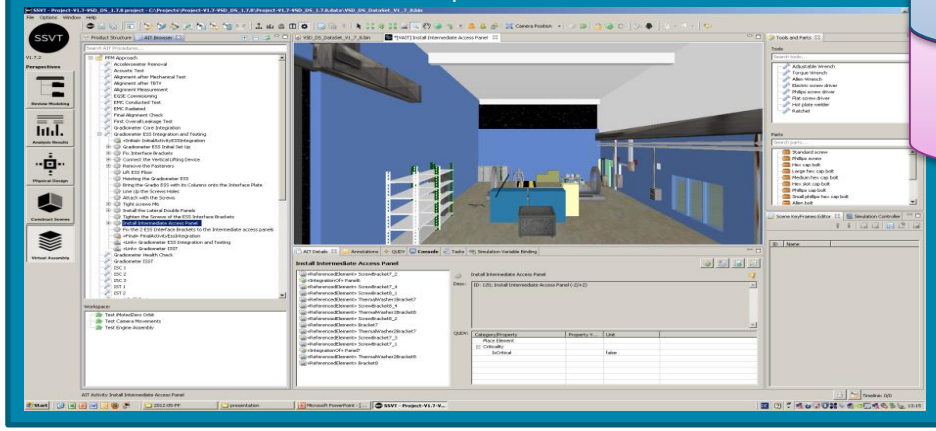


Visualization of all “physical” data

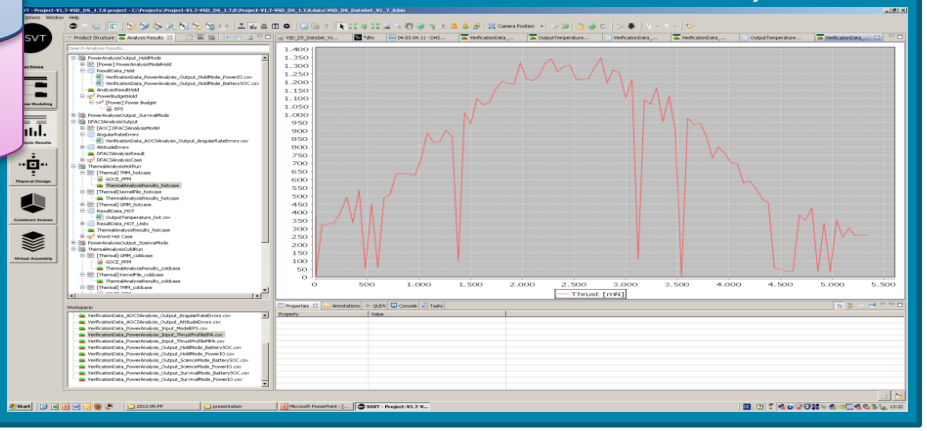




Definition and execution of animated AIT procedures



Visualization of analysis result data



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ECSS-E-TM-10-23 “Space System Data Repository” provided the scoping and definition of the underlying conceptual data model

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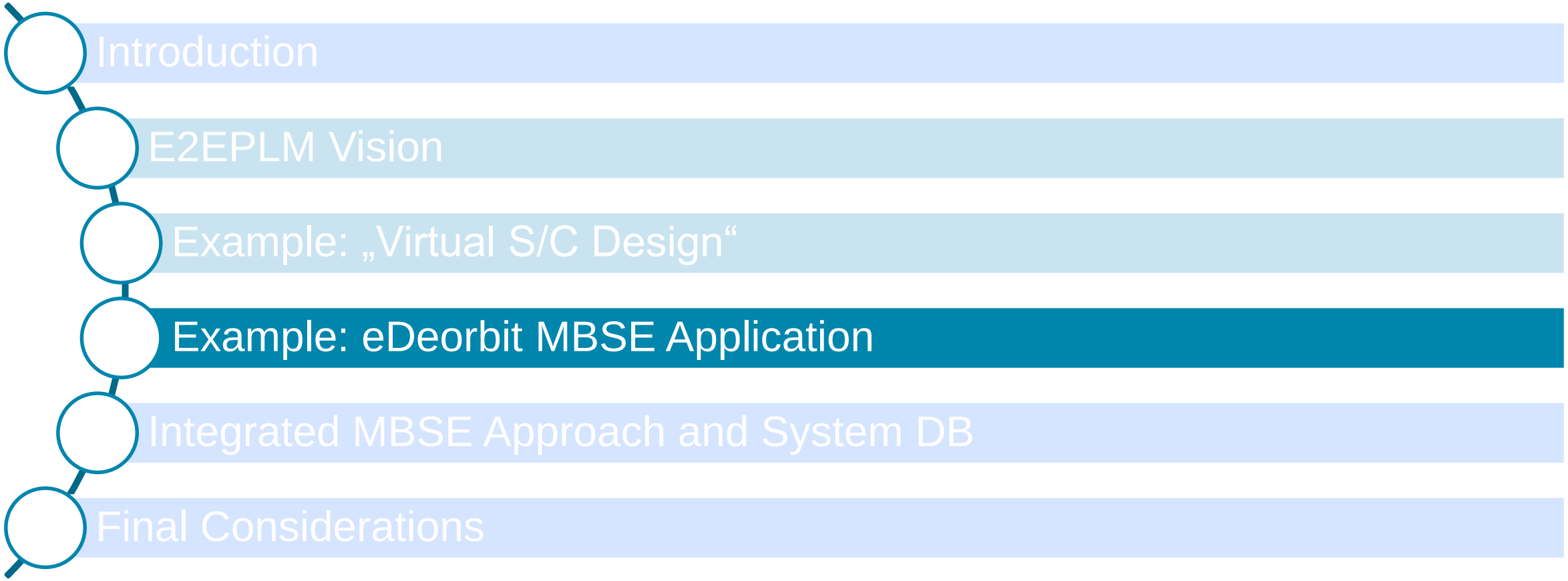
Overview



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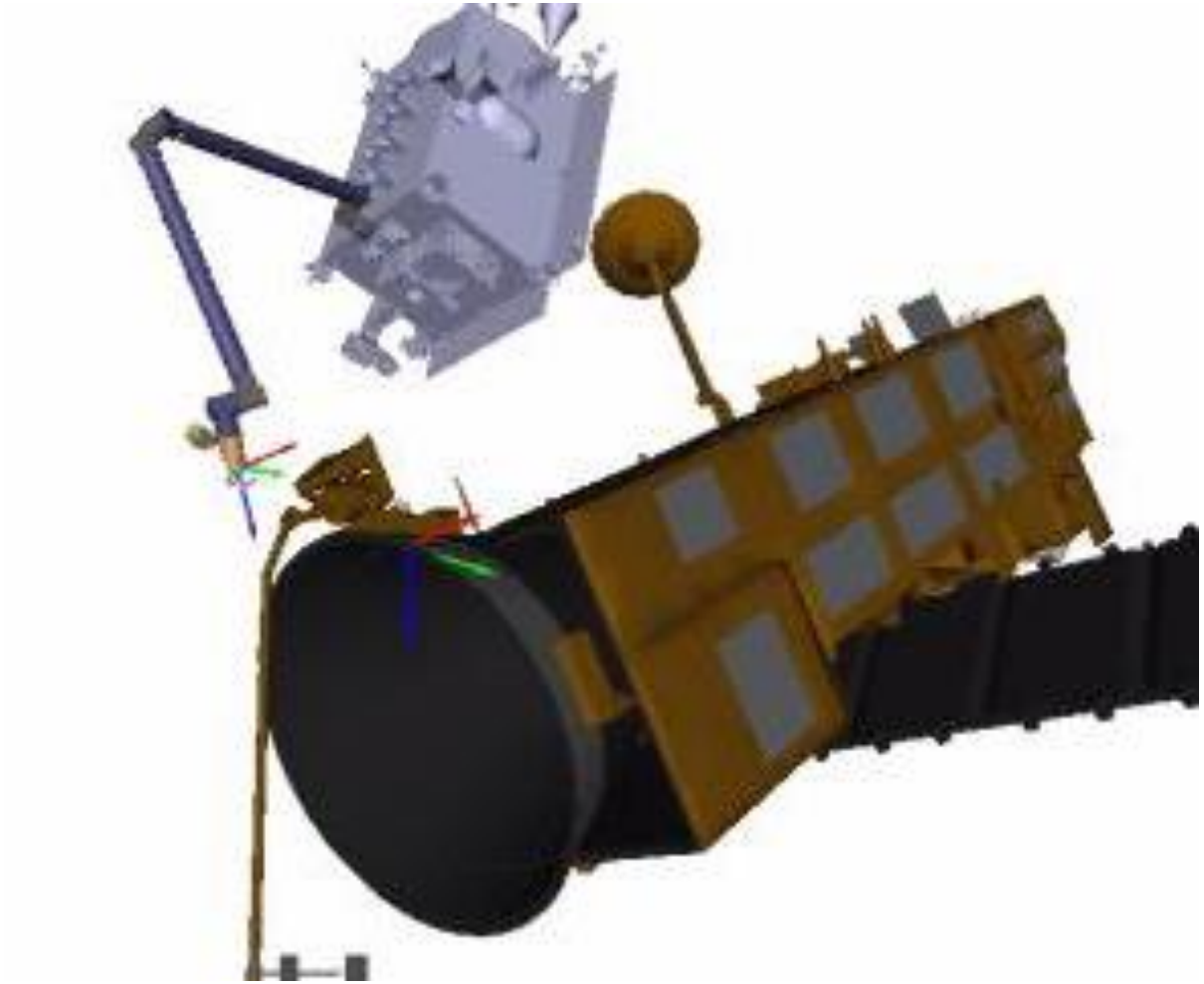
e.Deorbit Mission Concept

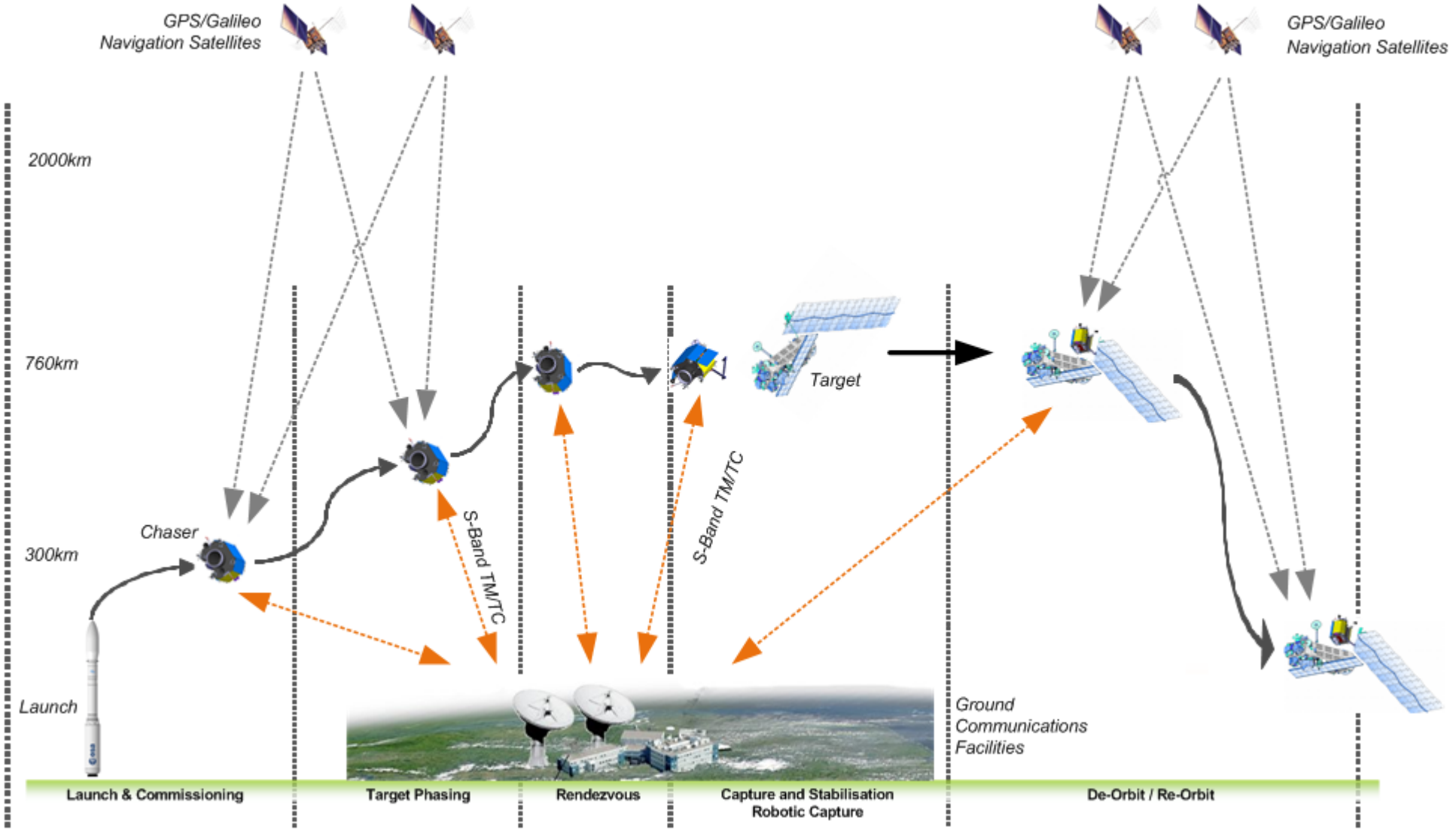


Navigate to the non-cooperative Target satellite and hold a relative position to the Target to allow the operation of the capture mechanisms

Capture of a non-cooperative and non-passivated Target satellite, which also tumble and stabilize it

De-orbit the coupled set of satellite stack (Target and Chaser) in a controlled way

e.Deorbit Mission Phases



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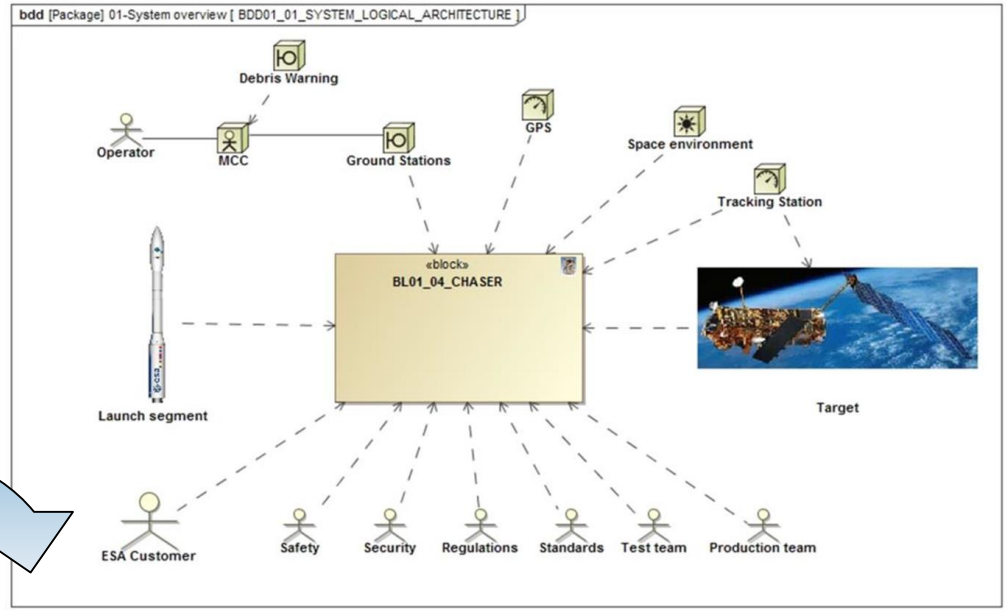
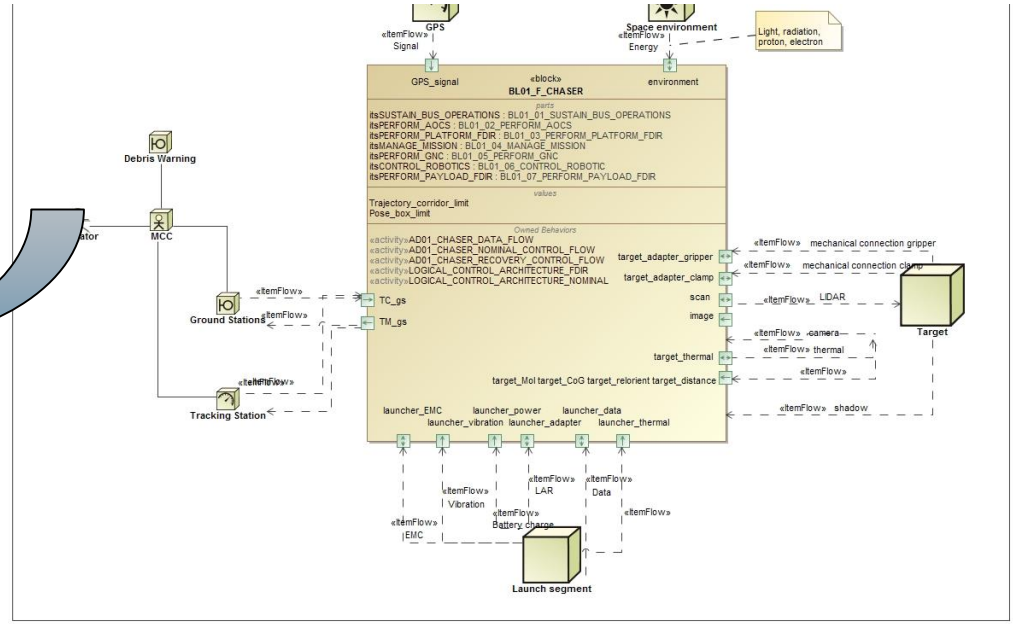
MBSE Application on e.Deorbit





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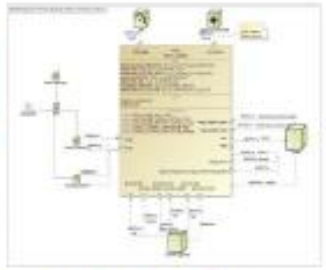
MBSE Application on e.Deorbit

Process based on Federated and Executable Models

Logical Model
Cameo SysML

Describe logical prop. & architectures

- System capabilities def.
- Mission scenario analysis
- System states and modes
- Functions and Safety
- Architectures

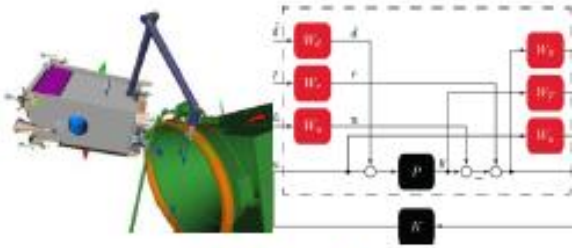


Physical Model
RangeDB

Describe physical prop. & architectures

- Product Tree
- System Budgets
- System sizing
- Physical architecture iterations

Geometrical / Dynamic Model



Exchange of model data in standardized data flows

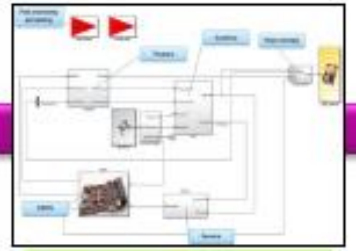
ModelCenter

Analyse & Validate System

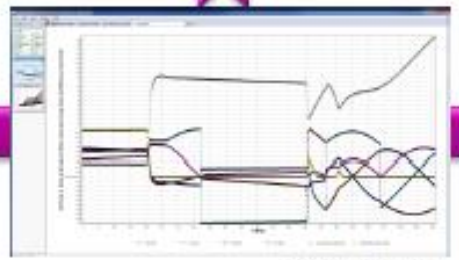
- Parameter trends
- Parameter coupling
- Optimisation
- Requirements verification

Analysis Flows

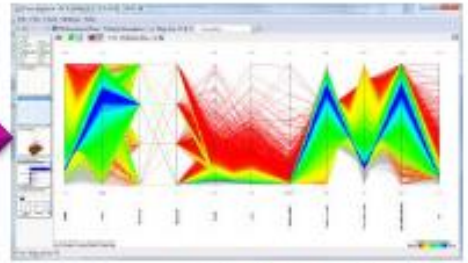
Domain Models



Generate physical data



Data analysis



Sensitivity, Optimization

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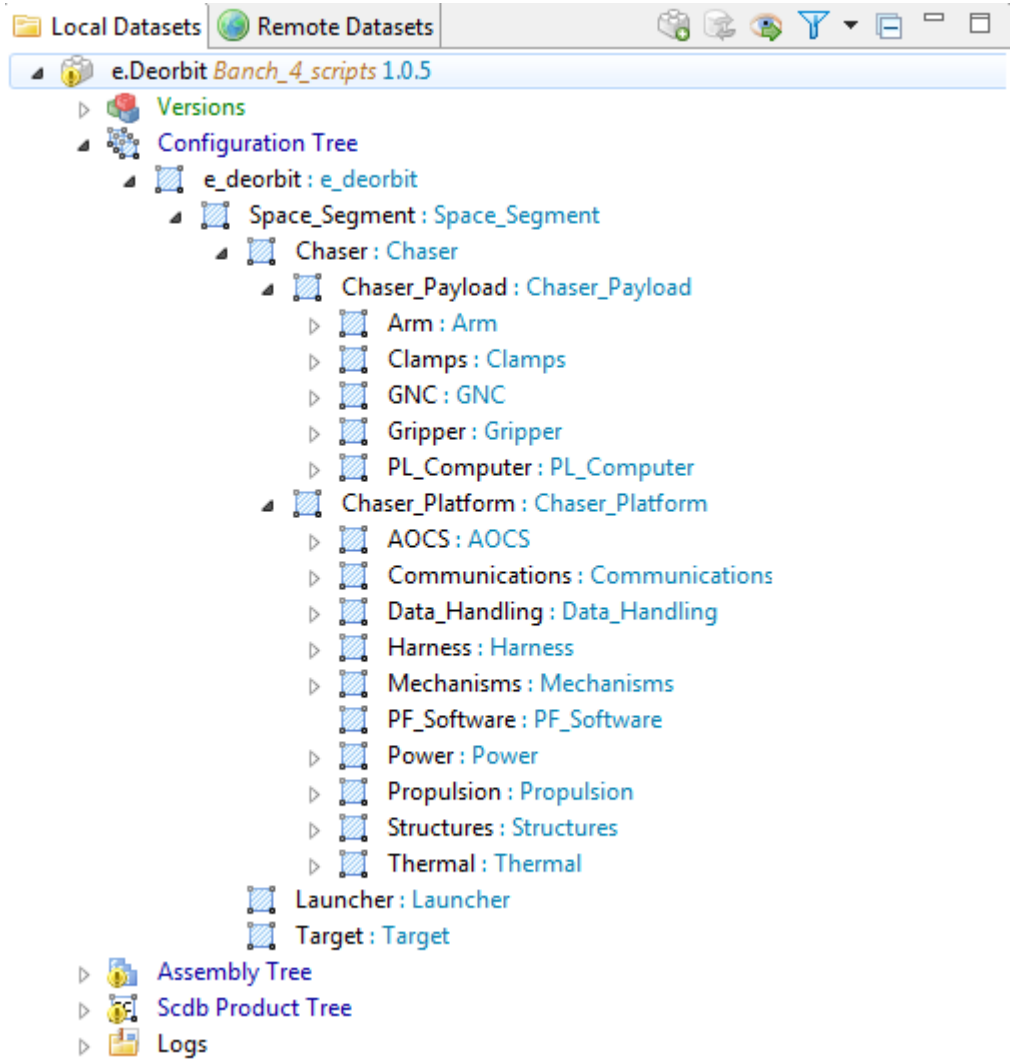
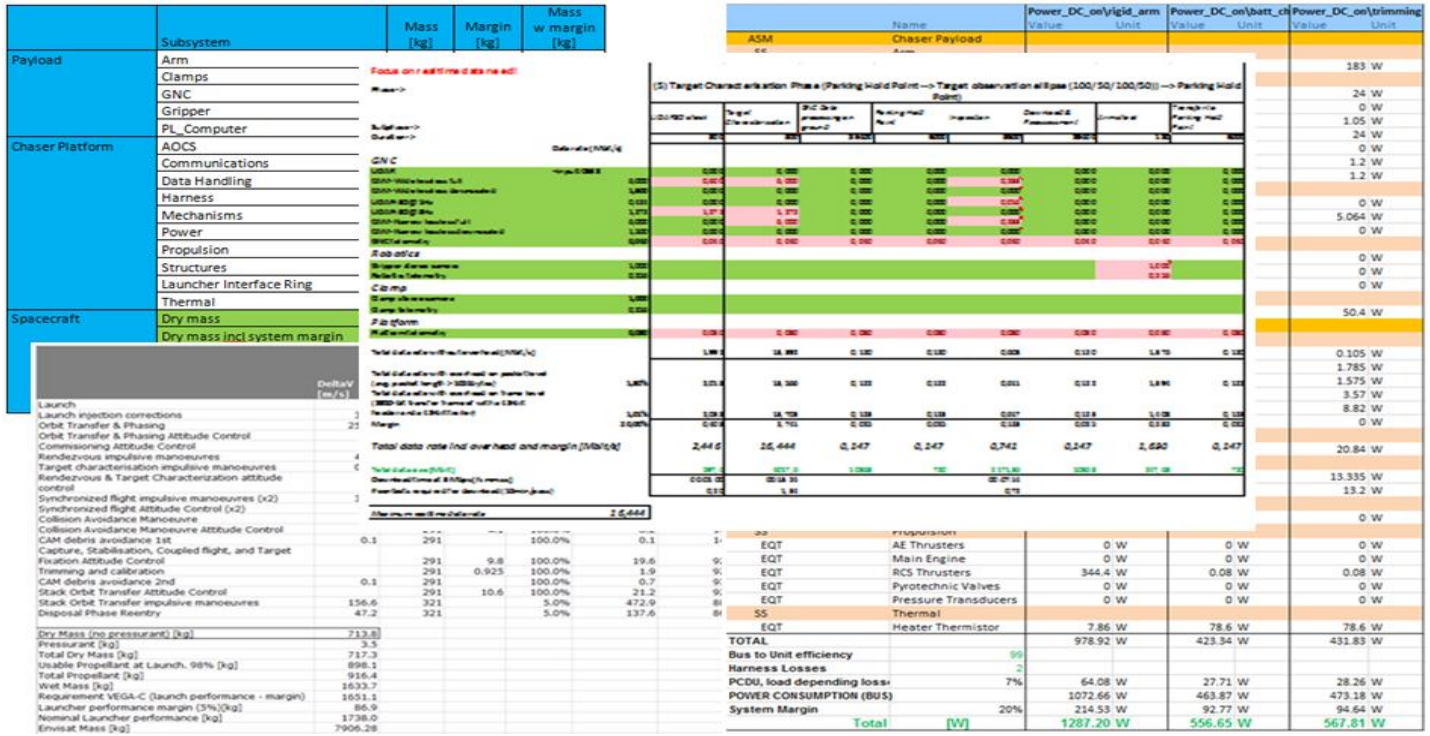
e.Deorbit: Product Tree Model

Collaborative description of the chaser physical architecture and management of the system budgets





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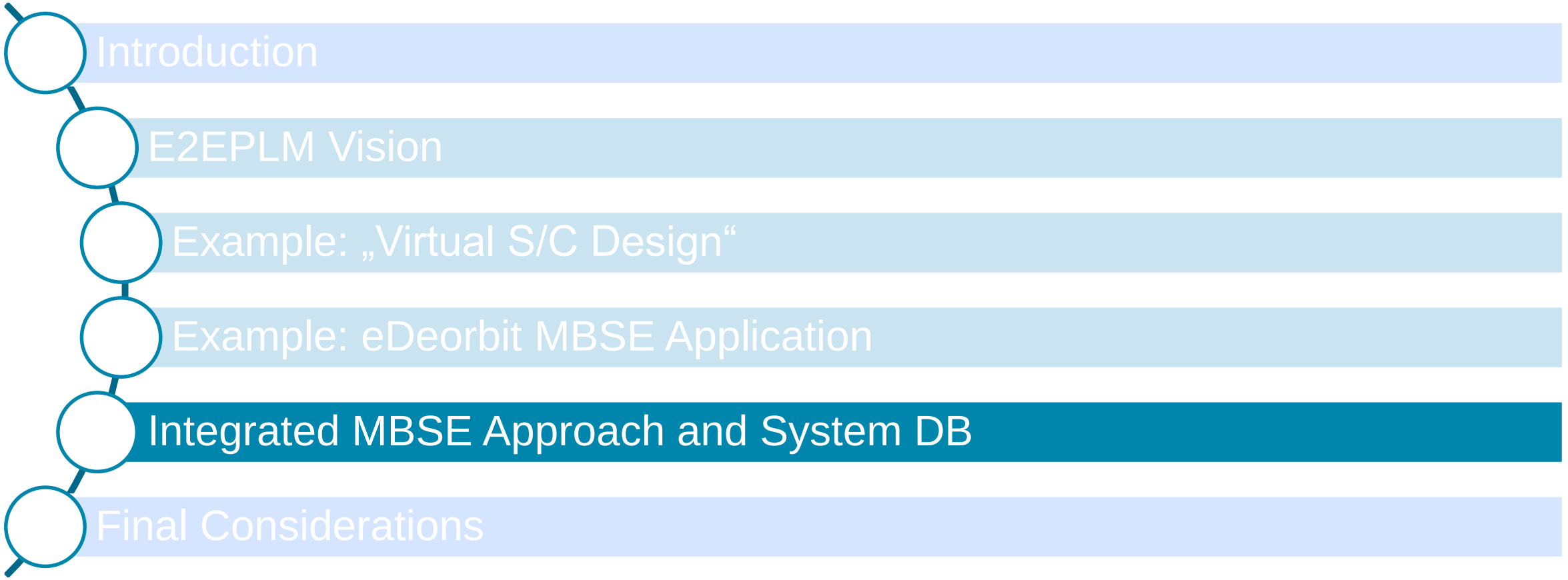
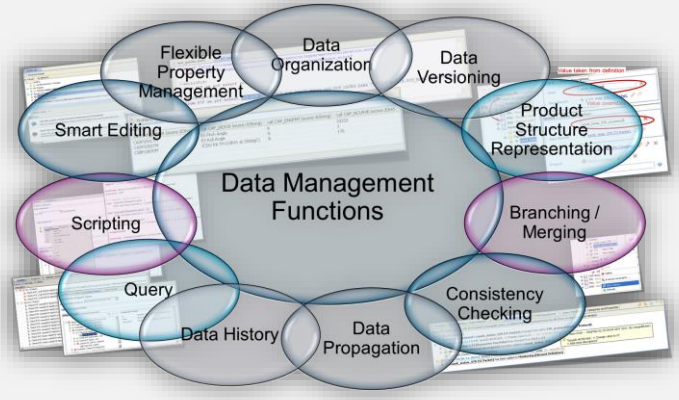
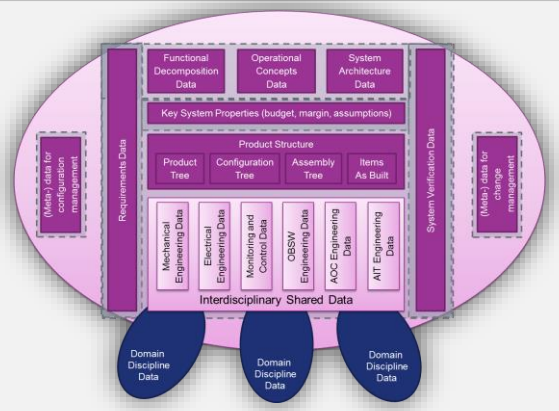
Overview


Introduction
E2EPLM Vision
Example: „Virtual S/C Design“
Example: eDeorbit MBSE Application
Integrated MBSE Approach and System DB
Final Considerations

RangeDB – Powerful and flexible Data Management

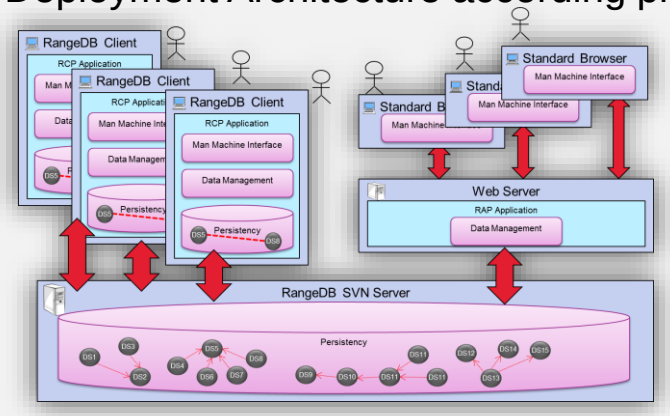


Powerful Data Management support day-2-day activities

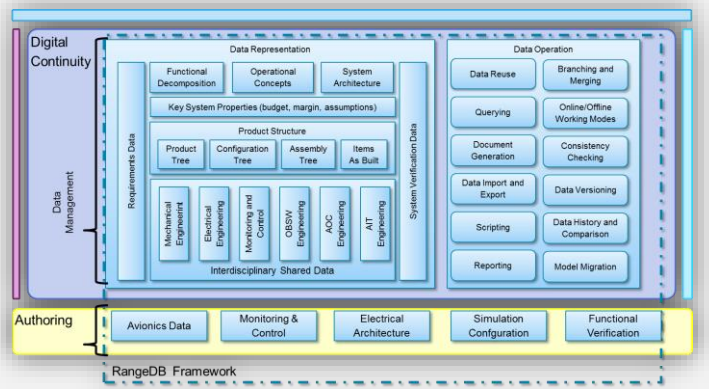


Semantic Data Model for multi-disciplinary Integration

Flexible Deployment Architecture according project needs



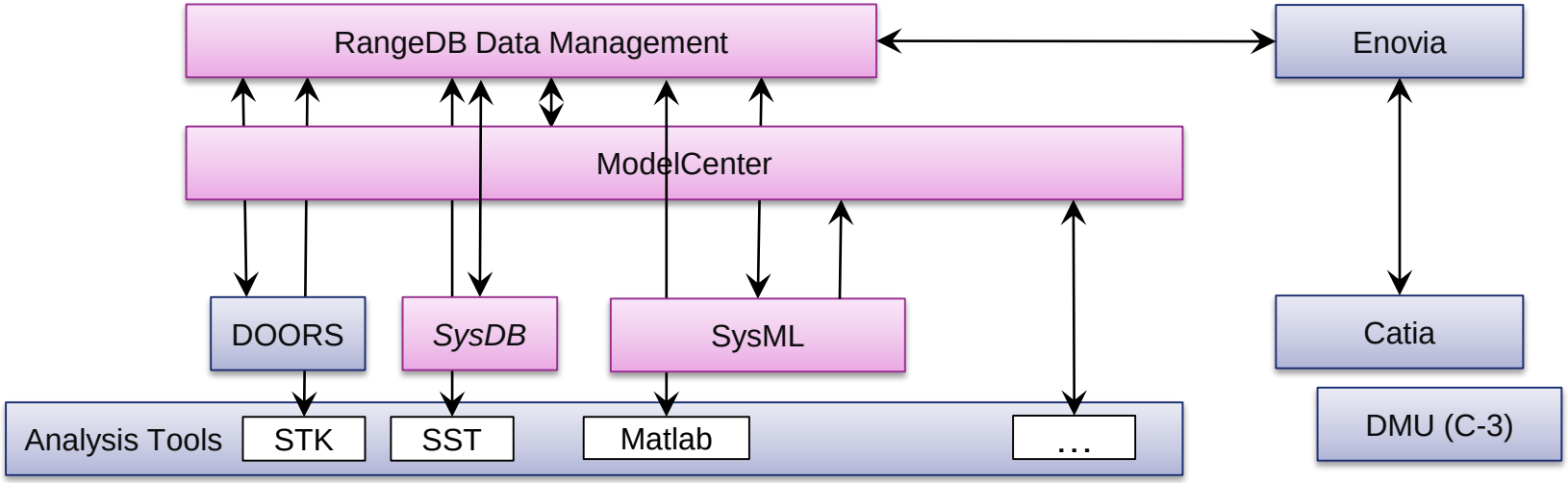
Stable and modular Framework enabling extensibility



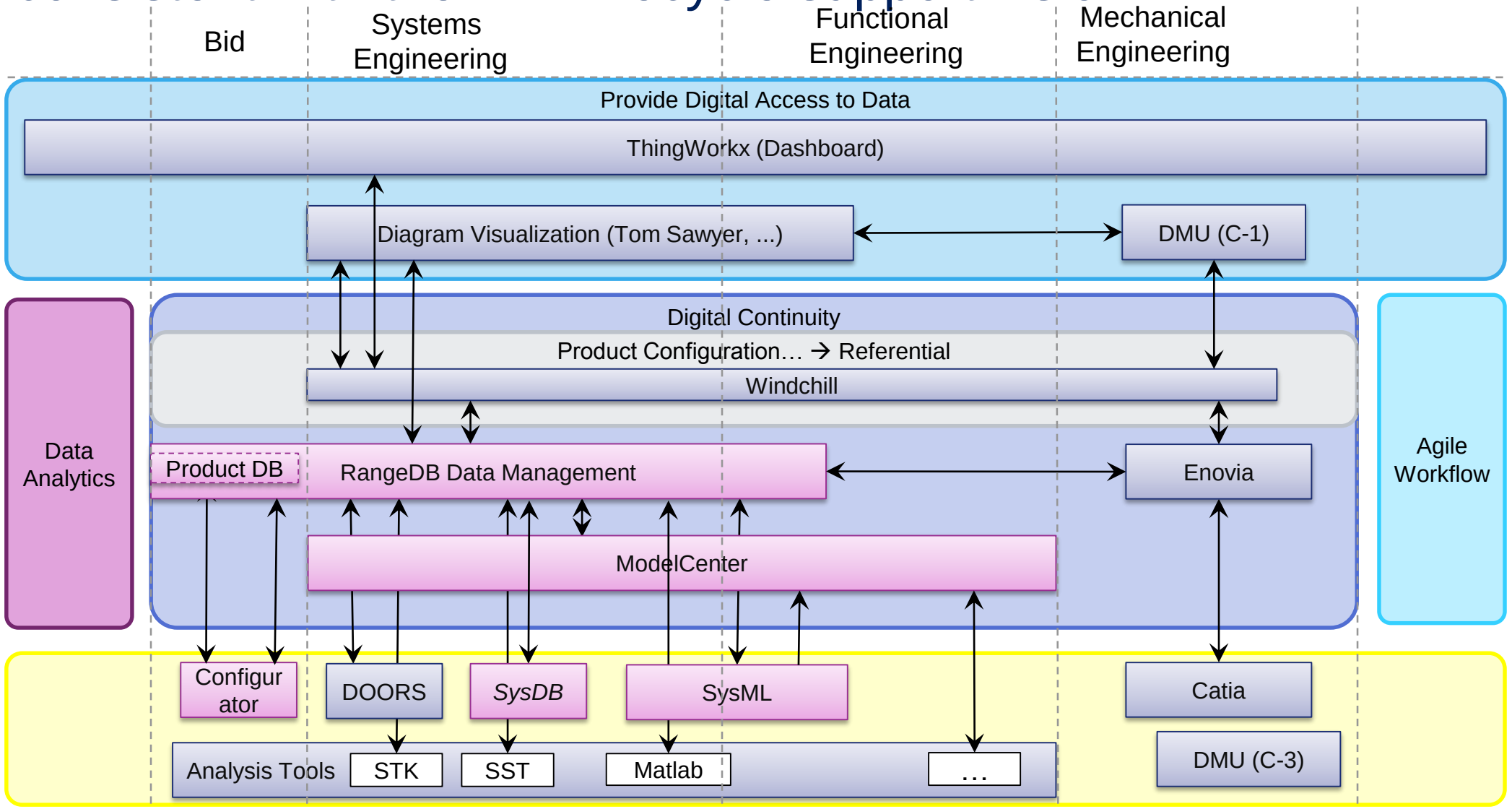
AIRBUS

Way forward for the system design environment (MBSE)

Preliminary reference environment demonstrated on various pilots as depicted blow



Way forward for the system design environment (MBSE) is fully consistent with the E2E lifecycle support vision



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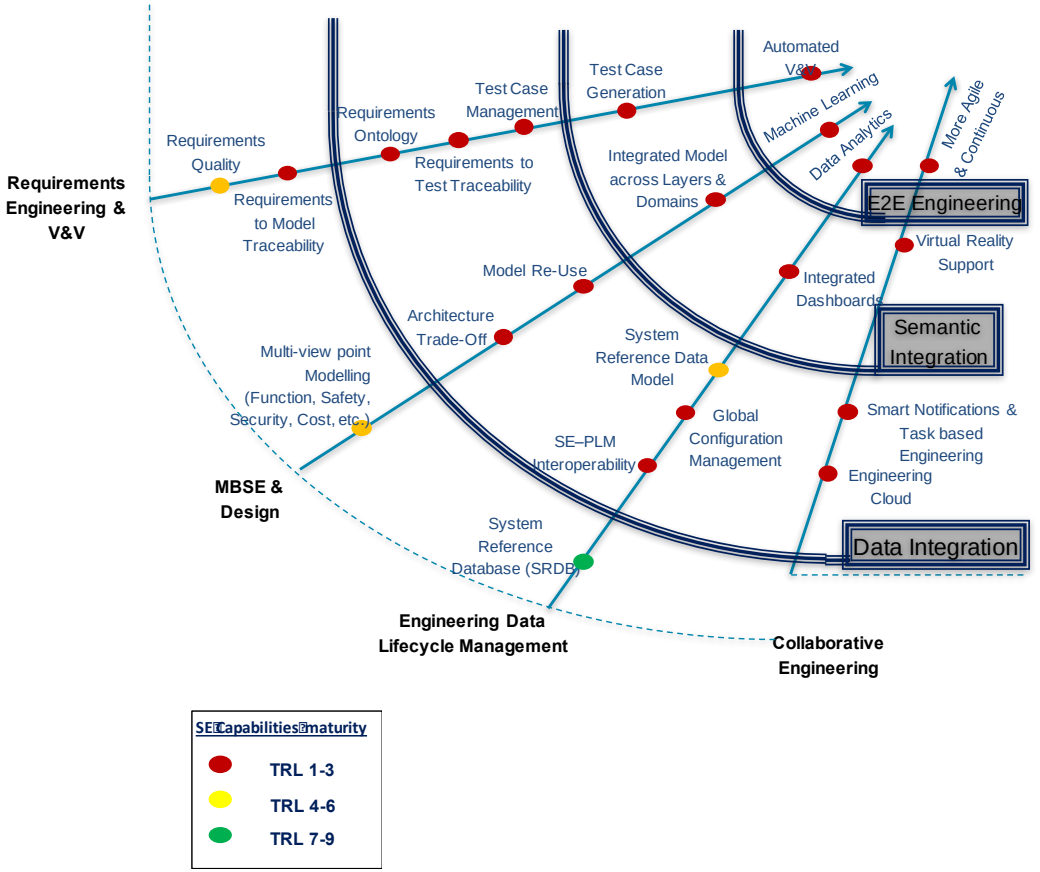
System Engineering Technology Roadmap

- Roadmap is structured into two dimensions:
  - Technology Clusters
  - System Engineering Technology (SET) Integration Levels

- SET Integration Levels
  - Major milestones towards an end-to-end engineering environment
  - Passing a level requires integration of specific technologies (i.e. dedicated integration project)

- System Engineering Technology (SET) Integration Levels
  - Data Integration (connecting data)
  - Semantic Integration (identifying rules how to connect & understand data)
  - End-to-End (end-to-end data manipulation and understanding)



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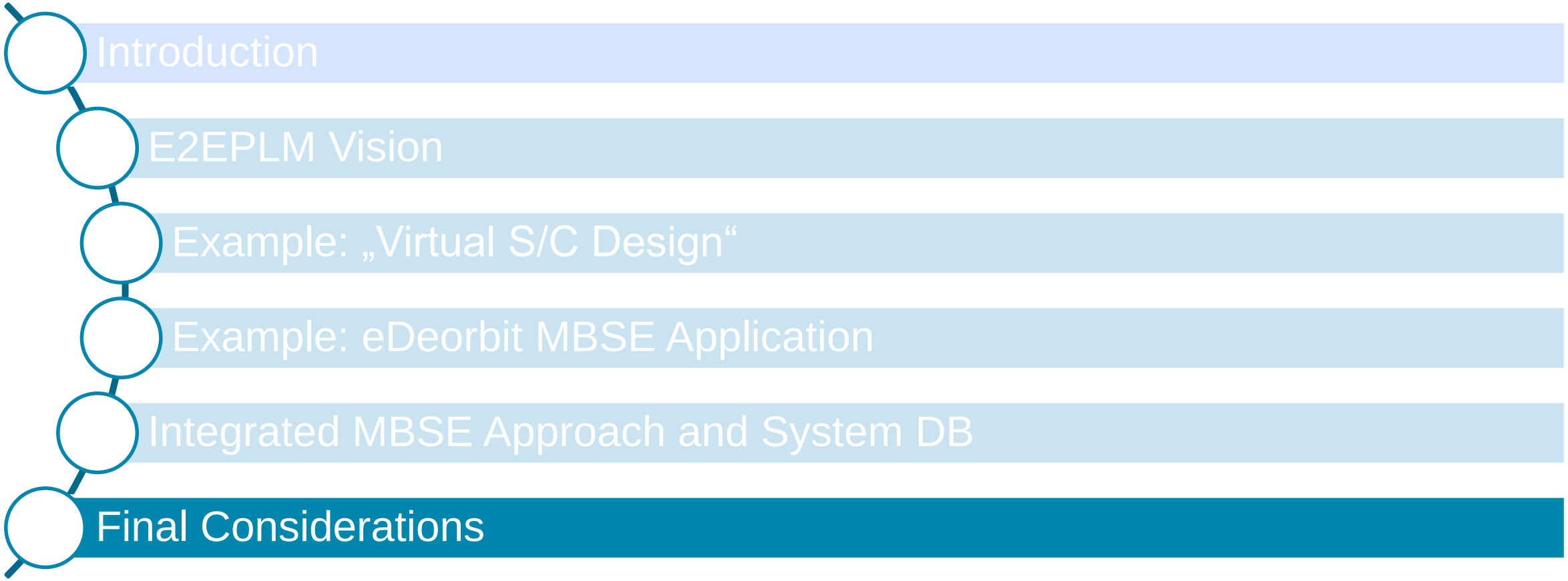
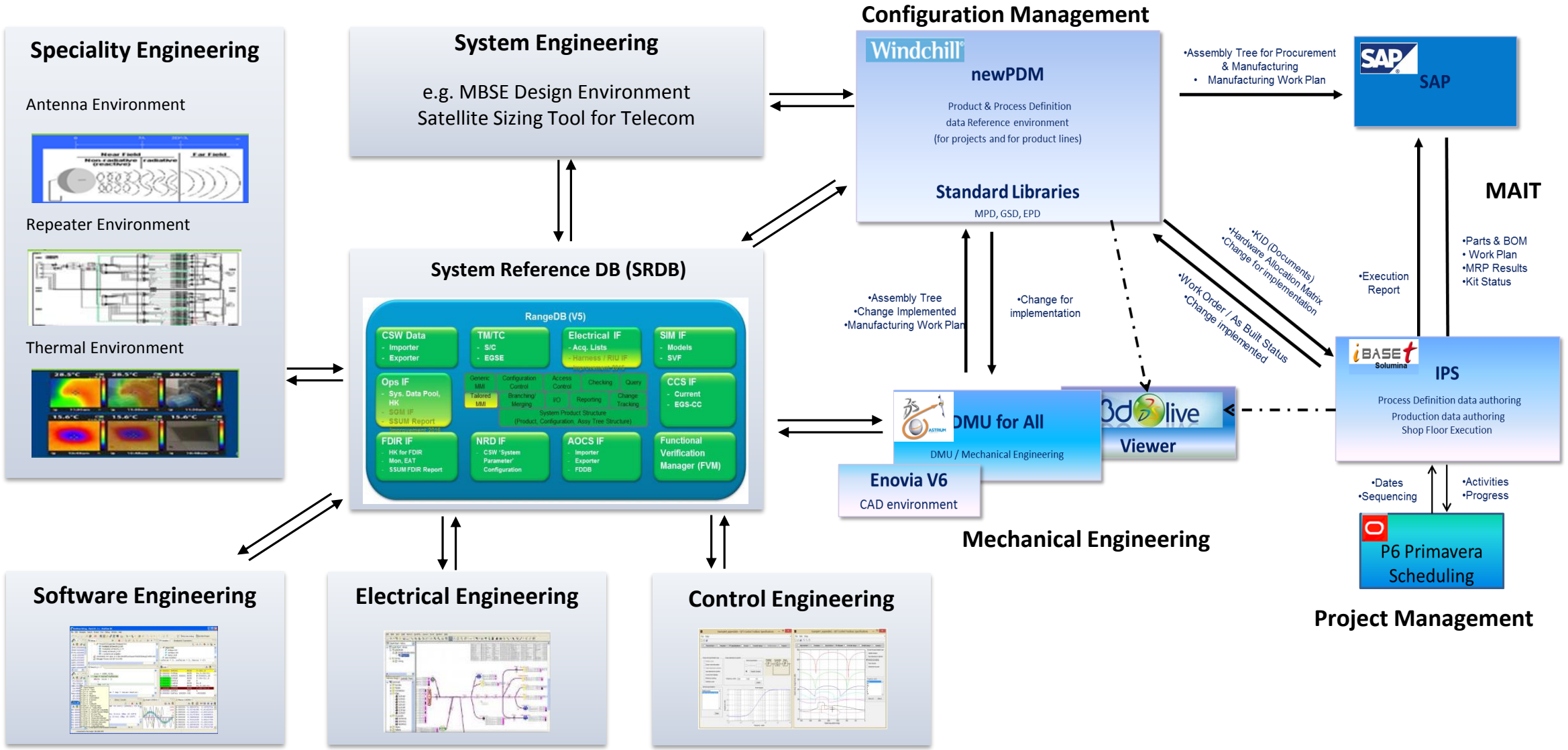
Overview


Introduction
E2EPLM Vision
Example: „Virtual S/C Design“
Example: eDeorbit MBSE Application
Integrated MBSE Approach and System DB
Final Considerations

Digital End-to-End (System & Product) Engineering



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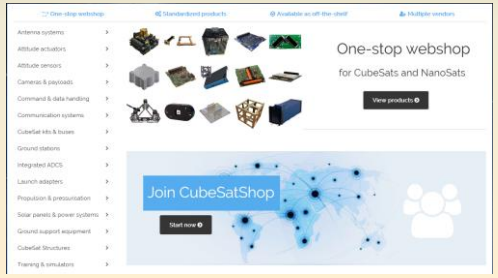
End-to-End Connected Company

CIs and Building Blocks Catalog & Configurator



Business Development & Sales

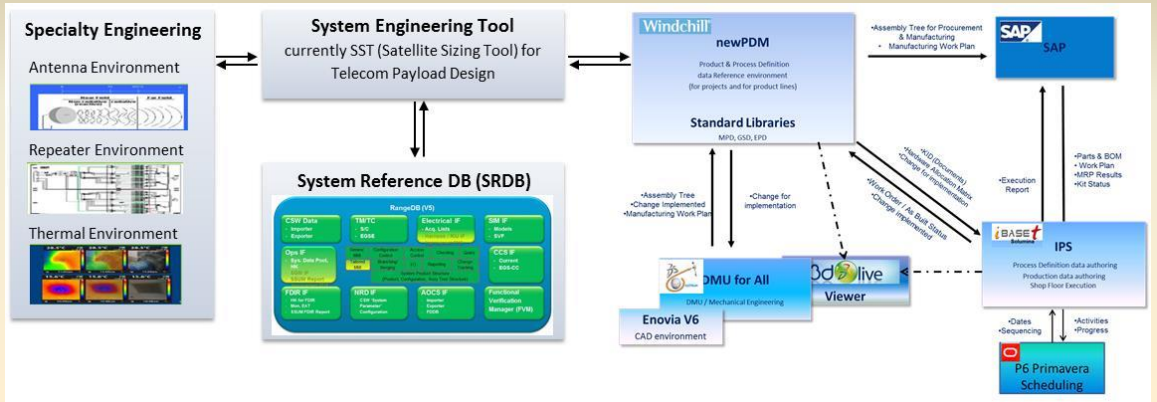
Proposal / Customization Team

Extended Enterprise
- Customer
- Partner
- Supplier

Big Data / Data Analytics

S/C Fleet Management Tool

Digital End-to-End Engineering



Cyber & Product Security

AIRBUS


Project Management
Cyber & Product Security
System Reference DB (SRDB)
Big Data / Data Analytics
MAIT
System Engineering
Extended Enterprise
Control Engineering
Mechanical Engineering
Software Engineering
Electrical Engineering
Configuration Management
Product Configurator


Project Management
Cyber & Product Security
System Reference DB (SRDB)
Big Data / Data Analytics
MAIT
System Engineering
Extended Enterprise
Control Engineering
Mechanical Engineering
Software Engineering
Electrical Engineering
Configuration Management
Product Configurator

Project Management

Cyber & Product Security

stem Reference DB (SR

ata Analytics MAIT System Engineering Extended Ent

ntrol Engineeri

Leveraging Technology for Systems Engineering Tools

FROM

Current systems engineering tools leverage computing and information technologies to some degree, and make heavy use of office applications for documenting system designs. The tools have limited integration with other engineering tools.

TO

The systems engi

with related fields. Systems engineering tools will integrate with CAD/CAE/PLM environments, project man-
agement and workflow tools as part of a broader computer-aided engineering and enterprise management
environment. The systems engineer of the future will be highly skilled in the use of IT-enabled engineering
tools.

, immersive
support data integration, search,
pport collaboration. Systems engineering tools will
tivity and knowledge representation to readily exchange information
. Systems engineering tools will integrate with CAD/CAE/PLM environments, project man-
agement and workflow tools as part of a broader computer-aided engineering and enterprise management
environment. The systems engineer of the future will be highly skilled in the use of IT-enabled engineering
tools.

From: A World in Motion – Systems Engineering Vision 2025 – INCOSE 2014

Cyber Security — Securing the System

FROM

Systems, personal and national security are increasingly being compromised due to the d… nected nature of our infrastructure. Engineers are hard pressed to keep up with th… increasing sophistication of the threats to our cyber-physical systems. Cyber… with only as an afterthought or not addressed at all.

TO

Systems engineering routinely incorporat… hance systems and information security and resiliency to cyber threats early an… yber defense capabilities over the full system life cycle, based on an increasi… ools and methods. Cyber security is a fundamental system attribute that system… and incorporate into designs using the following strategies:

- …nd system behavior
- …gement of access rights and privileges
- Use of testbeds for assessing new threats in fielded systems
- Supply-chain diligence
- Certification and accreditation standards
- Formal methods for identification of vulnerabilities

Systems engineering routinely incorporates requirements to enhance systems and information security and resiliency to cyber threats early and is able to verify the cyber defense capabilities over the full system life

From: A World in Motion – Systems Engineering Vision 2025 – INCOSE 2014

Virtual Engineering
Part of The Digital Revolution

FROM

Model-based systems engineering has grown in popularity as a w
ment-based approaches, but is still in an early stage of m
CAE.

TO

Formal systems m
ying, analyzing, designing, and verifying systems,
and is ful
odels. System models are adapted to the application do-
models for representing all aspects of systems. The use of internet-
ion and immersive technologies enable highly efficient and shared human
ems in a virtual environment that span the full life cycle from concept through
, manufacturing, operations, and support.

Formal systems modeling is standard practice for specifying, analyzing, designing, and verifying systems, and is fully integrated with other engineering models. System models are adapted to the application domain, and include a broad spectrum of models for representing all aspects of systems. The use of internet-

From: A World in Motion – Systems Engineering Vision 2025 – INCOSE 2014

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Collaborative Engineering: Integrating Teams and Organizations Across All Boundaries

FROM

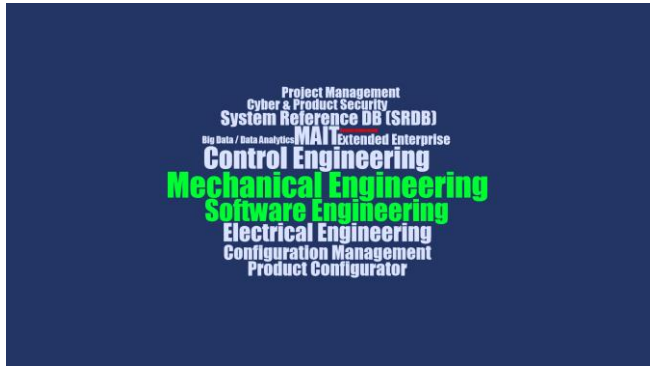
Today, systems engineering processes are often not well integrated with program management and discipline-specific processes such as hardware, software, test, manufacturin… operations, and logistics su… program and prod… time consuming an… among developmen… participants.

TO

In 2025 and beyond, syst… ns engineering will be a key in… collaborative enterprise… regions, cultures, … life cycle phases. … inary engineer- … ntegrated to … execution, … n will extend … stomers, … iers are inte- … development.

This will result in multi-disciplinary engineering workflows and data being integrated to support agile program planning, execution, and monitoring. The collaboration will extend across the supply chain so that customers, primes, subcontractors, and suppliers are integrated throughout all phases of development.

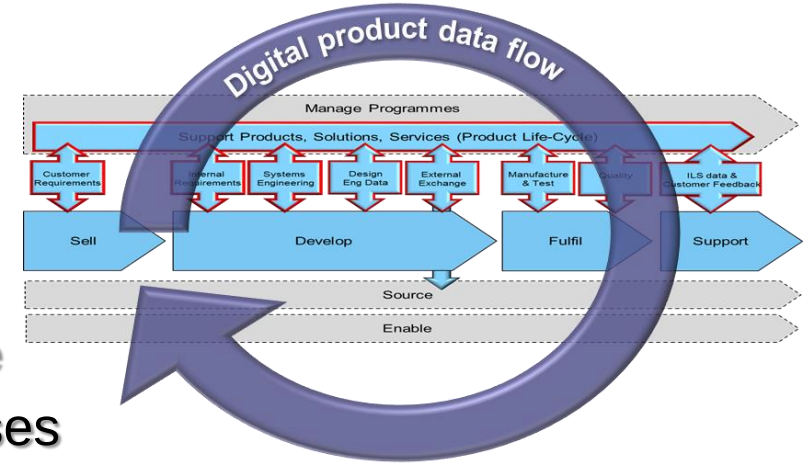
From: A World in Motion – Systems Engineering Vision 2025 – INCOSE 2014

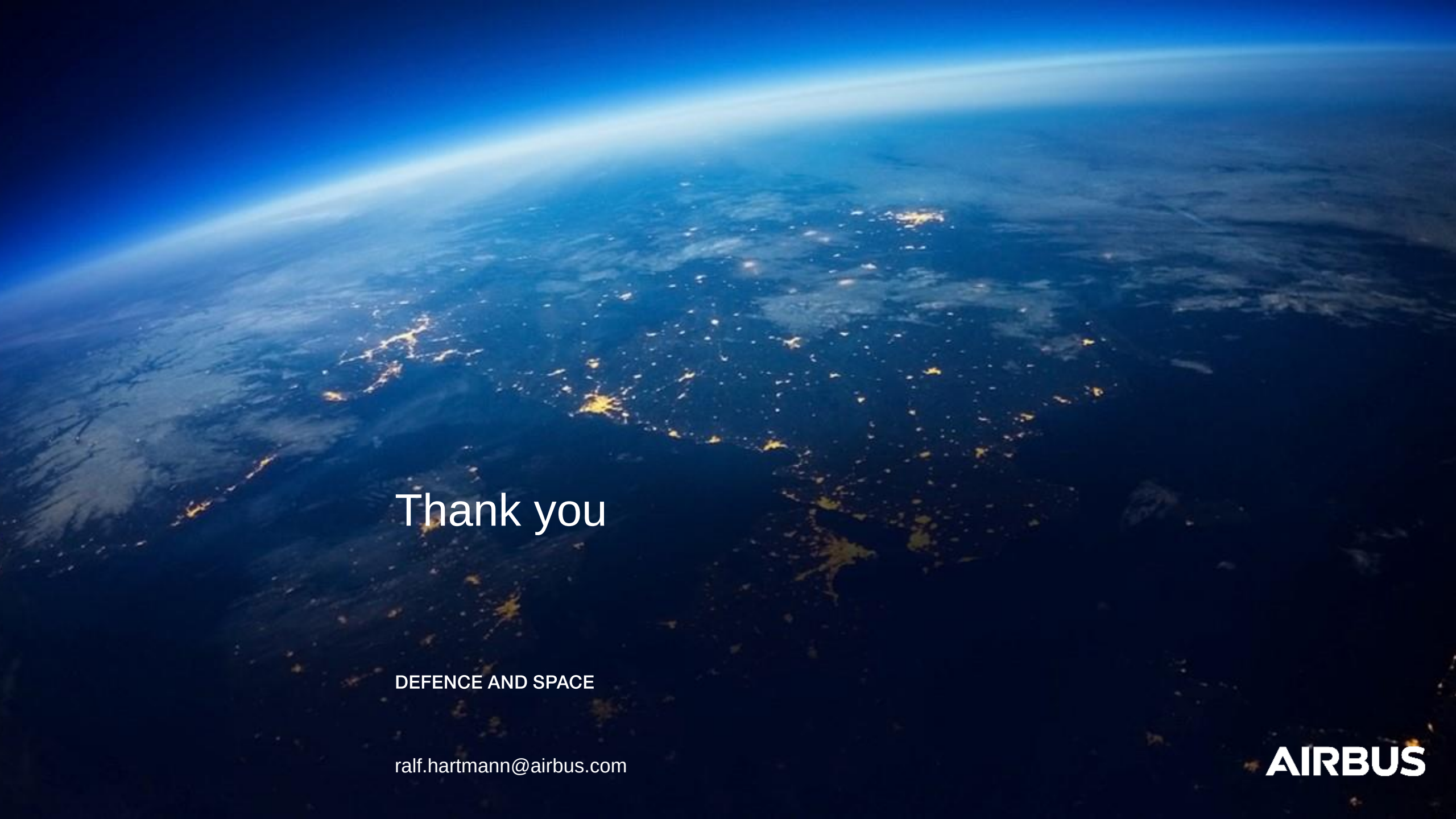


Catch up as a discipline
in digitalization

The 2 challenges for System Engineering

Shape the future
integrated processes





Thank you

DEFENCE AND SPACE

ralf.hartmann@airbus.com

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