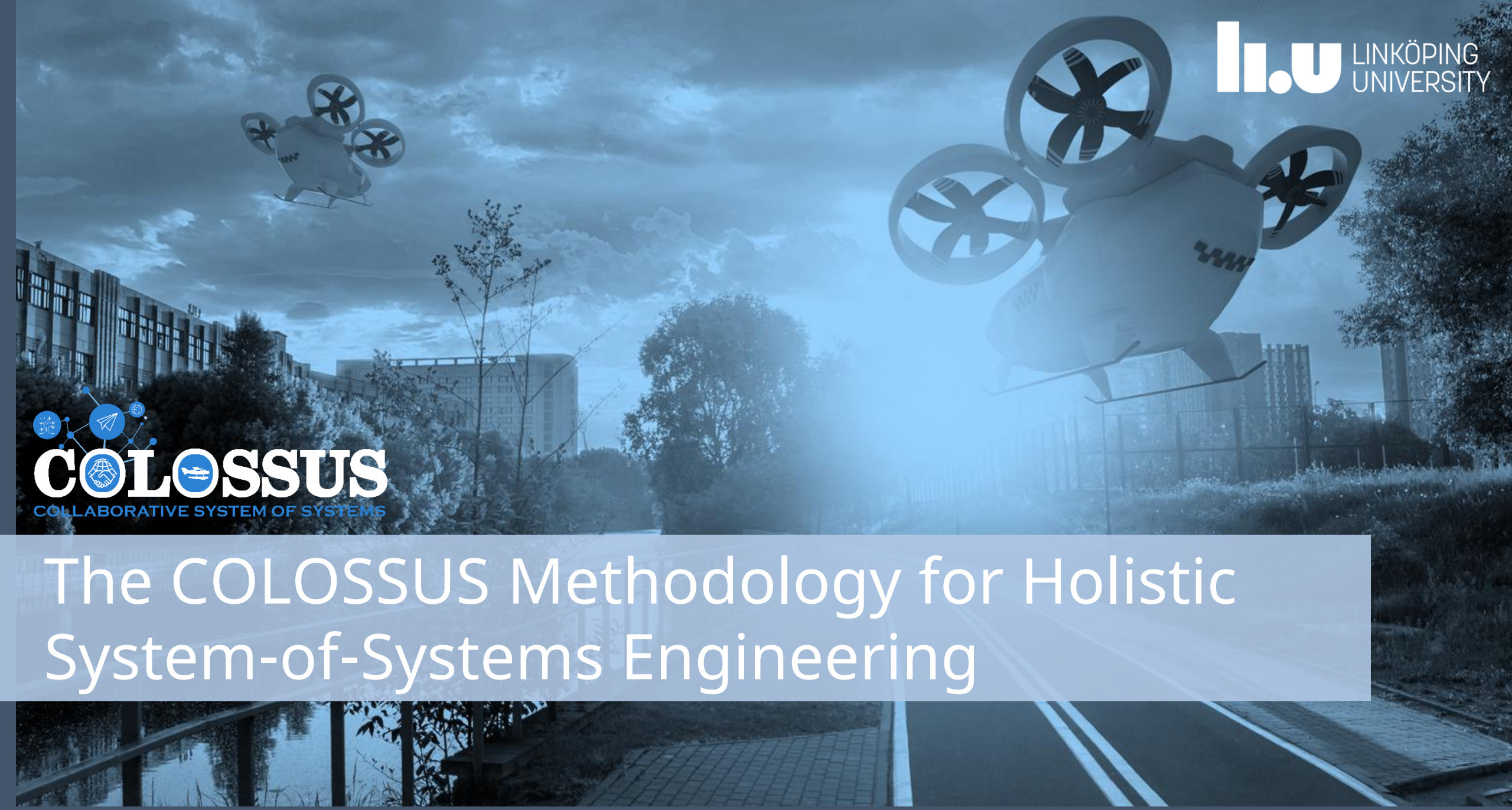


The COLOSSUS Methodology for Holistic System-of-Systems Engineering

Agenda

- What is COLOSSUS?
- What is a System-of-Systems?
- Project Overview and Approach
- The Case Study
- Methodology Overview
- Outlook
- Conclusions

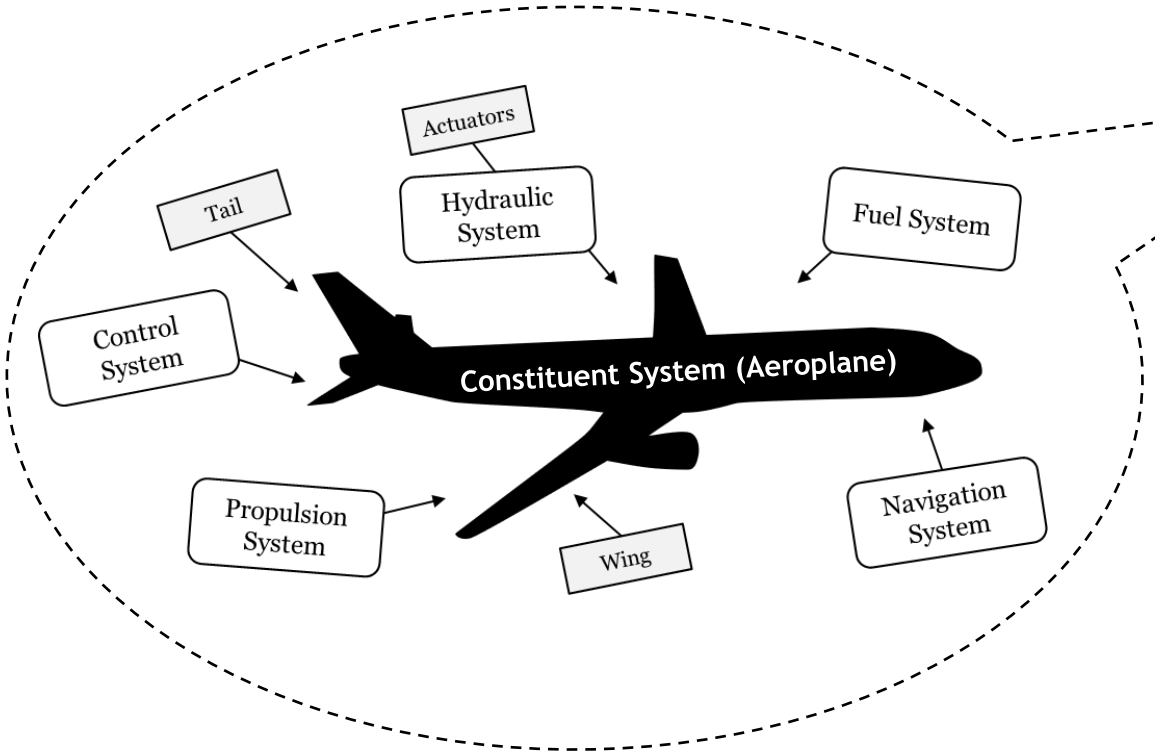
What is COLOSSUS?

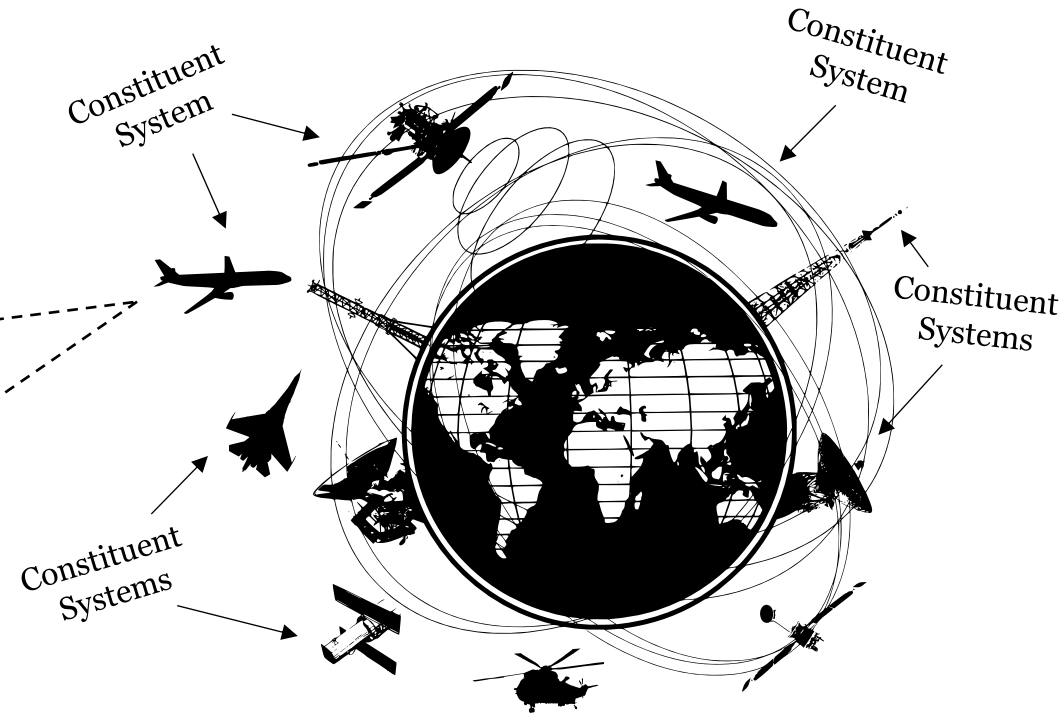
- Collaborative System of Systems Exploration of Aviation Products, Services & Business Models (COLOSSUS)
- Funded by the European Union under the Horizon Europe Program
  - Project Time Frame: 2023-2026
  - Funding Volume: 5 Million €
- The involved partners:
- The main objective:
  - To develop a system-of-systems design methodology which will enable the combined optimization of aircraft, operations and business models

German Aerospace Center
Institute of System Architectures in Aeronautics
Linkopings Universitet
Office National D'etudes Et De Recherches Aerospatiales
Università Degli Studi Di Napoli Federico II
Saab Aktiebolag
Costruzioni Aeronautiche Tecnam
Technische Universiteit Delft
GKN Aerospace
Thelsys GmbH
Institutul National De Cercetare-Dez voltare Aerospatiala "Elie Carafoli"
Politecnico Di Torino
Smartup Engineering Srl
Statens Vag- Och Transportforskningsinstitut
CFS Engineering

What is a System-of-Systems?

- System-of-Systems (SoS)?



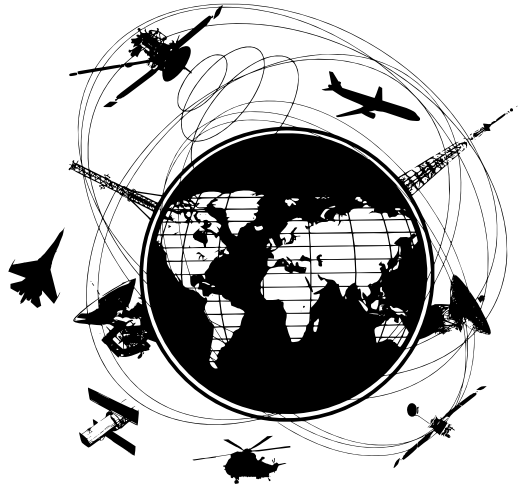


A system of systems is a collection of independent, interoperating systems that work together to deliver capabilities no single system can achieve alone

Each (constituent) system can operate on its own – but real value emerges when they collaborate

What is a System-of-Systems?

- Why a System-of-Systems perspective for future aircraft?
  - Aircraft no longer operate in isolation, they function within highly interconnected operational environments
  - Aircraft performance increasingly depends on networks, data sharing, and integration with other systems
  - Competitive advantage is driven by how well systems interoperate, not just by standalone capabilities
  - Therefore, future systems, such as aircraft, must be designed to fit into a broader system-of-systems context from the beginning
  - Adopting a system-of-systems perspective in early product development may enable greater efficiency, scalability, and adaptability by leveraging the strengths of each constituent system

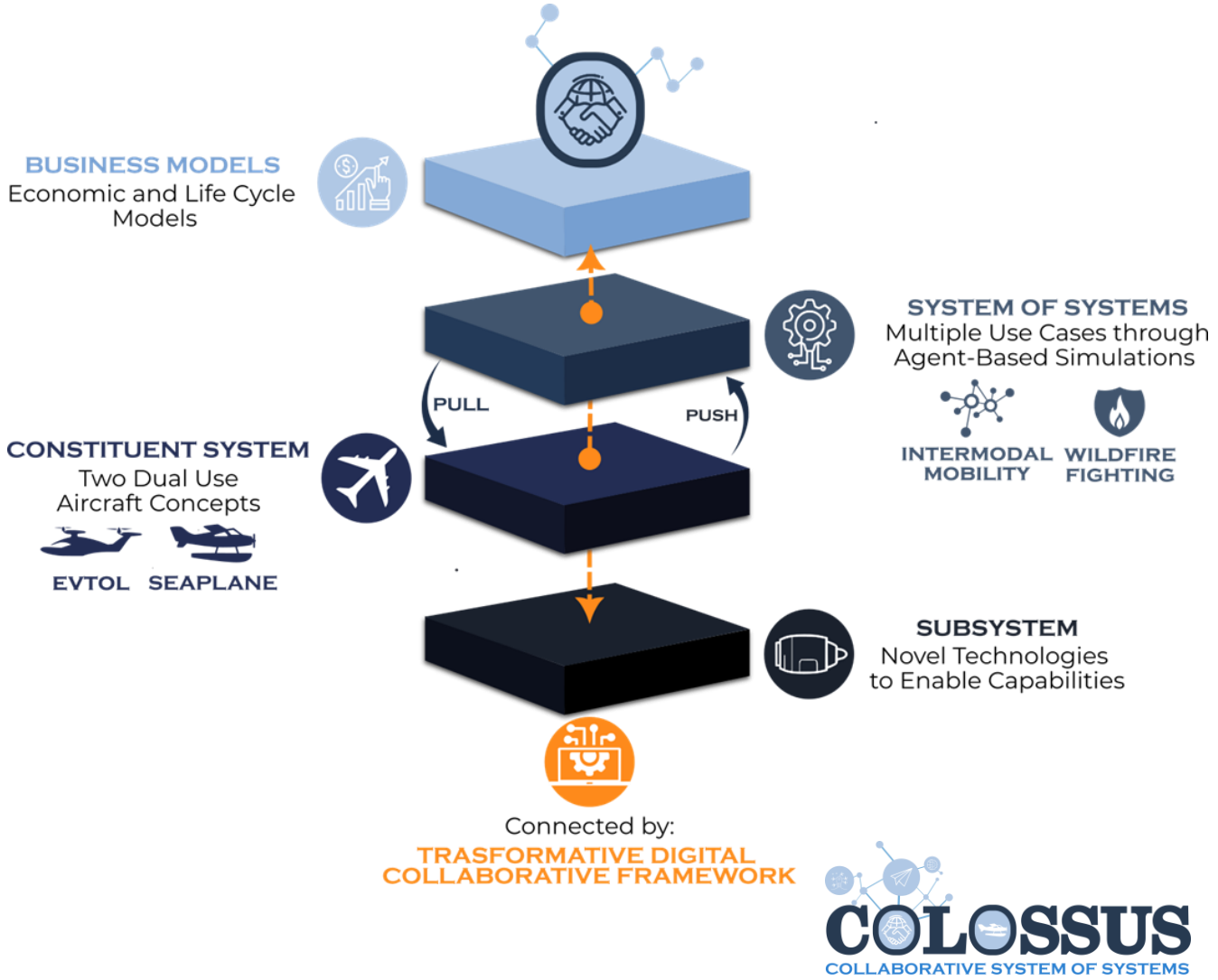


What is a System-of-Systems?

- System-of-Systems Engineering (SoSE)
  - A discipline for adding systems together in order to enable capabilities not achievable by the individual systems alone
  - Compared with Systems Engineering:
    - Systems Engineering deals with the design, integration, and management of individual systems
    - SoSE deals with the integration and coordination of multiple independent systems
      - For example, more focused on operational- and communication aspects, and the degree of centralized control
  - Systems Engineering Examples:
    - Designing a new car, aircraft, satellite, or developing a software application, etc.
  - System-of-Systems Engineering Examples:
    - Integrating air traffic control systems, defense systems that combine land, air, and sea capabilities, or smart city infrastructures that connect transportation, energy, and communication systems.

Project Overview and Approach

- A Multi-Level Approach
  - Spanning many different system levels!
  - Must integrate all levels together:
    - Business Model Design
    - System-of-Systems Design
    - Constituent System Design
    - Sub-Systems Design
  - Complex and demanding!
    - Questions about Computational effort and model fidelity become very relevant

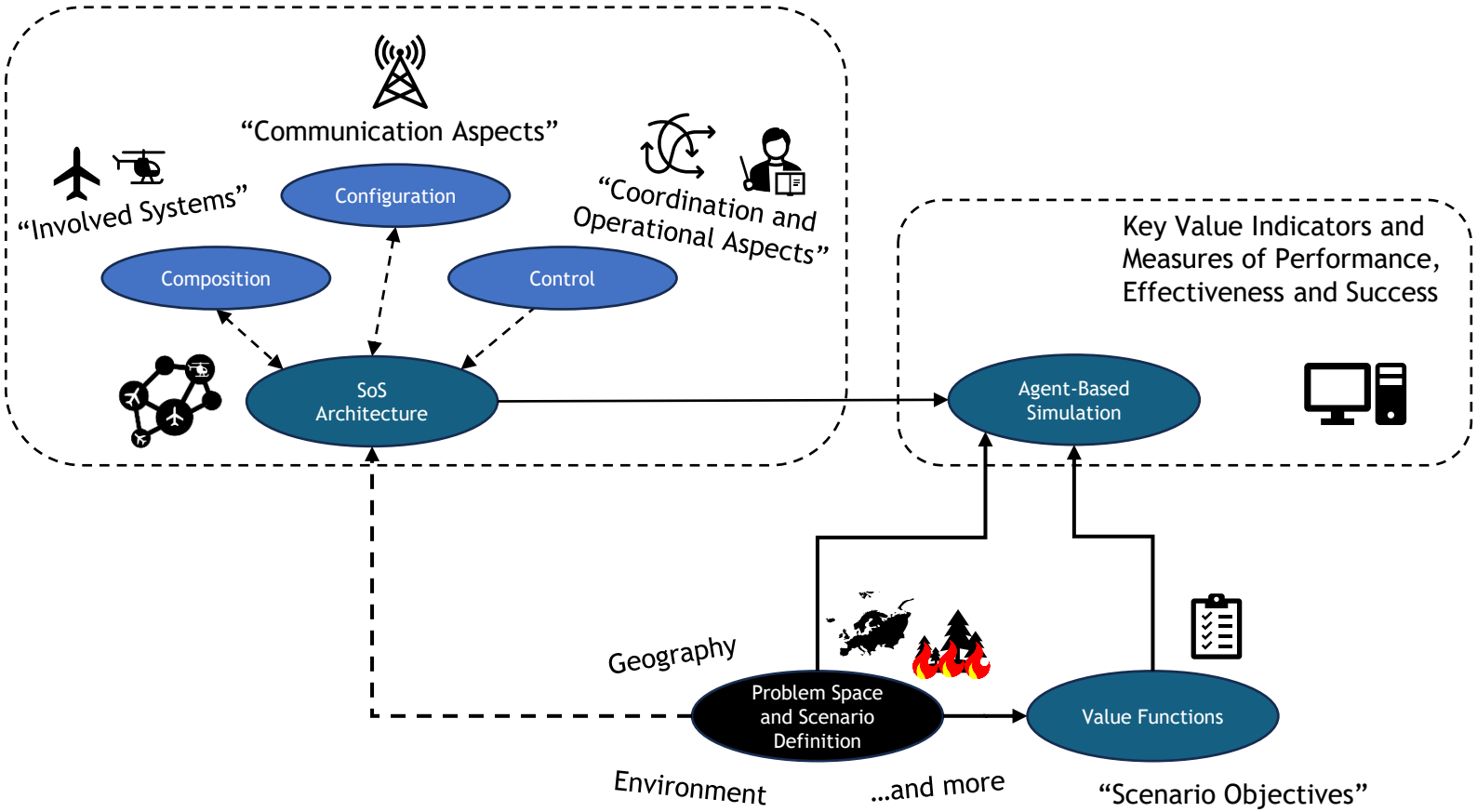


The Case Study (Wildfire Fighting)

- The main objective of COLOSSUS:
  - To develop a system-of-systems **design methodology** which will enable the combined optimization of aircraft, operations and business models
- The Problem:
  - Wildfires are an increasing problem worldwide due to climate change
  - Fighting wildfire is a coordinated activity that involves many stakeholders, systems and operational considerations

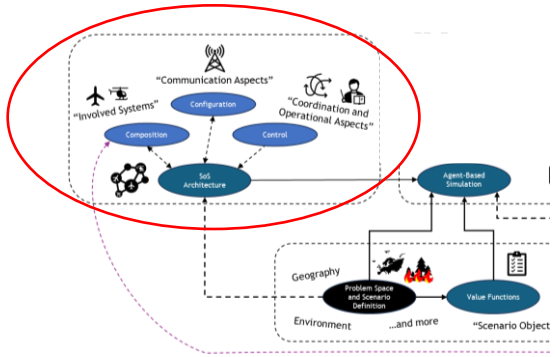
    → **System-of-Systems**
  - Product Pull Paradigm and Top-Down Approach
    - How can we design wildfire fighting System-of-System solutions and new aircraft from a top-down perspective?
    - Meaning that we start by breaking down the problem in a solution agnostic way to ultimately generate the top-level requirements for new aerospace systems to be developed in a system-of-system context (a product pull)

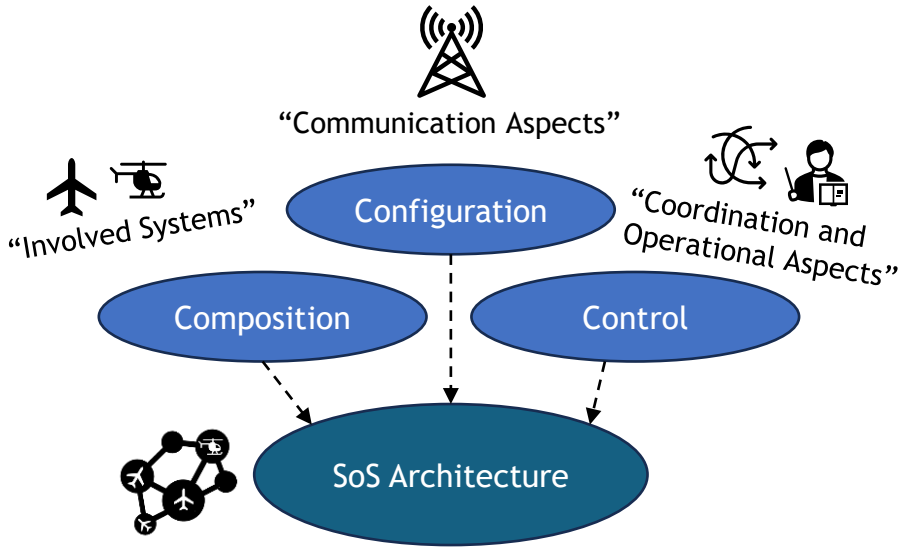
Methodology Overview



SoS Architectures Exploration

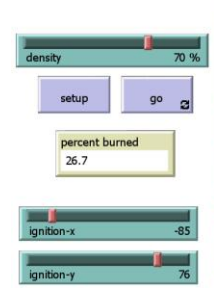
- System-of-System Architectures have three classes of design variables:
  - Composition
    - Type of systems involved, number of systems, functionality, etc.
  - Configuration
    - Communication, information flow, latency, bandwidth, etc.
  - Control
    - Operational aspects, strategies and tactics, type of decision making, prioritization, coordination, etc.
- Each unique set of these design variables is an SoS architecture that can be generated
- The performance of each generated SoS architecture must thereafter be explored against the defined scenario and corresponding objectives
- Done through modelling and simulation

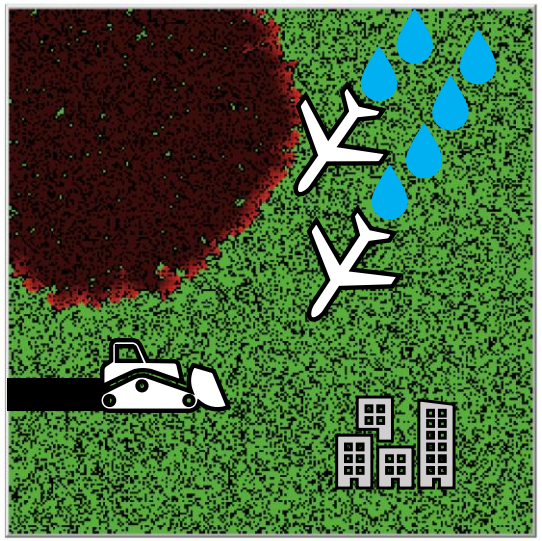




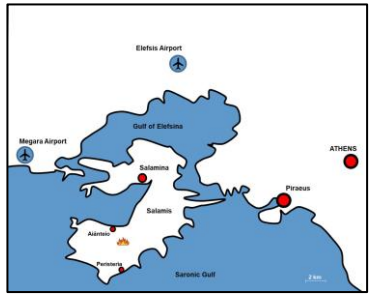
Agent-Based Simulation (ABS)

- ABS is a means for modelling and simulating SoS architectures in different environments:
  - Explore the interaction between multiple independent constituent systems that work together to achieve overarching goals
  - Helps in understanding the collective behaviour that emerges from the interactions of diverse constituent systems
  - Reinforcement Learning for agent behaviour!
  - Enabling the exploration of various operational scenarios and SoS architectures

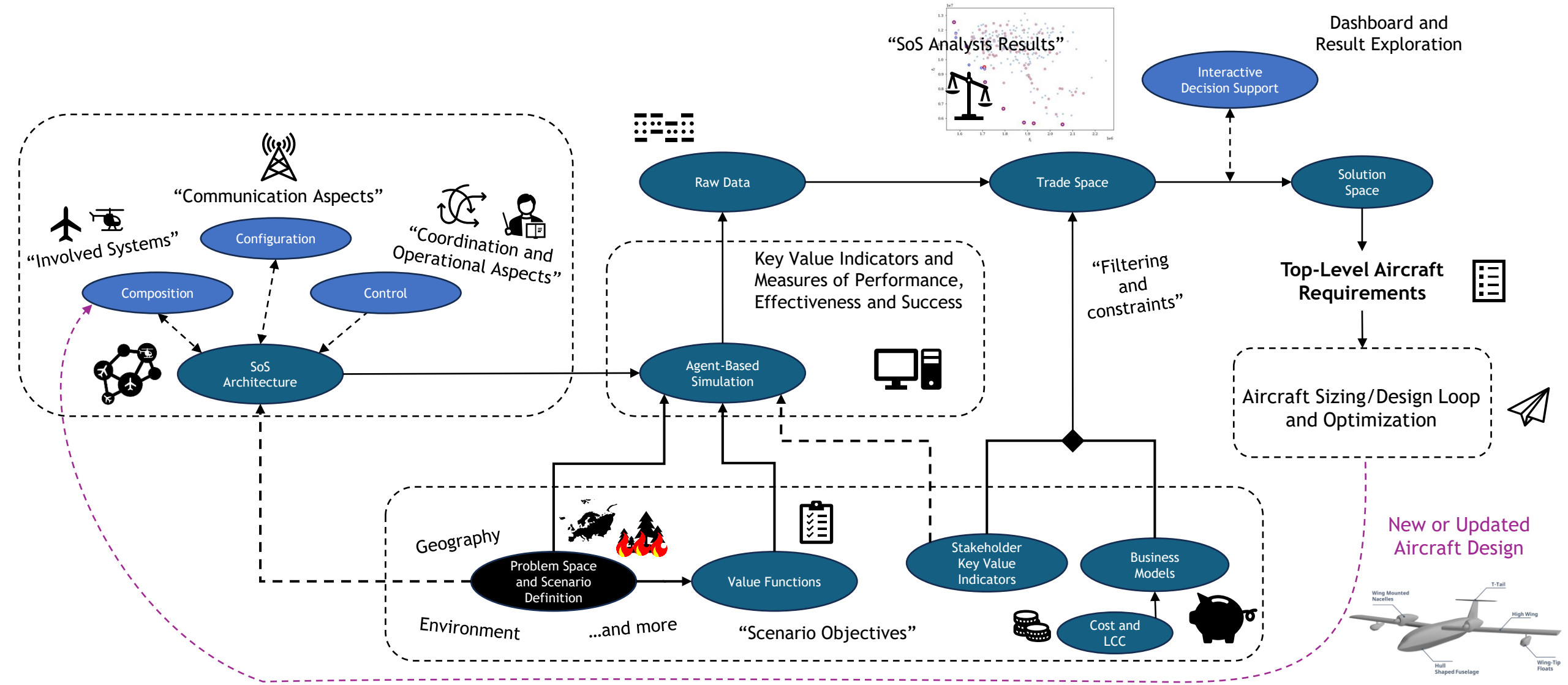




Agent =
Constituent System

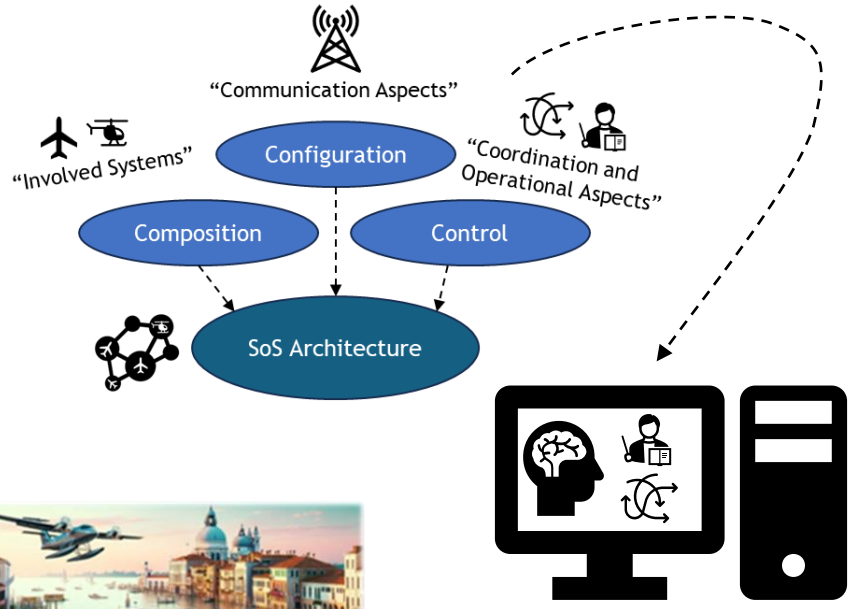


Methodology Overview



Outlook

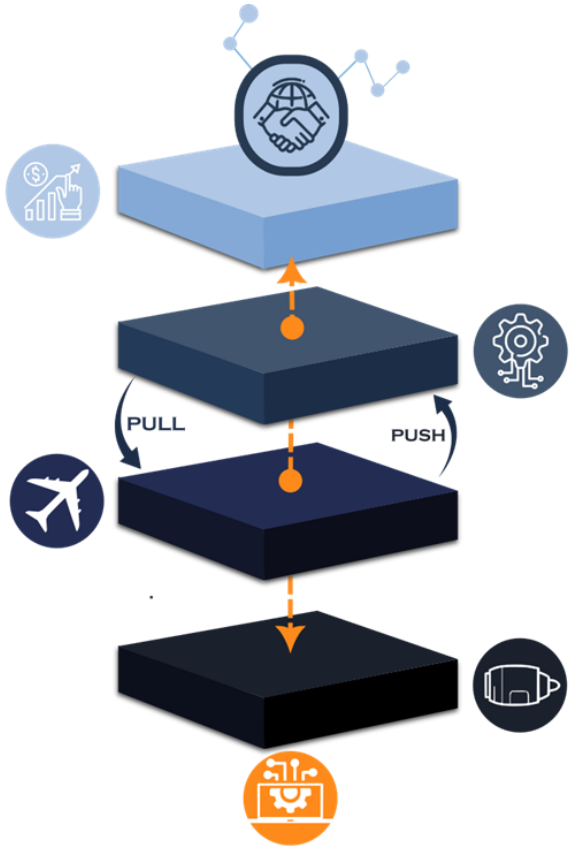
- Project is ending in April… Until then:
  - Running optimizations over many different wildfire scenarios to identify persistent and robust solutions
  - Exploring more aspects of System-of-System Architectures and add them to optimization variables
  - More exploration on Reinforcement Learning and agents' behaviour
    - Novel strategies and tactics? How to extract?
  - Expanding the studies beyond wildfire fighting and trying the method on other application areas within aviation
    - For example, Advanced Air Mobility
      -> Product Push Paradigm
  - And of course, more…



COLOSSUS
COLLABORATIVE SYSTEM OF SYSTEMS

Conclusions

- The main objective of COLOSSUS:
  - To develop a system-of-systems **design methodology** which will enable the combined optimization of aircraft, operations and business models
- The presented Methodology:
  - A first step towards defining a holistic methodology for system-of-systems engineering
- Many future possibilities!
  - The project has touched upon many aspects of system of systems, but there is still much to do!



COLOSSUS
COLLABORATIVE SYSTEM OF SYSTEMS

COLOSSUS
COLLABORATIVE SYSTEM OF SYSTEMS

COLLABORATIVE SYSTEM OF SYSTEMS EXPLORATION OF AVIATION PRODUCTS, SERVICES & BUSINESS MODELS

Thank You !

Scan me! ☺

Funded by the European Union

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