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Deutsches Zentrum
DLR für Luft- und Raumfahrt
German Aerospace Center

Product Pull Paradigm: Solving a System of Systems Problem for TLARs

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COLOSSUS Project | *EASN 2024*
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COLLABORATIVE SYSTEM OF SYSTEMS

Coordinated by
the German Aerospace Center
DLR

Agenda

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- Problem Statement
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- Methodology Overview
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- 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
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- COSTRUZIONI AERONAUTICHE TECNAM
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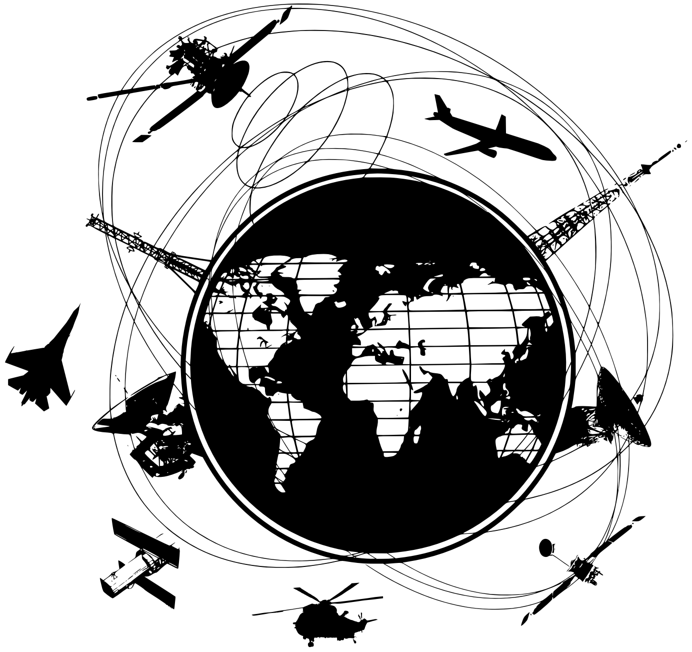
Introduction

- Having a System-of-Systems Perspective is becoming more and more important in today’s interconnected world
  - Ex: Aviation Transport System has high degrees of interconnection
- Taking a System of Systems approach in early product design is crucial
  - How will new systems integrate into the existing System of Systems?
- Deriving the requirements for new aircraft to be developed from a system-of-system perspective is therefore of great interest



Problem Statement

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German Aerospace Center

- Many of the challenges that aviation faces today are complex problems that involves more considerations than just the aircraft itself. For example:
  - Aerial wildfire fighting
  - Advanced air mobility
- These challenges are typical System-of-Systems Problems
- A System-of-Systems approach and perspective can thereby facilitate problem understanding and help address the challenges of modern aviation in new and innovative ways
  - This can be achieved by leveraging the strengths and functionalities of each constituent system involved

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Objective

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- The main objective of the COLOSSUS project:
  - To develop a system-of-systems design methodology which will enable the combined optimization of aircraft, operations and business models
- This is done through the two System-of-Systems use cases:
  - Advanced Air Mobility (ADAM)
    - Product Push Paradigm and Bottom-Up Approach
  - Wildfire Fighting (EVE)
    - Product Pull Paradigm and Top-Down Approach

(**E**co-friendly air **V**ehicles for multiple operating **E**nvironments ;-)

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The EVE Use Case (Wildfire Fighting)

- 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?
  - Analyse the problem in a solution agnostic way to derive the solution in a System of Systems context

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Methodology Overview

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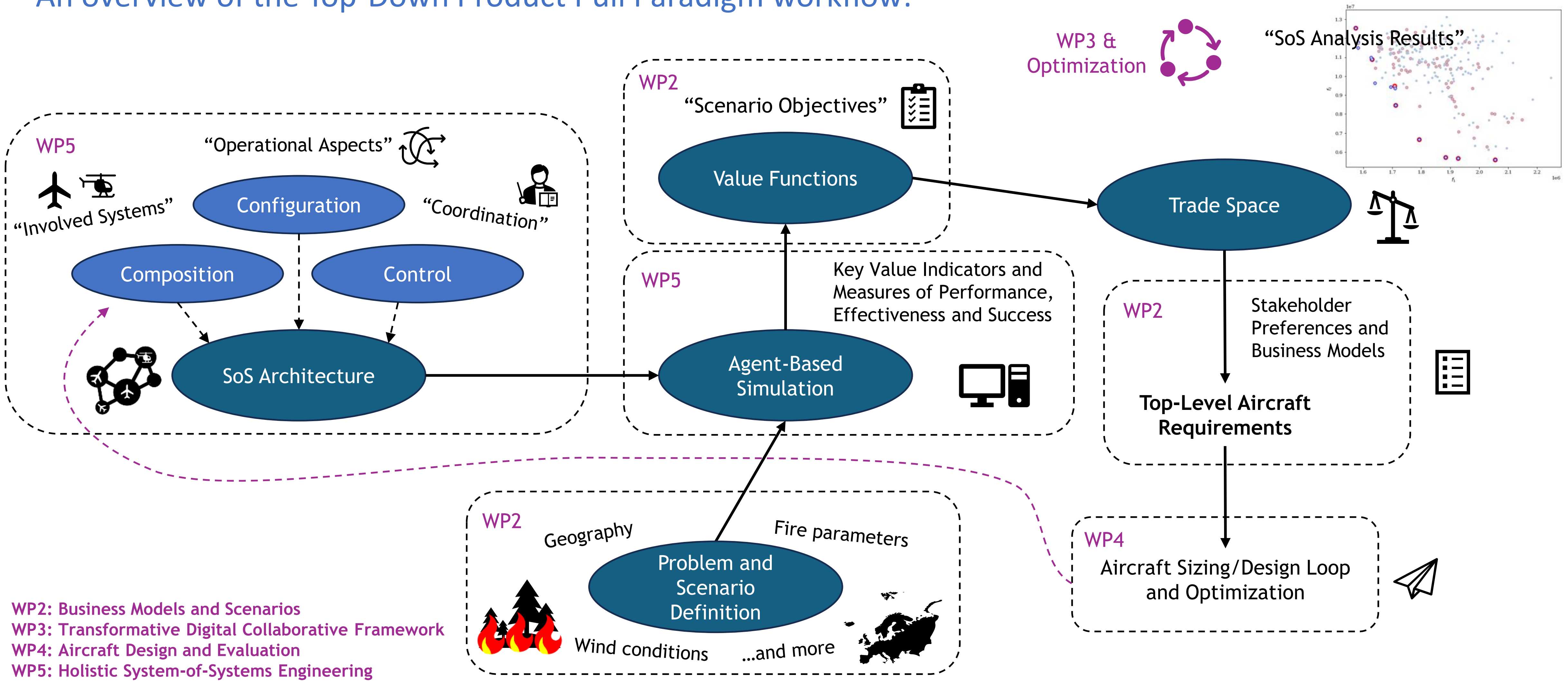
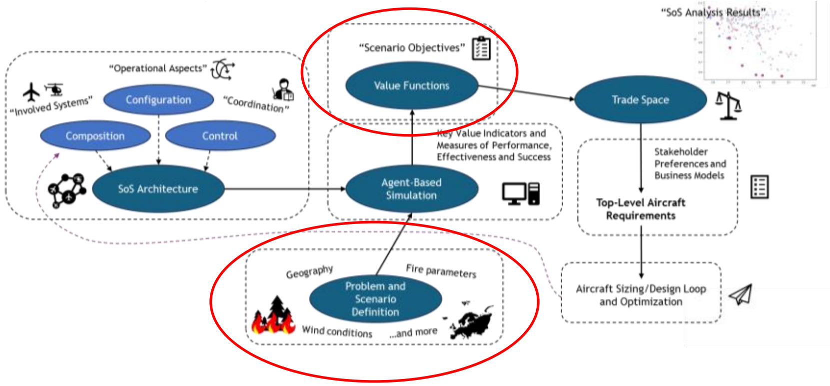
- An overview of the Top-Down Product Pull Paradigm workflow:

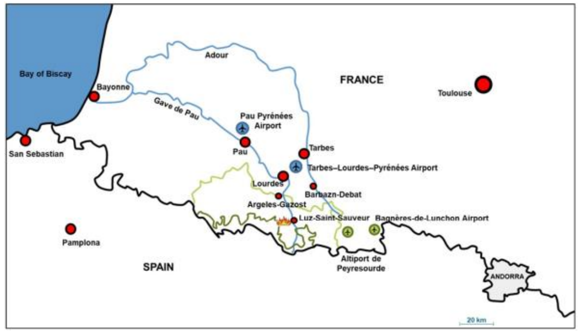


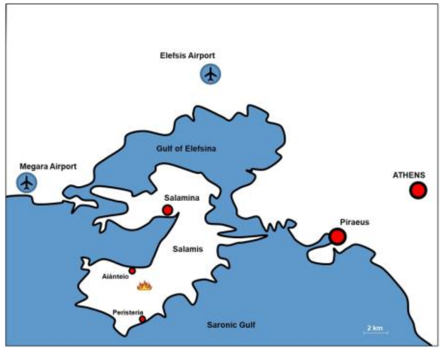
- WP2: Business Models and Scenarios
- WP3: Transformative Digital Collaborative Framework
- WP4: Aircraft Design and Evaluation
- WP5: Holistic System-of-Systems Engineering

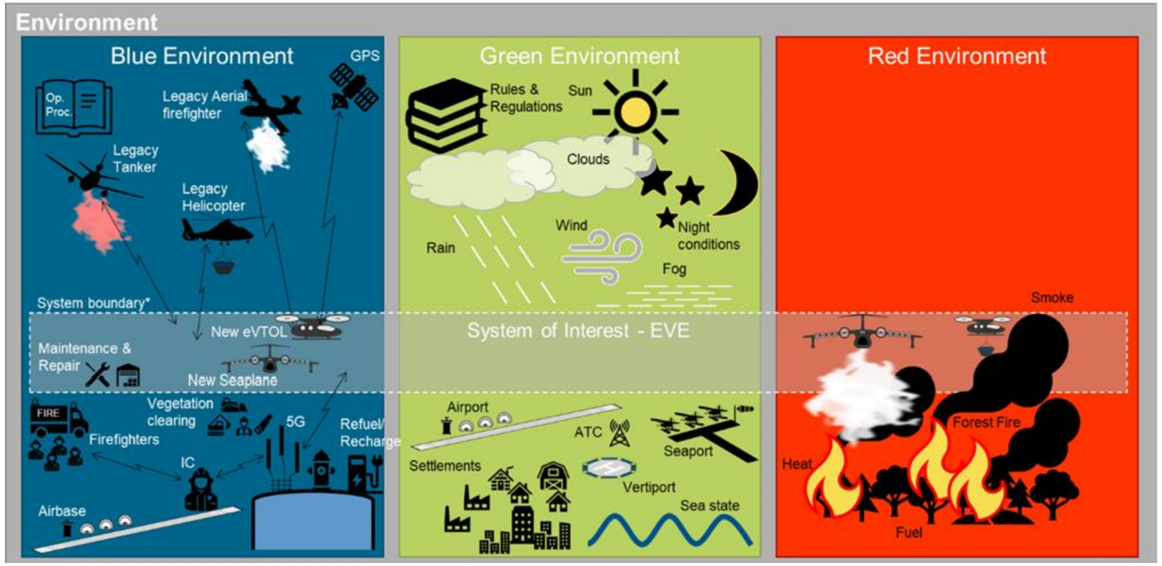
Problem and Scenario Definition



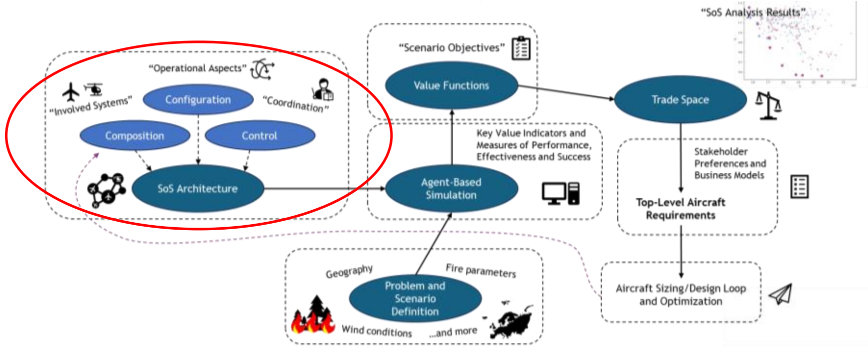
- The first step of the Top-Down Approach is to define the problem and relevant scenarios
- Two wildfire scenarios are used in EVE:
  - Mountain region (France/Spain)
  - Seaside region (Greece)
- The Scenario objectives:
  - Minimize wildfire damage
  - Minimize environmental impact
  - Minimize cost of operation



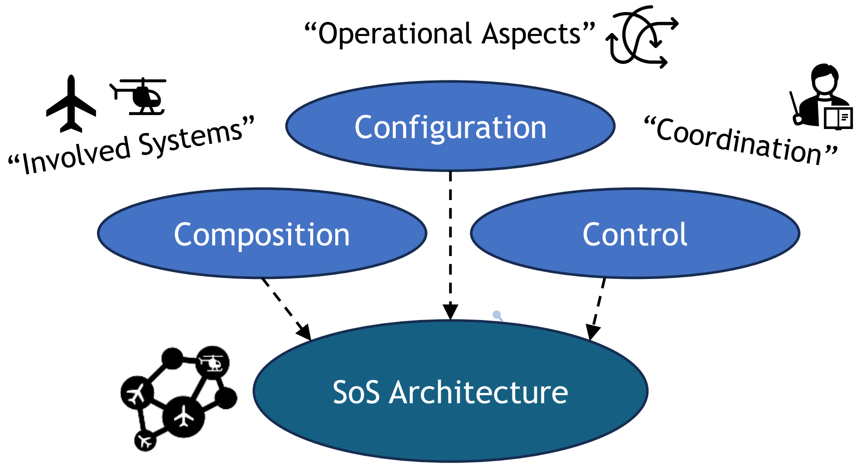




SoS Architectures Exploration

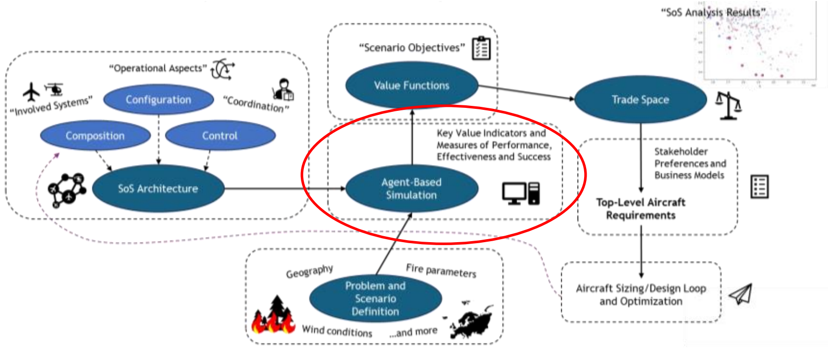


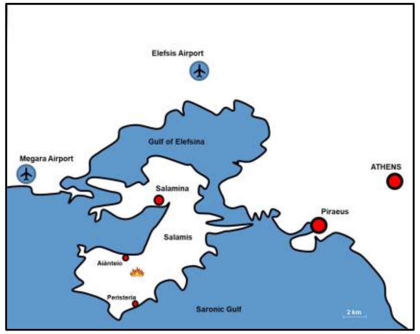
- System-of-System Architectures have three classes of design variables:
  - Composition
    - Type of systems involved, number of systems, functionality, etc.
  - Configuration
    - Operational aspects, strategy and tactics, interdependencies, etc.
  - Control
    - Type of decision making, prioritization, coordination, etc.
- Each unique set of these design variables is an SoS architecture that can be generated
- Each generated SoS architecture evaluated in the scenario w.r.t the objectives
- Done through modelling and simulation

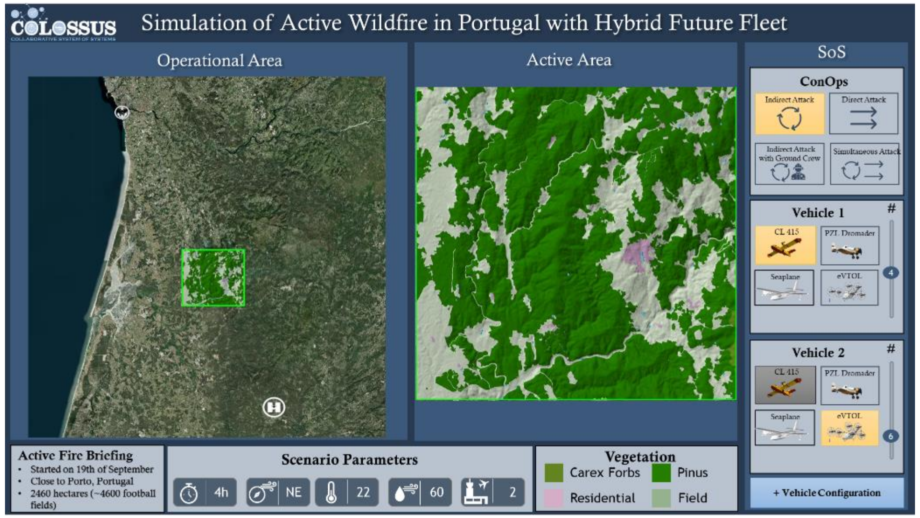


Agent-Based Simulation (ABS)

- 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
  - Enabling the exploration of various operational scenarios and SoS architectures







Simulation of Active Wildfire in Portugal with Hybrid Future Fleet

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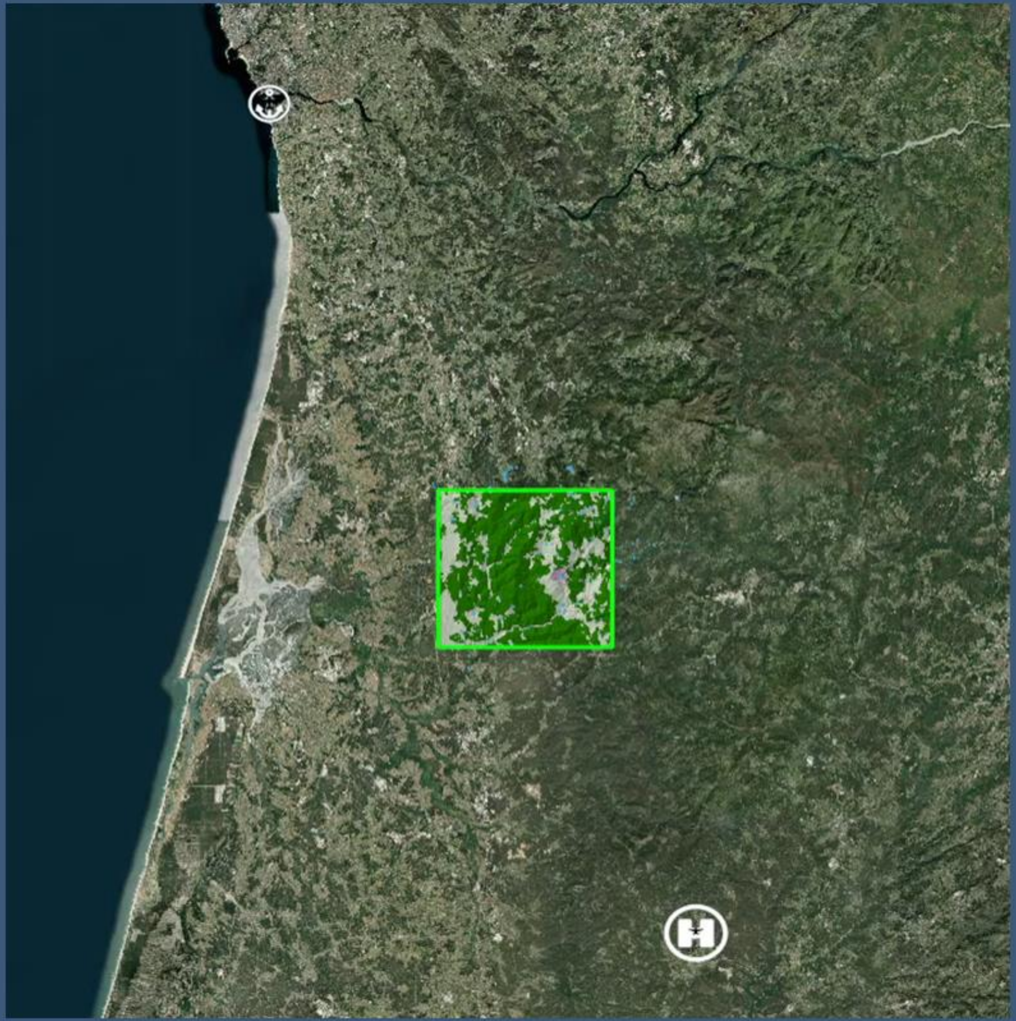
Operational Area



Active Area

SoS

ConOps

- Indirect Attack
- Direct Attack
- Indirect Attack with Ground Crew
- Simultaneous Attack

Vehicle 1

#

- CL 415
- PZL Dromader
- Seaplane
- eVTOL

4

Vehicle 2

#

- CL 415
- PZL Dromader
- Seaplane
- eVTOL

6

+ Vehicle Configuration

Active Fire Briefing

- Started on 19th of September
- Close to Porto, Portugal
- 2460 hectares (~4600 football fields)

Scenario Parameters

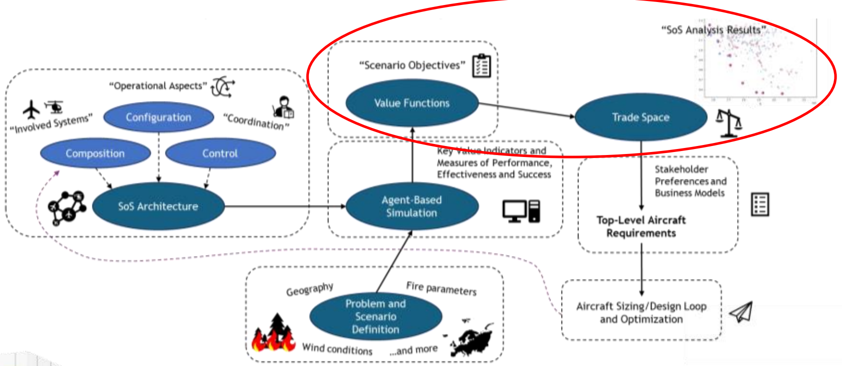
4h	NE	22	60	2

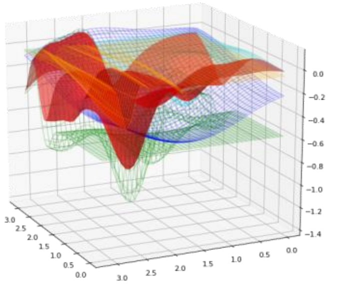
Vegetation

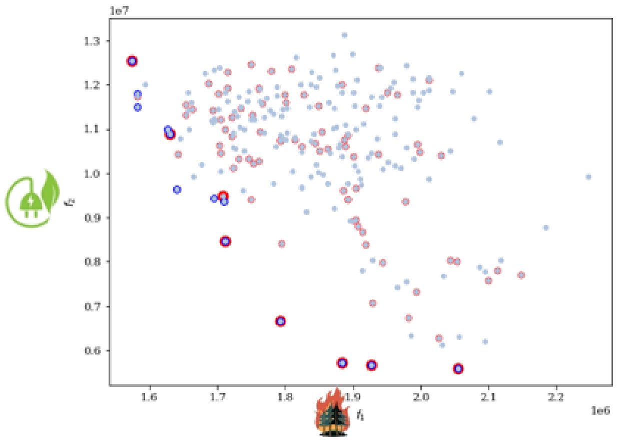
- Carex Forbs
- Pinus
- Residential
- Field

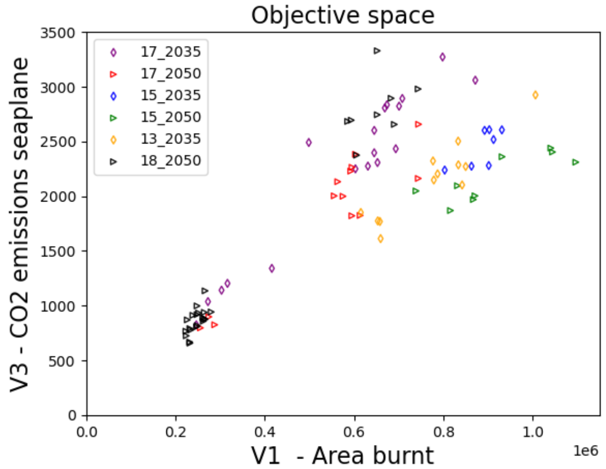
Optimization and Trade Space

- Optimization is used to run all SoS architectures for the different scenarios
- The scenario objectives are here represented as value (objective) functions for the optimizer
- Each SoS architecture is consequently evaluated against these value functions
- The result from the optimization studies is a trade space with different optimum solutions
- The resulting trade space is therefore a pool of potential solutions for the problem









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Top-Level Aircraft Requirements (TLARs)

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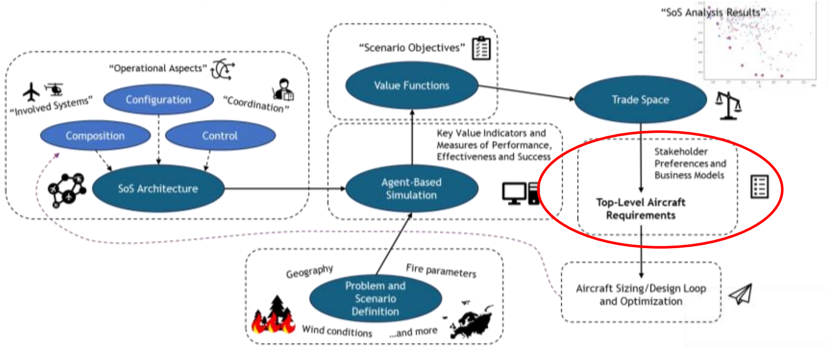
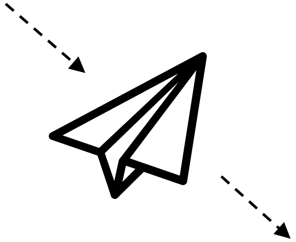
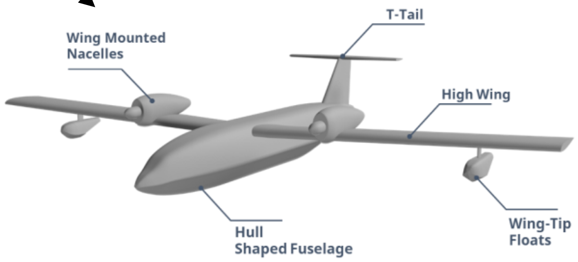
- A Pareto front can be identified based on stakeholder preferences and business models
- A single solution can then be identified based on the specific weightings of the stakeholder preferences
- The Top-Level Aircraft Requirements of the constituent system can then be identified







- The indicated TLARs can from here guide the design process of new aircraft solutions

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Initial Testing Results

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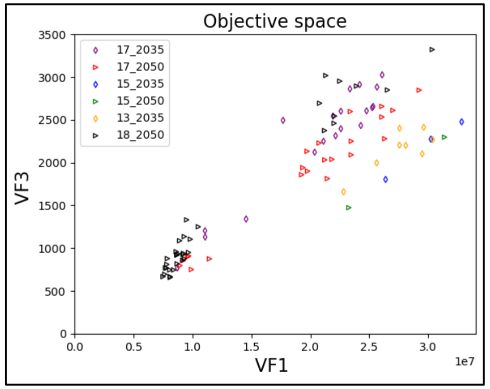
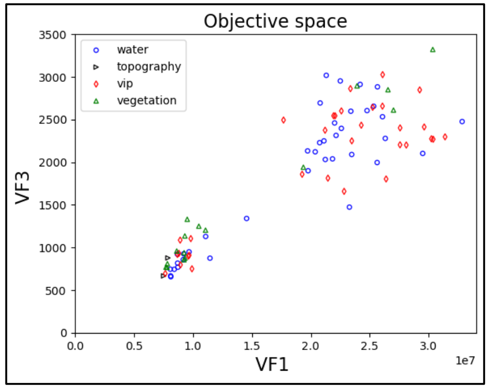
- An initial testing of the method shows promising results
- The used optimization process:
  - Super-Efficient Global Optimization coupled with Mixture of Experts (SEGOMOE)
  - Run with four types of variables considered:
    - Four different suppression tactics
    - Nine different fleet sizes for aircraft type 1
    - Nine different fleet sizes for aircraft type 2
    - Six possible design variations for aircraft type 2

      (→ 1944 possible solutions)
  - Value functions as objectives
- Additional sensitivity studies performed
  - On aircraft payload, speed and range

VF3 = Environmental Impact





VF1 = Burnt Area

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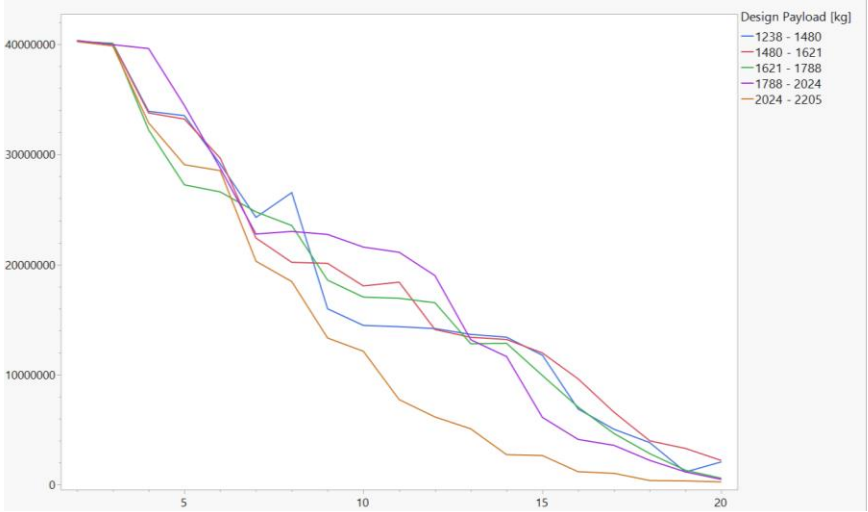
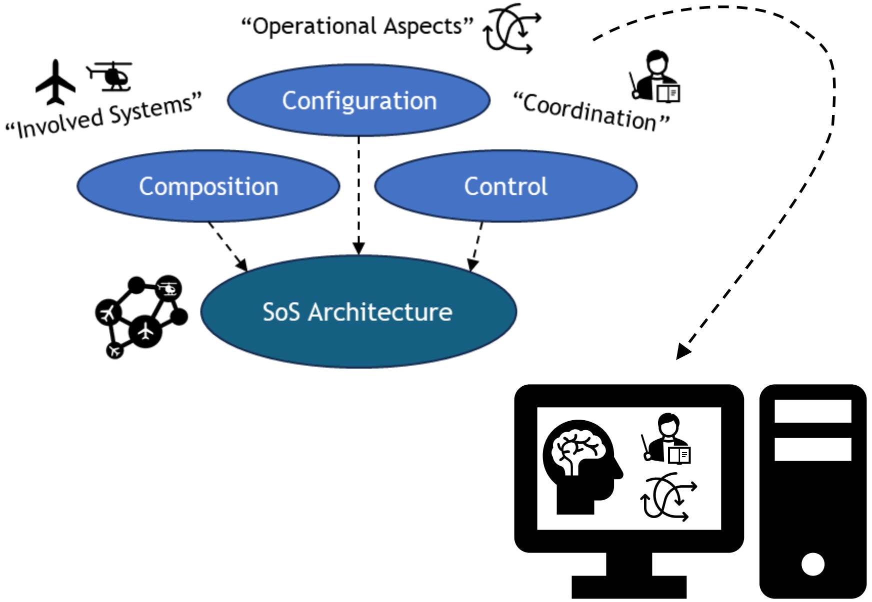


Fleet Size

Future Work

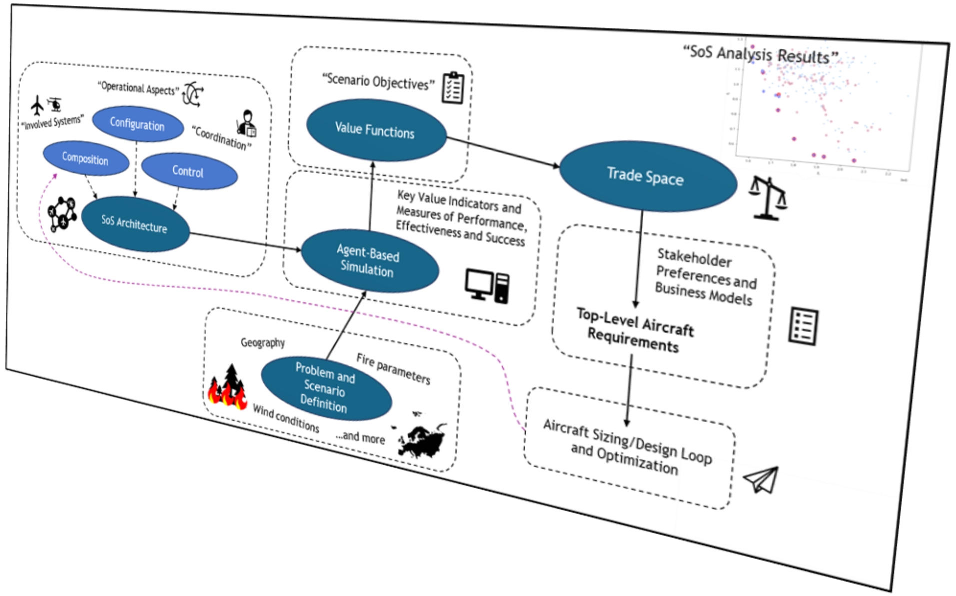
- An ongoing work!
- The most prominent future directions:
  - Analyses with more details and scenario considerations
  - Exploring more aspects of System-of-System Architectures and add them to the optimization variables
  - Adding reinforcement learning to control the agents' behaviour
    - Enabling more exploration capabilities on the coordination and operational aspects
- Long-term future endeavours:
  - Running the optimizations over many different scenarios wildfire scenarios to identify both optimum and robust solutions
  - Expanding the studies beyond wildfire fighting and trying the method on other application areas within aviation



Conclusions

- This study has shown how a System-of-Systems approach can tackle complex aviation challenges
- A method that illustrates a product pull paradigm and a top-down approach was introduced
- A case study was presented with the method to solve a System-of-Systems problem

- Key Contribution to the COLOSSUS project:
  - A holistic System-of-Systems engineering method to derive Top-Level Aircraft Requirements in a Product Pull paradigm is demonstrated



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

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