Development of UAVs for search missions by following a System-of-Systems Approach

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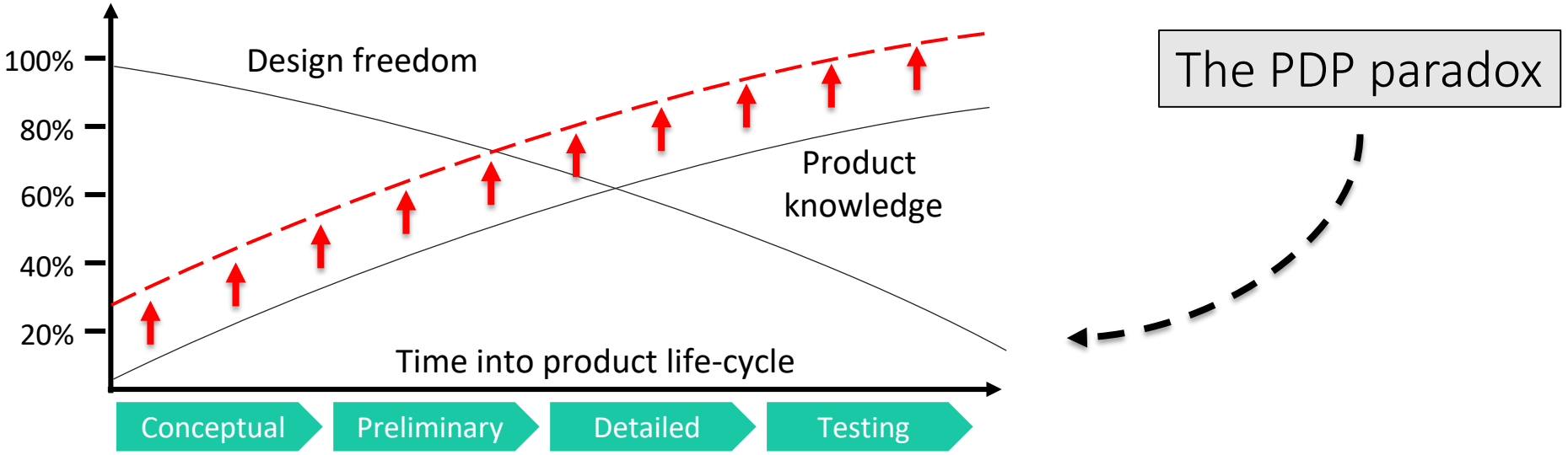
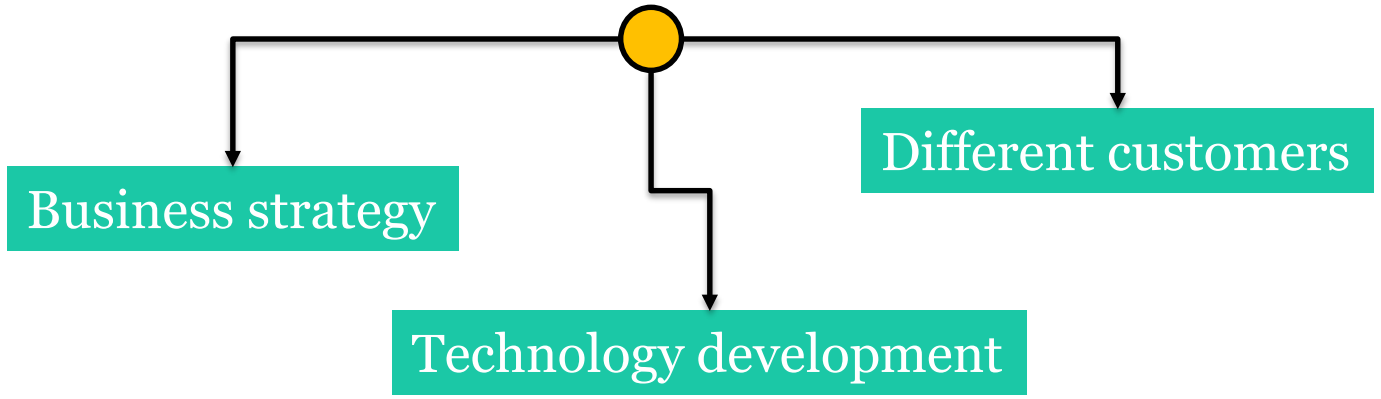
Background

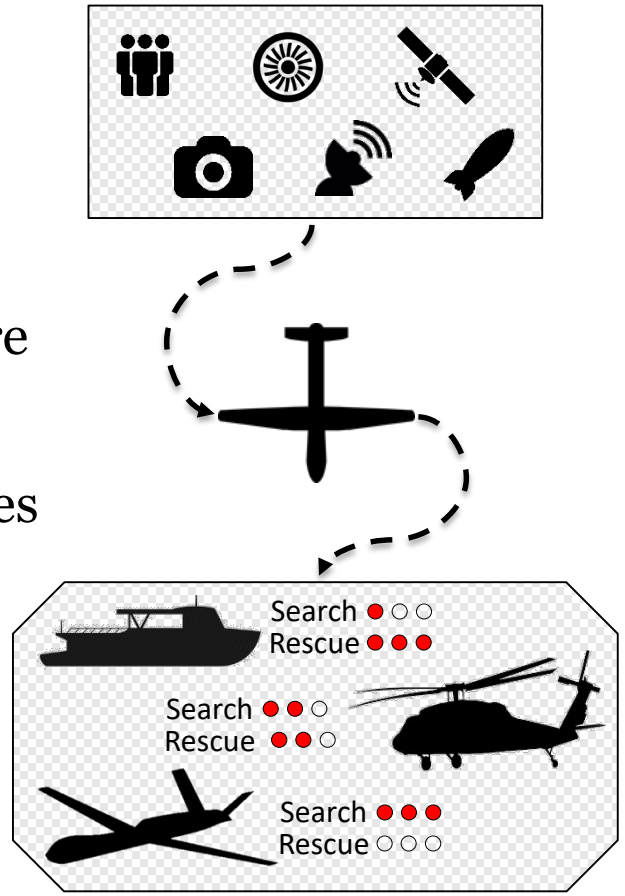
- Product Development Process (PDP)
  - Starts with an idea and ends with manufacturing
  - Design goes through many stages of refinements



Background

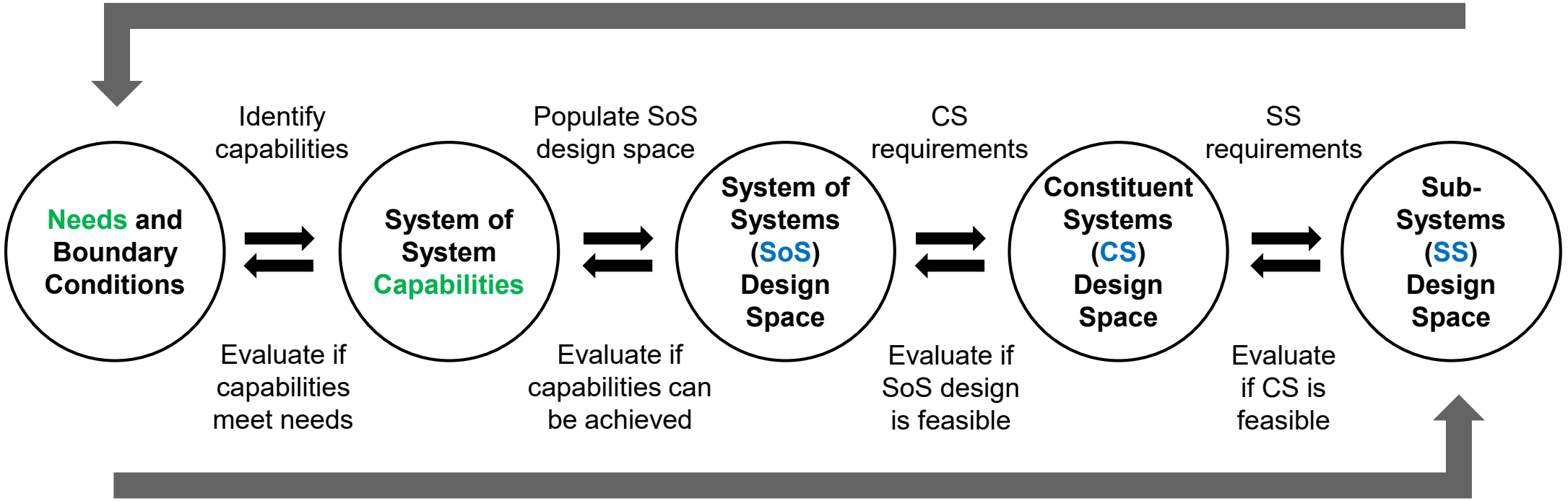
- Aerospace products are part of a network or a "System of Systems"
  - SoS analyses have been used in the way customer acquire new assets
  - Manufacturers should be able to perform similar analyses



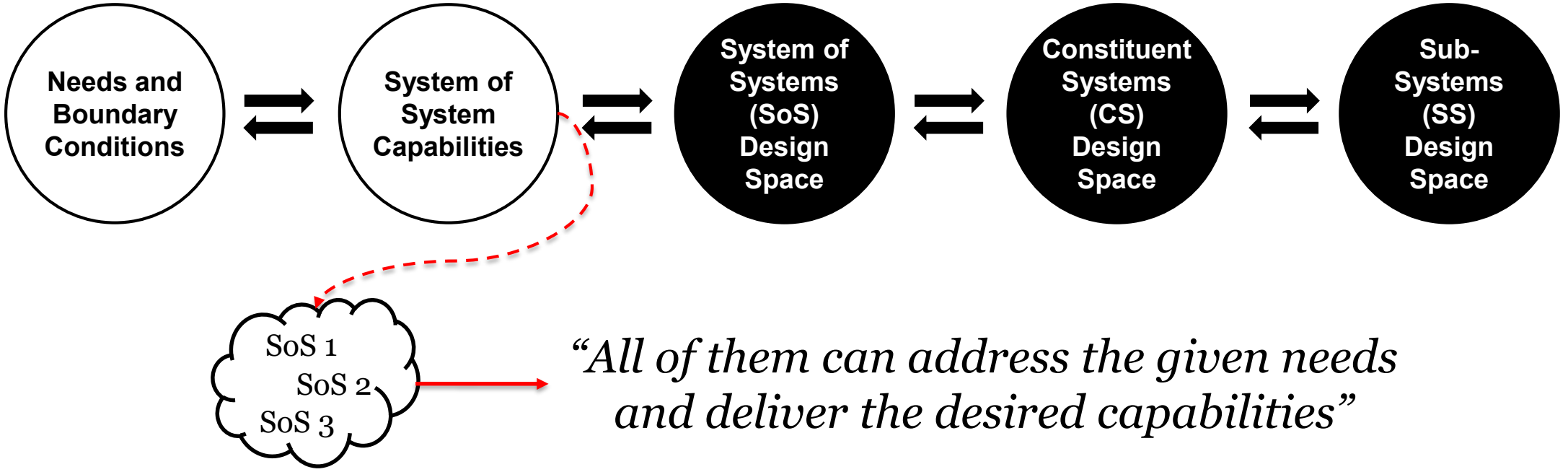


Background

"A holistic engineering approach to aeronautical product development"



Aim

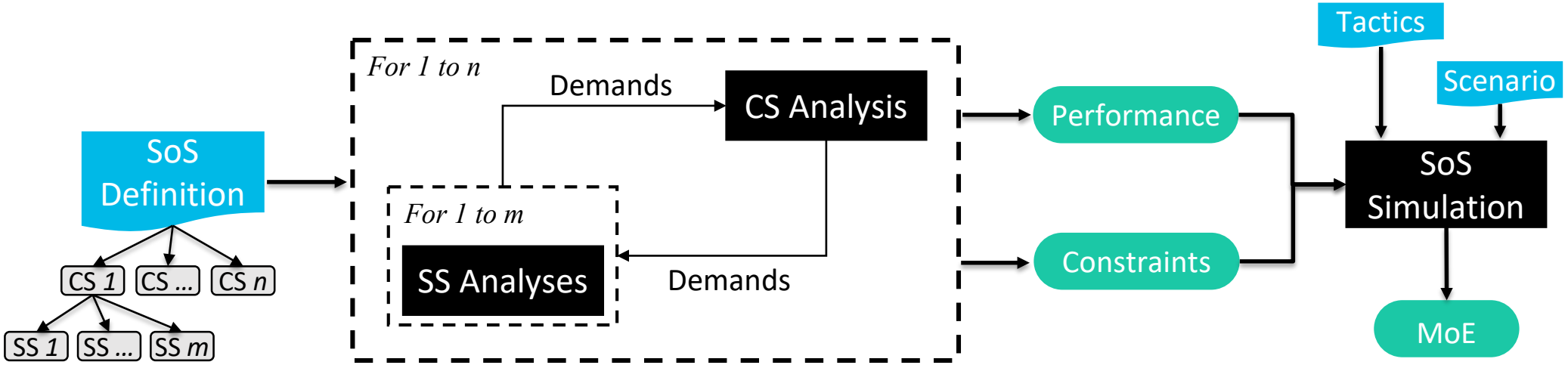


Which is better?

Can we get more?

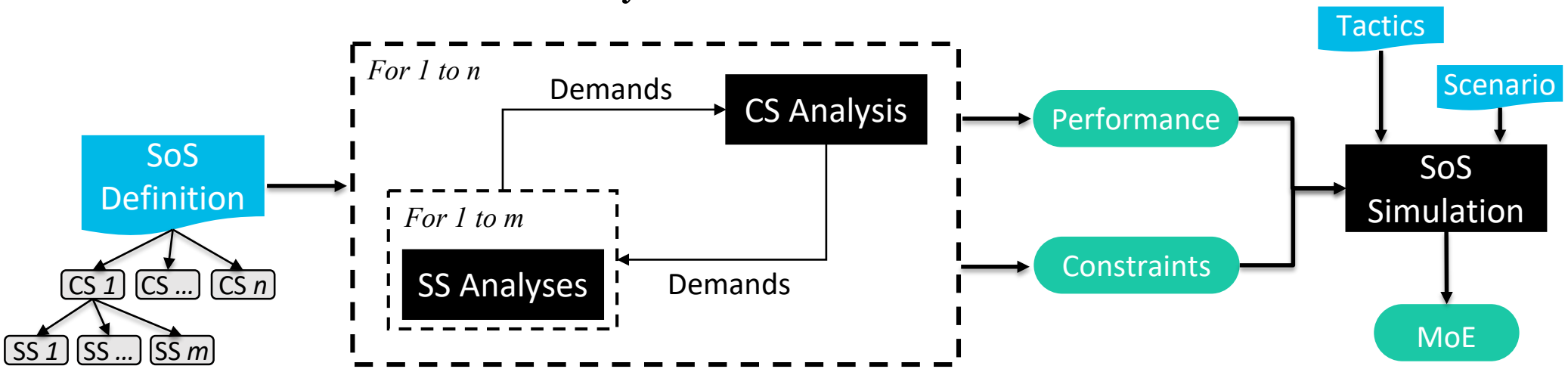
Identifying SoS Capabilities

- Framework for SoS design space population
  - First step is to define the SoS combinations to be evaluated
  - Second step is to identify the performance of each CS and SS
  - Third step is to simulate the entire SoS to extract the MoE

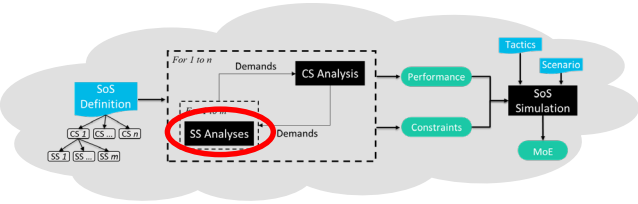


Identifying SoS Capabilities

- Framework for SoS design space population
  - Addresses all three levels of design
  - Not bound to any design space
  - Allows the use of multi-fidelity tools

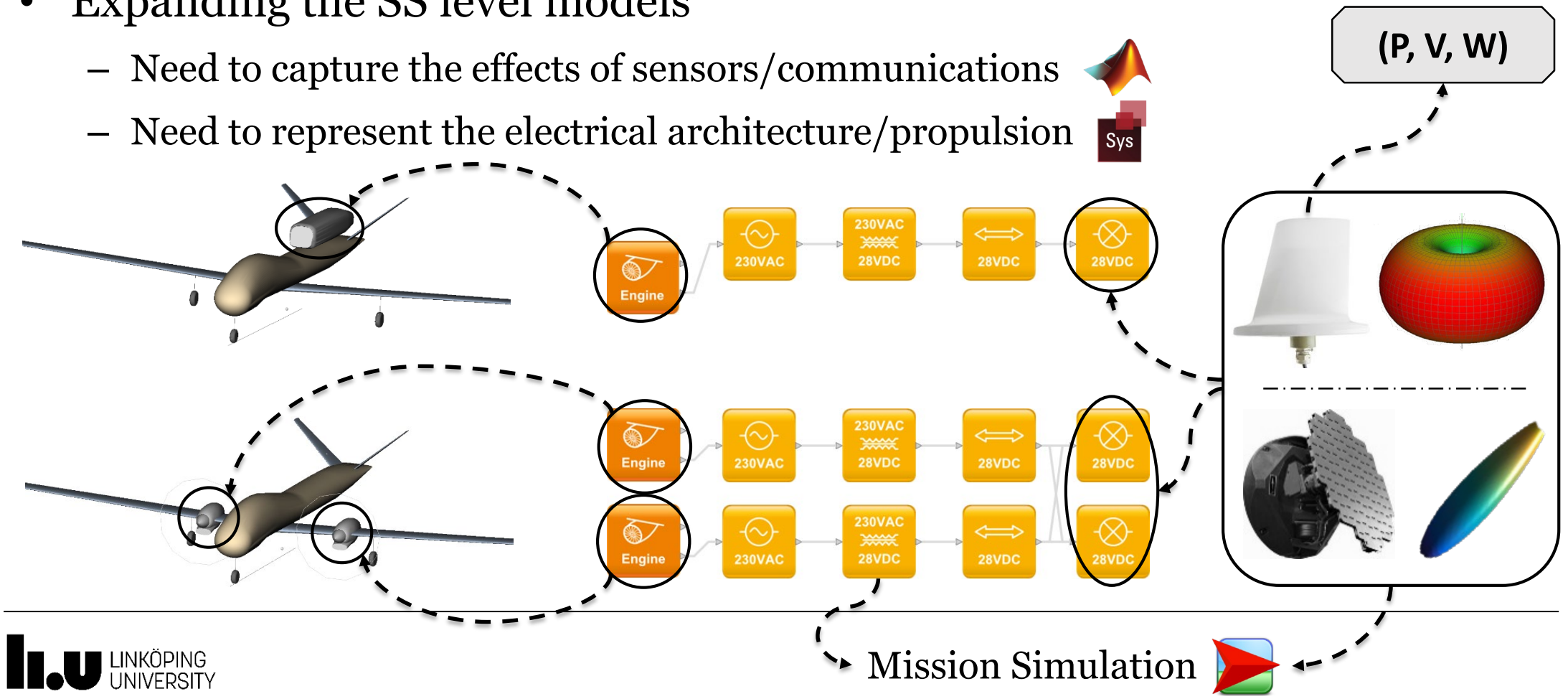


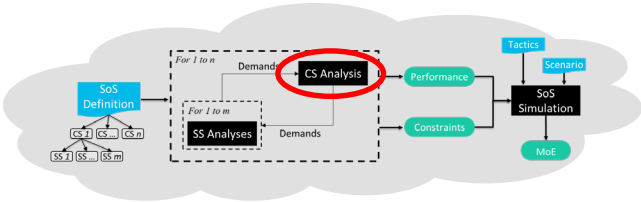
Implementation



Sub-System (SS) Models

- Expanding the SS level models
  - Need to capture the effects of sensors/communications
  - Need to represent the electrical architecture/propulsion





Constituent System (CS) Analysis

- Enhancing the CS level

Sys

Routing

Pathways

Sensors

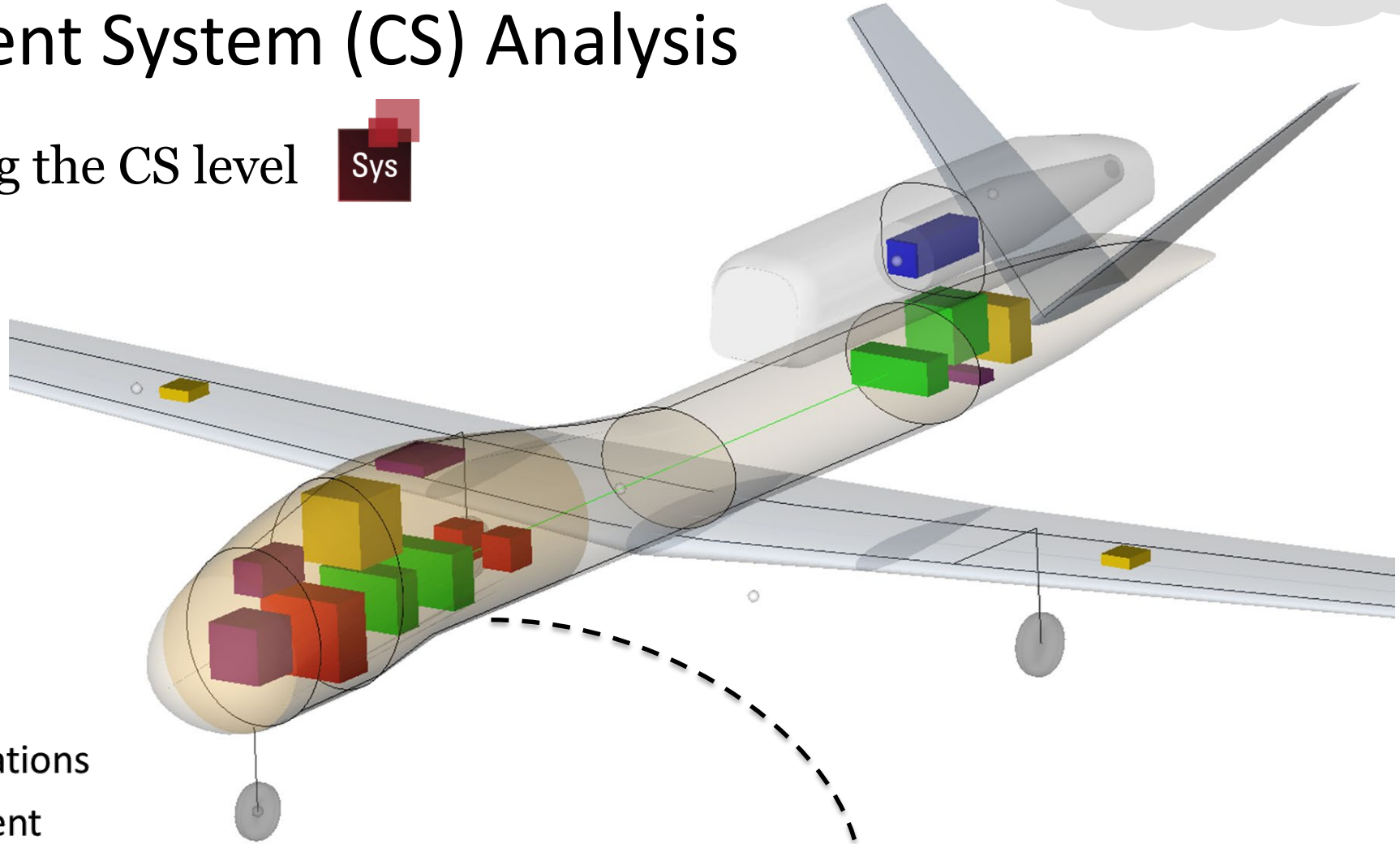
Engine

Electrical

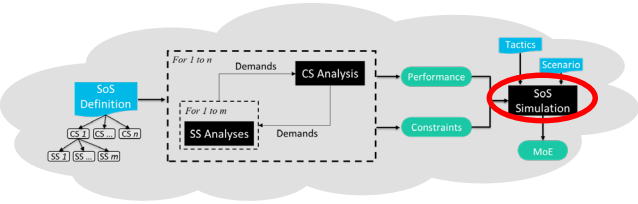
Avionics

Communications

Compartment



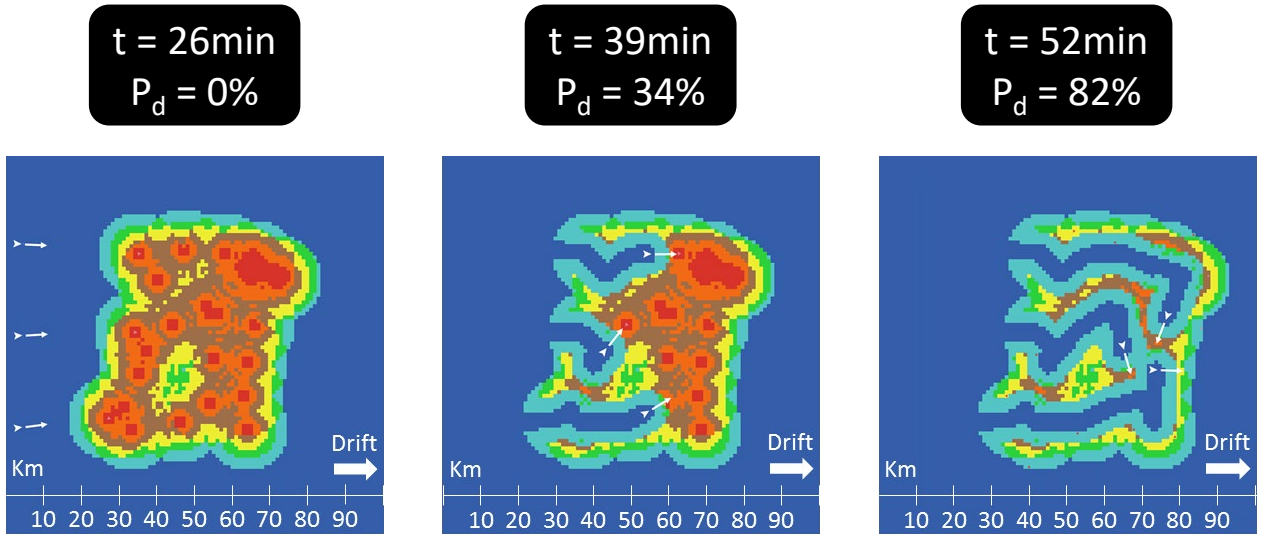
Mission Simulation

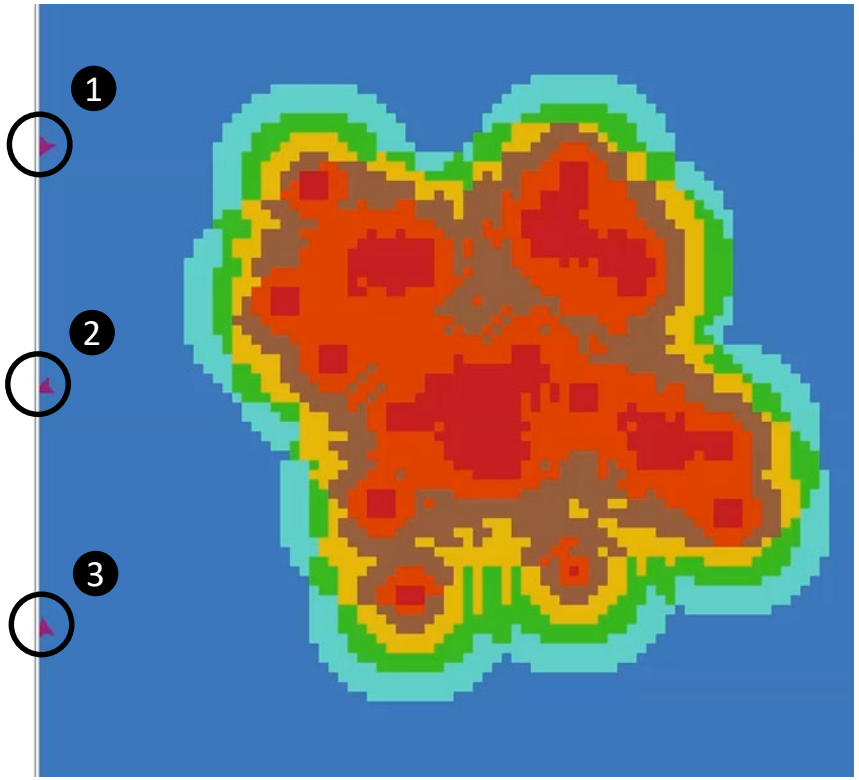


System-of-Systems (SoS) Simulations

Agent-based in NETLOGO

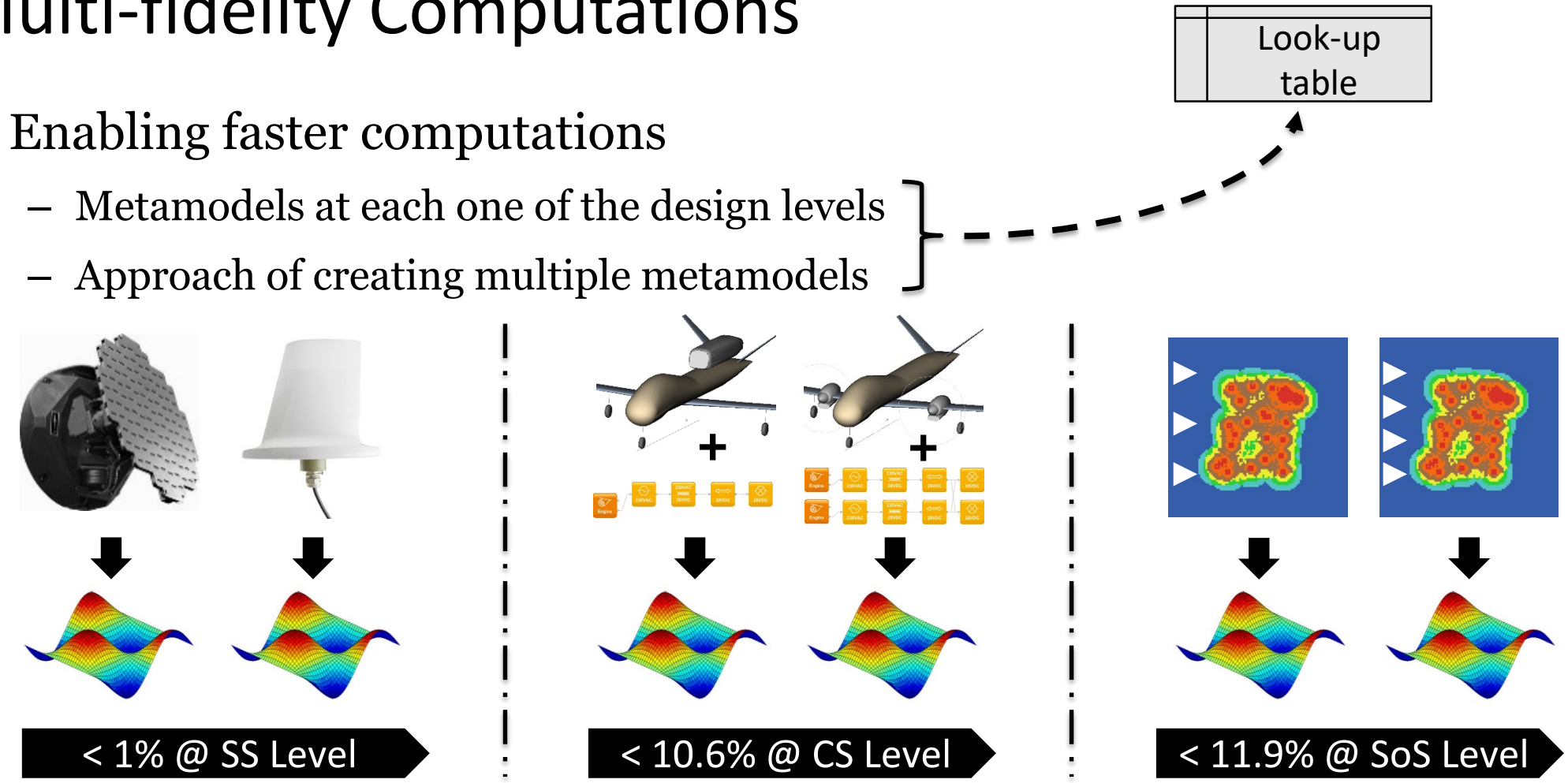
- Capturing the SoS level interactions
  - Collaboration (divide search, avoid overlap)
  - Realism (failure modes, false positives, drift)

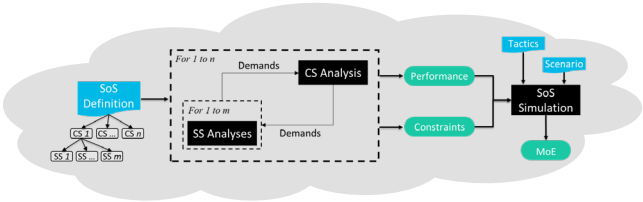




Multi-fidelity Computations

- Enabling faster computations
  - Metamodels at each one of the design levels
  - Approach of creating multiple metamodels





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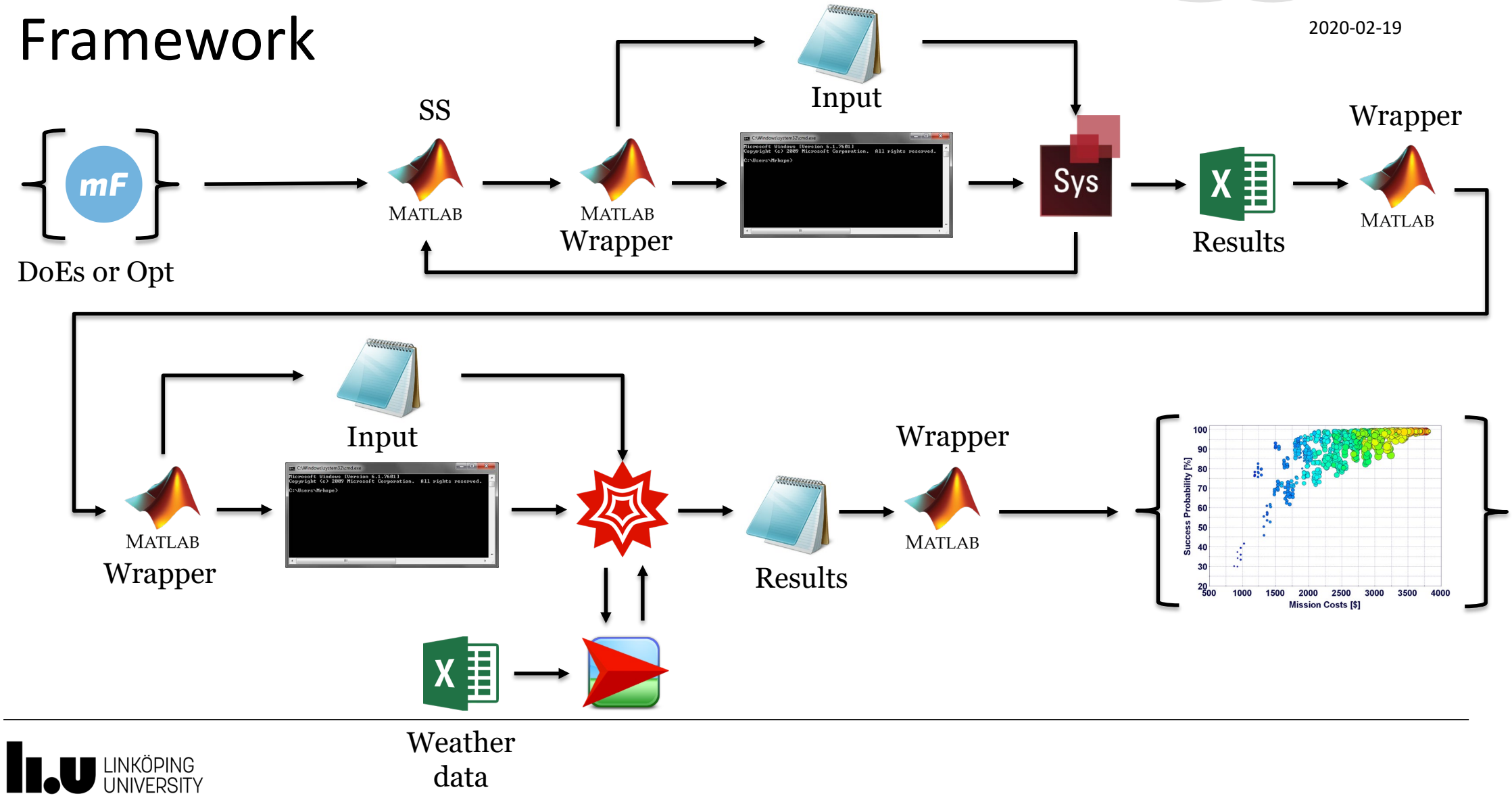
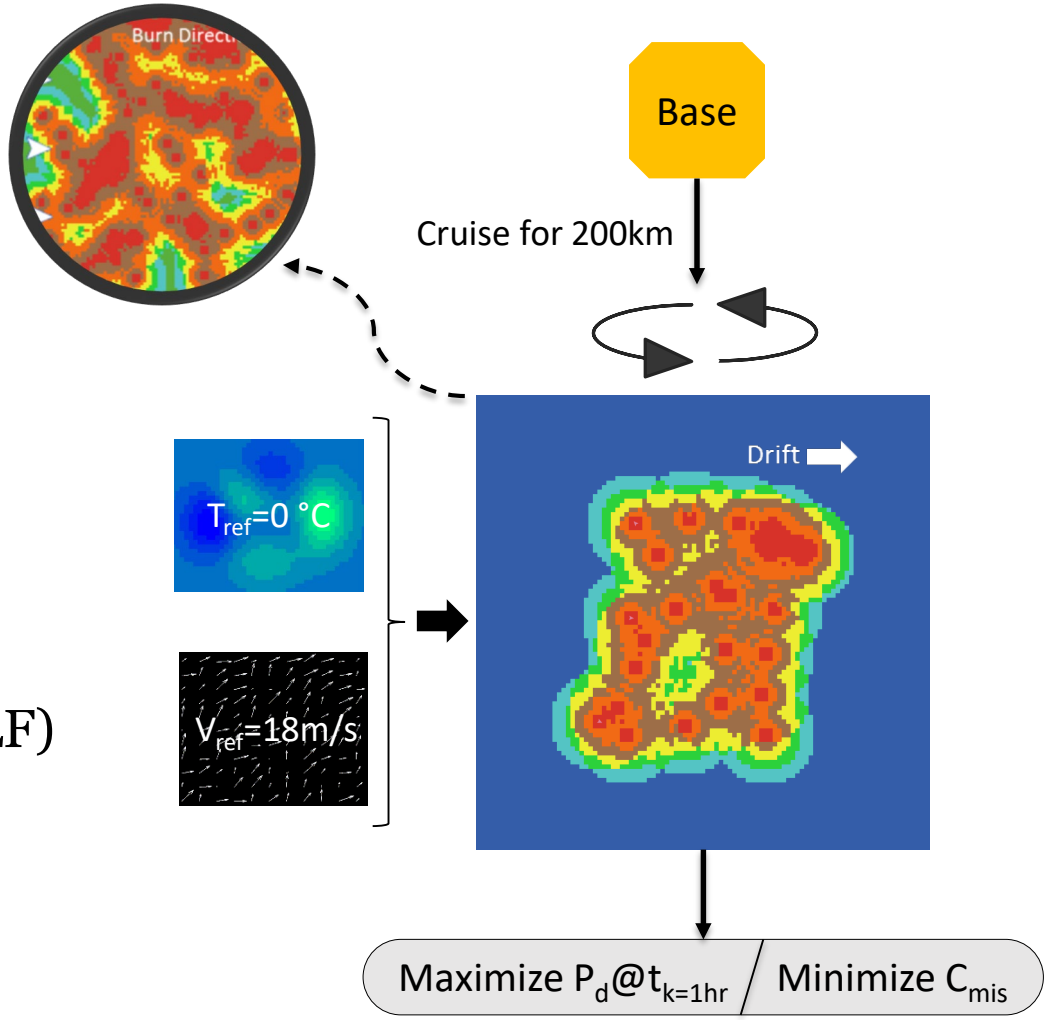
Framework



Proof Of Concept

Identifying SoS Capabilities

- Setting up a case study
  - Search for missing survivors/objects
  - Dynamic weather (sea & air) conditions
- Two operational scenarios
  - A) fleet of 3 existing UAV designs (HF)
  - B) fleet of 2-4 yet-to-be-designed UAVs (LF)
- Monitored capabilities (MoEs)
  - Detection probability VS Mission costs
  - Total payload / Fleet maintenance costs



Case Study 1 (HF)

10 existing UAV designs (A-J)

3 ACs combinations

Original framework

Identifying SoS Capabilities

- Results part A
  - A fleet of 3 existing UAV designs

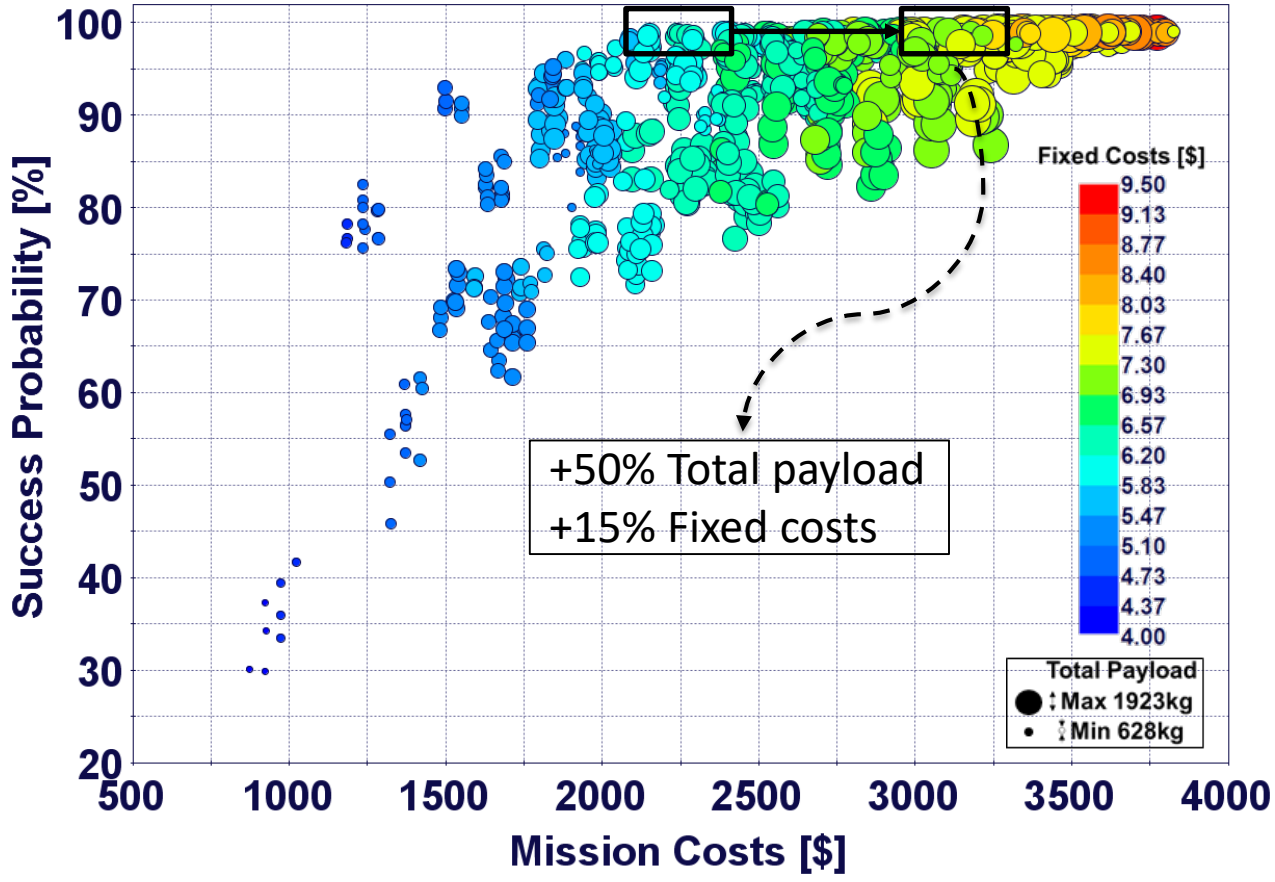
Pareto front

"Stagnation points"

Trade-off studies

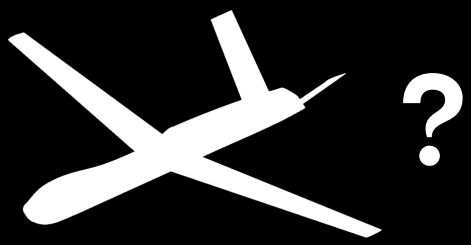
UAV combinations

More capabilities



Case Study 2 (LF)

Yet-to-de-designed UAVs
Combinations of 2-3-4 ACs



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Metamodel framework

Identifying SoS Capabilities

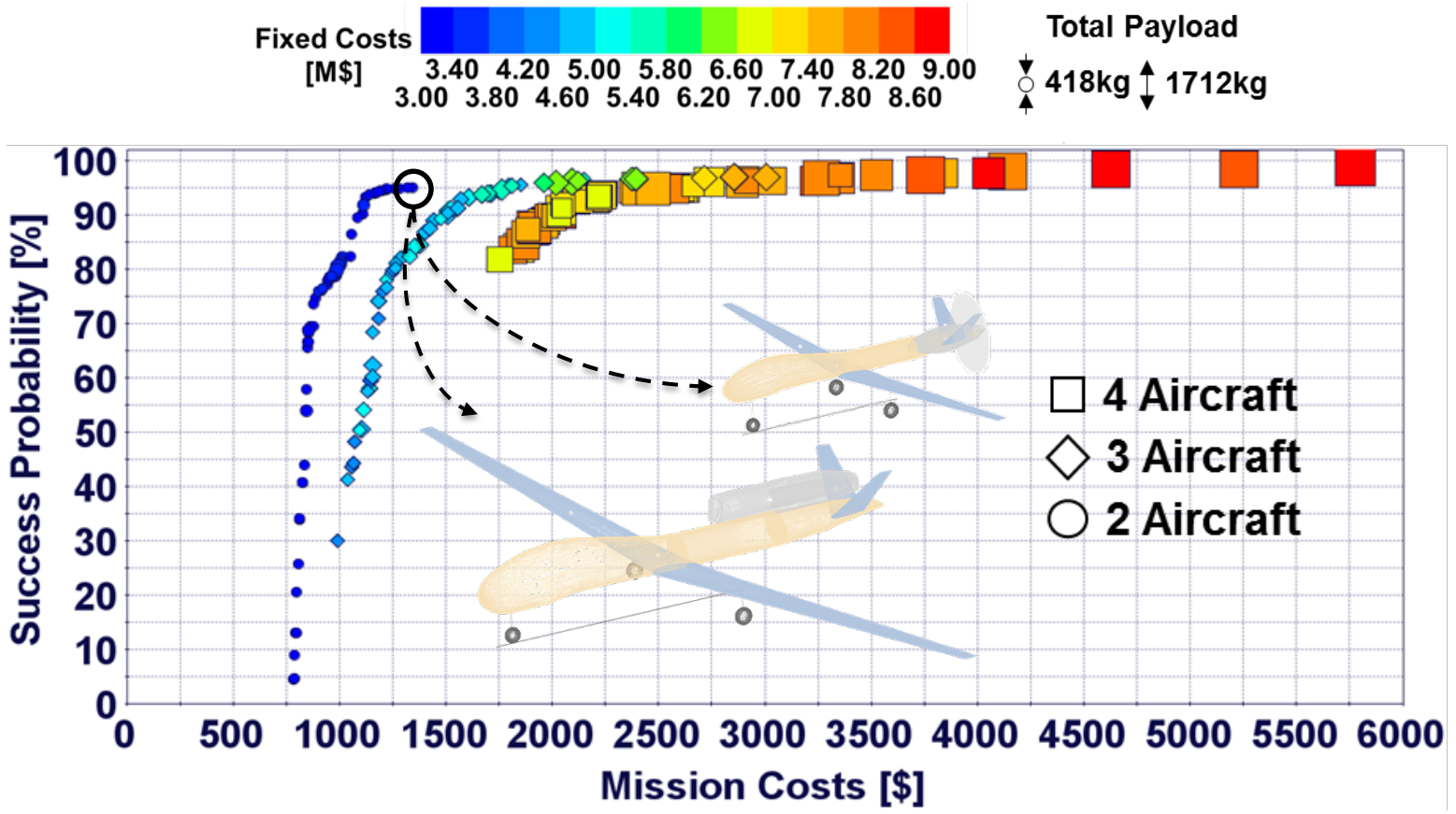
- Results part B
  - A fleet of 2-4 yet-to-be-designed UAVs

Extended Pareto front

"Stagnation points"

Trade-off studies

UAV designs



Concluding Remarks

Summary

- Technical developments
  - A methodology for populating the design space
  - Model development at all three system levels
  - A multi-fidelity design exploration framework
  - Surrogate models as a low-fidelity alternative
- Case study results
  - MoE depend on the chosen SoS
  - SoS bring forward new capabilities
  - Strong effect of scenario, tactics, and fidelity

What comes next?

- Airborne Early Warning & Control (AEW&C)

Thank you for your attention

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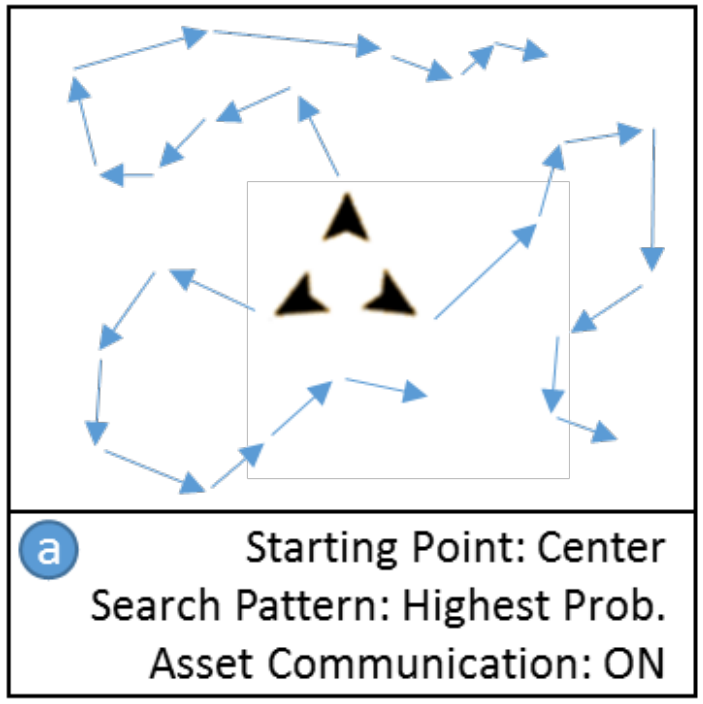
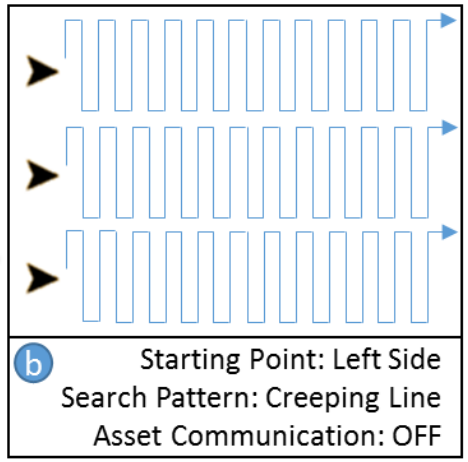
Backup Slides

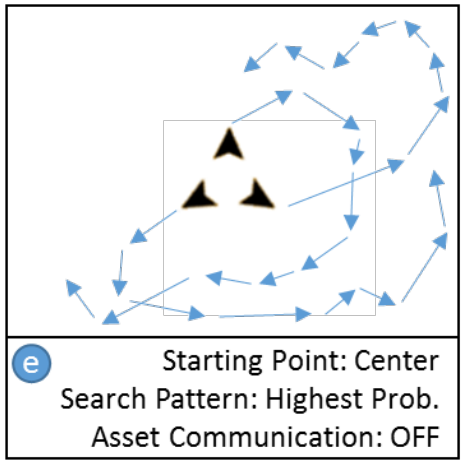
Aircraft tactics analysis



a Starting Point: Center
Search Pattern: Highest Prob.
Asset Communication: ON



b Starting Point: Left Side
Search Pattern: Creeping Line
Asset Communication: OFF



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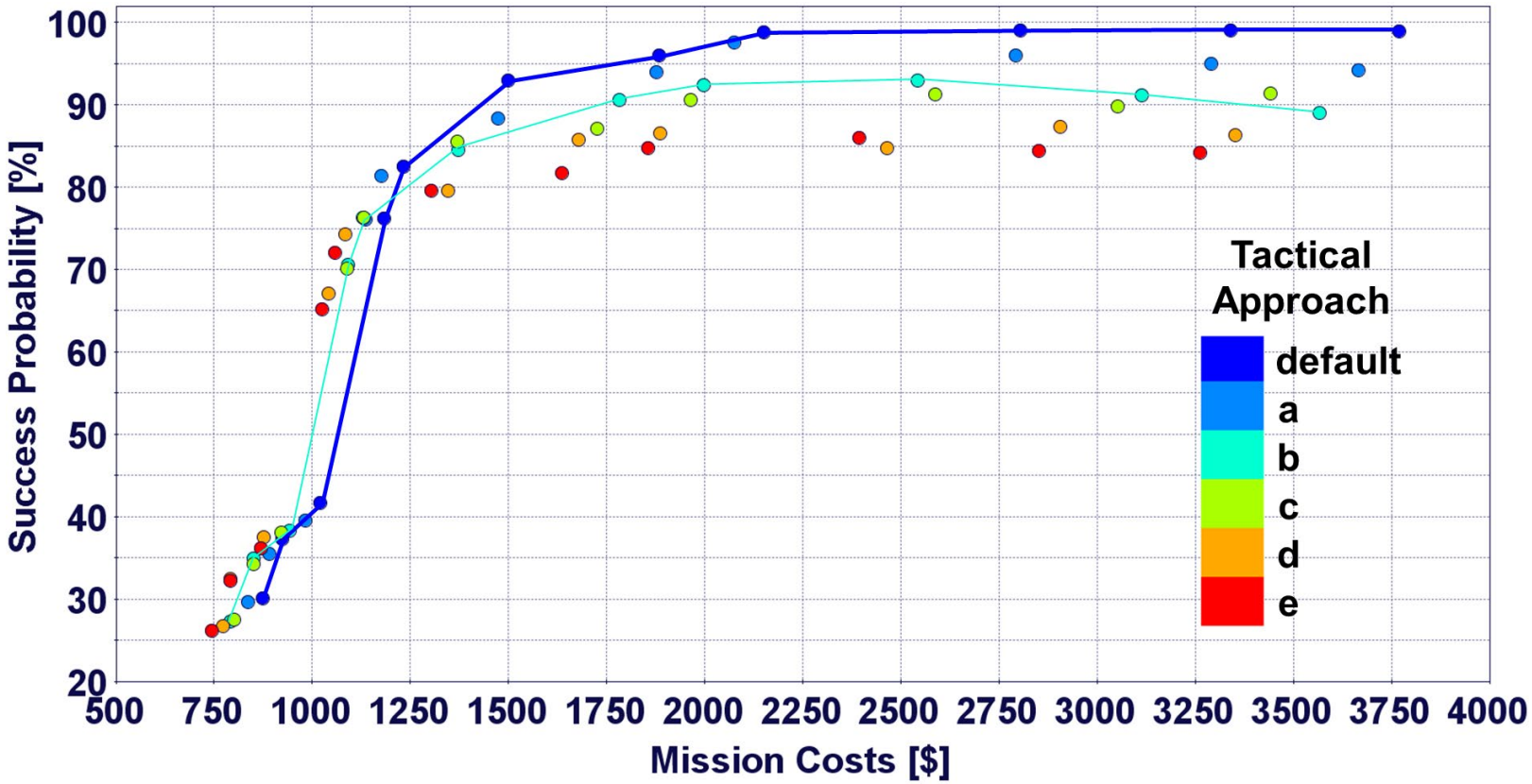
Aircraft tactics analysis



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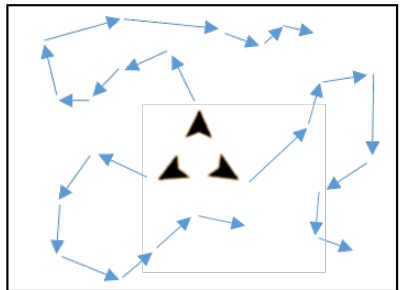

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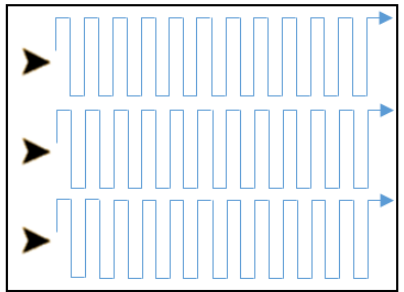

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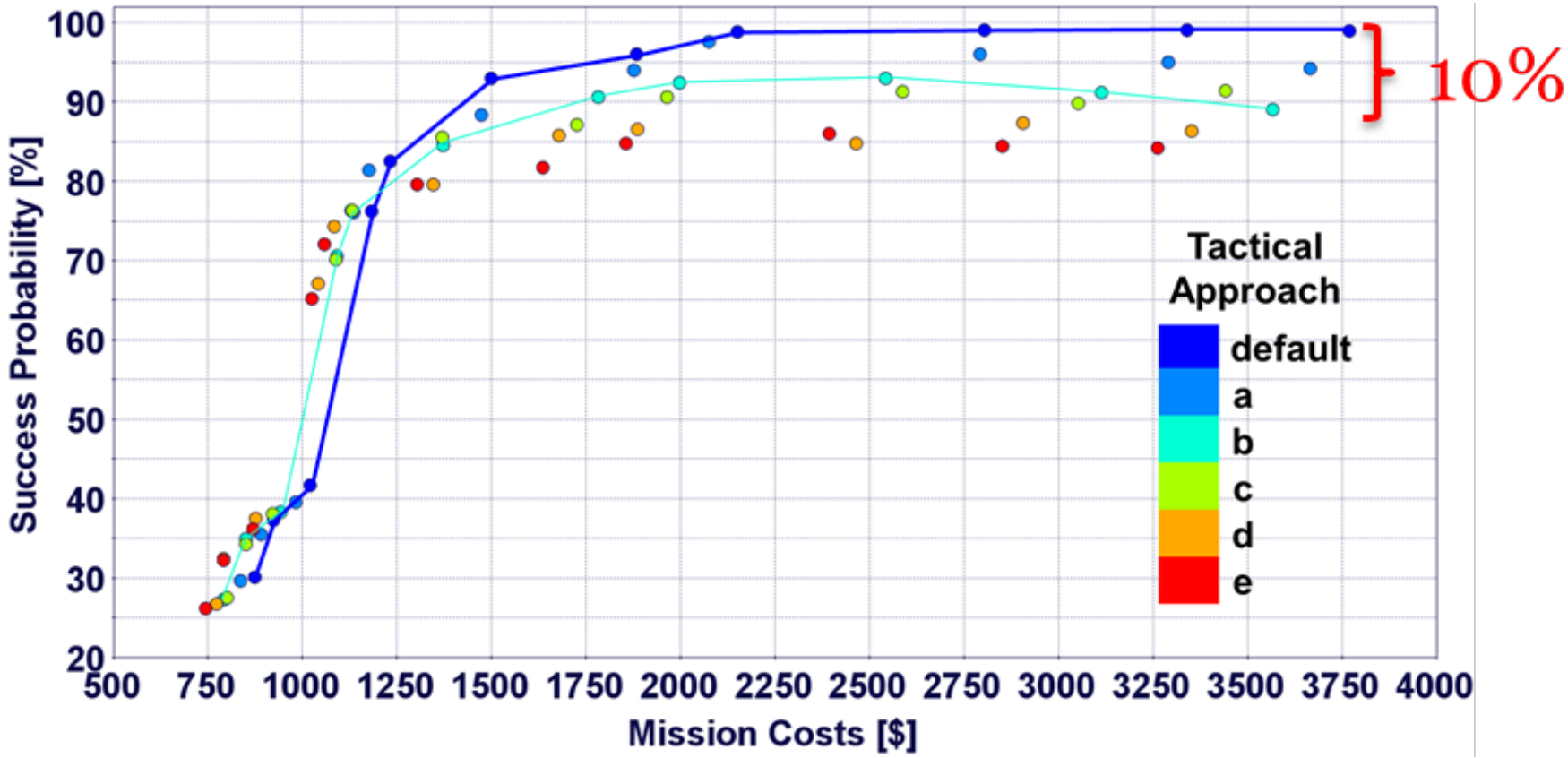
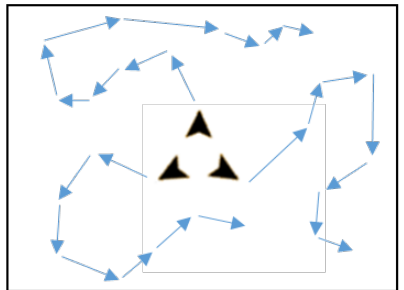


Aircraft tactics analysis



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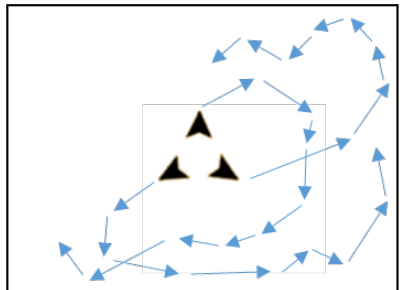
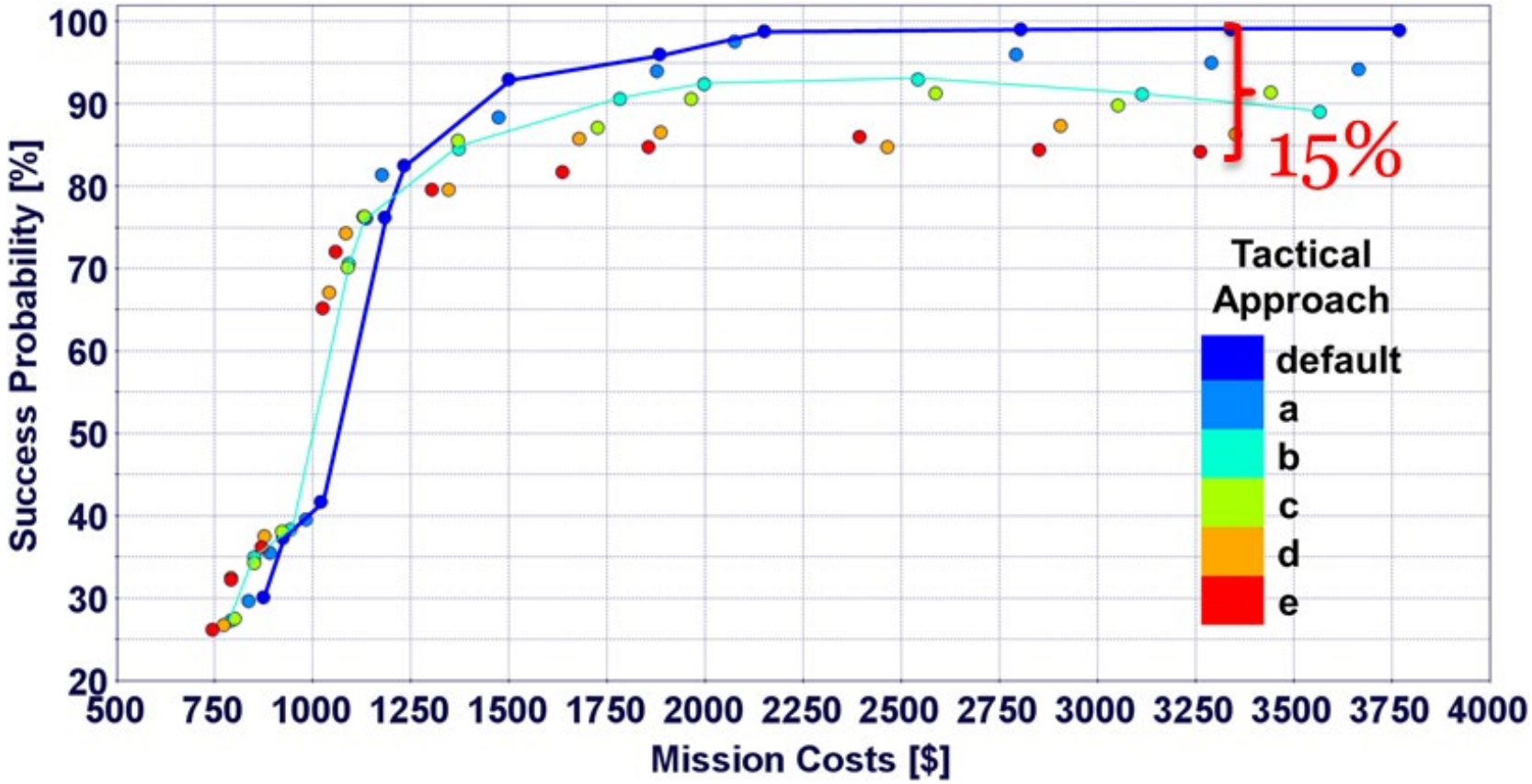
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