A Multi-fidelity Framework for Evaluating SoS of UAVs

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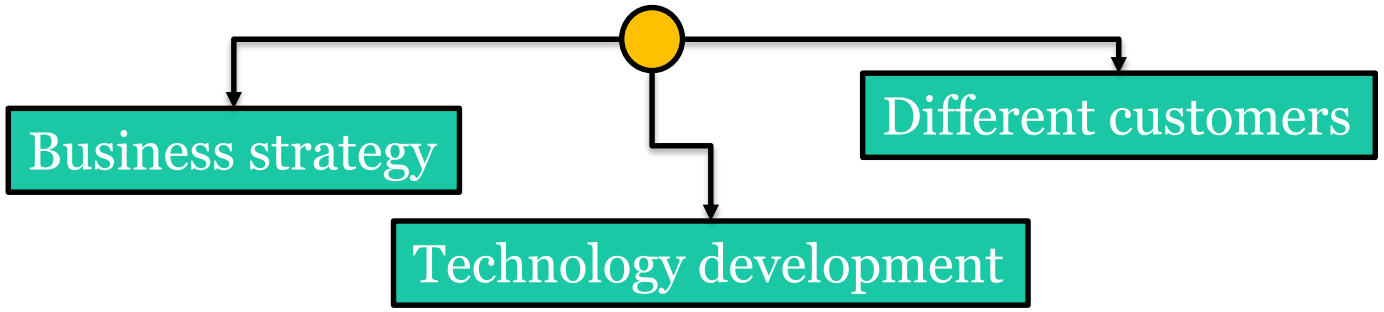
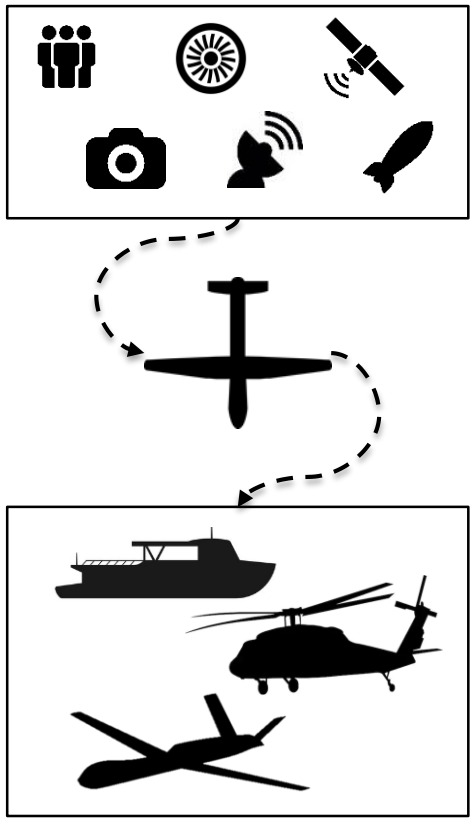
Background

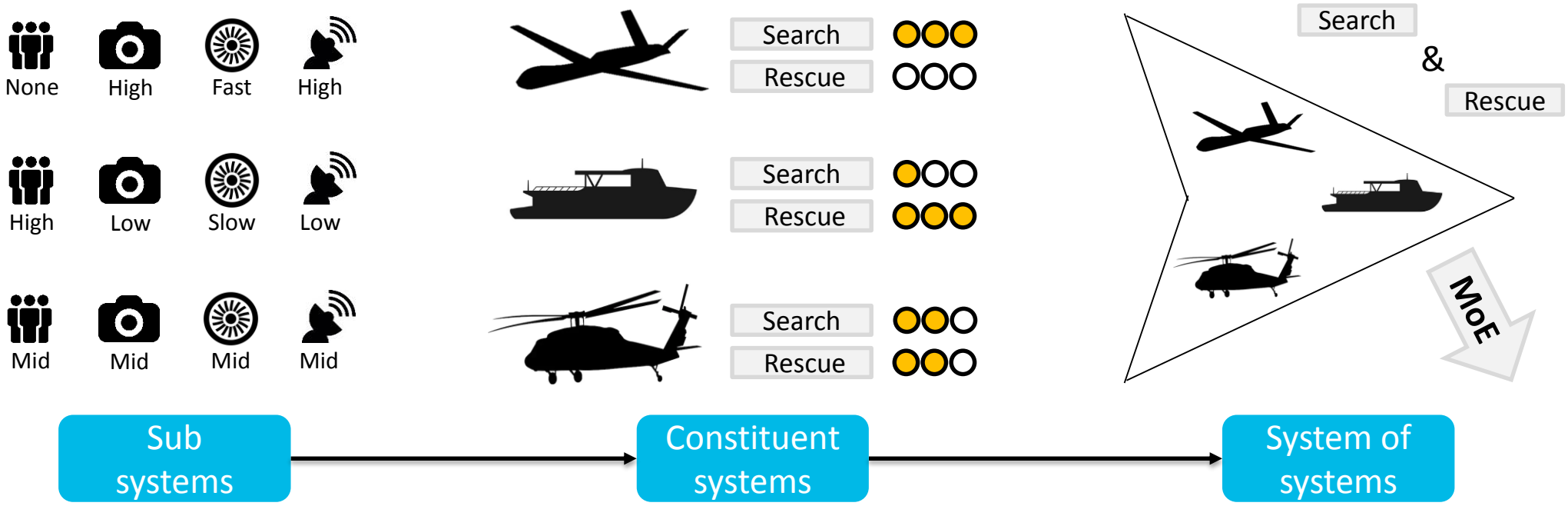
- Aerospace products are part of a network or a “System of Systems”
- SoS analyses have been used in the way customer acquire new assets
- Manufacturers should be able to perform similar analyses





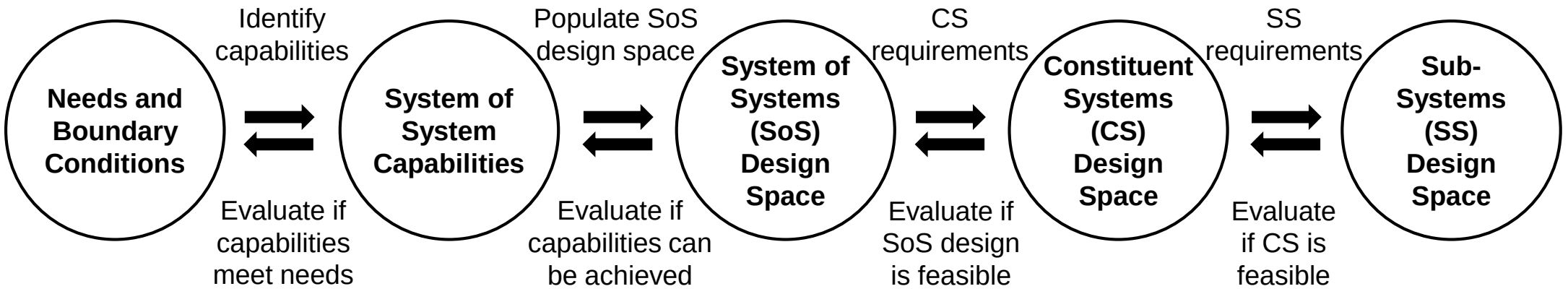
Background

"A SoS can bring forward new capabilities that are beyond those of individual system"

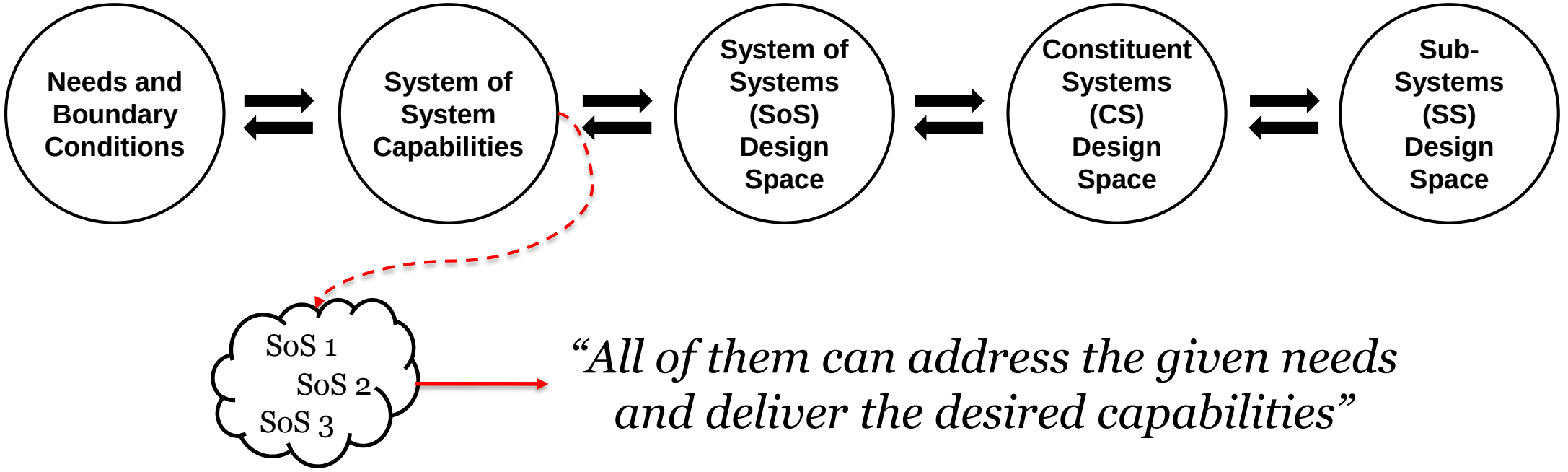


Background

"A holistic engineering approach to aeronautical product development"



Aim



Which is better?

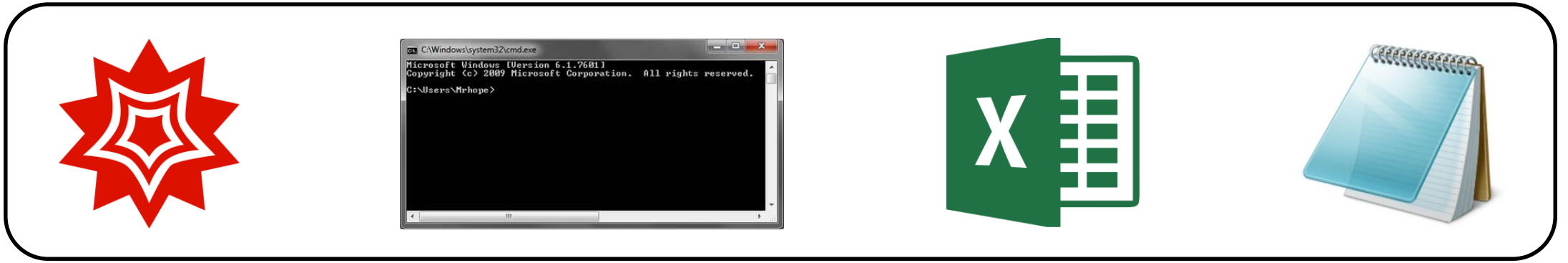
Can we get more?

Implementation

Tools


Sys


mF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Copyright (c) 2009 Microsoft Corporation. All rights reserved.
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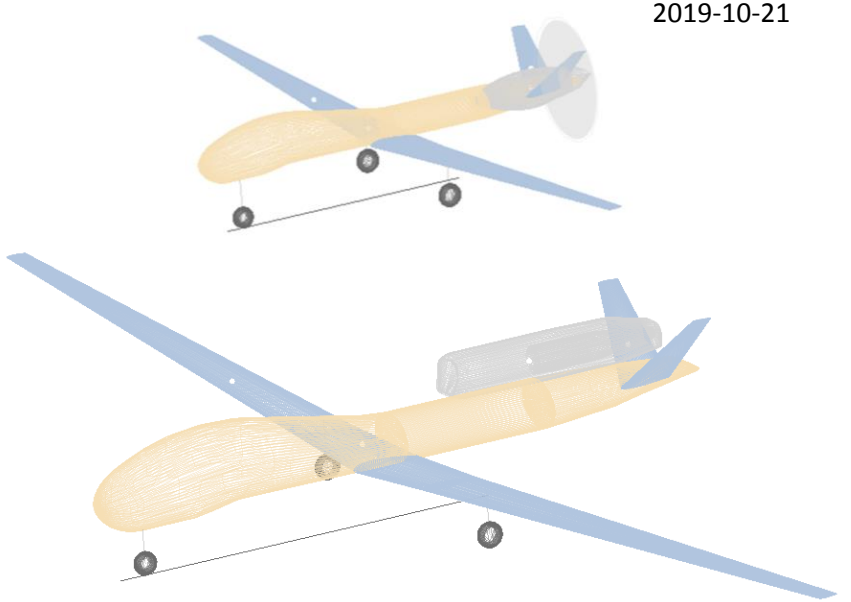
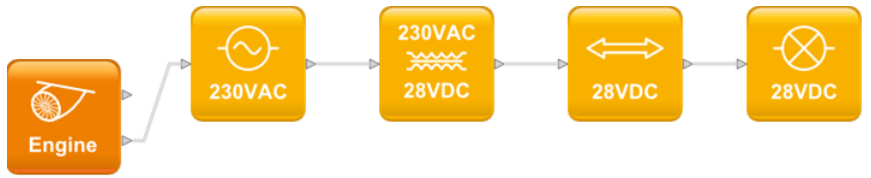
SS Analysis

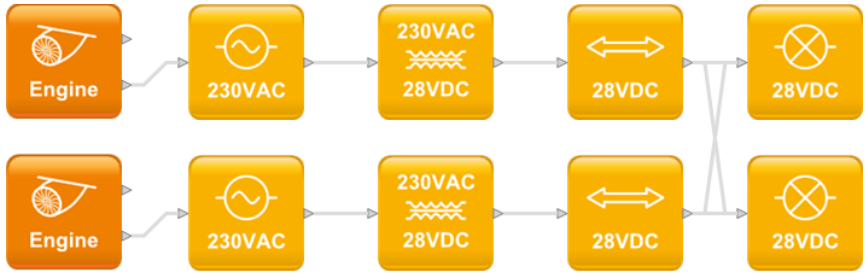
- EO/IR Sensor system
- LOS Communication system



- Miscellaneous systems
- Pathways and routing

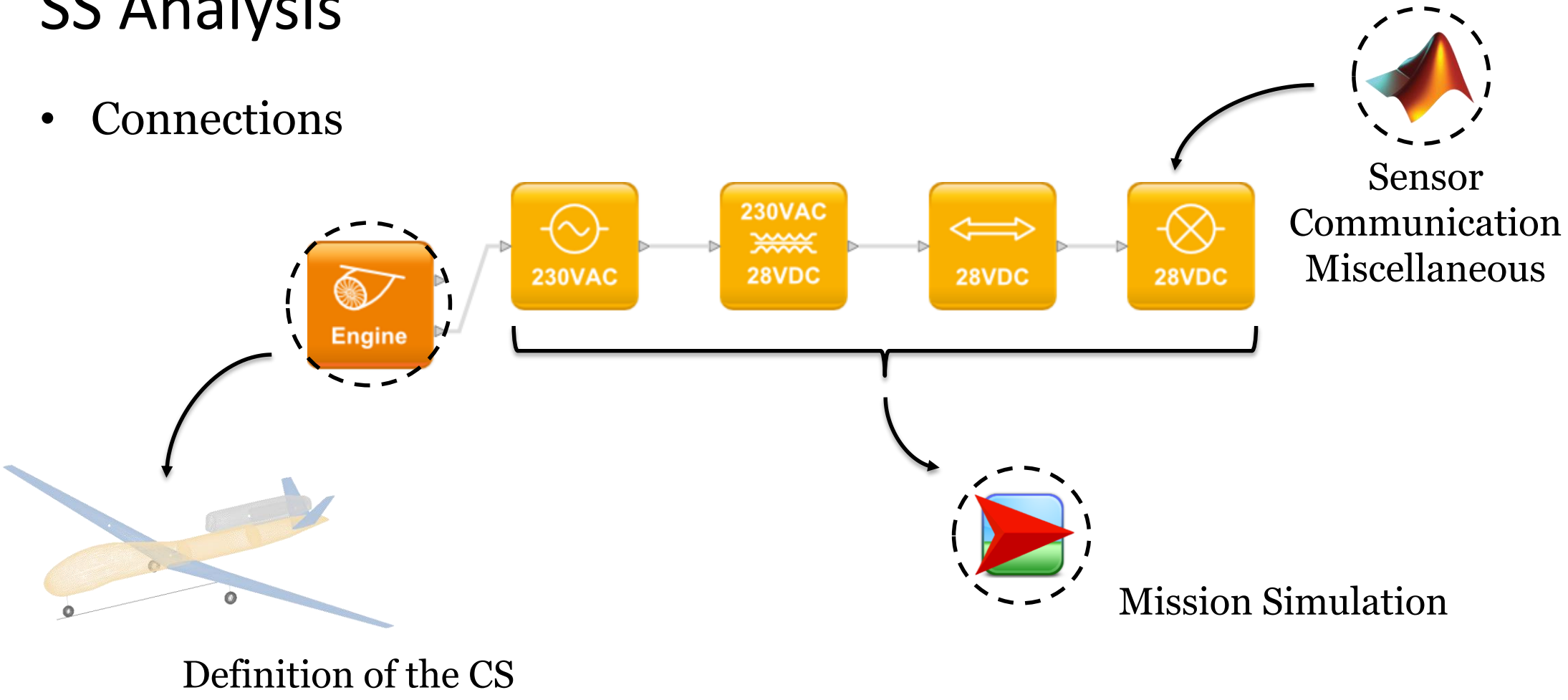


- Propulsion system
- Electrical system



SS Analysis

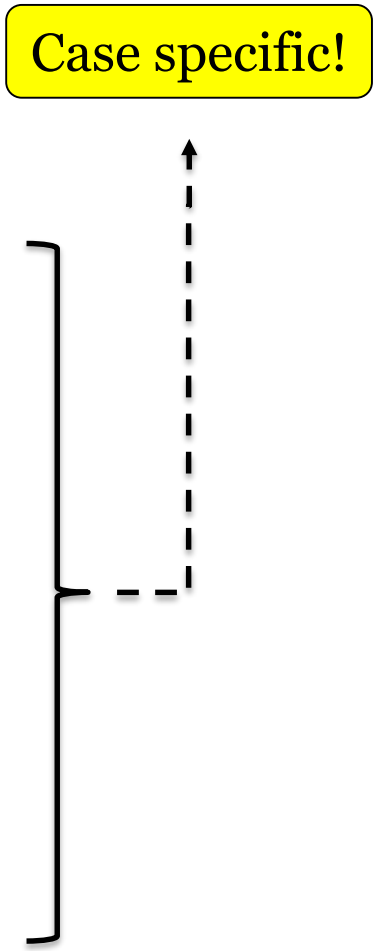
- Connections



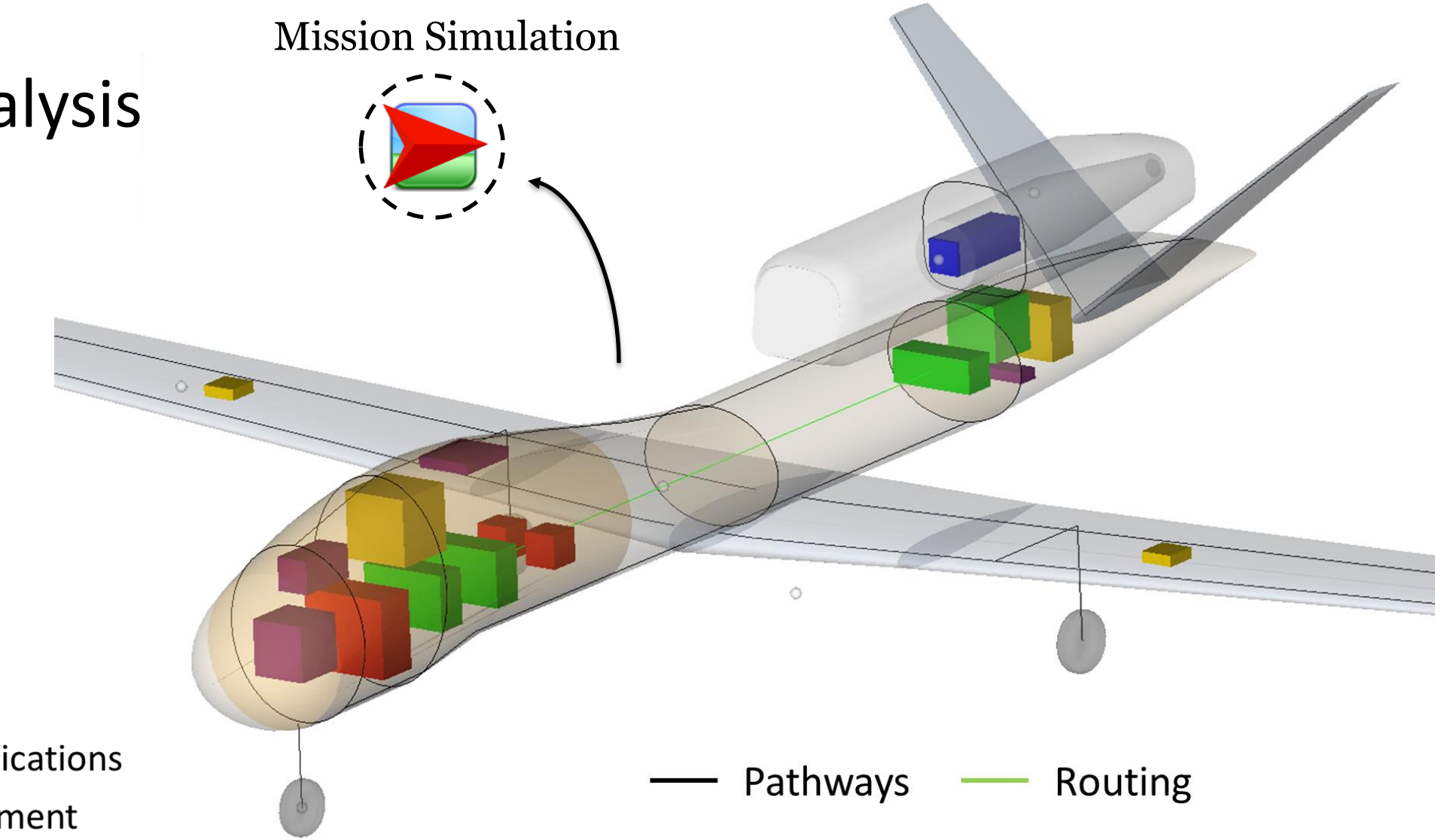
CS Analysis

- Exclusively implemented in PACE 

  - Use of calculation cases for sizing (*Range-MTOW, SM-WingX, StabilizerS-VolumeCoef*)
  - Use of ratios to decrease the geometry input parameters (*Wing Span, Fuselage Length*)
  - Use of ratios to decrease the design mission parameters (*Speed, Altitude, Range*)
  - Use of constraints to check feasibility and airworthiness (*Clearances, Stability, Performance*)

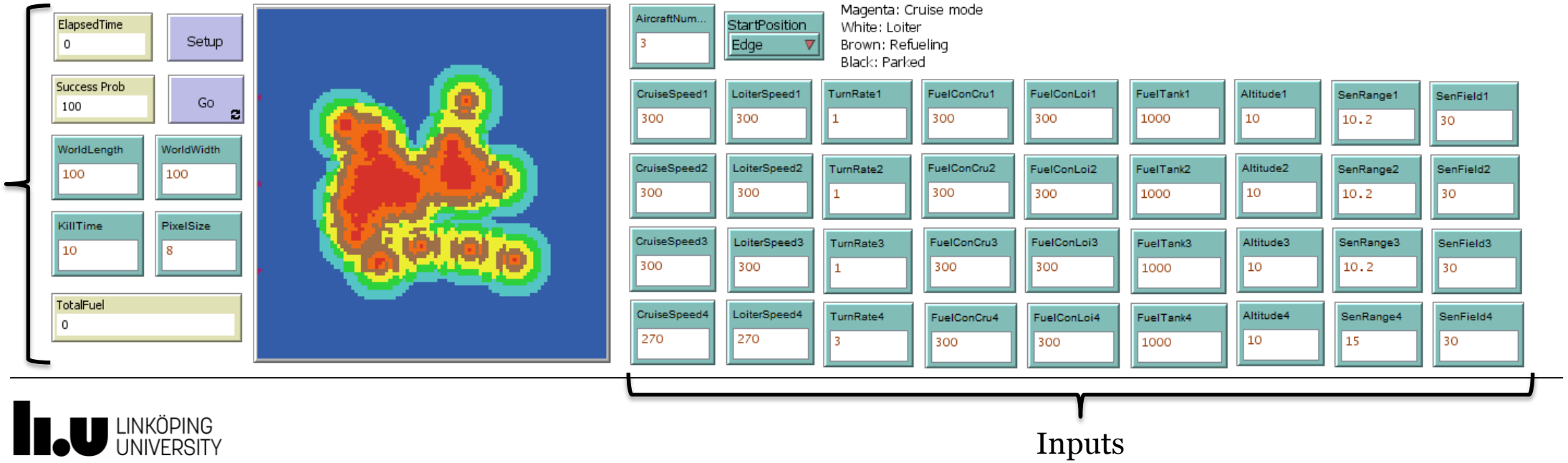


CS Analysis


Mission Simulation
Sensors
Engine
Electrical
Avionics
Communications
Compartment
Pathways
Routing

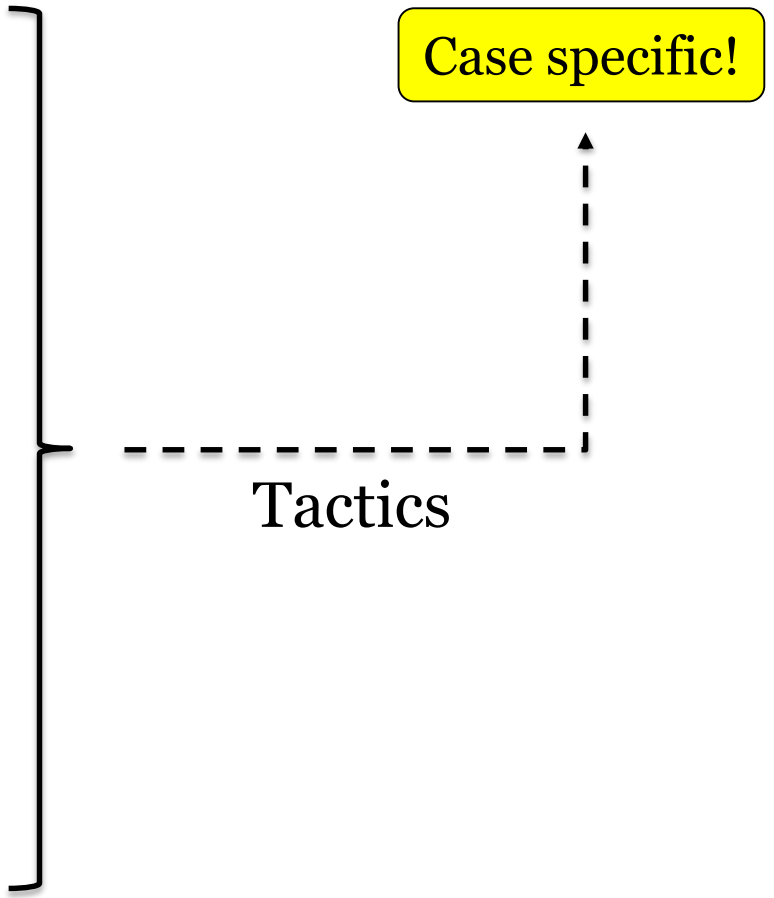
SoS Simulation

- Agent-based simulations in NETLOGO
  - Agents (“systems”)
  - World (“scenario”)
  - Rules of engagement (“tactics”)

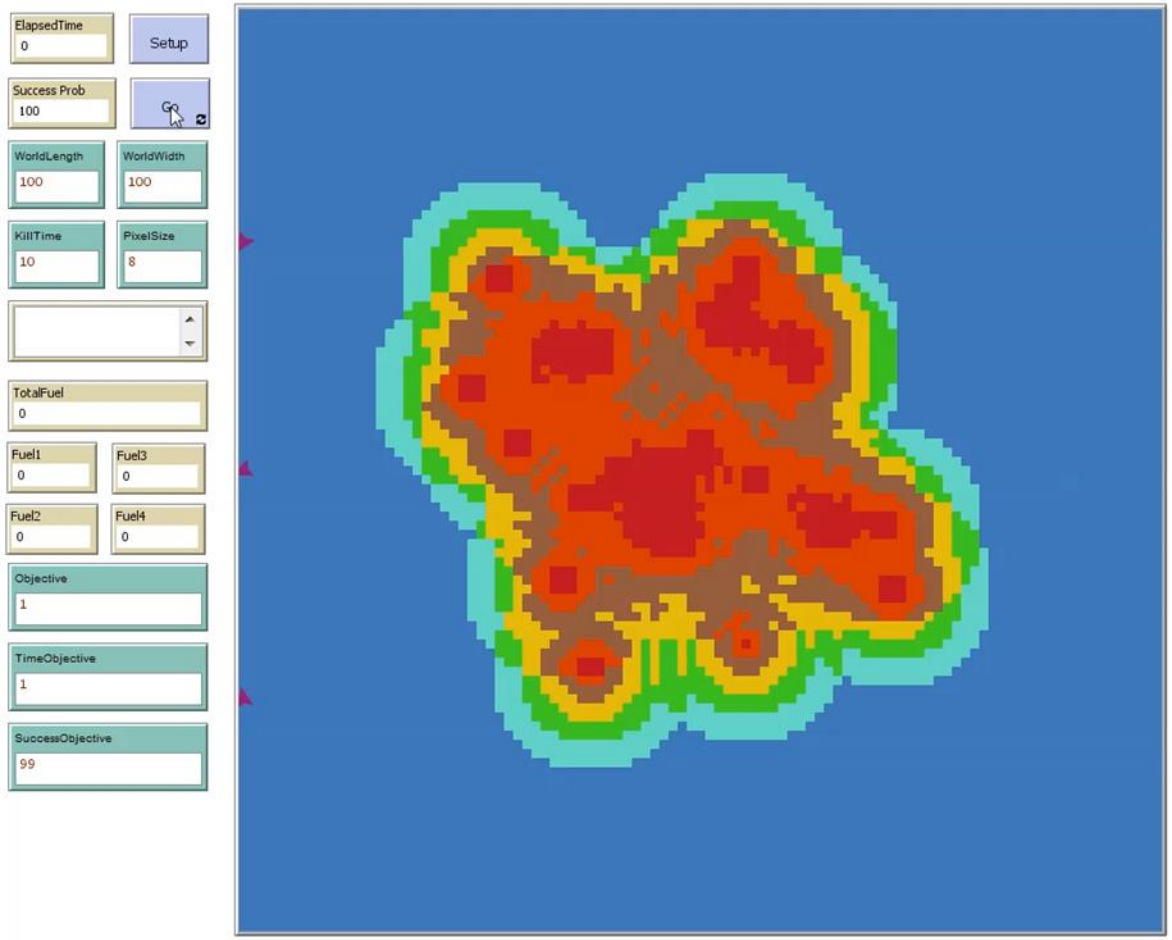


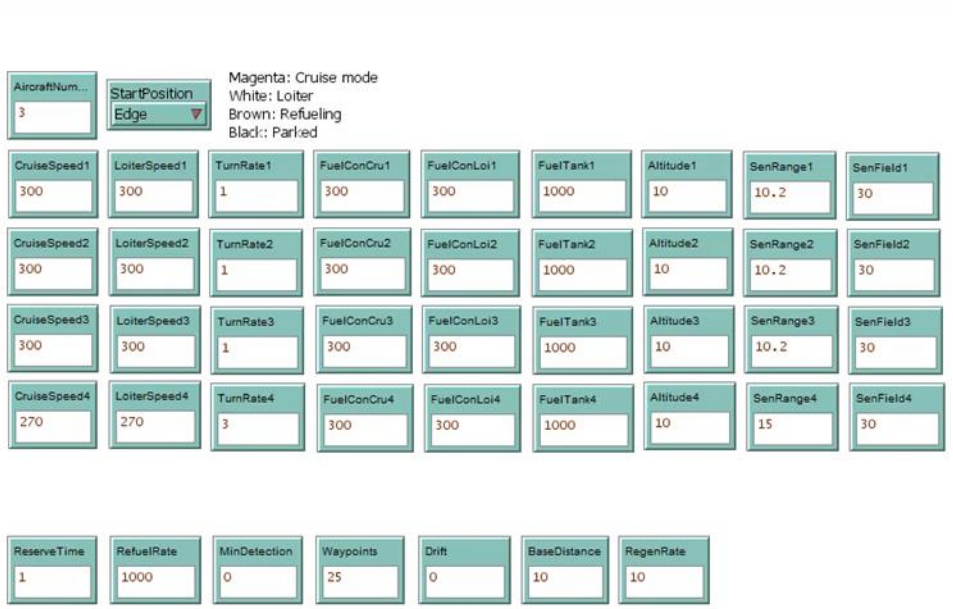
SoS Simulation

- General behavioral rules
  - Approach/depart sideways
  - Move to closest/highest probability
  - Do not leave the area bounds
  - Abort mission if failure occurs
- In communication range
  - Never fly towards scanned points
  - Never fly towards same point
  - Never fly close to each other



SoS Simulation



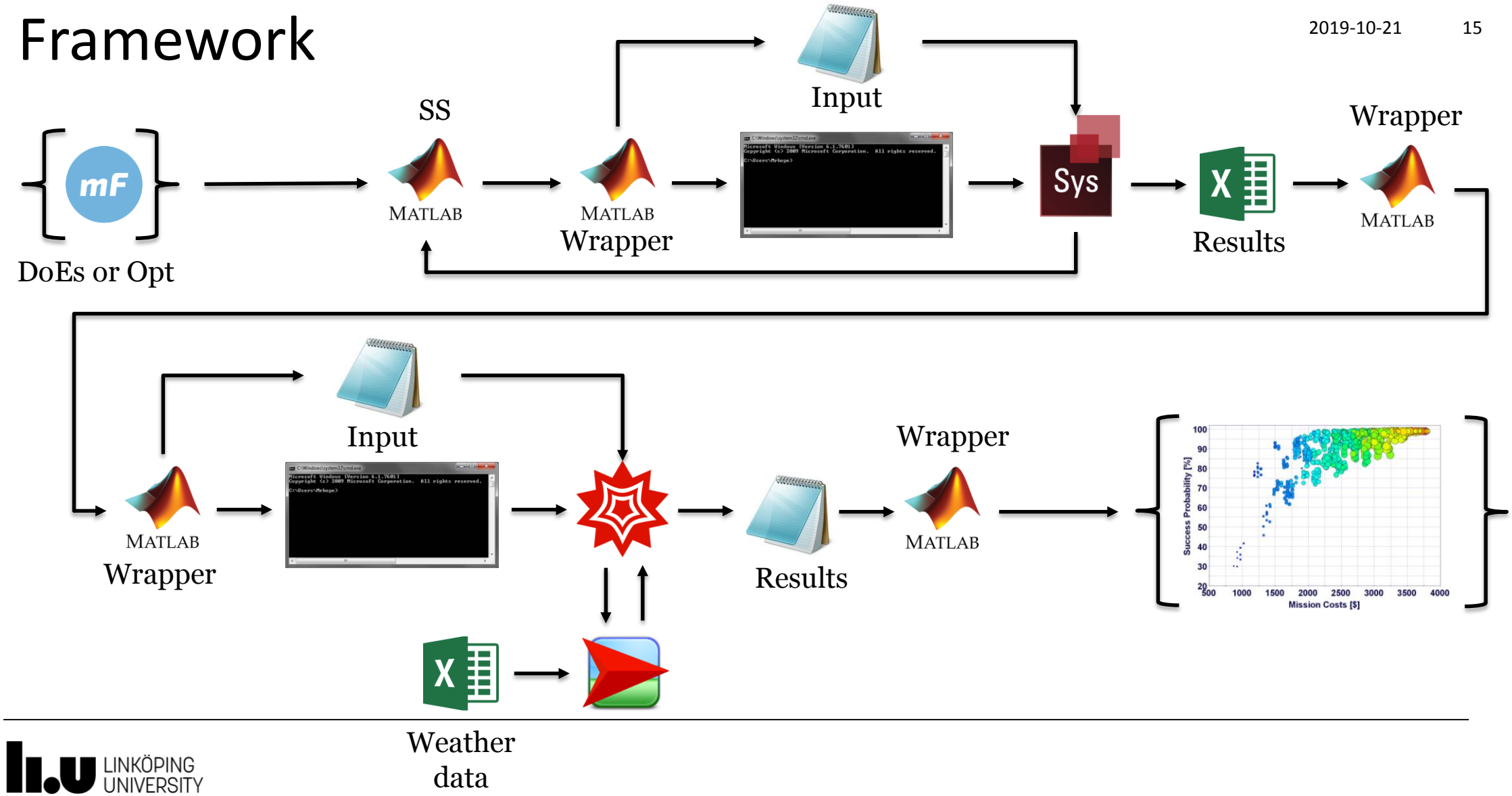


Speed in (km/h)
Turn rate in (deg/sec)
Consumption in (kg/h)
Fuel tank capacity in (kg)
Altitude in (km)
Sensor range in (km)
Sensor field in (deg)
Reserve time in (h)
Refuel rate in (kg/h)
Min detection in (-)
Waypoints in (-)
Drift in (km/h)
Base distance in (km)
Waypoint regeneration in (%)

Reserve time: The amount of time that each aircraft should have in fuel reserves
RefuelRate: The rate that the base is able to to refuel the aircraft
MinDetection: The minimum probability for skiping a waypoint
Waypoints: The number of survivors floating in the sea (defines the probability distribution)
Drift: The speed that the survivors are being carried away by currents
BaseDistance: The distance of the hypothetical starting point from the (0,0)
RegenRate: How many waypoints are regenerated if the objective probability is not reached

1 patch is 1 km
1 tick is 1 sec

Framework


SS
Input
Wrapper
mF
MATLAB
MATLAB
Wrapper
Sys
Results
MATLAB
DoEs or Opt
Input
Wrapper
MATLAB
Wrapper
Results
MATLAB
Success Probability [%]
Mission Costs [$]
Weather
data

Surrogate Models

- Validation
  - NRMSE
- SS level
  - <1%
- CS level
  - One surrogate @4000ULH -> 1.8%-19.8%
  - Multiple surrogates @500ULH -> 0.5%-10.6%
- SoS level
  - Multiple surrogates @500ULH -> 8.1%-11.9%

Case Study 1 (HF)

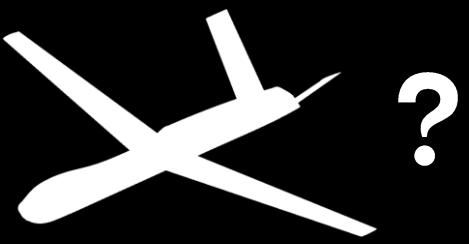
10 existing UAV designs (A-J)

3 ACs combinations

Case Study 2 (LF)

Yet-to-de-designed UAVs

Combinations of 2-3-4 ACs



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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

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