A System of Systems Approach for Search and Rescue Missions

Ludvig Knöös Franzén and Sofia Schön

LINKÖPING UNIVERSITY

Agenda

- Introduction
- Method
- Implementation of Case Study
- Conclusions

Introduction

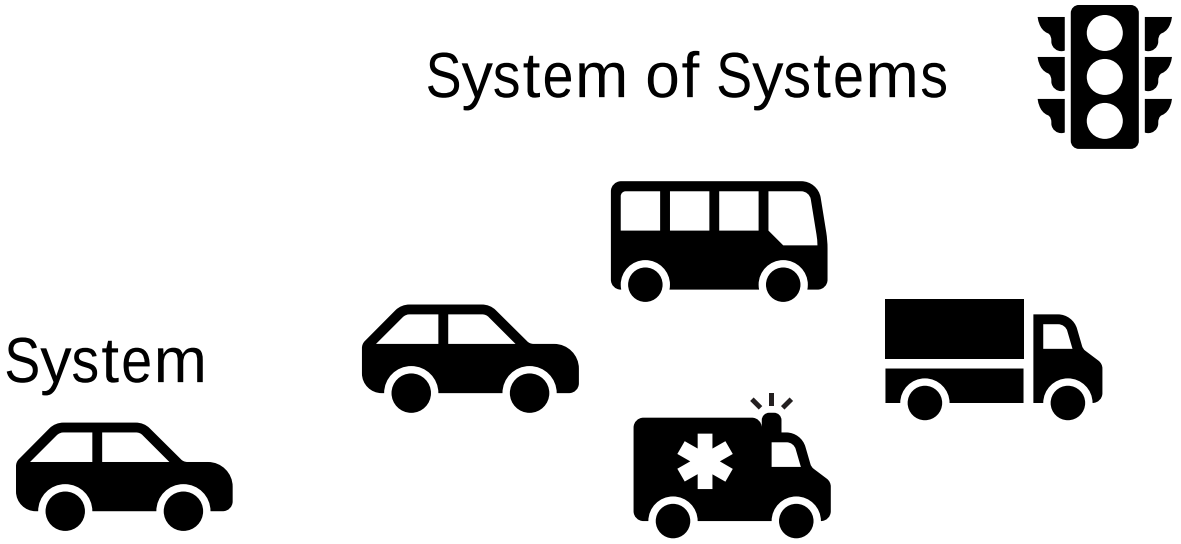
System of Systems, Holistic View, Purpose of Paper

System of Systems

"A System of Systems (SoS) is a collection of independent systems, integrated into a larger system that delivers unique capabilities. The independent constituent systems collaborate to produce global behavior that they cannot produce alone." INCOSE

Maiers Characteristics

1. Operational Independence of Elements
2. Managerial Independence of Elements
3. Evolutionary Development
4. Emergent Behaviour
5. Geographic Distribution

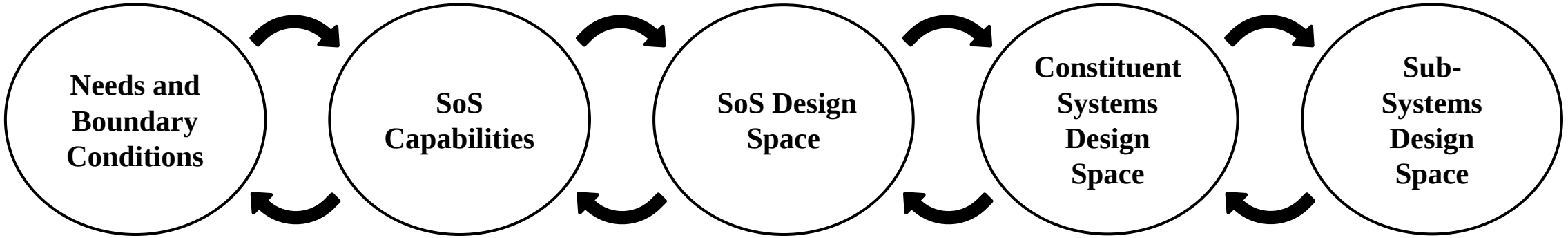


Challenges

- Increased complexity
- Interconnections between systems and the operational environment
- Changing operational environment
- Long lead times during development and long expected lifespans
- Changing requirements
- Forecasts needs to be incorporated early in the design process
- Predicting the future and facilitating system's survivability
- Desire to deliver capabilities over time

Holistic View

- Five intercorrelated levels of interest
- Design space explorations



Purpose of Paper

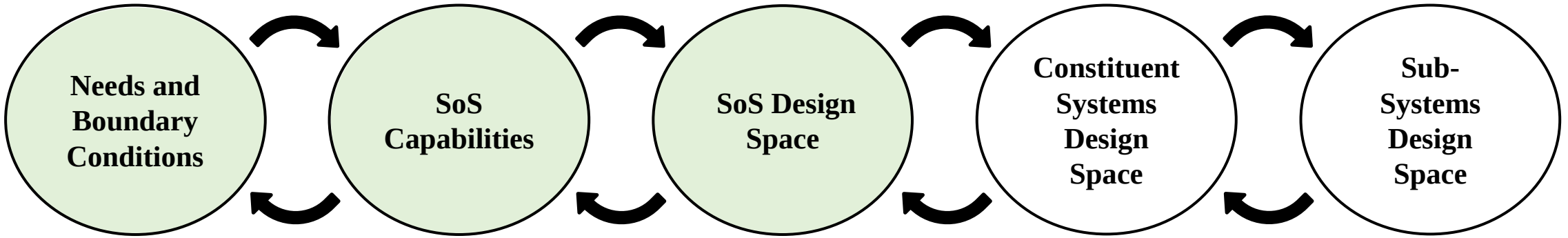
- An approach for realizing parts of the Holistic View
- Generate, reduce and evaluate a System-of-Systems design space
- Taking a System-of-Systems from a highly abstract level to a lower and more detailed level

Method

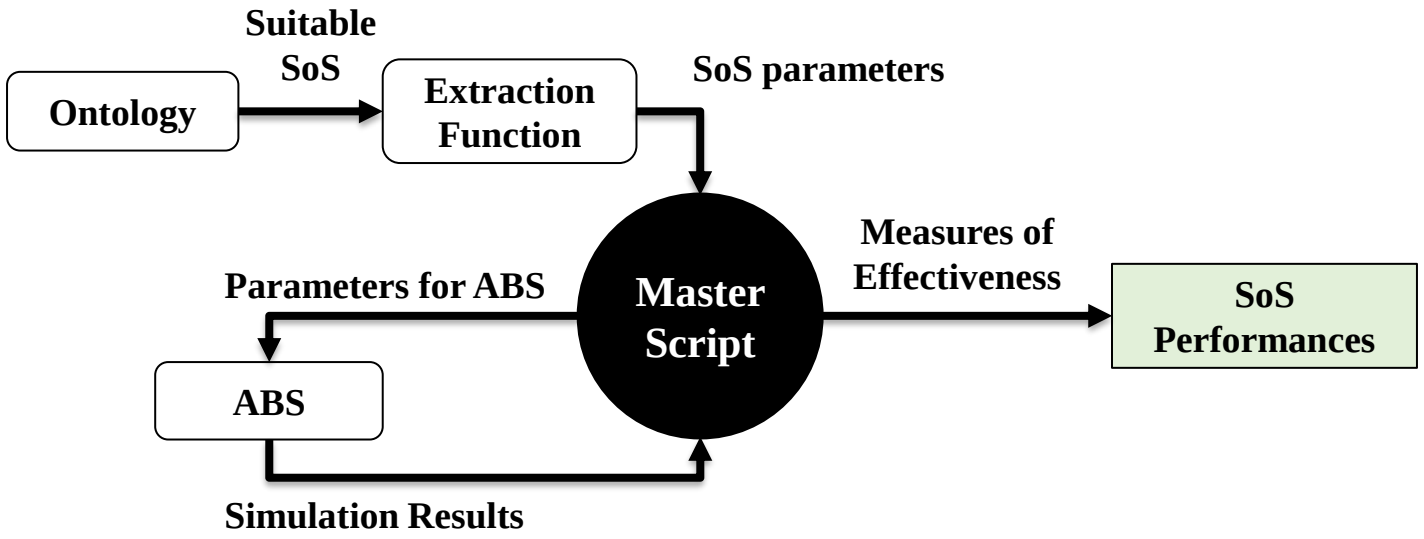
Approach, Method

Approach

- Ontology to describe a System of Systems on an abstract level
- Agent-Based Simulation to evaluate performance on a more detailed level



Method

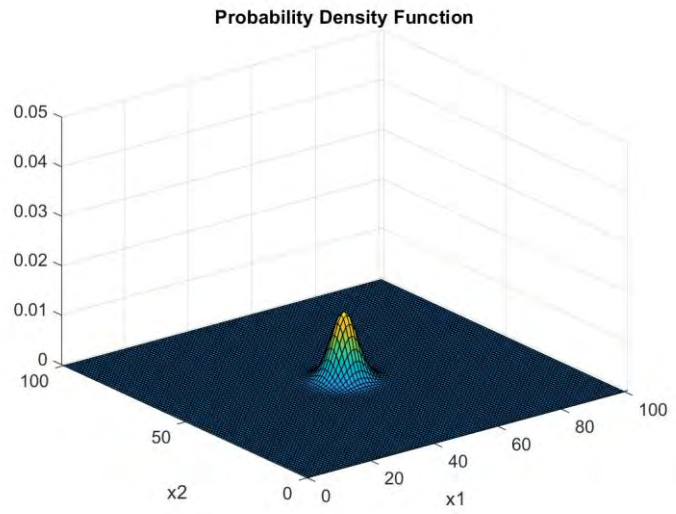

Suitable SoS
Ontology
Extraction Function
SoS parameters
Measures of Effectiveness
Parameters for ABS
Master Script
SoS Performances
ABS
Simulation Results

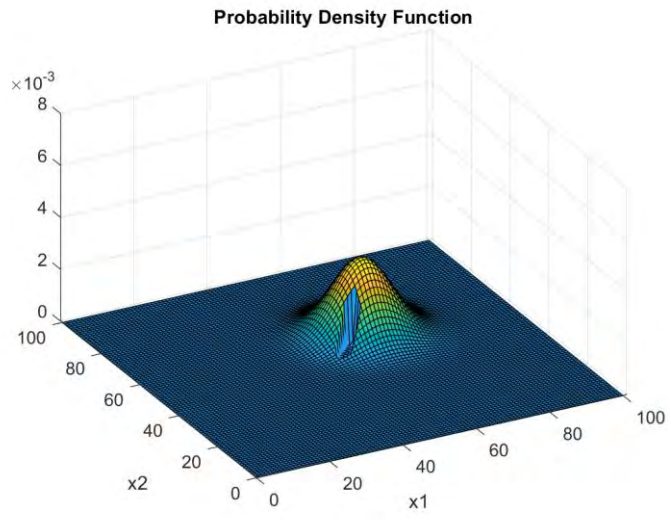
Implementation of Case Study

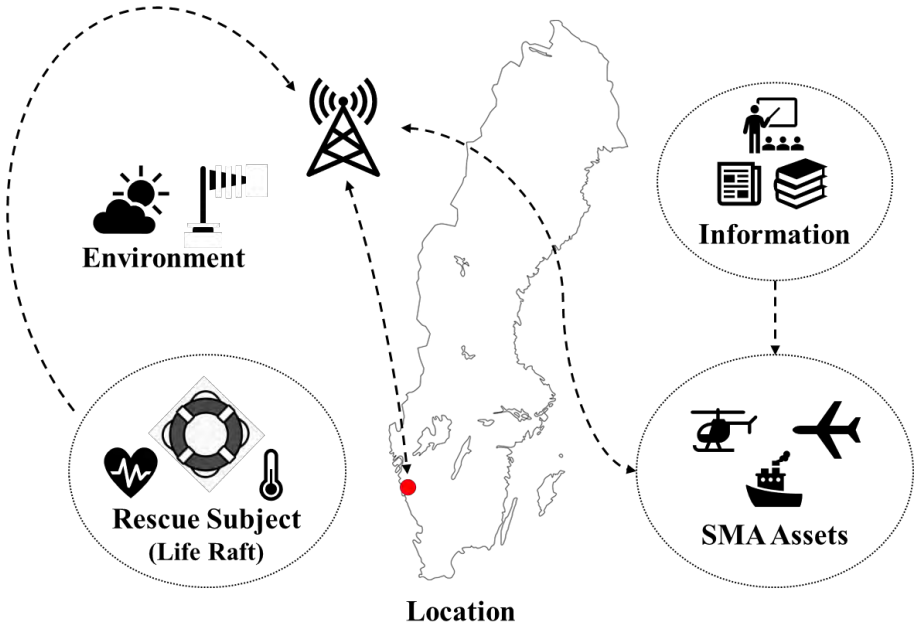
Search and Rescue, Ontology, Agent-Based Simulation

Search and Rescue Case Study

- 6 types of assets available
- Life Raft lost at sea with a Last Known Position
- Bayesian approach with PDF
- Constant drift in north east direction

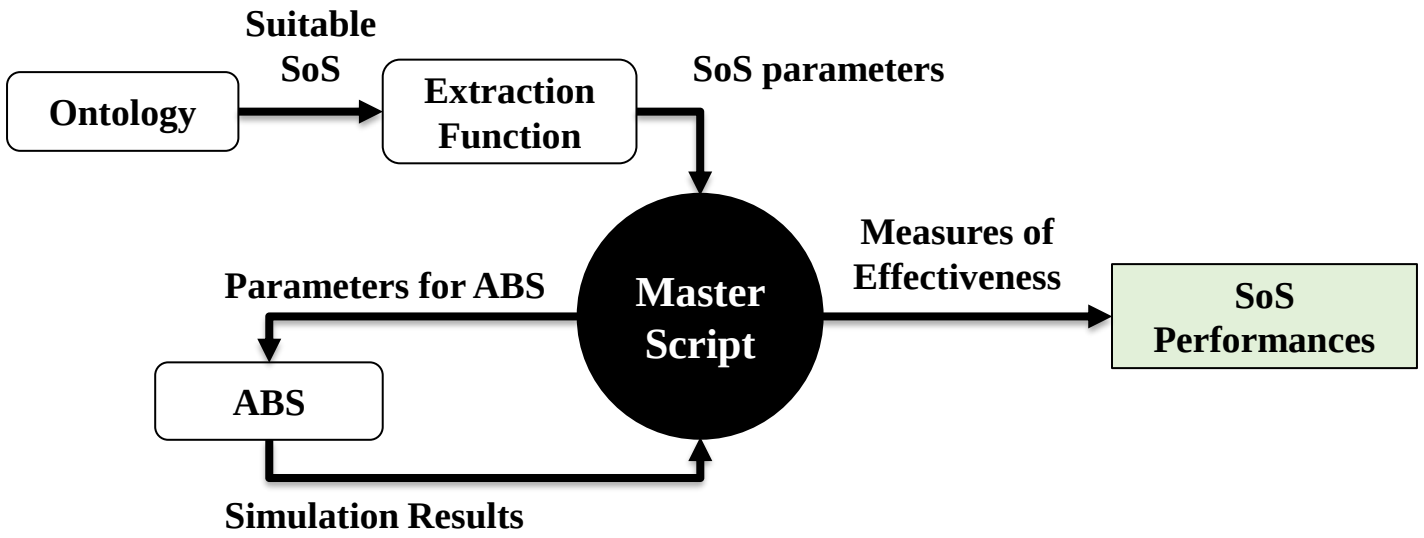




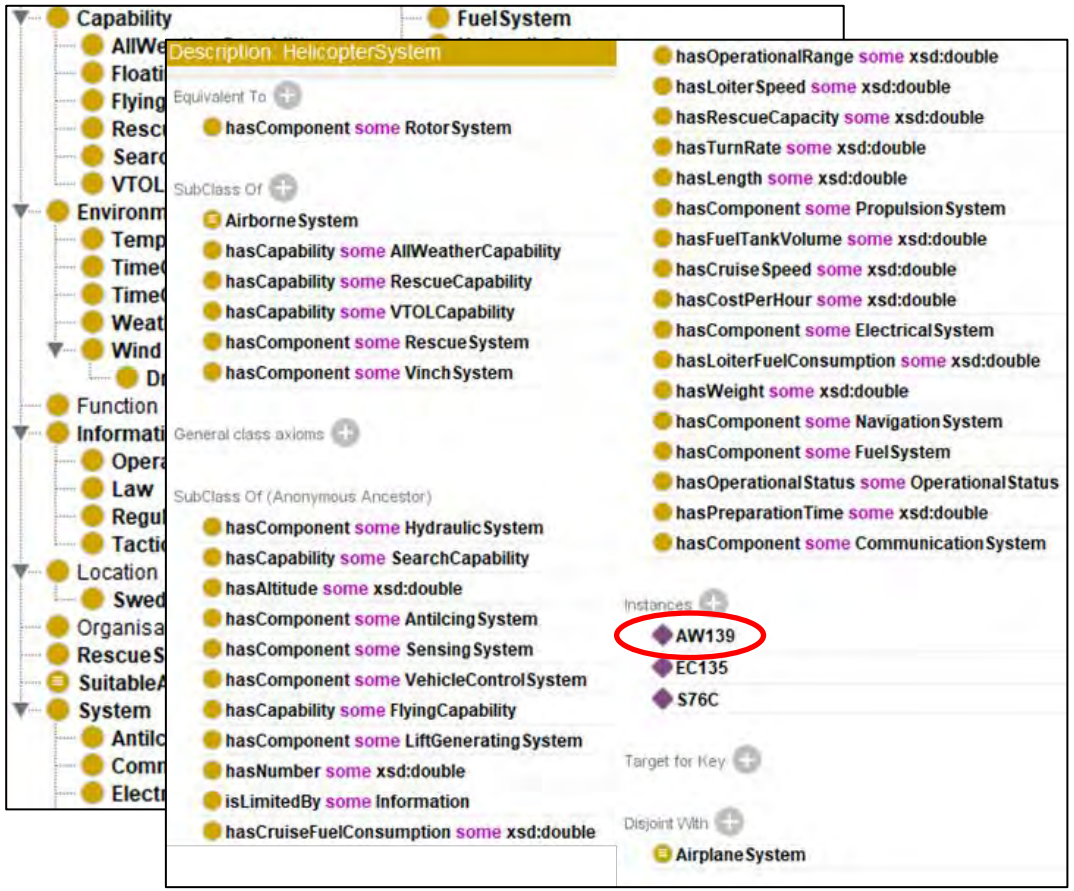


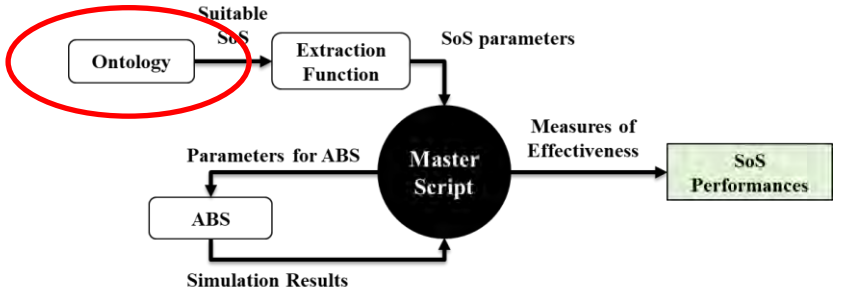
Search and Rescue Case Study

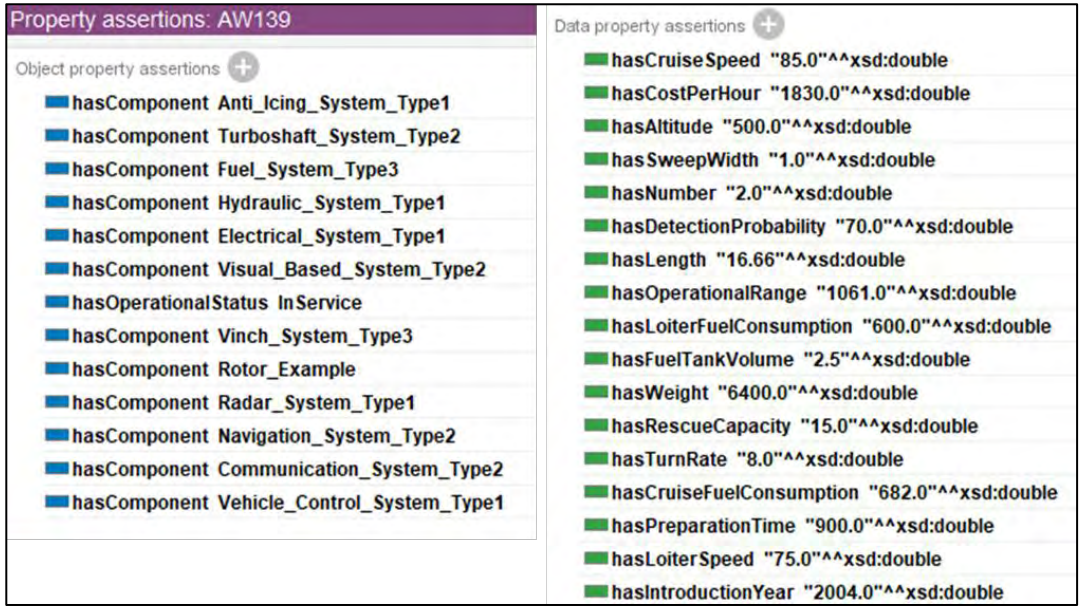
- Use method to generate, reduce and evaluate a SoS Design Space of different constellations of Search and Rescue assets



Ontology

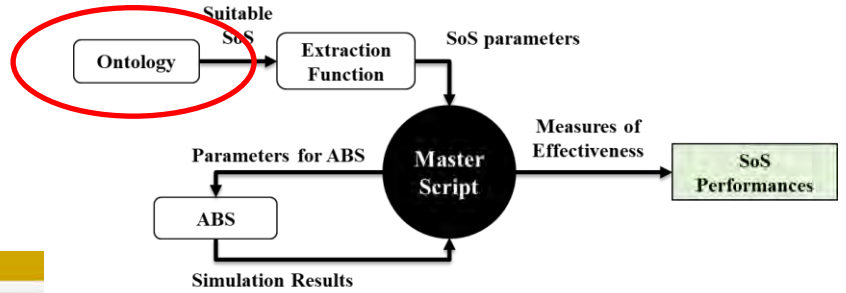

Capability
FuelSystem
Description: HelicopterSystem
Equivalent To
hasComponent some RotorSystem
SubClass Of
AirborneSystem
hasCapability some AllWeatherCapability
hasCapability some RescueCapability
hasCapability some VTOLCapability
hasComponent some RescueSystem
hasComponent some VinchSystem
General class axioms
SubClass Of (Anonymous Ancestor)
hasComponent some HydraulicSystem
hasCapability some SearchCapability
hasAltitude some xsd:double
hasComponent some AntiIcingSystem
hasComponent some SensingSystem
hasComponent some VehicleControlSystem
hasCapability some FlyingCapability
hasComponent some LiftGeneratingSystem
hasNumber some xsd:double
isLimitedBy some Information
hasCruiseFuelConsumption some xsd:double
hasOperationalRange some xsd:double
hasLoiterSpeed some xsd:double
hasRescueCapacity some xsd:double
hasTurnRate some xsd:double
hasLength some xsd:double
hasComponent some PropulsionSystem
hasFuelTankVolume some xsd:double
hasCruiseSpeed some xsd:double
hasCostPerHour some xsd:double
hasComponent some ElectricalSystem
hasLoiterFuelConsumption some xsd:double
hasWeight some xsd:double
hasComponent some NavigationSystem
hasComponent some FuelSystem
hasOperationalStatus some OperationalStatus
hasPreparationTime some xsd:double
hasComponent some CommunicationSystem
Instances
AW139
EC135
S76C
Target for Key
Disjoint With
AirplaneSystem


Ontology
Suitable SoS
Extraction Function
SoS parameters
Parameters for ABS
Master Script
Measures of Effectiveness
SoS Performances
ABS
Simulation Results


Property assertions: AW139
Object property assertions
hasComponent Anti_Icing_System_Type1
hasComponent Turboshaft_System_Type2
hasComponent Fuel_System_Type3
hasComponent Hydraulic_System_Type1
hasComponent Electrical_System_Type1
hasComponent Visual_Based_System_Type2
hasOperationalStatus InService
hasComponent Vinch_System_Type3
hasComponent Rotor_Example
hasComponent Radar_System_Type1
hasComponent Navigation_System_Type2
hasComponent Communication_System_Type2
hasComponent Vehicle_Control_System_Type1
Data property assertions
hasCruiseSpeed "85.0"^^xsd:double
hasCostPerHour "1830.0"^^xsd:double
hasAltitude "500.0"^^xsd:double
hasSweepWidth "1.0"^^xsd:double
hasNumber "2.0"^^xsd:double
hasDetectionProbability "70.0"^^xsd:double
hasLength "16.66"^^xsd:double
hasOperationalRange "1061.0"^^xsd:double
hasLoiterFuelConsumption "600.0"^^xsd:double
hasFuelTankVolume "2.5"^^xsd:double
hasWeight "6400.0"^^xsd:double
hasRescueCapacity "15.0"^^xsd:double
hasTurnRate "8.0"^^xsd:double
hasCruiseFuelConsumption "682.0"^^xsd:double
hasPreparationTime "900.0"^^xsd:double
hasLoiterSpeed "75.0"^^xsd:double
hasIntroductionYear "2004.0"^^xsd:double

Ontology

- Identified needs
- Reasoner
- Suitable Assets



Inferred Ontology

Description: SuitableAsset

Equivalent To
(hasCapability some FlyingCapability)
and (hasCapability some SearchCapability)
and (hasOperationalStatus value InService)
and (hasCruiseSpeed some xsd:double[>= "60.0"^^xsd:double])

SubClass Of
AirborneSystem

General class axioms

SubClass Of (Anonymous Ancestor)
hasComponent some HydraulicSystem
hasCapability some SearchCapability
hasAltitude some xsd:double
hasComponent some AntiIcingSystem
hasComponent some SensingSystem
hasComponent some VehicleControlSystem
hasCapability some FlyingCapability
hasComponent some LiftGeneratingSystem

Instances
AW139
Dash8Q300
EC135

Asserted Ontology

Description: SuitableAsset

Equivalent To
(hasCapability some FlyingCapability)
and (hasCapability some SearchCapability)
and (hasOperationalStatus value InService)
and (hasCruiseSpeed some xsd:double[>= "60.0"^^xsd:double])

SubClass Of

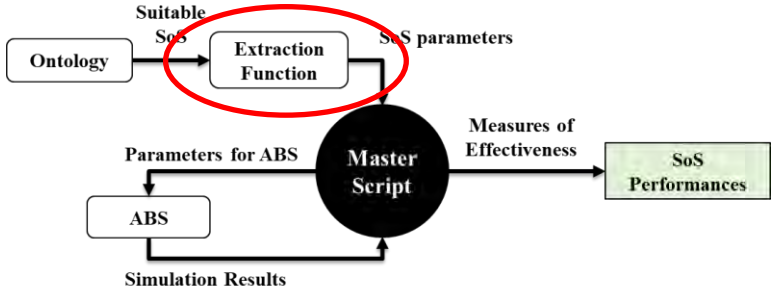
General class axioms

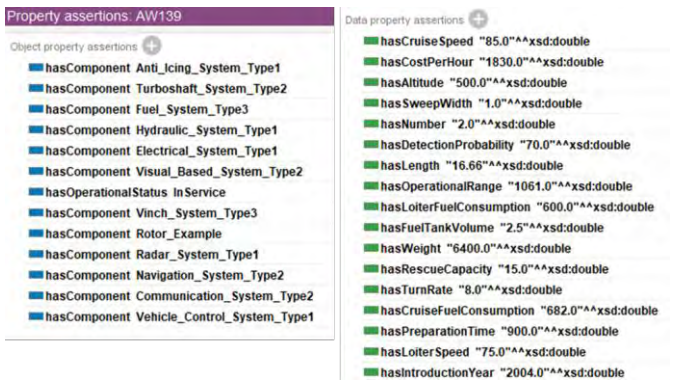
SubClass Of (Anonymous Ancestor)

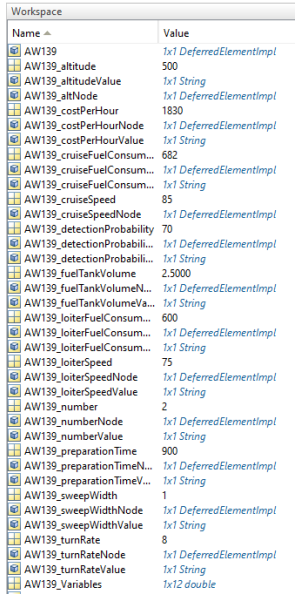
Instances

Extraction Function

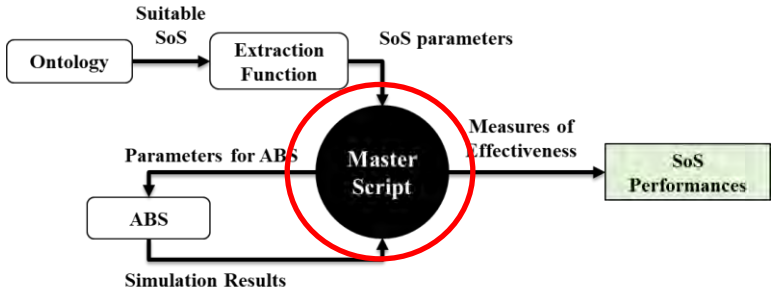
- Extracting ontology information
- XML-structure
- MATLAB navigation and variable assignments





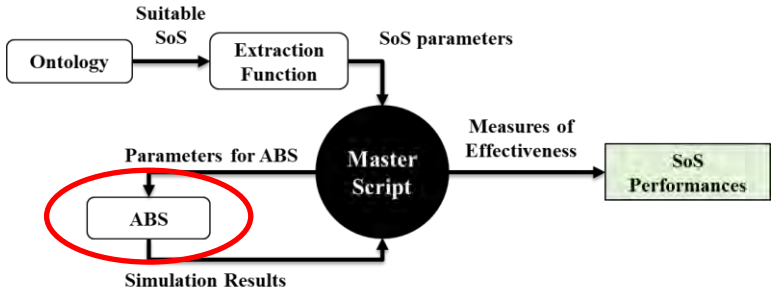


Master Script

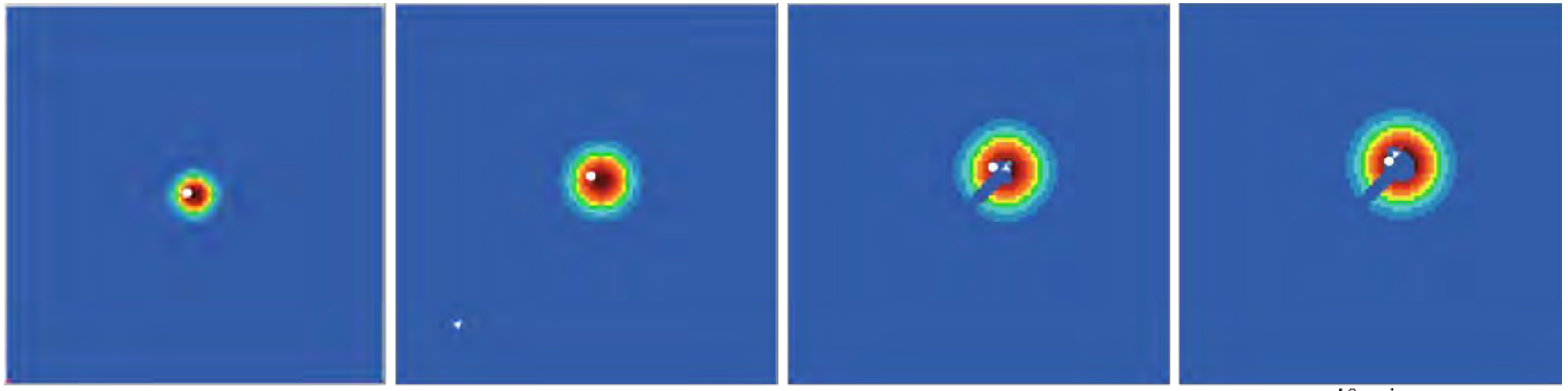


- Imports SoS data from Ontology
  - Number of each asset [AW139 Dash8Q300 EC135]
  - Asset performance values
  - Scenario values
- Sets up constellations of assets
- Define simulation control parameters
- Saves mission results and mission time

Agent-Based Simulation

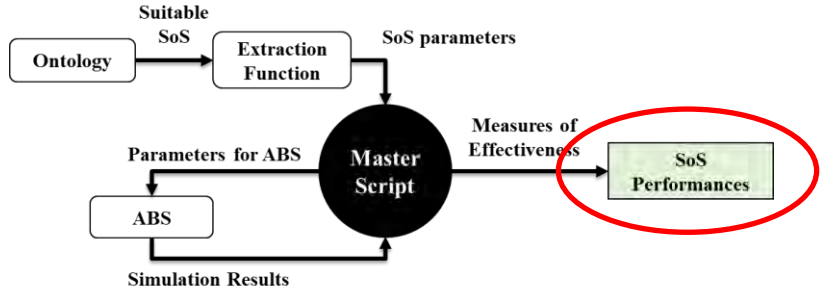


- Modeled in NetLogo
- PDF updated in MATLAB during simulation
- Greedy search tactic

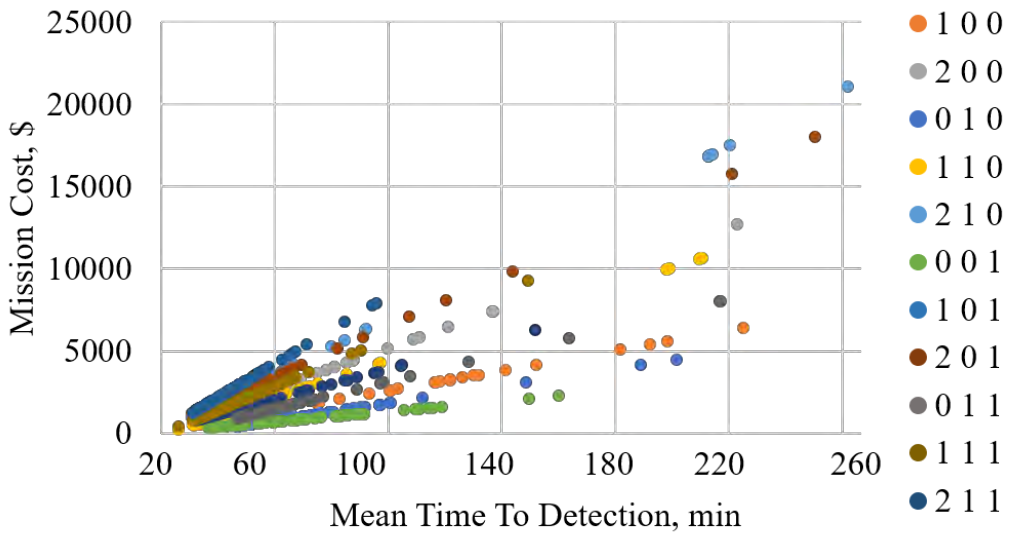


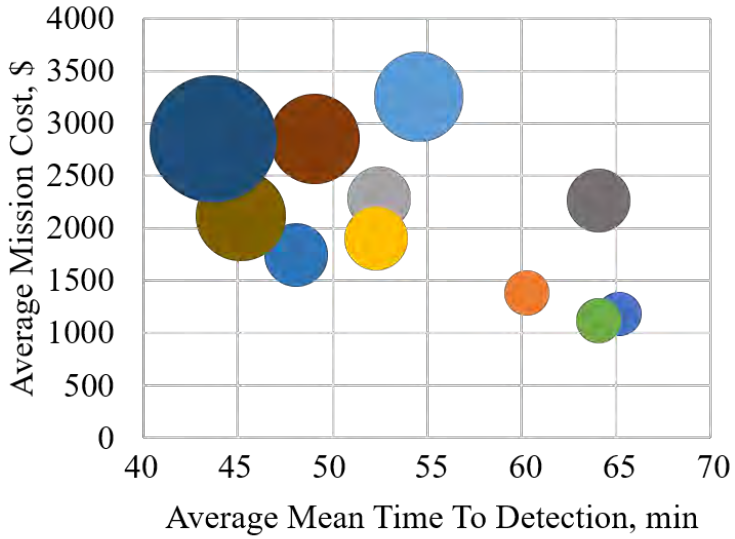
SoS Performances

[AW139 Dash8Q300 EC135]



Raw Data → Averages





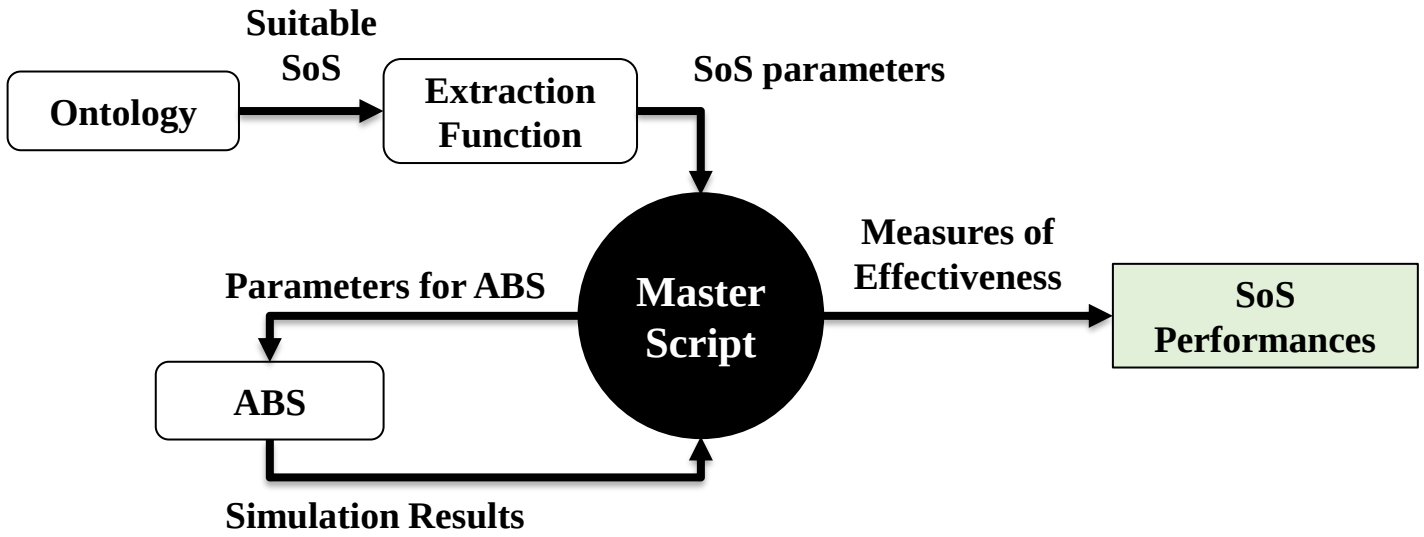
Costs based on:
– https://www.asianskymedia.com/news/2019/1/25/pre-owned-market-spotlight-leonardo-aw139
– https://www.conklindd.com/CDALibrary/ACCostSummary.aspx
– https://www.aircraftcompare.com/aircraft/bombardier-q300/

Conclusions

Results, Future Work

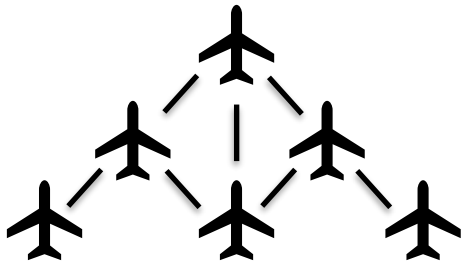
Results

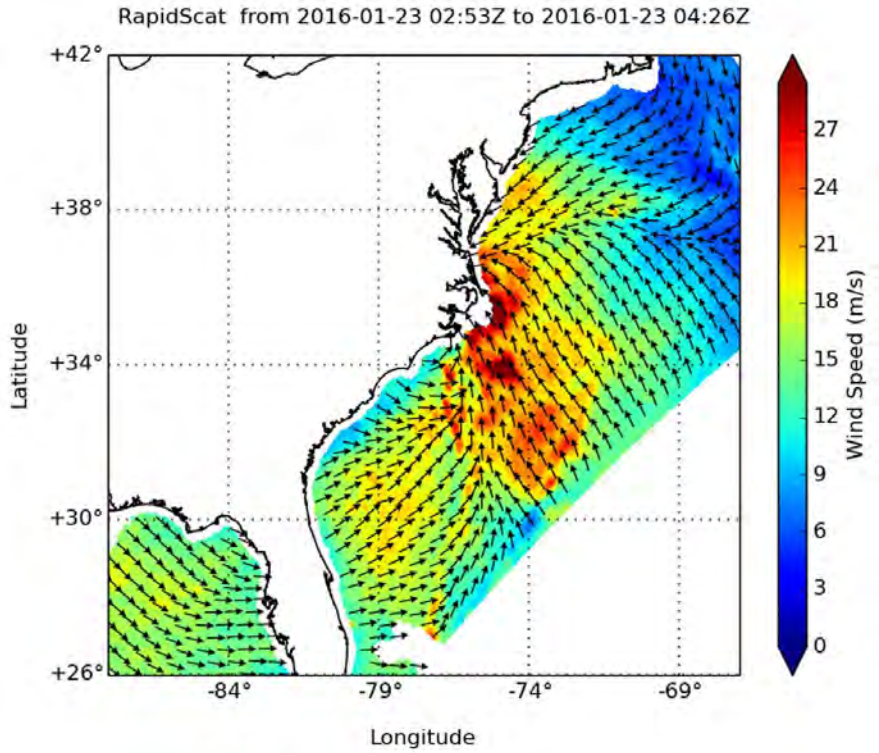
- Generate, reduce and evaluate a System-of-Systems design space
- Taking a System-of-Systems from a highly abstract level to a lower and more detailed level



Future Work

- Search and Rescue Case
  - Investigate different tactics
  - More approaches of PDF modeling
  - Use wind data and ocean currents data
- Method
  - Include constituent system and subsystem analyses
  - Introduce changes in external factors and explore the influence on the design space. What if?

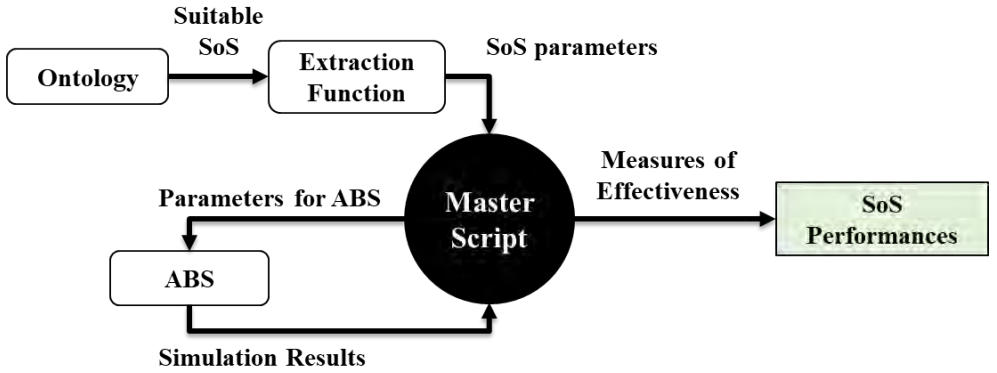


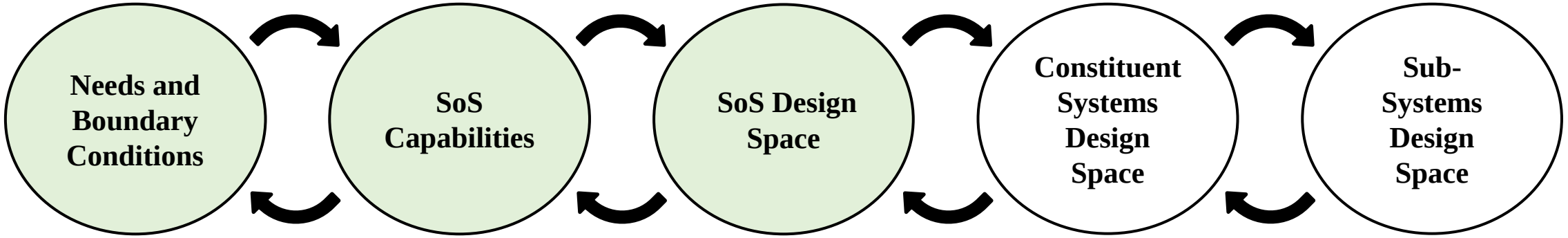


https://www.jpl.nasa.gov/spaceimages/index.php?search=ISS-RapidScat

Conclusions

- Realizes parts of the holistic view
- An initial approach





Thank you!

ludvig.knoos.franzen@liu.se
sofia.schon@liu.se

www.liu.se

LINKÖPING UNIVERSITY