34th Annual INCOSE international symposium

hybrid event

Dublin, Ireland
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Risk Assessment Method for Systems-of-Systems Internal and External Interactions

Using a case study of wildfire fighting

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Presentation Outline

Problem and Purpose

Method

Results of the case study

Discussion

Conclusion

Problem

We create systems without enough consideration of its impacts

Many diverse stakeholders, both internal and external

Risk assessments are most often done of the development of the internal system and of the technical risks.

Only a few stakeholders are often considered – not the most impacted ones

Leading to unintended consequences

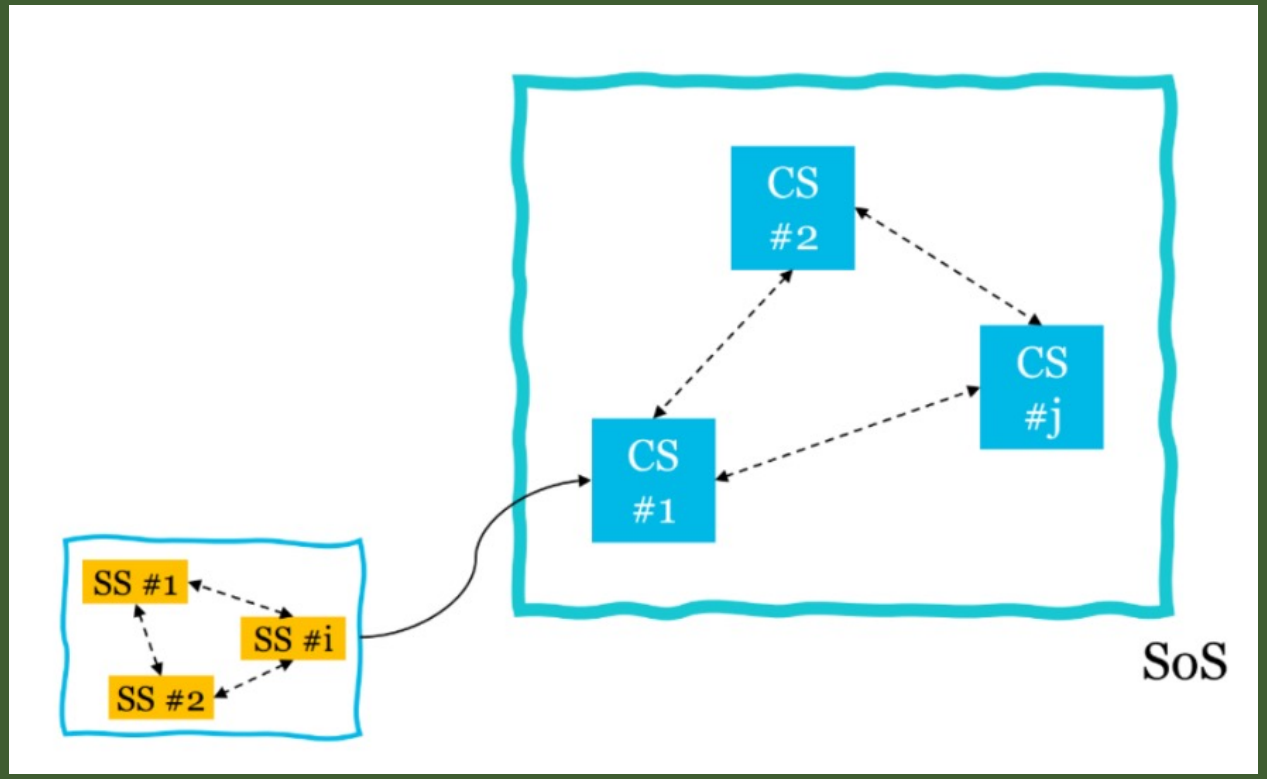
Planetary boundaries

Social inequality

Mental illness

System-of-Systems

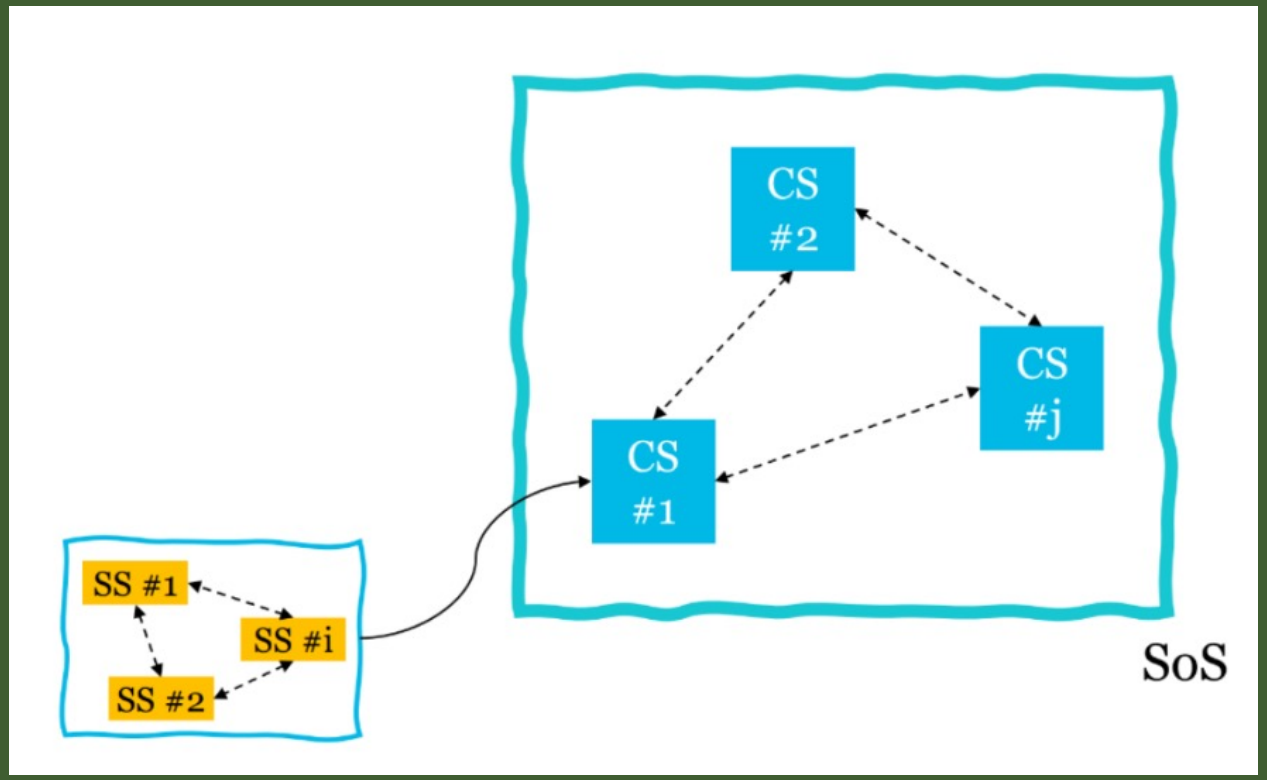
- Collaborative systems
- Five characteristics
- Identified by Interactions (Maier 1998)
- Useful for complex operations and organizations



Source: Jouannet, C. (2023). *Model Based System of Systems Engineering*. Lecture, Linköping University.

System-of-Systems

- Collaborative systems
- Five characteristics
- Identified by interactions (Maier, 1998)
- Useful for complex operations and organizations - tools
  - Independent management
  - Independent operated
  - Emergent behavior
  - Evolutionary behavior
  - Geographical distribution



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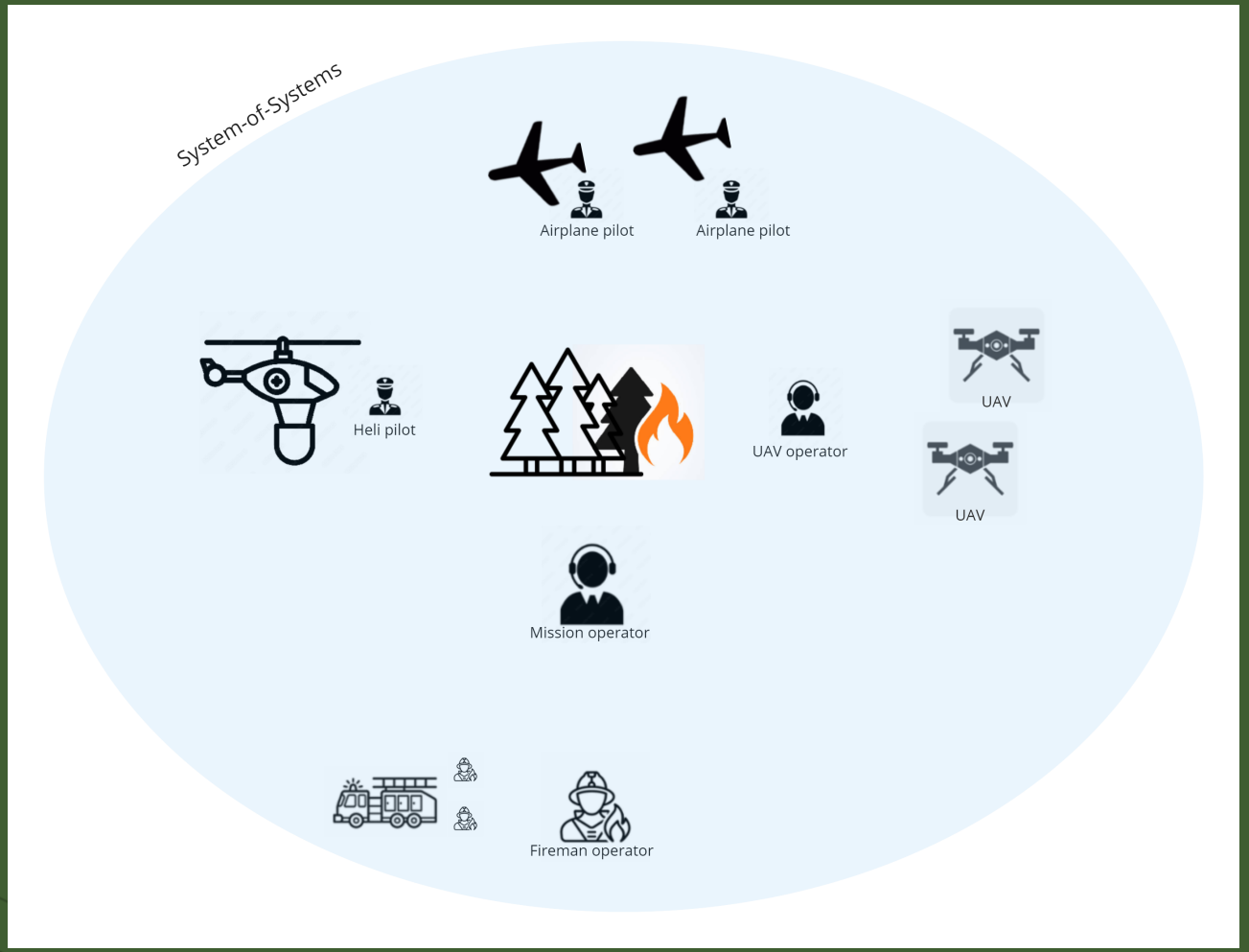


Purpose

Present a holistic risk assessment method during early stage Systems-of-Systems development

01

Benefit SoS developers to create safer system for all stakeholders, including the externally impacted.

02

04

Can be developed into high-level SoS requirements.

Comparing SoS alternatives

03

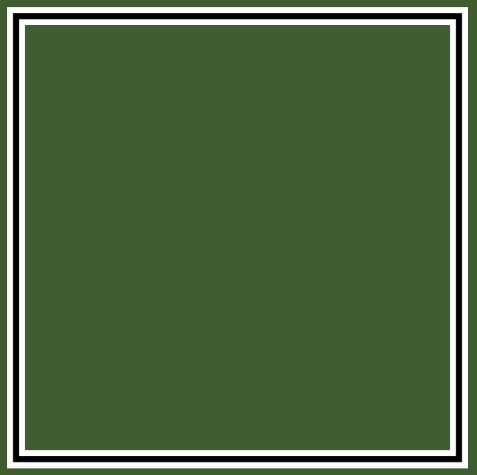
Starting point for discussion, how can a broader assessment be carried out?

Research Question

- How can risks of a directed SoSs internal and external interactions be assessed at an early stage of SoS development?

Scope and Limitations

- General and broad risk categories
- First iteration of a method
- Static SoS
- Only high-level SoS risks, not CSs risks



Method

System-of-Systems internal and external interactions

Severity, likelihood, interconnectedness

Using systems thinking (INCOSE)

System-of-Systems

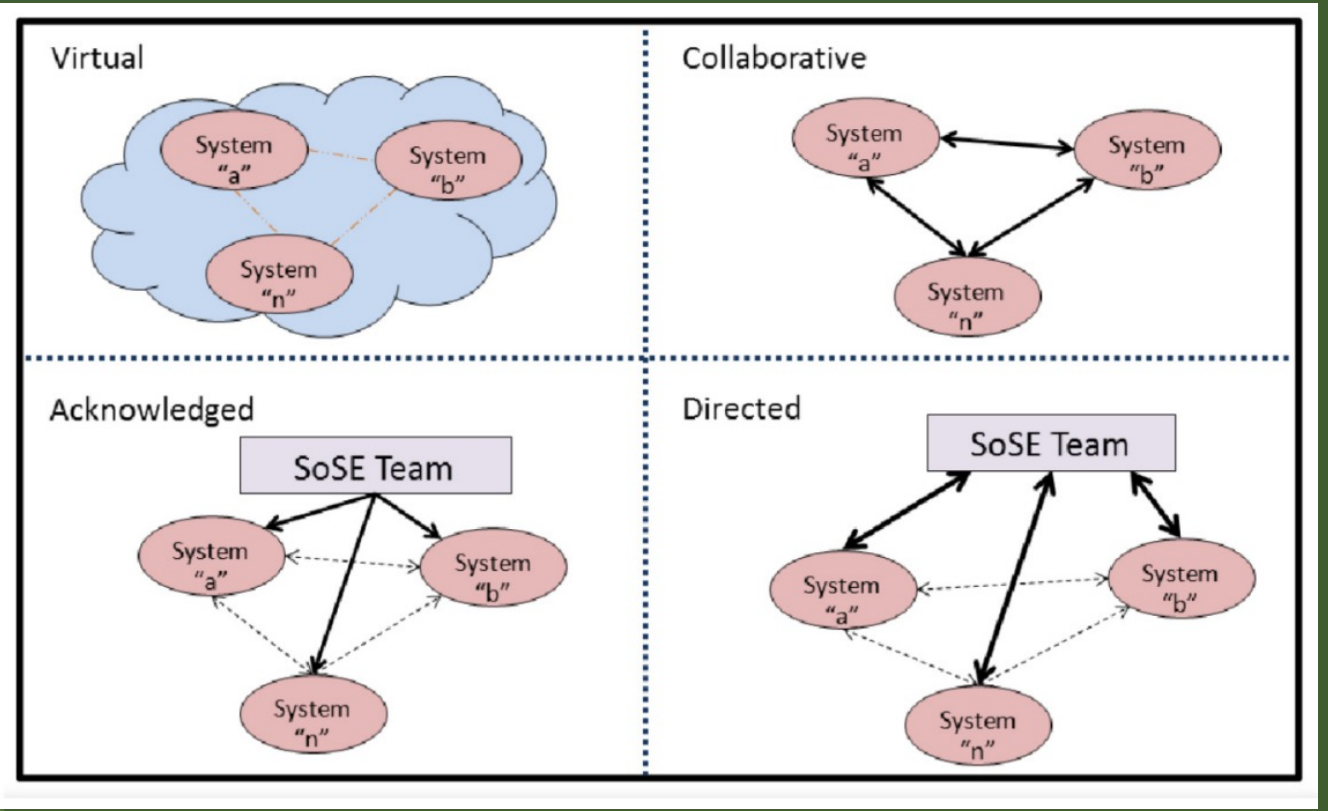
Four different types

Directed – Centralized decision and no other interests.
- Example: Emergency operation.

Acknowledged – Centralized operation but CSs have own interests.
- Example: Air Traffic Management

Collaborative – Decentralized decision making.
- Example: Decentralized energy systems

Virtual – No obvious common goal.
- Example: Internet



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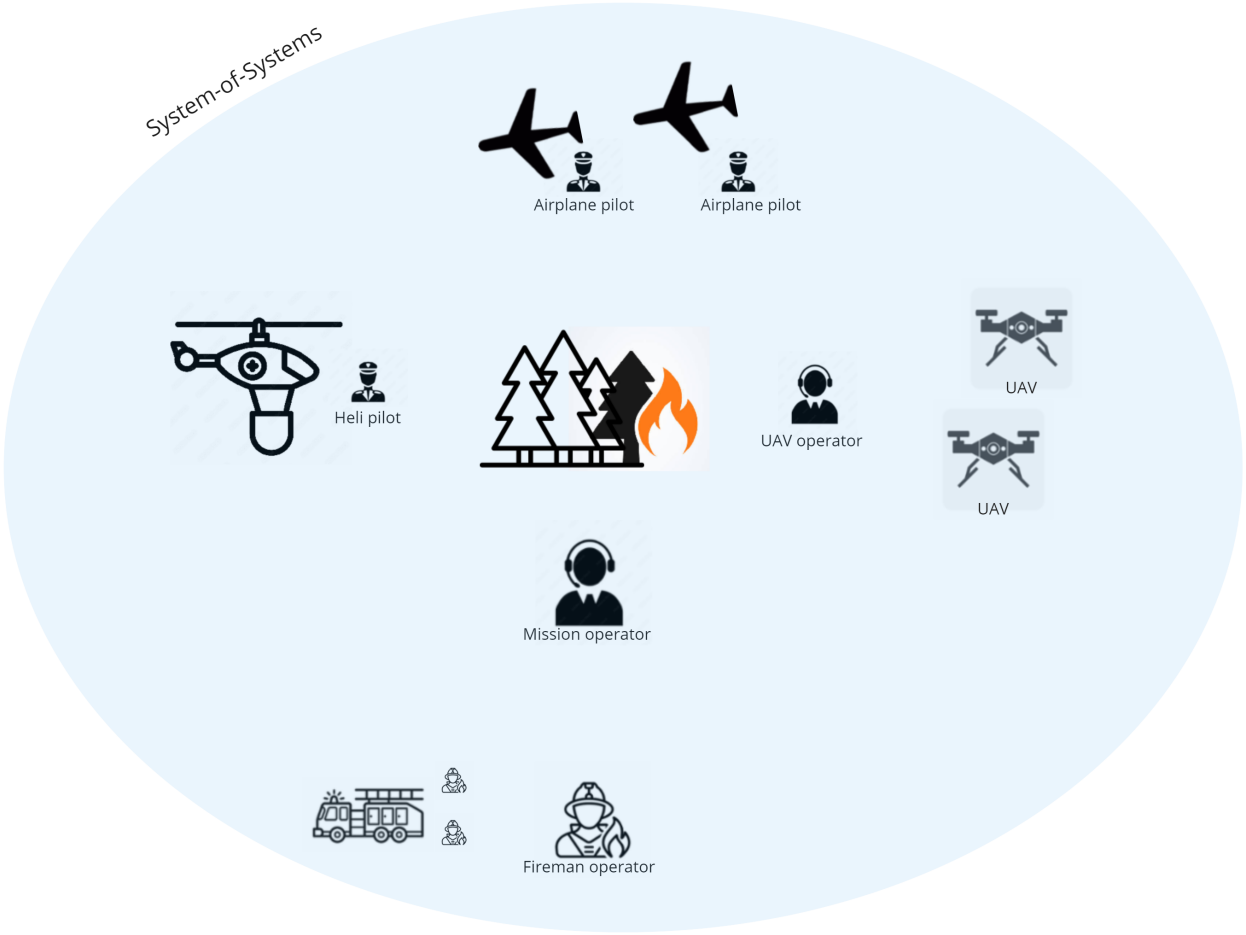
Case Study

- Wild Fire Fighting - Directed
- Fictional



Case Study

- Wild Fire Fighting - Directed
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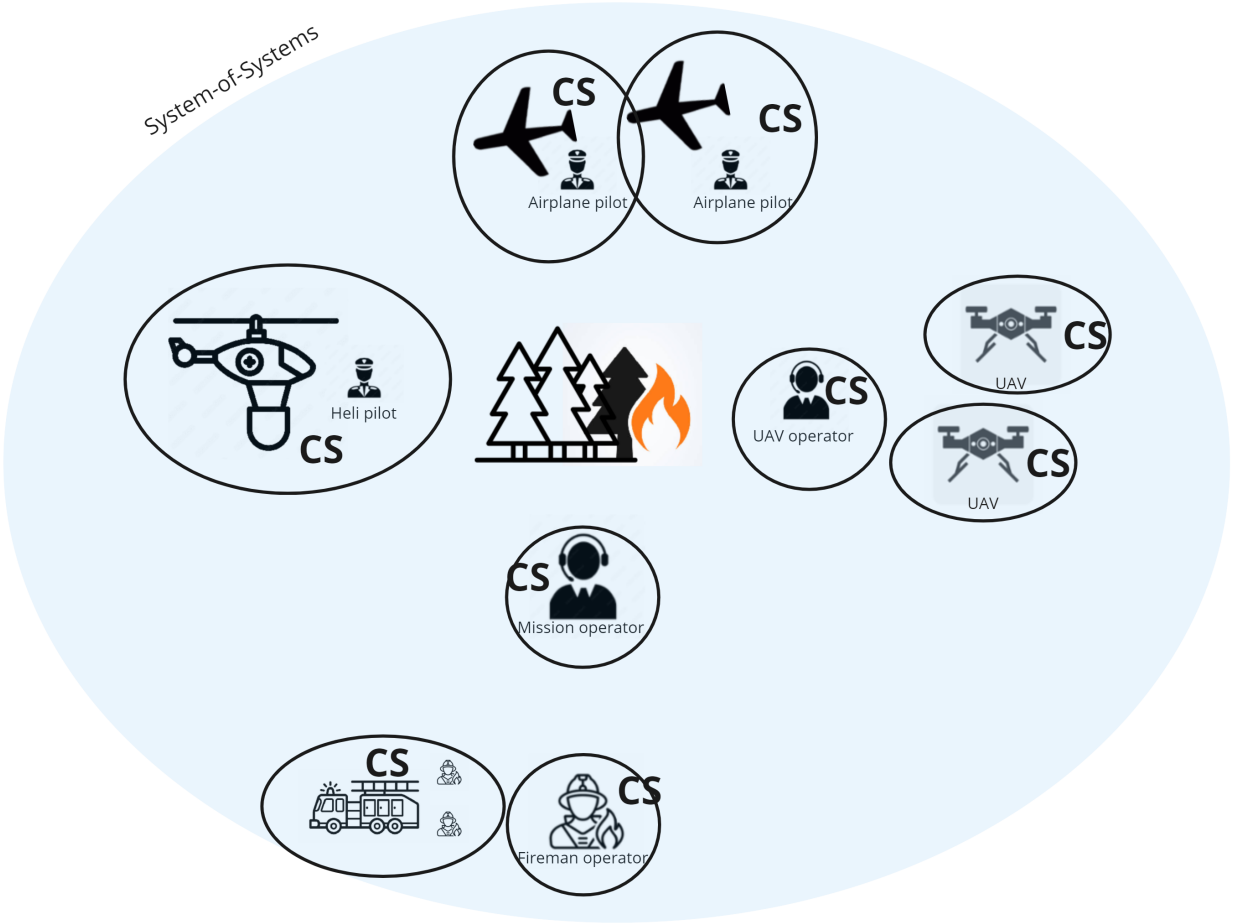
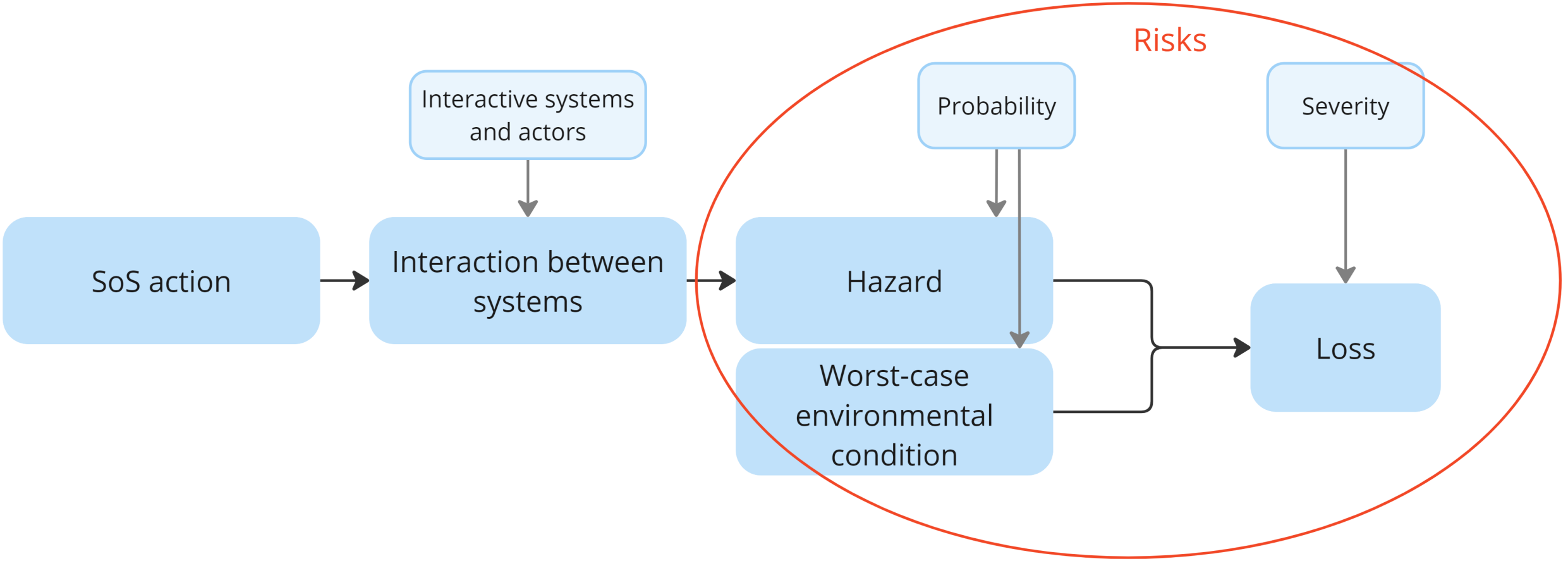


Risks Definition



Risk Assessment Method

1. Goal definition → 2. Interaction analysis → 3. Loss analysis → 4. Hazard analysis

- Purpose
- System in focus
- Depth of study
- Risk classification

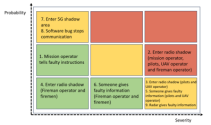
- Actions
- Interacting systems
- Interactions

- Hazards
- Worst-case environmental conditions
- Losses
- Rank risks

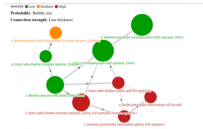
- Critical hazards

Output: Systems representation

Output: Risk matrix

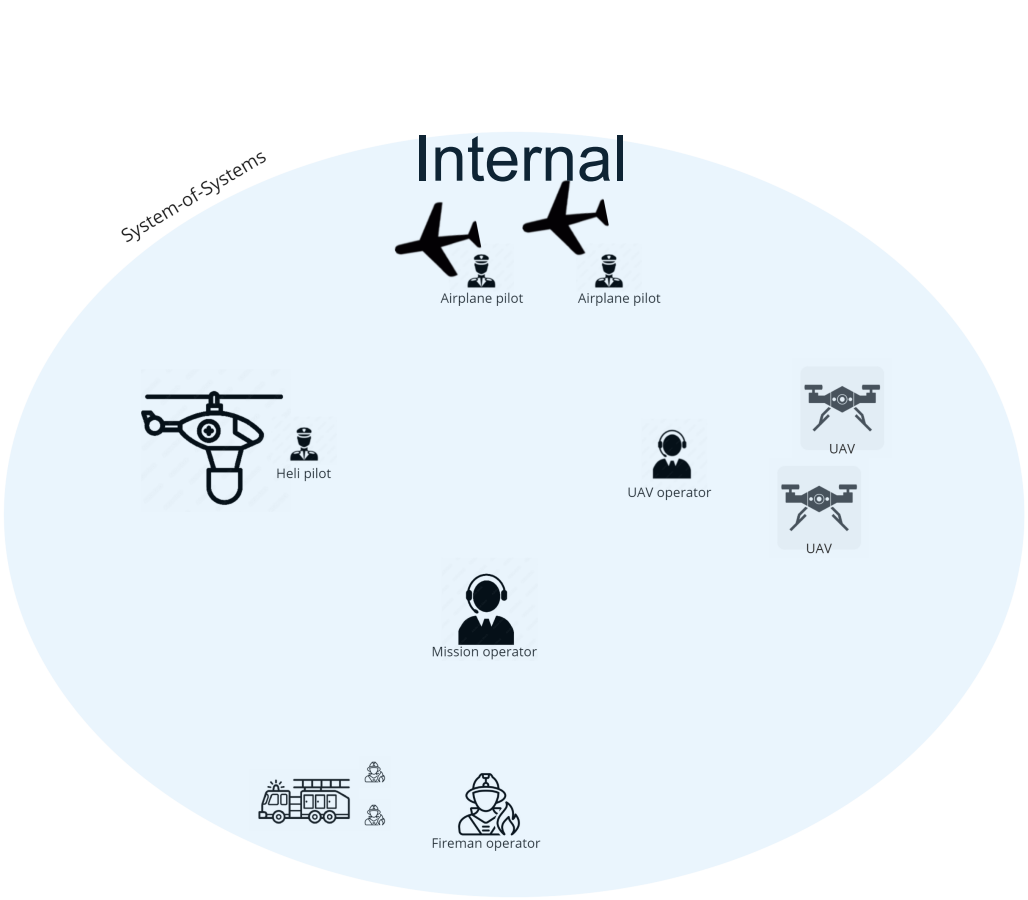


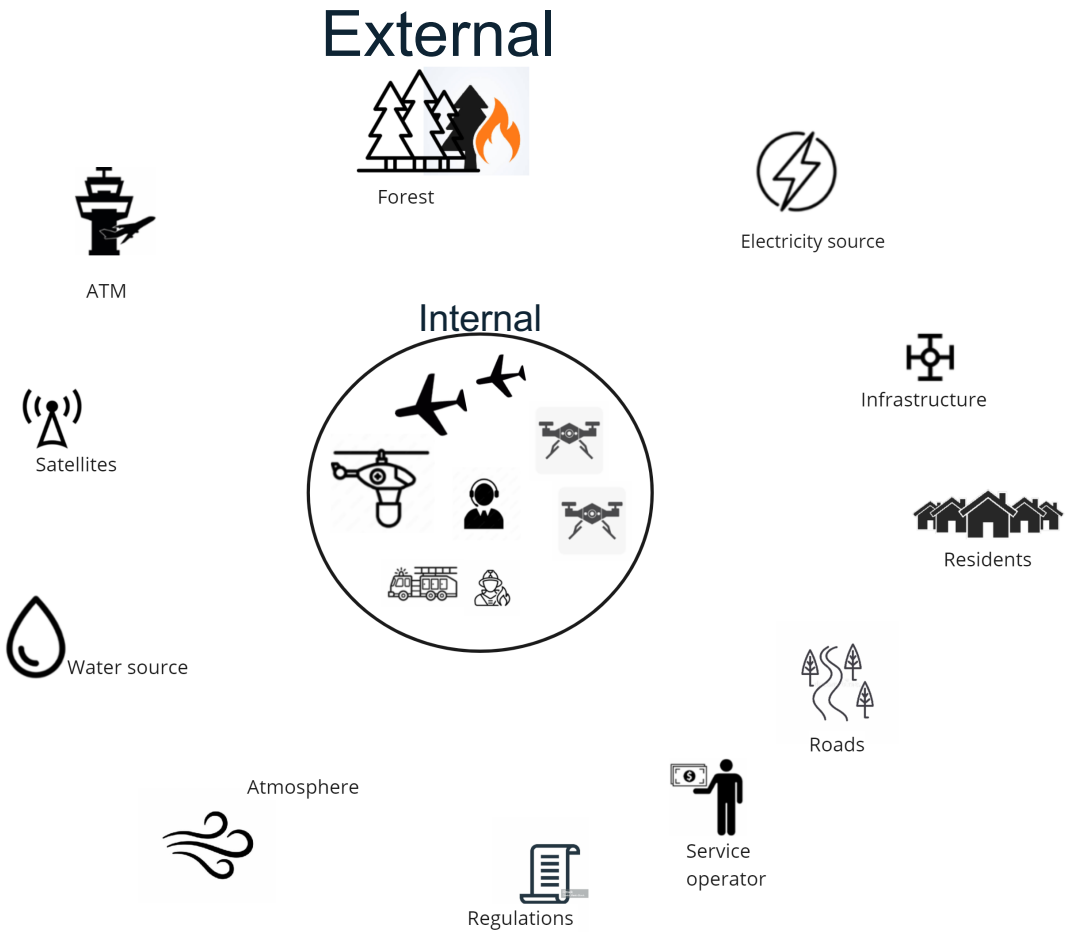
Output: Hazard network



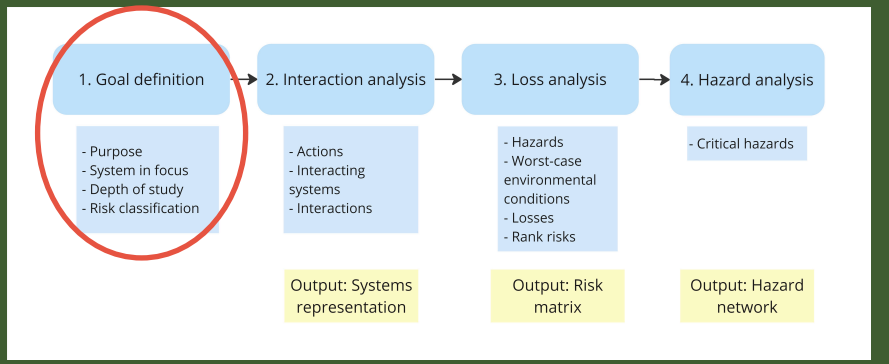
Results Case Study – Internal and External Interactions of a Wildfire Fighting SoS

Internal and External Systems





Internal – 1. Goal Definition



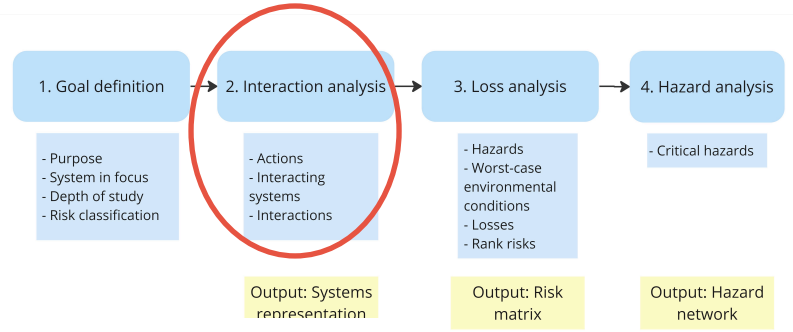
Purpose – Do a risk assessment to plan operation execution in early stage.

System in focus – Wildfire fighting SoS. 1 mission operator, 1 fireman operator and firemen,1 helicopter with pilot, 2 airplanes with pilots, 1 UAV operator with 2 UAVs.

Depth of study – Direct effects.

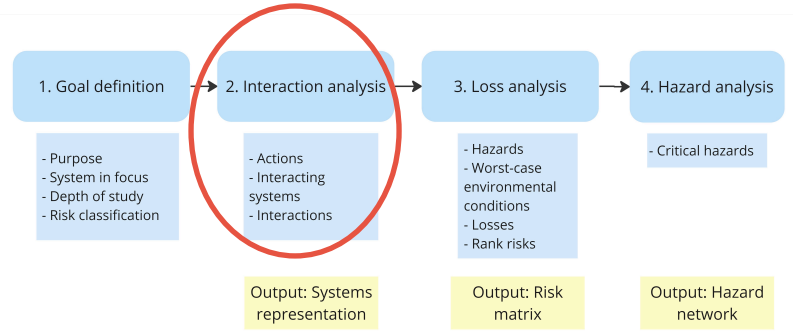
Risk classification – mission delay, human causality, and material loss.

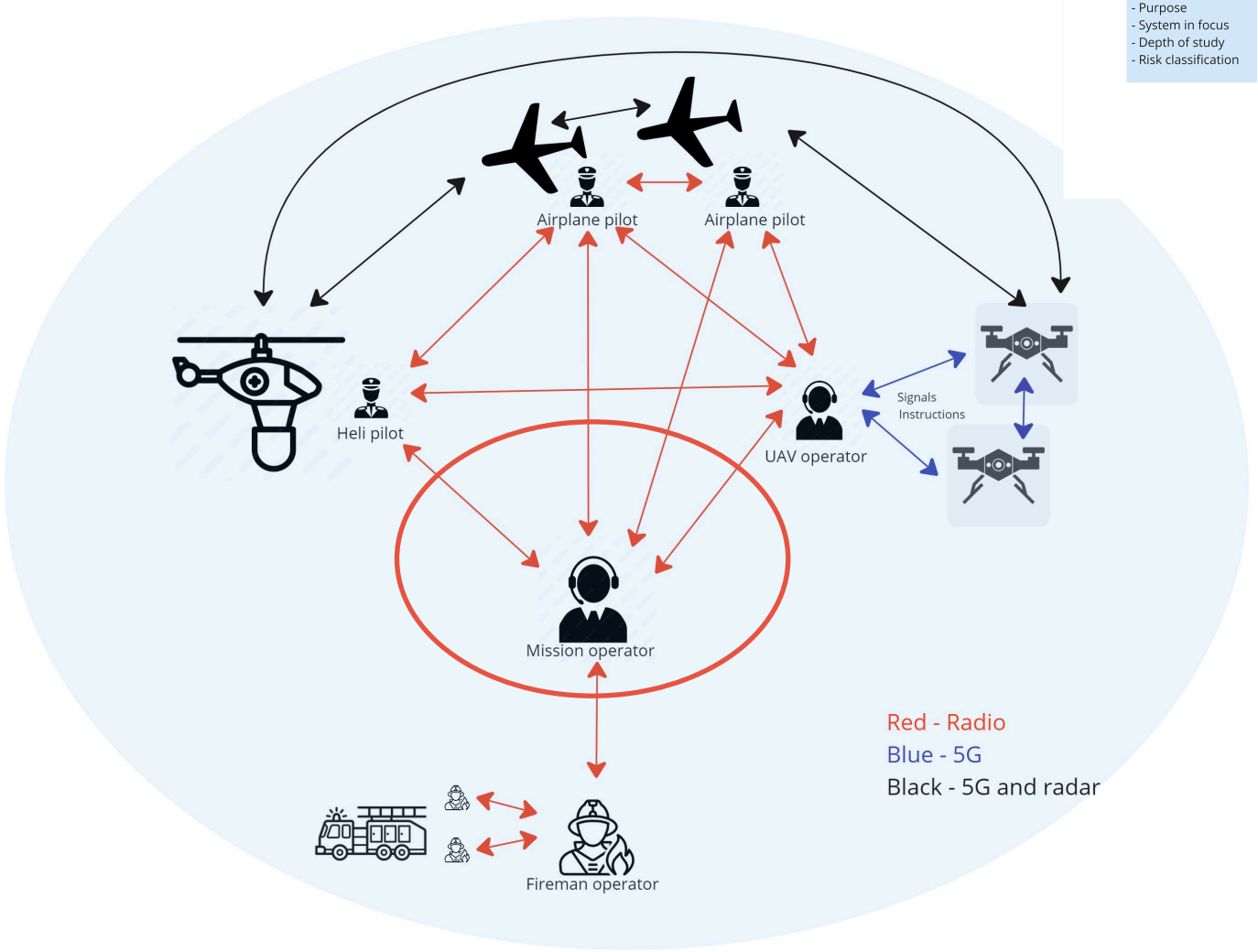
Internal - 2. Interaction analysis



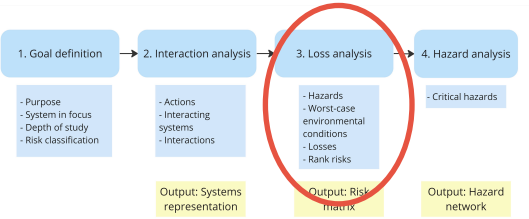
Action	Interactive actors and systems	Interaction
Mission operator gives instructions to active constituent systems	Mission operator, pilots, UAV operator and fire-man operator	Radio
UAV operator gives instructions to perform to UAVs	UAV operator and UAVs	Software using 5G
The flying agents share location and uses radar to prevent crashes in a shared airspace	All aircrafts	5G and radar
The pilots and UAV operator commu-nicates about fire state flying condition near the fire and about water dropping location	Pilots and UAV operator	Radio
Fireman operator gives instructions to firemen	Fireman operator and firemen	Radio

Internal - 2. Interaction analysis





Internal - 3. Loss analysis



Interaction	Interactive actor or system	Hazard	Type of hazard	Probability
Radio	Mission operator, pilots, UAV operator and fireman operator	1. Mission operator tells faulty instructions	Unwanted outcome of interaction	Medium
		2. Enters radio shadow	Disrupted interaction	Medium
	Pilots and UAV operator	3. Enters radio shadow	Disrupted interaction	Low
		4. Someone gives faulty information	Unwanted outcome of interaction	Low
	Fireman operator and firemen	5. Enters radio shadow	Disrupted interaction	Low
		6. Someone gives faulty information	Unwanted outcome of interaction	Low
Software using 5G	UAV operator and UAVs	7. Enter 5G shadow area	Disrupted interaction	High
		8. Software bug stops communication	Disrupted interaction behavior	High
5G and radar	All aircraft	9. Radar gives faulty information	Unwanted outcome of interaction	Low

Keywords:

a) Disrupted interaction
b) Changed interaction behavior
c) Unwanted outcome of interaction
d) New interaction

Internal – 3. Loss Analysis

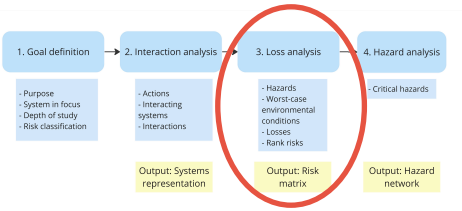
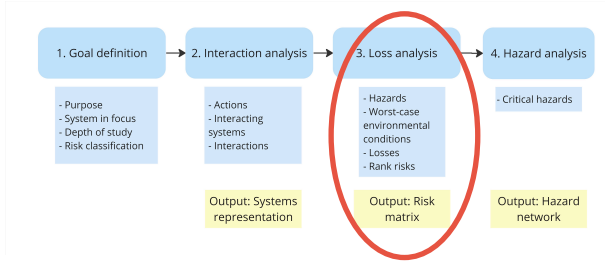
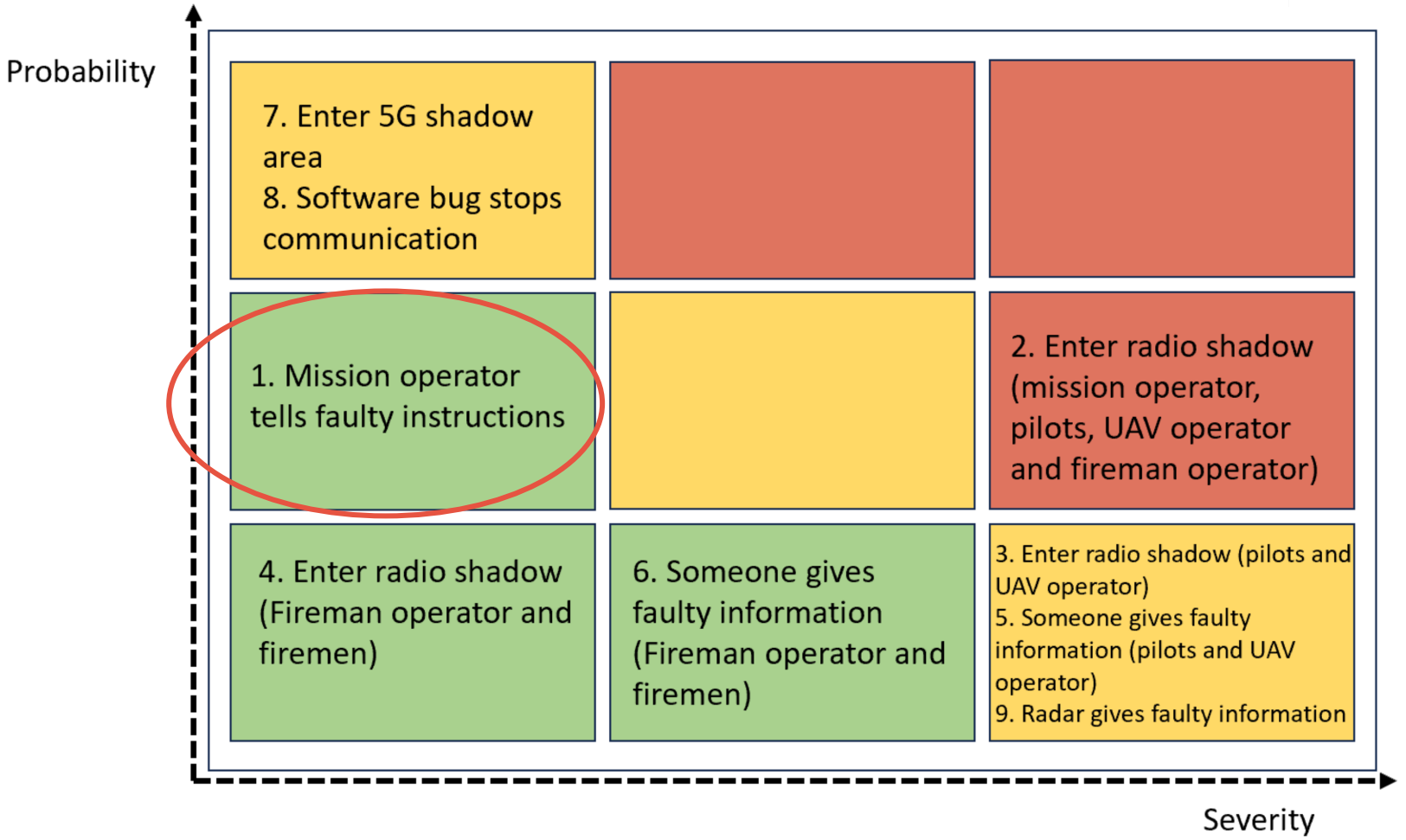


Table 4.3: Internal SoS hazards and environmental conditions leading to losses.

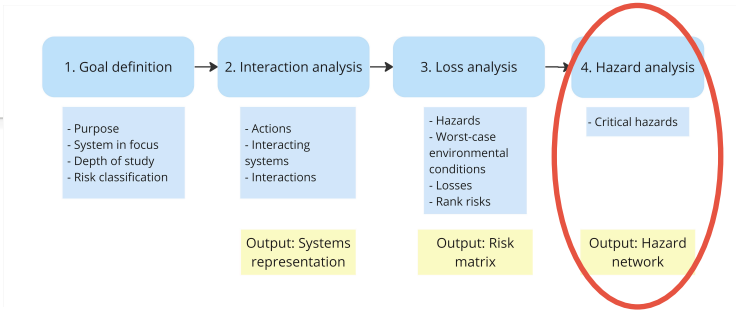
Nr	Hazard	Interactive actor or system	Worst-case environ-mental conditions	Loss	Severity
1.	Mission operator tells faulty in-structions	Mission operator, pilots, UAV oper-ator and fireman operator	Critical point of mission	Mission de-lay	Low
2.	Enter radio shadow	Mission operator, pilots, UAV oper-ator and fireman operator	Aircraft are close to each other	Human causality, material loss	High
3.	Enter radio shadow	Pilots and UAV op-erator	Aircraft are close to each other	Human causality, material loss	High
4.	Enter radio shadow	Fireman operator and firemen	Critical point of mission	Mission de-lay	Low
5.	Someone gives	Pilots and UAV op-	Aircraft are	Human	High

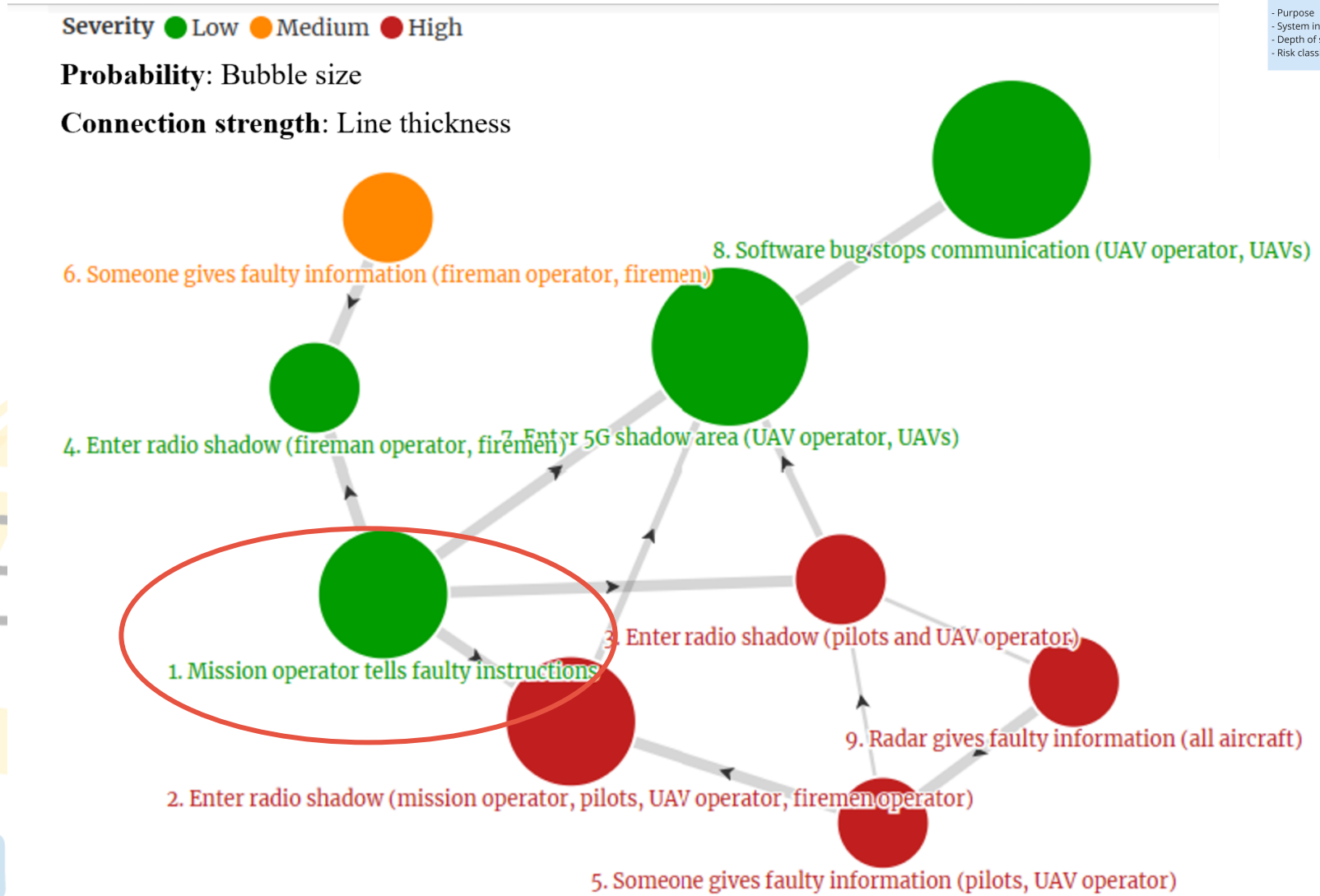
Internal – 3. Loss Analysis





Internal – 4. Hazard Analysis





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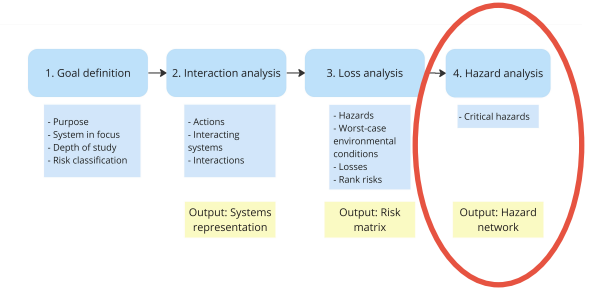
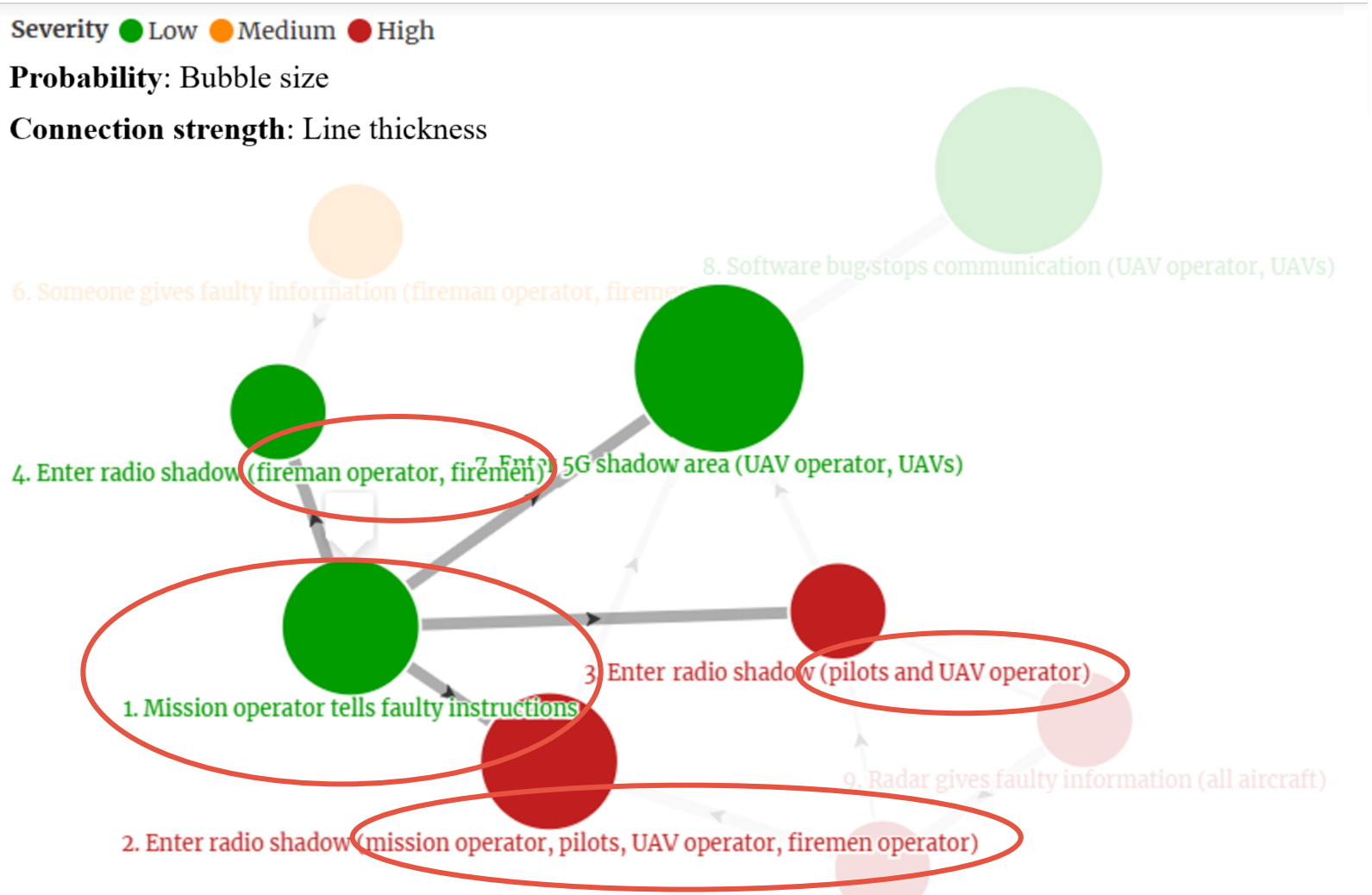
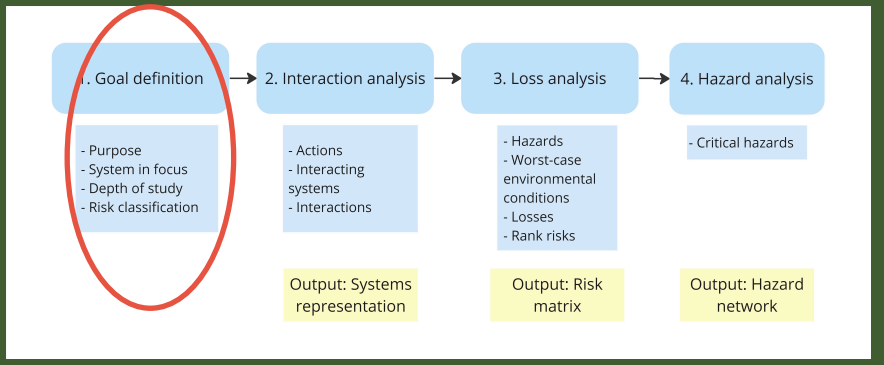




External – 1. Goal Definition



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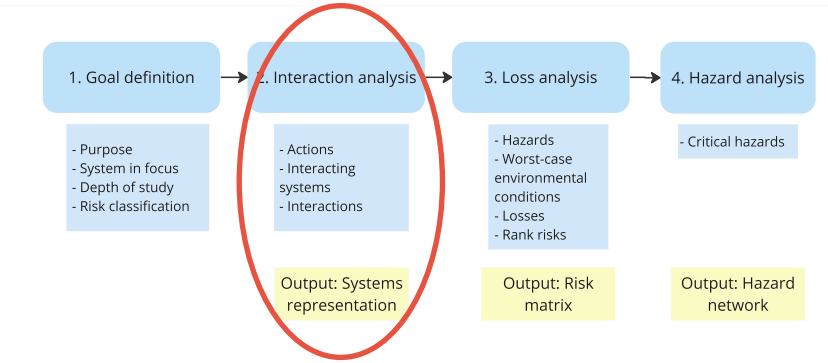
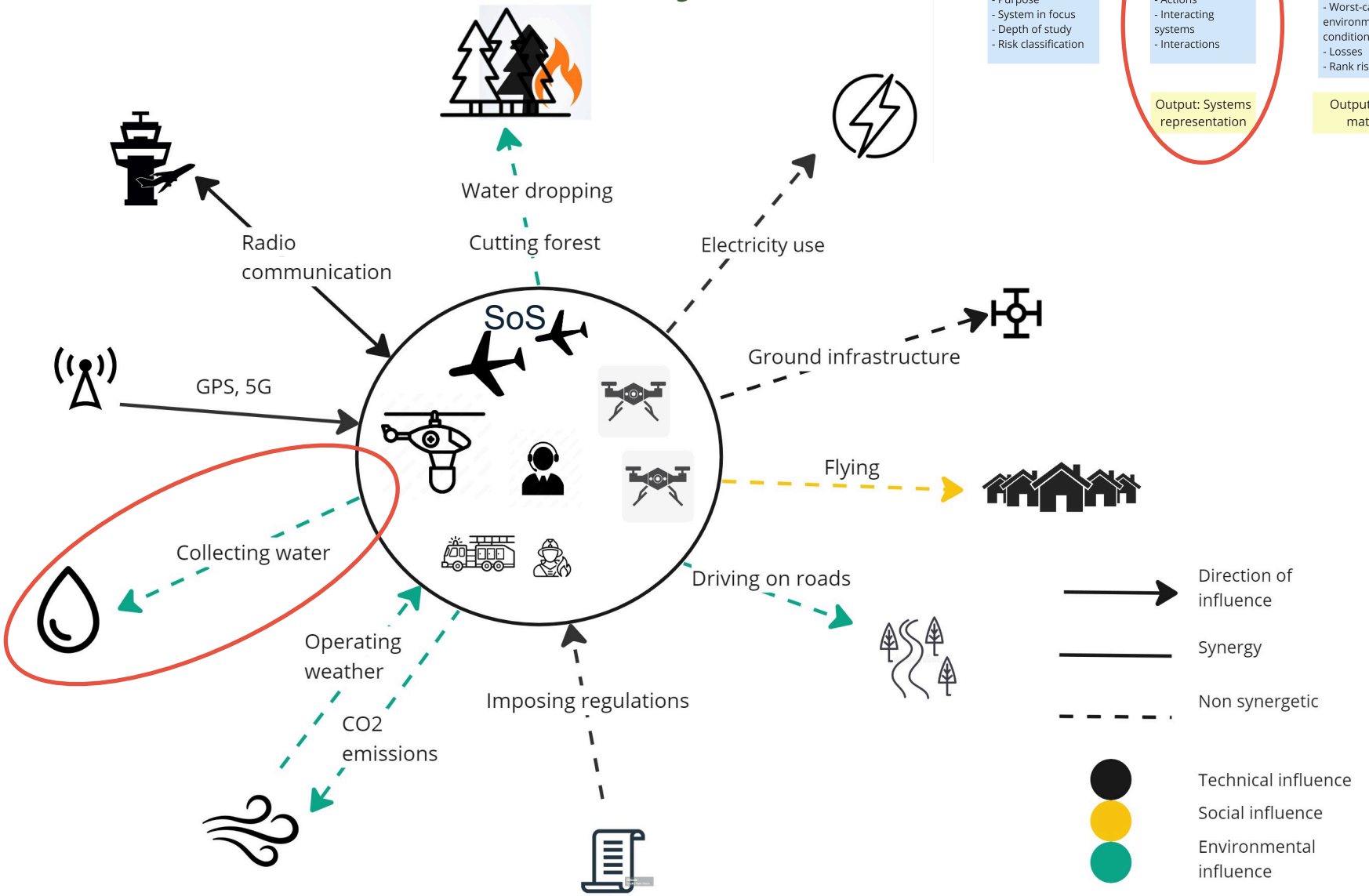
System in focus – Wildfire fighting SoS. 1 mission operator, 1 fireman operator and firemen,1 helicopter with pilot, 2 airplanes with pilots, 1 UAV operator with 2 UAVs.

Depth of study – Direct effects.

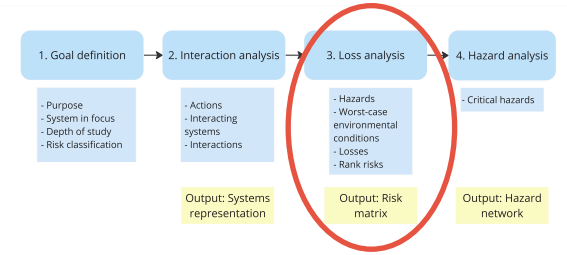
Risk classification – Mission, social, material, and environmental.

External - 2. Interaction analysis



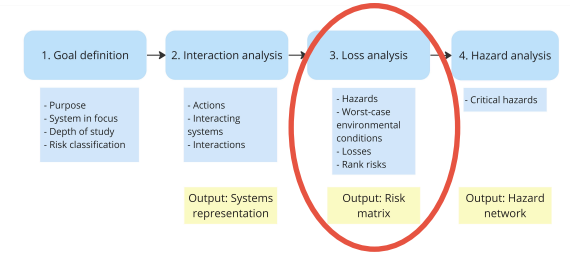


External - 3. Loss Analysis



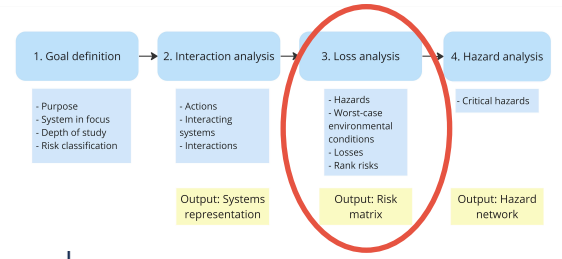
Interaction	Interactive actor or system	Hazard	Type of hazard	Probability
Aircraft using airport and vertiports, trucks drive on roads	Ground infrastructure	1. There is not enough ground infrastructure needed by the CSs	Disrupted interaction	Medium
CSs collects water	Water source	2. Water source gets depleted	Unwanted outcome of interaction	Low
		3. Lack of water sources	Disrupted interaction	Medium

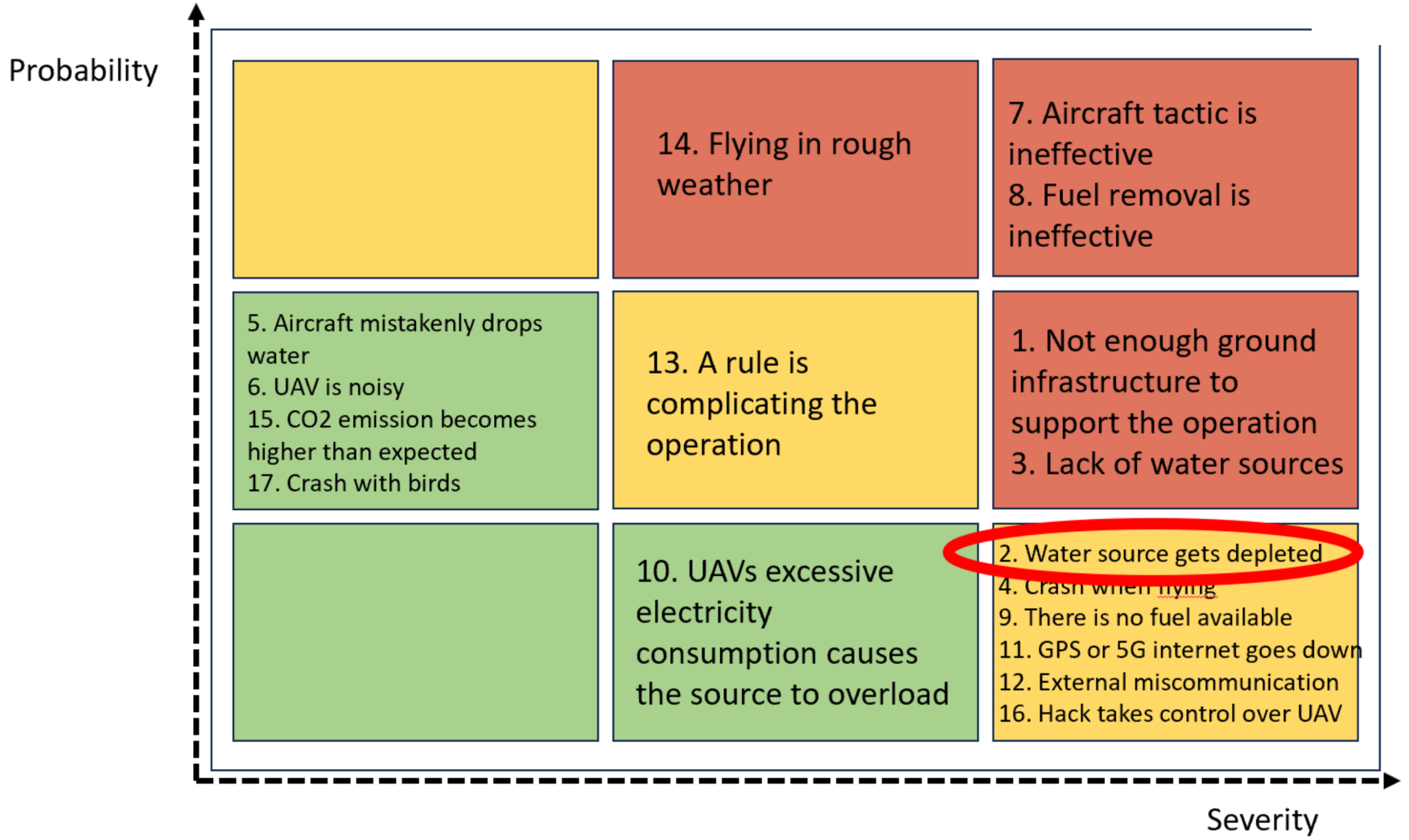
External - 3. Loss Analysis



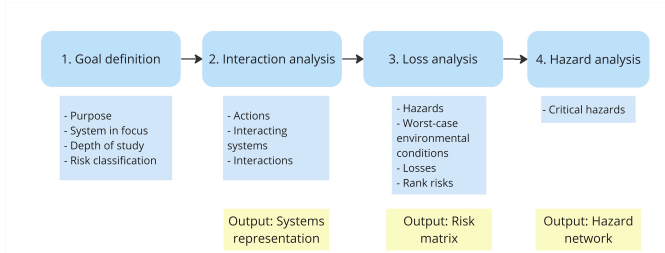
Nr	Hazard	External actor or system	Worst-case environmental conditions	Loss	Severity
1.	There is not enough ground infrastructure to support the operation	Ground infrastructure	Fireline is in inaccessible area	Mission	High
2.	Water source gets depleted	Water source	Other users are dependent on the same water source	Social	High

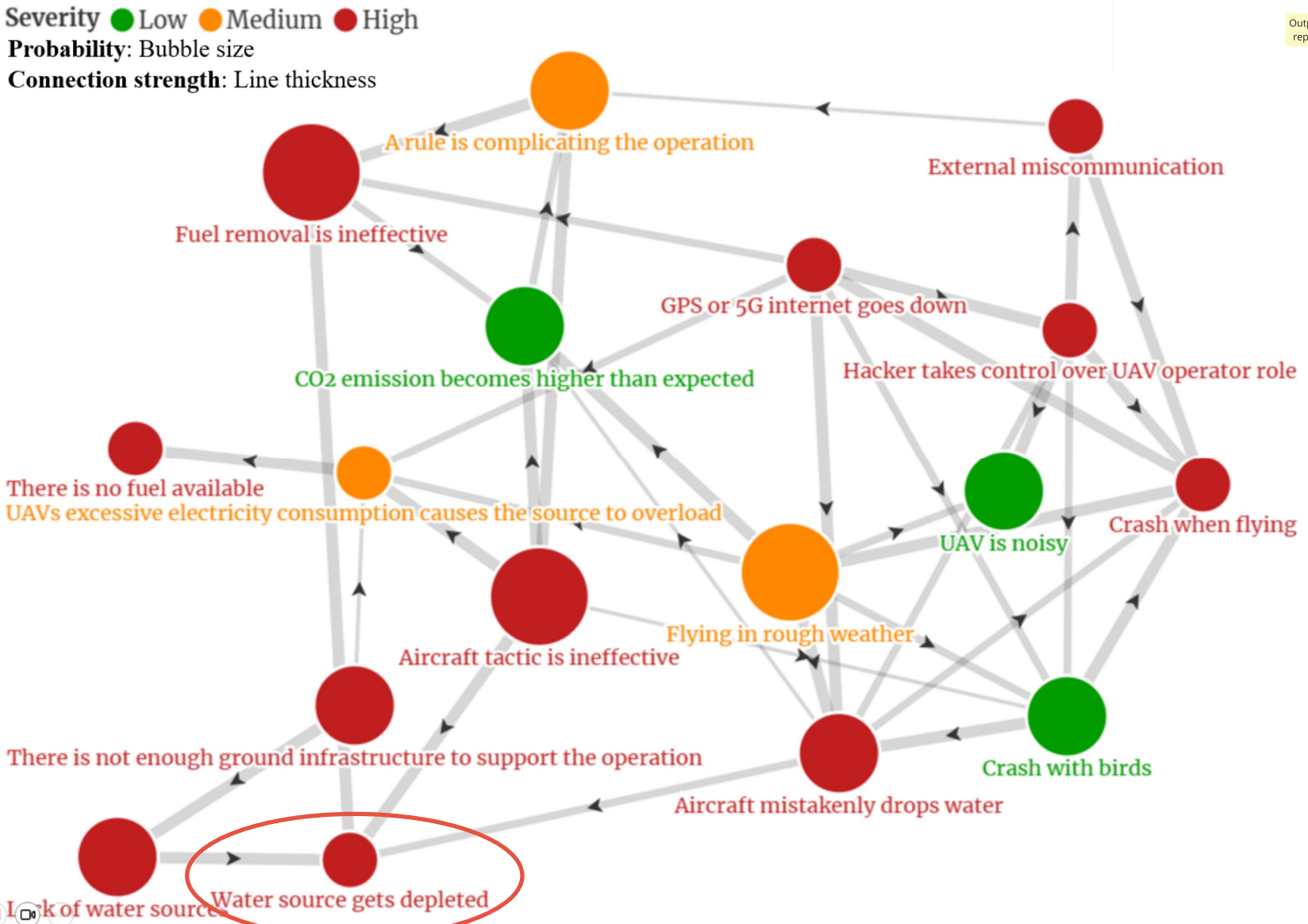
External - 3. Loss Analysis



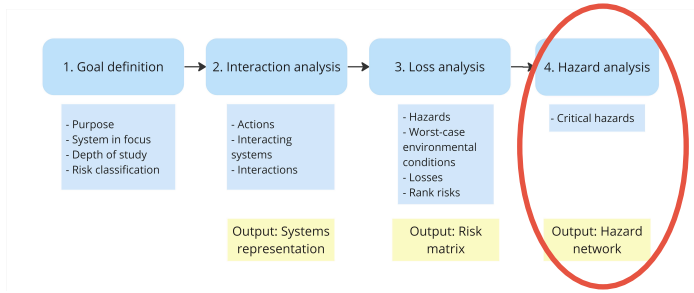


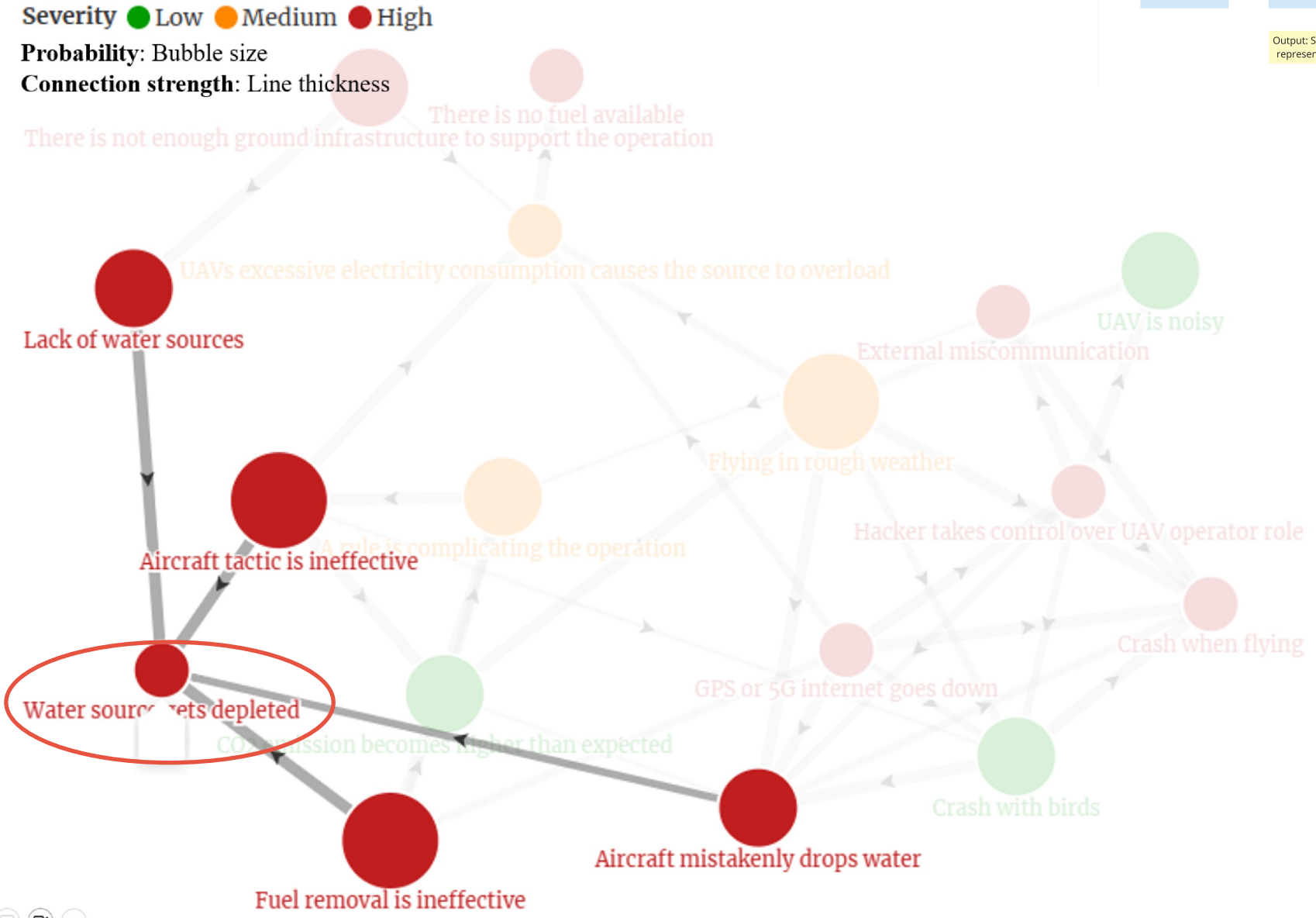
External – 4. Hazard Analysis





External – 4. Hazard Analysis

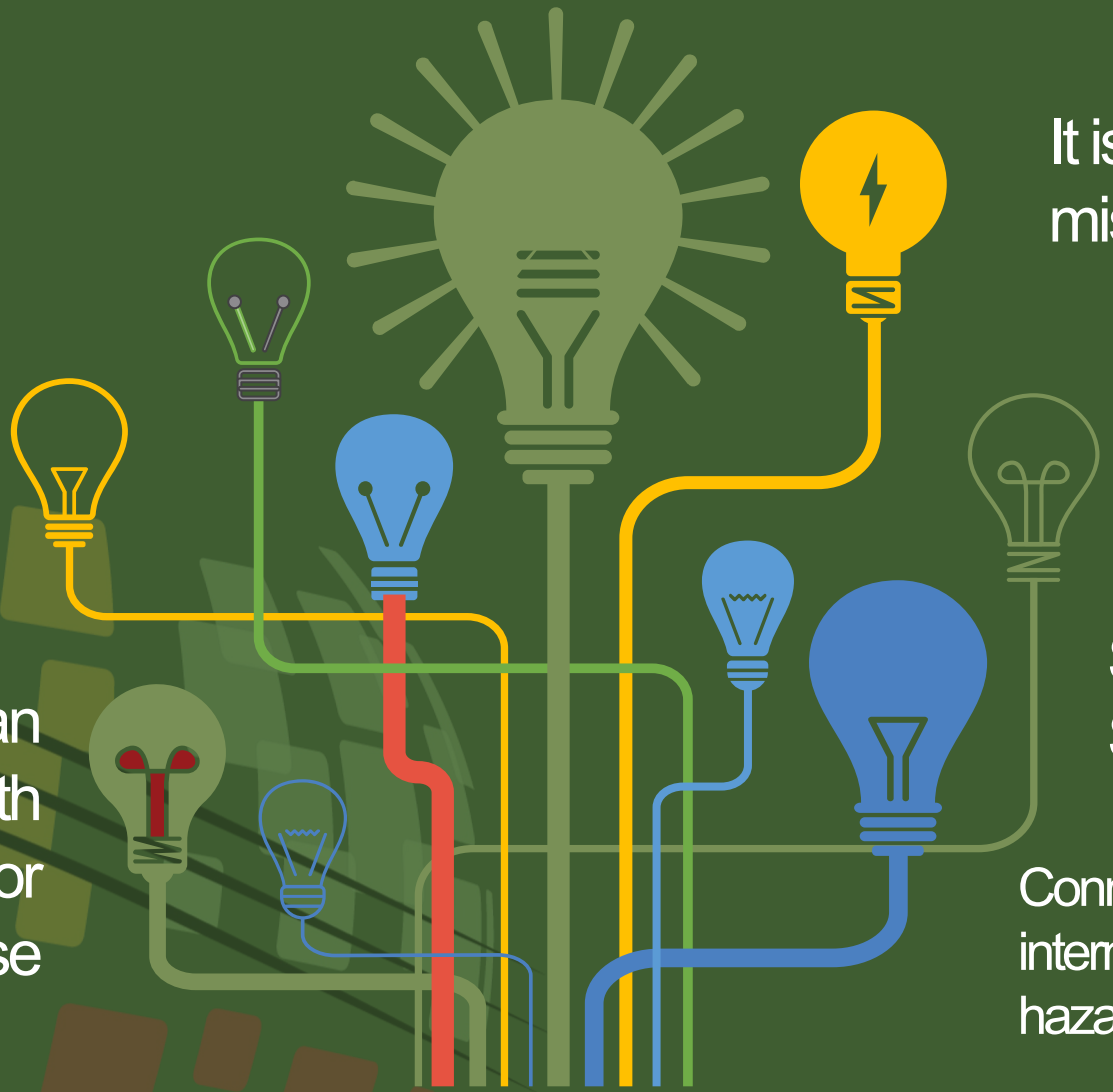




Discussion

Can be integrated with LCA for the use phase

The hazards can be identified with historic data or domain expertise



It is very broad and misses details

Cost-benefit analysis

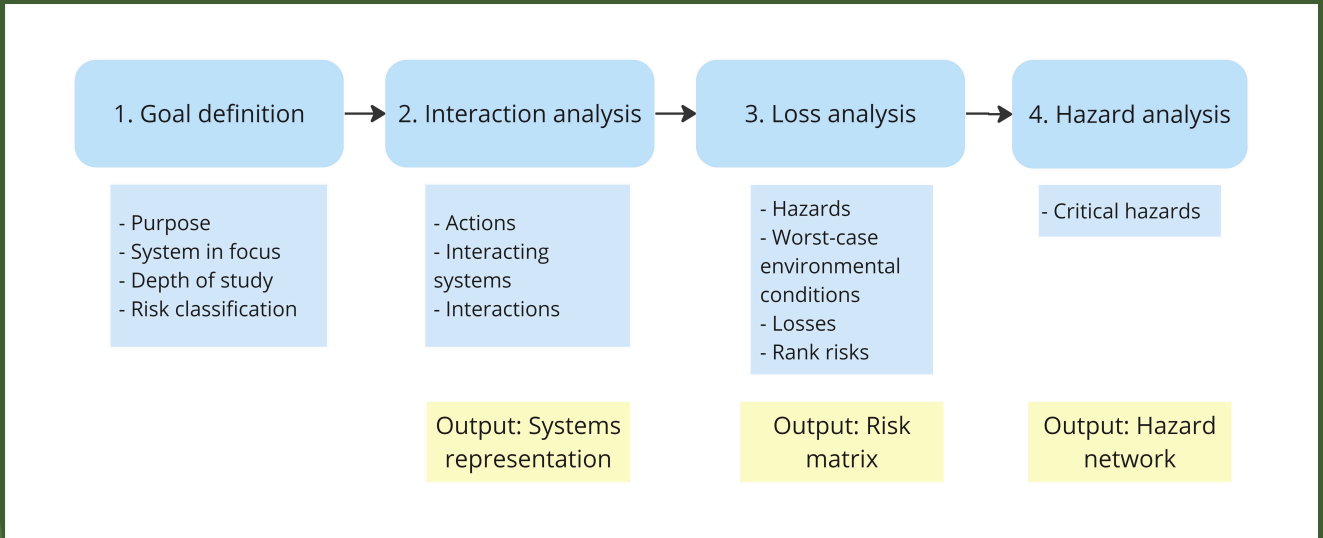
Static model while SoSs are dynamic

Connection between internal and external hazards

Conclusion

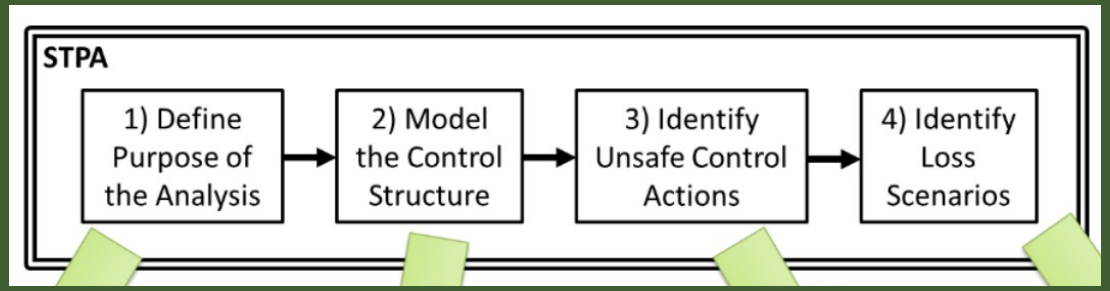
RQ: How can risks of a directed SoSs internal and external interactions be assessed at an early stage of SoS development?

- Using systems thinking
- Dividing interactions into internal and external
- Using system context diagram, risk matrix, and network analysis



References and Similar Work

- Systems Theoretic Process Analysis (STPA) Nancy Leveson, John P Thomas, 2018
- Mark W. Maier. “Architecting principles for systems-of-systems”. In: Systems Engineering 1.4 (1998), pp. 267–284
- Towards a Risk Analysis Method for Systems-of-Systems Based on Systems Thinking (Jakob Axelsson, Avenir Kobetski, 2018)
- Gaya Herrington. How Schneider Electric’s climate risks interact. Schneider Electric Sustainability Research Institute, 2023



34th Annual INCOSE international symposium

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Questions

- What similar work is already done?

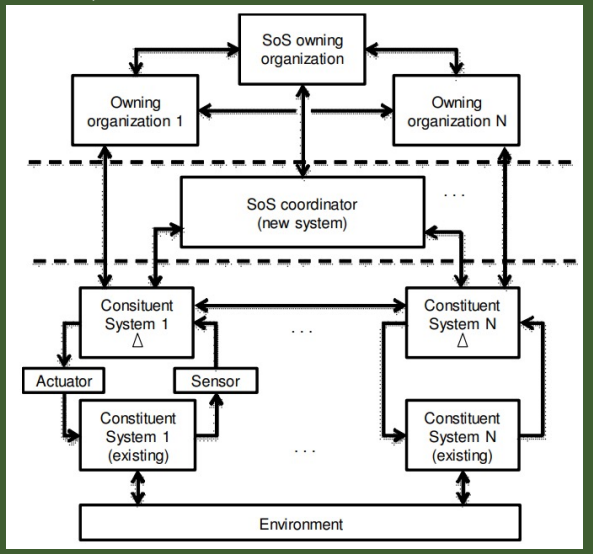
  - Life Cycle Analysis – identifying environmental and social impact during product life cycles

  - STAMP (System-Theoretic Accident Model and Processes) - using control theory to identify hierarchal risks

  - STPA (System-Theoretic Process Analysis)

- HAZOP - Hazard and operability study keywords

- Towards a Risk Analysis Method for Systems-of-Systems Based on Systems Thinking (Jakob Axelsson, Avenir Kobetski, 2018)



Questions

- What methodology did you do to conduct this work?

  Literature review -> a lot of own intuition -> followed my own method

Questions

- How was the information in the case study collected?

  The information is not validated. It is just an example of how it could be.

  It could be based on historical data and expertise knowledge.

Questions

- How high certainty would the results have?

  As high as extensive you did the analysis