

Research on Conceptual Model of Reliability in Systems-of-Systems

You are being invited to take part in an online survey regarding a Conceptual Model of Reliability in Systems-of-Systems. Your input will be very valuable to us as we try to gain a further understanding on the Systems-of-Systems Reliability field.

This survey contains 18 required questions and 15 optional questions. It should take approximately 30 minutes to complete. Participation is voluntary and you have the right to end your participation at any time.

Please answer each item as honestly as possible, and please respond to all items on the survey.

If you have any questions, please contact me at francisco.ferreira@uniriotec.br

Thank you very much.

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Research Supervisors

*Obrigatório

AUTHORIZATION TO USE AND DISCLOSE INFORMATION

By answering this questionnaire, you allow researchers to obtain, use and disclose the information generated from the data grouped as described below.

CONDITIONS

1. I understand that all information is confidential. I will not be personally identified and agree to complete the questionnaire for research purposes. Data derived from this survey can be published in journals, conferences, and blog posts.
2. I understand that my participation in this survey is entirely voluntary and that refusing to participate will not involve a penalty or loss of benefits. If I choose, I can withdraw my entry at any time. I also understand that if I decide to participate, I can refuse to answer open-ended questions that I don't feel comfortable with.
3. I understand that I can contact the researcher if I have any questions about the research. I am aware that my consent will not directly benefit me. I am also aware that the author will keep the data in a grouped way, collected in perpetuity, and will be able to use it for future academic works.
4. As I move on to the next section, I freely acknowledge my rights as a voluntary research participant, as described above, and provide consent to the researcher to use my data in conducting studies on the area mentioned above.

1. By completing and submitting this form you agree to the conditions. *

Marque todas que se aplicam.

☐ I accept the conditions.

Your profile

2. Name (optional)

3. What is your highest academic degree? *

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- ☐ Bachelor
- ☐ M.Sc.
- ☐ Ph.D.
- ☐ Other

4. In which sector do you work? *

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- ☐ Academy
- ☐ Industry
- ☐ Both academy and industry

5. Please inform your experience level in the following knowledge areas according to the scale below: *

Level	Experience	
0	None	No experience
1	I studied it in class or in a book	Very low experience degree
2	I used it in some projects in the classroom	Low experience degree
3	I used it in my own projects	Average experience degree
4	I used it in few projects in the industry	High experience degree
5	I used it in several industrial projects	Very high experience degree

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Evaluation of the Evidence- Based Model

A conceptual model represents a set of entities and relationships among these entities, which are part of a given domain of knowledge and help in understanding the domain in question. The model presented here represents a holistic vision of the elements and relationships involved in Systems-of-Systems Reliability.

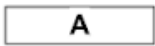
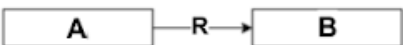
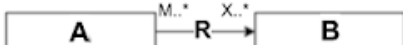
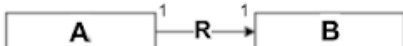
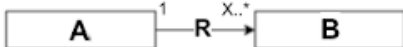



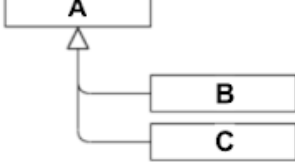
This section proposes a set of propositions to explain the elements and relationships involved in Systems-of-Systems Reliability. Each proposition is followed by evidence from studies in the area of Systems-of-Systems Reliability. The studies (evidence) are listed in <https://bit.ly/3ifyfma>, a glossary of terms used in the model is available in <https://bit.ly/3ulJ9LY>, and the complete model is available at <https://bit.ly/3ulGHFf>.

Guidance for the analysis of the propositions:

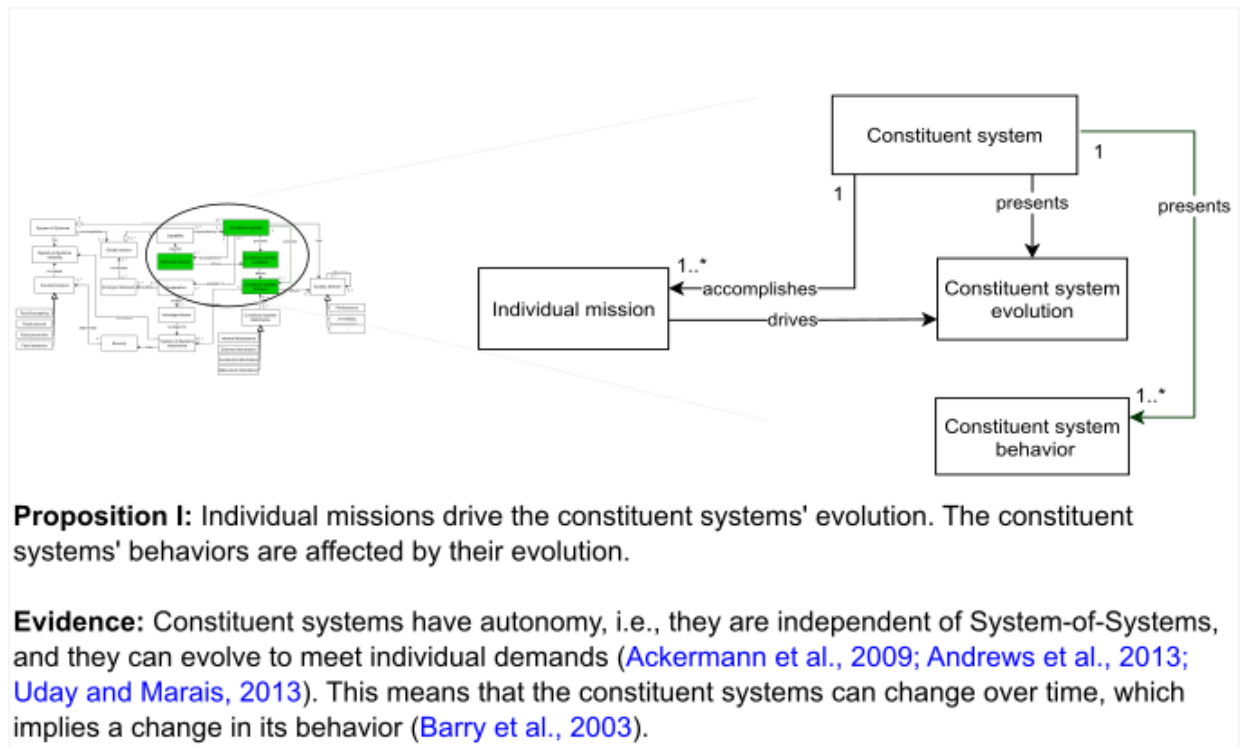
- Read the evidence carefully;
- Analyze the associated proposition;
- Verify the part of the model that represents the proposition;
- Mark your answer: ("I agree", "I do not agree", or "I do not know").

The conceptual model is described with the UML notation (<https://www.omg.org/spec/UML/2.5.1/PDF>). A brief description of the elements used in this model is presented in the table below.

Notation used in the conceptual model

	Represents an element "A" of the conceptual model.
	Represents a relationship between "A" and "B". The letter "R" represents the name of the relationship. The direction of the arrow represents the direction of the relationship.
	Represents that at least "M" instances of the element "A" have relationship with at least "X" instances of the element "B".
	Represents that exactly one instance of the element "A" has relationship with exactly one instance of the element "B".
	Represents that exactly one instance of the element "A" has relationship with at least "X" instances of the element "B".
	Represents an aggregation. "B" is part of "A".
	Represents that at least two instances of "B" are part of "A".
	Represents that one or more instances of "B" are part of one or more instances of "A".
	The arrow represents an inheritance. The elements "B" and "C" are subtypes of the element "A", which means that "B" and "C" inherit the properties of "A". However, "B" and "C" have particular properties.

6. Proposition I *

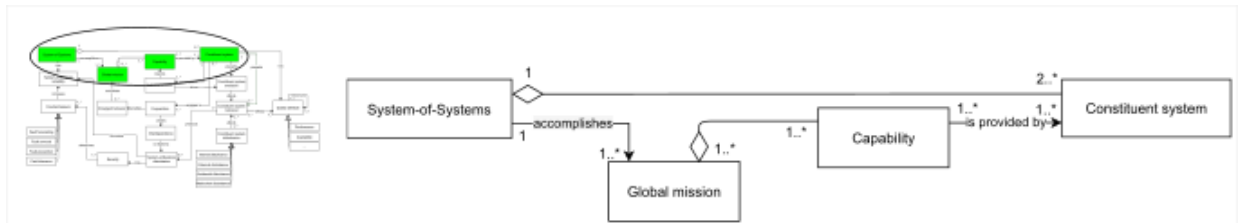


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- ☐ I agree
- ☐ I disagree
- ☐ I do not know

7. Please comment your answer. You can make suggestions and give examples if you wish.

8. Proposition II *



Proposition II: Constituent systems provide capabilities to System-of-Systems to accomplish one or more global missions.

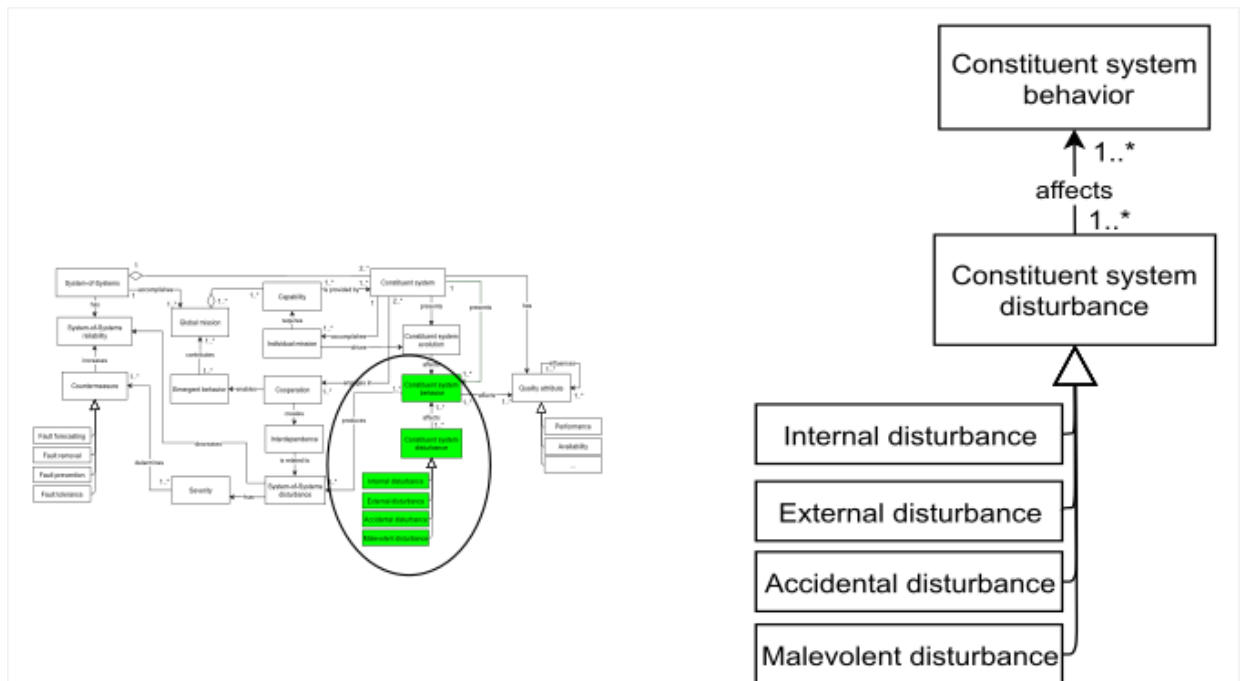
Evidence: System-of-Systems arises from the interaction among constituent systems. At the highest level, System-of-Systems corresponds to a collection of capabilities provided by a network of constituent systems that work in an orchestrated way to fulfill a common purpose (global mission) (Uday and Marais, 2013; Cavalcante, 2016).

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- ☐ I agree
- ☐ I disagree
- ☐ I do not know

9. Please comment your answer. You can make suggestions and give examples if you wish.

10. Proposition III *



Proposition III: The constituent systems' behaviors can be affected by disturbances.

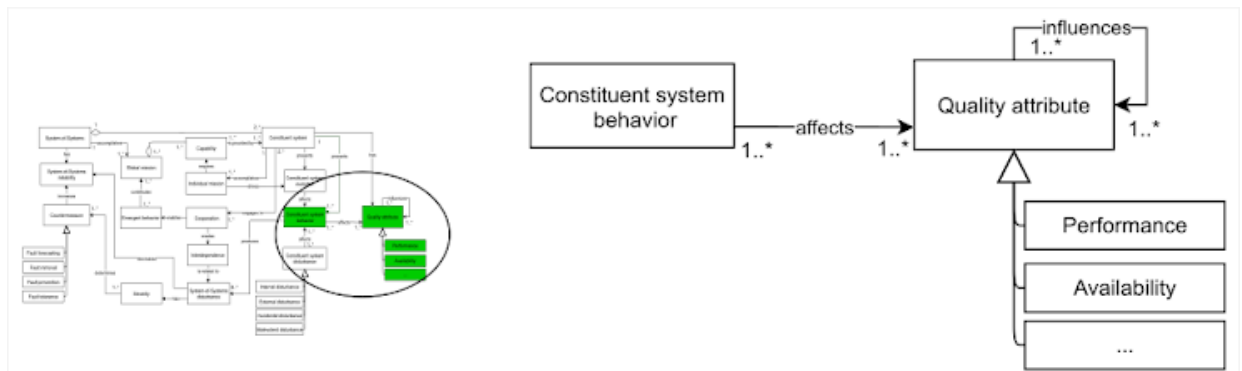
Evidence: A disturbance may negatively impact a system's ability to deliver value (Mekdeci et al., 2011). Disturbances in the constituent systems' behavior can be observed in the form of loss of performance, loss of capabilities, or complete shutdowns, for example (Cook, 2008; Uday and Marais, 2013; Wang et al, 2019). Disturbances can be generated by internal factors (e.g., components failures) (Cook, 2009; Tsilipanos, 2013), external factors (e.g., hacker attacks, natural disasters) (Ligaarden and Stølen, 2010), accidental actions (e.g., due to insufficient skills, stress, or fatigue) (Andrews et al., 2013; Tsilipanos, 2013; Bossuyt, 2019) or malevolent actions (e.g., erroneous inputs) (Tsilipanos 2013; Bossuyt, 2019).

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- ☐ I agree
- ☐ I disagree
- ☐ I do not know

11. Please comment your answer. You can make suggestions and give examples if you wish.

12. Proposition IV *



Proposition IV: The constituent systems' behaviors affect the quality attributes of that system, and quality attributes can influence each other.

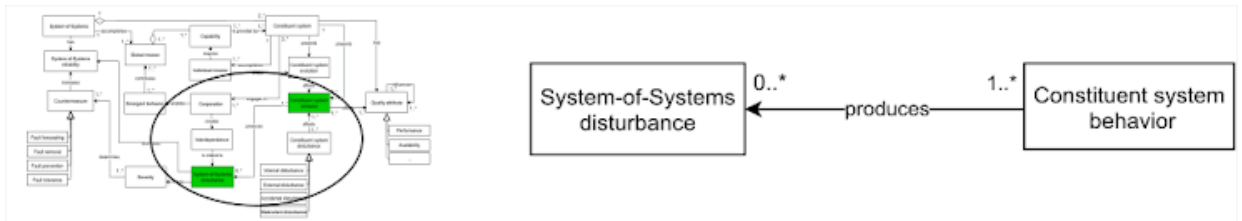
Evidence: Systems' behaviors can be specified in terms of quality attributes (Preiss et al., 2001; Sarjoughian, 2002), which can present a causal relationship, i.e., changes in a quality attribute can affect other quality attributes (Dromey, 1995; Broy, 2015).

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- ☐ I agree
- ☐ I disagree
- ☐ I do not know

13. Please comment your answer. You can make suggestions and give examples if you wish.

14. Proposition V *



Proposition V: The constituent systems' behaviors can produce disturbances at the System-of-Systems level.

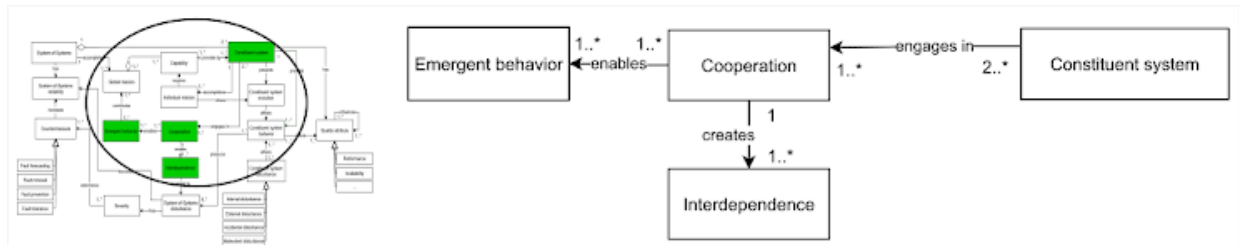
Evidence: System-of-systems' capabilities depend on the contribution of the constituent systems (Cook, 2009; Han et al., 2012), which are subject to behavior changes. If some of the constituent systems experience changes in their behavior (e.g., loss of performance, loss of functions, unavailability), the ability of a System-of-Systems to provide a capability can be affected (Eddaoui, 2018; Uday and Marais, 2013).

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- ☐ I agree
- ☐ I disagree
- ☐ I do not know

15. Please comment your answer. You can make suggestions and give examples if you wish.

16. Proposition VI *



Proposition VI: The cooperation among constituent systems creates interdependencies while enabling emergent behaviors.

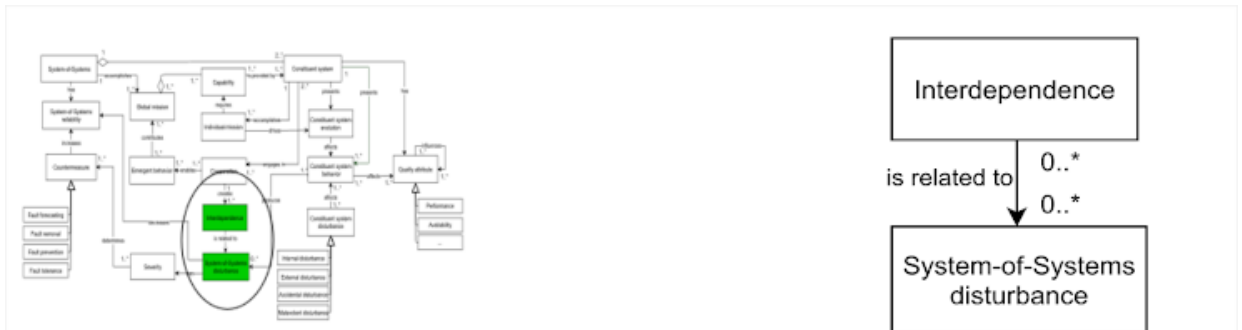
Evidence: The capabilities of System-of-Systems can not be credited to a single constituent system. Constituent systems work cooperatively for achieving a common goal, establishing relationships in a way that the ability of a constituent system to accomplish a task depends on the operation of other constituent systems (Ackermann et al., 2009; Cook, 2009; Ligaarden and Stølen, 2010; Guariniello and DeLaurentis, 2013; Fillipini and Silva, 2014; Eddaoui et al., 2018).

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- ☐ I agree
- ☐ I disagree
- ☐ I do not know

17. Please comment your answer. You can make suggestions and give examples if you wish.

18. Proposition VII *



Proposition VII: Interdependencies among the constituent systems are related to disturbances at Systems-of-Systems level.

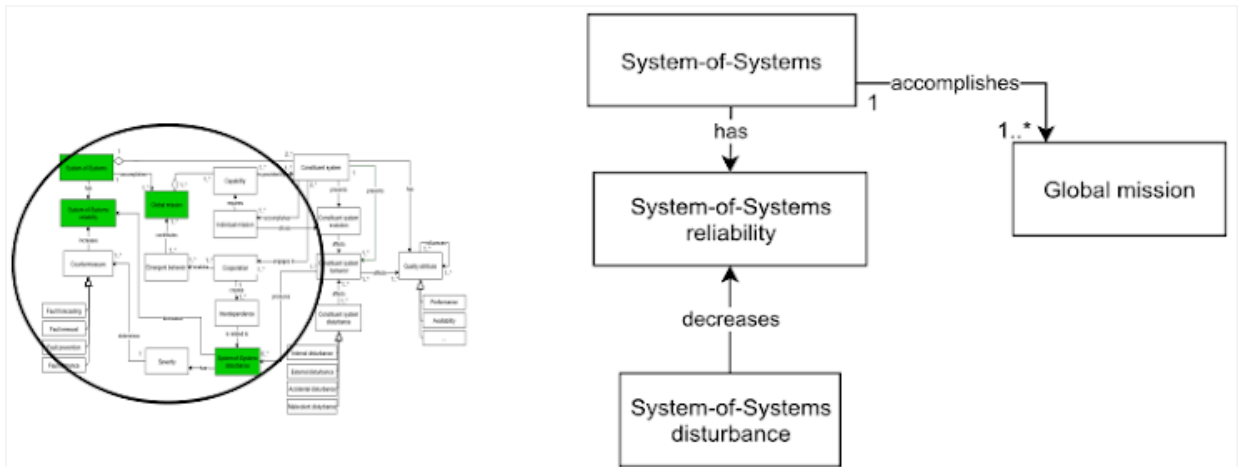
Evidence: While interdependencies enable capabilities at the System-of-Systems level, they can also affect the System-of-Systems negatively. High levels of dependencies imply an increased risk of cascading effect in System-of-Systems ([Ligaarden and Stølen, 2010](#); [Uday and Marais, 2013](#); [Han et al., 2012](#); [Wang et al., 2017](#)).

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- ☐ I agree
- ☐ I disagree
- ☐ I do not know

19. Please comment your answer. You can make suggestions and give examples if you wish.

20. Proposition VIII *



Proposition VIII: Disturbances at System-of-Systems level can decrease its reliability, i.e., the System-of-Systems ability to properly accomplish a global mission.

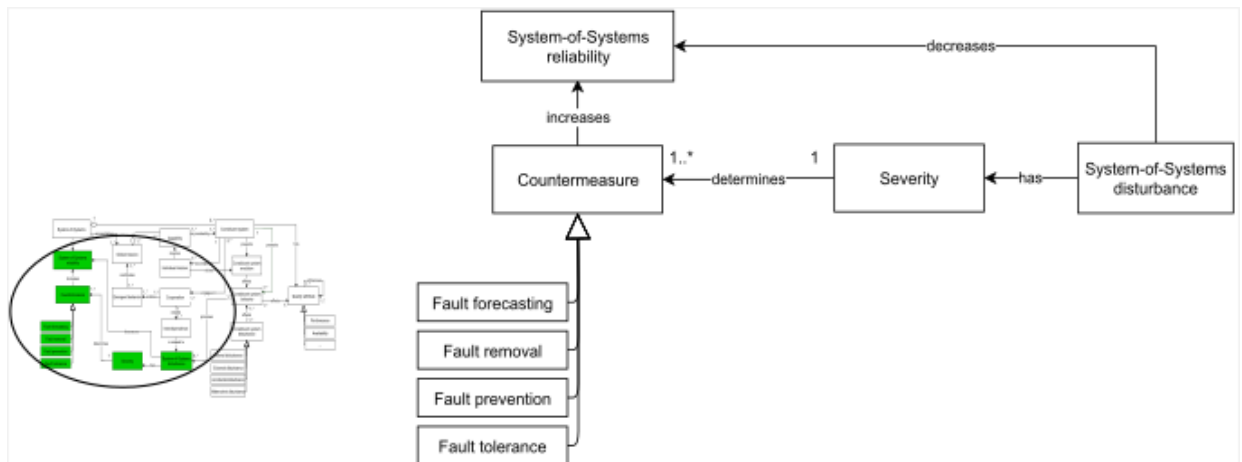
Evidence: As independent systems are connected to create a System-of-Systems, new behavioral properties can emerge from one or more systems behaving in unanticipated ways (Keating, 2009). Thus, Systems-of-Systems can experience unexpected disturbances that can result in reliability problems (Van Bossuyt, 2019), which can result in difficulties to System-of-Systems to accomplish a global mission.

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- ☐ I agree
- ☐ I disagree
- ☐ I do not know

21. Please comment your answer. You can make suggestions and give examples if you wish.

22. Proposition IX *



Proposition IX: The severity of the disturbances determines the countermeasures to increase the overall reliability of the System-of-Systems.

Evidence: The severity of disturbances determines the urgency and which countermeasures are potentially applicable to the situation (Cook, 2008). As stated in Proposition V, the behaviors of the constituent systems can produce disturbances at the System-of-Systems' level. Herein, we use the term disturbance instead of failure since malfunctions of Systems-of-Systems are not always the result of failures at the constituent systems' level. However, the nomenclature adopted to define the types of countermeasures for failures in traditional systems (Lyu, 1996) can also be used for disturbances in the context of Systems-of-Systems. There are four means to improve System-of-Systems reliability: (i) fault prevention, which aims to avoid, by construction, disturbance occurrences (Sanduka and Obermaisser, 2015; Mokhtarpour and Stracener, 2017); (ii) fault tolerance, which means providing continuous service despite disturbances (Uday and Marais, 2013); (iii) fault removal, which aims to detect the existence of disturbances and eliminate them (Ackermann et al., 2009; Stratton et al., 2009); and (iv) fault forecasting, which aims to estimate the presence of disturbances and the consequences of the occurrence of failures (Wang et al., 2017; Wang et al., 2019).

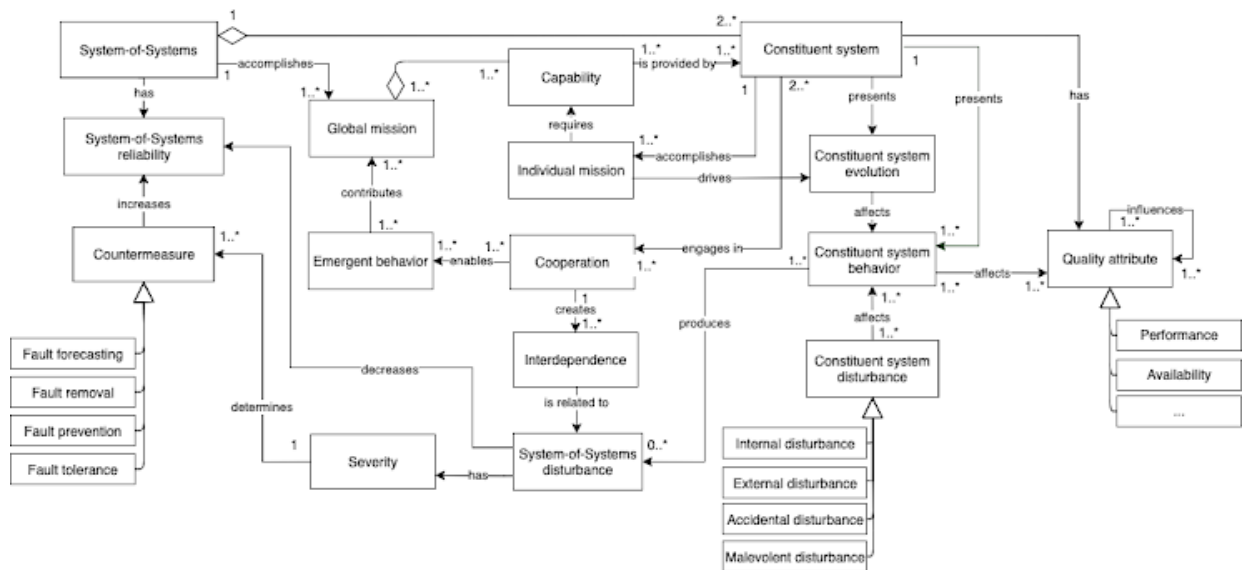
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- ☐ I agree
- ☐ I disagree
- ☐ I do not know

23. Please comment your answer. You can make suggestions and give examples if you wish.

Evaluation
of the
Model

Please consider the complete model when responding to the next questions. A PDF file with the model is available at <https://bit.ly/3ulGHFf>



24. Is the model free from ambiguities? *

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- ☐ Yes
- ☐ No
- ☐ I do not know

25. Please comment on your answer. You can make suggestions if you wish.

26. Are the elements of the model understandable by the System-of-Systems community? *

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- ☐ Yes
- ☐ No
- ☐ I do not know

27. Please comment on your answer. You can make suggestions if you wish.

28. In your opinion, was the model built with a minimum set of elements and relationships? *

Marcar apenas uma oval.

- ☐ Yes
☐ No
☐ I do not know

29. Please comment on your answer. You can make suggestions if you wish.

30. In your opinion, does the model include different scenarios regarding System-of-Systems Reliability? *

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- ☐ Yes
☐ No
☐ I do not know

31. Please comment on your answer. You can make suggestions if you wish.

32. Do you consider the model useful for theory and practice or just for one perspective? *

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- ☐ Yes
☐ No
☐ I do not know

33. Please comment on your answer. You can make suggestions if you wish.

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