

From Tracking to Wrecking: Practicability of Orbital Risk KPIs for Space Domain Management Decisions

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Object and Operator Behaviour

In Space Operations, the behaviour of the “operator person” shall become measurable based on Key Performance Indicators (KPIs). It is important that those KPIs can be monitored by the operator and, as independent and neutral as possible, by the administration.

Existing KPIs

Many KPIs identified so far are barely practicable for deriving appropriate Space Domain Management (SDM) decisions.

Reports	Time dynamic		Time relevance			Spotlight to		
	Static	Dynamic	Empiric		Model	Single Events	Group	System Behaviour
			Past	Near-Real-Time	Future Scenarios			
ESA Environment Report [7]	Yearly		X		X***			X
NASA ODQN [8]	Quarterly		X					X
AstriaGraph / Privateer [9]		Actual		X		X		
Space Sustainability Rating (SSR) [10][11]	Per Mission Phase	Limited*		Limited*	X		X	
LeoLabs Quarterly Report [12]	Quarterly		X				X	X
ShareMySpace Monthly Report [13]	Monthly		X			X		
EUSST Conjunction prediction [14]		Actual		X		X		
EUSST fragmentations [14]		Actual		X		X		
EUSST re-entry [14]		Actual		X		X		
STROM: Space Traffic Reports for Orbital Management (see Outlook section)	X	Daily	X	X		Limited**	X	X

Space Domain Management

Space Domain Management is the administrative responsibility. KPIs relevant for Space Domain Management describe the Risk-Making to Society.

The monitoring of the KPIs shall be possible for the space operator as well as for the administration, using similar or comparable tools, used independently from each other.

The KPIs shall be available for very different time intervals as summary as well as for specific events.

The risk expressed in the KPIs shall easily express the risk-making to the environment / to the society.

The KPIs should be retrievable from different tools expressing the same metric (comparability).

The KPIs shall allow to refer to (natural or juristic) persons per event / time period.

The KPIs shall have the quality to be used in administration and jurisdiction (evidence-based, representing empiric perceptions).

The KPIs shall allow to judge a deviation from rules and regulations (Yes / No) and to what extent the deviation was found evident (in the best case, in numbers from the metrics).

The requirements for KPIs for legislation, administration and jurisdiction are summarized in the above points.



SPACE ANALYSES

Sources:
All analytics and graphs © 2023 by
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Data: Space-Track.org
750 days -> 12mio conjunctions <5km

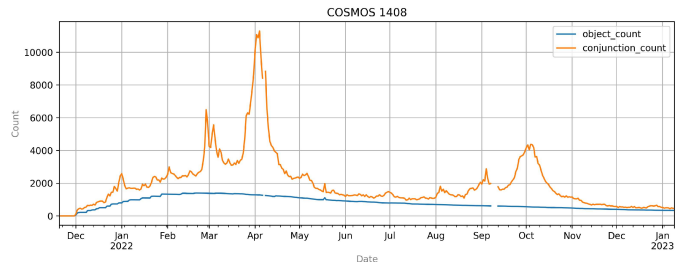
Cybernetics

The relation, interaction and dynamics of objects owned by and the behaviour of the operators towards a system, towards the public, towards society in general, requires to see sustainability in conjunction with the public, with society.

The one-to-one analysis is often a necessary abstraction to avoid that the system model would get too complex.

Cybernetics, the systemic approach, defines a model for the risk to the overall system (including the service users on ground) rather than attempting to create a model for the system itself.

That way, it avoids the aforementioned complexity problem.



As can be seen from the graph shown above, the number of objects is not necessarily a good risk indicator and the number of close conjunctions is clearly not only depending on it.

Cybernetics KPIs

There are two main differences to the other KPI approaches:

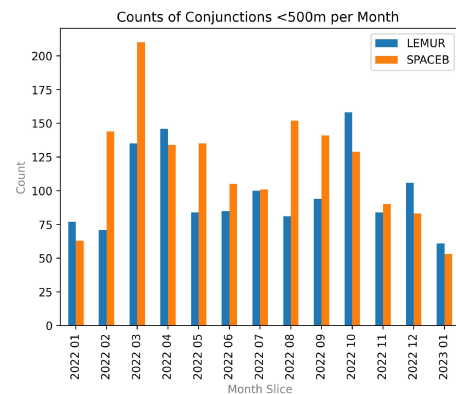
* Modelling the Risk instead of Modelling the System

* Risk is not only collision or breakup risk, but also includes endangerment. Therefore, each close approach beyond a defined threshold already counts as an event of risk-making.

A Cybernetics KPI for risk modelling of operator behaviour towards the system could for example be the Number of Conjunctions < 1 km (or 500m) for the operated satellite or constellation. This is a measurable KPI in the area of governance vs. person.

A second Cybernetics KPI, targeting the operations of large constellations is the Cascade Potential KPI we presented at the AMOS conference 2022 .

From this, we derive both an Individual and a System Cascade Potential KPI.



Conclusion

In this paper we showed and compared existing established parameters used in space operations to express threats to the environment. We assessed them for usability in the context of requirements from law-making, administration and jurisdiction. We also introduced a new parameter retrieved from the requirements and combined it with an already published one representing threats to the environment.

Following the philosophy of law, any threat to society shall be judged based on the behaviour of one or more persons or legal entities.

To establish and to safeguard a sustainable and resilient living together, behaviour rules are established with the aim of preventing threats to society. These rules are converted into laws and regulations by the legislation, implemented by the administration, and executed by jurisdiction.

The proposed Cybernetics KPIs could be used to regulate endangerment to the well-being of society. Moreover, deviations to laws and regulations can be identified on the merits and to the extent. This enables the possibility to judge the behaviour of space actors – based on the proposed KPIs – as compliant, or as negligent or even intentionally endangering the sustainable and resilient well-being of society.