Lessons learnt & outlook

Workshop on Collision Avoidance Challenge Results
23rd April 2021

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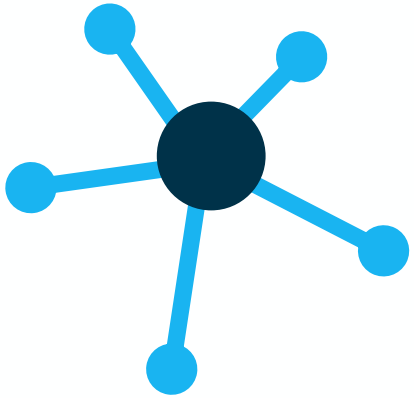
ESA Space Debris Office

Lessons learnt

Results compiled in T. Uriot et al., Astrodynamics, 2021

Overview of data preparation, competition setup, participant feedback

Data distribution



CDM dataset still available

Support research in line with the UN Guidelines on Long-Term Sustainability of Space Activities

- M.F. Palermo et al., 8th ECSD, 2021
- L. Ayala Fernández, 8th ECSD, 2021

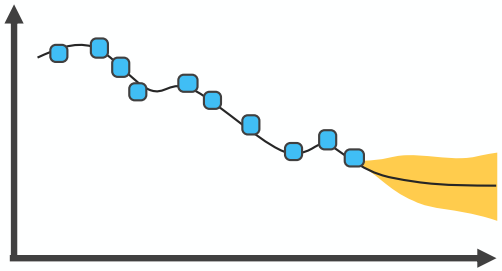
Limitations of the competition

Limited dataset **size** (199000 CDMs, 15000+ events): intrinsic

Very **unbalanced** dataset (131 events with $p_c > 10^{-5}$): intrinsic, but it can be mitigated with a different formulation

Metric emphasises false negative (translation of operational mind-set)

Potential for ML approaches



Indication that ML approaches can do better than naïve predictions

Open points after competition:

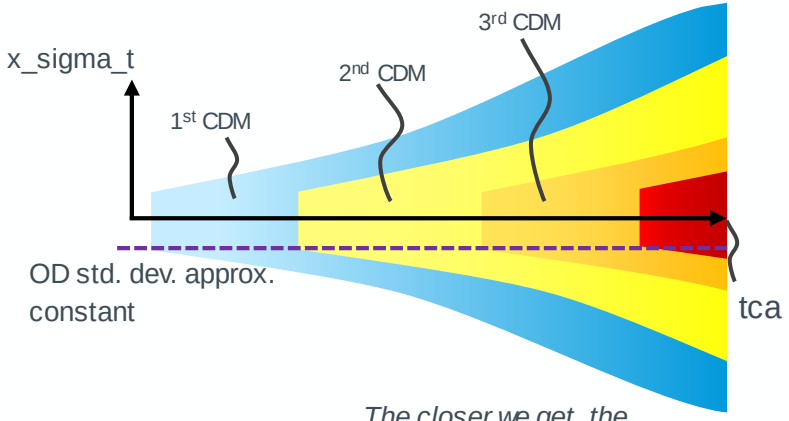
- **Risk** vs uncertainty
- **Feature** relevance
- **Time-series** exploitation
- Generation of **synthetic** data

Academic activities (concluded)

Problem formulation

Use ML to predict the evolution of the **position uncertainty**, affected by update delivery

- \- Need to handle miss distance separately
- \+ Potential to learn from the full dataset

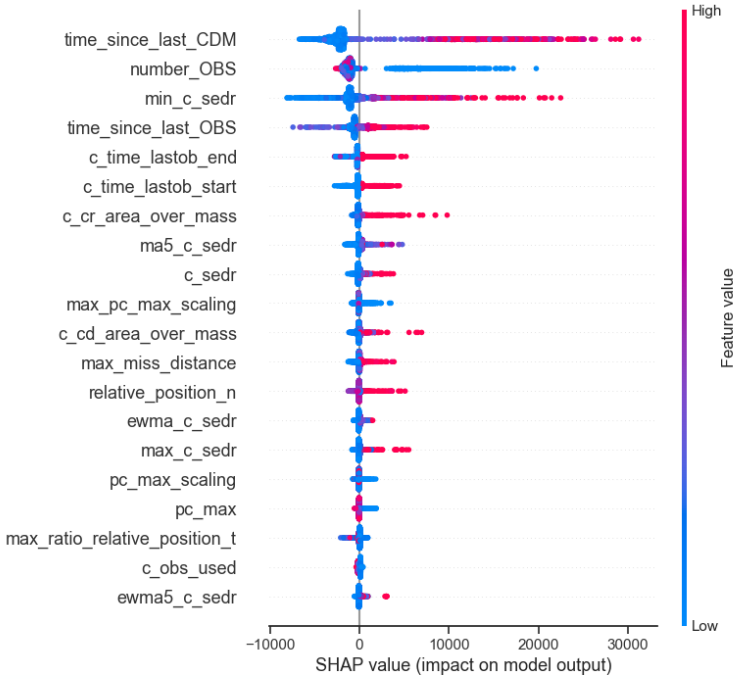


The closer we get, the less uncertainty at TCA

Master thesis with TU Darmstadt

► S. Metz et al., 8th ECSD, 2021

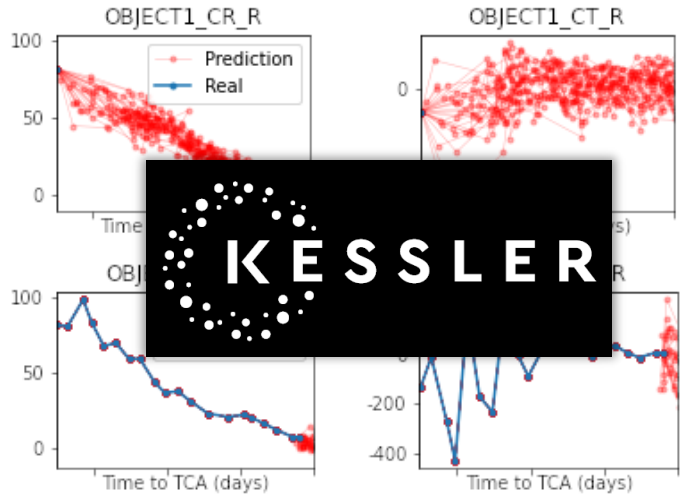
Analysis of several approaches and investigation of **feature relevance** for **explainable** results



FDL Europe 2020

► G. Acciarini et al., 8th ECSD, 2021

Exploitation of **time series**: LSTM trained to predict next CDM or event until TCA



Pipeline for the generation of a **synthetic dataset**

Academic activities (on-going)

ESA_LAB@Oxford

► S. Gogioso, AQC, 2020

Applicability of **Quantum Machine Learning** tested during the Kelvin competition

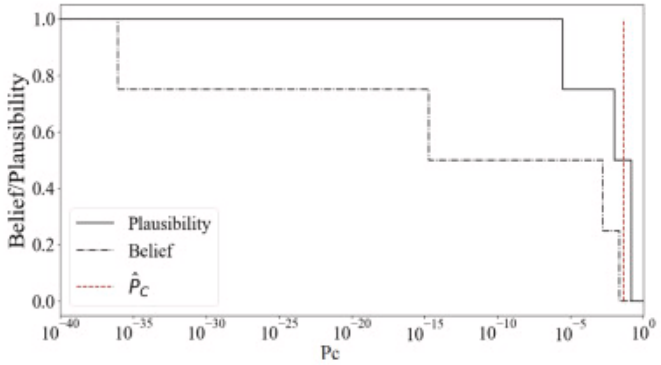
Follow-up Master Thesis based on the formulation in terms of **uncertainty** (on-going)

Elements under analysis:

- Development of an **hybrid** quantum-classical algorithm
- Suitable **encoding**
- Handling of **time series** (considering qubits constraints)

OSIP PhD University of Strathclyde

► L. Sànchez & M. Vasile, AA, 2020



Classification of collision events to capture and quantify epistemic **uncertainty** in the estimation of collision probability

Design of corresponding **collision avoidance manoeuvres** (including low-thrust cases), considering operational constraints

Industrial activities

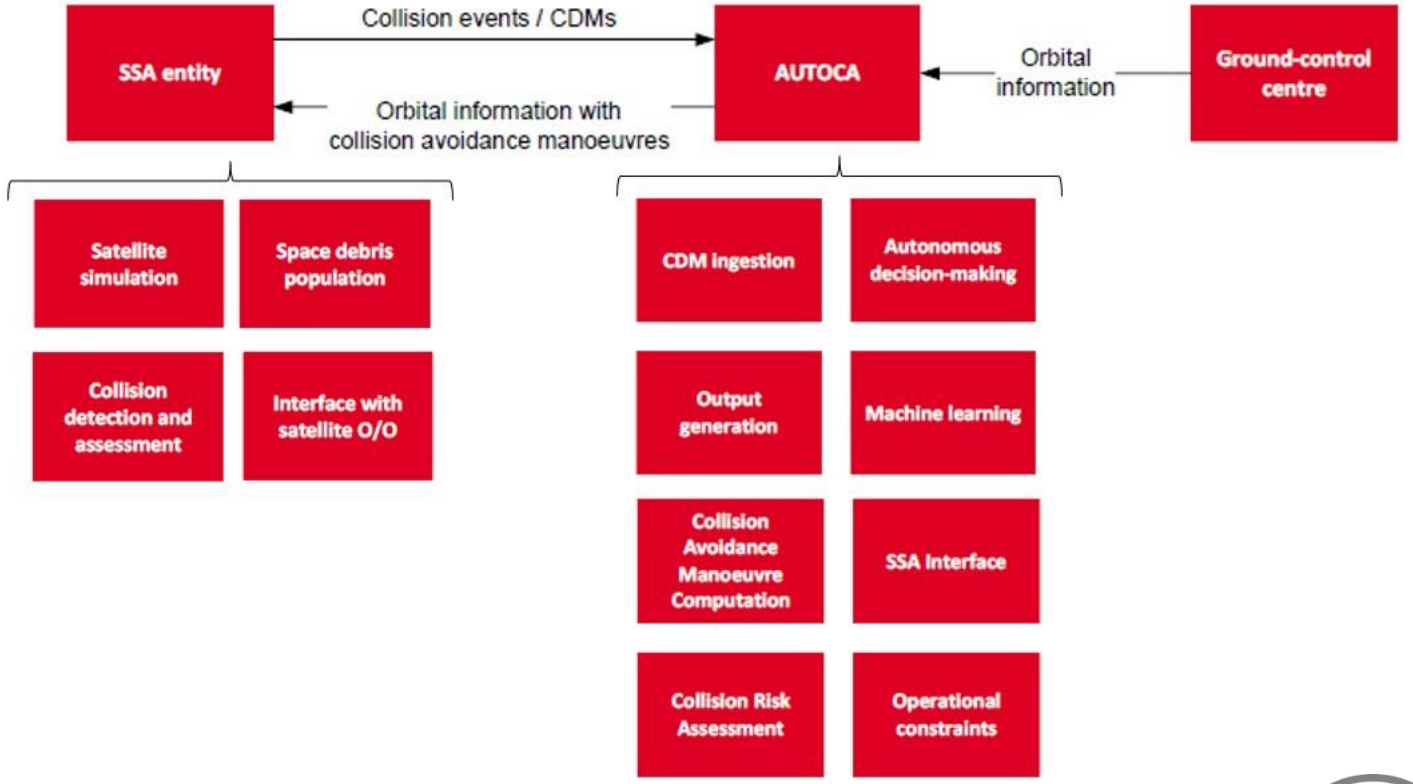
AutoCA (GMV)

► D. Stanculescu et al., 8th ECSD, 2021

On-going activity to develop an operational environment where machine learning models can be leveraged to predict expected **chaser updates** and the resulting **uncertainty evolution**

Development of a **software tool** that **operators** can use to train the machine learning model based on their own **CDM** collection

Integration within an **operational suite** able to handle not only conjunction decision, but also **collision avoidance manoeuvre** design considering operational constraints



ESA’s Space Safety Programme

Subscribed by Member States at Space19+ with 434M€ → **started Jan 2020**

Contribute to the **protection** of our planet, humanity and assets in space and on Earth **from hazard originating in space**

Need to protect assets through the **monitoring** of the space environment, and to have access to **independent** Space Safety data and services

Structure of the Space Safety Programme

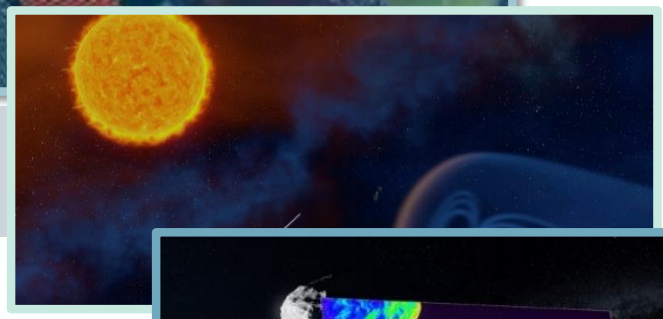
1 Core

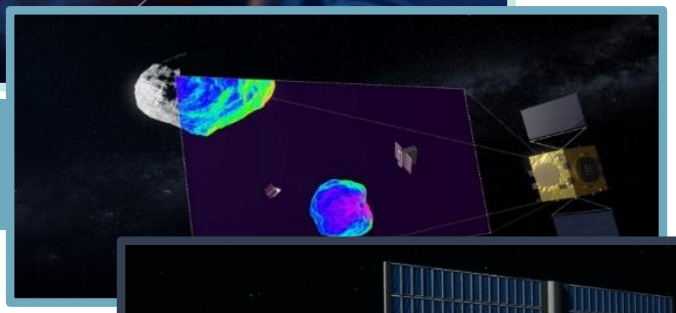
2 Space Weather L5 Mission

3 HERA

4 In-Orbit Servicing/Removal Mission

5 CREAM





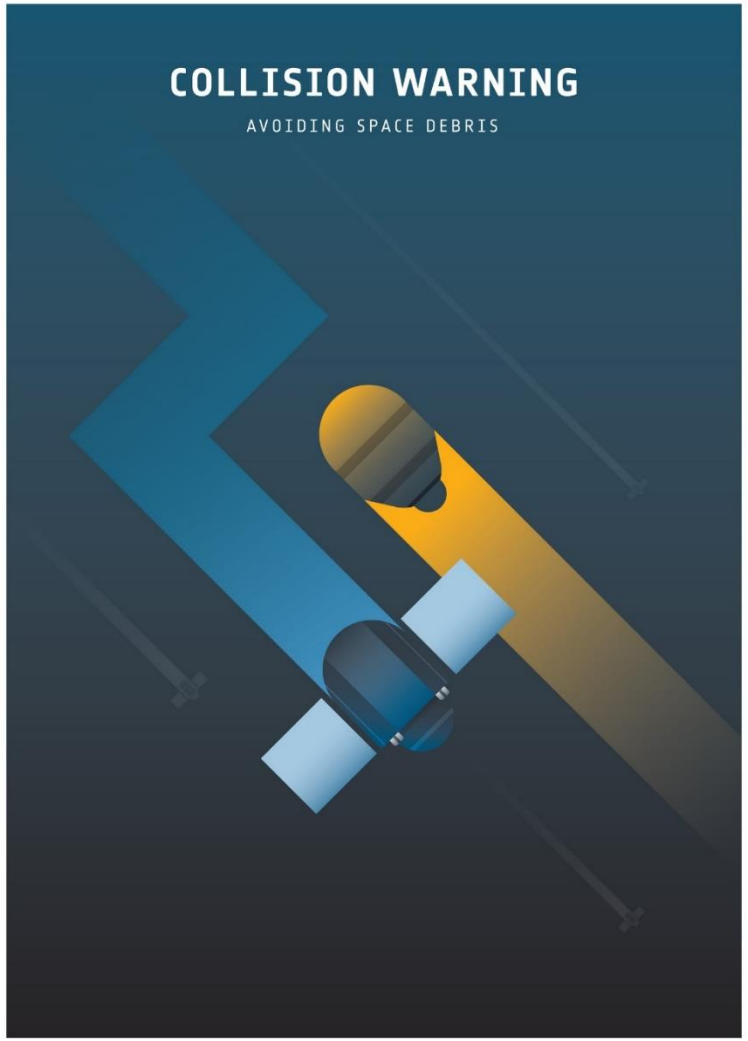
Collision Risk Estimation and Automated Mitigation

Reduce:

- Manpower efforts, especially for large constellations
- Time between manoeuvre decision and close approach
- Number of false alerts

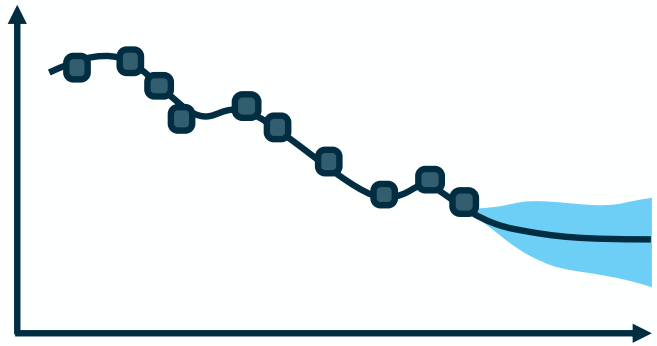
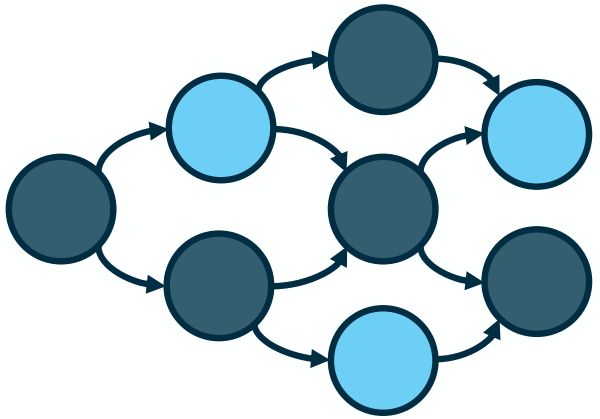
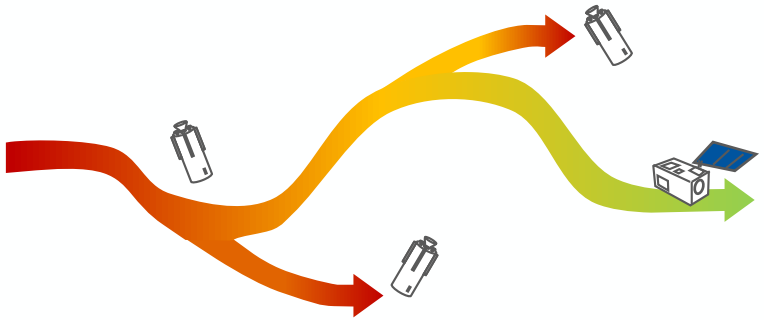
Tasks:

- Automate collision avoidance decisions
- Develop efficient ways to coordinate and command manoeuvres
- Demonstration through newly developed platform or existing missions



Automated avoidance manoeuvre decision and design

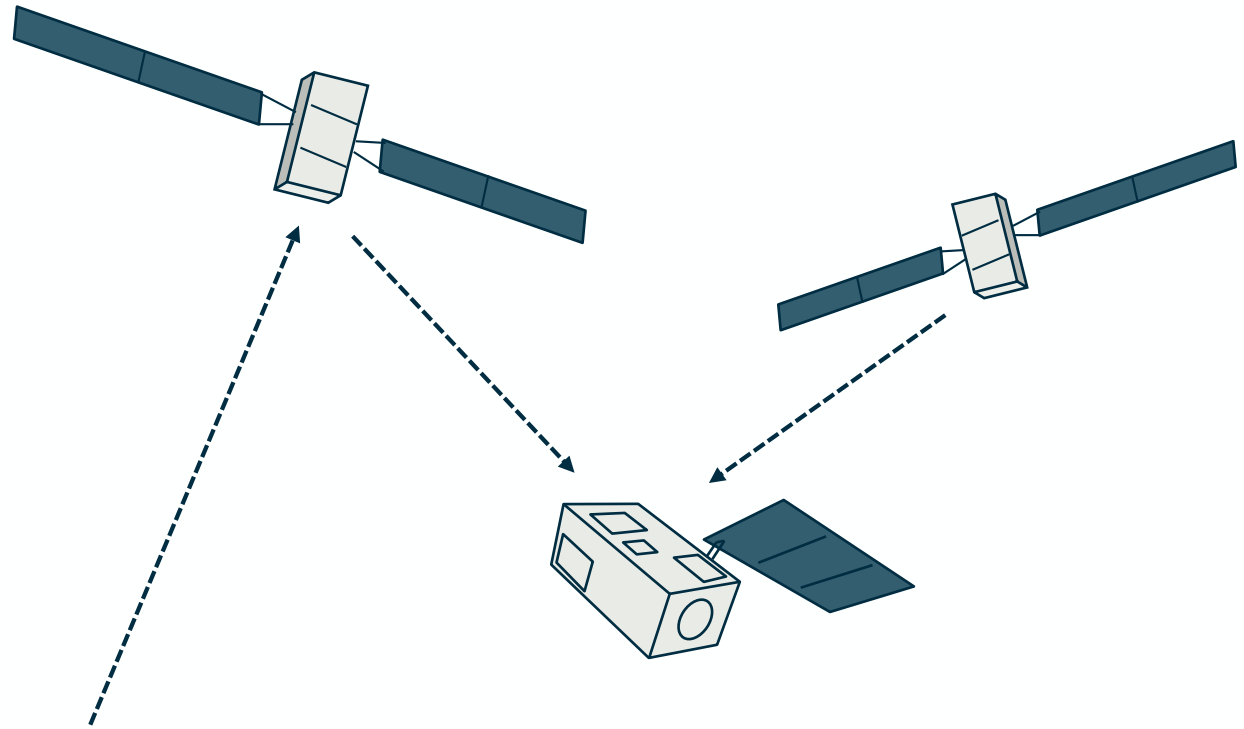
S1-CR-01

Assessment of historical conjunctions	Approaches for automated decision	Advanced avoidance strategies
		
Statistics & **machine learning** methods to identify driving parameters	Assessment of **robustness** & **explainability** Definition of **decision criteria**	Consider **global optimisation** and application to **low-thrust** missions **Prototype software** for full chain

De-risk activity (Neuraspace) collision risk management approach for New Space

Development and test of late commanding paths and operations concepts S1-CR-02

- Develop operational concepts involving **inter-satellite links** (ISL)
  - Trade-offs on split between **on-ground** and **in-space** processing
  - Trade-offs between ISL and large ground station networks
- Handling of **platform** constraints
- Feedback loop for **secondary conjunctions**
  - SST interface needed for screening
  - ML can support pre-classification of potential response plans
- Preparation for **demonstration** with operators



Means for coordination of operators and catalogue providers S1-CR-03

Current approach

Name

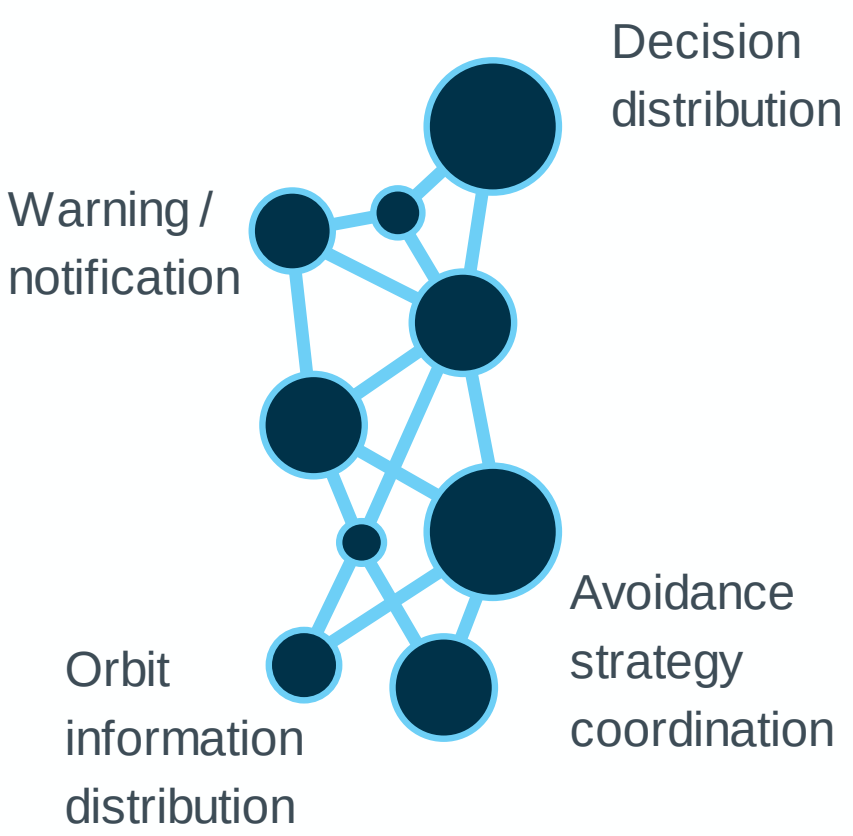
Email

Message

Tasks

- Assess suitability of existing protocols
- Prototype implementation
- Simulation environment
- Assess performance of different coordination strategies and data needs

Future approach



Supporting activities

Rules4CREAM

► M. Michel & R. Bertrand, ECSD, 2021

Development of different **rulesets**, also considering current practice in other domains (e.g. Air Traffic Management)
Evaluation of the proposed rulesets in **long-term environment** simulations
Derivation of requirements & constraints for technologies and **data-standards** to be developed

SW technologies4CREAM

Identify **safe communication protocols**
- Between operators
- With SST data providers (e.g. manoeuvre notification, tracking requests, screening)

Allows **coordination** (e.g. smart contracts and distributed ledger technology)
Access control & Data integrity

Conclusions

Space debris is an **operational reality** with around one collision manoeuvre every three months for the Sentinels. Each of these manoeuvres has a cost: **fuel**, **manpower**, **data outage**.

Changing environment: **improved sensor capabilities** (more objects) and **increased traffic** (more conjunctions with active satellites)

Interest in **reducing false alerts** and **manoeuvres**. Call for increased process **automation**, both in conjunction analysis and in the coordination process.

Several on-going & upcoming activities within ESA **Space Safety Programme**.

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