# Long-Term Data Analysis for Improved Risk Assessment regarding Orbital Assets

Valentin Eder(1), Christian Unfried(1)

(1) Space Analyses GmbH, Marxergasse 24/2, A-1030 Wien/Vienna, Austria
Email: valentin.eder@spaceanalyses.at, christian.unfried@spaceanalyses.at

### Actual situation in the implementation and development of risk assessment in Outer Space

Most of today's Space Surveillance and Tracking (SST) solutions and their usage scenarios consider risk assessment in the form of forecasting single events on a day-to-day basis, such as supporting collision risk analysis by providing conjunction prediction messages. While this represents a highly adequate quick-response process triggering the appropriate crisis management actions, this approach usually neither considers past events and historical anomaly evolutions nor does it lead to further forecasts beyond the single events in focus. Big Data (BD) analytics helps approach the problem in a different manner. Like for satellite telemetry and satellite communications, long-term data archives of orbital data and resulting multiple conjunction prediction data can be evaluated under the rules of systemic principles, logical constraints and methodological procedures to reveal insights on highly complex dependencies. These insights are seen as a potential key to performing an assessment of a "global" risk in outer space activities, to describing its history, and – considering relevant scenarios – to forecasting its potential future evolution.

Various efforts worldwide are spent to implement Space Tracking Management (STM) with the goal to comply with the UNOOSA COPOUS Long Term Sustainability Guidelines. These efforts show:

- the absence of a subordinate guiding methodology and framework structuring and coordinating all activities,
- missing metrics to squeeze success, deviations with comparable key performance parameters (KPI's)

To eliminate the shortcomings, a worldwide accepted framework, the UN-SPIDER Sendai Framework, is proposed.

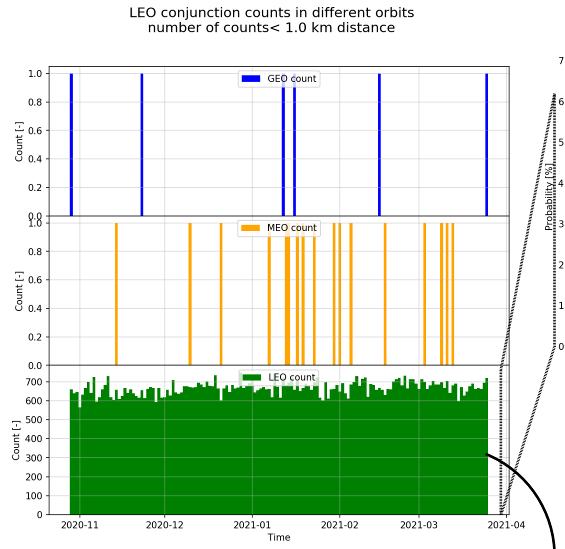
The Sendai Framework requires in Priority 4 (Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction) the monitoring of the actual risk of hazards.

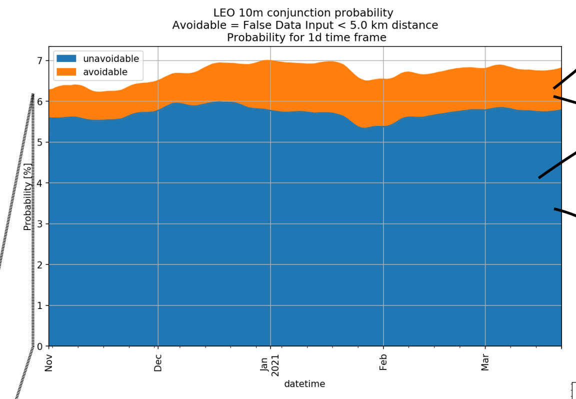
In our presentation, we also discuss the path towards a Space Pandemic Dashboard (as an analogy to current climate change and corona virus visualizations) and how historical data and its analysis can contribute to predicting future evolutions. Like in the relation between weather forecasting and climate analysis, like in the relation between medical status and epidemiological scenarios, the steps described represent the advancing from Space Debris Event Monitoring to Space Debris Risk Management. We draft the elements for a "global" risk estimation process and attempt to visualize the
various risk drivers and their interrelations. When we speak about risk in this context, we need to distinguish between the risk on the pure orbital infrastructure, i.e. the risk on the investment, and the operability of orbital objects including the availability, reliability and
integrity of the services realised using these assets, i.e. the operational risk (which, as we know, leads to the business continuity risk).

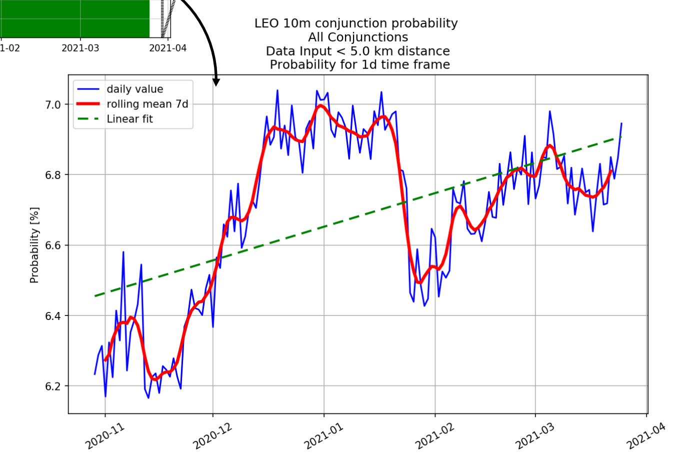
We draft the elements for a "global" risk estimation process and attempt to visualize the various risk drivers and their interrelations. When we speak about risk in this context, we need to distinguish between the risk on the pure orbital infrastructure, i.e. the risk on the investment, and the operability of orbital objects including the availability, reliability and integrity of the services realised using these assets, i.e. the operational risk (which, as we know, leads to the business continuity risk).

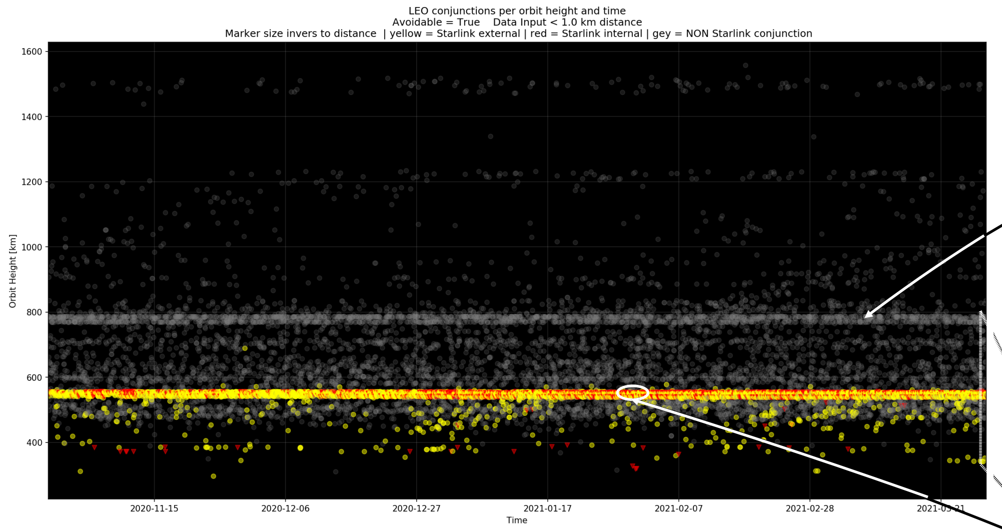
Our current analyses are performed on the basis of publicly available data such as the TLEs provided by CelesTrak. We shall discuss the advantages and limitations of this current range of data and their sources, and also the advantages and limitations of using further – parallel as well as complementary – data sets. This includes a critical view on the aspects of data integrity, data correctness and data usefulness and present an outline of possible future developments.

Valentin Eder valentin.eder@spaceanalyses.at
Christian Unfried christian.unfried@spaceanalyses.at
SPACE ANALYSES GmbH
Marxergasse 24/602
A-1030 Vienna, Austria
www.spaceanalyses.at
SPACE ANALYSES





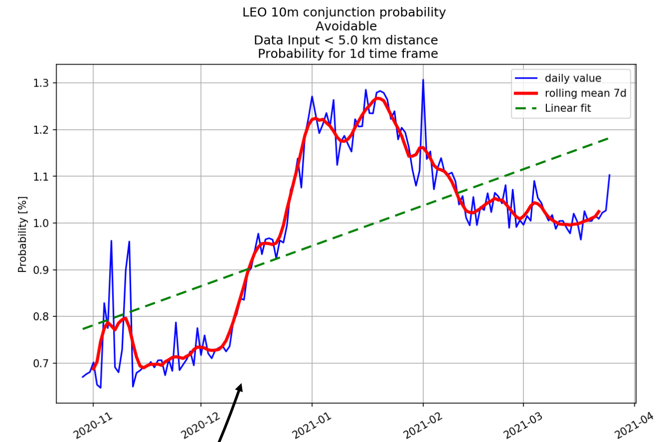


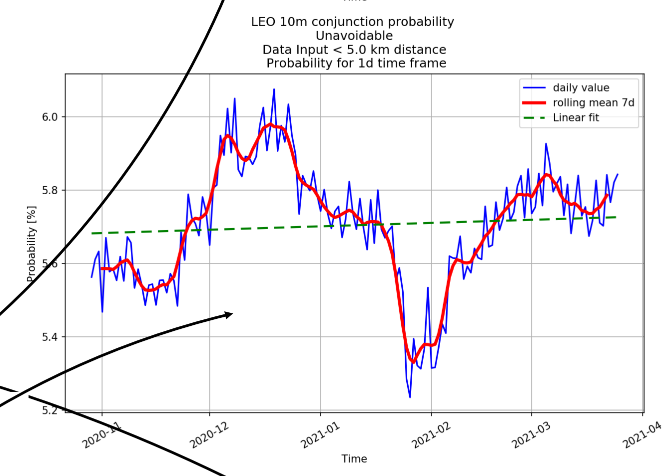


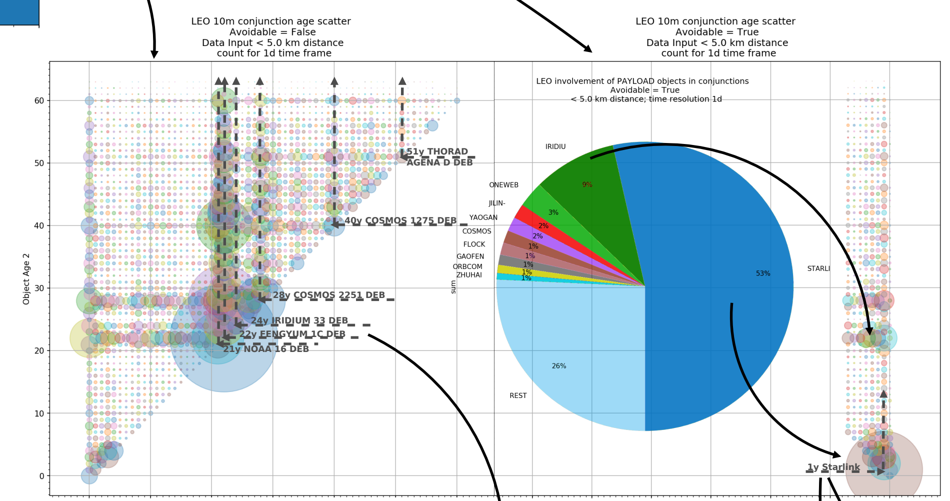
### The conjunctions

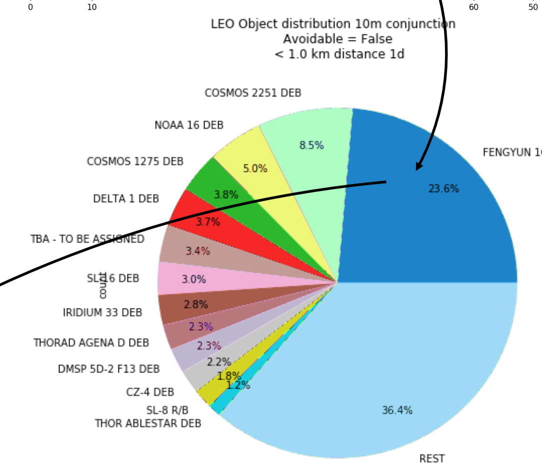
The graph (Top) shows all conjunctions of the Starlink constellation in red (internal) and yellow (external) with all others avoidable conjunctions in grey in the background depending on orbit.

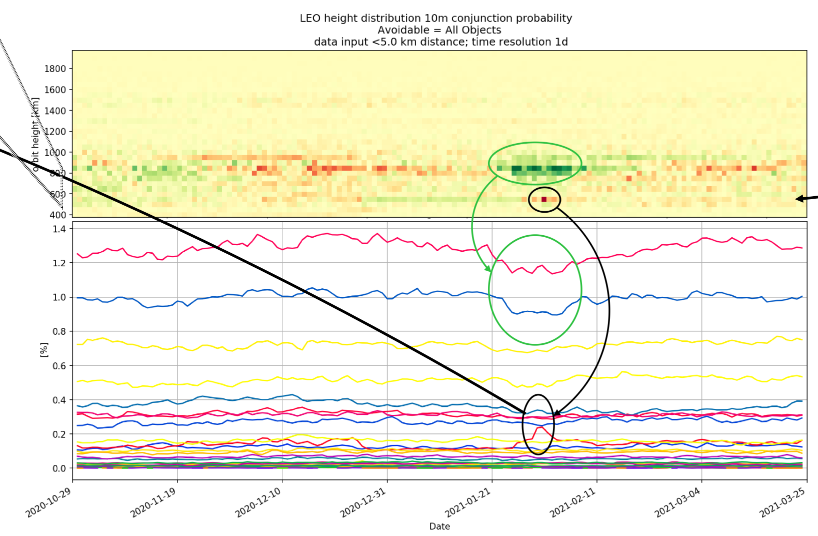
The high-risk events within the given constellation are represented by the size of the bubbles (high risk is bigger size). The regularity of the internal conjunctions within the constellation appear as red lines in the same orbit height. In the given data set the closest conjunction was between STARLINK-1206 and STARLINK-1618 as happened on the 2021-01-02.











Data analysis in Space Analyses (Vienna) of about 2.5 million conjunctions < 5km over the last 150 Days shows a set of developments that should enrich the actual discussions on STM and SEM. The systemic look to the conjunctions should bring answers where the collision risk is higher than in other 'regions' and shows actual trends.

### Avoidable and Unavoidable Conjunctions

In outer space there are conjunctions that are unavoidable (debris versus debris or any 'non-piloted' objects) and conjunctions that are possible to avoid where at least one of the objects can be moved (avoidable conjunctions). There is no publicly available data on what types of object have active propulsion systems but using the age and type of the object, an assumption can be made that only relatively new objects in LEO that are of a certain size are qualified as payload with propulsion. In addition, the concepts of a 'traffic-lanes' in outer space help to distinguish certain areas with different risk levels. In the given model, steps of 50km in orbit heights are chosen as 'orbit lane' definition. These two main classifications build the frame to look on different aspects of conjunctions in a daily time frame. The data input is the publicly available TLE data from space-track and although have a limitation on accuracy of single objects is usable for long period analyses (~20,000 objects @ >10cm).

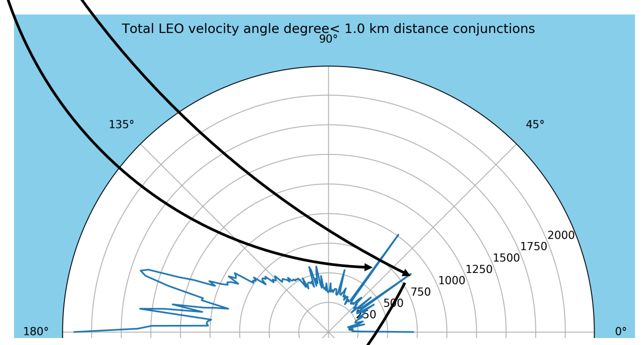
### Conjunction Probability

Taking a general view of the actual situation is to look at the probability of a statistical conjunction < 10m, as a collision risk (based upon actual accuracy of the space object position). The distribution of the space objects to each-other gives an estimate of the risk. So not only the number of objects in the lane/area but also the relative position of all objects in the 'swarm' influences the collision risk. The daily probability of a <10m conjunction for all orbits today is around 6.7% which means that statistically, each second week, two objects are <10m apart. The probability at the end of November 2020 was around 6.2%. The statistical time between two conjunctions <10m at the end of November was 2 Days longer than today. That means that the probability of conjunctions (and the probability of collisions) increases as the time between conjunctions gets shorter. The graph shows the daily probability in blue, the running mean of 7 Days in red and the progression line in green.

### Object Age

The question here is how long are items in space involved in conjunctions to estimate the actual risk of 'artificial input' to the 'system space'? Taking the example that if two objects 'meet' each-other and both are defined by the age of the launch in the object ID. The scatter plot on the left-hand side shows on the axis the age of the unavoidable conjunctions and the size of the bubbles shows the count of the conjunctions.

In this plot are some significant outcomes. In the conjunctions are items involved that have been orbiting for >60 years in space, so this includes items from the very beginning of space exploration. The ages of Fengyun 1C, for example, is 23 years, NOAA 16 is 22 years and Cosmos 2251 is 27 years. This gives some indication of the involved objects and their impact to conjunction counts leading to 'natural growth'. The small bubble on the 0,0 axis is items from the year 2021 involved in the 'space encounters'. Looking at the avoidable conjunctions age scatter plot (Right) gives a clearer picture of how old and new items interacting together. This occurs because objects are assumed to be <8 years in space and, thus, the scatter results are empty on the right-hand side. The largest bubbles are near the 0,0 axis point of around 1 year. That leaves the interpretation that most conjunctions will be between the latest satellites. The question now is, where is this coming from that explains the rise of conjunction probability of 79% in avoidable conjunctions within the 90 Day period looked at?



### Cross Traffic

A lane is an area of 50km 'thickness' around the Earth and the systemic look is comparable to a traffic lane on a highway but includes items 'cross traffic' cutting through the lane in all three dimensions. The event of a cross traffic collision has a high potential to spread the items into other orbits or, if it is
in the same constellation plane, to spread over the complete constellation. Looking at the unavoidable conjunction angle distribution a 'porcupine' picture appears and gives the following, possible, interpretation: Sharper peaks are more regular and repeat. Very regular conjunctions are most probably from the same constellation and not from debris. In the given chart the conjunctions at 40° and 50° are within the same constellation. The peak at 100° maybe rocket bodies and the rest are conjunctions with other items or debris. The peaks between 135° and 170° are classical debris conjunctions. The plot of the unavoidable conjunctions shows no sharp peaks which appears to be a logical conclusion as the distribution of space debris is not controlled and thus spread out in several directions. It also shows a clear peak in the directions between 160° to 180° i.e., nearly frontal with speeds up to 14km/s or above.

### Orbital Lane Conjunction Probability

The split of the risk of a 10m conjunction into orbital lanes, the recalculation of the conjunction probability for each lane per day separately in the plot to show the distribution is per lane and how it changes over time. The <10m conjunction probability has a similarity to the number of conjunctions but not in the same form.

The number of days between a conjunction is the inverse value of the conjunction probability, multiplied by 100. The conclusion here is that using TLEs does not show a significant risk of a conjunction or collision as, for example, in the 600km orbit lane the conjunction probability is only 0.2% that gives a statistic time gap of 500 Days. If 'system noise' (items >1cm) are included the time gap is then reduced to 14 Days.