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# SRASO: Using Space Weather Information for Spacecraft Operations Made Easy

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**Abstract**

Spacecraft can be highly influenced by the environment they are operating in. It is therefore key for spacecraft operators to be aware of the current and upcoming space weather conditions to be able to react accordingly. Additionally, recorded anomalies on a spacecraft can often be explained by space weather effects. A tool that can correlate space weather information with spacecraft telemetry is highly useful for operators. The Space Radiation Application for Spacecraft Operators (SRASO) is such a tool that provides spacecraft operators with an easy access to space weather datasets and models and allows to correlate with the own mission's telemetry.

**Keywords:** SSA, Space Weather, Space Operations, SPASE, Microservices

**Acronyms/Abbreviations**

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| *ESA* | = *European Space Agency* |
| *SPASE* | = *Space Physics Archive Search and Extract* |
| *SRASO* | = *Space Radiation Application for Spacecraft Operators* |
| *SWE* | = *Space Weather Environment* |

## 1. Introduction

The space weather environment can have severe effects on spacecraft and the services they provide. These effects can manifest in a variety of ways, for example:

- as radiation threatening on-board electronics,
- as charged particles building up in and on the spacecraft and creating a harmful charge,
- as atmospheric drag, that can disturb the spacecraft's angular momentum.

Due to the severity of these and other effects on the health of the spacecraft, it is key for operators to be aware and informed of their potential influence. In 2019, ESA started a project with Solenix called Space Radiation Application for Spacecraft Operators (SRASO). The main objective of this project is to design and implement an application that allows spacecraft operators to obtain a relevant picture of the current and forecasted environmental conditions that may affect their spacecraft. This application will soon be available and focus on:

- Monitoring and forecasting in-orbit space weather effects;
- Reporting space weather effects for post-event analysis;

both in combination with the operators own spacecraft telemetry.

A survey during the first phase of the project with spacecraft operators from ESA and private industry has shown that operators are typically taking space weather information from very different sources without the possibility to put it in relation with their spacecraft telemetry. SRASO aims to make using this information easier by providing one interface for space weather data sets, models and spacecraft telemetry.

There are two main challenges for designing such a tool:

1. The tool needs to provide a flexible and configurable approach for visualising data, to allow for efficient monitoring of spacecraft and their environment.
2. The tool needs to connect with distributed data and model sources and to align their non-standardised outputs.

To overcome these challenges, SRASO is designed as a modern web-application with a very flexible microservice architecture. The frontend is to a large extent based on the Grafana dashboard, providing operators with a large toolset for creating, analysing and sharing data visualisations. Supported visualisations include typical graphs, bar charts and counters, as well as 2D maps to visualise spatial data. With these tools effective correlation of spacecraft telemetry with various space weather data sets and physical model outputs is possible.

The aforementioned microservice architecture solves the second challenge. Each kind of data or model source has one specific data or model broker. Based on the SPASE metadata description, all datasets and models are indexed within the system. Each broker is responsible for the conversion of data sets and model outputs in the simple timeseries format that SRASO requires to be able to merge all data streams together.

The following sections will show in detail how these challenges can be solved.

## 2. Monitoring Spacecraft and their Space Weather Environment

Over the last years, various open-source data visualisation solutions have emerged, e.g. Grafana[*] or Kibana from the Elastic Stack[†]. These solutions allow to create analytical dashboards that are built with panels. Panels are single visualisations, e.g. graphs, diagrams or heatmaps. Arranged in a dashboard, panels can provide a concise synopsis of a specific system. As Kibana is tightly coupled to other tools in the Elastic Stack, such as Logstash or Elasticsearch, Grafana was used instead for this project as it provides more flexibility in terms of data providers and customisation.

Dashboards are powerful tools for efficient monitoring of assets and environments. In the space sector, the main use cases for analytical dashboard solutions relate to observing the health of spacecrafts, providing cleaner views on incoming telemetry or visualising trends in the data to detect anomalous behaviour. However, data visualisation techniques can also be a proper tool to investigate interesting facts, e.g. how space weather affects spacecraft on various positions of its orbit via a combination and correlation of different data sets.

Grafana allows to create logical groups of panels by creating several dashboards. This can facilitate the monitoring tasks by creating dedicated dashboards for certain mission aspects or groups of related space weather information. With these features spacecraft operators can create dashboards that show very general information about their satellite or constellation and the environment they are operating in. It is possible to create dedicated dashboards for each satellite in their constellation or dashboards showing certain parameters of all satellites in the constellation. Figure 1 shows how such a dashboard can look like in SRASO.

[*] https://grafana.com
[†] https://www.elastic.co/products

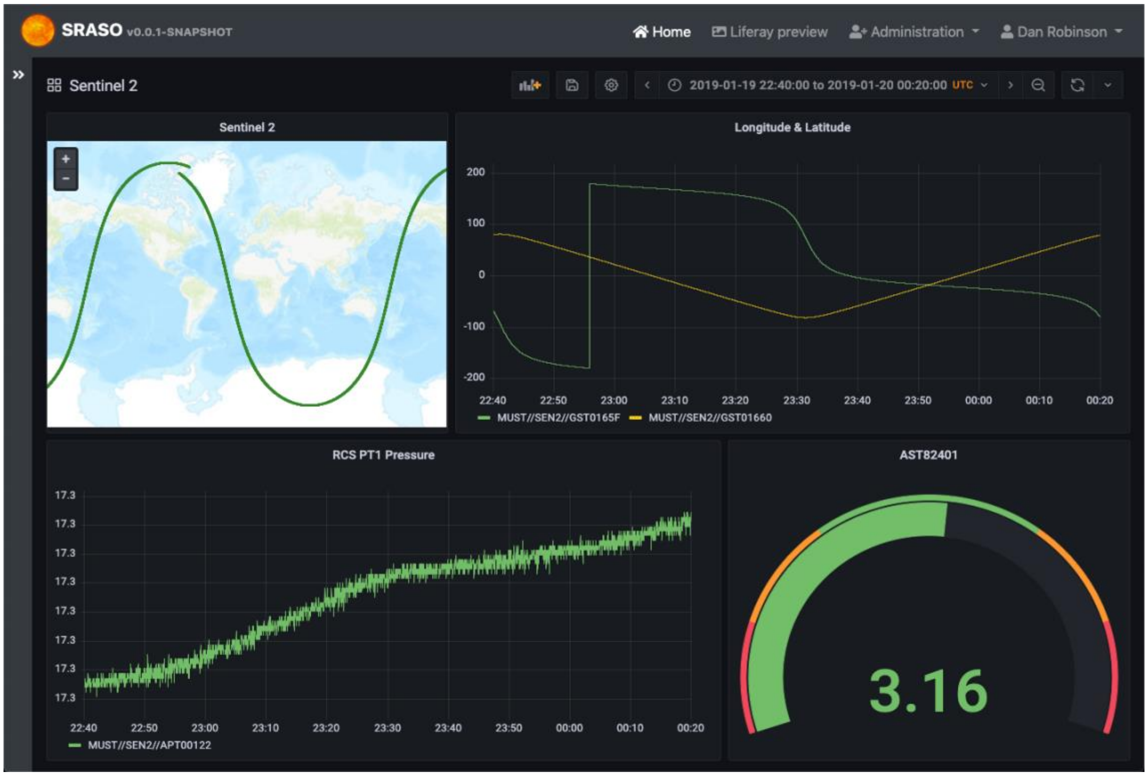


**Figure 1. A Dashboard in the SRASO User Interface**

The chosen user interface is particularly useful to correlate different information, e.g. the number of anomalies with solar activity indices. To better see correlation in the data it is possible to place panels with the relevant information next to each other and compare values within a period of time. However, it is also possible to configure a panel to show data from multiple resources to allow direct correlation and comparison, as shown in Figure 2.


**Figure 2. Data Visualisation in Multiple Panels**

One disadvantage of such dashboards is that they need an operator to actively monitor them. However, the space weather environment is very dynamic and conditions can change any time. Since it is not feasible for the human operators to permanently check the data by themselves, SRASO contains an alarming feature to automate this process. Alarming lets each user define thresholds on each parameter or model. If any of those thresholds is crossed in either direction an email notification is automatically sent in a timely fashion to a configurable set of recipients.

The definition of multiple thresholds allows for defining different danger levels. Values above the highest threshold or lower than the lowest threshold can be considered as critical outliers. Values between the two highest and two lowest thresholds can be considered as alarming, while values in between can be considered as nominal.

All these features can support the overall monitoring but having access to spacecraft telemetry and space weather information in one tool can also aid post-event analysis after the occurrence of an anomaly. A particular useful approach is to add all relevant information with descriptions in a report. An example of a report is shown in Figure 3. Reporting plays an important role in sharing of information provided by SRASO. It aids in discussions and decision making by rendering space weather or mission related data transparent to all participating stake holders. To provide maximum flexibility, SRASO allows users to build reporting dashboards providing standard layout and styling features to change text colour, text style, tables, etc. Users with the required access are able to visualise the reports within the application and can export the dashboard as PDF.

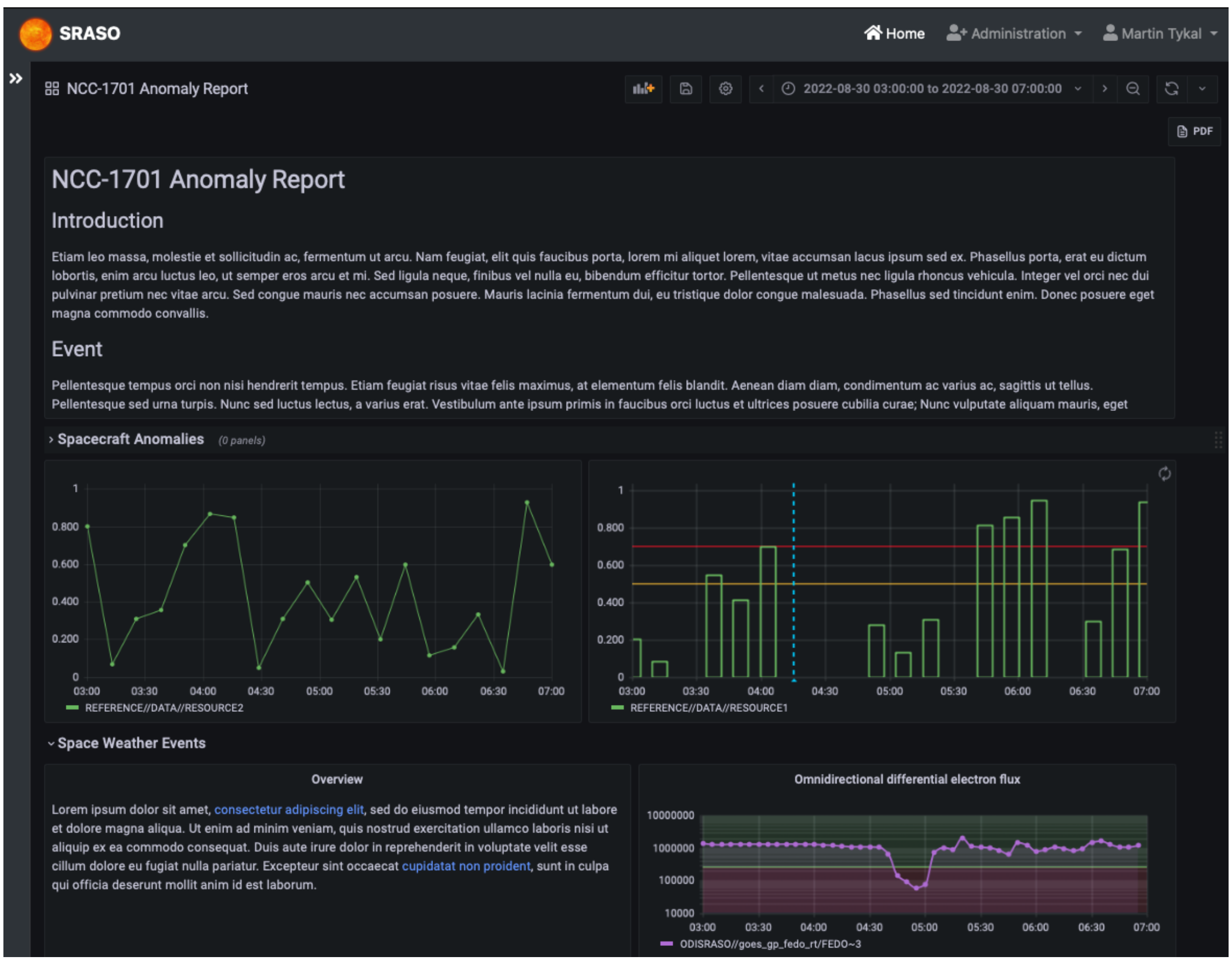

**Figure 3. Reporting Dashboard**

## 3. Providing Unified Access to Space Weather Datasets, Models and Spacecraft Telemetry

As described above, one of the main challenges of providing a tool for spacecraft operators to monitor space weather information and their mission's telemetry is to interface with several different data and model sources. On one side, there are the missions. Spacecraft missions have typically dedicated repositories for their telemetry. Due to the sensitive nature of this data, these repositories are often well secured and access is restricted. On the other side, there are many providers of space weather data sets and models. Luckily, many of these providers are part of ESA's federated SWE Network. However, how can the data from these very different sources be combined?

First, there needs to be a baseline for defining the data. It is adding a lot of complexity if all kinds of data formats, including images, binary, etc., must be considered. For this type of application, it is sensible to define timeseries data as the baseline format. This means the system can process any data that consists of timestamps and values. Of course, it cannot be expected that all data and model providers output their data into timeseries. However, the data sets relevant for this use case are based on measurements. Either by onboard sensors to create a spacecraft's telemetry or sensors to measure the space weather environments. The output of relevant models typically has a time component as well. Consequently, it is typically not too complex to convert data in the required timeseries format.

Second, a design needs to be created that allows for flexibly adding and removing distributed data and model sources to the system. For such a use case microservice architectures have been proven useful. In short, this architecture allows to register distributed services with a central component, which can then handle the overall communication.

In order to provide a compatible communication bus, the SRASO Application uses Data Brokers to store and retrieve data from different data sources and to convert to the required data format. Models are accessed using Model Brokers. Both Data and Model Brokers are external to the core application and the services in the design. A central and redundant Data Manager communicates with the various data sources and models through their brokers, as shown in Figure 4. It ensures that models are executed and data from the various data sources is made accessible. Data and Model Brokers are software components that provide a common interface to communicate with data sources and models by providing a standardized HTTP REST API. These common interfaces are used by SRASO to interact with the Brokers. They can either be integrated with the Data Sources or Models directly or be configured as an intermediate layer that is hosted separately and communicates with the Data Source or Model. The chosen design ensures that deprecated sources are removed from the system automatically without impairing the overall application, while new data sets and models can be flexibly added and made available to the allowed users.

The main advantage of this technical approach for scientists and spacecraft operators is that their data and models can be used within SRASO in conjunction of the wealth of data provided by the ESA Space Weather Service Network. The fact that the above-mentioned brokers can be hosted remotely implies that scientists and operators can register brokers from their own environments, ensuring the sovereignty of their data. A secure authentication approach ascertains that only authorised user and user groups gain access to the provided data and models.

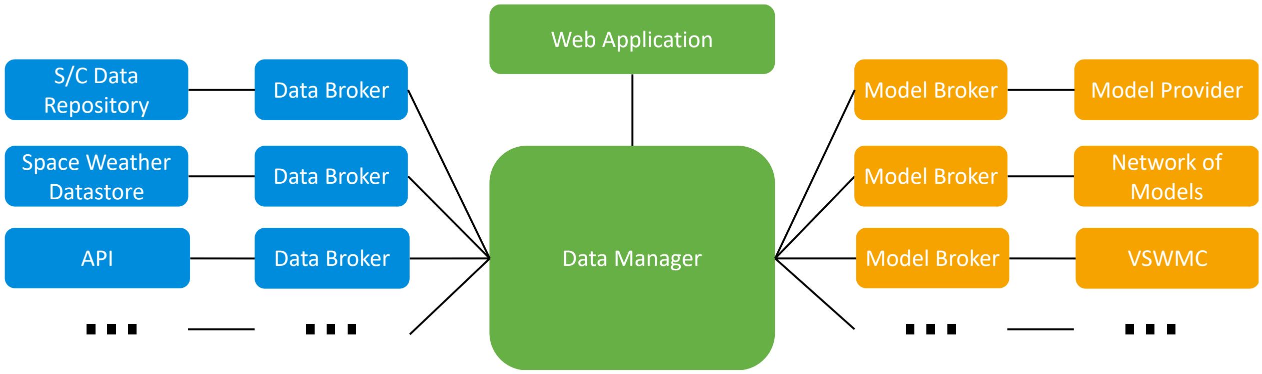

**Figure 4. Data and Model Brokering**

A part of this challenge is to find a meta data model with which the data can be described and found in the web application. The ESA Space Weather Service Network is moving towards the usage of the SPASE[‡] data model for describing its various products. SPASE is a set of terms and values along with the relationships between them that allow describing all the resources in a heliophysics (originally, now with ever widening application scope) data environment. The intent of this Data Model is to provide the means to describe resources, most importantly scientifically useful data products, in a uniform way so they may be easily registered, found, accessed, and used. In order to use the SPASE framework, resource XML files need to be produced for every data and model provider product. For products in ESA's Space Weather Service Network, XML files should become available from the product providers in the near future, probably through a dedicated SPASE registry server. For data and models outside the network, it is expected that SPASE descriptions will have to be generated from scratch. These resource files are part of the brokers to define the underlying data sets or models.

## 4. Conclusions

Using space weather information in spacecraft operations is facilitated if all required data can be visualised in a configurable fashion to allow correlation and reporting in one tool. The challenge of adequately representing information can be solved by utilising a dashboard solution like Grafana. This solution allows for creating and grouping visualisations and with out-of-the-box functionality allows to assess relations between data. It constitutes a straightforward approach to allow efficient monitoring of spacecraft telemetry and space weather information. This concept is taken a step further by enabling an automated monitoring approach that notifies operators of changes in parameters of interest.

Using space weather information in spacecraft operations unfolds its full potential when used together with near real-time spacecraft telemetry. Providing this telemetry securely to a publicly available tool like SRASO is a challenge itself. In this case this challenge was solved by utilising a flexible microservice architecture that enables operators and scientist to access their data from within the application, while ensuring no unauthorised access is possible. All data stays within the realms of the data owners.

It is worth overcoming the described challenges to provide spacecraft operators with a tool that facilitates using space weather information in their daily work to ensure safe operations in a hazardous radiation environment.

[‡] https://spase-group.org/data/