CURRENT STATUS OF WEB SERVICES AT ESA'S SPACE DEBRIS OFFICE

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ABSTRACT

ESA's Space Debris Office provides multiple web based services to the space flight community. This includes among others a front-end to its space object database DISCOS (Database and Information System Characterising Objects in Space), the web portal SDUP (Space Debris User Portal) providing access to ESA tools developed by the Space Debris Office, and the Re-entry Prediction Front-end and Fragmentation Database.

This paper will introduce all available web based tools and outline their function, focusing on the recent developments and the technology behind.

Keywords: Web Service; Space Debris; Object Database; Re-entry Prediction; In-orbit Fragmentation Analysis; Collision Avoidance.

1. INTRODUCTION

In 1989 ESA has developed the Database and Information System Characterising Objects in Space (DISCOS) to support space debris research and operations [1] [2]. Objects in DISCOS comprise all unclassified satellites, upper stages, mission related objects and fragments thereof, which are or have been in orbit. Where known (e.g. not for fragments) mass, shape, dimensions, cross section, owner, launch information and mission objectives are stored. For already re-entered objects the re-entry date is recorded while lifetime prediction are available for objects still on orbit.

Besides the objects database, DISCOS also contains detailed physical properties of launch vehicles as well as details on all known fragmentations. As of 9. April 2021 DISCOS contains 355 launch vehicles, including failed ones, and 570 fragmentations. Table 1 lists selected statistics on the objects currently stored in DISCOS.

Since the creation in 1989 DISCOS is under continuous maintenance and development, with monthly data updates. This makes it an invaluable treasure trove for space debris studies and statistics as well as operational services like collision avoidance and re-entry predictions.

Table 1. Statistics on the objects stored in DISCOS as of 9. April 2021

Type	All	In Orbit
All Objects	50,306	24,831
With physical properties	18,945	9,100
Payloads	10,671	6,513
Rocked bodies	6,410	2,546
Debris pieces	33,219	15,772

Using DISCOS object data and USSTRATCOM TLEs, the Space Debris Office routinely predicts upcoming re-entries, performs detailed analyses on high interest re-entries, and ad-hoc risk assessments to missions after severe fragmentation events. To support these processes, the Space Debris Office also does its own solar activity prediction, based on publicly available solar activity data, with the SOLMAG tool.

It is the Space Debris Office's goal to make these predictions and analyses and the DISCOS database available to a broad user spectrum, as it is of high interest to the whole space flight community within Europe and the rest of the world. Supporting Space Debris related studies and operational collision avoidance is the main target, but its usage is not limited thereof. To provide access for the space flight community, web based technologies are the natural choice in light of current technology standards. A whole family of web services is hosted and maintained by the Space Debris Office, with the focus set on intuitive use, function, security, and harmonised look-and-feel.

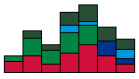
Already established are DISCOSweb, visualising part of the DISCOS data in a human-readable form, and the Space Debris User Portal. The latter is serving as distribution point for ESA's risk and mitigation analysis tools MASTER (Meteoroid and Space Debris Terrestrial Environment Reference), DRAMA (Debris Risk Assessment and Mitigation Analysis), and Oriundo (risk assessment for uncontrolled re-entries). Both DISCOSweb and the

Space Debris User Portal got an update recently, making it easier to use and improving stability. DISCOSweb now also includes an API for everyone's use.

Also released a few years ago are the re-entry front-end and fragmentation database. The former is giving an overview on upcoming space object re-entries and providing detailed analyses for high-interest events. The latter provides up-to-date risk analyses of in-orbit fragmentations and their implications for other missions.

2. SPACE DEBRIS OFFICE WEB FRONT-ENDS

2.1. DISCOSweb (discosweb.esoc.esa.int)



In order to make DISCOS data accessible to a wide audience, a web front-end called DISCOSweb was developed and is now in its third major version. It provides access to the object, launch, launcher, launch site, launching state and organisation, and fragmentation data available in DISCOS. It provides this in an interactive manner with comprehensive search and filtering features. This allows the user to click through the available data pages after finding an initial starting point. Statistic diagrams and tables complete the picture (see Figure 1).

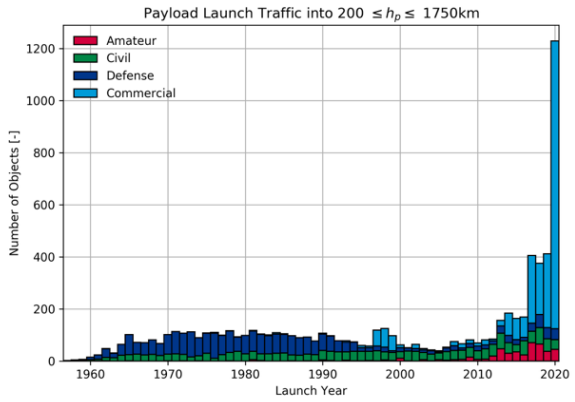


Figure 1. DISCOSweb diagram example (history of launch traffic to LEO)

Data pages not only show information on an object, launch, or other data entry, but also show other related information. For example a link to the launcher from an object page. Figure 2 shows the objects table with filter features. Figure 3 shows an excerpt from the object page for the Cryosat 2 satellite.

An API with elaborate filter and search options allows all users to fetch and embed DISCOS data in programs and scripts. The usage is documented at discosweb.esoc.esa.int/apidocs.

ESA provides access to DISCOSweb free of charge to the general public.

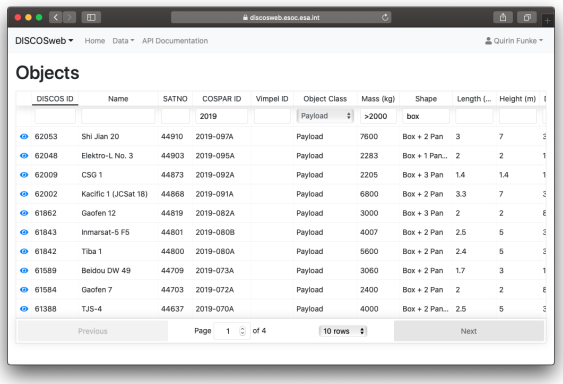


Figure 2. DISCOSweb objects table with filter features

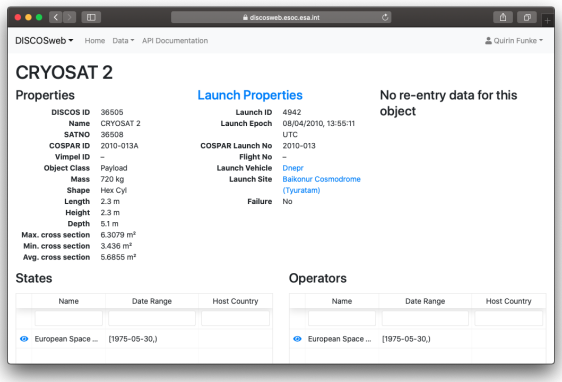


Figure 3. DISCOSweb object page for Cryosat 2

2.1.1. DISCOSweb Operations API (discosweb-api.sdo.esoc.esa.int)

In addition to the DISCOSweb API, ESA also offers the DISCOSweb Operations API which is targeted for use in operational services like collision avoidance. Although the available data is actually less than with the normal API, its features are a stable interface, higher availability, and announcements for outages.

Everyone with an operational need (e.g. collision avoidance) can apply for an account for the DISCOSweb API via email to space.debris.support@esa.int. This application needs to include proof of the operational need.

2.2. SDUP (sdup.esoc.esa.int)

The Space Debris User Portal (SDUP) was set up in 2014 as a download portal for the MASTER and DRAMA software and got renewed recently. It provides installers, patches and documentation on the software and takes care

of licence management. Figure 4 shows the MASTER download section of SDUP.

SDUP also includes online access to Oriundo, a casualty risk estimation tool for uncontrolled re-entries.

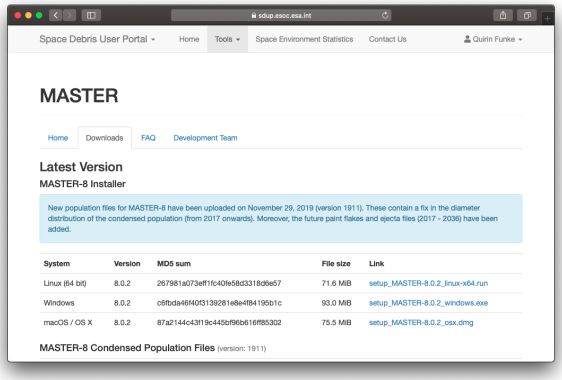


Figure 4. MASTER download section on SDUP

2.2.1. MASTER

The Meteoroid and Space Debris Terrestrial Environment Reference (MASTER) is a detailed model of the space debris and micro meteoroid environment, based on modelling launch and fragmentation events.

It serves as source for statistical flux analyses, from which average collision rates and satellite failure probabilities can be derived.

ESA provides this software free of charge to the general public.

2.2.2. DRAMA

The Debris Risk Assessment and Mitigation Analysis tool (DRAMA) is a set of five programs helping satellite programs to assess the compliance with ESA Space Debris Mitigation Requirements.

With the ARES tool the expected amount of collision avoidance manoeuvres can be determined. MIDAS computes the collision flux and damage statistics for a mission. OSCAR can determine the remaining orbital lifetime after end of mission and analyse disposal manoeuvre options. CROC is used to compute projected cross-sectional area of complex bodies. SARA does a re-entry and survivability analysis as well as an on-ground casualty risk estimation and was upgraded recently.

ESA provides this software free of charge to the general public.

2.2.3. Oriundo

Oriundo is a tool for on-ground casualty risk estimation for uncontrolled re-entries. A part of it is an advanced 1D population density distribution model as shown in Figure 5. This model is based on the Gridded Population of the World data set as baseline and the UN World Population Prospects to determine future population density distributions.

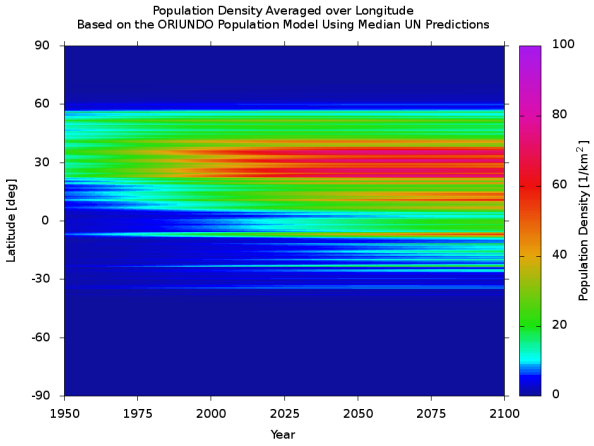


Figure 5. Latitude dependent population density history and prediction

The online tool of Oriundo can compute the casualty probability for a given casualty cross section, inclination and re-entry year.

The casualty cross section, required as input parameter to Oriundo, can be determined with re-entry analysis tools like SARA of DRAMA. It thus serves as a supplement to any re-entry analysis tool without a risk analysis part, or when risk values compatible with ESA's space debris mitigation requirements are needed.

2.2.4. SOLMAG

Required for DRAMA are up-to-date solar activity predictions. These are computed by the Space Debris Office with the SOLMAG tool and served to the public on the SOLMAG web interface.

2.3. Re-entry Front-end (reentry.esoc.esa.int)

The Space Debris Office performs automated re-entry predictions on a daily basis. The Re-entry Front-end makes them available to everyone via a visually appealing and responsive interface (Figures 7 and 8). It is possible to filter upcoming and recent re-entries to the users need, allowing to quickly gain an overview of the current situation. Details such as the history of predictions

and apogee/perigee height evolution (Figure 6) are available for each predicted re-entry. Possible subscriptions to re-entry events with email alerts make following events easy.

An advanced service, also provided via the Re-entry Front-end, is available to national alert centres of ESA member states. This service includes more detailed and reliable predictions and support by space debris experts.

A public blog about past re-entry events and information pages on re-entry history, modelling and observations, as well as a list of debris pieces found on ground top the front-end off.

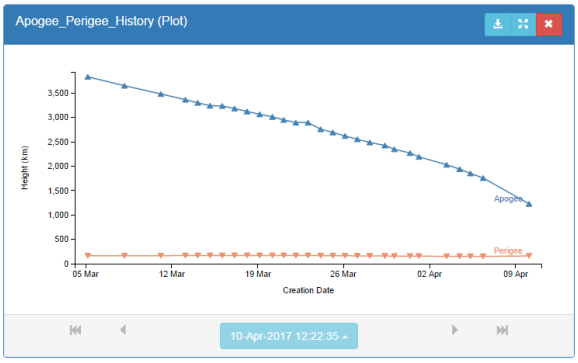


Figure 6. Apogee and perigee evolution plot of the Re-entry Front-end

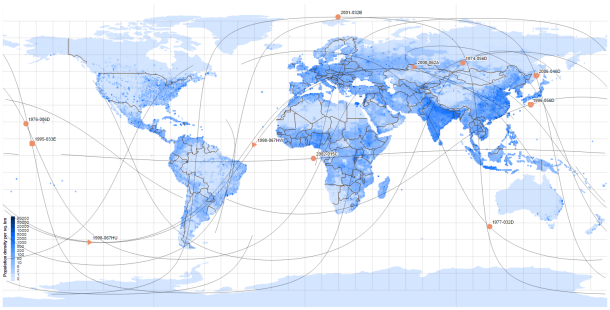


Figure 7. Re-entry Front-end live view

2.4. Fragmentation Front-end (fragmentation.esoc.esa.int)

Directly after fragmentation events like the collision between Cosmos 2251 and Iridium 33 or the NOAA 16 fragmentation, the imminent effect on the collision risk for other satellites is of high interest for satellite operators. With the BUSTER tool, the Space Debris Office has the possibility to analyse recent fragmentations based on DISCOS data and USSTRATCOM TLEs. By determining the effect on the space debris population, the relative change in collision risk can be computed. The results of

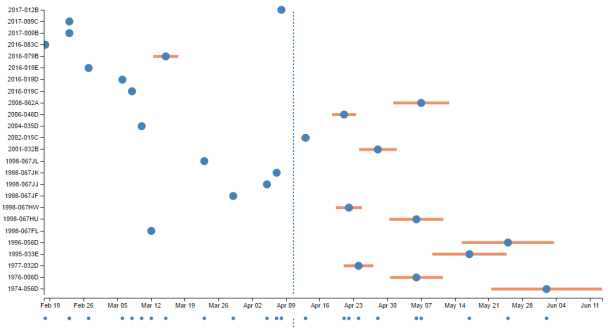


Figure 8. Re-entry Front-end Gantt chart view

the BUSTER tool are made available on the Fragmentation Front-end.

Figure 9 gives an example for a plot visualising the altitude-dependent relative risk increase effect of a fragmentation. Common data products like Gabbard plots (Figure 10) are available as well.

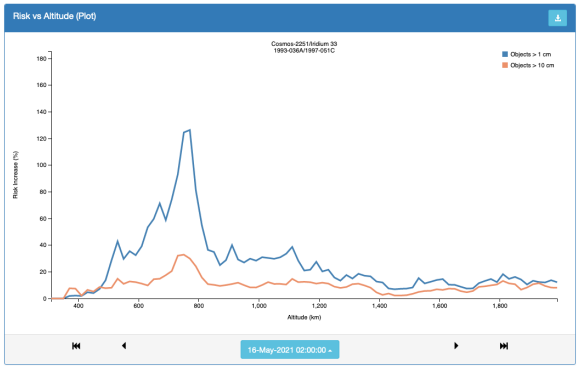


Figure 9. Risk increase plot by the Fragmentation Front-end

3. TECHNOLOGY

Two dedicated and redundant servers, located at ESOC in Darmstadt, host the web front-ends of the Space Debris Office. For security reasons, front-ends and data provision back-ends are separated and run in different virtual machines.

A common user management and authentication service unifies the accounts. The user only needs to create one account with one password for all services.

The Re-entry and Fragmentation Front-ends were developed by CGI. They are single-page applications written in JavaScript and using Node.js on the server. The front-end layout is based on the Bootstrap framework.

DISCOSweb and SDUP were developed in-house. DISCOSweb is a single-page application written in Type-

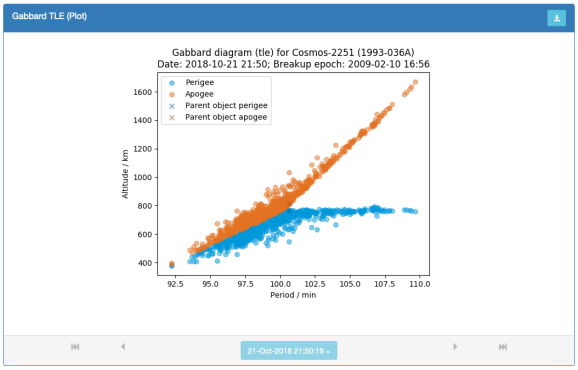


Figure 10. Gabbard plot by the Fragmentation Front-end

Script. The API is implemented in Python. SDUP is served using server-rendered HTML templates.

4. CONCLUSIONS

The introduction to the web front-ends of ESA's Space Debris Office shows a broad range of covered space debris related topics. They target a large spectrum of users, including private individuals, scientists, and satellite operators doing collision avoidance.

The front-ends are made available to everyone worldwide and free of charge.

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