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

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ABSTRACT

ESA's Space Debris Office is providing 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 recently published Re-entry Front-end for querying daily updated re-entry predictions.

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 [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 and mission objectives as well as an image 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 10. April 2017 DISCOS contains 311 launch vehicles, including failed ones, and 294 fragmentations. Table 1 lists selected statistics on the objects currently stored in DISCOS.

Table 1. Statistics on the objects stored in DISCOS as of 10. April 2017

Type	All	In Orbit
All Objects	42,470	18,421
With physical properties	15,703	6,552
Payloads	7,479	4,263
Rocked bodies	5,481	1,973
Debris pieces	28,942	11,619

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

Using DISCOS object data and USSTRATCOM TLEs, the Space Debris Office routinely predicts upcoming re-entries as well as 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 as well as 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 to it. Web based technologies, to provide access for the space flight community, 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). These are complemented by web pages of more static nature, like the SOLMAG solar activity predictions. In order to facilitate operational collision avoidance, SCARF (Spacecraft Conjunction Assessment and Risk Front-end) has been developed and used within ESA since 2015. It has been made available to third-party collision avoidance partners now.

Recently the Space Debris Office released the re-entry front-end, giving an overview on upcoming space object re-entries and providing detailed analyses for high-interest events. In addition DISCOSweb was upgraded to include a machine friendly REST API which can be integrated in, for example but not limited to, collision avoidance processes. Soon to be released is the fragmentation front-end, which will provide up-to-date risk analyses of in-orbit fragmentations and their implications for other missions.

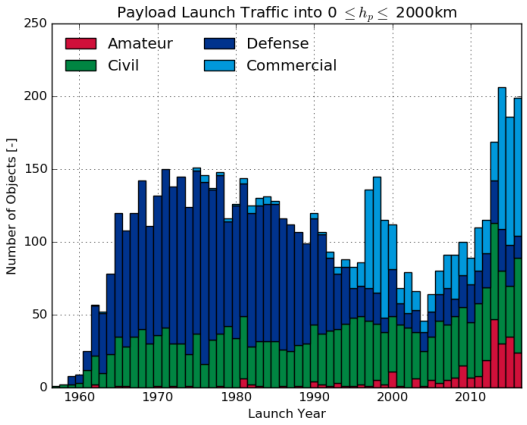


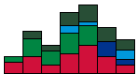
Figure 1. DISCOSweb diagram example (history of launch traffic to LEO)

2. ESTABLISHED FRONT-ENDS

To make the DISCOS data not only available within the Space Debris Office of ESA, but to open it to a wider audience, the DISCOS web front-end, or short DISCOSweb, has been developed. As part of a major upgrade in 2013/2014 DISCOSweb also got a companion with the Space Debris User Portal (SDUP), providing access to the ESA tools MASTER (Meteoroid and Space Debris Terrestrial Environment Reference Model) [1] and DRAMA (Debris Risk Assessment and Mitigation Analysis) [4] [3].

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.

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



DISCOSweb provides access to the object, launch, launcher, launch site, launching state and organisation, and fragmentation data available in DISCOS. It does provide this in an interactive manner with many search options. 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).

Data pages are actually concatenating information on an object, launch, or other data entry. Like this the user gets all related information in one place, with links to other data entries. For example a link to the launcher from an object page. Figures 2 shows an excerpt from the object page of the Cryosat 2 satellite.

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

The Space Debris User Portal (SDUP) was set up in 2014 as download portal for the MASTER and DRAMA software. It provides installers, patches and documentation on the software and takes care of the licence management. Figure 3 shows the MASTER download section of SDUP.

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

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

Name	CRYOSAT 2
COSPARID	2010-013A
SATNO	36508
Mass	720.000 kg
Classification	Payload
Shape	Hex Cyl
Lenght	2.300 m
Height	2.300 m
Depth	5.100 m
X_SECT_MAX	6.308 m^2
X_SECT_MIN	3.436 m^2
X_SECT_AVG	5.686 m^2
Re-Entry Epoch	(value not available)
Country	European Space Agency (ESA)
Organization	European Space Agency
Image	
Image Source	http://www.skyrocket.de/space /space.html Gunter's Space Page
COSPARLaunchNumber	2010-013
LauncherName	Dnepr
Site	Baikonur Cosmodrome (Tyuratam)
PRED_DECAY_DATE	2302-04-29
REMAINING LIFETIME UNCERTAINTY	57.01
Mission Type	Scientific
Activity Status	ACTIVE

Figure 2. Excerpt from the DISCOSweb object page of Cryosat 2

and survivability analysis as well as an on-ground casualty risk estimation. An upgrade of SARA is currently in development.

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 4. 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.

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,

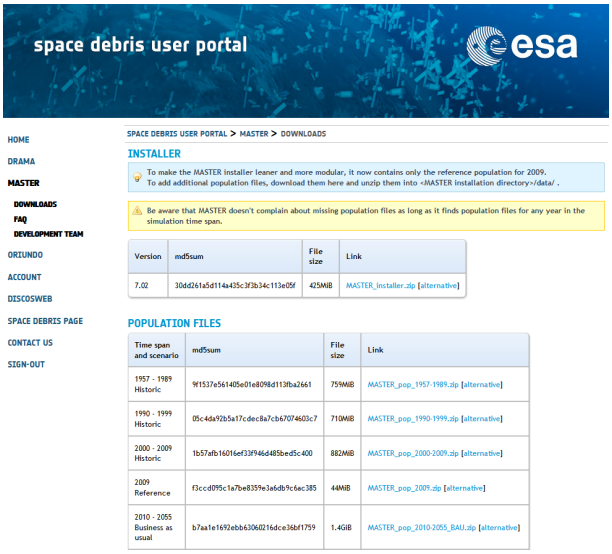


Figure 3. MASTER download section on SDUP

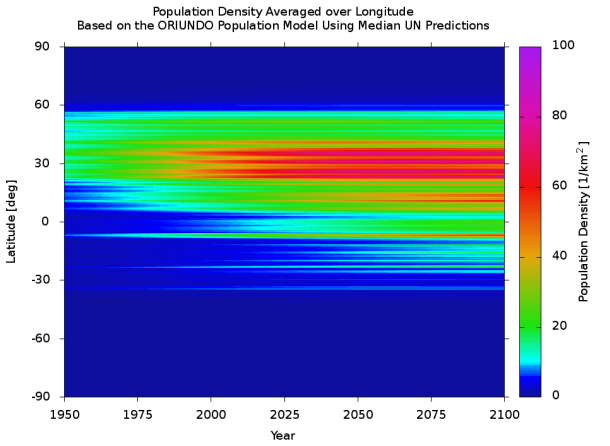


Figure 4. Latitude dependent population density history and prediction

or when risk values compatible with ESA's space debris mitigation requirements are needed.

2.3. SOLMAG (static.sdo.esoc.esa.int/SOLMAG)

The SOLMAG solar activity history and predictions, as needed by the orbital lifetime assessment tool OSCAR of DRAMA, can be obtained via the SOLMAG web interface. From all presented web interfaces SOLMAG is the most basic one, being purely based on file transfer.

3. RECENT ADDITION

On top of these established services the Space Debris Office has published three additions recently, as reaction to common request: the Re-entry Front-end, SCARF and the DISCOSweb API. They are introduced in the following subsections.

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

The Space Debris Office is performing 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 6 and 7). 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 5) 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.

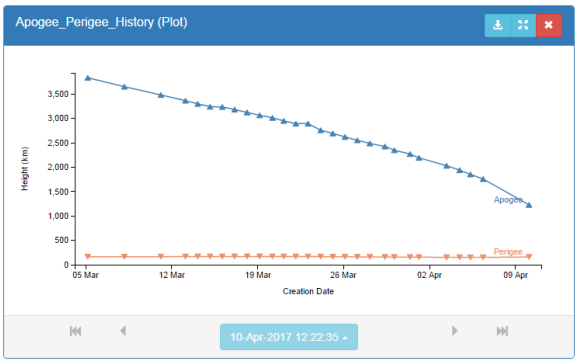


Figure 5. Apogee and perigee evolution plot of the Re-entry Front-end

3.2. SCARF

The Spacecraft Conjunction Assessment and Risk Front-end (SCARF) is used in the Space Debris Office since 2015 already to support operational collision avoidance. It visualises and summarized the current threat situation and is used to track analysis status and avoidance action planning. Being designed for both spacecraft managers and debris analysts, it can give a quick overview of the current threat situation (Figure 8) as well as support in depth analyses and reports.

Recently this tool has been made available to external partners as well for their missions.

3.3. DISCOSweb REST API

With the DISCOSweb REST API object properties from the DISCOS database are easily accessible from programs and scripts. With the command

```
curl -u user:password \
https://discosweb.esoc.esa.int/api/objects/39634
```

the object properties of Sentinel 1A can be queried. This will return the following JSON string


```
{
    "satno":39634,
    "cosparId":"2014-016A",
    "name":"Sentinel-1A",
    "objectClass":"Payload",
    "mass":2157.0,
    "shape":"Box + 4 Pan",
    "length":1.6,
    "height":3.42,
    "depth":21.04,
    "xSectMax":57.919,
    "xSectMin":2.56,
    "xSectAvg":23.4875,
    "xSectRcs":10.6944,
    "country":"EUROPEAN SPACE AGENCY (ESA)",
    "reentryEpoch":null,
    "visMagnitude":null,
    "organisation":"European Space Agency"
}.
```


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 should include a prove of the operational need.

4. FRONT-ENDS IN DEVELOPMENT

4.1. 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 the BUSTER tool will be 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) will be available as well.

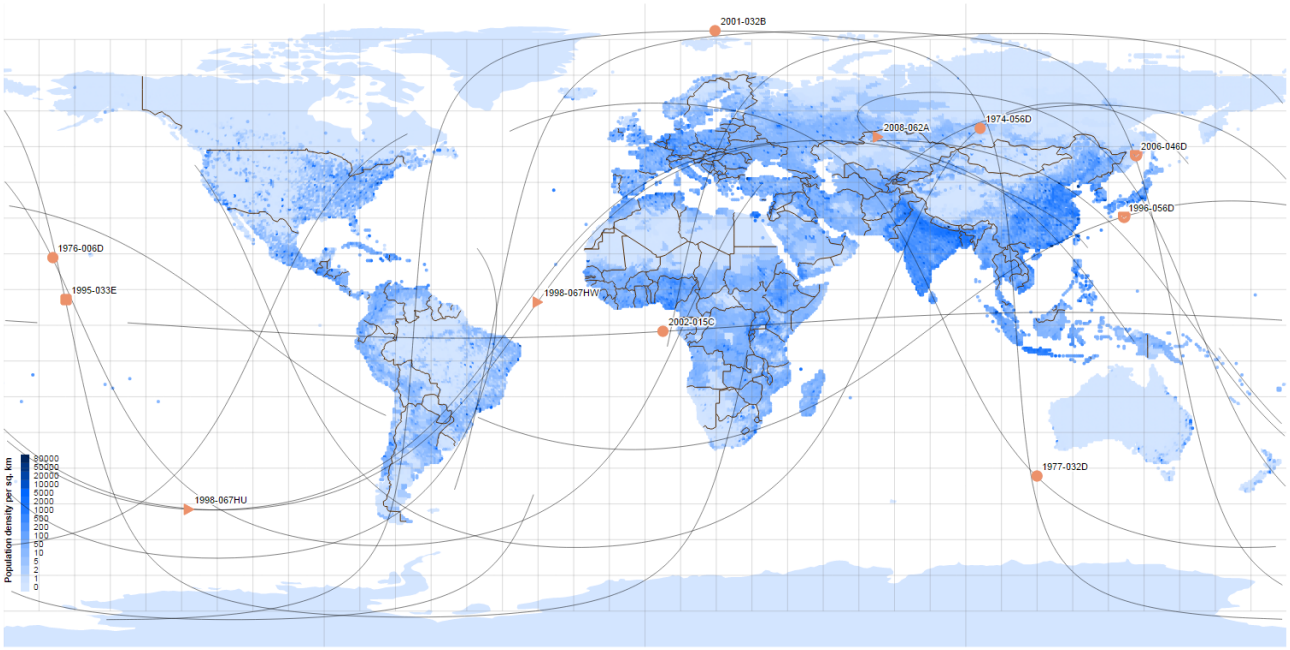


Figure 6. Re-entry Front-end live view

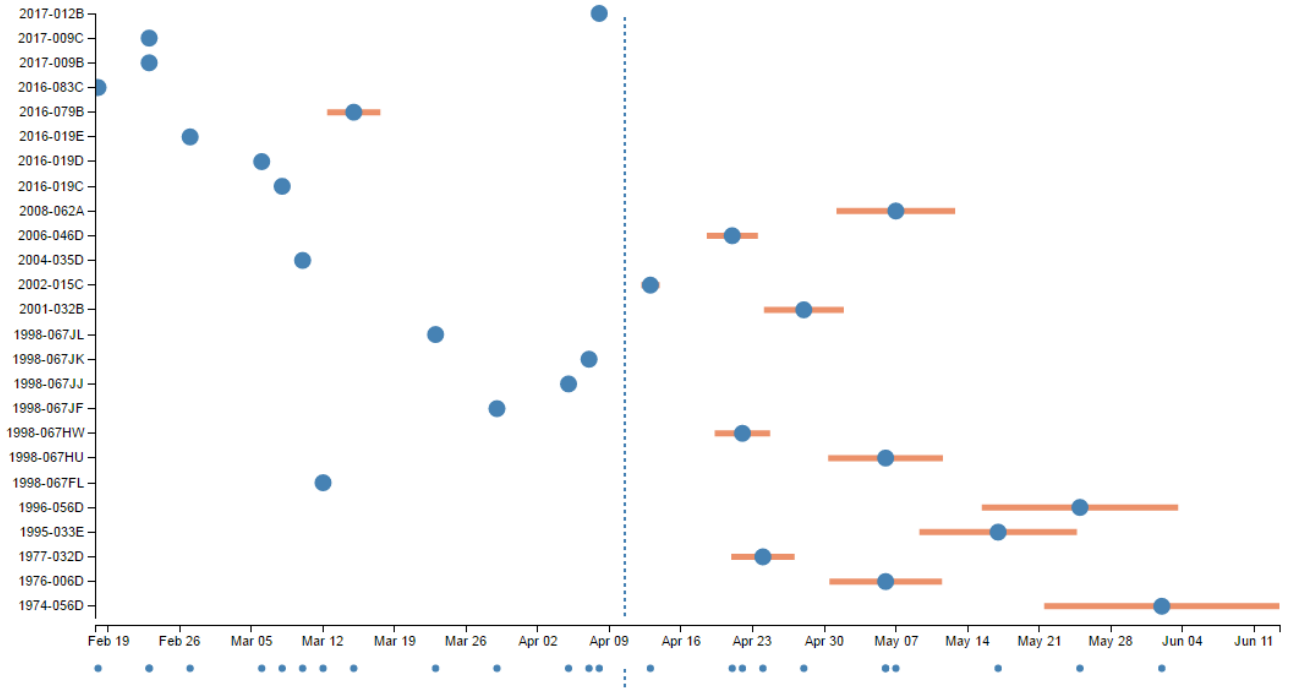


Figure 7. Re-entry Front-end Gantt chart view

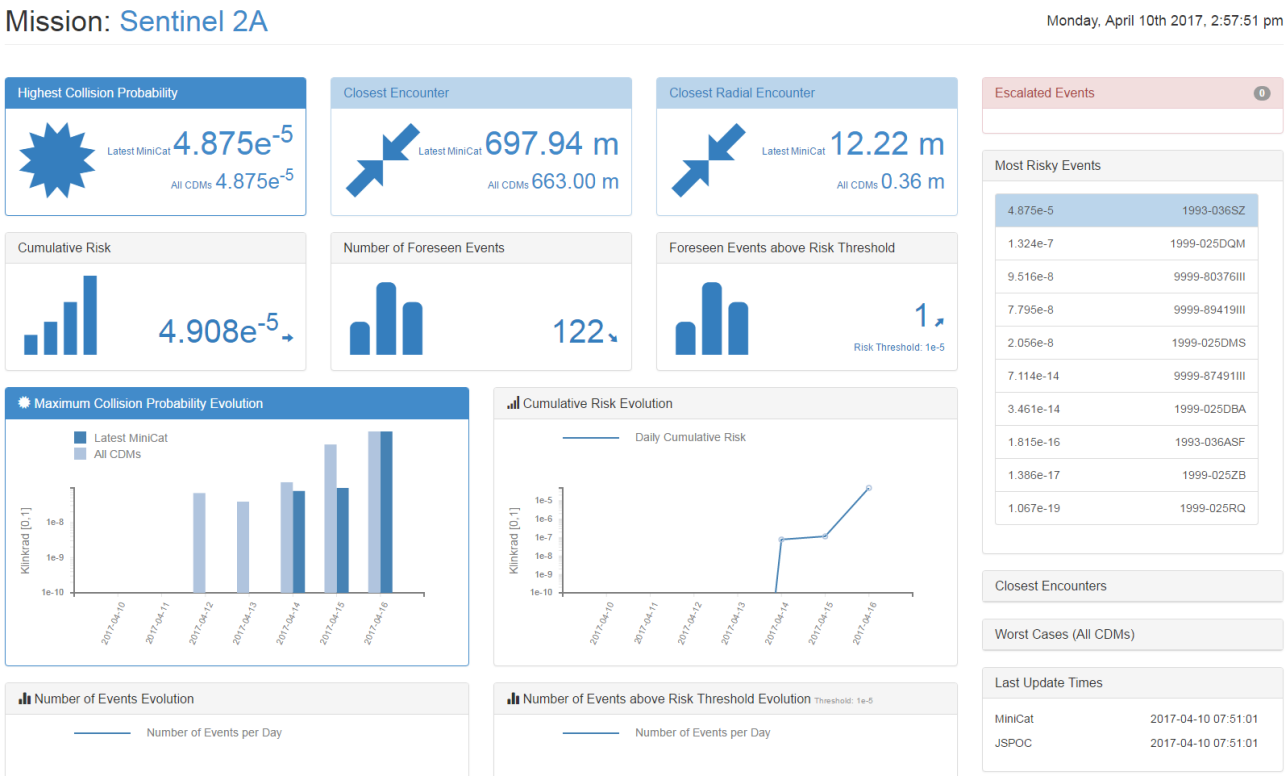


Figure 8. SCARF mission dashboard

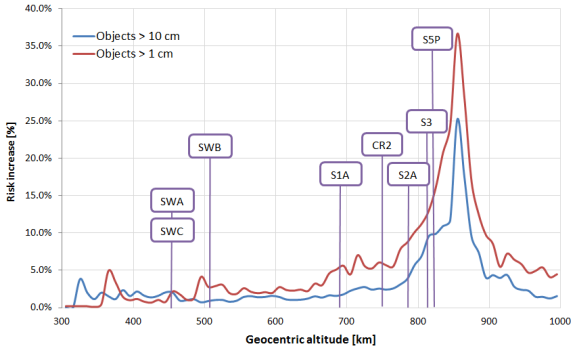


Figure 9. Example risk increase plot as it will be provided by the Fragmentation Front-end

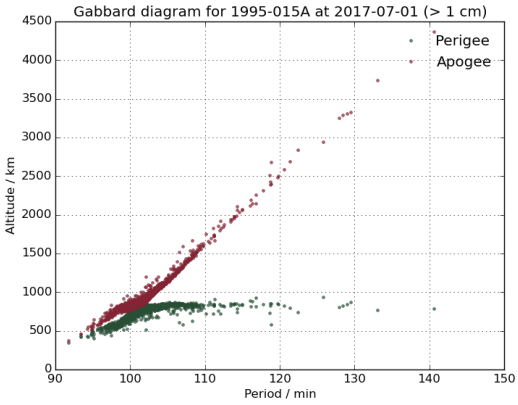


Figure 10. Example Gabbard plot as it will be provided by the Fragmentation Front-end

5. TECHNOLOGY

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

A common user management and authentication service unifies the accounts on the new developments. The user only needs to create one account with one password for all services. Continuous effort is done to integrate the existing front-ends, too.

SCARF, Re-entry and Fragmentation Front-ends have been developed by CGI. They are based on JavaScript on browser and server side using the Node.js runtime. The front-end layout is based on the Bootstrap framework.

DISCOSweb and SDUP have been developed by Elecnor Deimos. They are based on Java servlets hosted by a GlassFish server.

6. 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, from private individuals over scientist to satellite operators doing collision avoidance.

The front-ends are made available to as many people world-wide as possible. Reducing the account limitations further is an ongoing effort of the Space Debris Office.

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