The ESA Space Collaborative Observation Platform (SCOOP), objectives and functionalities

N. Sánchez-Ortiz[(1)], M.J. Enriquez-Pavón[(1)], B. Murcia[(1)], Matteo Di Paolantonio[(1)], S. Müller[(2)], J. Lorenz[(2)], V. Braun[(3)],T. Flohrer[(4)]

[(1)] Deimos Space, Ronda de Poniente 19, 28760, Tres Cantos, Madrid, 28760, Spain,
Email: noelia.sanchez@deimos-space.com
[(2)] Institute of Space Systems, Technische Universität Braunschweig, Hermann-Blenk-Str. 23, 38108 Braunschweig, Germany
Email: sv.mueller@tu-braunschweig.de
[(3)] IMS Space Consultancy at ESA/ESOC Space Debris Office (OPS-GR), Robert-Bosch-Str. 5, 64293 Darmstadt, Germany,
Email: Vitali.Braun@esa.int
[(4)] ESA/ESOC Space Debris Office (OPS-GR), Robert-Bosch-Str. 5, 64293 Darmstadt, Germany,
Email: Tim.Flohrer@esa.int

ABSTRACT

This paper describes the Space COllaborative Observation Platform (SCOOP). The SCOOP tool is intended to facilitate the organisation of collaborative coordinated space object observation campaigns of loosely connected sensor operators, in order to allow the observation of interesting events related to the space debris population. Such needs are to characterise space objects, e.g., the determination of area-to-mass ratios, or the observation with dedicated specialised techniques. Other examples are the determination of the attitude motion that needs coordinated parallel observations with distributed sensor installations. These technique may be of interest in the context of the IADC (Inter-Agency Space Debris Coordination Committee) observation campaigns, or especially for satellite laser-ranging (SLR) to non-cooperative objects. The system provides a complete back-end process providing all the capabilities required along an observation campaign to compute the derived orbit and also to correlate, if needed, observations with orbital data from existing catalogues. The tool has also a secondary objective to act as a place where new techniques and algorithms can be tested; to this end, an interface to external services is also provided (through REST and Web interfaces). Within the scope of object characterisation and ad-hoc campaigns, the system allows defining survey and tracking campaigns, which can be executed in a parallel approach.

The functionalities provided by the system include the capability to generate pass predictions of the objects to be observed (in case of tracking campaigns) for the contributing sensors, share the observations provided by the contributors, execute orbit determination for the observed objects, provision of accurate orbits (if available), allow correlating observations against the existing objects catalogue. In addition, the tool allows providing performance reports for each contributing sensor, and per observation campaign.

The system has been designed to make use of existing underlying functionalities. For the pass prediction and orbit determination functionality, ESA's ODIN tool is used. ODIN is normally used by ESOC for operational orbit determination when re-entry, conjunction and other events are analysed through observations from ground-based sensors. For the correlation activities, a correlation prototype tool used in the Space Debris Offices integrated. It allows tracing the provided observations against the TLE catalogue.

Different user roles are available within the system, one focused on administration activities, and another one for nominal use. Among this latter type, the users are differentiated in Observational Data Provider (ObDP), Orbital Data Provider (OrDP) and Data Consumer Profile (DCP), allowing to meet the needs of a wide variety of users.

1 INTRODUCTION TO SCOOP

1.1 Objective

The main objective of the **S**pace **CO**llaborative **O**bservation **P**latform (SCOOP) is facilitating the organisation of collaborative coordinated observations campaigns of sensor owners willing to participate voluntarily, in an ad-hoc way, in order to allow the observation of interesting events related to the space

Proc. 7th European Conference on Space Debris, Darmstadt, Germany, 18–21 April 2017, published by the ESA Space Debris Office
Ed. T. Flohrer & F. Schmitz, (http://spacedebris2017.sdo.esoc.esa.int, June 2017)

object population. The tool has also a secondary objective to act as a place where new techniques and algorithms can be tested; to this end, an independent interface to external services is provided.

Considering radar and optical (including passive and active) techniques, ESA's key objectives for the activity are:

- analyse in depth the requirements from the scientific space debris observer and modelling communities for coordinated, collaborative, observations and other support functions;
- design and implement a prototype database-controlled mechanism supporting survey and follow-up instruments, allowing coordinating distributed collaborative observations of high-interest objects and the support of organising the collection and dissemination of the data required for various techniques in object characterisation;
- implement links to existing orbit determination and propagation, pass prediction, and data correlation facilities;
- deploy a prototype at ESOC, and demonstrate the capabilities using a simulated observation campaign.

organize an user workshop to obtain feedback on the developed prototype and use this for optimizing the design. The system is expected to be operational by mid-2017.

1.2 Users

The following user profiles are defined on SCOOP:

- **System Administration Profile (SAP)**. This profile has full access to the configuration and use of the system. It is the only user authorized for campaign creation and closure, user registration and management, and in general the highest authorized profile within the system.
- **Campaign Administration Profile (CAP)**. This profile is intended to manage all the aspects related to a campaign which is registered in the system. He/she is appointed by the System Administrator and is able to configure and close the campaign and accept users among those registered in the system.
- **Observational Data Provider (ObDP).** This profile mainly books for observation slots, provides observations and reports observation conditions. He/she may retrieve further observational data and/or orbital information to support the observations (computing pointing for scheduling the observation).
- **Orbital Data Provider (OrDP).** This profile is intended to provide orbital information as computed from the observations or through independent data sets (operational orbit for example).
- **Data Consumer Profile (DCP).** This user can retrieve information but it is not intended to provide any observational nor orbital data. For example, IADC experts may be associated to this particular profile as they shall be able to access the orbital evolution to perform additional analysis.

A user may be assigned to a subset of profiles. In those cases, the user would accumulate the access rights corresponding to the different profiles.

1.3 User Collaboration within SCOOP

In order to foster the collaboration between users, and in order to account for the different capabilities provided by those profiles it has been proposed to use a schema based on:

- **User Figure of Merit (FoM)**, which is measured in the basis of the contribution to a particular campaign. It can be used for measuring and comparing different providers within a campaign.
- **User Karma**, which is proposed as a way of marking users which cannot contribute to a campaign but still can be interested on data retrieval (in basis of their past good data records). For example, a particular observatory, which normally contributes to former campaigns, but cannot provide data for the current one due to any constraints, or eventual unavailability, could still be allowed to access the campaign data if it accumulates enough Karma. This Karma function is increased as the number of contributing campaigns increases and as a function of the FoM of every campaign, and it decreases as the time passes without further contributing campaigns. For the Data Consumer profile, it is assumed that he has constant Karma value, independent of data provision.

2 FUNCTIONALITIES AND REQUIREMENTS

SCOOP functionalities and requirements are defined in the basis of initial ESA requests, and the information retrieved from the user community along a dedicated user workshop.

2.1 User Workshop Feedback

Within the user workshop for user requirements definition, we looked to identify the applications which can be used to exploit the database content for obtaining scientific and engineering results.

Initially, a questionnaire was distributed among possible users. Once answers were analysed, they were discussed in a dedicated meeting for compilation of feedback.

The users contributing to the questionnaire can be classified as follows:

- Large research community is represented
- Observation data providers were majority among users
- Passive optical sensor operators show the larger interest, which may be related to the relative larger number of those sensors when compared with radar and SLR systems.

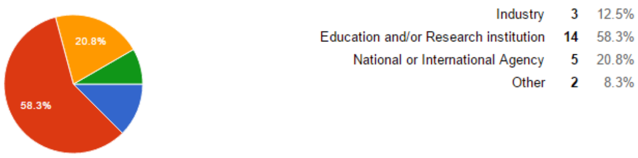

Figure 1: Organization type of questionnaire responders

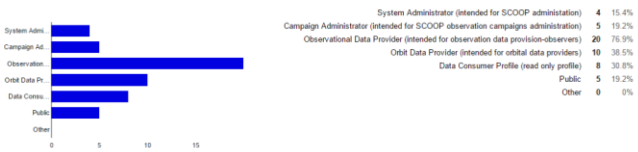

Figure 2: User profiles preferred by the questionnaire respondents

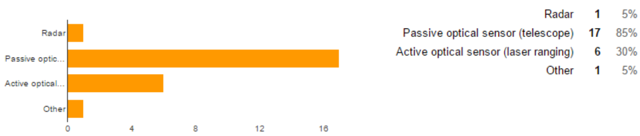

Figure 3: Sensor types handled by Observation Data Providers

Figure 4: Observation types interesting for Observation Data Providers

2.2 Functionalities

Three basic applications are: the pass prediction, the orbit determination and the correlation functions. In addition to the applications for orbit and observations processing, the system allows a number of applications for data retrieval (orbits and observations). Additionally, functionalities for observation opportunities booking, registering, data provision is implemented for proper front-end and back-end process.

Among the discussed functionalities within the user workshop, the larger interest was shown to that of providing and retrieving observations and orbital data from the system. Interest on the capacity to compute an orbit out of the provided observations was also stated. Orbit and Covariance propagation functions seemed not to be that useful for the users, although a pass prediction function was defined as interesting tool. Similarly, a functionality allowing correlation of observations with objects in existing catalogues was also demanded.

Other functionalities were also discussed as: signal analysis, format exchange tools, initial orbit determination tool, sensor calibration tool and problem specific applications.

A summary of the compared declared priorities is provided in next figure:

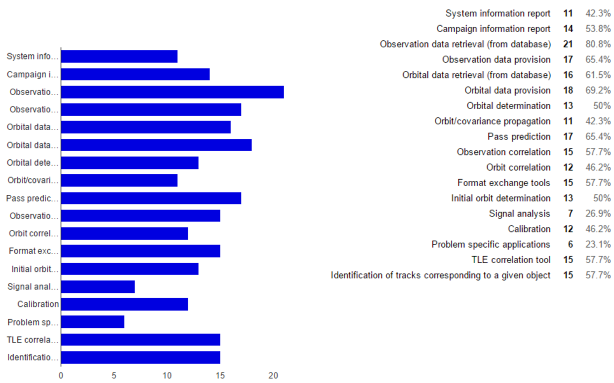

Figure 5: Compared declared priorities for all the offered functionalities

2.2.1 Pass Prediction

Pass prediction is intended to compute the visibility time windows of an object from different observing sites, and the observation features in terms of angular, distance, or relative velocity. Pass prediction function requires estimating the state vector of an object along a time interval.

The prediction of the object state vector along the time interval is done by calling to a propagation function which is fully integrated into the pass prediction function. ESA's ODIN Software is used for provision of the low-level pass prediction functionality.

2.2.2 Orbit Determination

The orbit determination functions intend to compute the orbit which better fits a set of observables. The observables are introduced in an estimator that allows achieving an estimate of the system state, and possibly the covariance (uncertainty) of the estimated state. The estimate state does not only include the object state vector, but also some other parameters like perturbation coefficients (drag and SRP coefficients), station biases, etc. ESA's ODIN Software is used for provision of the orbit determination functionality.

2.2.3 Correlation

This functionality is intended to provide information on correlation of observations and/or orbits against objects in a catalogue. A catalogue is not maintained by the SCOOP system, which is not intended for such purpose. Correlation is based on the use of external data (TLE for example).

3 HIGH LEVEL ARCHITECTURE

The SCOOP system solution is implemented following a Service Oriented Architecture (SOA) where the core modules that compound the whole system provide Web services to exchange the data and access to their functionalities.

The Web services are based on the REpresentational State Transfer (REST) architectural style compounding a commonly called RESTful API (Application Programming Interface). The high level logical architecture of the SCOOP system and the external services integrated in SCOOP is shown in the Figure 6.

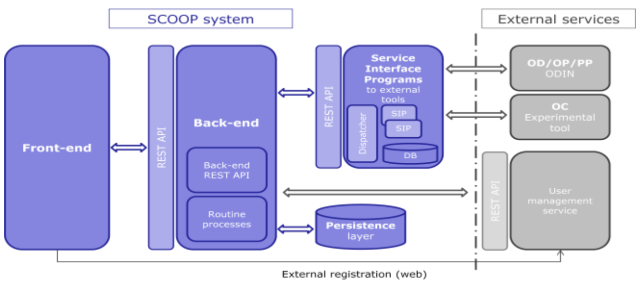

Figure 6. High-level architecture of SCOOP system

The **Front-end** is a web-based Human Machine Interface (HMI) to the SCOOP system. This module is responsible for providing remote access to accredited users to the data and functionalities available for each profile. All the data and actions to be executed from the front-end are retrieved and requested through the REST API provided by the back-end. The only exception to this statement is the user registration that is made in the user management service's HMI (external to SCOOP system), for this reason the SCOOP front-end redirects to the user management service to allow the users to sign up to SCOOP.

The **Back-end** is the module that provides a REST API for data exchange between the persistence and the front-end layers. Additionally, the REST API allows the users to execute on-demand the externals tools from the front-end. Finally, the back-end authenticates and authorizes the users against the user management service when the user signs in to the SCOOP system via the front-end. This module is the one in charge of executing the two types of back-end procedures, the routine procedures that are processes to be run periodically as crontab activities and the data-driven procedures that are processes to be executed to update the baseline information triggered by some events.

The **Database** is the module responsible for the persistence of the data in the SCOOP system.

The **Service Interface Programs** make up the module that implements the interfaces to the external tools that define the way that the different actors in the system can use and interact with the Service Programs (external tools). These external tools are the Orbit Determination, the Pass Prediction and the Orbit/observation correlation. These tools are not developed in the frame of this project and the Service Interface Program of each tool acts as client of these tools. This module provides a REST API to be used by the back-end, requested by the user from the front-end, and the routines processes.

The following elements in the architecture are out of the SCOOP system scope; however it is worth mentioning them since they provide core functionalities to the SCOOP system:

- The **Service Programs** (external tools) are the tools provided by ESA to be integrated in the SCOOP system as services. The tool for the Orbit Determination and the Passage Prediction functionalities is ODIN whereas an experimental tool is used for the Orbit Correlation functionality.
- The **User Management Service** is used by the back-end to manage users, in order to register, authenticate and authorize them in the SCOOP system. This service is integrated to the ESA's active directory seamless for SCOOP.

3.1 SCOOP Backend Database

The Back-end module is composed by three sub-modules: **Back-end Database** where the data is persisted and stored, **REST API** which allows access to data storage and provides an interface between the Back-end Database and the Front-end, and **Routine Processes** which implements maintenance functionalities and upgrade activities of the Back-end Database.

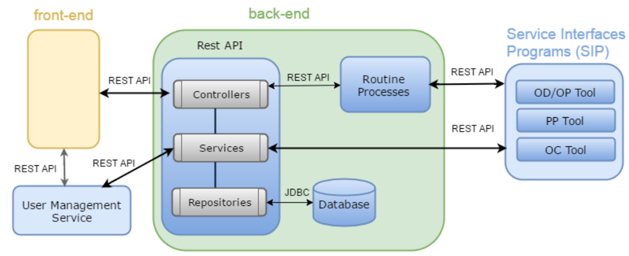

Figure 7. Back-end module

The **User Management Service** is an external module provided by ESA, developed out of the scope of the project which provides a REST API interface to authenticate user access to the system and register new users. The **Back-end Database** is the component in charge of data storage, which is based on PostgreSQL 9.4.6 database server.

The back-end REST-API sub-module is responsible for managing the data interchange between the Back-end Database and the Front-end. It handles data insertion (campaign definitions, sensor configurations, booking passes), data browsing (search, filtering, sorting and numerical/graphical representations), data uploads/downloads (sensor provided observations and operator-determined orbits, files, reports…), etc.

3.2 SCOOP Backend Processes

A dedicated module implements internal processes which are executed periodically in order to perform maintenance activities and define which inputs, among all contributions, become part of the set of information which is made available to the different users and tagged as the most reliable or to-be-used information.

Two types of Back-end routines are implemented:

- **Data Driven Routines**: these activities are executed to process the received data (observations and orbit data).
- **Periodic Routines**: this procedure is executed periodically (for example once a day) and updates the baseline information.

3.2.1 Data Driven Routines

The Data Driven Routines are executed when new contributions (observations or orbit data) are uploaded by the users, so these procedures are implemented in Java as part of the REST API. The following routines are available:

1. **<u>Process Observation Routine</u>**: to be executed whenever new observation data set is received.
2. **<u>Process Orbit Routine</u>**: to be executed whenever new orbit data set is received.

These routines are depicted in the following flowcharts.

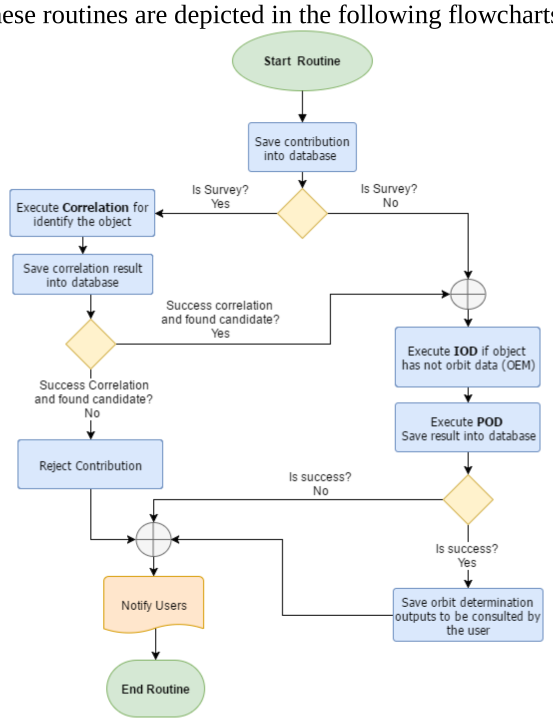

Figure 8. Data Driven Routine for processing observations

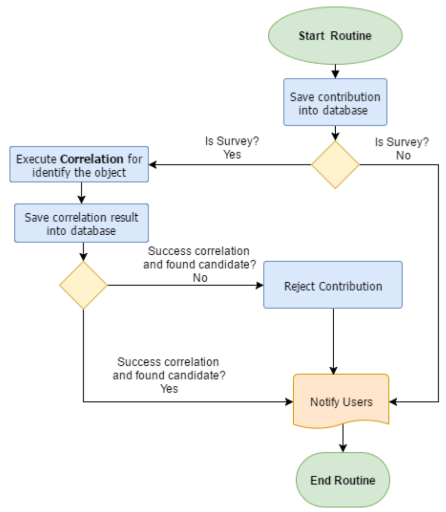

Figure 9. Data Driven Routine for processing orbit data

3.2.2 Periodic Routines

The Periodic Routines run as crontab activities (periodicity of process execution is configurable). Python 3.5.2 has been selected as the scripting language to implement it.

It is performed one routine process per campaign, so it is possible to have different periodicity for each campaign. The Routine processes will be executed concurrently.

Routines are Campaign-dependent. The flowcharts Tracking and Survey campaigns are provided below:

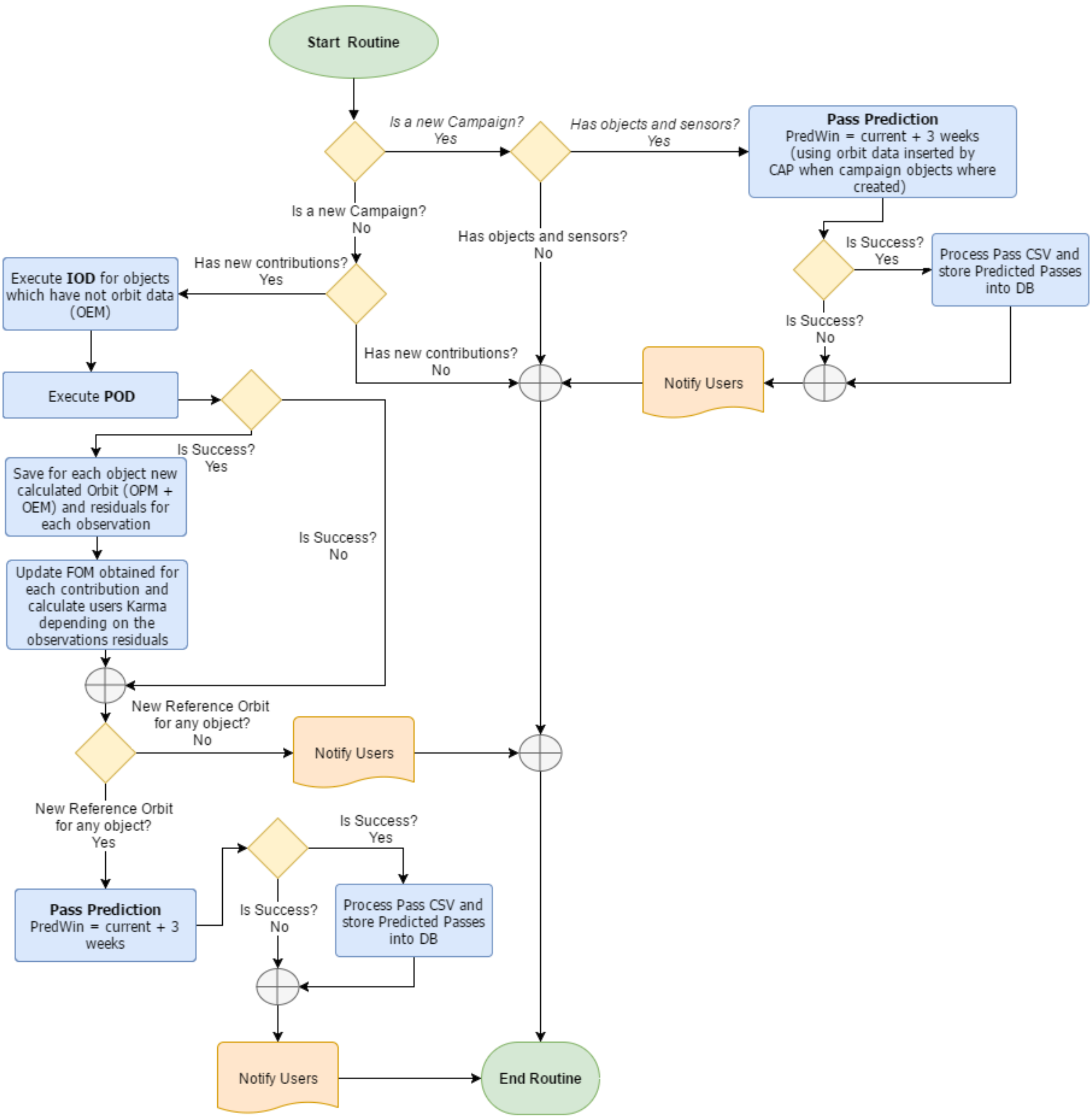

Figure 10. Back-end Periodic Routine for Tracking Campaign

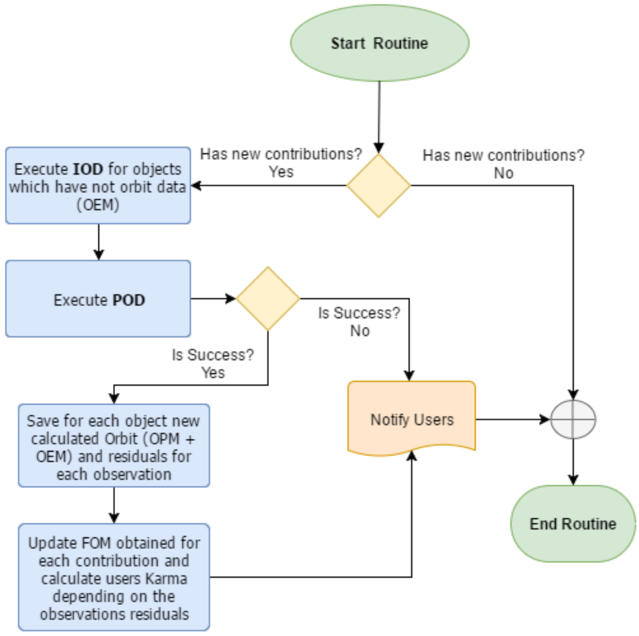

Figure 11. Back-end Periodic Routine for Survey Campaign

3.3 SCOOP SIPs

The Service Interfaces Programs (SIPs) provide a REST API interface for executing external tools through a common Dispatcher.

The Dispatcher's responsibility is to parse Service execution requests, extract Service input data from them and to execute the requested Service Interface Program (SIP) with the Service-specific input data.

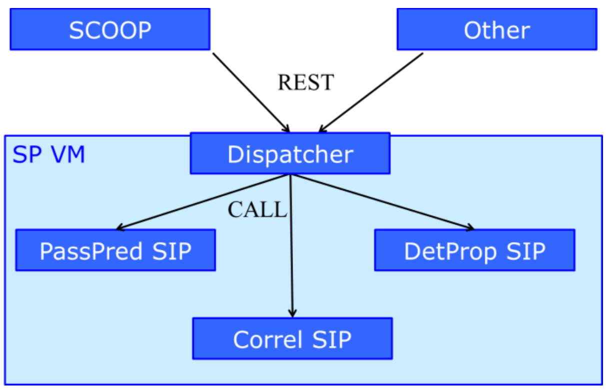

Figure 12. SIP architecture

The requested SIP expects as input data the SI input data specific to the implemented Service. Currently, the Services supported are those of the pass prediction, orbit determination and correlation described above.

The SIP then converts this data into the input data ("native" input data) necessary to execute the Service Programs (SP). Because of this, a SIP implements the "bridge" between Dispatcher and SP. SIPs are SP-specific meaning that one SIP has to be developed per SP intended to be connected to SCOOP.

After conversion of input data, the SP is executed by the SIP.

The caller of the Dispatcher does not know which exact SP is executed in the background. The caller only has knowledge of the general Interface Control Document (ICD) and the ICD of the Service to be executed. This enables exchangeability of the actual SP used.

Upon execution completion the same process applies the other way round: The SIP collects the native output data of the SP, converts it into Interface data format and delivers it to the Dispatcher.

The caller of the Service execution request is not blocked until the Service has completely finished. Instead, it is possible to "ask" the Dispatcher – via special REST requests – if the execution has already finished. If so, the output data can be accessed via another request.

Of course, there can be more than one request to execute a specific Service be pending at the same time. Furthermore, the Service Interfaces machine has a limited number of processors. Thus, load management is another responsibility of the Dispatcher.

It should also be noted that SPs are intended to be executed by SCOOP-external users. Such users can use the SP from other software (systems) or users which use direct calls to SI machine. While such users are not the main focus of the SCOOP system development, architecture choices have been made based on this requirement.

3.4 SCOOP Front-end

SCOOP user can, through the system front-end, sign-in into the system, access to the dashboard (with information on past and current campaigns, karma and FoM parameters, campaigns information details, etc), join and leave campaigns, download pass prediction window data, book passes to inform the administrator of intended activity to contribute to campaigns, upload observation or relevant orbital data, download campaign summary information, make proposals for new campaigns or comment on existing campaigns.

Functionalities restricted to the campaign administrator are those of editing campaign information, objects, contributing sensors and users.

4 ACKNOWLEDGEMENT

The work presented in this paper is done within ESA/ESOC Contract 4000115836/15/D/SR. The ESA project is carried out by DEIMOS Space S.L.U. and Institute of Space Systems (IRAS) /Technische Universität Braunschweig (TUBS).

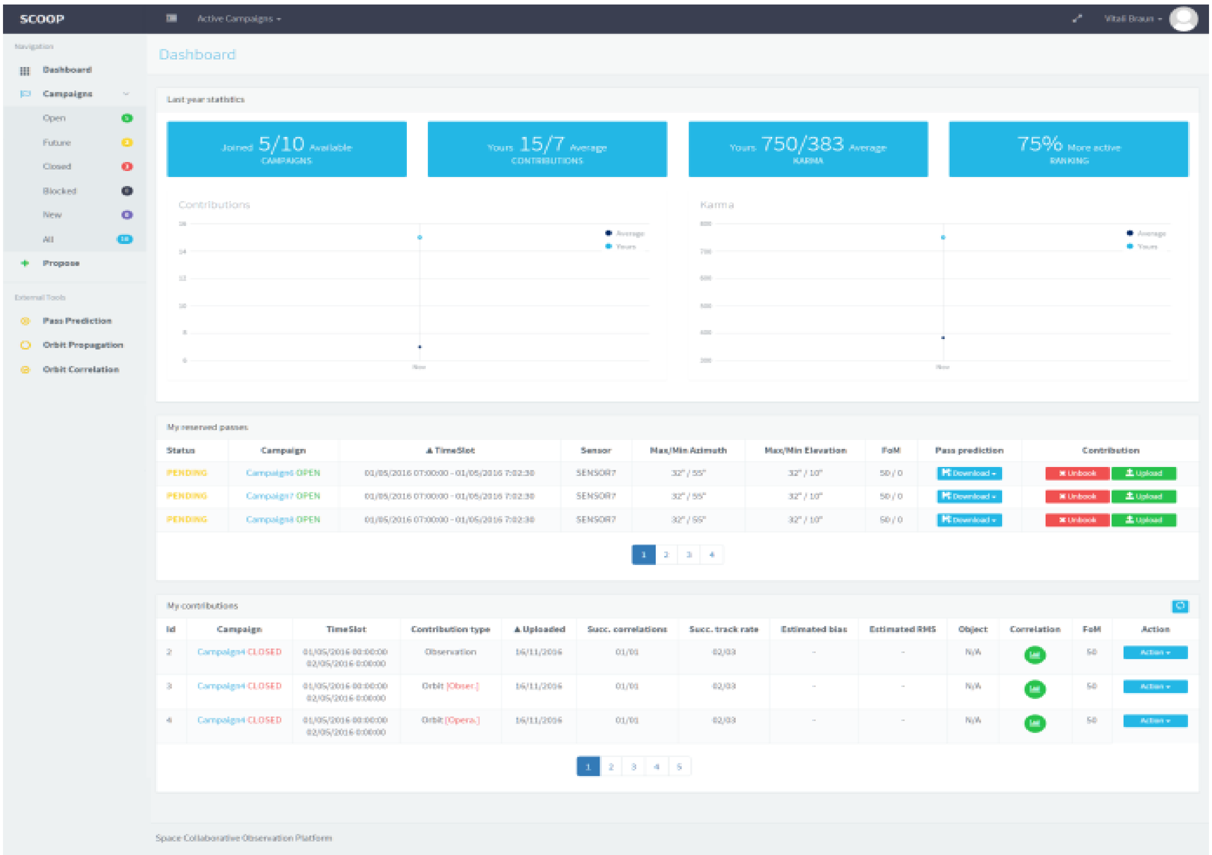

Figure 13. SCOOP Dashboard View

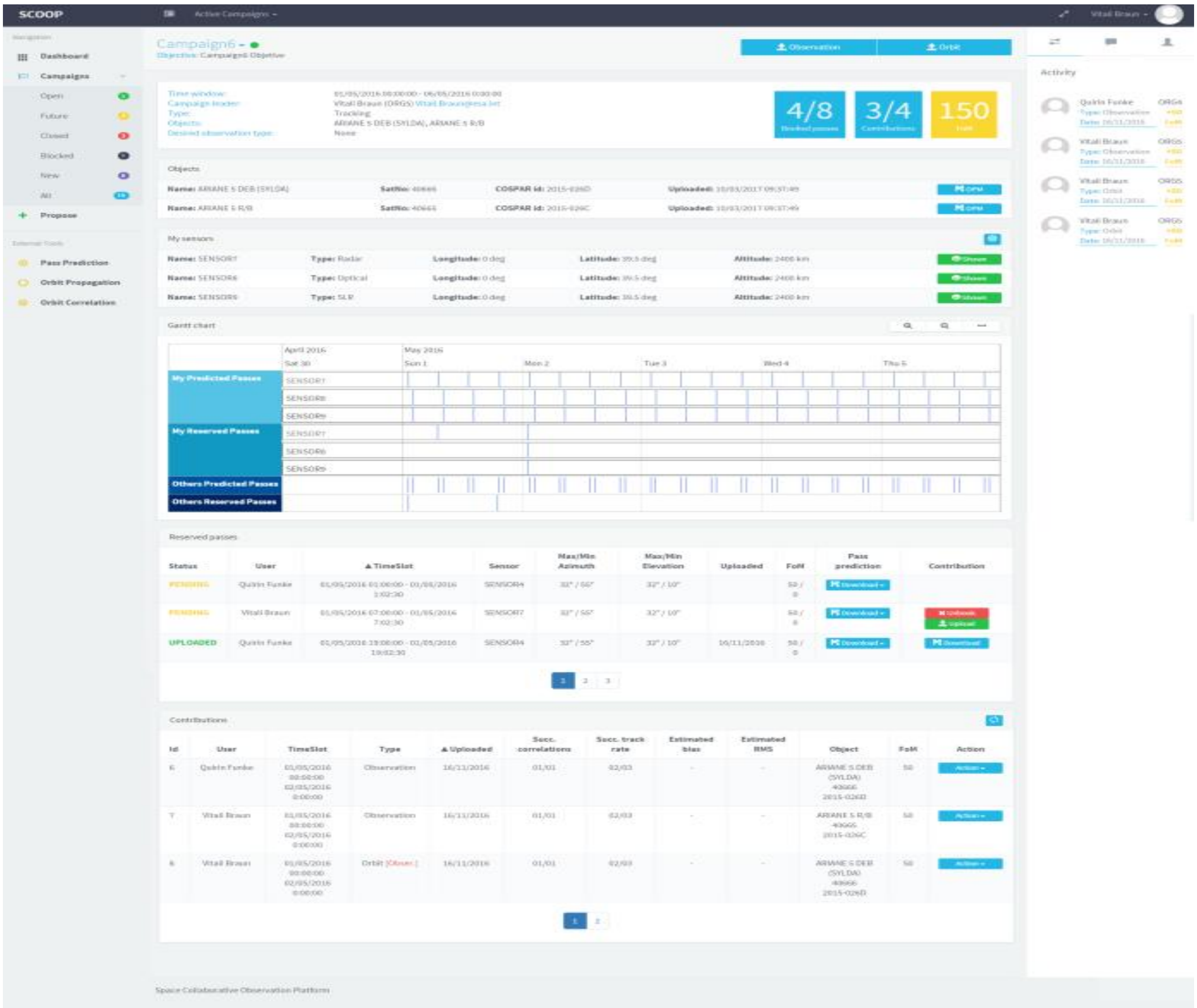

Figure 14. SCOOP Campaign Details View