

AN OPPORTUNITY MODEL STRATEGY FOR SCHEDULING NEO OBSERVATIONS

K. Mokos⁽¹⁾, K. Davies⁽¹⁾, J.S. Pedersen⁽¹⁾, P. Bohn⁽¹⁾, R. Gad⁽¹⁾

⁽¹⁾Terma GmbH, Europaplatz 5, 64293 Darmstadt, Germany, Email: {knm, ked, jnp, prb, ruga}@terma.com

ABSTRACT

Over the past decade, space situational awareness (SSA) has gained more and more attention. A range of SSA programs has been launched globally, ranging from cataloguing of debris in near-Earth orbits to detection of asteroids with close approaches to Earth. The currently in-development ESA Fly-eye telescope aims at continuously scanning the sky for Near Earth Objects (NEOs). Important goals include maximizing the area that can be covered within a given time interval and to minimize the time for achieving a full coverage. Thus, the optimization of the telescope observation schedule is critical.

The NEO Fly-eye telescope Tasking system is responsible for planning and optimizing this schedule as a sequence of nightly observations to be made by the Fly-eye telescope. The planning and optimization approach is based on the experience gained from the development of the Sapphire Processing and Scheduling Facility (SPSF) of the Canadian Sapphire program, which has comparable optimization goals. In addition, the Fly-eye Tasking system allows the inclusion of the latest available NEO observation information and customizations such as user-defined observation targets. Optimization problems of this nature are sufficiently complex that it is not practical to compute a global optimum in a timely manner on standard processing resources. Hence, a heuristic is employed in order to achieve good optimization within a few seconds using a normal processor.

The logic behind the Fly-eye telescope Tasking system is based on the concept of opportunity modelling. Opportunity modelling entails defining for each of a specific set of aspects of a potential observation a “figure of merit” function that is included in the calculation of the relative value of each observation. The combination of the figure of merits of all parameters results in an observation opportunity graph. This expresses the relative value of performing an observation at a certain time.

Optimizing the aforementioned opportunity graph, the Tasking system endeavours to ensure that the most relevant observations are included in each nightly schedule, taking into account the telescope’s own previous observations as well as recent observations by other telescopes. The observation schedule can be adapted by the operator to include observations taking information from priority lists from various sources, including the Minor Planet Center and JPL Scout, sky

coverage information, and operator defined observation targets.

The concept of opportunity modelling used for the Fly-eye telescope Tasking system was already successfully employed in the SPSF for scheduling RSO (Resident Space Objects) image acquisitions for the Canadian Sapphire space surveillance mission. This space-born telescope monitors space debris and satellites within an orbit of 6,000 to 40,000 kilometres above Earth, providing data to the US Space Surveillance Network, and has been operational since launch in 2013. The Sapphire scheduling system, which determines the observations to be made, generates a daily schedule for several hundreds of observations from thousands of potential observation targets on a 24-hour basis.

Although the goals of the Fly-eye telescope for NEO observations and the Sapphire mission for space debris tracking are substantially different in nature, it is shown that the planning aspects for each have very similar demands, and opportunity modelling is applicable to both.

1. INTRODUCTION

The NEO Telescope Tasking system generates commands for the Near Earth Object Survey Telescope (NEOSTEL - also known as “Fly-eye”), and the data produced by the telescope will be processed by software produced by the currently ongoing project P3-NEO-XII Telescope Data Processing Chain.

The NEO telescope tasking function implemented by the Tasking system will schedule survey observations, follow-up observations, and the necessary calibration observations of a ground-based telescope. While the main use case will be the NEO Survey Telescope NEOSTEL, it shall be easily adaptable to other telescopes (e.g. the ESOC Test-Bed Telescope), if they support the Scheduling and Commanding Message (SCM) standard [1].

The Tasking system allows scheduling and commanding of both telescope and camera(s). It allows planning and scheduling of observations, and interfaces with the telescope to actually execute them.

The most important factors behind the Tasking system design and implementation are high performance and sky coverage. At the top level, the following functions are provided:

- a) Preparation of survey observations
- b) Preparation of follow-up observations
- c) Preparation of calibration observations

- d) Preparation of individual exposures / pointings (user request observations)
- e) An interactive visualisation and planning interface
- f) Scripting of observations, including the support of the Scheduling and Commanding Message standard
- g) Commanding of telescope and cameras for maintenance operations
- h) Communication to command CCD cameras and telescope.

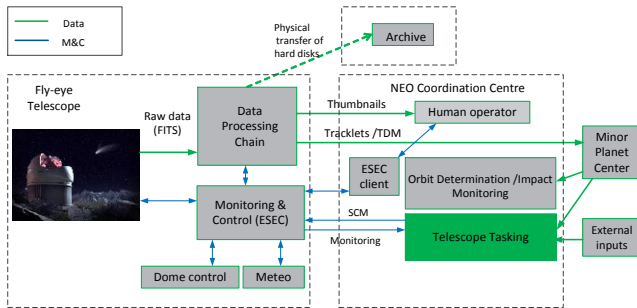


Figure 1: Tasking system External Context

The diagram in *Figure 1* shows the context of the Telescope Tasking system in relation to the other elements of the complete system. The Tasking system generates and sends schedules of commands in the form of SCM files to the telescope control system.

The Tasking system receives inputs from the following sources:

- NEODYs [1], for ephemerides data for near-Earth objects
- ESA NEO Coordination Centre, JPL Scout [2] and user defined lists for Priority Lists for near-Earth objects [9]
- Minor Planet Center, Sky Coverage page, for information on external sky coverage [3]
- Telescope Control System, for responses to commands sent to the telescope

The processing steps needed in order to carry out the tasking of the telescope observations are separated into three different top-level groups:

- Propagation of ephemerides and pre-selection of visible objects
- Computation of figure-of-merit (FoM) per object over observation period
- Optimization of opportunity graph for all objects

This paper is organized as follows. Related work is presented in Section 2. A brief overview of ephemeris propagation is given in Section 3, which is followed by an introduction to the opportunity model strategy (Section 4) and the FoM optimization (Section 5). Detailed system design and schedule generation use case

scenario is presented in Section 6. The graphical user interface and resulting schedule is described in Section 7. The paper wraps up with conclusions and future work in Section 8.

2. RELATED WORK

The planning and optimization approach is based on the experience gained from the development of the Sapphire Processing and Scheduling Facility (SPSF) of the Canadian Sapphire program [7]. The Sapphire mission is to detect and catalogue debris in low-earth orbit employing a space-based telescope. The SPSF facility was developed to schedule observations, and process resulting images from the telescope in order to determine trajectory of non-stellar resident space objects. The resulting tracklets are used to update the U.S. Satellite Catalogue that is used by both NORAD and Canada to provide space situational awareness. The SPSF includes several subsystems: an observation scheduling module, an image processing module, and a calibration module. It has been operational for several years (and still is).

The NEO Telescope Tasking system shares a substantial amount of similarities with the SPSF and the SPSF has been used as a solid reference during the requirements analysis and implementation. During the SPSF development, several optimization algorithms were tested including stochastic ant colony traversing, simulated annealing, a metaheuristic genetic algorithm, as well as a modified greedy algorithm. Comparing these algorithms to brute-force solutions it was found that a modified greedy algorithm performed virtually identically (<0.5 % in total FoM) to a brute-force implementation, but at a much higher computational speed. Thus, the modified greedy algorithm described in Section 5 was employed as a baseline for the tasking system as well.

Similar work related to NEO scheduling strategies has been performed in [4]. In that thesis different survey strategies for near-Earth object detection with ESA's Fly-Eye telescope were investigated. The author of that thesis also developed a program which simulates the observation sequence for a complete night. In this thesis only survey scheduling was performed and no use of input from other telescopes was taken into account.

Detection of asteroids by a satellite has also been demonstrated using LISA Pathfinder Star Trackers as instruments when they are not used for navigation [8].

3. EPHEMERIS PROPAGATION

A number of ephemerides need to be propagated in order to correctly evaluate pointing data and prioritize observations:

- Asteroid and comet orbits
- Earth and other planetary orbits
- Lunar orbit

Planetary and lunar ephemerides are computed in advance with the accuracy required for telescope pointing using the OreKit low-level space dynamics library [6]. These ephemerides are stored – as part of the tasking system database – and interpolated during operational use.

Asteroid and comet ephemerides are based on a selectable subset of the Near Earth Object Dynamic Site (NEODys) [2], JPL Scout [3] or user defined information sources.

It should be noted that for the vast majority of NEOs there is no need for accurate propagation of the orbital elements; however, for some rare instances it is needed to include perturbing bodies in the propagation.

In addition to the actual propagation – which is only performed when a given object has updated orbital elements – a preliminary selection of the ephemerides will filter out all objects with a pointing vector angled less than 90 degrees (configurable) from the Sun-vector, as these objects will in general not be visible. This rough filtering of ephemerides reduces the computations.

4. OPPORTUNITY MODEL STRATEGY

In order to optimize the schedule to be generated by the tasking system, each potential object to be observed (a minor planet, a comet, a user-requested pointing, a tessellation element of the sky in a survey, a follow-up request, a calibration task, etc.) needs to be assigned a certain figure-of-merit (FoM). This figure-of-merit takes into account a number of significant properties of the object which may degrade (or increase) the quality of the observation with respect to other potential objects.

This can be closeness to the Moon (which will increase straylight contribution), closeness to the Sun (especially important during dawn/dusk time periods), closeness to high-density parts of the Milky way, etc. but also user-configurable priorities are used to scale the figure-of-merit. If the object is not visible, it is assigned a FoM of zero.

The FoM is unitless and the value has no absolute meaning. The only use of the FoM is to prioritize objects relative to each other. Thus, an object with a FoM value of 218.3 will more likely be scheduled than an object with a value of 194.2 – at a given epoch – and is assumed to be approximately 12% more valuable.

The FoM for each potential object will vary over time, so the FoM will be computed at a configurable epoch distance. For the SPSF a 5 second epoch distance was used. However, due to the low dynamics of ground-based observatories, the epoch distance can be increased significantly, thus improving the computation speed.

The assignment of a FoM to each potential object for each epoch is called opportunity modeling in the following and makes it possible to generate an object/epoch-graph through which a path may be optimized as described in Section 5. This graph optimization also depends on the repointing time for the

telescope for a given pair of consecutive observation targets.

The following parameters affect the figure-of-merit:

Observation type

The observation type (follow-up, calibration, survey, user request) affects the FoM through a user-defined scaling function. Observation type affects also the overall priority of the observation or alternatively a strategy where timeslots are allocated for each observation type.

Elevation angle

Atmospheric seeing generally degrades the observation at lower elevation angles, meaning that the relative value of a low-elevation observation should be smaller than that of an equivalent high-elevation observation. A user-defined scaling function is available for the operator. In addition, there is a minimum elevation angle for which observations should be performed.

Custom exclusion zones

Custom exclusion zones are introduced in order to exclude specific areas of the sky in both elevation/azimuth and RA/DEC coordinates.

Priority

The priority (urgent, necessary, useful, low priority) will scale the FoM based on a user-defined scaling function. Operator entered priority Some objects may require elevated priority. In these cases, the operator may choose to assign a priority to the object that scales the FoM directly.

Forced inclusion/exclusion

In cases where an object needs to be observed, the use of a forced inclusion may be used to assign the object the highest FoM. This will ensure that the object will always be included in the observation schedule if there are any viewing opportunities. Correspondingly, a forced exclusion can be added if an unwanted object is automatically inserted in the schedule.

Schedule lock-out

During scheduled maintenance periods, the use of schedule lockouts will ensure that scheduling will be paused. The schedule generation will still be able to optimize the opportunity graph outside the maintenance period.

Moon

Observations near the Moon will generally be affected by more straylight and thus have a lower value than equivalent observations at farther angular distance away from the Moon. An optional user-defined scaling

function will be provided taking into account the lunar angular distance as well as lunar phase.

Sun

A user-defined scaling function dependent on the pointing-solar angle will be provided for scaling the observation FoM. This is especially useful near dawn/dusk periods where there can be significant variations in straylight on the night sky. Additionally, a minimum angle of the Sun below the horizon will be used to identify the time for first and last observations in a night.

Milky way

Observations near the Milky Way galactic center or plane are influenced by high star density and correspondingly high background brightness. An optional user-defined scaling function is provided taking into account closeness to the Milky Way galactic center and plane.

Time until viewing opportunity ends

The time until a viewing opportunity ends can optionally be used to scale the FoM using a user-defined function for survey and follow-up observations. This ensures that tessellations or NEOs soon to be blinded will get higher priority in the schedule.

Number of visits

The number of visits will affect the FoM in a non-linear way: Whenever the number of visits (within a configurable time period) reaches a configurable threshold, the FoM is reduced in order to minimize (or completely eliminate) the probability of another visit.

Allocated percentage for specific observation types

Each observation type (survey, follow-up, calibration, etc.) can be assigned a minimum timeslot percentage per observation period. Once this timeslot allocation has been reached, the FoM for each observation within the given observation type can optionally be scaled by a user-defined scaling function in order to prioritize other observation types.

5. FoM OPTIMIZATION

5.1. Overall Optimization Strategy

The optimization of the FoM graph as described in the previous section can be performed in several ways. However, before the actual optimization can be performed, the optimization strategy needs to be selected. Although a FoM has been assigned to each observation object for each epoch, other considerations may be applicable for the planning.

In particular, the operator may not want to rely solely on computed FoMs and priorities to select the best

observations as there may be top-level requirements for minimum time spent on survey images, user-requested images, follow-up requests, etc. As such, the operator is able to select between different optimization strategies. The NEO Tasking system allows selection of one of the following optimization strategies:

- Optimization based on object/epoch opportunity graph: This strategy assumes that the configurable weights for each observation type and individual settings for FoM computation for each observation is set to reasonable values in order to obtain a given number of observations in each observation category (e.g. survey, follow-up, user request, etc.). The advantage of this approach is that if all weights and settings are correctly adjusted, the generated observation schedule is optimal. The disadvantage is that it requires elaborate analysis of inter-parameter dependencies.
- Optimization based on defining a list of time intervals within each of which only a defined set of observation object types are allowed to be observed: In a typical telescope mission scenario there are certain top-level requirements to be met regarding minimum number of observations (or observation time) for each type of observation. In this optimization strategy the amount of time spent on a given observation type affects the generated observation schedule in order to give higher priority to observation categories that have not yet fulfilled the minimum observation time goal.

5.2. Optimization Algorithm

In order to generate an optimal schedule based on the object/epoch opportunity graph, a modified greedy algorithm is applied to the object/epoch opportunity graph described in Section 4, for determining the optimal schedule. The optimization algorithm takes into account the repointing time of the telescope when the telescope is commanded to move from one position to the next.

The basic processing steps of the algorithm are as follows: Initially, select the object with highest FoM for the first valid epoch. For all the remaining epochs:

- For each epoch for the next N (configurable, typically 2-3 times the maximum expected observation time) “look-ahead” epochs:
 - Compute repointing time from previous object to all other potential objects in current epoch
 - Compute a temporary ‘effective’ FoM indicating the value of the observation, taking into account the total observation time, including repointing time and settling time.

- Select the next object/epoch-pair node based on the highest ‘effective’ FoM as computed above.

In essence, this modified greedy algorithm thus always selects the path with highest local ‘effective’ FoM.

5.3. Modification of the Schedule

Using the opportunity graph methodology as described above makes it very simple to modify the schedule after generation:

- Deletions are simply performed by removing the epoch/object pair from the schedule. This will not influence the schedule as such, but in order not to waste observation time, the operator may wish to re-optimize the schedule with the selected object/epoch node removed in order to generate a schedule with other observations in place of the removed observation.
- Insertion of operator-selected objects is performed by inserting the new object in the existing opportunity graph and rescheduling. If the operator wishes to insert the observation object at a given epoch, this is simply done by assigning the object a high priority at the given time.
- Updating visibility constraints just requires updating the opportunity graph after the reached epoch and a re-scheduling from that point onwards.

6. SYSTEM DESIGN

6.1. System Decomposition

The top-level system decomposition and identified interfaces are presented in *Figure 2*.

The top-level components are:

- Import Handler: retrieves inputs from a multitude of sites and injects these into the Data Store
- Scheduler: lays out a schedule of observation requests for the upcoming period, taking the observatory location and characteristics into account. These requests encompass time, direction, and duration of exposure along with other parameters.
- Management Handler: starts up the total population of threads, and supervises these, e.g. identifying stalled threads and restarting threads after configuration changes.
- Tasking MMI: supports remote operator interaction with the system, either in a browser (based on a web server) or on a command line (using a secure shell connection). This supports browsing and inspection of stored elements (including schedules and derived data), and

provides the means for the operator to manually reschedule observations after having changed priorities.

- Export Handler: transforms due scheduled requests into telescope commands, forwarding these to the telescope.
- Data Store: is a combination of a relational database and simple files in the file system.

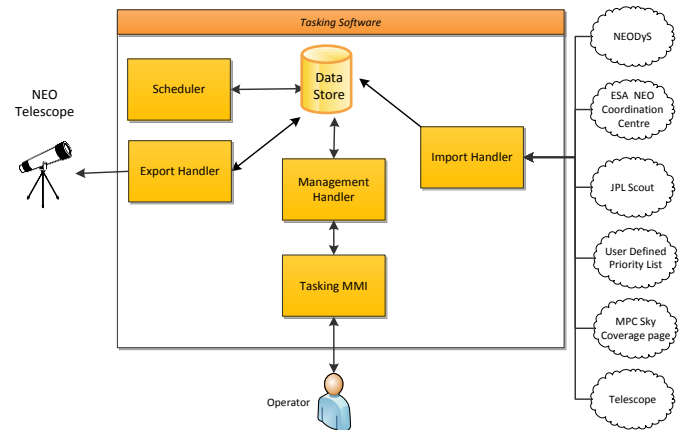


Figure 2: Top-Level System Decomposition

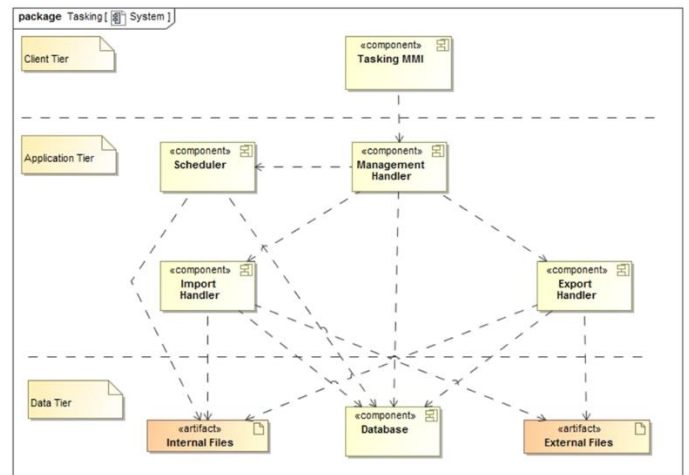


Figure 3: Top-Level Software Architecture

6.2. System Architecture

The software has been divided into three tiers, as shown in *Figure 3*.

The Client Tier consists of one component only, the Tasking MMI, which is the main interface to the user for commanding the system and for seeing responses.

The Application Tier contains the components that implement the logic of the NEO Telescope Tasking system. The Management Handler controls the other components and handles communication with the MMI. The Scheduler produces a schedule upon request. The Import Handler retrieves NEO inputs from external sites and command responses from the telescope. The Export

Handler exports schedules in SCM format to the telescope.

The Data Tier contains the various data elements used by the other components. Internal Files includes configuration files for the system as well as an internal intermediate representation of generated schedules. The Database contains the latest generated and approved schedule as well as previous approved and exported schedules. The External Files are files received by the Import Handler and files ready to be sent by the Export Handler.

6.3. Schedule Generation Use Case

Generating a schedule of commands is the primary use case for the Tasking system and encompasses the majority of functions that the Tasking system provides. Generating a new schedule of telescope commands is initiated by the user, using the provided web-based Tasking MMI. The user will first update the schedule parameters. The schedule parameters are those parameters that are applicable to the complete schedule, and include for example:

- Required number of visits of each selected survey object during one night
- Minimum required and maximum desired times between visits of survey objects
- Dither value
- Exposure time

After setting the schedule parameters, initiate the generation of the initial schedule. The schedule is generated by the Scheduler. Schedule generation has two major steps:

- FoM calculation: This can take a few minutes, mostly depending on the number of NEO propagations to be performed, if any. For detailed description see Section 4.
- Schedule optimization: This is the processing intensive part of the workflow, with the generation typically taking some minutes. For survey-only schedules, the generation will usually be completed in less than a minute. For detailed description see Section 5.

The user can now work on the schedule, making desired modifications, and regenerating the schedule iteratively, until it is ready to be used. Once the user is satisfied with the schedule, it is submitted to the database. It is then automatically retrieved by the Export Handler, the SCM file is generated and is sent to the telescope control system.

The SCM file can be manually edited using an SCM Editor, after the complete process of generating the schedule has been completed. Note, that editing the SCM at this stage means that inconsistencies in the planning could be introduced (for example, by extending an observation by too large a time), and the optimizations made by the Tasking system could be disturbed.

7. GRAPHICAL USER INTERFACE

The web-based graphical user interface is a Single Page Application (SPA) based on the Angular 6 framework and HTML5/CSS (*Figure 4*).

The graphical user interface is divided into three distinct panes: The navigation pane (left), the main pane (middle) and the status pane (right).

The screenshot displays a web-based graphical user interface for survey management. It is divided into three main panes: a left navigation pane, a central main pane, and a right status pane.

Navigation Pane (Left): Contains a vertical list of menu items: Management, Survey, Follow-up, Calibration, User Requests, Observatory, Settings, Generate, Schedule, and Test Area. The 'Survey' item is currently selected and highlighted.

Main Pane (Center): Displays 'Survey Parameters' with a link to 'See settings page for general parameters and weight values for figure-of-merit/rank computation.' Below this is a table with three columns: Parameter, Value, and Notes.

Parameter	Value	Notes
Number of visits	4	Number of visits during one night.
Minimum inter-visit time	15	minutes. Minimum time between visits.
Desired maximum inter-visit time	60	minutes. Desired maximum time between visits.
Dither value	3.6	pixels. Random dither value for later visits
Exposure time	30	seconds
Tessellations file	src/test/resources/data/tesse Location on server	

Status Pane (Right): Titled 'Status', it shows the current time as 'January 10, 2019 at 2:10:51 PM GMT+1'. Below this, it lists the status of various system components: Management Handler running, Import Handler running, Export Handler running, and Database running. A section titled '% allocation to survey' shows: 0.00% allocation to follow-up, 0.00% allocation to camat-list-itembration, and 0.00% allocation to user-requests.

Figure 4: Graphical User Interface

7.1. Navigation Pane

The navigation pane (left) merely shows the individual sections accessible to the operator. Whenever the operator selects an item in the navigation pane, the application will change the main pane (middle) to the selected function. The user may select within the following functions:

- **Management:** When selected, the operator will be allowed – if logged in as administrator – to restart threads and databases. In addition, configuration files can be reloaded.
- **Survey:** In this pane the operator may review and modify specific survey parameters for the upcoming schedule generation.
- **Follow-up:** In this pane parameters are set for scheduling priority lists as received from MPC or JPL Scout.
- **Calibration:** Calibration pane. This pane defines all parameters for calibration tasks to be performed.
- **User-Requests:** In this pane the operator may enter directions or specific NEOs to include in the schedule.
- **Observatory:** In this pane the observatory location and observatory specifics can be viewed and edited.
- **Execute:** This pane is selected when all other parameters have been reviewed and modified by the operator. The pane basically has two options: Store the selected parameters to configuration file(s) and (re-)generate schedule.
- **Schedule:** In this pane, the generated schedule can be reviewed, modified, and eventually submitted for the backend to transmit it using the export daemon once the deadline for transmission to the telescope is reached.

7.2. Status Pane

In the status pane (right) the overall status of the entire tasking subsystem is summarized. The status of each of the threads and the database is reported, and some of the main parameters (e.g. observation type time allocation in the current schedule etc.) are listed. Additionally, important times (e.g. schedule generation time, next SCM transmission, next observation) is shown.

The colour of the status pane will change if any of the daemons issues warnings, errors or are not reachable from the backend.

7.3. Main Pane

In the main pane (middle), the content corresponding to the selected section in the navigation pane is shown. In *Figure 4*, an example of the Survey parameters main pane

is shown. Once a given parameter-set is used for schedule generation, the content of the parameters in the graphical user interface is stored in the configuration files and the backend will use these parameter-sets for the actual schedule generation. As such, the graphical user interface only shows status, parameters, schedule, etc., but does not do the actual computations.

Once the operator has reviewed the scheduler parameters, he can request in the Execute pane to generate selected night schedule (i.e. the tasking system's backend will start to compute the schedule). Once complete, the schedule will be submitted to the database and automatically shown on the Schedule pane. An example of a complete night schedule is shown in *Figure 5* and *Figure 6*.

Scheduled Items description of this section

Submit to database Refresh Schedule Generate SCM only

#	DateTime	Type	Name	Right ascension	Declination	Observation Successful
1	2018-03-14T17:31:23.000	Survey	R10D19	85.95412045078118	40.06991331001553	true
2	2018-03-14T17:32:05.288	Survey	R11D18	88.10470320547041	33.38858019734748	true
3	2018-03-14T17:32:48.273	Survey	R11D19	94.13202302027848	40.069913310015494	true
4	2018-03-14T17:33:30.512	Survey	R12D18	95.76264460501454	33.38858019734751	true
5	2018-03-14T17:34:16.657	Survey	R9D20	85.55682105212882	46.754138684790554	true
6	2018-03-14T17:34:58.559	Survey	R10D20	94.55050476144989	46.75413868479058	true
7	2018-03-14T17:35:41.801	Survey	R12D19	102.30992568977577	40.069913310015494	true
8	2018-03-14T17:36:28.380	Survey	R12D17	90.02457771586735	26.7091714565990784	true
9	2018-03-14T17:37:13.693	Survey	R13D18	103.42058600455869	33.38858019734748	true
10	2018-03-14T17:37:56.846	Survey	R13D17	97.22427498597977	26.709171456599081	true
11	2018-03-14T17:38:44.643	Survey	R11D20	103.54518947077098	46.75413868479055	true
12	2018-03-14T17:39:33.985	Survey	R11D17	82.82632793313674	26.709171456599086	true
13	2018-03-14T17:40:21.350	Survey	R14D17	104.42047728132856	26.709171456599079	true
14	2018-03-14T17:41:07.048	Survey	R13D19	110.48782815927305	40.069913310015494	true
15	2018-03-14T17:41:54.802	Survey	R8D21	87.4634603754791	53.44280699802384	true
16	2018-03-14T17:42:44.221	Survey	R14D18	111.07852740410283	33.38858019734748	true
17	2018-03-14T17:43:32.477	Survey	R9D21	97.7452981153697	53.44280699802382	true
18	2018-03-14T17:44:17.038	Survey	R12D20	112.539872180092	46.754138684790554	true
19	2018-03-14T17:45:07.759	Survey	R13D16	93.47869226150749	20.031035662578027	true
20	2018-03-14T17:45:49.840	Survey	R12D16	86.5568876424281	20.03103566257805	true
21	2018-03-14T17:47:23.000	Survey	R10D19	85.95412045078118	40.06991331001553	true
22	2018-03-14T17:48:23.000	Survey	R11D18	88.10470320547041	33.38858019734748	true
23	2018-03-14T17:49:05.985	Survey	R11D19	94.13202302027848	40.069913310015494	true

Figure 5: Example of generated schedule

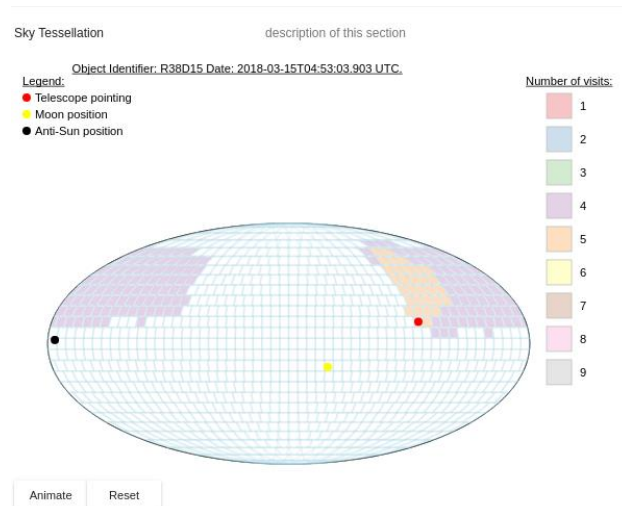


Figure 6: Visualization of generated schedule

8. CONCLUSIONS

The large field of view of the new Fly-eye telescope and with that the large possible observable sky area per night has brought up the necessity to investigate new space situational awareness tasking system strategies. In this

paper the Fly-eye telescope Tasking system, developed by Terma A/S, is presented.

The logic behind the telescope Tasking system is based on the concept of opportunity modelling, which entails defining for each of a specific set of aspects of a potential observation a “figure of merit” function that is included in the calculation of the relative value of each observation. The figure-of-merit calculation algorithm takes into account a large list of parameters which may degrade (or increase) the quality of the observation with respect to other potential observations (e.g. closeness to the Moon, closeness to the Sun, closeness to high-density parts of the Milky way, etc), but also user-configurable priorities are used to scale the figure-of-merit.

The Tasking system endeavours to ensure that the most relevant observations are included in each nightly schedule, by generating an object/epoch-graph through which a path may be optimized (taking into account the telescope’s own previous observations as well as recent observations by other telescopes).

The telescope tasking function implemented by the Tasking system schedules several types of observations: survey observations, follow-up observations, and the necessary calibration observations of a ground-based telescope.

The Tasking system allows scheduling and commanding of both telescope and camera(s). It allows planning and scheduling of observations, and interfaces with the telescope to actually execute them. While the Tasking System's main use will be the NEO Survey Telescope, it is easily adaptable to other telescopes, in particular if they support the Scheduling and Commanding Message (SCM) standard.

For future work a real time weather data information can be considered to assist the end-users and fully automatize the planning process.

9. REFERENCES

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2. NEODyS (Near Earth Objects Dynamic Site): <https://newton.spacedys.com/neodys/>
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