Fully Automated Mission Planning and Capacity Analysis Tool for the DEIMOS-2 Agile Satellite

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ABSTRACT

The DEIMOS-2 mission, launched in June 2014 and currently carrying out routine operations, is aimed at operating an agile small satellite for high-resolution Earth Observation applications. The spacecraft can be steered to accurately point the payload up to 45° off-nadir. The platform agility makes mission planning a complex optimization problem, which is cumbersome for human operators. Automation emerges as a key enabler for the mission planning and exploitation process. This paper presents the "Capacity Analysis and Mission Planning Tool" developed by DEIMOS to produce feasible acquisition sequences from a set of user areas of interest. By feasible, we mean they do not overlap and they fulfil the platform constraints: attitude manoeuvring agility and stability requirements, on-board memory and downlink, power production and battery capacity. Besides the significant workflow enhancement obtained by the full automation of mission planning, the tool is also able to optimize the mission return by repeating the scheduling exercise and selecting the best-performing mission timeline. In addition, the tool can simulate the execution of user-defined sequences of spacecraft operations (i.e., mission timelines), thanks to a high-fidelity system simulator, and detect any possible resource conflict in terms of agility, power and memory.

INTRODUCTION

The DEIMOS-2 Mission

Following the successful launch and on-going operations of the medium-resolution wide-swath DEIMOS-1 satellite, a new Earth Observation (EO) mission of the Spanish DEIMOS series has been designed, developed, complete with all its space and ground segment components, and launched in June 2014.

The DEIMOS-2 mission is aimed at operating an **agile small satellite for high-resolution EO applications** [1]. The mission features an agile spacecraft that can be steered to accurately point the pushbroom-type optical payload, which can provide **75-cm pan-sharpened and 4-m multi-spectral images** with a 12-km swath at an altitude between 590 km and 640 km. The multi-spectral capability includes 4 channels in visible and near-infrared spectral range (red, green, blue and NIR).

The off-nadir tilting capability of the SpaceCraft (S/C) is intended to improve the revisit time performance and enhance the operational flexibility, by significantly reducing the time interval to take images on areas of interest. While the across-track tilt angle for nominal image acquisitions is ±30º, the satellite can be configured to achieve ±45º off-nadir pointing capability, i.e., an extended Field of Regard (FoR) for data collection with short revisit time in emergency situations. Moreover, high-quality observations can be performed close to nadir (small FoR) to enable background mapping. This allows single-strip imaging of areas of interest, multi-pointing imaging of close-enough targets, single-pass stereo imaging by along-track pitch angle manoeuvres and tessellation imaging.

Fig. 1. DEIMOS-2 Flight Model during Integration.

DEIMOS Imaging (DMI), a company of the ELECNOR DEIMOS Group, operates the mission from its premises in Spain. Most of the customers will send their observations requests to DMI, who will take care of the entire operations chain and send the resulting products to the customers. However, some other customers will be authorized to build the acquisition sequences for their areas of interest (under certain constraints) and directly download their data to their own ground station (GS). This scheme, along with the general variety of urgency and criticality levels amongst customers and their requests, results in a vast and complex exercise when it comes to plan the operations of the spacecraft.

Platform Resource

The DEIMOS-2 mission is based on a small platform with a well-balanced allocation of its resources. These play a key role in the planning of the operations. In order to maximize the mission return, it is of paramount importance to distribute the workload as much as possible. This way the resources are used at best and duty cycle saturation is limited.

The **agility** is ensured by a set of four reaction wheels distributed on a tetrahedron (around the Z-axis) plus another one on the X-axis to give extra torque on the roll axis. This allows roll manoeuvres of 60° to be completed in about 80 seconds. However, some tranquillization time is required to reach the pointing stability allowing for good image quality. Overall, the manoeuvring time is highly dependent on the rotation angle and axis.

Power is provided to the bus by four solar panels mounted on the rear panel of the platform. Their orientation is fixed with respect to the satellite. Attitude thus plays an important role in power production as well.

The platform features 256 Gb of **memory**, enough for storing about 6500 km^2 of imaging. It is therefore of critical importance to carefully allocate memory usage as a function of the priority, quality and urgency of the requested images, especially with a product catalogue where very urgent single scenes (10x10 km) are mixed with country-wide background mapping projects. As soon as needed (full memory of urgent image just shot), the satellite has to download the data to a GS. This is done through a specific attitude steering that does not allow Earth Observation and has an impact on power production.

The resources are accumulative, their consumption rates are highly variable and they directly interact with each other. So, the feasibility of an isolated image acquisition cannot be known without taking into account the entire timeline of operations. Modelling the resource consumption with constant margins to save computation time (e.g. constant slew time between images, constant power production) usually leads to large errors. Coping with these levels of uncertainty is only done through the use of generous margins causing the mission planning to be too conservative, with poor mission return.

GENERAL ARCHITECTURE OF THE CAPACITY ANALYSIS AND MISSION PLANNING TOOL

Optimized for agile satellites, the **Capacity Analysis and Mission Planning (CAMP) Tool** developed by DEIMOS provides both enhanced long-term mission return analyses and a sound prototype for a fully-automated mission planning chain, working on short-term operational horizons.

The Capacity Analysis and Mission Planning tool is constructed around **two main modules** (see Fig. 2). On top of the inputs shown on the diagram (orange blocks), both modules share a wide set of inputs describing the orbit, the ground segment and the 3 modelled platform resources: AOCS, power and data handling.

The **first module generates feasible mission timelines** (MTL, sequence of operations). From a set of areas of interest (AoI), it analyses the orbital geometry to find observation opportunities and builds full MTLs that respect the constraints imposed by the system resources (modelled with some approximations).

It is also able to repeat the scheduling exercise and select the best-performing MTL from the point of view of mission return (taking also cloud forecast into account). Finally, it provides results and plots about the **coverage performance** of the selected MTL over the simulation time.

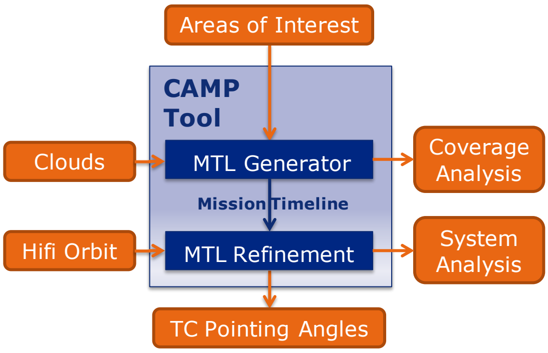


Fig. 2. General Architecture of the CAMP Tool.

The **second module simulates the execution of the selected MTL** by the spacecraft, thanks to a high-fidelity system simulator. It combines the MTL and the high-fidelity orbit propagation (based on operational orbit determination) to derive the **pointing angles to be uploaded to the satellite**. It then uses state-of-the art models to simulate the AOCS, the power management and the data flow. It produces a **thorough reporting of the satellite system state** at any moment and detects any possible resource conflict. An MTL coming from the MTL generator has no reason to create any conflict under nominal conditions, as it uses fair models of the on-board resources plus security margins.

AUTOMATED MISSION TIMELINE GENERATION

The tool receives as input the users' requests, represented by AoIs, and transforms them into targets. Through a geometric analysis, involving the propagated satellite orbit, the targets' position and some user-defined constraints, all the possible observation events are selected. They are ordered by priority and then passed to a scheduler that, thanks to approximate models of the satellite resources, generates a mission timeline satisfying the platform constraints. The MTL performance is evaluated by means of a figure of merit (FoM) and the ordering and scheduling process can be repeated in order to maximize the mission return.

The architecture of the Automated Mission Timeline Generator is shown in Fig. 3.

Areas of Interest (AoI) and their Representation

The AoIs requested by the users can be of various types:

- an entire **country**, selected among a list covering all the nations on the Earth with territorial extension greater than 100 km^2, to be observed as background-mapping (low priority);
- a generic **polygonal region**, defined by a list of geographical coordinates, to be observed as background-mapping;
- **urban atlas**, representing cities to be observed as background-mapping;
- a **pin-point target area**, defined by single-point coordinates and with an extension of less than 100 km^2;
- an area to be observed with the **stereoscopic** technique, meaning that the S/C takes two consecutive images of the same region, but with different pitch angles;
- an area to be observed with the **tessellation** technique, meaning the S/C takes contiguous parallel strips during the same flyover.

Each inserted AoI is characterised by some data, such as constraints over the Observation-Zenith Angle (OZA, incidence angle) range, Sun-Zenith Angle (SZA, target Sun illumination angle) range, maximum continuous acquisition length, valid observation time window and the maximum percentage of cloud coverage to consider the image of acceptable quality.

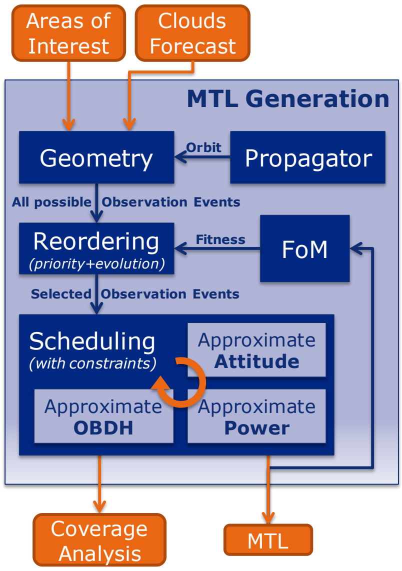


Fig. 3. Architecture of the CAMP Automated MTL Generator.

Each AoI is characterized by a priority level reflecting the urgency and/or profitability of the request.

Once the mission scenario is defined, the AoIs are split and translated into **targets** (i.e. along-track strips) composed by a series of cells mapped onto a grid that samples the surface of the Earth. DEIMOS-2 is an agile platform, but its **attitude must remain fixed during imaging**. The instrument is therefore not able to follow an arbitrary shape on the Earth surface. From this reason rises the need to define grid cells aligned with the satellite ground track.

CAMP stores a **country-based composite grid** in which all cells have been defined in order to have the same surface, independently from their geodetic location. Each grid is built in order to limit the overlap of cells due to latitude and the cell dimension is optimized to maximize the area covered by a single data take, depending both on the latitude and the roll angle. Each cell of the map is aligned with the satellite ground track and the cell dimension (in ground km) is assumed to be the same for every grid, i.e. for every country. An example is shown in Fig. 4.

The tool comes with a pre-computed reference grid, but the user can replace it with a custom-made one.

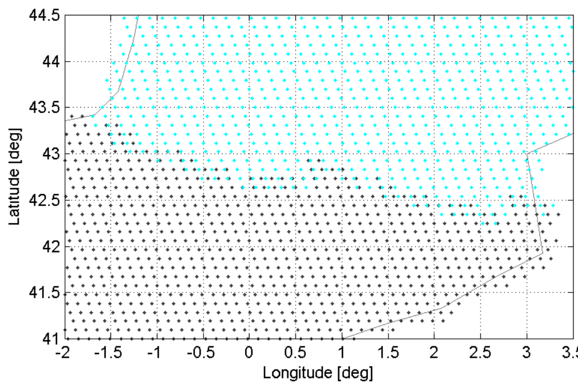


Fig. 4. Example of Country-Based Grid (Spain-France Border).

Geometrical Analysis

From the orbit propagated during the simulation time, and the visibility constraints inserted in input, CAMP detects, for each target in the AoIs, all the possible observation **events**, together with all the potential contacts between the satellite and the ground stations.

During this analysis, **cloud forecast** are automatically downloaded from the internet and, depending on the observation period and geographical location, a filter is applied to discard the potential poor quality images. Cloud data are obtained from Global Forecast System (GFS) downloaded from http://nomads.ncep.noaa.gov/. The NOAA server is constantly updated supplying cloud forecast with intervals of 3 hours up to 8 days ahead. If the simulation lasts more than 8 days, a target can be rejected with a probability proportional to the estimation of the AoI average cloud cover inserted in input. Possible payload and ground station **outages** are also taken into account, together with ground stations working hours that limit their availability.

Priority-Based Ordering

The list of candidate observation events is ordered by importance, following the **priority level**. Since the priority value is unique for each AoI, but each AoI is represented by many targets and the same target can have multiple observation opportunities, the priority itself is not sufficient to order the candidate events. A random criterion is then applied to order the events in the same priority group.

Mission Timeline

The output of the CAMP tool is a MTL file with a **sequence of operations** that the satellite should perform in order to fulfill its mission. The different operations are grouped into system modes:

- Sun-pointing housekeeping: the satellite's solar panels pointing to the Sun in order to maximize the power production.

- Nadir-pointing housekeeping: during eclipse the satellite camera pointing to Nadir.
- Image acquisition: target pointing for image acquisition purpose.
- Orbit maintenance and control: the thrust vector pointing along the desired direction of thrust.
- Download: the on-board antenna pointing towards the ground station antenna.

Relevant information is provided for each operation, covering start and stop epoch, the target to observe and the associated AoI in case of imaging, and the ground station to point in case of download.

Scheduling

Due to the highly combinatorial nature of the planning problem, a complete search is not feasible. Following the work of Globus et al. [2] the mission timeline is built by means of a **greedy scheduler** that, starting from the first events in the ordered list of candidate events, tries to insert into the MTL as many events as possible. The scheduler scrolls the entire list and it plans an event if it does not overlap with already scheduled events and if it does not violate any of the satellite's system constraints: attitude manoeuvring agility and stability requirements, on-board memory and downlink, power production and battery capacity. Otherwise, the event is left unscheduled.

An observation event is not dealt as a monolithic piece, but depending on the already scheduled events, it can be shrunk to fit the timeline. In this way not the whole observation event is discarded, but only a part of it.

With this approach the tool always generates a **feasible mission timeline**. The tool gives also the user the possibility to insert mandatory events that have to be scheduled with the highest priority, for example orbit maintenance manoeuvres or urgent images, by means of an external file.

Resource Modelling

Since every time the scheduler tries to insert an event it checks the platform constraints, the satellite resources have to be modelled balancing accuracy and speed.

The DEIMOS-2 **attitude** manoeuvre is modelled with the approximation that the reaction wheels (RW) provide a constant maximum torque during transition and thus that the angular velocity follows a triangle-like shape with constant acceleration and deceleration rates. The total manoeuvre time is decomposed into a slew time, to reduce the pointing errors, and a tranquillization time, to stabilise the line of sight. The tool embeds an ad-hoc torque envelope model based on the nominal RW mounting of the DEIMOS-2 satellite to accelerate the computation. It also allows the user to specify any other RW mounting, in order to enable the simulation of the platform's behaviour in case of AOCS failures. During ground station downlinks, the attitude is optimized to take advantage of the X-band antenna gimbals and maximize power production. These gimbals are modelled taking into account both their guidance and actuation. The tool models also the time required to allow the payload preparation before taking an image and the time needed to permit the satellite's memory to post-process the image just acquired.

Images are stored in the satellite's **memory** until they can be downloaded to the ground when the satellite passes over a ground station. To model the evolution of the on-board mass memory occupation, a fixed download data rate is considered, while the acquisition data rate can be considered either constant or variable. Constant values can be defined by the user, while variable acquisition data rate takes into account the geometry of each possible observation and camera characteristics. The contacts with ground stations are limited only to those guaranteeing the memory never overflows. Ground stations can be characterized by various additional inputs, including priorities, working hours, minimum and maximum contact time and custom azimuth/elevation terrain mask.

The **power system** model of DEIMOS-2 used by the scheduler is a simplified version of the full model used by the Mission Timeline Refinement. The power production of the solar panels is computed on the basis of the attitude and without taking into account their temperature variation. Each system mode is associated to a constant power load, and the (variable) power production during a given event is averaged, based on the assumption of a constant bus voltage. This way, the integration of the Depth of Discharge (DoD) evolution is performed event by event, instead of time step by time step. The scheduling of data takes and downlinks into the timeline is subjected to battery limitations so that the battery maximum DoD is never trespassed.

Fitness Assessment

The goodness of a MTL can be evaluated through a fitness function, called also **Figure of Merit (FoM)**. The FoM is related to mission exploitation drivers and its computation should be flexible in order to reflect the client needs. The user is let free to evaluate his/her own FoM, as the function code has been left open to edition, with a vast set of available inputs.

Schedule Optimization

Besides generating a feasible mission timeline, the tool is also able to **optimize** the mission return, maximizing the FoM described in the previous section, by means of a **genetic algorithm**. It is a population-based algorithm inspired by the theory of evolution that evolves towards a global, or near-global, optimum solution. It starts with a randomly generated population of individuals, i.e. the ordered list of events, generates feasible MTLs, thanks to the greedy scheduler, and at each iteration it selects the best fitting solutions to create offspring through crossover and mutation. This is repeated until some condition is satisfied, like the maximum number of iterations, the maximum optimization time or the maximum number of iterations without fitness improvement.

Daily Mission Planning
One of the key objectives of the CAMP Tool is to be a **prototype for the fully-automated operational DEIMOS-2 Mission Planning Facility**, being able to deal with a classical daily mission planning scenario. In an operational context, the scenario to be anlysed will change dynamically due to several customers with many requests in the pipeline (some new plus some already planned but not yet accomplished) and a short-time horizon due to the short-term weather forecast and to frequent insertion of new customer requests into the system. The CAMP Tool functionalities have therefore been augmented in order to be able to consecutively re-plan a mission exploitation scenario, as many times as needed, taking into account already observed targets and new possible AoIs.

Code Parallelization
For long-term analyses with many and extended AoIs, the geometrical analysis, the scheduling and the optimization could become bottlenecks from a runtime point of view. To overcome this problem the tool code has been parallelized, thanks to the MATLAB Parallel Computing Toolbox. In this way the simulation time can be divided by the number of the cores in the computer.

MISSION TIMELINE REFINEMENT

The MTL Refinement Module has two main functions: check the real-life feasibility of an MTL and derive the final angles that will be sent to the satellite AOCS to precisely point its line of sight towards the desired ground targets. It is built as described by Fig. 5.

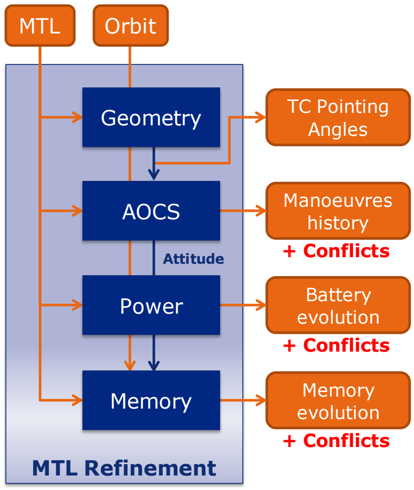


Fig. 5. Architecture of the CAMP MTL Refinement Module.

High-Fidelity Orbit Propagation
The CAMP Tool includes a numerical propagator that is able to simulate the full Earth gravitational field (various models available) and perturbations such as the atmospheric drag (including Jacchia-Bowman ECSS-compliant model), third-body gravity pull and solar radiation pressure. Being a prototype of the operational mission planning chain, CAMP is also able to bypass its propagator and take as input the high-fidelity propagation based on the latest DEIMOS-2 orbit determination data and performed by the operational flight dynamics (FD) module.

Attitude Commands Refinement
CAMP's MTL Generation Module uses quite sophisticated but still approximate models for orbit propagation. It also makes some assumptions on the ability of the satellite to steadily observe contiguous grid cells that greatly accelerate its geometrical analysis of the problem. The first task performed by the MTL Refinement Module is to compute the precise command angles corresponding to each data take present in the MTL. These command angles are then fed into the spacecraft AOCS Simulator.

High-Fidelity Resources Modelling
Like for orbit propagation, CAMP features an **attitude** propagator based on the fixed-torque model used in the MTL Generation Module. It works with any RW mounting configuration. However, it can be bypassed in order to use a state-of-the-art DEIMOS-2 AOCS Simulator using the on-board software.
The computed attitude is then fed into the power model. It includes solar panels, battery, battery charge regulators (BCR) and the **power** loads that are associated to each system mode. The power model algorithm uses the propagation and satellite attitude results, to evaluate the solar panels position with respect to the Sun and to obtain the solar flux and the flux incidence angle at each epoch. It takes into account solar flux, Earth albedo and InfraRed (IR) radiation, absorption and emission coefficients and the view factors between the satellite and the Earth. Additionally, the user shall define the solar array dimensions, the panel efficiency and the fill factor. The outcome is a profile of power production over the simulation duration. The battery is modelled with a maximum capacity, maximum charge rate, and two efficiencies: for charge and discharge process. Applied to the power input or output, they give the Depth of Discharge (DoD) variation.
On-board **mass memory** evolution depends on the maximum memory capacity, and on the stored images. The CAMP algorithm considers a constant download data rate. But it allows the user to select between defining a constant production rate and providing the inputs to compute a variable value. For this resource, there are no differences between the MTL refinement algorithm and the one used for scheduling.

Conflicts Analysis
The MTL Refinement Module produces a step-by-step reporting of the state of the S/C resources, organized in the form of composite plots easing the diagnosis of conflicts, such as the one presented in Fig. 6. Each resource is plotted against time, being its X-axis tied to Gantt charts showing the illumination status of the S/C (Sun-lit/eclipse, bottom row), the MTL content (one coloured segment for each system mode, second row from the bottom), resource-related events (slews and tranquillizations, third row) and conflicts (fourth row, empty in Fig. 6).

The conflicts currently detected by CAMP are the following:

- **Agility**: if the MTL features a system event that has to start before the end of the attitude transition preceding it (slew + tranquillization).
- **Power**: when the MTL results in a trespassing of the maximum DoD accepted by the user.
- **Memory**: when the MTL features an EO event that at some point acquires data while the memory is full. A conflict arises also when the time between two consecutive images is not enough for the memory to post-process the first image and for the instrument to prepare for the second one.
- **GS antenna**: when the MTL features a downlink event that does not match the precise geometric computations made by the MTL Refinement Module.
- **On-board antenna**: when the MTL features a manoeuvre to point the on-board antenna toward the GS antenna that requires a higher gimbal angle rate than the maximum allowed.

CAMP also features an interactive viewer offering a 3-D animated representation of the satellite orbit and attitude during the entire simulation time. A screen shot is presented in Fig. 7.

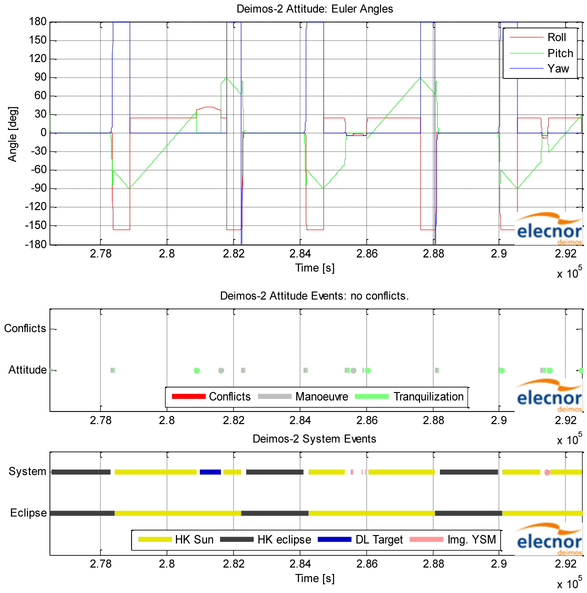


Fig. 6. Example of Conflict Analysis Composite View.

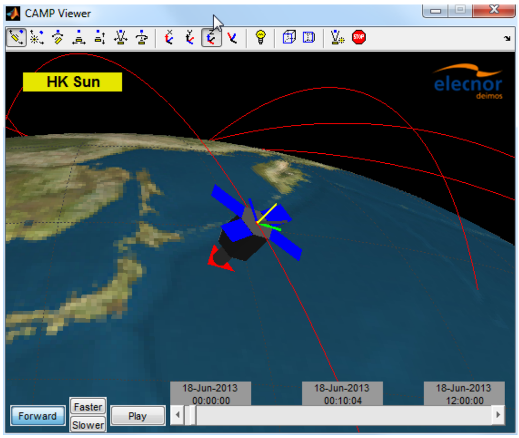


Fig. 7. CAMP Viewer.

SIGNIFICANT APPLICATIONS

The followings applications reflect the two main purposes of the tool: analyse the capacity of the mission over the long term and automate daily mission planning.

Long-Term Capacity Analysis Scenario

It is based on a fictional business case, which represents the typical possible use of the DEIMOS-2 mission. We assume a customer based in Colombia, who needs 3 different products with different characteristics and levels of criticality:

- the **monitoring of the border with Venezuela** for security purposes: maximum priority, maximum possible temporal resolution, but low image quality required (off-nadir angle < 45°);
- an **urban atlas**: the mapping of the 10 largest cities of the country, for urban monitoring purposes. A middle level of image quality is accepted (off-nadir angle < 30°);
- the **background mapping** of the highly-populated department of Valle del Cauca, with no urgency, but high image quality (off-nadir angle < 5°).

Fig. 8 shows the result of the automated MTL generation over 48 days (3 DEIMOS-2 orbit repeat cycles). The observed grid cells are shown in red. The AoIs are in green, except for the never-observed ones, which are shown in light blue. In this case the priority assignment has clear effects on the way the scheduler works: much effort is dedicated to the observation of the border, less to the cities and less to the Valle del Cauca department.

Even if the Colombia-Venezuela border is roughly aligned on the ground track (NNW to SSW: DEIMOS-2 flies on an ascending orbit), its complicated shape and the narrowness of the swath make it necessary to have frequent attitude manoeuvres to re-centre the LoS.

In order to demonstrate the flexibility of the CAMP tool, 2 other cases have been run on the same scenario, varying the priority levels of the different AoIs. Summarizing, the ordering of the AoIs in the 3 cases were:

1. Case 1: 1 Colombia-Venezuela border, 2 city areas, 3 Valle del Cauca department (see Fig. 8).
2. Case 2: 1 city areas, 2 Valle del Cauca department, 3 Colombia-Venezuela border.
3. Case 3: 1 Valle del Cauca department, 2 city areas, 3 Colombia-Venezuela border.

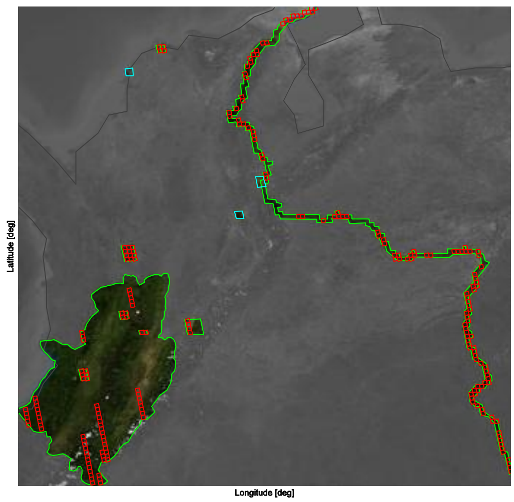


Fig. 8. Observed Areas in Colombia after 3 DEIMOS-2 Orbit Repeat Cycles.

Table 1 shows the relative coverage achievement for each AoI after 48 days for the 3 cases. The results clearly show how strongly the priority heuristic drives the scheduling process, before the FoM-based optimization refines the quality of the MTLs.

	Border	Cities	Cauca
Case 1	72%	70%	7%
Case 2	70%	100%	9%
Case 3	60%	70%	31%

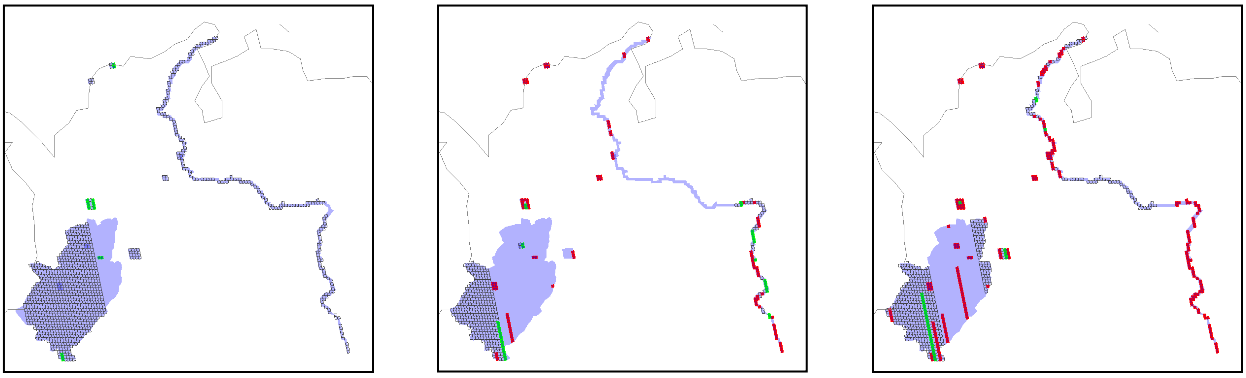
Table 1. Solution Performance Sensibility w.r.t. AoIs Priority Order. Coverage Performance for each AoI after 48 days.

Short-Term Mission Planning Scenario

The following CAMP use-cases reflect the final objective of the tool to be a prototype for the automated DEIMOS-2 Mission Planning Facility.

Daily Mission Planning Scenario

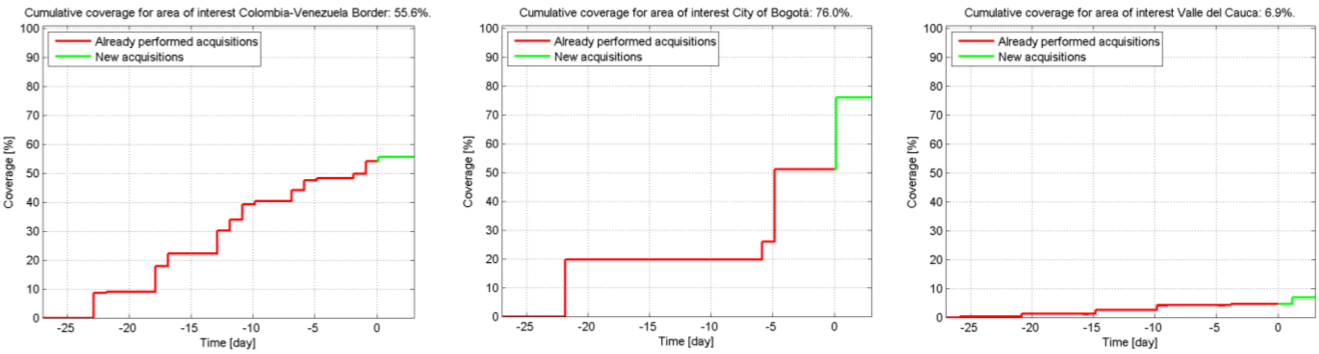
This scenario is based on the same AoIs and hypothesis of the scenario presented in the previous section, with priority levels corresponding to case 2. To reproduce the DEIMOS-2 current mission planning baseline, the scenario has been run 10 times, each time with a timeframe of 3 days, giving a total simulation duration of 30 days. At every new run, the already observed areas have not been considered in the mission timeline generation. Fig. 9 shows the covered areas after 3 days (a), after 15 days (b) and at the end of the simulation (c). The grid cells observed during previous cycles are shown in red, while the new ones are in green.



(a) (b) (c)

Fig. 9. Observed Areas in Colombia after 3 days (a), 15 days (b) and 30 days (c).

The evolution of some AoIs coverage with time is presented in Fig. 10: the border between Colombia and Venezuela on the left, the city of Bogotá in the centre and the Valle del Cauca region on the right. The red part of the line represents the cumulative coverage obtained during previous planning cycles, while the green part highlights the increment in coverage obtained during the last 3-day simulation performed.



(a) (b) (c)

Fig. 10. AoIs Coverage Evolution: Colombia-Venezuela Border (a), City of Bogotá (b) and Valle del Cauca (c).

Scenario with Many AoIs

This scenario is highly populated and it considers 135 cities across Europe, Africa, South America and the Middle East, in urban atlas mode, plus 3 countries for background mapping: Colombia, Switzerland and Azerbaijan. Fig. 11 shows a global view of this scenario. The simulation has been run on a time horizon of 3 days, similar to the DEIMOS-2 current mission planning baseline.

When starting the planning exercise, the scenario was not empty; it had already been run on CAMP 10 times, by cycles of 3 days each time, to demonstrate the capacity of the tool to run on an on-going operational scenario. The AoIs observed during one of the 10 past cycles are shown in green, the AoIs observed during the last cycle are shown in red and the never-observed areas are shown in light blue. Fig. 12 shows a magnification of the Middle East region, where the observed geo-located scenes are visible within their AoIs.

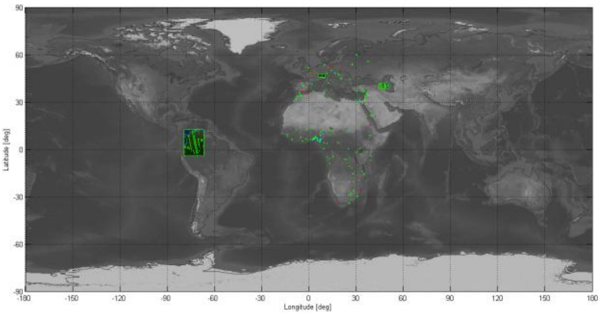


Fig. 11. User-Selected AoIs for Short-Term Mission Planning.

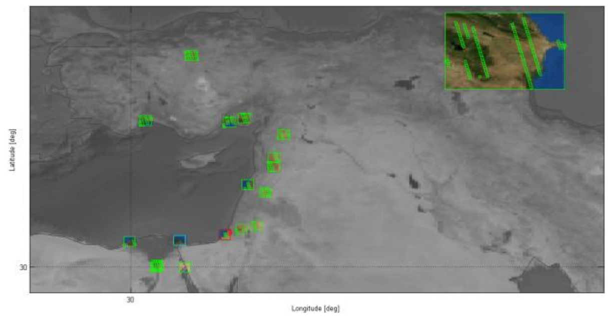


Fig. 12. Light Blue: AoI never observed; Green: AoI already observed; Red: AoI recently observed.

Fig. 13 shows an example of the GFS total **cloud cover** product used by CAMP.

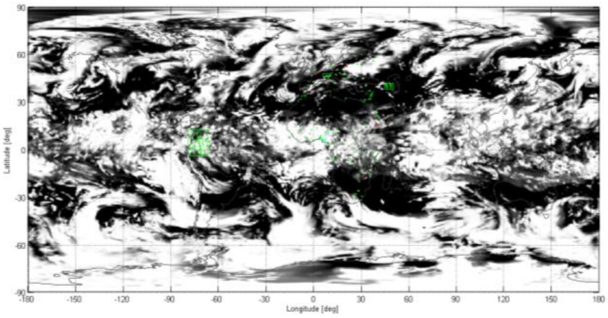


Fig. 13. Snapshot of the GFS Total Cloud Cover Data with Half-Degree Resolution.

An illustration of the impact of cloudiness on the scheduling can be seen on Fig. 14. It shows the average cloud coverage on Africa during the 3 last days of planning: the heavy presence of clouds in central Africa makes it almost impossible to observe the numerous targets located in the region. Southern Africa, on the other hand, has less cloud coverage, allowing for 3 observations in the last planning cycle (red AoIs).

With its large amount of targets, this scenario gives a good idea of the advantage of having an automated scheduler in the mission planning chain. The CAMP prototype does the same job as many operators working in parallel, faster and better.

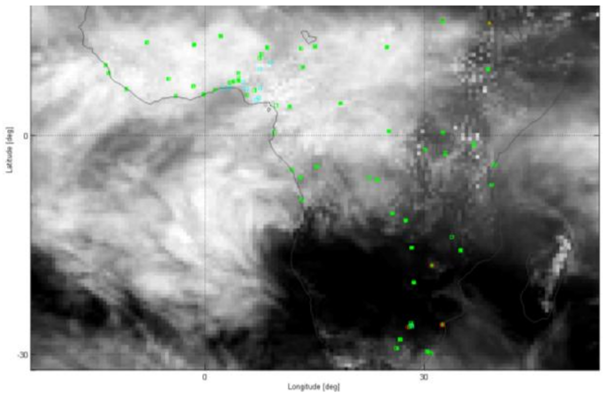


Fig. 14. Average Cloud Cover over Central Africa during 3 days and AoI.

CONCLUSIONS AND WAY FORWARD

This paper has presented a Capacity Analysis and Mission Planning Tool developed by DEIMOS to support the design and the exploitation of its new high-resolution EO mission: DEIMOS-2. The CAMP Tool provides the key simulation capabilities to enable the Mission Designers and Mission Exploitation Analysers to perform long-term mission and system capacity analysis; at the same time, it yields the computational means to be used by the Mission Planners and Operators in the real-life daily mission planning cycle.

It has been described how the CAMP Tool is able to automatically translate a set of customer areas of interest, with complex characterisation and constraints, into a detailed sequence of operations. The MTL is always compliant with on-board resources: agility, power and memory. Finally, it is chosen as the best-performing MTL amongst a set of peers generated during a process of optimization driven by genetic algorithms.

The MTL Refinement Module of the CAMP Tool yields the capability to integrate an operational mission planning chain, by taking care of the high-fidelity quality-testing of its produced MTLs and by enabling their translation into telecommand pointing angles that match the accuracy required by a very narrow swath instrument.

These capabilities have been illustrated in two use-cases: a long-term capacity analysis and a real-life daily mission planning cycle. Future work includes the full agility exploitation and the integration into DEIMOS-2 ground segment.

Last but not least, although the CAMP Tool development has been tailored to the specific operations scenario and platform capacity of the DEIMOS-2 mission, its modular architecture and flexible data flow management allow its potential tuning and customisation to deal with capacity analysis and automated mission planning tasks for similar EO missions based on agile satellites.

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