MISSION PLANNING FOR MOMS-2P

Martin Wickler, German Zoeschinger

DLR/GSOC Oberpfaffenhofen, D-82234 Wessling, Germany

Fax: +49 / 8153 / 28-1451
E-mail: Martin.Wickler@dlr.de, German.Zoeschinger@dlr.de

ABSTRACT. The spatial high-resolution Modular Optoelectronic Multispectral Scanner (MOMS-02) operating outside the PRIRODA-module of the Russian space station MIR will provide digitized high-resolution images of the earth, suitable for thematic and three-dimensional topographic mapping. MOMS-2P (MOMS-02 on PRIRODA) is a co-operative project between Russia and Germany (sponsored by DARA); the operational phase of which is expected to last 18 months starting in summer 1996. The control of and planning for the MOMS-2P camera is done by DLR/GSOC in Germany in co-operation with the PRIRODA group at the Russian control center ZUP near Moscow. The user community, consisting of Germans and Russians, has highly demanding requirements, which range from imaging whole continents to performing repetitive data imaging over small earth targets under certain seasonal and lighting conditions. On the other hand a set of operational constraints limits the possible data take opportunities (e.g. not more than 10 minutes data imaging per day are available, tape for data recordings has a capacity of 60 minutes, data dumping conflicts with recording). This calls for a sophisticated planning concept to exploit the assigned resources efficiently. This paper describes the planning concept, developed for MOMS-2P, which profits from experience gained by MOMS-planning at GSOC during the Space Shuttle mission D-2. The concept is based on a distributed planning approach. It makes use of the so-called “envelope method”, which in this case regulates the exchange of requirements and resource availabilities between GSOC and ZUP, and ensures that the MOMS-planning at GSOC is harmonized with the overall PRIRODA-planning at ZUP. The planning is carried out in three stages with an ever increasing level of detail. In the top level plan, covering a period of three months, a subset of targets is selected taking into account seasonal constraints and user-defined priorities. The so-called two week plan reflects an observation timeline, which is optimized for data takes and dumps, using statistical weather information to prefer target areas with expected low cloud coverage in this time frame. Finally a one day plan allows for consideration of actual weather and any off-nominals. The concept is realized using the GSOC mission planning system with tailored add-ons developed for MOMS-2P, especially focusing on visualisation of groundtracks and scheduling of a large number of activities. In summary the MOMS-2P planning is an example for an optimizing planning concept for any kind of future earth observation missions.

1. INTRODUCTION

The spatial high-resolution Modular Optoelectronic Multispectral Scanner (MOMS-02), earlier versions of which flew successfully on the Space Shuttle missions STS-7, STS-11 and STS-55 (D-2), was sent up to the space station MIR in spring 1996 and installed on the new module PRIRODA. The orbit inclination of 51° provides observation opportunities over Germany. Routine operations started in July 1996 and are expected to continue for at least 18 months.

MOMS data are recorded on a tape recorder on-board, which has a capacity of one hour, and are dumped at a later time over two groundstations (Neustrelitz and Obninsk). MOMS-2P operations are conducted from GSOC, which transmits command schedules to the Russian control center ZUP for review and uplink. The command schedule is the final result of the mission planning activities described below.

This paper presents the basic ideas of how it is intended to perform mission planning for MOMS on PRIRODA. In the next future experiences from the commissioning phase will be worked in and the concept will be fine-tuned.

2. GENERAL MISSION PLANNING TASKS

Mission planning in this context means developing a plan for all the activities that are to be executed on-board a spacecraft. This plan is reflected in a command schedule for unattended operations or in a crew activity plan for activities where crew is involved.

Mission planning roughly is structured into the following tasks:

- collection and analysis of availabilities, requirements and constraints
- generation of events or opportunities (which are time windows dependent on the orbit)
- scheduling of experiments and system activities
- generation of outputs needed for subsequent execution of the plan and production of documentation.

3. AVAILABILITIES, REQUIREMENTS AND CONSTRAINTS FOR MOMS-2P

The mission planning team as part of the operations personnel (OPS) has two major interfaces. On one side there is the organization responsible for system functions of the spacecraft, which is providing the overall resource availabilities for the respective payload (such as MOMS or PRIRODA). In the following this will simply be called the “system”. On the other side there are the experimenters and their representative organizations (the user community) with their intent to have experiments performed. The mission planning team as the mediator attempts to fulfill the user requirements as far as possible according to the availabilities and under the given constraints.

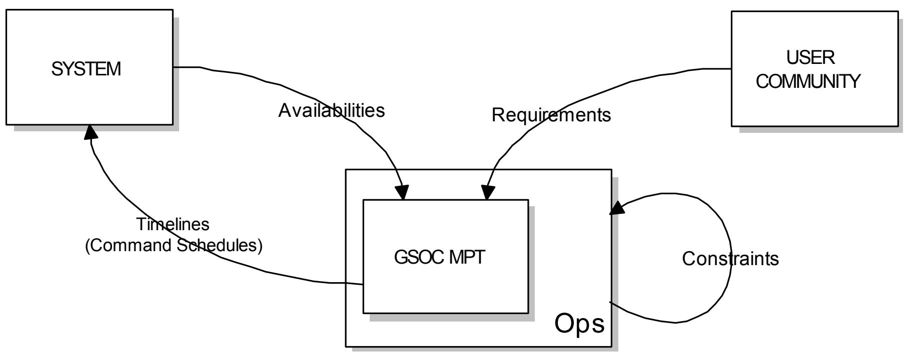

Figure 1: Availabilites, Requirements and Constraints

To give an overview of the problem domain the mission planning process for MOMS-2P has to deal with some typical examples for availabilities, requirements and constraints are listed below.

3.1 AVAILABILITIES FROM THE SYSTEM

The system provides the resources and time windows that are necessary to perform experiments. These resources and time windows are considered as availabilities for the mission planning process. In the case of MOMS-2P they are restricted for the following reasons:

- Station power is generally low.
- Earth oriented attitude is not available all time.
- The MIR station orbit is not ideal for earth observation purposes. It often leads to repetitive groundtrack patterns with big areas in between which can not be seen by the MOMS camera for a long time.
- Data takes can not be planned within 270 minutes after a dump.
- There must be a minimum delay of 5 minutes between data takes and dumps (tape repositioning).
- Data takes are to be focused in periods of 90 minutes duration.

3.2 REQUIREMENTS FROM THE USER COMMUNITY

The requirements for MOMS-2P expressed by the user community fall into three different groups:

- one data take of a well-defined earth target

  ore than one data take of a earth target under different (seasonal) conditions
- imaging wide areas (parts of continents).

The information necessary to unambiguously identify an experiment must be analyzed in detail and must be transformed into computer readable form. The information comprises of:

- descriptive information about the experiment and the experimenter (name, address of the responsible PI)
- target specification (name, coordinates)
- observation conditions (sun elevation, parallel to other PRIRODA experiments, operations mode)
- time requirements (when, duration, number of performances)
- resource usages (power, tape recorder)
- priority - experiments can belong to one of five different priority groups: calibration, commercial, pilot, imaging and science
- stereo data takes require starting 20 seconds before the target area is overflown and extending operations 20 seconds after target overflight (front and back looking beams)
- prime and corresponding backup data takes are to be performed within a TBD time period

3.3 CONSTRAINTS FROM OPS

The operational handling of MOMS-2P levies a variety of constraints:

- replanning a timeline especially due to the short-term requests must be quick and easy
- logging of all mission planning relevant information of each data take must be done
- detailed weather statistics (provided by ECMWF) and weather forecasts to optimize for minimum cloud coverage are to be used by the planning process
- all commands for data takes and dumps have to be sent to ZUP many hours in advance of the execution of the activity
- the mean observation time is restricted to five minutes per day and per dump station (Neustrelitz and Obninsk)
- data takes do not need to be continuous, the five minutes limit may be filled up by many short data takes

- data take operations have priority over dumps, which might result in tape changes that have to be done by a crew member of the MIR station - 10 tapes usable for MOMS data are on-board the MIR station
- all data takes required by the German side are to be dumped via Neustrelitz, all data takes required by Russia are to be dumped via Obninsk

4. THE MISSION PLANNING CONCEPT

4.1 GENERAL

MOMS-2P is only one sensor on the PRIRODA module but there are explicit requests for combining certain MOMS-2P observations with those from other PRIRODA sensors. The user community frequently requires parallel data takes with different other PRIRODA experiments. Additionally data takes from other PRIRODA experiments covering the same area are required, but not necessarily at the same time.

For these reasons MOMS data takes cannot be planned like for a stand-alone experiment. MOMS planning must be harmonized with the planning of other PRIRODA experiments to a high extent.

Two possibilities exist how to manage this:

(A) Planning of the other PRIRODA experiments is done at ZUP. This would lead to an approach that ZUP distributes MOMS resource envelopes to GSOC reserving the time windows where MOMS operations can take place. GSOC then would take into account the overall PRIRODA timeline to identify all other experiments which require to be coordinated with MOMS observations. In an iteration cycle with ZUP the MOMS timeline is harmonized with the overall PRIRODA timeline.

(B) The second possibility would be that the whole PRIRODA planning is done at GSOC. In this case ZUP would provide resource envelopes for the complete PRIRODA payload and GSOC would do the planning for all PRIRODA sensors. Using this approach a lot of flexibility could be gained for MOMS and PRIRODA planning.

Starting with possibility (A) at the beginning of the mission a smooth transition to possibility (B) is expected as the mission progresses in time.

4.2 AVAILABILITIES, REQUIREMENTS AND CONSTRAINTS COLLECTION

All requirements from the user community are collected electronically. The used data base is set up in such way that all the detailed experiment information can be entered by the responsible experiment scientists or the experiment representatives themselves or by a member of the mission planning team.

MP relevant system availabilities and OPS constraints must also be available in computer readable form. Especially it is important to get:

- suitable orbit information of the MIR station
- an attitude timeline (as an envelope) of the MIR station
- resource availability profiles (for all relevant system resources like power)
- the overall PRIRODA timeline in case PRIRODA planning is done at ZUP.

For information exchange with ZUP an automated file transfer system is used.

4.3 ORBIT PROPAGATION AND EVENT ON/OFF TIMES GENERATION

Orbit propagation and event generation are major tasks for MOMS-2P mission planning. All possible on/off times (or opportunities) for the requested observations and all data dump possibilities are calculated depending on the predicted MIR-orbit and the pre-defined MIR-attitude. Large target areas, for which complete coverage is required, are subdivided into smaller parts so that the completeness of coverage can easily be tracked.

4.4 ACTIVITY SCHEDULING

The timeline generation or the experiment scheduling is an automated process which uses as input the calculated opportunities and the set of experiment requirements and determines for a specified time frame, which is defined by the envelopes provided by ZUP, a schedule under the given constraints that is optimized for minimum cloud coverage and experiment priority.

The result is a chronological list of all experiments that are to be performed in the specified time frame. This list is called the timeline and is the basis from which the command schedule is derived that is sent to ZUP.

4.5 LOGGING, OUTPUTS AND DOCUMENTATION

For MOMS planning it is necessary to get feedback of the success of performed data takes. This is especially important for experiments requiring a complete coverage of wide areas.

Beside the experiment timeline in computer readable form a various list of other products are generated. These include data uplink and downlink schedules and documentation for the user community about planned experiments and their resource usages.

4.6 MISSION PLANNING PHASES

The MIR station orbit changes daily due to changes in the upper atmosphere and attitude changes needed to keep the solar panels aligned. Long-term predictions cannot take into account the occasional docking operations or orbit maintenance maneuvers. This is the reason why the error of propagating a groundtrack increases with how much longer the look-ahead period lies in the future. Since all MOMS planning depends on the accuracy of the propagated orbit the planning is done in three stages with an ever increasing level of detail:

- the long-term planning covering a period of three months
- the mid-term planning covering a period of two weeks
- and the short-term planning which is done for every day.

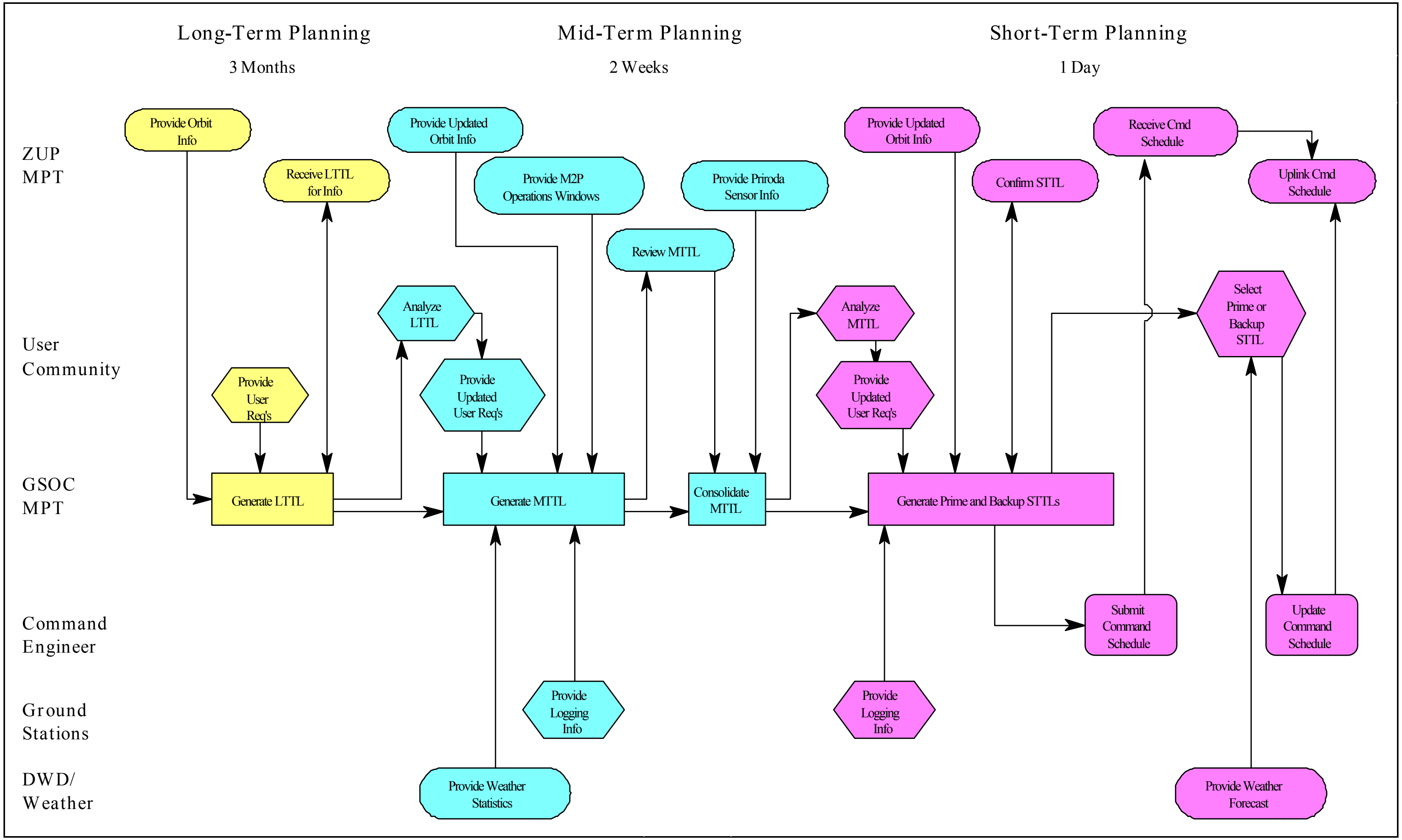

Figure 2 The Mission Planning Phases For MOMS-2P

4.6.1 LONG-TERM PLANNING

The PRIRODA mission is separated into time increments with a duration of 3 months. The long-term planning covers this time frame. Within this process a rough pre-selection of the possible experiments is done. The rules of this pre-selection take into account user requirements, general lighting conditions and overall restrictions in system availabilities. The long-term timeline (LTTL) is primarily useful to filter and extract those experiments from the whole data base, which are to be planned in the mid-term timeline. Depending on the system resource availabilities (e.g. during any docking activities no attitudes useful for PRIRODA are possible) a consolidated target observation proposal is generated. It contains a list of experiments reflecting experiment priority as well as the probability to perform it within a certain time frame. This probability depends on the target size, on the required lighting conditions and on specific time requirements.

4.6.2 MID-TERM PLANNING

Each 3-month-increment is separated into mid-term increments with a duration of 10 to 20 days. The exact duration depends on major MIR station events like orbit maneuvers, reboosts or dockings.

Mid-term planning allows considering new or updated requirements from the user community.

In a first step for the pre-selected experiments from the LTTL, which fall into the corresponding mid-term time increment, the experiment priority is adjusted according to the logging information. This is especially essential when imaging wide areas: in an extreme case for example if only a small target is missing in an otherwise completely covered area the corresponding activity would get assigned a very high priority.

From statistical climatology data so-called suitability functions are generated for each experiment which could be planned in the mid-term time frame. These functions set preferences for those observations having scheduling possibilities during low cloud coverage.

The resource availability envelopes from ZUP define the gross time windows when MOMS observations can take place. Within these time windows observations are planned under the constraint that data takes do not exceed 10 minutes per day in the average and lie within one orbit (which is 90 minutes).

Taking into account the timelining of the other PRIRODA experiments an automated scheduling process then produces a MOMS timeline which is optimized for experiment priority and low cloud coverage.

Since the on-board tape recorder capacity is limited to one hour the scheduling must ensure that data can be dumped accordingly. This might lead to the problem that possible data takes are lost because during these data take times dumps have to be planned into the timeline.

Should the actual MIR station groundtrack pattern (which varies slowly with time) not allow to cover targets having assigned a very high priority then the possibility exists to request a slight attitude change of the MIR station if this allowed observing the target.

4.6.3 SHORT-TERM PLANNING

The mid-term increment is again divided into 1-day increments (this 1-day increment covers the time from 8:00 ZUP time to 8:00 ZUP time of the following day). For each day a prime short-term timeline (STTL) and one or more backup timelines are generated.

The STTL is the basis for the command schedule. The STTL contains:

- the detailed on/off-times of the MOMS-camera (for the prime and backup data takes)
- the scheduled ground station contact times for tape dumps (as proposals for the OPS-team)

- the required attitude of the MIR station
- additional experiment information (experiment name, mode, altitude, latitude, longitude).

The STTL (with the corresponding command schedule) must be available at ZUP 6 days before experiment execution will take place. Three days before execution the possibility exists to compensate for orbit uncertainties by requesting a slight change in the MIR station attitude. Roughly 21 hours before the STTL gets valid (the exact time depends on the visibility of Russian groundstations) GSOC OPS together with the user community decide whether to go for the prime or for the backup plans. This decision mainly depends on the weather forecasts for the planned target areas. If the weather is bad for prime and backups, the prime is default - planned data takes will not be canceled.

Short-term planning takes into account:

- the latest orbit information
- the latest MIR/PRIRODA timeline
- responses to the MTTL from the user community
- ZUP response to the MTTL
- weather forecasts
- need for attitude change requests.

4.6.4 LOGGING

Information about the success of a data take is fed back to the future planning process. It influences the priorities of selected activities during the mid-term planning. Data takes over areas with less than 10% cloud coverage are considered good and the corresponding activity is considered completed.

Therefore the following mission planning relevant logging items must be stored in computer readable form:

tart and stop time of the successful parts of all data takes
- experiment specific information (e.g. the mode of the experiment)
- orbit information valid at the start time (of each successful part of a data take)
- the MIR attitude during the data take.

Start and stop times are received from the ground stations Neustrelitz and Obninsk. The orbit information is calculated from the Global Positioning System data stream which is downlinked with the science data. The attitude information and the specific experiment information is received from ZUP as part of the MIR/PRIRODA housekeeping data stream.

5. SUMMARY

Mission planning for the MOMS camera installed on the PRIRODA module of the MIR station takes into consideration the long duration character of the mission by evaluating already performed data takes and feeding this information back into the planning process. From the use of statistical cloud coverage data it is expected that the limited time available for MOMS operations is exploited more efficiently and the area covered by data takes will be increased compared to conventional planning.

ACKNOLEDGEMENT

The project this paper bases on was funded by DARA (Deutsche Agentur für Raumfahrtangelegenheiten GmbH) under the identification 50 EE 9537. The responsibility for this paper is with the authors.

ABBREVIATIONS

ECMWF	European Centre for Medium-Range Weather Forecasts
GSOC	German Space Operations Center
LTTL	Long-Term Timeline
MP	Mission Planning
MPT	Mission Planning Team
MTTL	Mid-Term Timeline
OPS	Operations Personnel
STTL	Short-Term Timeline
ZUP	Zentr Uprawlenija Poljotom (MIR Mission Control Center)

REFERENCES

[1] Mission Planning Concept and System for MOMS-2P and PRIRODA, M. Wickler, G. Zoeschinger, DLR/GSOC, M2P-GSO-G70-SP-001, July 1995

[2] A Mission Planning Concept and Mission Planning System for Future Manned Space Missions, M. Wickler, DLR/GSOC, October 1994

[3] European Centre for Medium-Range Weather Forecasts: http://www.ecmwf.int/