J. Astron. Space Sci. 20(3), 227–238 (2003)

# DESIGN AND IMPLEMENTATION OF THE MISSION PLANNING FUNCTIONS FOR THE KOMPSAT-2 MISSION CONTROL ELEMENT

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*(Received August 4, 2003; Accepted August 28, 2003)*

## ABSTRACT

Spacecraft mission planning functions including event prediction, mission scheduling, command planning, and ground track display have been developed for the KOMPSAT-2 mission operations. Integrated event prediction functions including satellite orbital events, user requested imaging events, and satellite operational events have been implemented. Mission scheduling functions have been realized to detect the mission conflicts considering the user specified constraints and resources. A conflict free mission scheduling result is mapped into the spacecraft command sequences in the command planning functions. The command sequences are directly linked to the spacecraft operations using eXtensible Markup Language (XML) for command transmission. Ground track display shows the satellite ground trace and mission activities on a digitized world map with zoom capability.

*Keywords:* satellite event, mission scheduling, command planning, ground track, MAPS, KOMPSAT-2

## 1. INTRODUCTION

KOrea Multipurpose SATellite-2 (KOMPSAT-2) is the following program of the KOMPSAT-1, which is currently carrying out the multipurpose missions such as earth observation, ocean color monitoring, and some scientific experiments. Specifically the KOMPSAT-2 mission is focused on the realization of 1 m panchromatic and 4 m multi-spectral high-resolution images for Geographic Information System (GIS) and the composition of printed maps and digitized maps while the KOMPSAT-1 has 6.6 m panchromatic images. The satellite will be launched by Rockot-KM launch vehicle from Plesetsk, Russia in 2004. The mission orbit of the satellite is a sun-synchronous circular orbit with a mean altitude of 685.13 km, an inclination of 98.13 degrees, and a local time of ascending node (LTAN) of 10:50 AM same as the KOMPSAT-1 satellite except for phasing of the orbital position. This implies that two satellites can be separated in terms of time in the same orbit (Lee 2000, Kim et al. 2003).

The KOMPSAT Ground Station (KGS) is comprised of Mission Control Element (MCE) and Image Reception and Processing Element (IRPE). MCE is responsible for telemetry reception and monitoring, mission analysis and planning, command planning and transmission, and satellite simulation. IRPE is used for image reception and processing. MCE communicate with the satellite upward and downward via S-band link while IRPE receives only via X-band link. The MCE consists of

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four subsystems such as Tracking, Telemetry and Command (TTC), Satellite Operations Subsystem (SOS), Mission Analysis and Planning Subsystem (MAPS), and Simulator subsystem (SIM). TTC provides the S-band uplink and downlink communications with the satellite. SOS provides satellite housekeeping telemetry data processing, state of health monitoring, and command generation and execution (Jung et al. 2002). MAPS provides the satellite mission planning, incorporates user requests, defines satellite configurations, and prepares operation schedules (Lee et al. 2002a). MAPS also provides the satellite operation functions such as orbit determination, orbit prediction, antenna pointing data generation for tracking. SIM provides support functions rather than direct operational function such as anomaly resolution support and operation personnel training (Lee et al. 2002d).

KOMPSAT-2 MCE MAPS has new functions and features for the high resolution imaging mission and operational conveniences. Precise orbit determination using Differential GPS (DGPS) technique for 1 m ($1\sigma$) positioning accuracy is implemented (Lee et al. 2002c). The mission scheduling function will be developed in-house for the operational convenience unlike the KOMPSAT-1 adopted the Commercially Off-The-Shelf software (COTS) such as GREAS (Galiber & Dimitrov 1998, Dimitrov & Galiber 1998). The command planning results are directly connected to the SOS for the secure commanding using eXtensible Markup Language (XML).

Mission planning consists of functions such as event prediction, mission scheduling, command planning, and ground track display. The event prediction provides satellite and ground related event such as contact time for the ground stations, eclipse time due to the earth and moon, and satellite sensor intrusion time. The mission scheduling provides a satellite operation timeline including satellite camera operation, image dump, telemetry dump, and orbit maneuver operations. The command planning converts the mission scheduling result into the command mnemonic set for telecommand transmission. The ground track display provides satellite ground trace and mission activities on a digitized world map with zoom capability.

In this paper, design and implementation of the mission planning functions in MAPS for the KOMPSAT-2 MCE are presented. An Object Oriented Design (OOD) approach is used for the process of subsystem analysis and design (Pooley & Stevens 1999). Subsystem analysis is composed of Use-Case Model and Domain Model. Subsystem design consists of User Interface Design and Architecture Design. Logical View, Implementation View, Process View, and Deployment View are the four views of the architecture design (Kruchten 1995). Implementation of the mission planning software was performed with C++, an Object Oriented Programming language. Qt tool kit by Trolltech was used for implementing the graphical user interface and application program (Trolltech 2003).

## 2. DESIGN OF THE MISSION PLANNING FUNCTIONS

Figure 1 shows the functional structure and interfaces of the MAPS in KOMPSAT-2 MCE. As shown in the figure, the Mission Planning (MP) consists of functions such as event prediction, mission scheduling, command planning, and ground track display. The event prediction provides event prediction data such as contact time for the ground stations, eclipse time due to Earth and Moon, and sensor intrusion time. The mission scheduling and timeline generation provides the capabilities for the mission scheduling and generates the mission timeline. The command planning provides the capabilities for generating the command plan compatible to telecommand for the direct commanding in SOS. The ground track display provides the capabilities for the ground track display of satellites on the world map for the mission plan and operation's support. The MP is newly designed and implemented for the KOMPSAT-2 mission using Object Oriented Design (OOD) methodology.

Figure 2 shows a process of the mission planning operations including the event prediction,

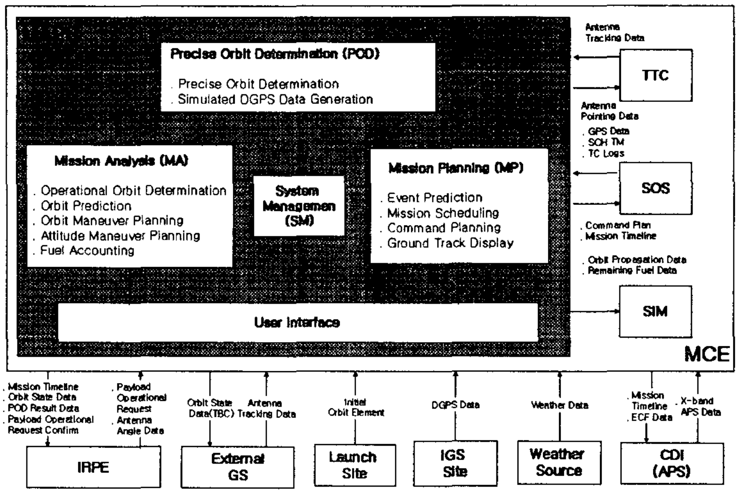


Figure 1. Functional structure and external interfaces in MAPS.

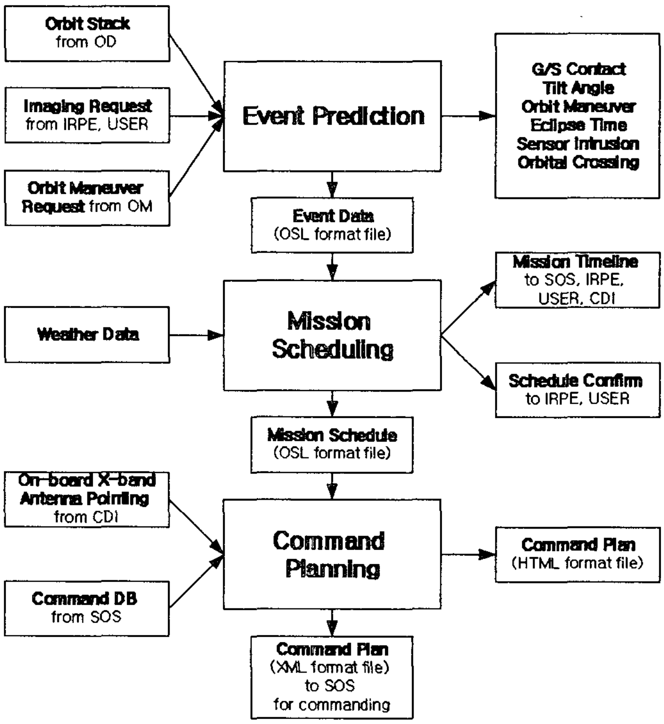


Figure 2. Mission planning flow.

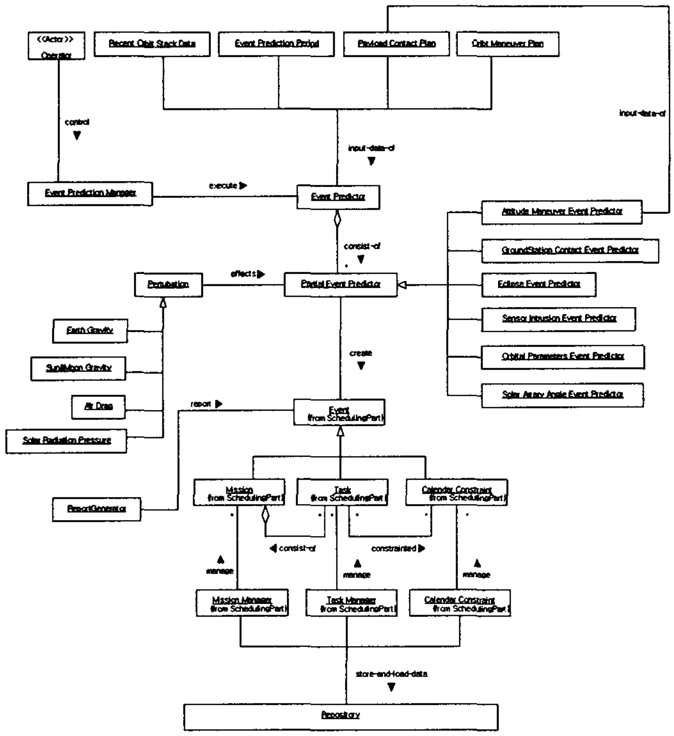


Figure 3. Class diagram of the event prediction.

mission scheduling, and command planning. The KOMPSAT-1 mission scheduling results can be referenced in the KOMPSAT-2 mission scheduling by using common Object Scheduling Language (OSL). After the successful mission scheduling, individual mission timeline and imaging schedule result (confirm or reject) can be transmitted to independent imaging requesters such as IRPE and USER. On-board X-band antenna pointing generation function is developed as Customer Developed Item (CDI).

The event prediction function generates the satellite orbital events based on the ground station locations, orbit maneuver plan, and camera operation plan from satellite image users. Precision attitude maneuver angles for satellite imaging and orbit maneuver are calculated in the event prediction function. The satellite orbit prediction is included in the event prediction functions. The following events are predicted in the event prediction function.

- Satellite contact time in specific ground stations
- Eclipse due to the earth and moon
- Satellite pass time in equator, pole, apogee, and perigee
- Satellite earth sensor interferences due to the sun and moon
- Satellite attitude maneuver for imaging and orbit maneuver

Figure 3 presents a class diagram of event prediction in domain modeling. The class diagram shows the related classes and their relationships.

Mission scheduling function should allocate various satellite activities in the time frame without

Table 1. Example of the KOMPSAT-2 mission scheduling elements.

| Elements | Examples |
|---|---|
| Mission | Imaging, On-board image data dump, Orbit maneuver, Telemetry dump |
| Tasks | Attitude maneuver, On-board X-band antenna positioning |
| Constraints | Eclipse, Contact time, Sensor interference |
| Resources | On-board memory for imaging, On-board fuel, Ground station availability |

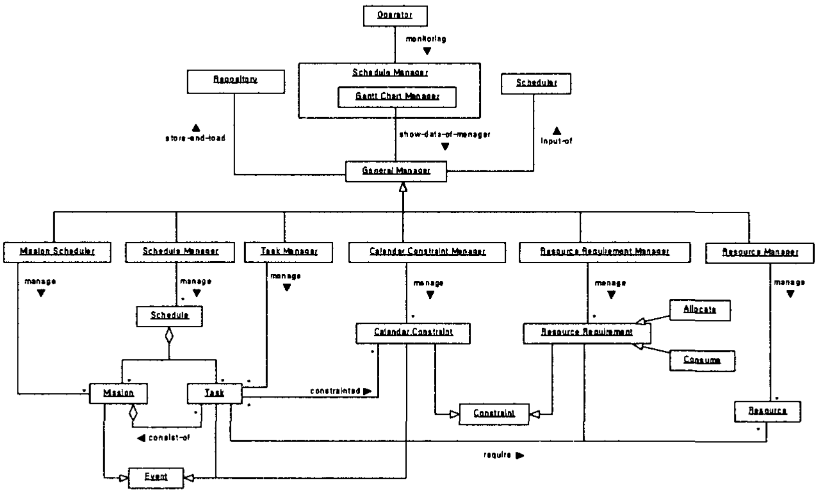


Figure 4. Class diagram of the mission scheduling.

any conflict among the missions. In mission scheduling, a satellite mission is composed of more than one task, and the mission should consider the constraints and resources. The event prediction result which is formatted in OSL is used for the input of the mission scheduling. Each satellite event is mapped into the mission, task, and constraint by the predefined rule. The relationship among the missions, tasks, constraints, and resources are also defined to detect the mission conflicts. Table 1 shows example of the elements in the mission scheduling.

Relationship between the mission and task can be 1 to 1 or 1 to n. In an imaging mission, three tasks such as the attitude maneuver task for pointing the target before imaging, image acquisition task, and attitude maneuver task for re-orientation after imaging are included. Constraints act as a certain task should include or exclude a certain constraint. For example, telemetry data dump and on-board image data dump should be performed during the satellite-ground station contact time. Resource is required for completing a certain task as the satellite on-board memory is required for storing the satellite image in the imaging task. There are two types of the resources. One is the allocatable resource and the other is consumable resource. The allocatable resource is considered as reusable resource such as on-board memory and the consumable resource cannot be reused once it used such as on-board fuel. Mission scheduling generates a conflict free mission timeline for the satellite operation based on the missions, tasks, constraints, and resources.

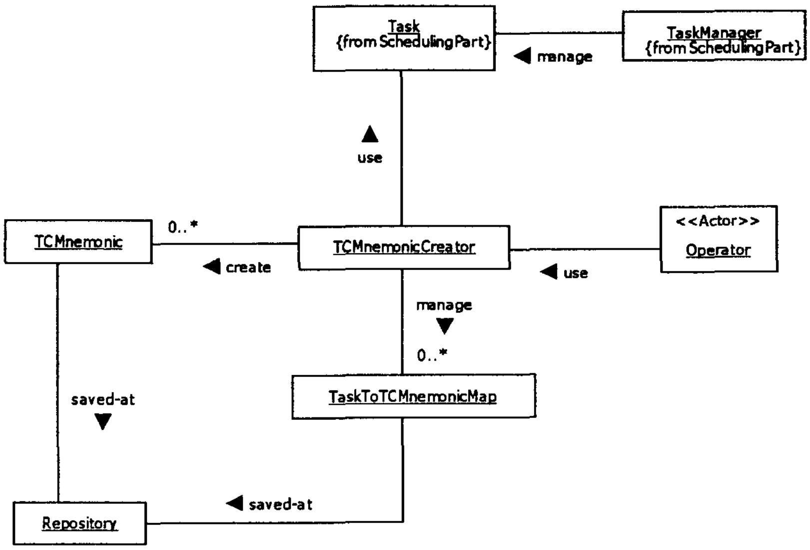


Figure 5. Class diagram of the command planning.

Instead of using COTS software such as the GREAS for the KOMPSAT-1 project, in-house development of the spacecraft mission scheduling was performed for customizing the software to the KOMPSAT-2 specific mission. The design of the software is focused on the automation of the scheduling process to reduce the operators' activities and the integration of the scheduling results into the command planning process. Figure 4 shows the class diagram of the mission scheduling in domain modeling process.

Satellite command should be transmitted from ground station to the satellite for completing the mission according to the planned mission timeline. Command planning function translates the tasks in the mission scheduling result into the satellite command mnemonics for command transmission. Satellite command sequences for a specific task can be predefined.

Different command sequences can be selected according to the parameter values in a specific task using predefined mapping rule (Lee et al. 2002b). The final result of the command planning is a XML format command file, which is sent to the Satellite Operations Subsystem (SOS) for commanding to the satellite during the contact time. Using XML format command files, the SOS operator can get the same command files as the MAPS command planner. This prevents the SOS operator from mistyping the command sequences in case of using the MAPS generated command sheets like the KOMPSAT-1 operation. Figure 5 shows the class diagram of the command planning in the domain modeling process.

## 3. IMPLEMENTATION OF THE MISSION PLANNING FUNCTIONS

Event prediction is implemented as two executables. One is the 'Orbit Propagator' for predicting the position of the satellite, sun, and moon. The other is 'Event Manager' for extracting the user specified satellite events from ephemerides of the satellite, sun, and moon. Figure 6 shows the

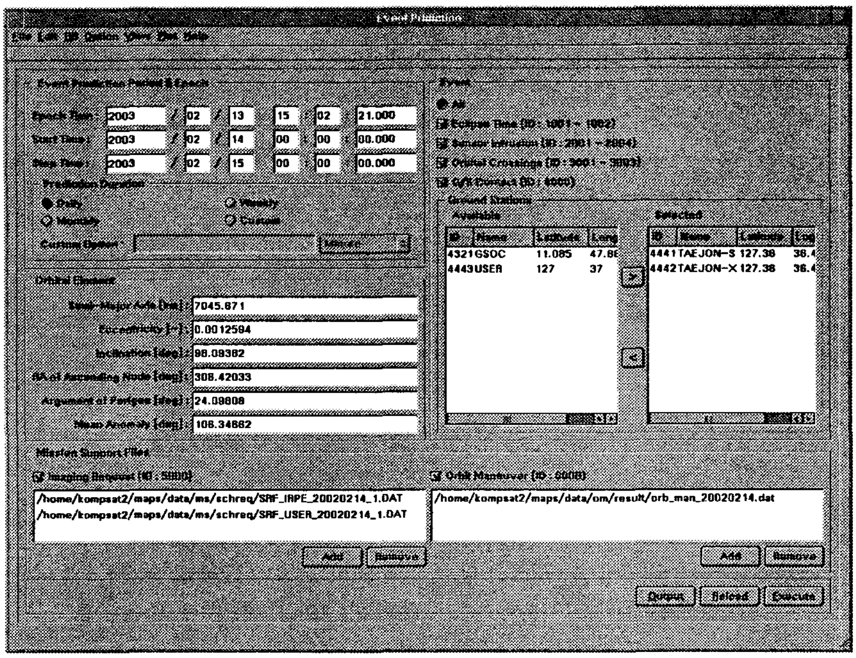


Figure 6. Event prediction main window.

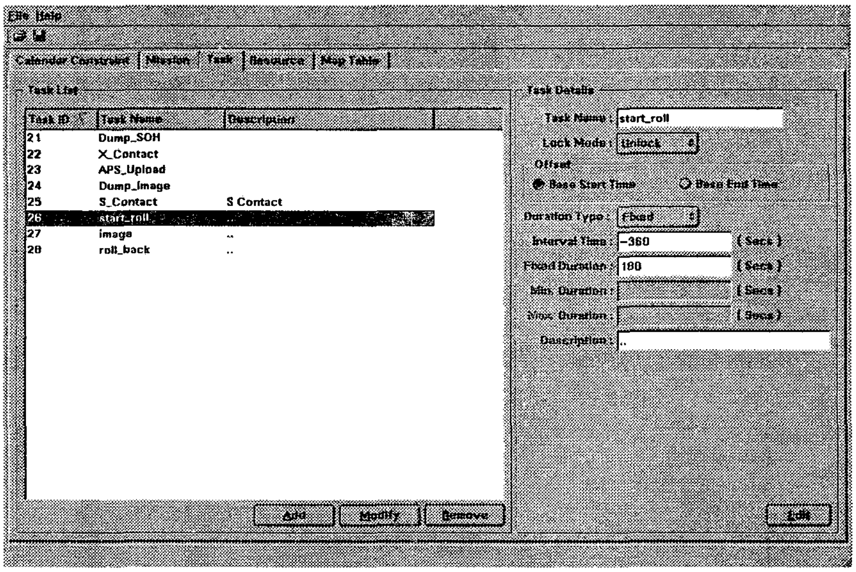


Figure 7. Template editor window in mission scheduling.

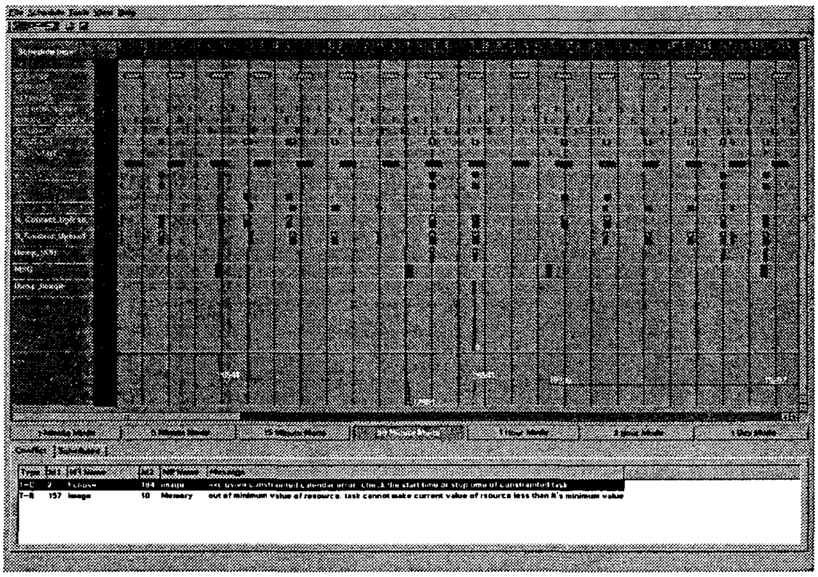

Figure 8. Gantt chart in mission scheduling.

event prediction main window. The orbital elements of the satellite are automatically searched from orbit determination database. Imaging requests and orbit maneuver plan are another input for event prediction. Satellite attitude maneuver angle for imaging and orbit maneuver is also calculated in the event prediction process. The event output is formatted in OSL for mission scheduling.

Mission scheduling is implemented as two executables. One is the 'Template Editor' that defines the properties of the missions, tasks, constraints, and resources and their relationships. The other is 'Scheduler' that shows the Gantt chart from event prediction results, detects any conflict among the missions, and generates mission timeline.

Figure 7 shows the 'Template Editor' window for defining tasks. Four elements in the mission scheduling such as constraints, missions, tasks, and resources are defined in the window environment. The relationships among the scheduling elements are defined in the Map table for the detection of the conflict.

Figure 8 presents a Gantt chart in the mission scheduling. All of the scheduling elements are shown in the chart as a time-order. Mission conflicts and their reasons are listed in the bottom of the chart. And also, the conflict related missions and constraints (or resources) are connected by a line for easy resolution of the conflict.

Command planning function is implemented as 'Command Planner' and 'Command Updater'. The Command Planner converts the mission scheduling results into the satellite command plan by using mapping rule. And it provides editing capability for add/delete the commands. The Command Updater reads command database in the Satellite Operations Subsystem using SQL. Spacecraft commands should be uploaded before starting the actual mission in the mission scheduling. In order to do it, ground station contact time in the near future is displayed in the command planning window as shown in Figure 9. The operator can select the contact time and related missions for commanding. The unselected missions remain in the command planning window for commanding at the next

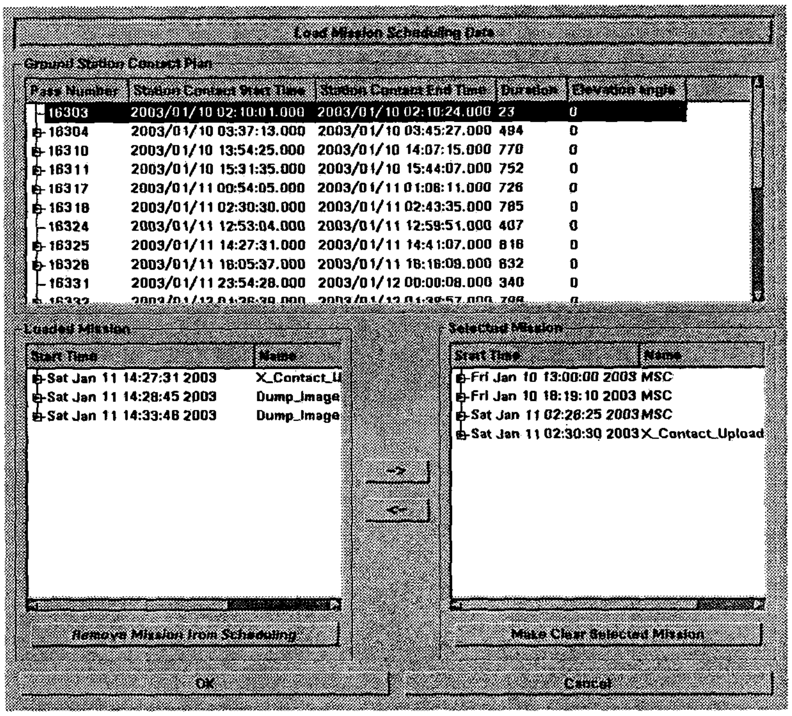


Figure 9. Command planning window.

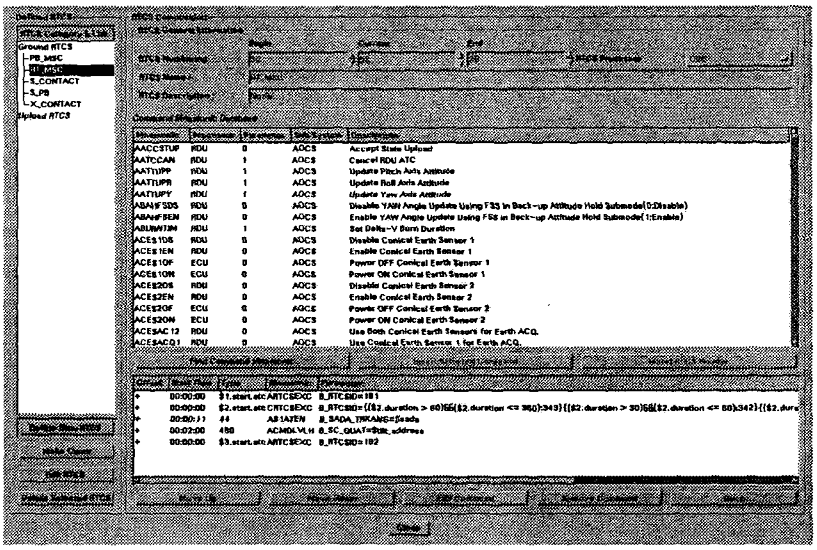

Figure 10. Relative time command sequences definition in command planning.

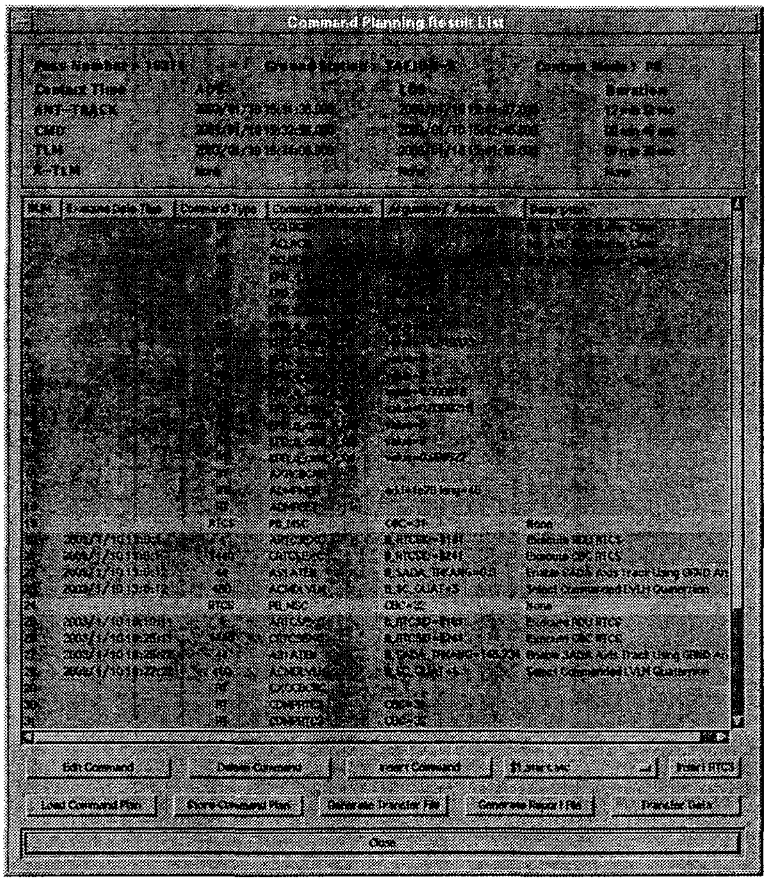

Figure 11. Command editing window.

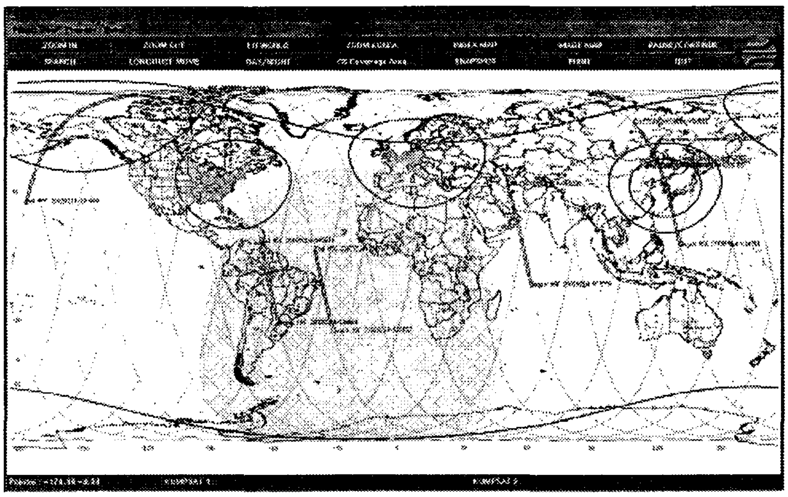

Figure 12. Ground track display.

ground station contact.

The selected missions are converted into the spacecraft commands by using predefined mapping rule. Mapping rule is implemented such that the different command sequences can be selected for the same mission according to the parameters in it. For the imaging mission, attitude tilt angle and imaging time are the key parameters for selecting the different command sequences. Figure 10 shows the window for defining the missions and the related relative time command sequences.

After converting the selected missions into the spacecraft commands, command editing window in Figure 11 is popped up. In the window the user can confirm the command sequences and edit the commands for immediate requests. The comfirmed command sequences are saved as XML format for tranferring to SOS and HTML format for users.

Figure 12 shows the ground track display window. The ground track display is implemented as one executable. Satellite ground track data file is generated in the orbit prediction executable. Mission timeline is generated in the mission scheduling.

## 4. CONCLUSIONS

Design and implementation of the mission planning functions in the Mission Analysis and Planning Subsystem for the KOMPSAT-2 Mission Control Elements are presented. A standard Object Oriented Analysis and Design (OOAD) methodology was successfully applied to the analysis and design process. In the software implementation process, Object Oriented Programming (OOP) language such as C++ with Qt library was used for code reusability, functional extendibility, and system reliability. All of the functions in the mission planning have been tested in the MAPS subsystem test completed in May 2003. The MAPS will be installed in the KOMPSAT Ground Station (KGS) and tested for the external interfaces. After completing the final acceptance test, the system is ready for launch of the KOMPSAT-2 in 2004.

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