LRO MPS

Mission Planning and Scheduling System for NASA’s Lunar Reconnaissance Mission

GSAW 2009

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OVERVIEW: LRO Mission

- The Lunar Reconnaissance Orbiter (LRO) is the first mission in NASA's planned return to the moon.
- LRO will launch in Q2, 2009
- Objectives
  - find safe landing sites
  - locate potential resources
  - characterize the radiation environment
  - test new technology
OVERVIEW: LRO Mission Planning & Scheduling (MPS): Functions

MISSION CRITICAL FUNCTIONS:
- **Produce an integrated schedule** of non-conflicting, coordinated ground and space segment operations
- **Build Stored Command Loads** (Relative and Absolute Time Sequences)
- **Generate Ground Pass Scripts** for Automation
- **Build Ephemeris Load Files**

MISSION SUPPORT FUNCTIONS:
- Slew Maneuver Planning
- Onboard Memory Modeling
- Execution Verification Feedback
- Generation of Activity Reports
## OVERVIEW: LRO MPS Heritage

LRO MPS is based on **flexplan**, also selected for:

<table>
<thead>
<tr>
<th><strong>Metop</strong> – European Organization for the Exploitation of Meteorological Satellites (EUMETSAT): Joint mission with NOAA</th>
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</thead>
<tbody>
<tr>
<td>- Launched October 19, 2006</td>
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<tr>
<td>- Currently operational.</td>
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<tr>
<th><strong>SMOS</strong> (Soil Moisture and Ocean Salinity) – European Space Agency (ESA):</th>
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<tbody>
<tr>
<td>- Final release accepted in 2006</td>
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<tr>
<td>- Expected launch in mid-2009</td>
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<thead>
<tr>
<th><strong>LDCM</strong> (Landsat Data Continuity Mission– Landsat 8) – NASA Goddard Space Flight Center (GSFC) / US Geological Survey (USGS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Expected launch in 2012.</td>
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OVERVIEW: Interfaces

- MPS interfaces with various elements using a file based transfer.
OVERVIEW: Architecture

MPS

flexplan module
Optional module

Key:
EI – External Interface
MEP – Mission Environment Preparation
TEG – Tailored Event Generation
PIC – Product Input Customization
SG – Schedule Generation
CR – Conflict Resolution
RQT – Report Query Tool
SE – Schedule Execution

GN – Ground Network
FDF – Flight Dynamics Facility
T&C – Telemetry and Command

Oracle Central Database

Adapters
XML Adapter

Load Builder
CCSDS Packetizer

MOC

File Exchange (XML, ASCII, etc.)

GNSO Schedule
Activity Requests
Orbital-events, Maneuvers
Events/Requests
Command/Procedure DB
MPS Reports
flexplan Log
Execution Status
Command/Procedure Schedules
Command/Procedure Loads

GN Station
Science Centers
FDF
...

T&C

RTS Export
CR
RQT
Cmd
TEG
Log
PIE
SE

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SCHEDULE GENERATION PROCESS

1. Ingest products into MPS
2. Add, modify, or delete an event
   - Yes: Generate PIC
   - No: Proceed to Schedule Generation
3. Initiate Schedule Generation
4. Review schedule
5. MOT modifies, deletes, or adds sequences
   - No: Proceed to Schedule Generation
   - Yes: Ready to conflict check
6. Ready to conflict check
   - Yes: Initiate Conflict Resolution
   - No: Proceed to Schedule Generation
7. Review schedule for conflicts
8. Conflicts
   - Yes: Resolve conflicts
   - No: Proceed to Schedule Generation
9. Generate Executable Schedule
10. Generate ATS and pass scripts
11. Approve and sign products
12. Products ready for operations
INPUTS: Processing

- LRO MPS receives and processes **over 100 different input events** belonging to more than 15 categories from various internal and external elements of the MOC.

- **Inputs** include:
  - Space or ground events identifying periods of time in which mission activities must or must not take place
  - Events of possible interest and relevance to some or all LRO scheduling elements
  - Specific request to add activities with certain characteristics to the schedule at a specific time or during a particular event

- All the inputs are not required to generate a daily schedule.
**INPUTS: Generic Input XML Schema**

- **flexplan** implements a single open XML schema for all planning inputs, of any type.
- The schema structure provides a flexible XML message that easily maps to any information of the planning inputs.

```
Tracks input file

Start of the scheduling period being updated

End of the scheduling period being updated

Event or request information

<EVENT>
  <UTC_Start_Time>26-oct-2008 12:28:42.000</UTC_Start_Time>
  <Duration>12878</Duration>
  <Event_Description>FDF09_OMNI_DS24</Event_Description>
  <Sat>GRD</Sat>
  <Entity>Omni</Entity>
  <List_of_Event_Parameters>
    <Event_Parameter>
      <Event_Part Name>ORBIT</Event_Part Name>
      <Event_Part_Value>1</Event_Part_Value>
    </Event_Parameter>
    <Event_Parameter>
      <Event_Part Name>MAX_ELEV</Event_Part Name>
      <Event_Part_Value>6.494</Event_Part_Value>
    </Event_Parameter>
    <Event_Parameter>
      <Event_Part Name>TIME_MAX_ELEV</Event_Part_Name>
      <Event_Part_Value>2008302.122842</Event_Part_Value>
    </Event_Parameter>
  </List_of_Event_Parameters>
</Event>
```

**XML:** eXtensible Markup Language
MISSION DEFINITION: Operational Issues

- Off-line process performed during the definition phase of the mission.
- Create and define all the data structures that will be used routinely to generate schedules.
- These data structures reside in the MPS Oracle database.
- Master Schedules with all scheduling rules reside in configuration controlled repositories.
- The data in the MEP implements the set of operational requirements for the LRO Orbiter.
- The Mission Definition can be updated during the operation phase as required.
MISSION DEFINITION: Resources and Events

- **Resources:**
  - Configured to keep track of the resource usage and avoid scheduling of conflicting tasks.
  - Allowed to create Analytical modeling of physical elements (e.g. solid state recorder) based on schedule activities.
  - Can represent logical elements (e.g. availability of personnel).

- **Events:**
  - Planning inputs automatically ingested by *flexplan*
  - Defined by category and source
  - Can have input parameters and predefined attributes
MISSION DEFINITION: Scheduling Rules

- Information from scheduling inputs and resources are used in user-defined scheduling rules to add tasks to the schedule.
- Rules are saved in files and are placed under Configuration Management.

Scheduling Input Event

```xml
<Event>
  <Event_Param_Name>START_TIME</Event_Param_Name>
  <Event_Param_Value>2009-01-25 13:00:00.000</Event_Param_Value>
</Event>
```

Mission Scheduling Rule

```xml
WHEN

there is a Event [] called Event_name such that name equals "GNS01_S-BAND"

THEN

assert [ ] Task []
so that parentEvent = Event_ID
and name = START_CONTACT
and offset = -600 * 1000

assert [ ] Task []
so that parentEvent = Event_ID
and name = START_CONTACT

and addIntParameter(true, "ASYEAR", getYear(Event_startUTC))
and addIntParameter(true, "AGSDOY", getIntDOY(Event_startUTC))
and addIntParameter(true, "ACSHOUR", getIntHour(Event_startUTC))
and addIntParameter(true, "ACSMIN", getIntMinute(Event_startUTC))
and addStringParameter(true, "ACTION", Event_entity)
```
SCHEDULE GENERATION: Operational Issues

- Involves populating a working schedule with instances of Sequences.
- The majority are inserted automatically during the execution of rules, triggers are the scheduling inputs.
- User selects set of rules to use for a given schedule.
SCHEDULE GENERATION: Orbiter and Ground Schedule

- The LRO MPS schedules Orbiter and Ground activities simultaneously on a single time line.

- Orbiter Activities are exported in the Absolute Time Command Sequence Loads (ATS).

- Ground Activities are exported in a series of Pass Scripts.
CONFLICT RESOLUTION: Constraint Checks

- All schedules generated by the MPS are checked for:
  - Timing relationship constraints
  - Resource consumptions violations
  - All command parameter values must be within DB limits

In addition, user defined constraint rules are supported:
- Maximum Orbiter commands per schedule and per second
- Maximum slews per orbit and per day
- Maximum slew angle and duration
CONFLICT RESOLUTION: Display Notification

Timing Constraint

OOL Constraint

Resource Constraint

Resource availability

Over consumption

Nominal resource usage
AUTOMATION: Ground Pass Scripts

- Automation of nominal supports is driven with **pass scripts** generated by the MPS.
- Pass scripts conform to formats from the Satellite Test and Operations Language (**STOL**) used by the LRO Telemetry and Command (T&C) system.
- The T&C system reads the pass scripts using a STOL procedure developed by the Mission Operations Team.
- Once the pass script is read successfully, the T&C system will queue each of the scheduled activities as defined in the pass script.
Activity Plan: Overview

LROMPS *Activity Plan Manager* is:
- A web based application
- Protected by secure access for multiple user levels

LROMPS *Activity Plan Manager* allows the user to:
- Access mission planning reports
- View the activity map
- Share comments to the activity map and reports
Activity Plan: User’s Interface

- Displays past, current and future LRO ground and Orbiter events and activities and associated reports.
Thank you

GMV LROMPS Team

www.gmvflexplan.com
www.gmv.com
ACRONYMS LIST

- ATS: Absolute Time Sequence
- CR: Conflict Resolution
- DMS: Data Management System
- DB: DataBase
- EI: External Interface
- ESA: European Space Agency
- EUMETSAT: European Organization for the Exploitation of Meteorological Satellites
- FDF: Flight Dynamics Facility
- GN: Ground Network
- GSFC: Goddard Space Flight Center
- LDCM: Landsat Data Continuity Mission
- LRO: Lunar Reconnaissance Orbiter
- MEP: Mission Environment Preparation
- MOC: Mission Operations Center
- MPS: Mission Planning System
- NASA: National Aeronautics and Space Administration
- NOAA: National Oceanic and Atmospheric Administration
- OOL: Out Of Limits
- PIC: Product Input Customization
- RQT: Report Query Tool
- RTS: Relative Time Sequence
- SE: Schedule Execution
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- SMOS: Soil Moisture and Ocean Salinity
- STOL: Satellite Test and Operations Language
- T&C: Telemetry and Command
- TEG: Tailored Event Generation
- USGS: United States Geological Survey
- XML: eXtensible Markup Language
- WWW: World Wide Web