LRO MPS

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

GSAW 2009

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LRO MPS OVERVIEW

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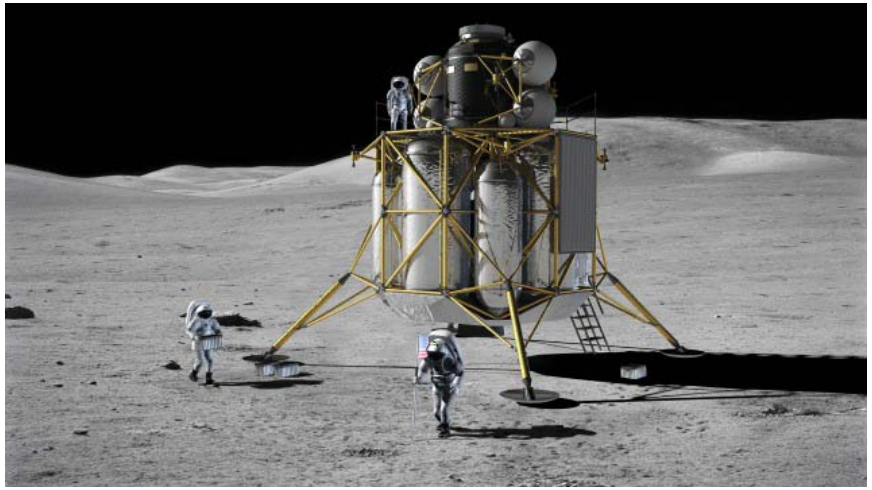
OVERVIEW: LRO Mission

- 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

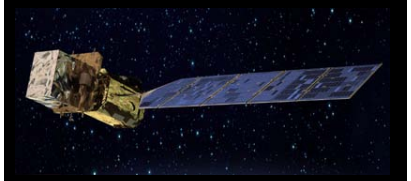
- LRO MPS is based on ***flexplan,*** also selected for:

Metop – European Organization for the Exploitation of Meteorological Satellites (EUMETSAT): Joint mission with NOAA

- Launched October 19, 2006
- Currently operational.

SMOS (Soil Moisture and Ocean Salinity**)** – European Space Agency (ESA):

- Final release accepted in 2006
- Expected launch in mid-2009

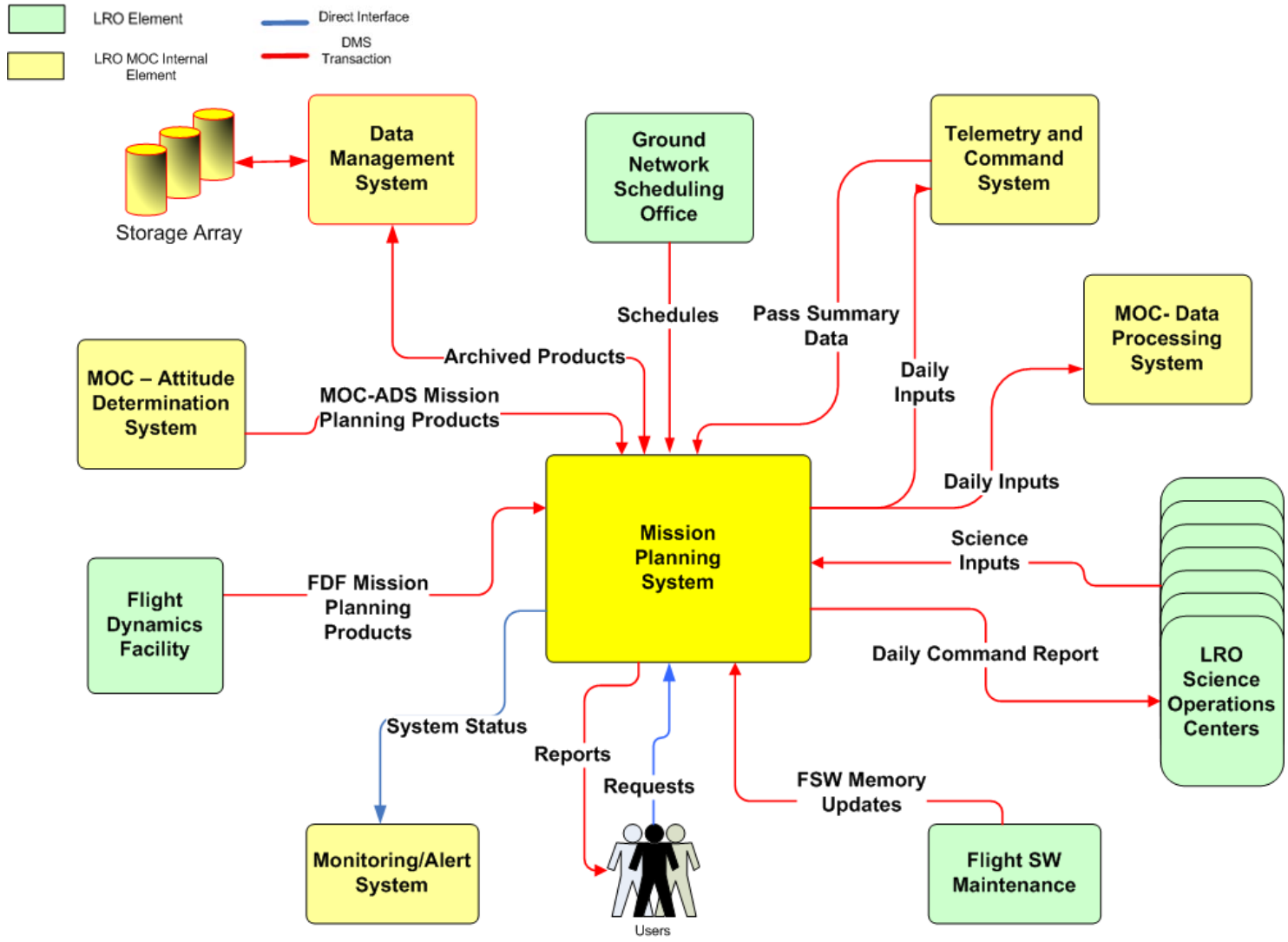


LDCM (Landsat Data Continuity Mission - Landsat 8)– NASA Goddard Space Flight Center (GSFC) / US Geological Survey (USGS)

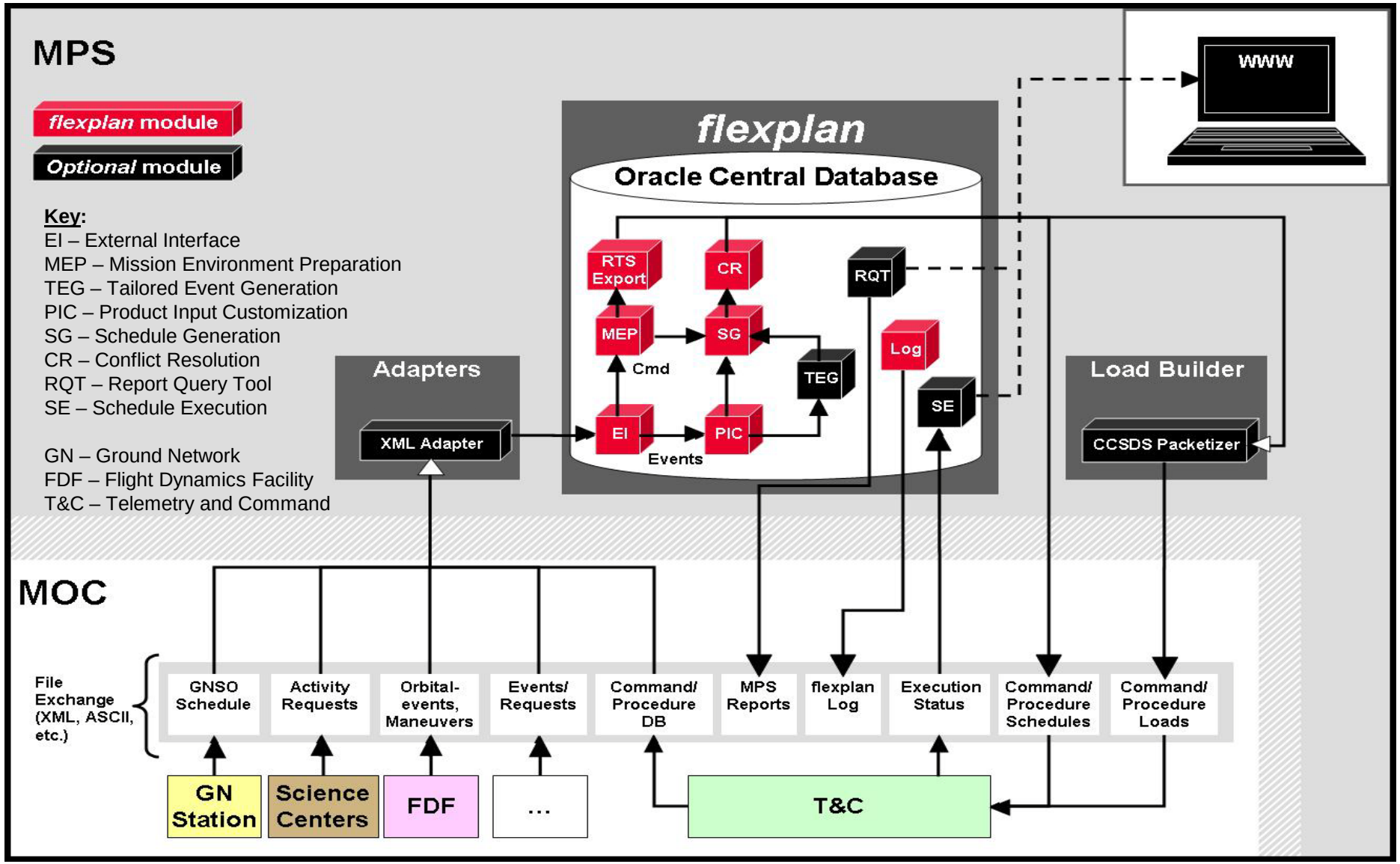
- Contract awarded in Sept 2008, development in progress.
- Expected launch in 2012.

OVERVIEW: Interfaces

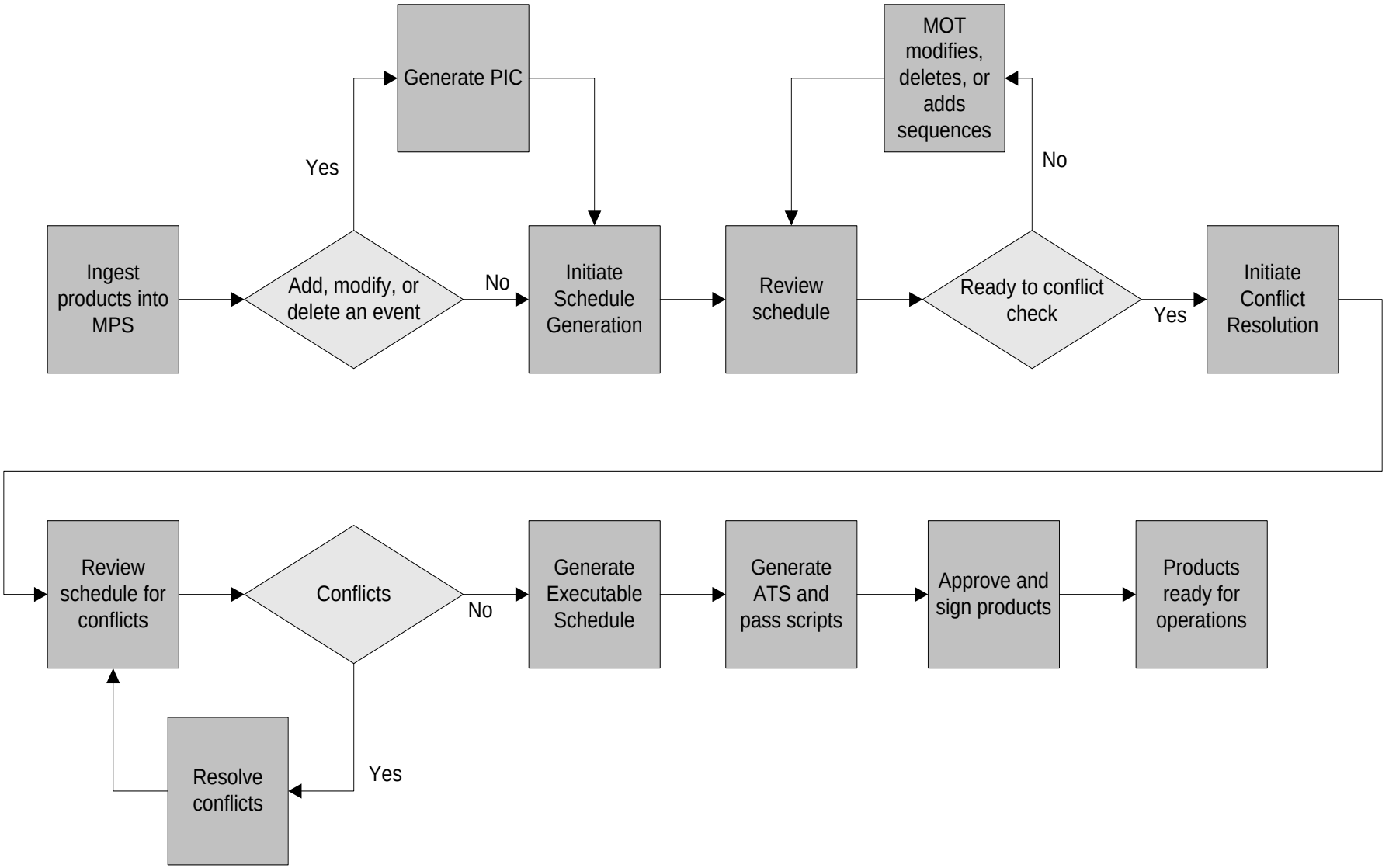
- MPS interfaces with various elements using a file based transfer.



OVERVIEW: Architecture



SCHEDULE GENERATION PROCESS

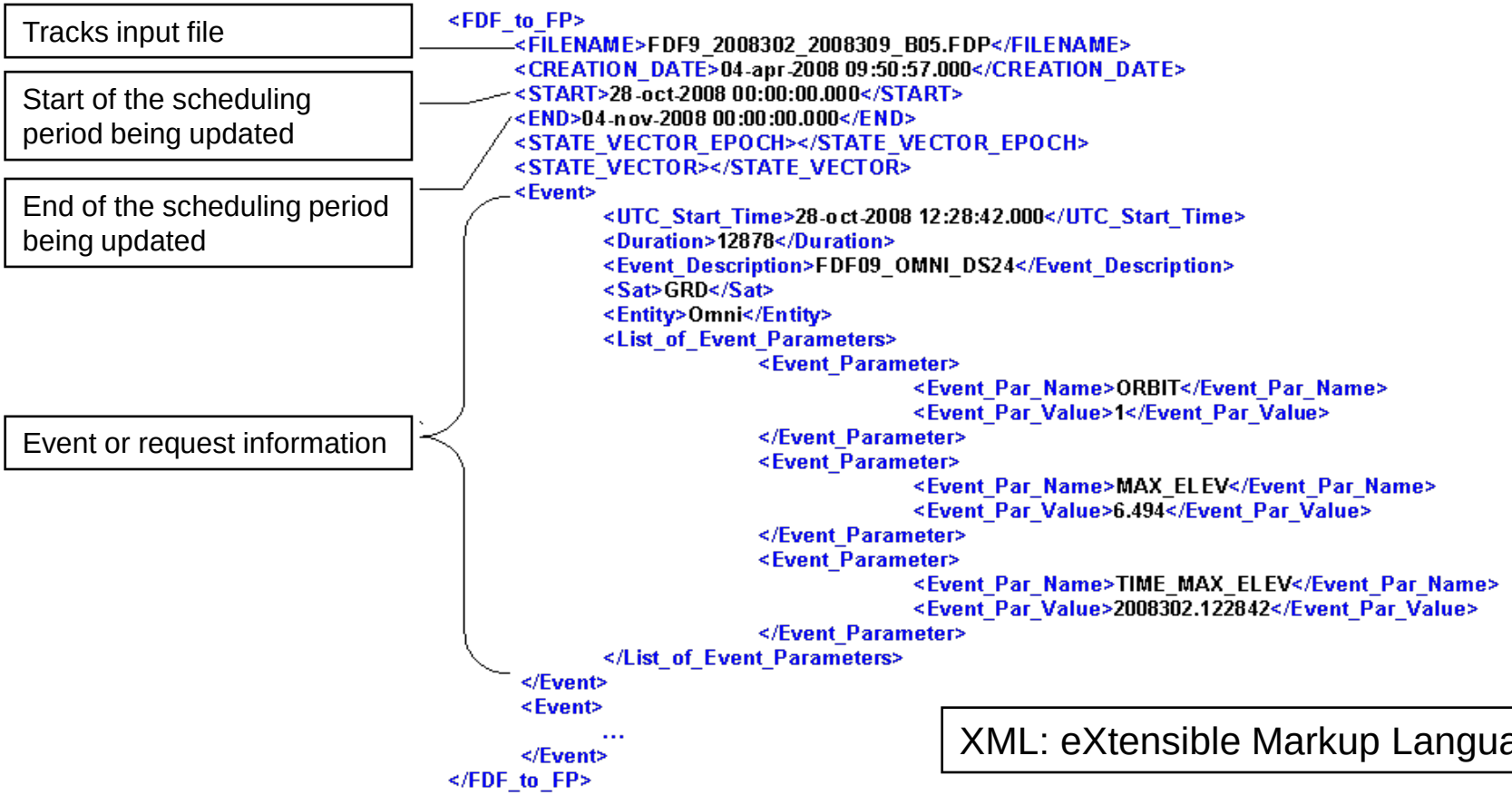


INPUTS: Processing

- 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.



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

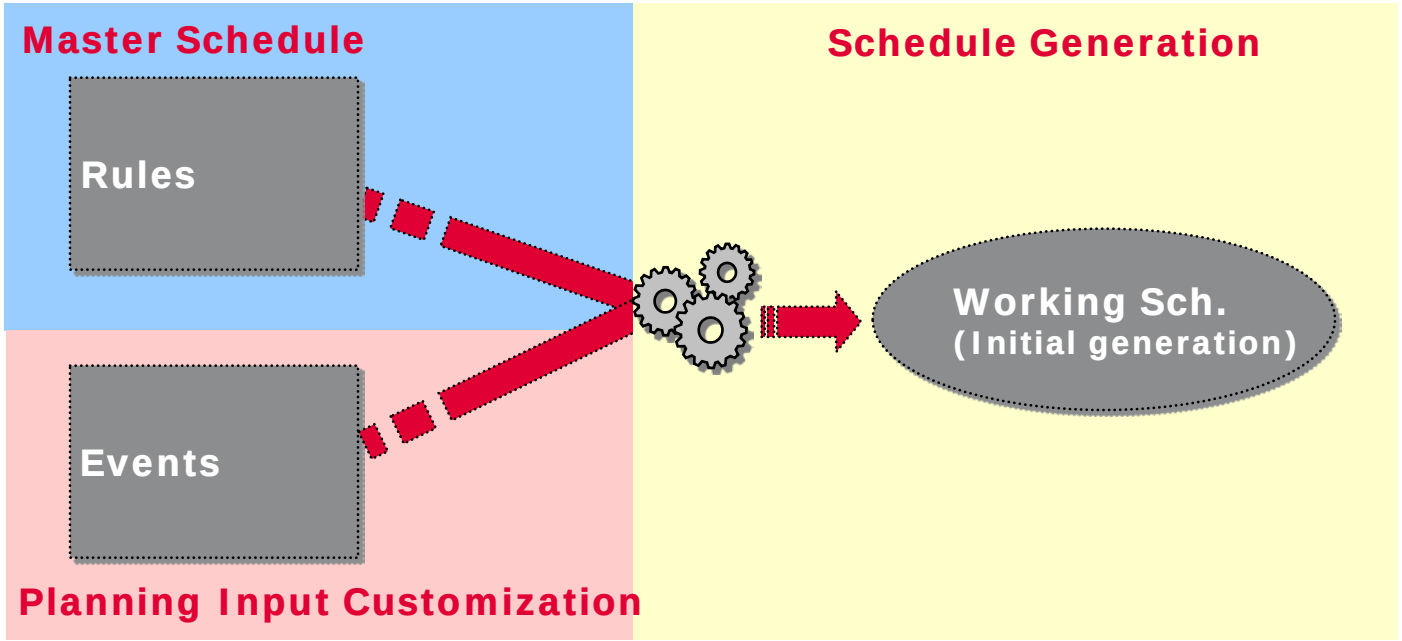
```
<Event>
    <UTC_Start_Time>15-jan-2009 01:22:18.000</UTC_Start_Time>
    <Duration>4386000</Duration>
    <Event_Description>GNSO1_S-BAND</Event_Description>
    <Sat>GRD</Sat>
    <Entity>LR1S</Entity>
    <List_of_Event_Parameters>
        <Event_Parameter>
            <Event_Par_Name>AUTOMATION</Event_Par_Name>
            <Event_Par_Value>AUTOMATED</Event_Par_Value>
        </Event_Parameter>
        <Event_Parameter>
            <Event_Par_Name>LRO_ANTENNA</Event_Par_Name>
            <Event_Par_Value>HGA</Event_Par_Value>
        </Event_Parameter>
        <Event_Parameter>
            <Event_Par_Name>S_ANTENNA</Event_Par_Name>
            <Event_Par_Value>S1</Event_Par_Value>
        </Event_Parameter>
        <Event_Parameter>
            <Event_Par_Name>KA_START</Event_Par_Name>
            <Event_Par_Value>2009-015-01:32:18</Event_Par_Value>
        </Event_Parameter>
    </List_of_Event_Parameters>
</Event>
```

Mission Scheduling Rule

```
WHEN
    there is a Event [ ] [ called ?event ]
      [where]
      such that name.equals("GNSO1_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,"AOSYEAR",getYear(?event.startUTC)) [...]
        and addIntParameter(true,"AOSDOY",getIntDOY(?event.startUTC)) [...]
        and addIntParameter(true,"AOSHOUR",getIntHour(?event.startUTC)) [...]
        and addIntParameter(true,"AOSMIN",getIntMinute(?event.startUTC)) [...]
        and addStringParameter(true, "STATION", ?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.

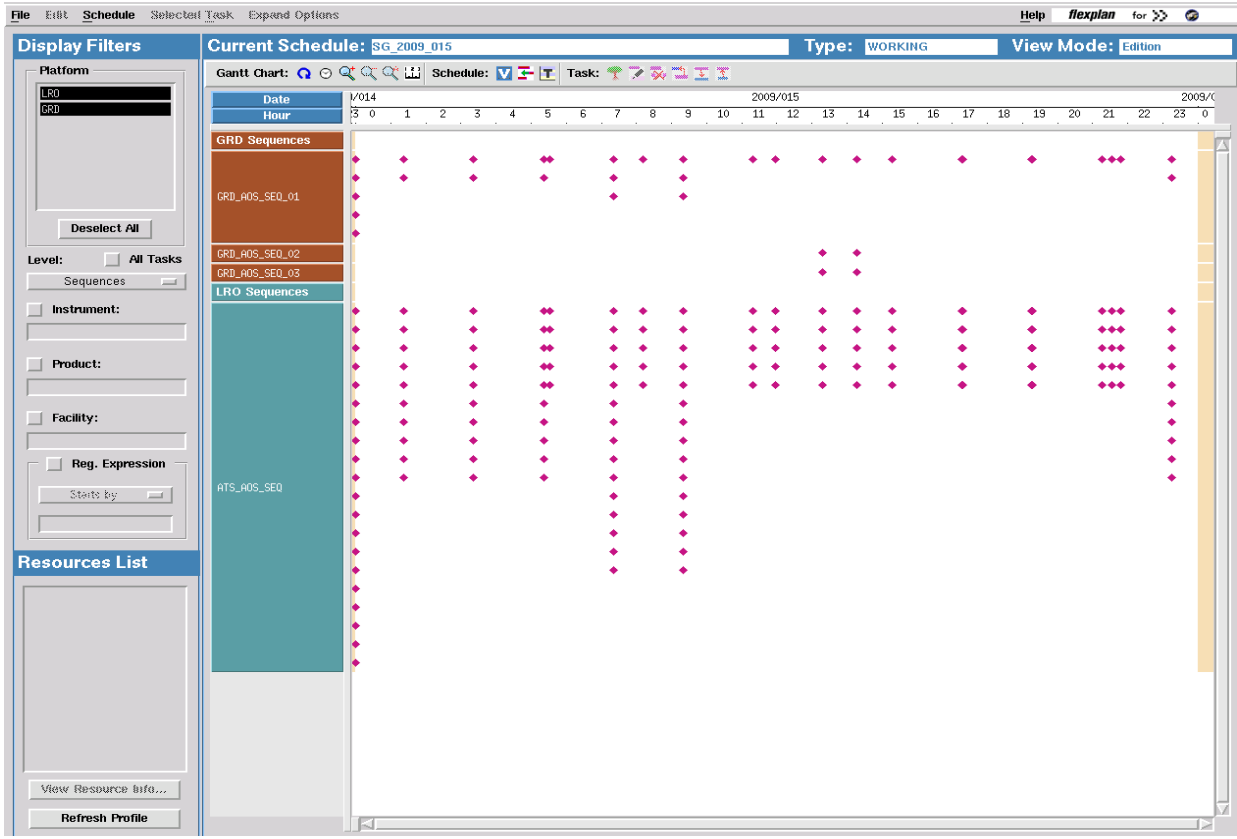


SCHEDULE GENERATION: Orbiter and Ground Schedule

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

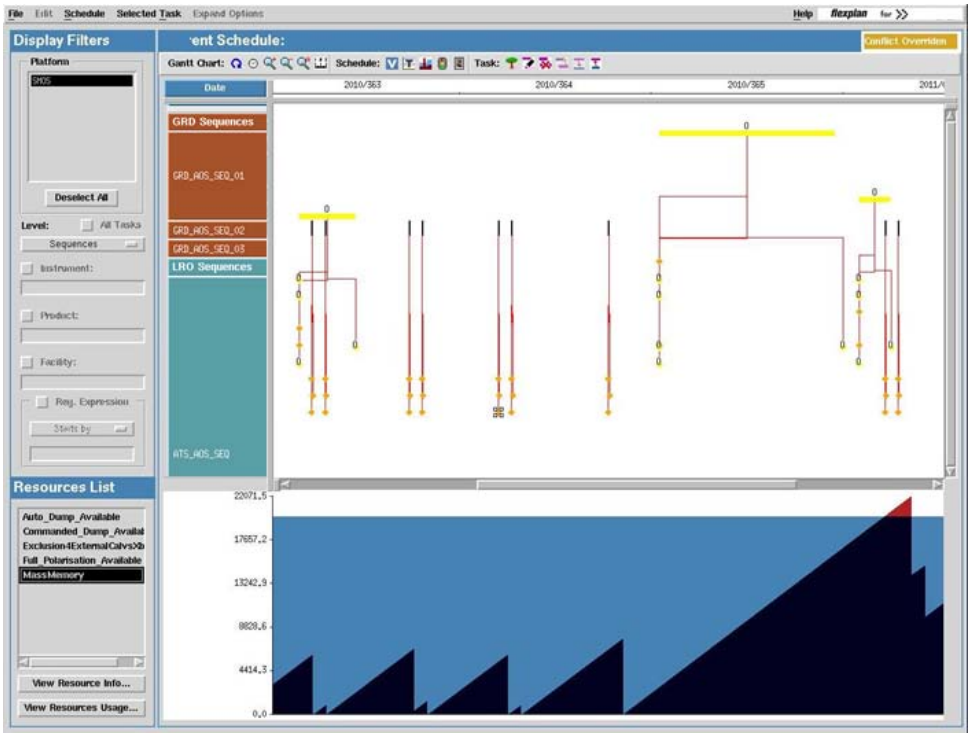
- Orbiter Activities are exported in the Absolute Time Command Sequence Loads (ATS).

- Ground Activities are exported in a series of Pass Scripts.



CONFLICT RESOLUTION: Constraint Checks

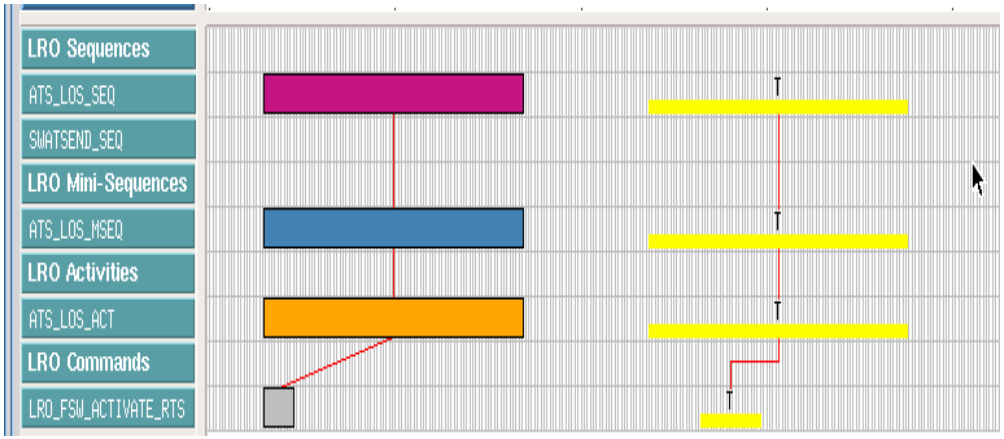
- All schedules generated by the MPS are checked for:
  - Timing relationship constraints
  - Resource consumptions violations
  - All command parameter values must be within DB limits



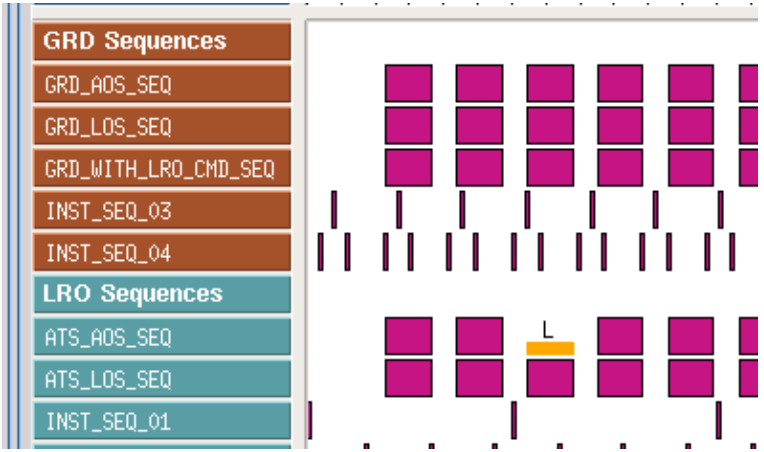
In addition, user defined constraint rules are supported:

- Maximum Orbiter commands per schedule and per second
- Maximum slews per orbit and per day
- Maximum slew angle and duration

CONFLICT RESOLUTION: Display Notification

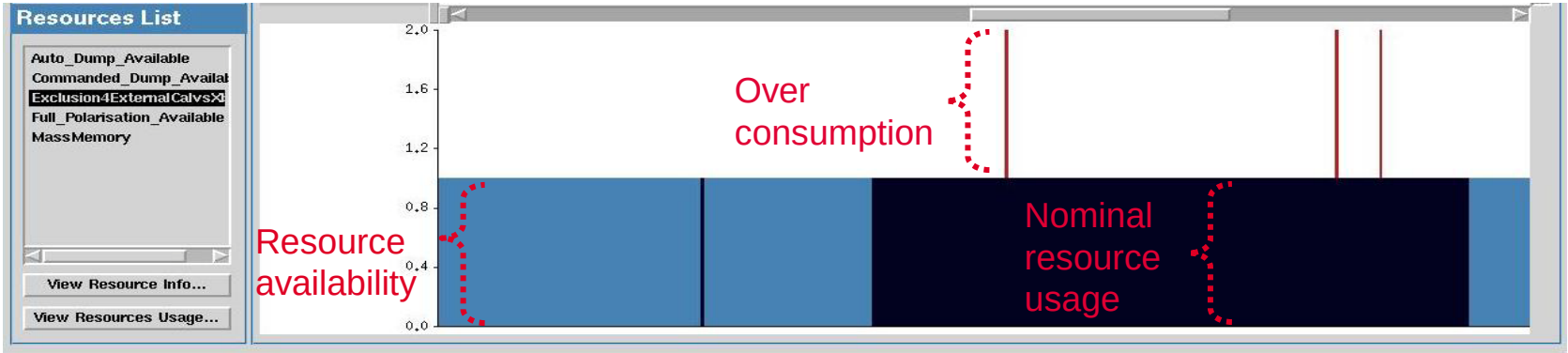


Timing Constraint



OOL Constraint

Resource Constraint

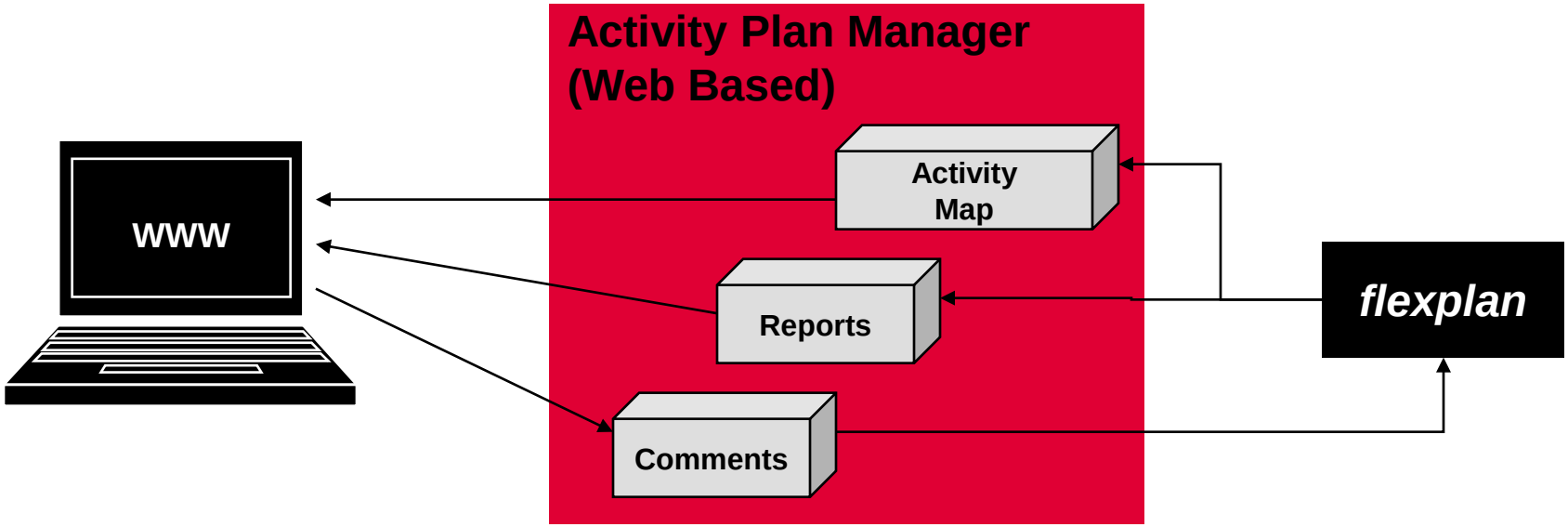


AUTOMATION: Ground Pass Scripts

- 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.

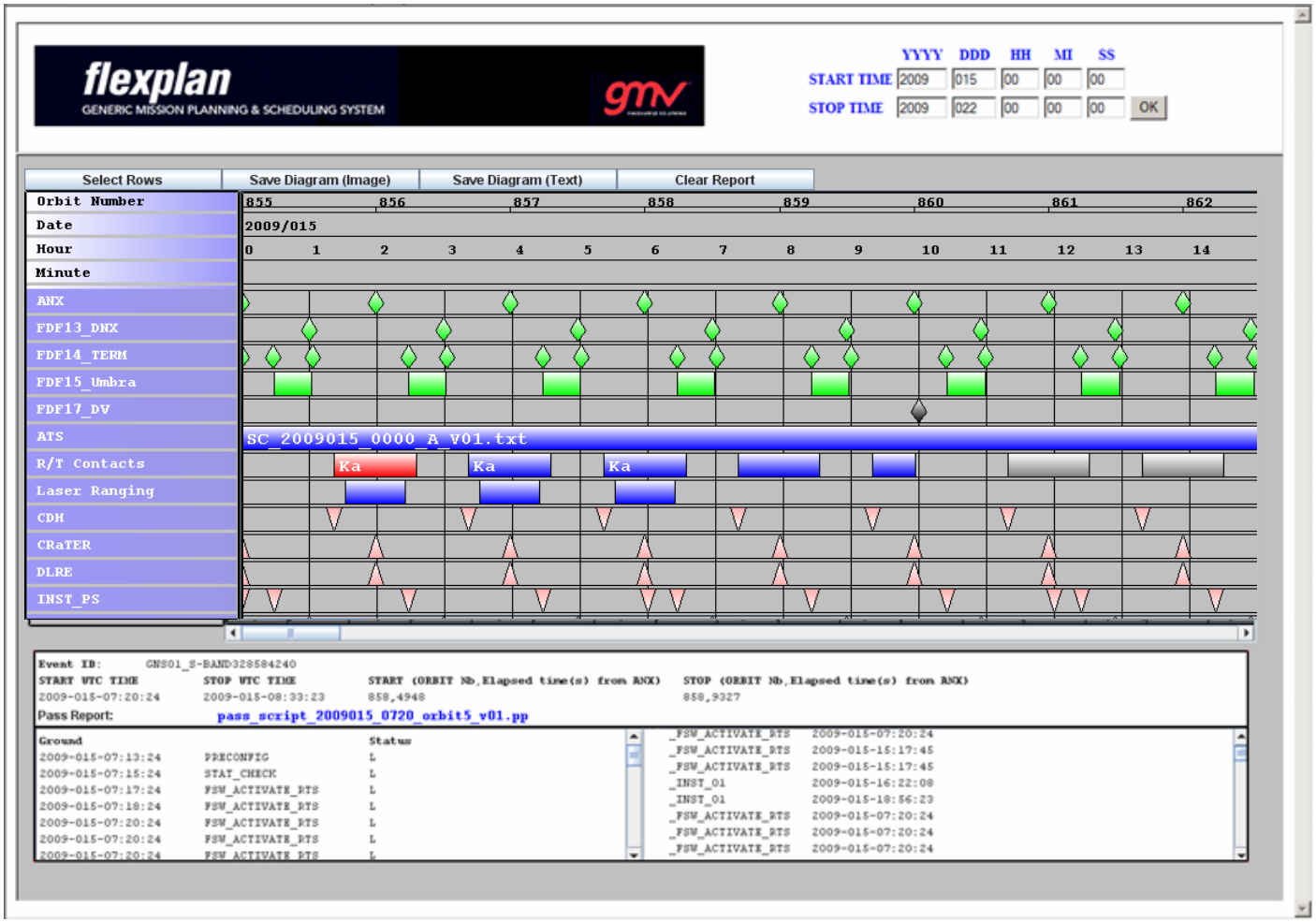
Activity Plan: Overview

- 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.



CONCLUSIONS: UNIQUE FEATURES OF THE LRO MPS

- Compared to other missions, the LRO MPS presents some unique features that have been very valuable for the mission preparation and soon for operations.
  - The **operator has full control of the evolution of the MPS**, no need for software changes. Why?:
    - **Fully table-driven**: All the characteristics of the mission (resources, event types, command parameters, limits, etc) are stored in a database and can be modified easily by the operators.
    - **Soft rules**: MPS logic for schedule generation is stored in rules that can be edited by the operator.
  - Extensive use of **XML interfaces** for exchange of information with external systems. Easier integration, automatic validation of inputs.
  - **Web interface** to provide external access to MPS information.
  - **CCSDS load builder** generator fully integrated within MPS.

Thank you

GMV LROMPS Team

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ACRONYMS LIST

- ATS: Absolute Time Sequence
- CR: Conflict Resolution
- DMS: Data Managent 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
- SG: Schedule Generation
- 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