LRO MPS

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

GSAW 2009

GMV
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LRO MPS OVERVIEW

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

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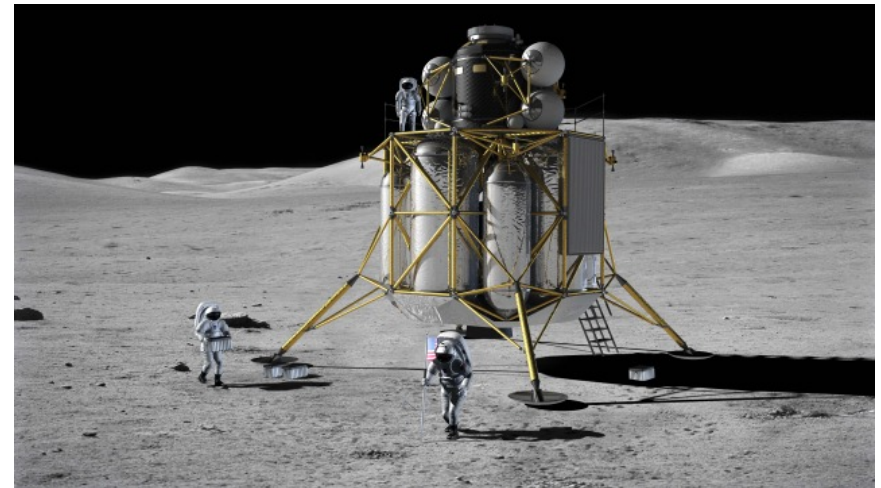
OVERVIEW: LRO Mission Planning & Scheduling (MPS): Functions

■ 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

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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 MissionLandsat 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.
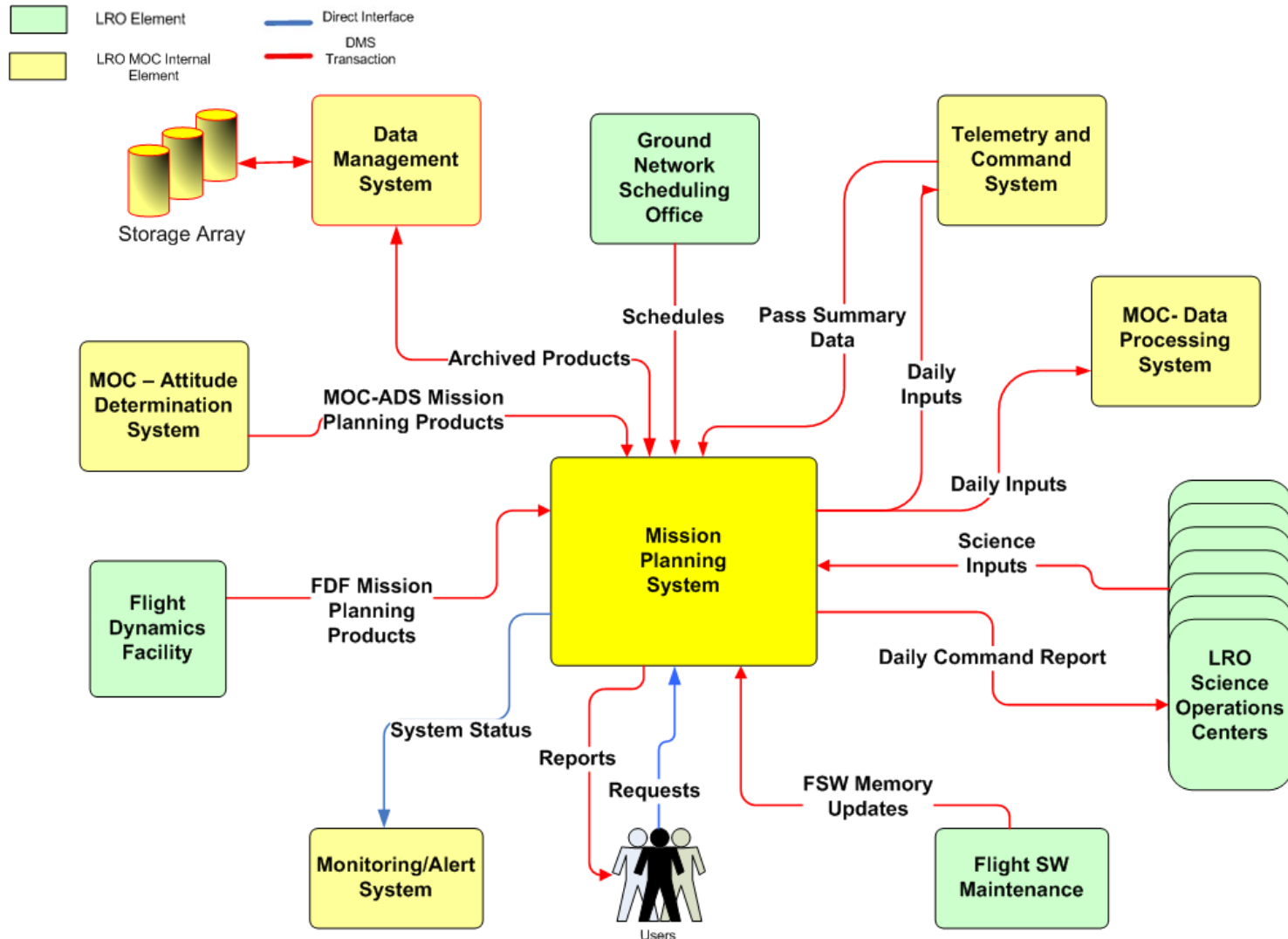
OVERVIEW: Architecture
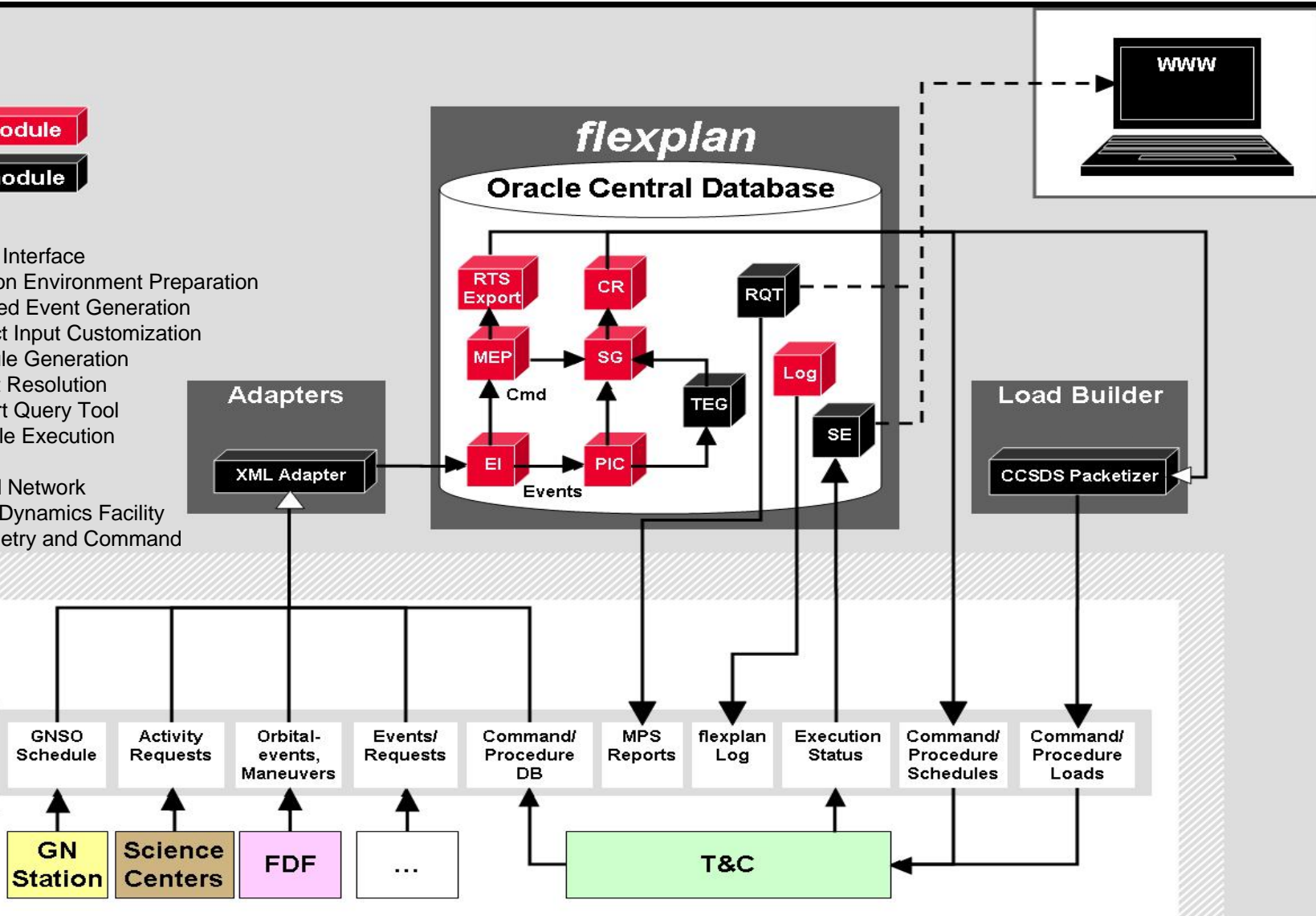
SCHEDULE GENERATION PROCESS
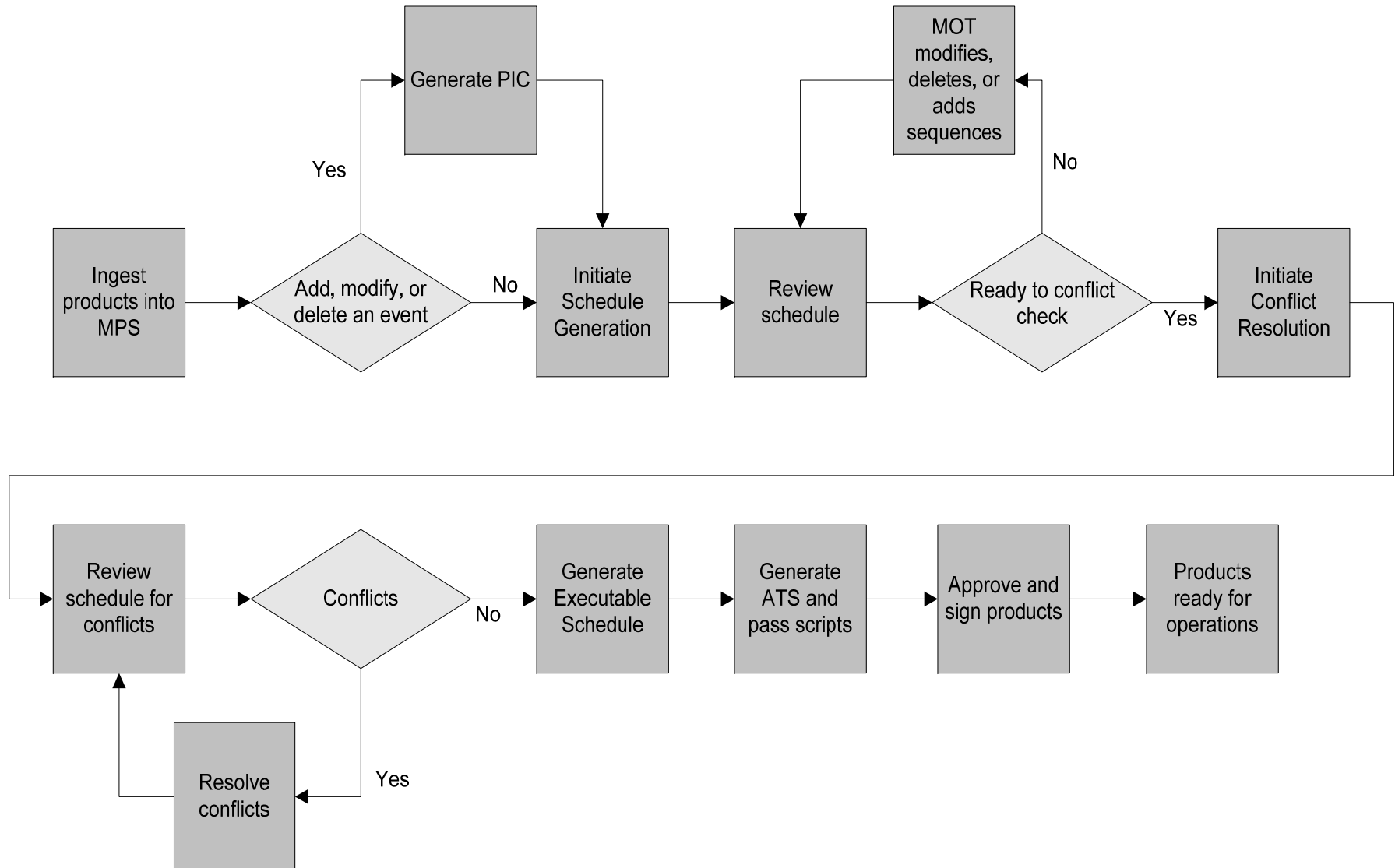
INPUTS: Processing

- 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.

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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	

```
<FDF_to_FP>
    <FILENAME>FDF9_2008302_2008309_B05.FDP</FILENAME>
    <CREATION_DATE>04-apr-2008 09:50:57.000</CREATION_DATE>
    <START>28-oct-2008 00:00:00.000</START>
    <END>04-nov-2008 00:00:00.000</END>
    <STATE_VECTOR_EPOCH></STATE_VECTOR_EPOCH>
    <STATE_VECTOR></STATE_VECTOR>
    <Event>
        <UTC_Start_Time>28-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_Par_Name>ORBIT</Event_Par_Name>
                        <Event_Par_Value>1</Event_Par_Value>
                </Event_Parameter>
                <Event_Parameter>
                        <Event_Par_Name>MAX_ELEV</Event_Par_Name>
                        <Event_Par_Value>6.494</Event_Par_Value>
                </Event_Parameter>
                <Event_Parameter>
                        <Event_Par_Name>TIME_MAX_ELEV</Event_Par_Name>
                        <Event_Par_Value>2008302.122842</Event_Par_Value>
                </Event_Parameter>
        </List_of_Event_Parameters>
    </Event>
    <Event>
        ...
    </Event>
</FDF_to_FP>
```

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.

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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

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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) [...]
```
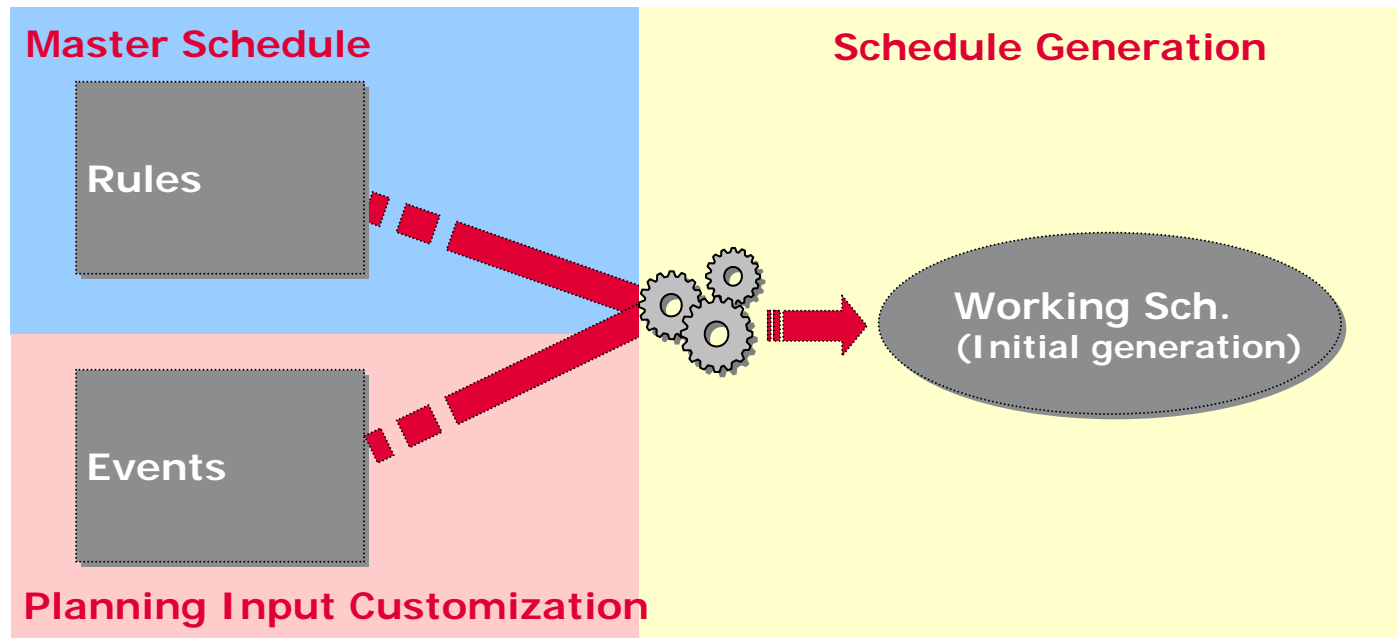
SCHEDULE GENERATION: Operational Issues

- 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.

Master Schedule

Rules

Events

Planning Input Customization

Schedule Generation

Working Sch. (Initial generation)

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.
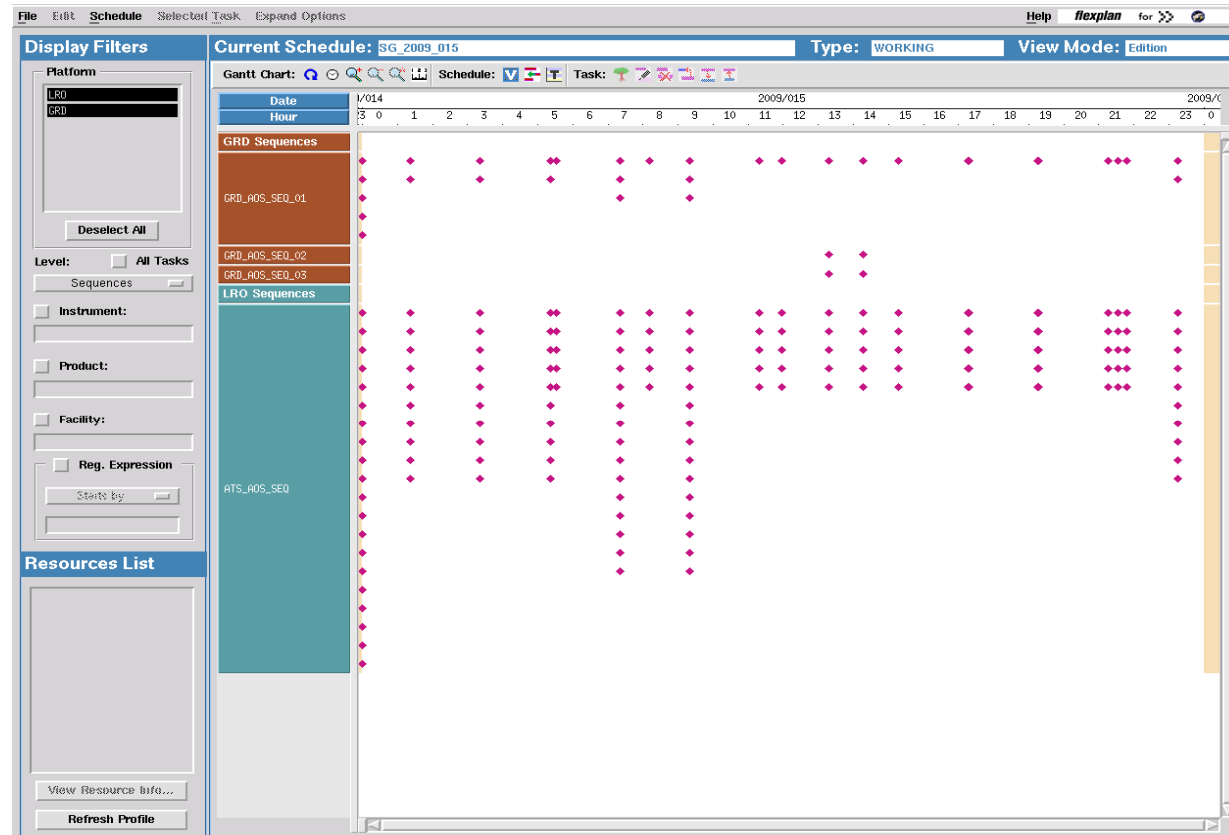
# CONFLICT RESOLUTION: Constraint Checks

- **All schedules generated by the MPS are checked for:**
  - Timing relationship constraints
  - Resource consumptions violations
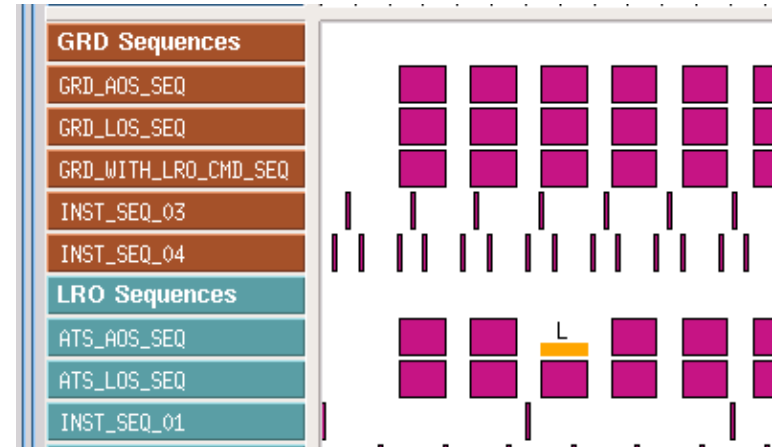 - All command parameter values must be within DB limits
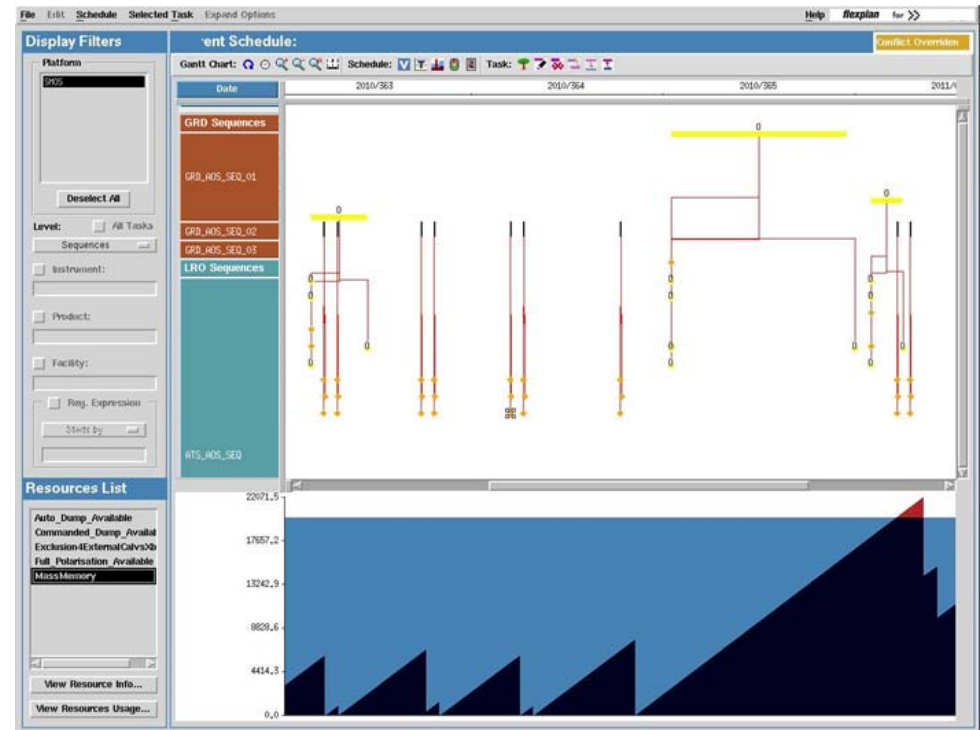
In addition, user defined constraint rules are supported:
- Maximum Orbiter commands per schedule and per second
- Maximum slews per orbit and per day
- Maximum slew angle and duration
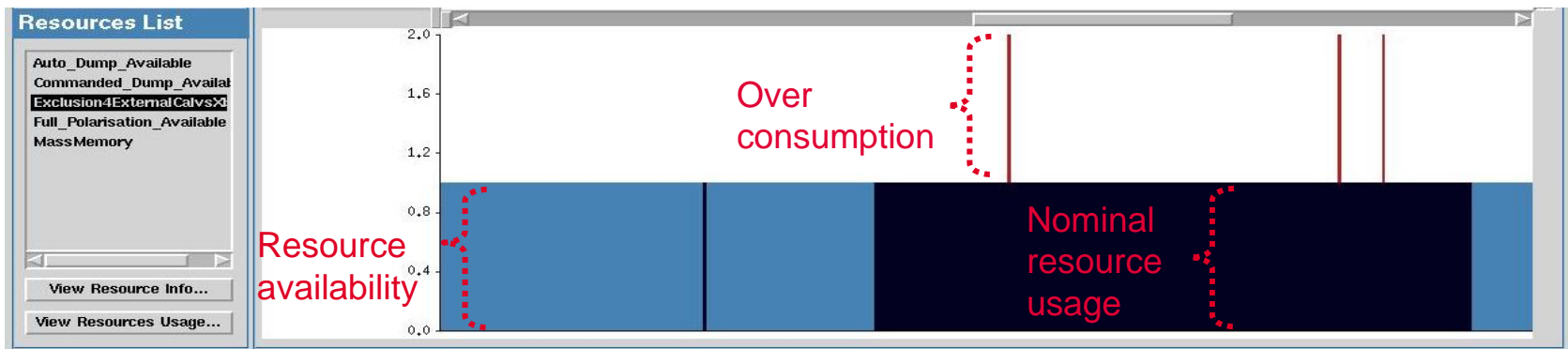
CONFLICT RESOLUTION: Display Notification
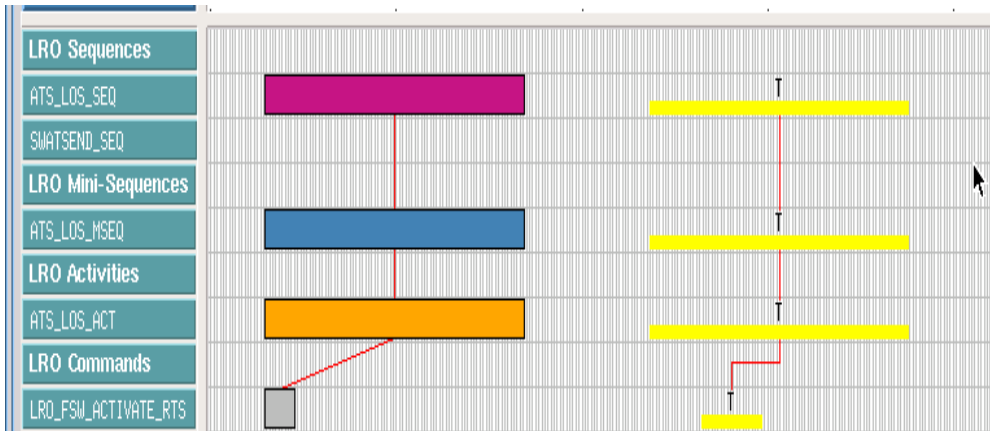
Timing Constraint

OOL Constraint

Resource Constraint

Over consumption

Resource availability

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.

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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 Manager (Web Based)

WWW

Activity Map

Reports

Comments
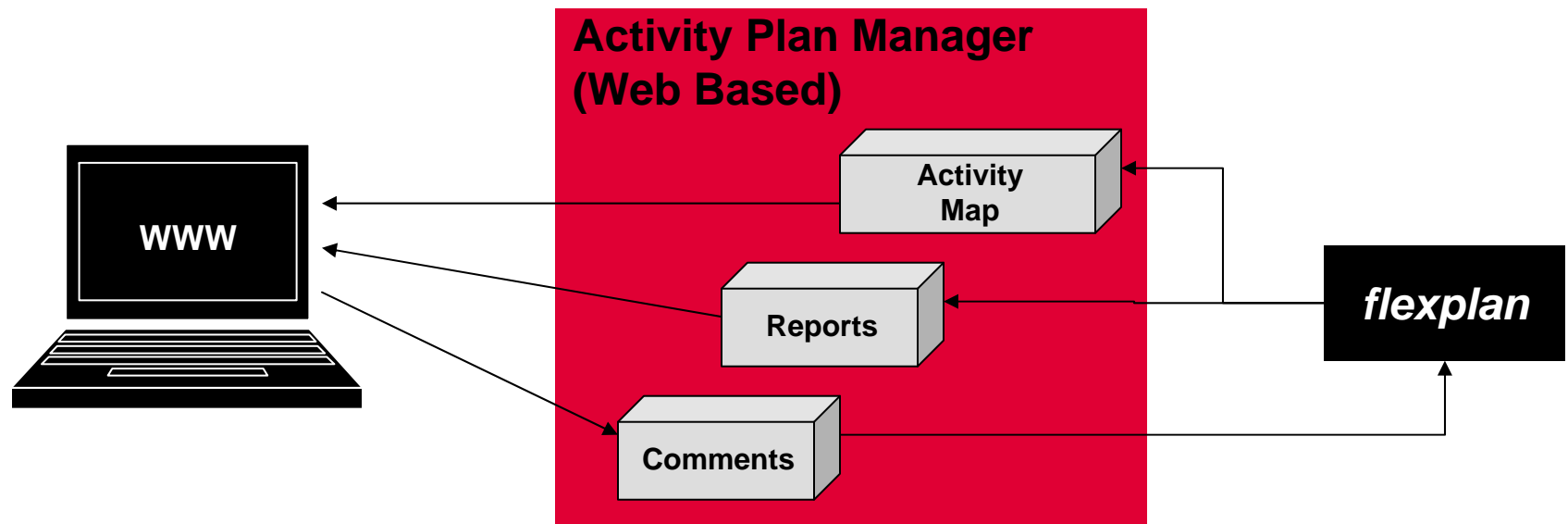
flexplan

Activity Plan: User's Interface

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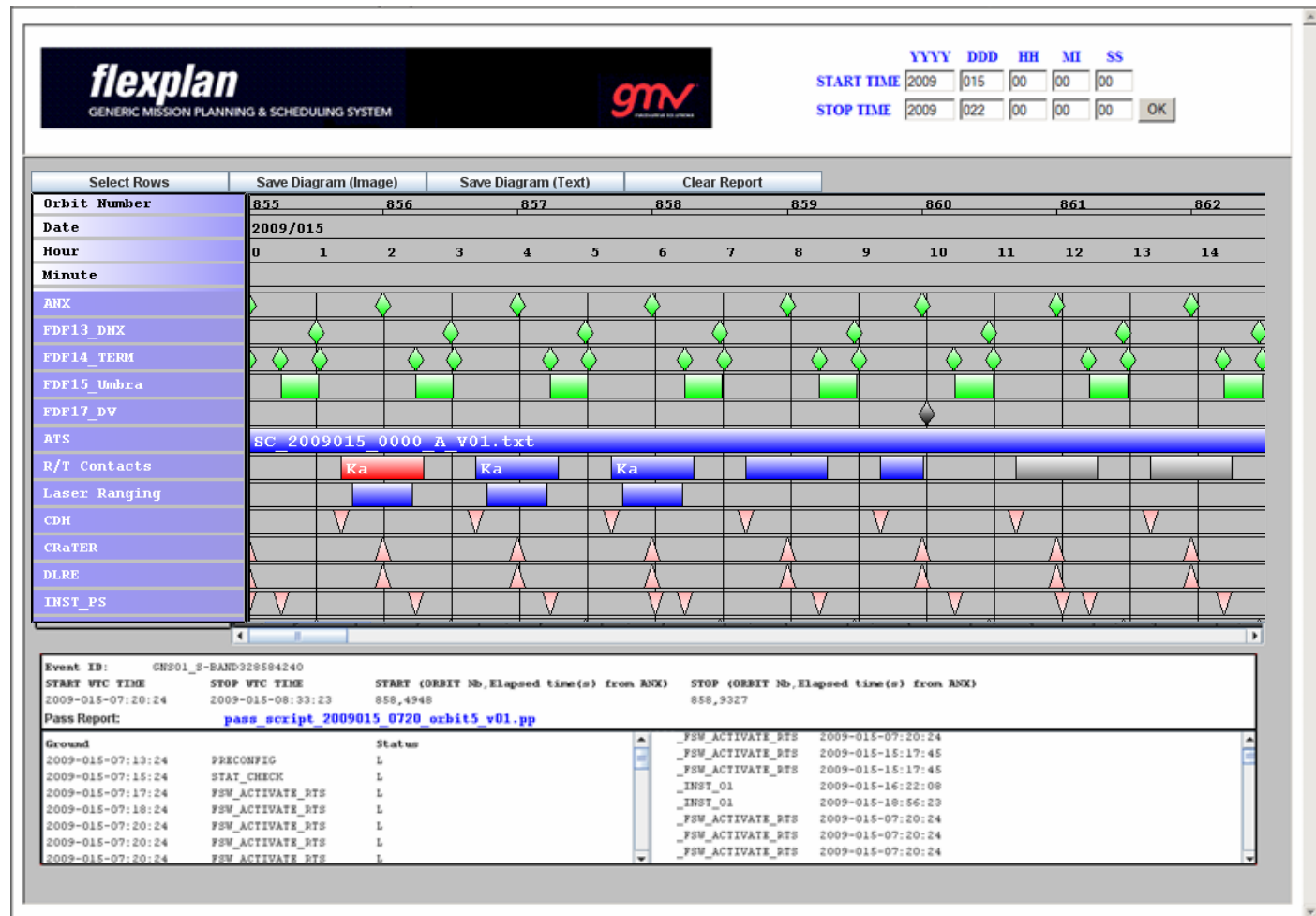
Thank you

GMV LROMPS Team

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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

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