Reducing the Cost of Ground System Development and Mission Operations Using Automated XML Technologies

Presented By Colette Wilklow
Jesse Wright, David Noble, Kathryn Sturdevant, Joseph Snyder

Fifth International Symposium on Reducing the Cost of Spacecraft Ground Systems and Operations (RCSGSO)
July 8-12, 2003, Westin Hotel, Pasadena, California
Overview

- The Problem
  - Rationale
  - Solution
- What is XML?
- Dictionary Management
- Report Generation
- Lessons Learned
- Future Work
- Conclusion
The Problem

- Spacecraft flight and ground system development must occur in parallel
  - The system must be able to adapt to design changes in the flight system as they occur

- Ground system development must occur before mission operations team is fully staffed
  - The ground system must be highly configurable to meet anticipated needs of mission operations personnel
Rationale

- We needed a well structured interface
  - allows for the possibility of automated ground system updates
  - enables mission operations personnel to reconfigure the system to meet their needs without possessing advanced programming skills
Solution

- Use XML to define the interfaces between the flight and ground system
  - Automate command and telemetry dictionary generation and deployment
- Use XML to configure ground tools used for mission operations
  - Automate report generation and deployment
What is XML?

- Extensible Markup Language
- XML is a "meta-markup language"
  - Data is in human-readable text form
    - Can be edited with simple text editors and/or specialized tools
- As Java gives us "portable code", XML is intended to provide "portable data"

```xml
<?xml version="1.0"?>
<greeting>
  <message>
    Hello World!
  </message>
</greeting>
```
Flexible Input

XML SOURCE

<channel>A</channel>
<channel>B</channel>

<channel>A</channel>
<channel>B</channel>
<channel>C</channel>

Stylesheet

XSLT PROCESSOR

FORMATTED OUTPUT

A
B

A
B
C
Flexible Output

XML SOURCE

<channel>A</channel>
<channel>B</channel>
<channel>C</channel>

PROCESSOR

XSL Stylesheet
via XSLT Processor

XSL Stylesheet
with Formatting Objects
via XSLT Processor

SAX or DOM Parser via Perl,
Python or Java

FORMATTED OUTPUT

HTML documentation

PDF documentation

Configuration files for additional tools
Dictionary Management

- The flight team provides XML versions of both the command and telemetry dictionaries.
- Automation scripts (XSLT, Python) are used to generate and deploy:
  - Configuration files
    - used by the ground system to process the telemetry and generate commands
  - Dictionary documentation
- This entire process can be completed by a full time employee in ~4 hours from receipt of the XML from the flight team.
<?xml version="1.0"?>
<channel_parameter_table>
  <header>
    <project>Example Project Documentation</project>
    <version ver_id="X" date="X" owner="X"/>
  </header>
  <channel_definitions>
    <channel id="A-AAAA" size="X" type="XXXXX"
      subsystem="XXX" source="XXX">
      <module>XXX</module>
      <fsw_name>XXX</fsw_name>
      <gds_title>XXX</gds_title>
      <ccl_parameter>XXX</ccl_parameter>
      <ccl_process>XXX</ccl_process>
      <time_type>XXX</time_type>
      <dn_conversion>XXX</dn_conversion>
      <dn_format/>
      <eu_format/>
      <eng_units>XXX</eng_units>
      <children>
        <child>XXX</child>
      </children>
      <sample_rate/>
      <range_type>XXX</range_type>
      <range>
        <min/>
        <max/>
      </range>
      <maturity>XXX</maturity>
      <description>XXX</description>
    </channel>
  </channel_definitions>
</channel_parameter_table>
<table>
<thead>
<tr>
<th>A-AAAA</th>
<th>GDS Name: XXX</th>
<th>Review:</th>
<th>Maturity: XXX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsystem: XXX</td>
<td>Size: X bit</td>
<td>Type: XXXXX</td>
<td>Source: XXX</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Description: XXX</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FSW Name: XXX</td>
<td>Range Type: XXX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FSW Module: XXX</td>
<td>Range Min:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sample Rate:</td>
<td>Range Max:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Time Type: XXX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>States:</td>
<td>Derived Channel Information</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCL Process: XXX</td>
<td>CCL Parameter: XXX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DN-EU Conv: XXX</td>
<td>EU Units: XXX</td>
<td></td>
<td>Derived Children:</td>
</tr>
<tr>
<td>DN Format:</td>
<td>EU Format:</td>
<td></td>
<td>Parents:</td>
</tr>
<tr>
<td>Test Selection Criteria</td>
<td></td>
<td>Cruise Selection Criteria</td>
<td></td>
</tr>
<tr>
<td>Update</td>
<td>Criteria</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Real Time: XXX</td>
<td>XXX</td>
<td>XXX</td>
<td>XXX</td>
</tr>
<tr>
<td>Recorded: XXX</td>
<td>XXX</td>
<td>XXX</td>
<td>XXX</td>
</tr>
<tr>
<td>Fault Selection Criteria</td>
<td></td>
<td>Surface Selection Criteria</td>
<td></td>
</tr>
<tr>
<td>Update</td>
<td>Criteria</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Real Time: XXX</td>
<td>XXX</td>
<td>XXX</td>
<td>XXX</td>
</tr>
<tr>
<td>Recorded: XXX</td>
<td>XXX</td>
<td>XXX</td>
<td>XXX</td>
</tr>
</tbody>
</table>
### Example Project Documentation

<table>
<thead>
<tr>
<th>A-AAAA</th>
<th>GDS Name: XXX</th>
<th>Type: XXXXX</th>
<th>Review:</th>
<th>Maturity: XXX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subsystem: XXX</td>
<td>Size: X bit</td>
<td>Source: XXX</td>
<td>MPF ID:</td>
<td></td>
</tr>
</tbody>
</table>

**Description:** XXX

**FSW Name:** XXX  
**FSW Module:** XXX  
**Sample Rate:**

**States:**

- CCL Process: XXX  
- DN-EU Conv: XXX  
- DN Format: XXX

**CCL Parameter:** XXX  
**EU Units:** XXX  
**EU Format:** XXX

#### Test Selection Criteria

<table>
<thead>
<tr>
<th>Update</th>
<th>Criteria</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real Time</td>
<td>XXX</td>
<td>XXX</td>
<td>XXX</td>
</tr>
<tr>
<td>Recorded</td>
<td>XXX</td>
<td>XXX</td>
<td>XXX</td>
</tr>
</tbody>
</table>

#### Fault Selection Criteria

<table>
<thead>
<tr>
<th>Update</th>
<th>Criteria</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real Time</td>
<td>XXX</td>
<td>XXX</td>
<td>XXX</td>
</tr>
<tr>
<td>Recorded</td>
<td>XXX</td>
<td>XXX</td>
<td>XXX</td>
</tr>
</tbody>
</table>

| Range Type: XXX | Range Min: | Range Max: | Time Type: XXX |

**Derived Channel Information**

- Trigger Channel:
- Derived Children: XXX
- Parents:

<table>
<thead>
<tr>
<th>Test Selection Criteria</th>
<th>Update</th>
<th>Criteria</th>
<th>Low</th>
<th>High</th>
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<td>XXX</td>
<td>XXX</td>
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<td>Update</td>
<td>Criteria</td>
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<tr>
<td>Recorded</td>
<td>XXX</td>
<td>XXX</td>
<td>XXX</td>
<td>XXX</td>
</tr>
</tbody>
</table>
Example Project Documentation (EPD)
Example - Mission System
Volume X: Telemetry Dictionary
8.1a

Author: E. X. Ample

Approved:

Grand Poohbah, Project Manager

Big Kahuna, Deputy Project Manager

Big Kahuna, Deputy Project Manager

Printed copies of this document may not be current as they should not be used for official purposes

October 24, 2002

Jet Propulsion Laboratory
California Institute of Technology
Report Generation

- Motivation – to automatically process mission data and populate outputs that would otherwise be hand-generated by mission operations personnel
- MER Report Generation is a suite of XML definitions, Java and Python tools and XSL Transformations
**Appetizers**

*End of Pass Summary Overview Reports*
This report gives an overview of telemetry from the most recent Sol, including channelized telemetry, event reports and data product accounting. This report is intended to provide a quick look at spacecraft data in support of the initial downlink assessment.

*Initial Conditions Reports*
These reports are created to support the needs of spacecraft modeling tools to have the most up-to-date knowledge of Rover states. These reports are generated from telemetry and are then ingested in the various tools including those used for Planning & Scheduling, Rover Modeling and Power Modeling.

*Main Courses*

*End of Pass Detailed Reports*
This report gives a detailed summary of telemetry from the most recent Sol, including channelized telemetry, event reports and data product accounting.

**Special of the Sol**

*End of Sol Reports*
This report gives a detailed summary of telemetry from the most recent Sol, including channelized telemetry, event reports and data product accounting.

**Build Your Own Report**

*Capabilities***
Subscribe to one or more of packet application identifier counts, event reports, latest telemetry channels, telemetry channels on change, all telemetry channels, new product availability and values to be plotted by an external plotting tool.

*Output Formats*
ASCII text, Encapsulated Comma-Separated Value (ECSV), Extensible Markup Language (XML), HyperText Markup Language (HTML), and Portable Document Format (PDF).

*New capabilities may be added upon request*
Telemetry Stream

- ACS
- Mobility
- Science
- Power
- Thermal

Report Definition

<subscribe>Mobility</subscribe>
<subscribe>Power</subscribe>
<subscribe>Thermal</subscribe>
It is worthwhile to spend time carefully defining the XML schema
- The schema defines the rules for what is allowed in a given XML file
- This will save time in later development!
  - Almost all code updates in the last year for the telemetry dictionary generation/deployment process were due to schema changes

Use multiple XML files if data is orthogonal
- Generally, XML is only as useful as the data it describes
It’s important to understand the pros and cons of various XML parsers

- Parsers using DOM are good if you need to randomly access the document elements
- Parsers using SAX are good if you are processing a very large XML file
  - In the case of our telemetry dictionary, we are talking ~100,000 tags!
- Some are more mature than others and newer ones may not have certain capabilities, look for parsers that adhere to the W3C XML Recommendation
Future Work

- Complete conversion of tools to become a standard toolkit for new missions
- Investigate automatic generation of XSL stylesheets and report definitions
Conclusion

- XML has greatly improved our ability to quickly propagate changes in the flight system to the ground system.
- We have developed a highly configurable system that has improved our ability to define and process information efficiently and accurately.
- We have developed and supported this system with minimal staffing and have designed a system that will be applied to future missions, thus reducing the cost to this and future projects.