Files from Mars: Java™ in the MER Data Infrastructure

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TS-1416
Goal

Examine challenges and tradeoffs in the development of software for a ground system supporting the Mars Exploration Rovers.

This work was performed at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.
Agenda

Background
Challenges
Simplicity
Extensibility
Reuse
Summary
Q&A
Agenda

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Mission Overview

Two robotic geologists exploring Mars

Credit: NASA/JPL/Cornell

Detail of 'Cahokia' panorama
http://photojournal.jpl.nasa.gov/feature/cahokia
MER-A (Spirit) Traverse to Sol 450
http://photojournal.jpl.nasa.gov/catalog/PIA07849

Credit: NASA/JPL/MSSS/NMMNH
MER-A (Spirit) and Mars Pathfinder flight spare

Height: 1.5m
Width: 2.3m
Length: 1.6m
Mass: 174kg

Credit: NASA/JPL
Credit: Maas Digital LLC, NASA/JPL

Credit: NASA/JPL/Cornell/USGS/University of Mainz

Credit: NASA/JPL/Cornell/ASU

http://athena.cornell.edu/

JavaOne 2005 Conference | Session TS-1416 |
NASA's Science Objectives

- Long-term science goals for Mars Exploration:
  - Determine whether **Life** ever arose on Mars
  - Characterize the **Climate** of Mars
  - Characterize the **Geology** of Mars
  - Prepare for **Human Exploration**

http://marsrovers.jpl.nasa.gov/science/

java.sun.com/javaone/sf
MER's Science Objectives

The scientific objectives of the Mars Exploration Rover mission are to:

1. Search for and characterize a variety of rocks and soils that hold clues to past water activity. In particular, samples sought will include those that have minerals deposited by water-related processes such as precipitation, evaporation, sedimentary cementation, or hydrothermal activity.
2. Determine the distribution and composition of minerals, rocks, and soils surrounding the landing sites.
3. Determine what geologic processes have shaped the local terrain and influenced the chemistry. Such processes could include water or wind erosion, sedimentation, hydrothermal mechanisms, volcanism, and cratering.
4. Perform "ground truth" -- calibration and validation -- of surface observations made by Mars orbiter instruments. This will help determine the accuracy and effectiveness of various instruments that survey Martian geology from orbit.
5. Search for iron-containing minerals, identify and quantify relative amounts of specific mineral types that contain water or were formed in water, such as iron-bearing carbonates.
6. Characterize the mineralogy and textures of rocks and soils and determine the processes that created them.
7. Search for geological clues to the environmental conditions that existed when liquid water was present. Assess whether those environments were conducive to life.

Actors

- Scientists
  - Evaluate images and other data
  - Plan rover activities
- Engineers
  - Evaluate rover health, state, performance
  - Build rover activity commands
  - Keep everything working
Downlink Data Flow

Not to scale.
Significantly simplified.
Downlink Data Composition

MER-A (Spirit) Sols 1-400
Percentage of data volume

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Deadline

- MER-A Launch Window
  - June 8, 2003 – June 24, 2003

- MER-B Launch Window

- Two opportunities per day

- 10 days required between launches
Planetary Alignment

MER Landing Press Kit, 12-1-03
Tactical Timeline

- 15 hours to create next sol's commands
  - Evaluate health, etc
  - Evaluate science
  - Determine science goals
  - Plan activities
  - Build and validate commands
## Risk

### Mars Missions, from 1/1/1970 to 1/1/2004

<table>
<thead>
<tr>
<th></th>
<th>Attempts</th>
<th>Successes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orbiters</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>Landers</td>
<td>13</td>
<td>4</td>
</tr>
<tr>
<td>Rovers</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

MER Landing Press Kit, 12-1-03
Budget

Primary Mission: $820 Million USD

- Spacecraft Dev and Science Instruments: $645M
- Launch: $100M
- Mission Ops and Science Processing: $75M

MER Landing Press Kit, 12-1-03
Visibility

- First 3 days after landing:
  - 1 Billion web hits
  - 15 Terabytes downloaded by web browsers

Agenda

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Q&A
Loose Coupling

- Benefits
  - Component reuse
  - Component pluggability
  - Parallel development

- Drivers: cost, risk
Criteria

- Usability
- Correctness
- Testability
- Reliability
Options

- Service Lookup
- Inversion of Control
- JavaBeans and InfoBus
- Message Pub / Sub
Options

- Service Lookup
- Inversion of Control
- JavaBeans and InfoBus
- Message Pub / Sub
Message Classes

**Message**

- `getType() : String`

**MessageSubscriber**

- `<<interface>>`
- `handleMessage(Message)`

**MessageContext**

- `publish(Message)`
- `subscribe(type: String, Subscriber)`
Message Classes

**Message**
- `getType() : String`

**MessageSubscriber**
- `handleMessage(Message)`

**MessageContext**
- `publish(Message)`
- `subscribe(type:String, Subscriber)`

**BaseMessageHandler**
- `handleMessage(Message)`

**MessageContextFactory**
- `createMessageContext()` : `MessageContext`
Message Publisher

public class MyPublisher {

    private MessageContext messageContext;

    public MyPublisher(MessageContext context) {
        this.messageContext = context;
    }

    public void demonstratePublish() {
        SampleMessage message = new SampleMessage();
        messageContext.publish(message);
    }

}
public class MySubscriber implements MessageSubscriber {

    public MySubscriber(MessageContext messageContext) {
        messageContext.subscribe(SampleMessage.TYPE, this);
    }

    public void handleMessage(Message genericMessage) {
        SampleMessage message;
        message = (SampleMessage) genericMessage;
        // ... do something with the message
    }
}
Subscriber to Multiple Messages

messageContext.subscribe(FooMessage.TYPE,
   new BaseMessageHandler() {
      public void handleMessage(Message genericMessage) {
         handleFooMessage((FooMessage) genericMessage);
      }
   });
messageContext.subscribe(BarMessage.TYPE,
   new BaseMessageHandler() {
      public void handleMessage(Message genericMessage) {
         handleBarMessage((BarMessage) genericMessage);
      }
   });
Assembling Components

MessageContext context = new MessageContext();
context.setVerbose(verbose);

ProductInput input = addProductInput(context);
if (dump) {
    addProductDumpOutput(context);
}
ProductBuilder builder = addProductBuilder(context);
ProductStorage storage = addProductStorage(context);
addProductSummaryOutput(context);
addExternalSubscribers(context);

input.read();
## Lines of Code for Message Package

Including Test Classes

<table>
<thead>
<tr>
<th>Description</th>
<th>Lines</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brackets</td>
<td>59</td>
<td>8.70%</td>
</tr>
<tr>
<td>Whitespace</td>
<td>70</td>
<td>10.32%</td>
</tr>
<tr>
<td>Comments</td>
<td>345</td>
<td>50.88%</td>
</tr>
<tr>
<td>“Significant”</td>
<td>204</td>
<td>30.09%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>678</td>
<td></td>
</tr>
</tbody>
</table>
Would I do it again?

- Yes
- Reused for other missions
- Watching for creeping complexity
Data Product Storage

- Product files
- Product metadata
- Product part metadata
Schema Design

<table>
<thead>
<tr>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
</tr>
<tr>
<td>Filename</td>
</tr>
<tr>
<td>Command</td>
</tr>
<tr>
<td>Series</td>
</tr>
<tr>
<td>CreationTime</td>
</tr>
<tr>
<td>TotalParts</td>
</tr>
<tr>
<td>etc</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ProductPart</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
</tr>
<tr>
<td>Product</td>
</tr>
<tr>
<td>PartNumber</td>
</tr>
<tr>
<td>DataFilename</td>
</tr>
<tr>
<td>DataOffset</td>
</tr>
<tr>
<td>DataLength</td>
</tr>
<tr>
<td>etc</td>
</tr>
</tbody>
</table>
Why Not?

- Procedures
  - Installation, configuration, maintenance
- Validation tests
  - Performance, scalability, reliability
- Third party software evaluations, DBA, ...
- Time
Product Metadata

- XML
- Regular line breaks
Locations

Complete Products
products/<type>/<subtype>/<command>_<series>_<time>.dat
products/<type>/<subtype>/<command>_<series>_<time>.emd

Partial Products
<command>_<series>_<time>_Partial-_<counter>.pdat
<command>_<series>_<time>_Partial-_<counter>.pemd

Parts Cache
products/parts/<filename>/*.dat
products/parts/<filename>/*.emd

Alternate Views
sol/<NNN>/ssw/products/created/<typename>/<filename>
sol/<NNN>/ssw/products/received/<typename>/<filename>
Would I do it again?

- Not exactly
- Add database
  - Develop procedures off critical path
- Keep files
  - Accessible to scripts, people
Agenda

Background
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Simplicity
**Extensibility**
Reuse
Summary
Q&A
Product Action Triggers

• Requirement:
  • Trigger actions on product arrival
Product Action Triggers

- Initial requirement:
  “Users can register to be notified by email when a product arrives”
Product Action Triggers

- Filter criteria
- Script execution
Configuration

<subscriptions>
  <script>
    <trigger complete="yes" partial="no"/>
    <filter>
      <allow apid="50" subtype="78"/>
    </filter>
    <path>subscriptions/scripts/uncompress</path>
  </script>
</subscriptions>
Multiple Uses

- Science processing
- Generic uncompression
- Text representations
- Multiple directory hierarchies
However...

- Never did email product notification
However...

- Never did email product notification
- Email reports had high-level summaries
Would I do it again?

- Yes, but...
- With JMS message publishing
Product Display

- XML Data Dictionary
  - Values
  - Units
  - Lookup tables
  - Arrays of values
  - Arrays of arrays
  - “Opaque” blocks handled by external viewers
External Viewers

- Images
- Complex data structures
- Special formatting
- Reports
Hazcam Image

% mer_dp_view img_image_loco_fhl/*.dat | more

Filename:  img_image_loco_fhl/f0006-000-0000_003_0161168693-127.dat
Type: img_image_loco_fhl - LOCO Compressed Image, Left Front Hazcam
Spacecraft: MER A (SCID=254)
Packetized: 2005-045T04:00:14.932 - 0161625954.245
ERT: 2005-045T06:10:23.782
APID=25 Subtype=9 Version=2
  Image ID: 1000012323
  Camera ID: Front Left Hazcam
  Filter ID: No filter/unknown
  Array PMA Coordinate length 3
    [0] PMA Coordinate: 0.000000
    [1] PMA Coordinate: 0.000000
    [2] PMA Coordinate: 0.000000
  PMA Pointing Argument: 0
  Image Acquire Request: Acquire Image
  Shutter Subtraction Request: None

Credit: NASA/JPL/Caltech
# UHF Link Report

Filename: products/047/010/e0105-001-0005_001_0134188770-155.dat  
Type: uhf_link_rep - UHF Link Report  
Spacecraft: MER A (SCID=254)  
DVT: 2004-093T14:38:43.195 - 0134188770.155  
APID=47 Subtype=10 Version=0  
product_viewer: viewUhfDps products/047/010/e0105-001-0005_001_0134188770-155.dat

Report for "UHF Link Report" data product (47/10)  
Product Version: 0  
File Name: products/047/010/e0105-001-0005_001_0134188770-155.dat

Accounting

---

File size: 12028 bytes  
Time span: 1000 seconds  
Number of samples: 999  
Sample period: 1 second

<table>
<thead>
<tr>
<th>Start</th>
<th>End</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCLK:</td>
<td>134188770.61377</td>
</tr>
<tr>
<td>Osc. Temp (DN)</td>
<td>12633</td>
</tr>
<tr>
<td>Osc. Temp Status</td>
<td>Good</td>
</tr>
<tr>
<td>PA Temp (DN)</td>
<td>0</td>
</tr>
<tr>
<td>PA Temp Status</td>
<td>Good</td>
</tr>
</tbody>
</table>

--Samp-----SCLK---Rx_Pwr(DN)---Word 4---Tx_State---RC_Tone---TC_Tone---Link_Qual---Bit_Sync---Car_Lock-----TAC-----RAC

<table>
<thead>
<tr>
<th></th>
<th>SCLK</th>
<th>Rx_Pwr(DN)</th>
<th>Word 4</th>
<th>Tx_State</th>
<th>RC_Tone</th>
<th>TC_Tone</th>
<th>Link_Qual</th>
<th>Bit_Sync</th>
<th>Car_Lock</th>
<th>TAC</th>
<th>RAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>134188771</td>
<td>8197</td>
<td>0x0094</td>
<td>Off</td>
<td>No_Tone</td>
<td>No_Tone</td>
<td>Good</td>
<td>No_Lock</td>
<td>No_Lock</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>134188772</td>
<td>8404</td>
<td>0x0094</td>
<td>Off</td>
<td>No_Tone</td>
<td>No_Tone</td>
<td>Good</td>
<td>No_Lock</td>
<td>No_Lock</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>134188773</td>
<td>8409</td>
<td>0xf008</td>
<td>Off</td>
<td>No_Tone</td>
<td>No_Tone</td>
<td>Bad</td>
<td>No_Lock</td>
<td>No_Lock</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>134188774</td>
<td>8400</td>
<td>0xf008</td>
<td>Off</td>
<td>No_Tone</td>
<td>No_Tone</td>
<td>Bad</td>
<td>No_Lock</td>
<td>No_Lock</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Would I do it again?

- Yes, but...
- Add type/length/value data types
- Add formatting plugin (XSL, Velocity, etc)
Agenda

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Reuse

Summary
Q&A
Reuse Across Missions

- Cassini
- Deep Impact
- Dawn
- MRO
- MSL
Package Dependencies

- report
- product
- evr
- message
- app
- log
- util
- sfdwu
- ecp
General Libraries

- report
  - product
    - evr
      - message
      - app
      - log
      - util
      - sfdu
        - ecp
Domain Specific Libraries

- report
- product
- evr
- message
- app
- log
- util
- sfdu
- ecp
Application Specific Code

- report
- product
- evr
- message
- app
- log
- util
- sfdu
- ecp
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Summary

- **Simplicity** to handle risk, cost, schedule
- **Extensibility** to handle uncertainty
- **Reuse** to handle risk, cost, schedule
- **Know your users**
  - One size does not fit all
  - Requirements documents are not enough
  - Use assumptions that fit reality
For More Information

- Science Instruments Home Page
  - http://athena.cornell.edu/
- MER Analyst's Notebook
  - http://anserver1.eprsl.wustl.edu/
- Basics of Space Flight
  - http://www.jpl.nasa.gov/basics/
- Introduction to the AMMOS Ground System
  - http://eis.jpl.nasa.gov/~betsy/mm/intro.htm
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