

Files from Mars: Java™ in the MER Data Infrastructure

David Noble

Principal Consultant

Oak Grove Consulting

<http://marsrovers.jpl.nasa.gov/>

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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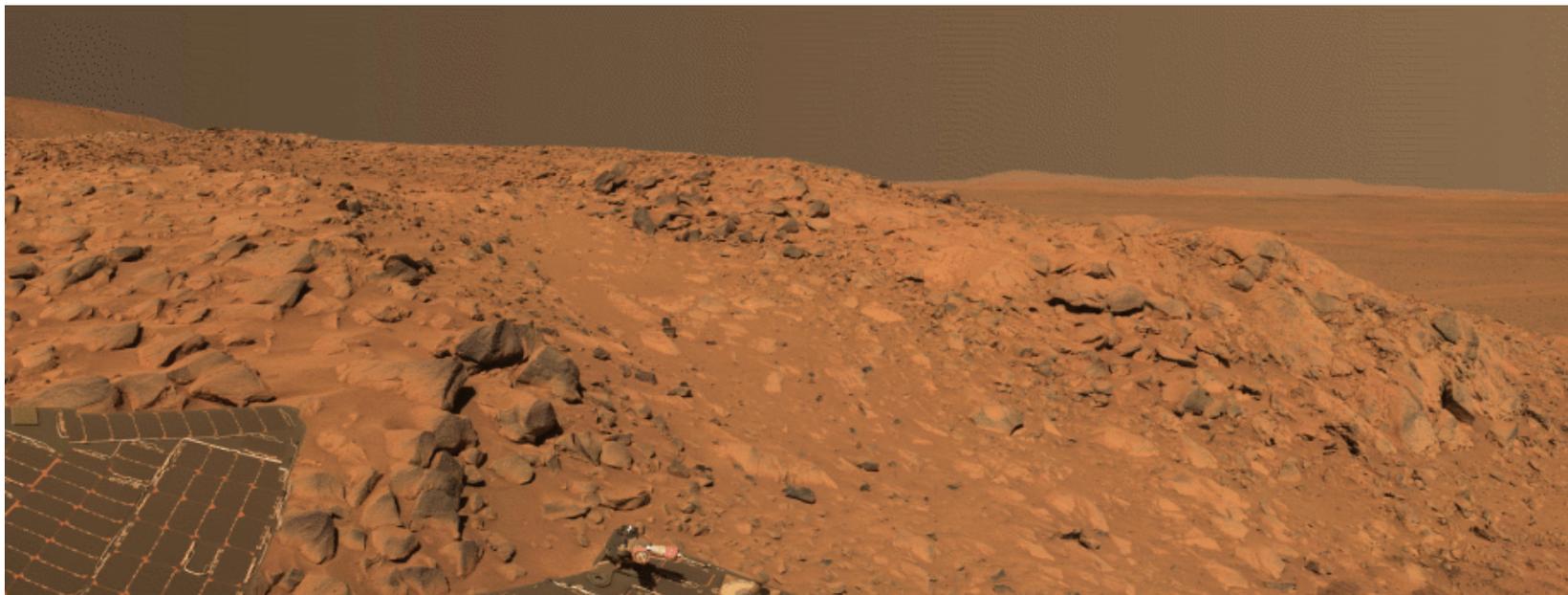
Reuse

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Q&A

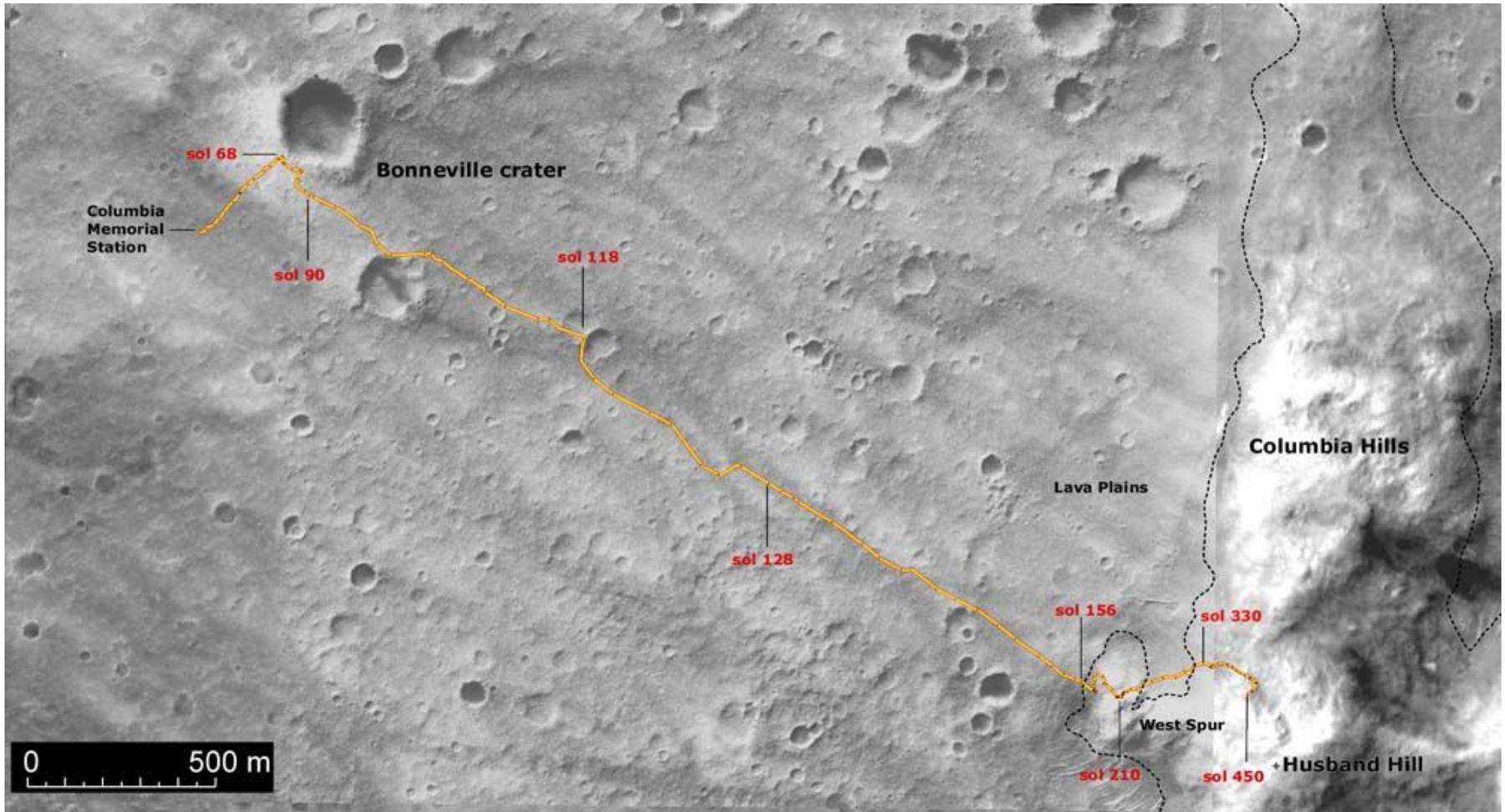
Mission Overview

Two robotic geologists exploring Mars



Credit: NASA/JPL/Cornell

Detail of 'Cahokia' panorama
<http://photojournal.jpl.nasa.gov/feature/cahokia>



Credit: NASA/JPL/MSSS/NMMNH

MER-A (Spirit) Traverse to Sol 450
<http://photojournal.jpl.nasa.gov/catalog/PIA07849>

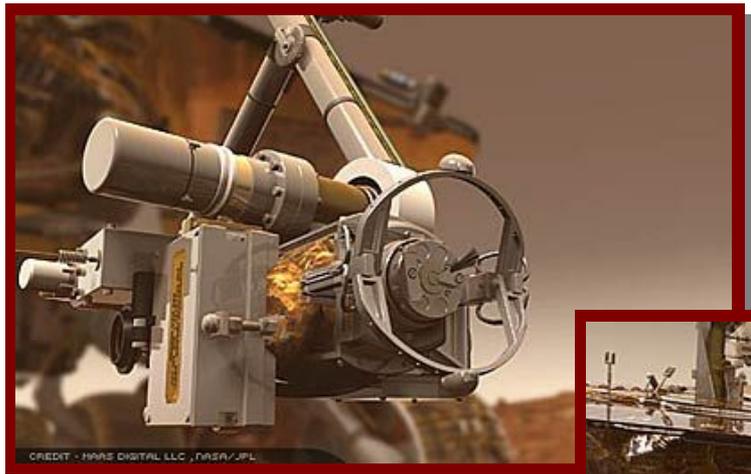
Height: 1.5m
Width: 2.3m
Length: 1.6m
Mass: 174kg



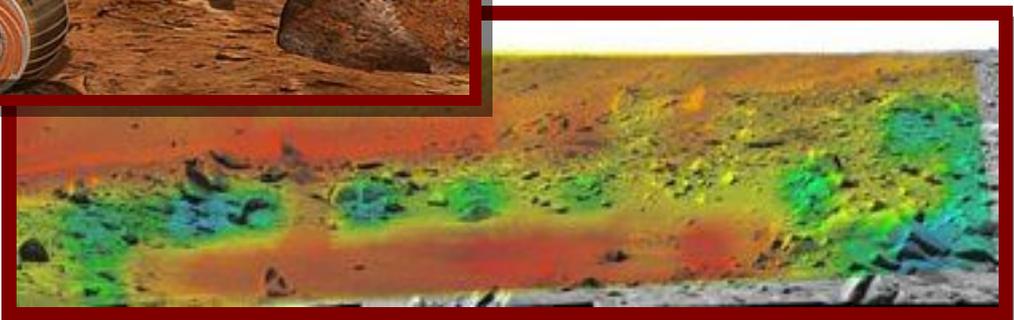
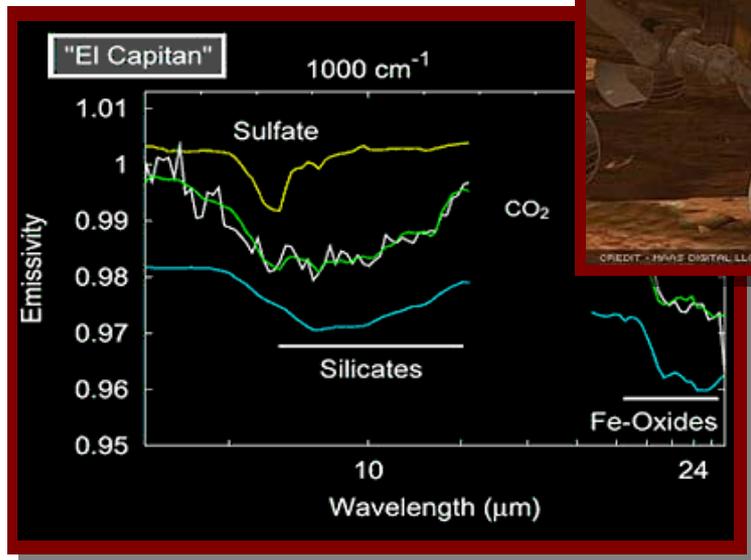
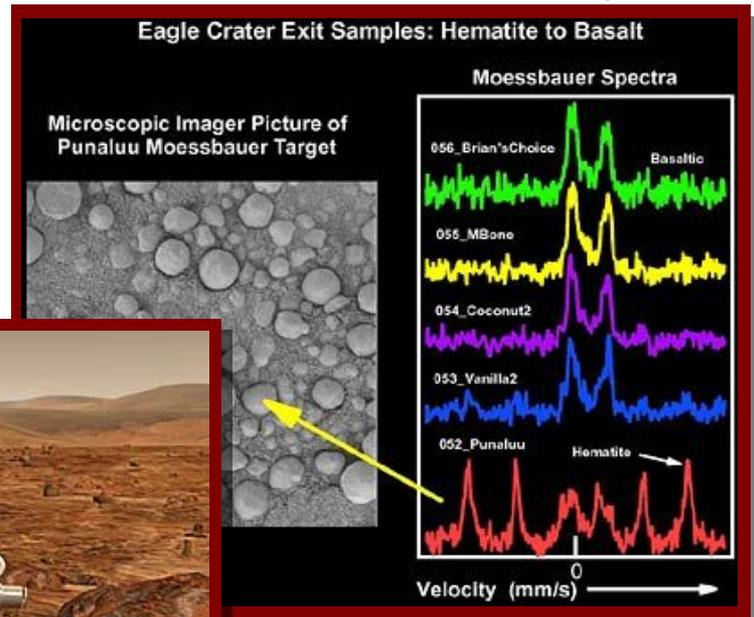
Credit: NASA/JPL

MER-A (Spirit) and Mars Pathfinder flight spare
http://marsrovers.jpl.nasa.gov/gallery/spacecraft/mer2002_1106_b231.html

Credit: Maas Digital LLC, NASA/JPL



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



Credit: NASA/JPL/Cornell/ASU

Credit: NASA/JPL/Cornell/ASU

<http://athena.cornell.edu/>

java.sun.com/javaone/sf

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**

MER's Science Objectives



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

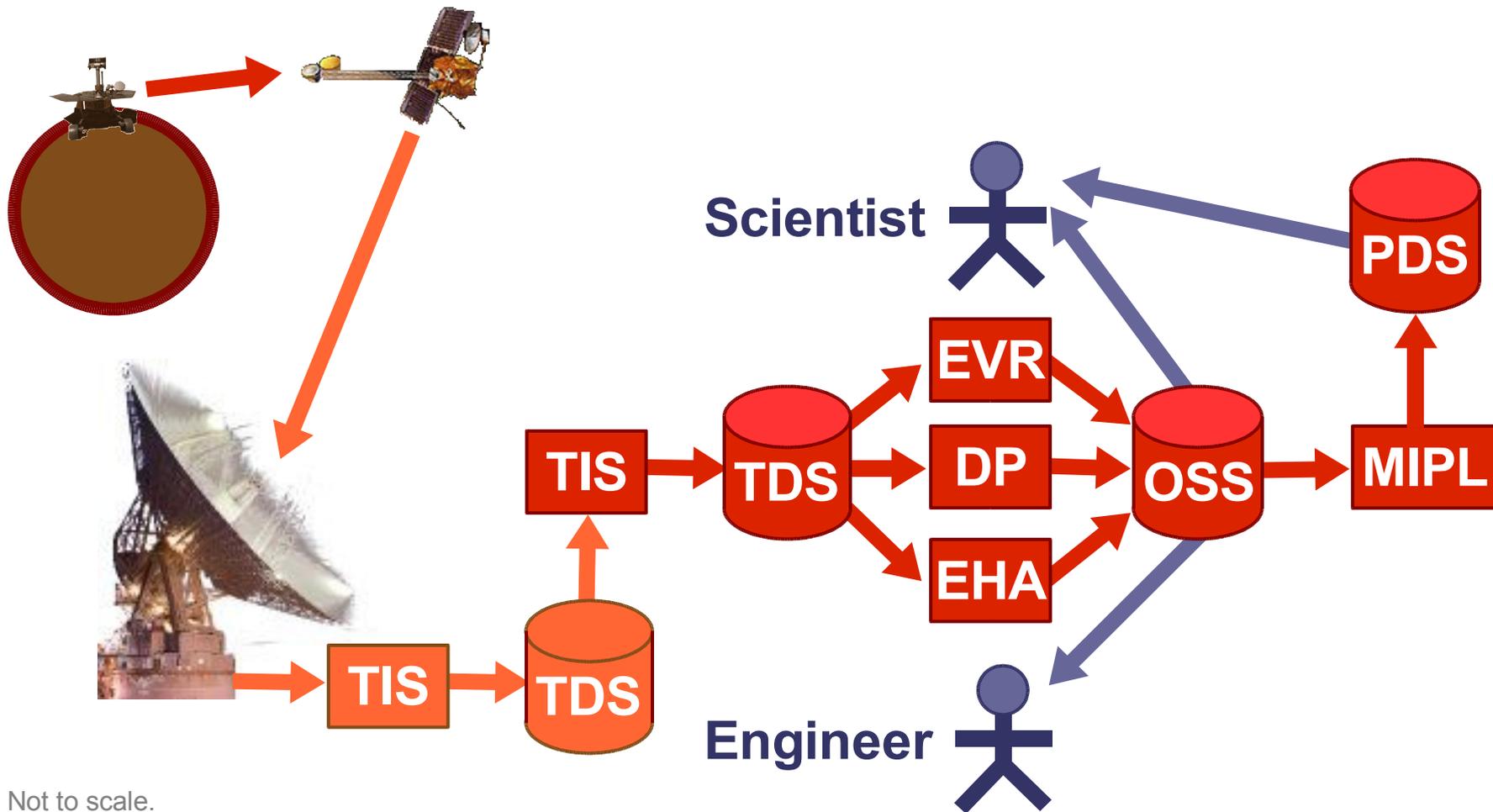
1. Search for and characterize a variety of rocks and soils that hold clues to past **water** activity. In particular, samples sought will include those that have minerals deposited by **water**-related processes such as precipitation, evaporation, sedimentary cementation, or hydrothermal activity.
2. 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

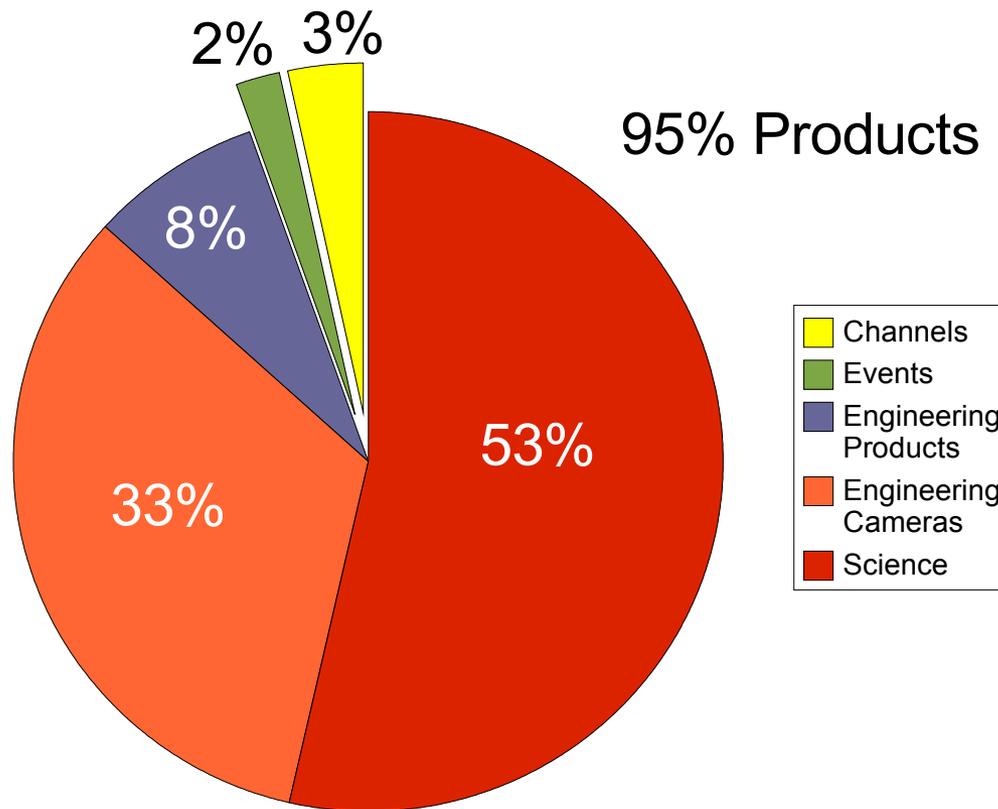
- Scientists
 - Evaluate images and other data
 - Plan rover activities
- Engineers
 - Evaluate rover health, state, performance
 - Build rover activity commands
 - Keep everything working

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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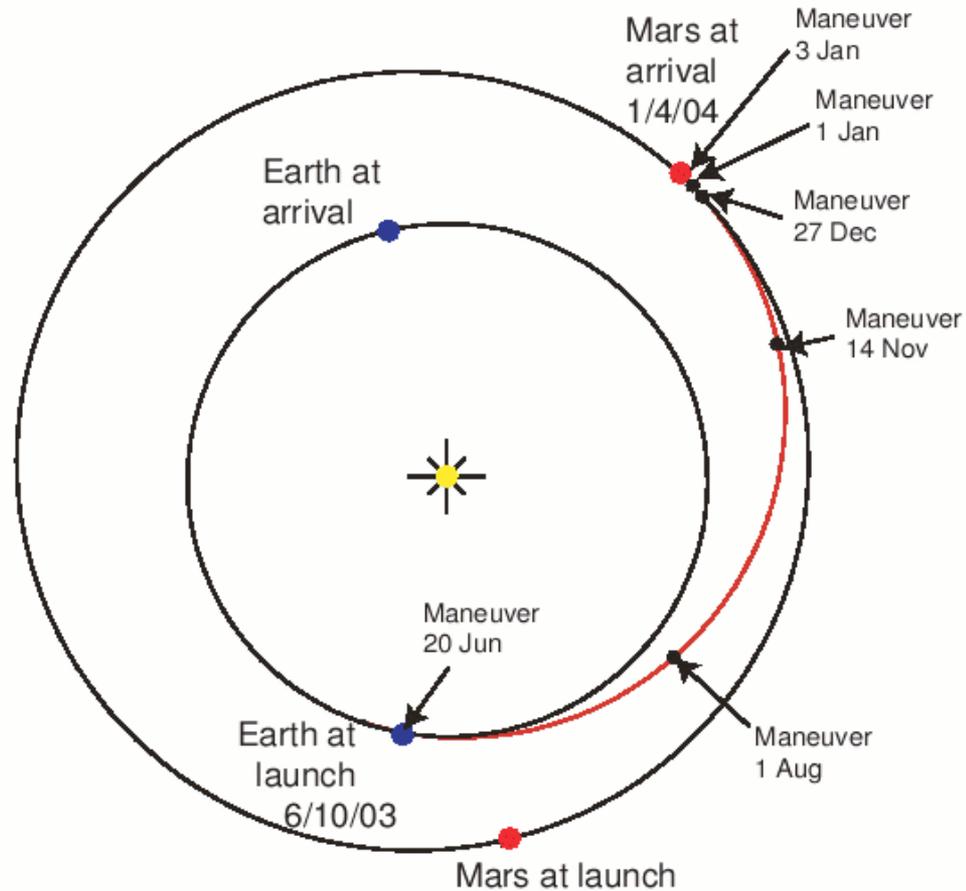
Summary

Q&A

Deadline

- MER-A Launch Window
 - June 8, 2003 – June 24, 2003
- MER-B Launch Window
 - June 25, 2003 – July 15, 2003
- Two opportunities per day
- 10 days required between launches

Planetary Alignment



MER Landing Press Kit, 12-1-03
<http://marsrovers.jpl.nasa.gov/newsroom/merlandings.pdf>

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

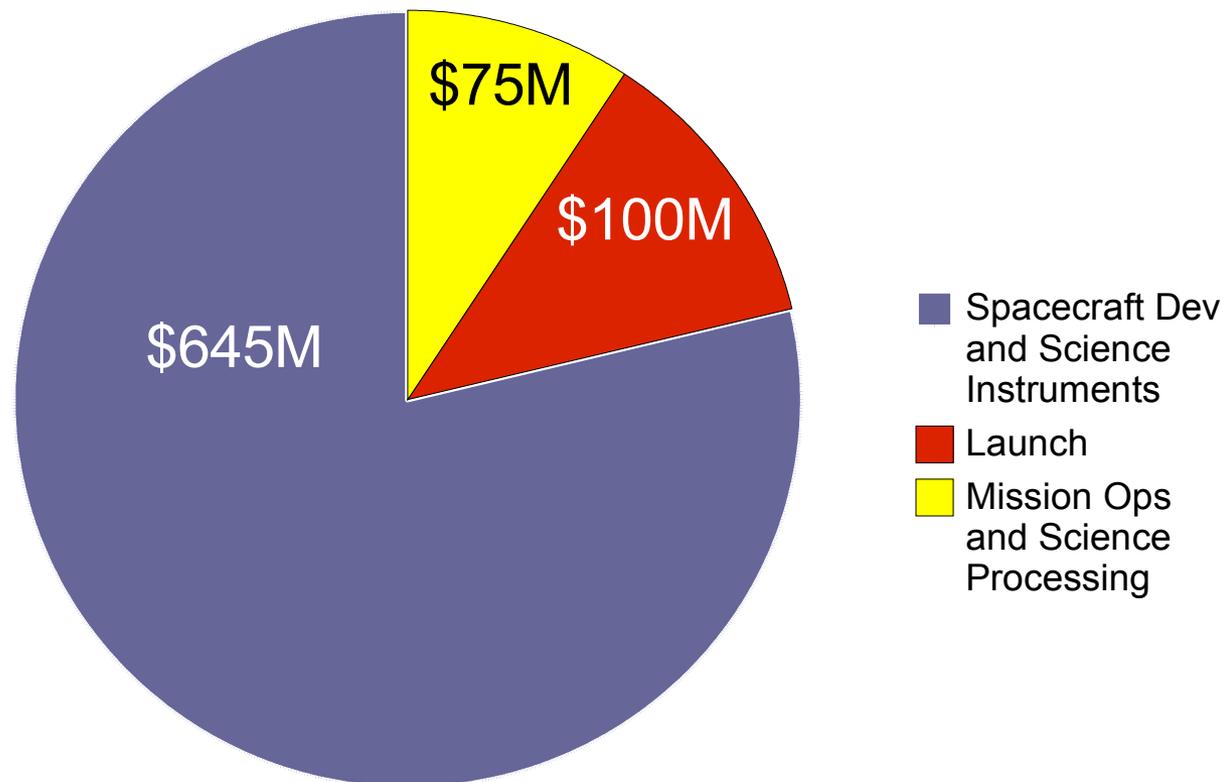
	Attempts	Successes
Orbiters	11	4
Landers	13	4
Rovers	1	1

MER Landing Press Kit, 12-1-03

<http://marsrovers.jpl.nasa.gov/newsroom/merlandings.pdf>

Budget

Primary Mission: \$820 Million USD



MER Landing Press Kit, 12-1-03

<http://marsrovers.jpl.nasa.gov/newsroom/merlandings.pdf>

Visibility

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

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Loose Coupling

- Benefits
 - Component reuse
 - Component pluggability
 - Parallel development
- Drivers: cost, risk

Criteria

- Usability
- Correctness
- Testability
- Reliability

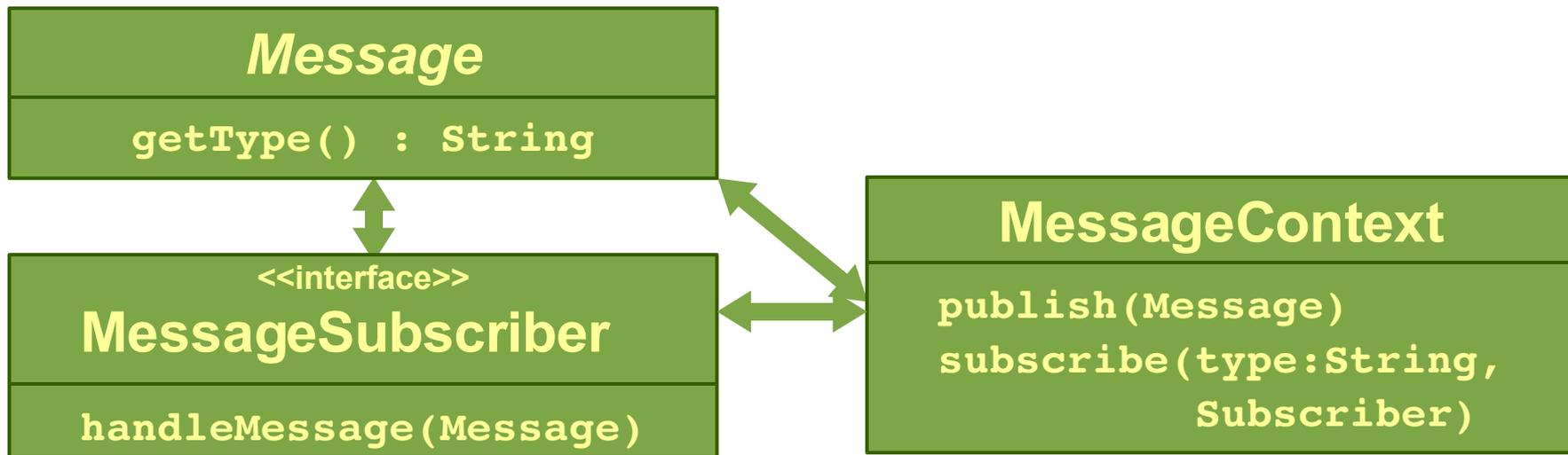
Options

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

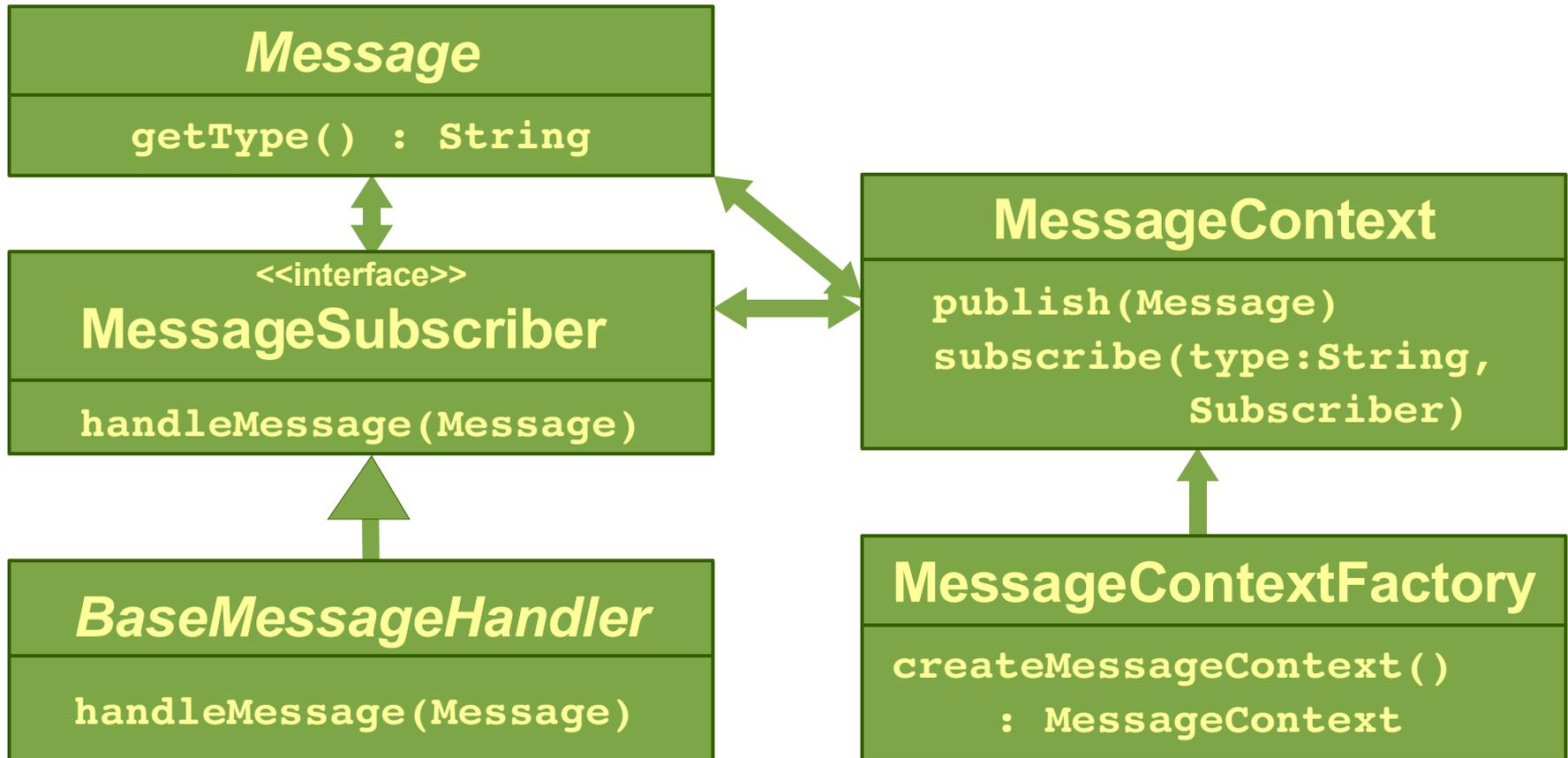
Options

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

Message Classes



Message Classes



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);  
    }  
  
}
```

Message Subscriber

```
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

	Lines	Percent
Brackets	59	8.70%
Whitespace	70	10.32%
Comments	345	50.88%
“Significant”	204	30.09%
Total	678	

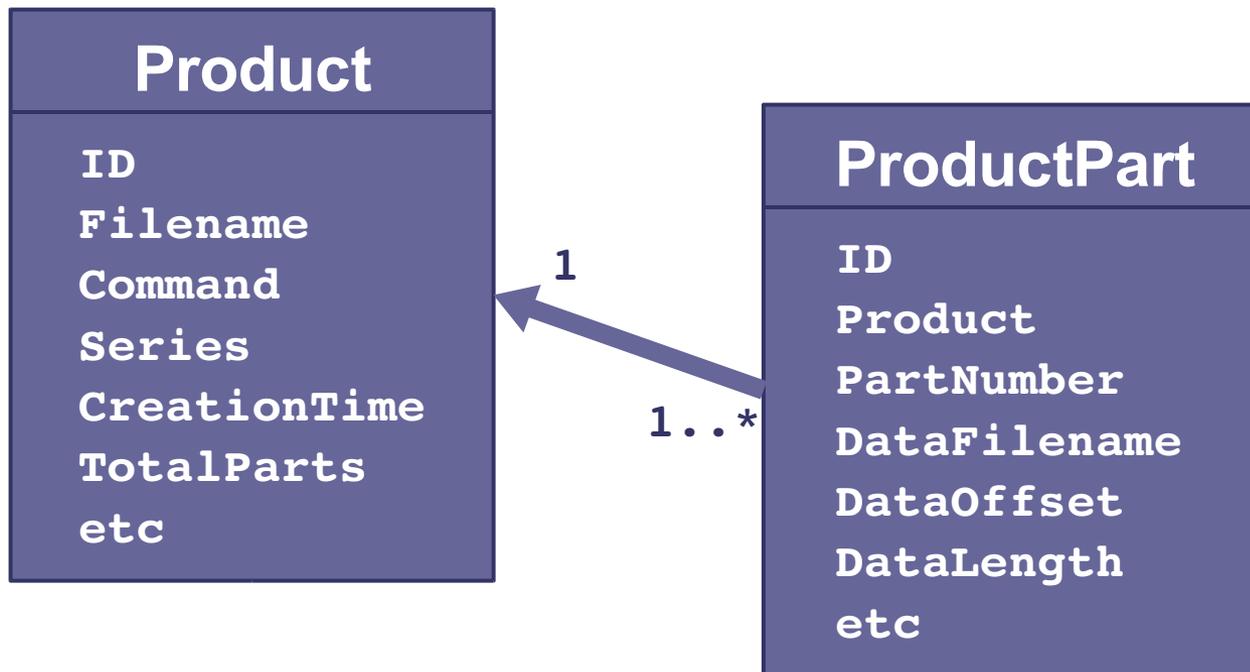
Would I do it again?

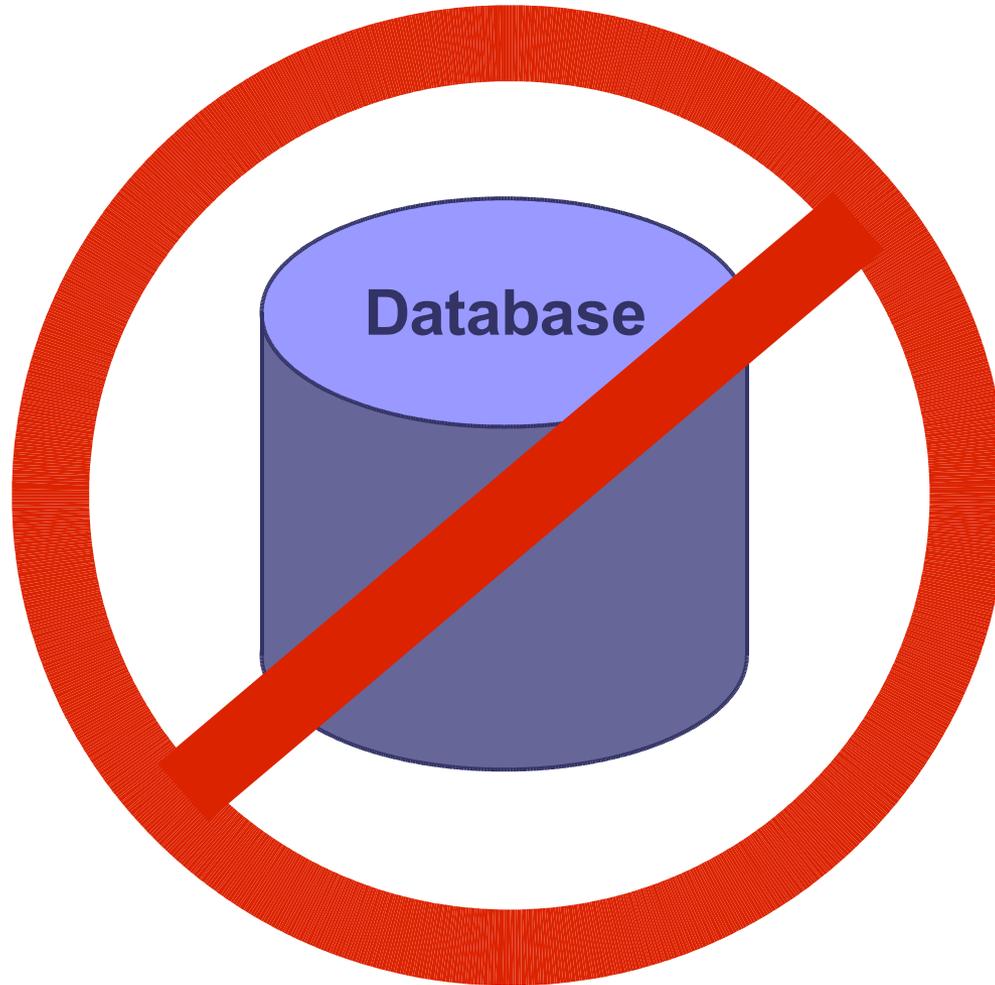
- **Yes**
- Reused for other missions
- Watching for creeping complexity

Data Product Storage

- Product files
- Product metadata
- Product part metadata

Schema Design





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

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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)
DVT:      2005-039T20:59:11.217 - 0161168693.127
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
Packetized: 2004-093T16:28:59.022 - 0134195386.103
ERT:      2004-093T16:55:10.744
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
    
```

```

-----
                                Start                End
-----
SCLK:      134188770.61377      134189770.50879
Osc. Temp (DN)      12633                12911
Osc. Temp Status    Good                Good
PA Temp (DN)        0                  0
PA Temp Status      Good                Good
    
```

```

--Samp-----SCLK---Rx_Pwr(DN)---Word 4---Tx_State---RC_Tone---TC_Tone---Link_Qual---Bit_Sync---Car_Lock-----TAC-----RAC
  1  134188771      8197  0x0094      Off  No_Tone  No_Tone      Good  No_Lock  No_Lock      0      0
  2  134188772      8404  0x0094      Off  No_Tone  No_Tone      Good  No_Lock  No_Lock      0      0
  3  134188773      8409  0xf008      Off  No_Tone  No_Tone      Bad   No_Lock  No_Lock      0      0
  4  134188774      8400  0xf008      Off  No_Tone  No_Tone      Bad   No_Lock  No_Lock      0      0
    
```

Would I do it again?

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

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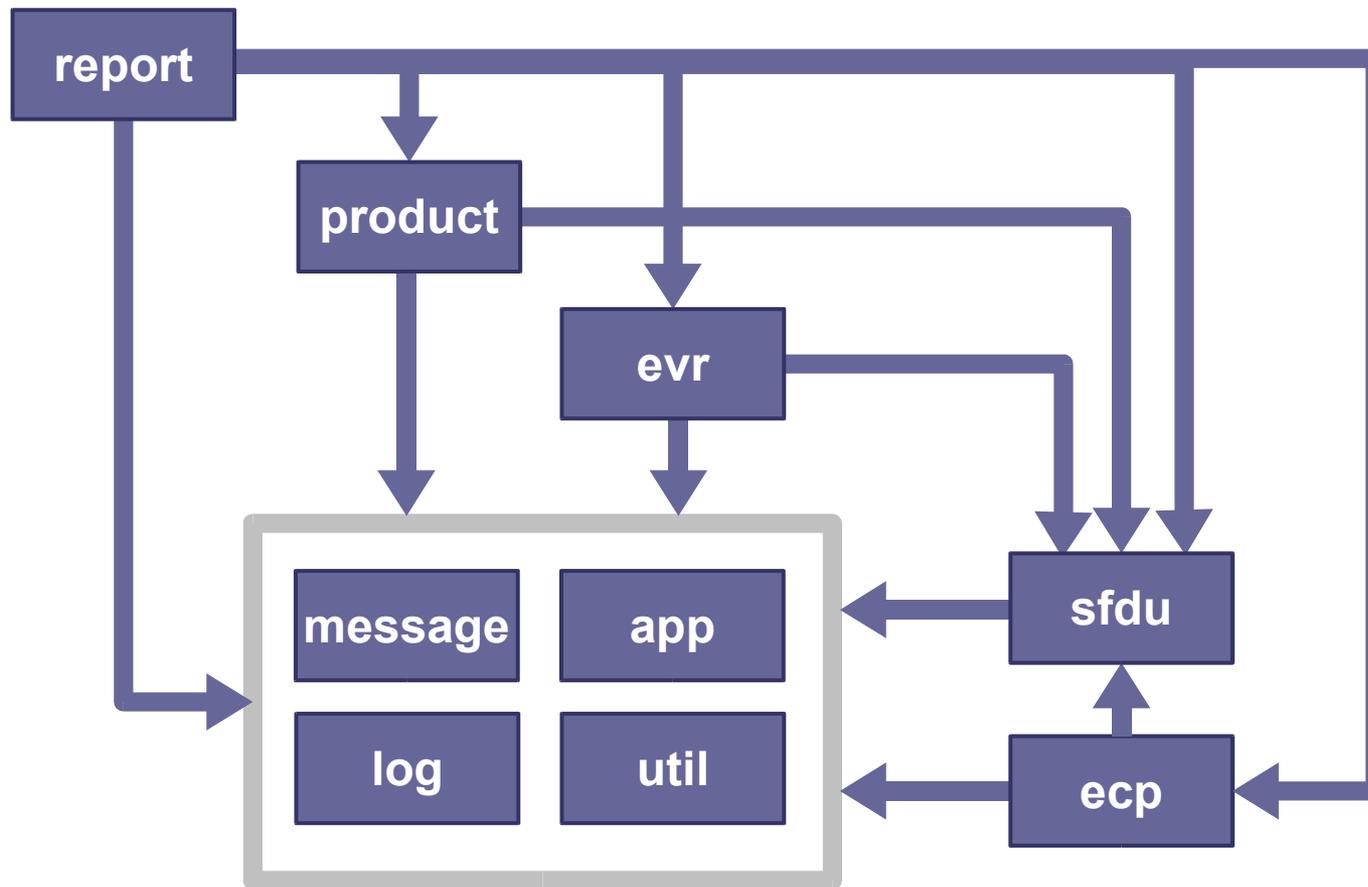
Summary

Q&A

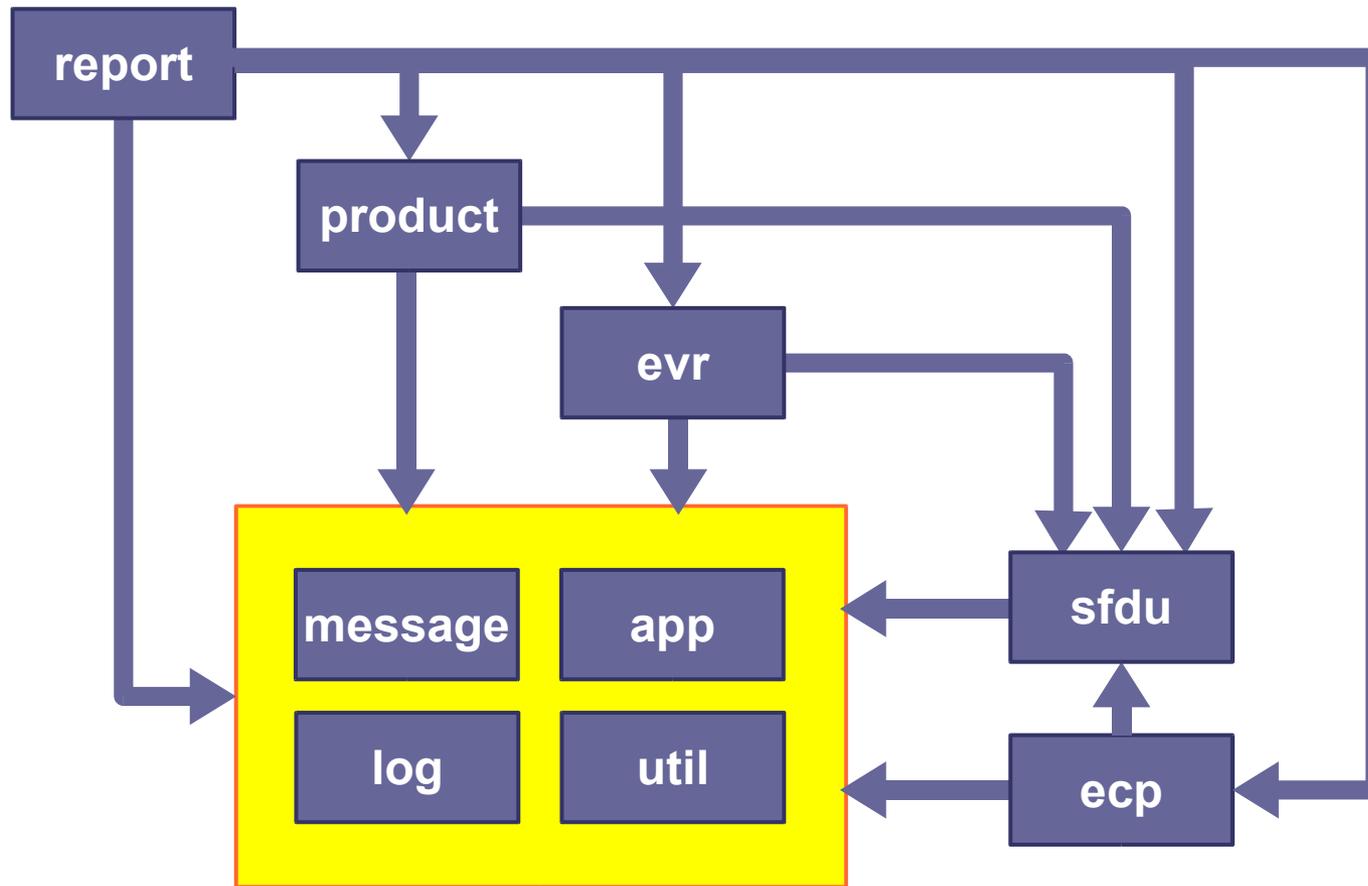
Reuse Across Missions

- Cassini
- Deep Impact
- Dawn
- MRO
- MSL

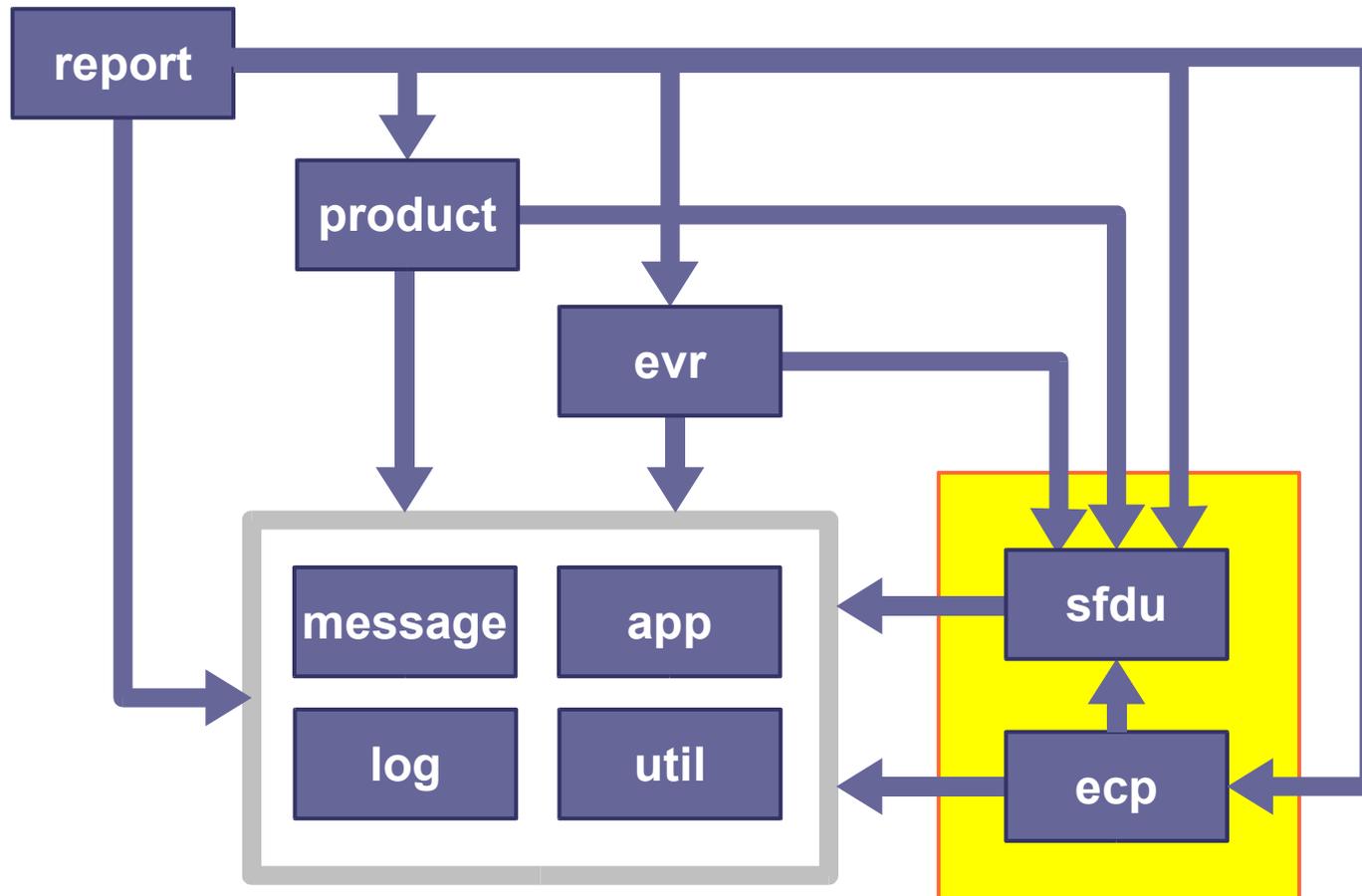
Package Dependencies



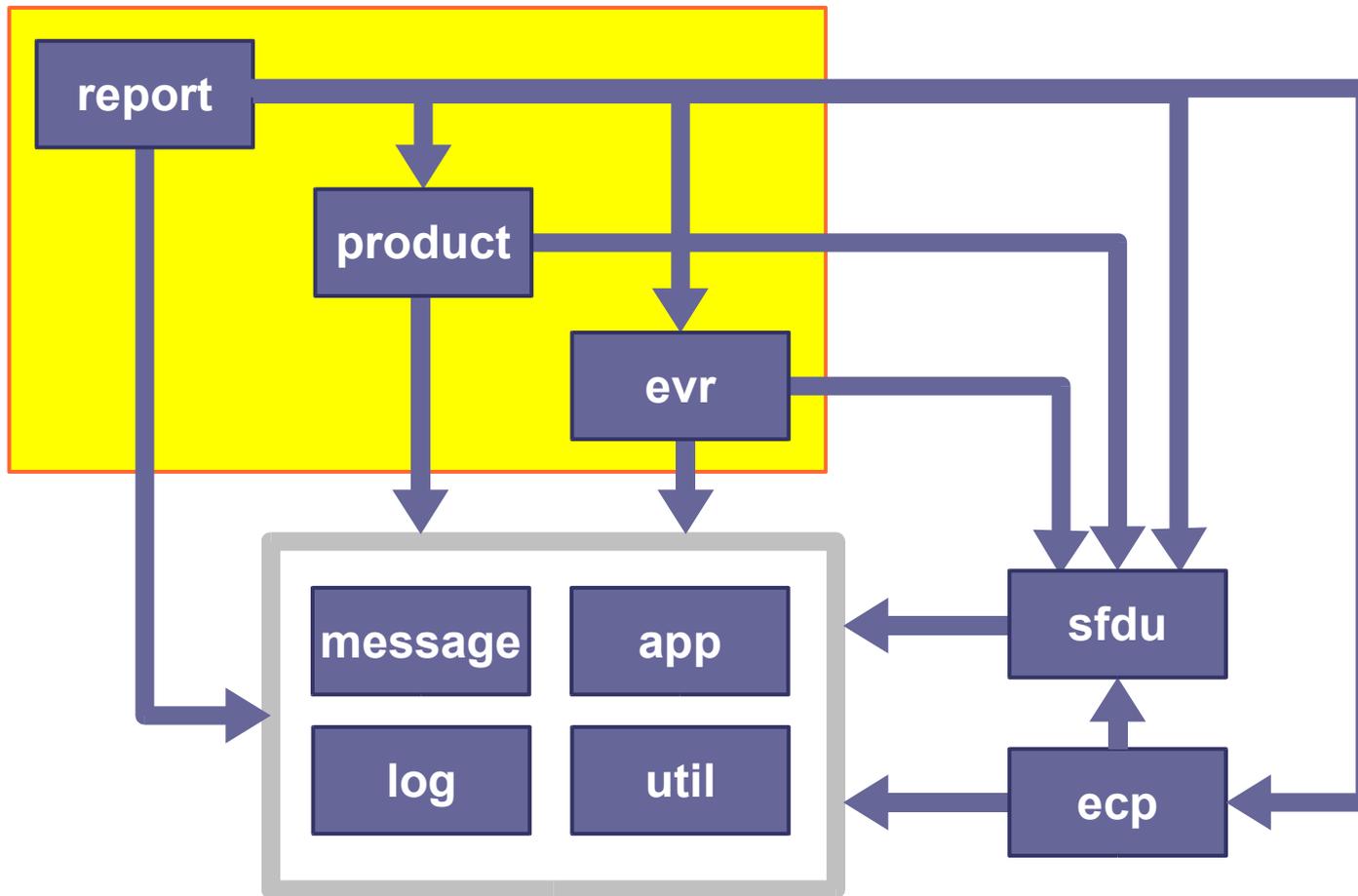
General Libraries



Domain Specific Libraries



Application Specific Code



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- **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>

Q&A

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