How DOORS Helps JPL Get to Mars and Beyond

Best Practices in Metrics, V&V and Traceability

Margaret H. Smith
Jim M. Grimes
Ross M. Jones
Trisha Jansma

Jet Propulsion Laboratory
California Institute of Technology
Outline

Overview of DOORS Use at JPL

- Topic 1: Metrics
- Topic 2: Verification and Validation (V&V)
- Topic 3: Traceability
JPL use of DOORS at JPL
Statistics

– 800+ users
– 600+ users have taken our in-house DOORS training.
– 50 DOORS licenses
– 50 projects have used DOORS, 22 are active
– 15 years using DOORS, preceded by 8 years using in-house TRACER tool.
– 5 years of a standard process with in-house training
– 2 System Analysts for daily project support
– 1 Full-time Equivalent (FTE) Systems Engineer for defining the method, teaching and project consultation
DOORS Provenance – According to JPL

JPL TRACER (1988) dBASE compiled with Clipper

Reverse engineered from code and user manual distributed on NASA COSMIC software site or from a JPL subcontractor/partner

QSS DOORS (1996)

1990 TRACER User Guide – Stoller/Boyle

Telelogic DOORS (2000)

1988 TRACER IEEE paper - Stoller

IBM Rational DOORS (2008)

Acquisition

Acquisition
# Sample Project Sizes

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- **Large legacy infrastructure project**
- **Medium complexity earth orbiting mission**
- **Smaller complexity lunar mission (JPL managed)**
- **Large complexity deep space mission (JPL managed)**

Not in this Sample: Flagship mission

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**Note:** Number of objects includes all objects in formal modules: table cells, headers, regular objects with or without text or OLE content.
Why Have a Standard Process?

- DOORS is a general purpose tool and there are many possible ways to use it.
- For the first 15 years we used DOORS, each new project reinvented the wheel.
  - Big projects could afford to invent their own method and have internal support.
  - Small projects couldn’t afford to reinvent.
  - We now have more small projects and fewer big projects.
- Projects trying to run the old document-centric process in DOORS were not taking advantage of the tool’s capabilities.
- Projects were making mistakes, blaming DOORS, and delaying import of requirements into tool as late as possible.
  - Managing requirements in spreadsheets and not getting the benefits of early sharing and collaboration.
What Has and Hasn’t Been Standardized?

**Has**
- Ownership, allocation and negotiation mechanism
- Attributes and their definitions – for requirements and V&V planning/tracking
- Views and Filters – traceability between 2 or 3 levels, allocation status, subsets of requirements information.
- High-level requirements template
- Scripts – Requirement Maturity Metrics, and V&V Burndown and Statistics and numerous housekeeping scripts used by DOORS System Analysts (Sas).
- Tools – Trace Tree Tool for graphically displaying individual requirements traceability and project requirements mapping.
- Practices – the JPL Systems Engineering practices that culminate in requirements.
- Licensing and Support – the JPL institution purchases DOORS licenses for use by all projects and funds two Systems Analysts (support).
- Training/Deployment – Engineers who are involved in requirements work attend a JPL developed 2-day training that teaches basic DOORS tool use and the JPL standard method.

**Hasn’t**
- Requirements levels and element decomposition
- Detailed requirements templates
- DOORS collaboration method with partners and subcontractors

Acknowledgement: *We owe the success of the JPL Institutional Requirements and V&V Tracking process and training program to Richard Stoller (retired), and Karen Boyle (who sadly passed away in February, 2011).*
• Maturity Definition:
  + V&V Method/Approach defined
  + Rationale defined
  + Linked to parent(s)
  + Links exist to this requirement from Satisfiers (including V&V activities)
  + Satisfier (lower level owner) accepts allocated requirement
    - TBD, TBR, TBCs

• Requirement Maturity Metric script:
  – Implemented in DOORS Extension Language (DXL)
  – Generates per module statistics across all modules in a Project, one module per row
  – Produces .csv file of statistics.
  – Project can customize output to suit their Project Management/reporting needs.
  – Provides a quick summary of requirement progress and facilitates comparison between modules.
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Note: The table includes columns for various metrics such as module version, last modified date, total requirements, unknown capability, gold plating, and allocations undecided or under negotiation.
**What Has Changed Today?**

Daily email to Project’s requirements owner

Assessing Requirements activity and churn

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Requirements are marked **Modified** if any attribute, with the setting **Affect change dates** turned on, has been changed since the last time this report was generated.
Verification Planning and Tracking

• JPL Projects have been recording Verification information in DOORS for the last 10 years.

• Initial benefit -- requirements changes were immediately visible to engineers responsible for verifying requirements because verification activity artifacts and verification events were now linked directly to requirements.

Other benefits:
• Lower tooling cost—use existing institutionally supported tool and support.

• Enables useful views of requirements, verification planning & status, and verification events.

• Projects can use as-is or customize a generic DXL script to generate verification statistics and graphics.

• Saves projects money through reuse of tooling and method.
Verification Process

**Project Verification Planning**
- Get DOORS Training / consulting

**Requirements Development**
- Develop V&V method, venue and approach

**Verification Activity Planning**
- Verification Activity Groups defined
- Reqmts to VA mapping captured
- Schedule VA activity completion (need by) date
- Plans and procedures developed outside DOORS and hyper-linked from the DOORS VA

**Verification Activity Execution**
- Execute VA procedure, analyze results and determine status
- Record status of the VA (procedure) run and create problem/failure reports (if needed)
- Cognizant person approves VA execution result
- Cognizant person approves that the requirement has been verified

**Verification Status Reporting**
- Generate V&V burndown charts and statistics and present at management meetings
- Take corrective action (if necessary)
- Cognizant person approves VA execution result
- Cognizant person approves that the requirement has been verified

7/18/2013
Caltech – Jet Propulsion Laboratory
M. Smith - 12
Verification Elements

Definitions

**VI** – Verification Item, is anything that needs to be verified. All requirements become Vis when they are being verified.

**VA** – Verification Activity. The testing activities described in a single Test Plan, Procedure or Analysis. A group of associated VAs are a VA Group (VAG)

**VE** – Verification Event. A run or execution of a VA.

VE data elements originate in the AR and are pushed to VE to complete the status picture.
Verification Attributes

V&V Activity Planning

V&V Activity Execution

V&V Status Reporting

**VI or ITL item**
- object identifier (ID)
- statement of requirement
- rationale
- ...
- method
- verification approach
- audit status
- audit completed on (date)
- audited by

**VA**
- activity name or activity group name
- VA priority
- VA status
- VA owner
- venue
- date scheduled (for completion)
- date completed
- plans and procedures
- PFRs

**VE**
- VA id (a reference)
- .... data imported from AR
- url of Activity Report
- url of test data directory

**Test Data Directory**

**Activity Report (AR)**

**Test Plan**
- version

**Test Procedure**
- version
Project Module Configurations

VIM – Verification Item (Requirements) Module
VAM – Verification Activity Module
VEM – Verification Event Module

**Multiple VAMs** reflecting the Project’s requirements structure or V&V organization.

**A single VAM** for the Project’s complete requirement tree
- partition VAM to give owners granular write access

**Combined VAM and VEM** for projects that only need information on the latest run/execution.
Verification Item (VI) Burndown

A pick list allows selection of any group of VIMs for this chart.

Count of VIs (modules included selected from pick list):
- Scheduled = total number of VIs remaining to be completed per schedule
- Actual = total number of VIs remaining to be completed actually
- Not Confirmed = total number of VIs remaining to be Confirmed-Final
- Not Scheduled = total number of VIs remaining to be completed but not scheduled
Verification Activity Burndown

A pick list allows selection of any group of VAs for this chart.

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<td>9/8/2009</td>
<td>14</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>10/8/2009</td>
<td>14</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>11/8/2009</td>
<td>14</td>
<td>14</td>
<td>8</td>
</tr>
<tr>
<td>12/8/2009</td>
<td>14</td>
<td>14</td>
<td>8</td>
</tr>
</tbody>
</table>

Scheduled = total number of VAs remaining to be completed per schedule
Actual = total number of VAs remaining to be completed actually
Not Scheduled = total number of VAs that are not completed and are not scheduled
## Verification Item Statistics

from V&V Burndown Script that generates data to Excel

**Count of VIs in VIMs** (shall statements only)

| VIM NAME | Total VIs | VIs Linked to VAM | VIs Linked to VAGs | VIs Linked to VAs | VIs Auto Verif | VIs Conf Verif | VIs Not Linked to VAM | VIs Linked to Reject | VIs Not Linked to a VA | VIs Not Auto Verif | VIs Not Conf Verif | VIs Not Verif and Late | V&V Engr Responsible for this VIM |
|----------|-----------|------------------|-------------------|------------------|----------------|----------------|----------------------|---------------------|---------------------|-------------------|----------------|-------------------|--------------------------|----------------------------------|
| VIM1     | 625       | 600              | 15                | 575              | 200            | 150            | 25                   | 10                  | 50                  | 425               | 450            | 5                 | John Jones               |
| VIM2     | 500       | 500              | 10                | 485              | 100            | 75             | 0                    | 5                   | 15                  | 400               | etc            | 5                 | Susie Jones              |
| VIM3     | 1000      | 1000             | 0                 | 1000             | 0              | 0              | 0                    | 0                   | 0                   | 1000             | etc            | 0                 | Mary Smith                |
| ...      | ...       | ...              | etc               | etc              | etc            | etc            | etc                  | etc                 | etc                 | etc               | etc            | etc               | ...                       |
| VIM n    | 200       | 200              | 5                 | 190              | 25             | 5              | 0                    | 5                   | 10                  | 175               | etc            | 0                 |                            |
| Total    | 2325      | 2300             | 30                | 2250             | 325            | 230            | 25                   | 20                  | 75                  | 1975             | etc            | 10                |                            |

Relationships:  B=C+H; I is not included in D; E=C-I-D; J=B-E=H+I+D; K=B-F; L=B-G

M = VIs not auto verified AND scheduled completion date is missed or has not been scheduled or is not linked. Any object containing the word “shall” enclosed in quotes (“shall”) is not included in any statistic.
### Verification Activity Statistics

from V&V Burndown Script that generates data to Excel

<table>
<thead>
<tr>
<th>VA NAME*</th>
<th># of VI Parent Links</th>
<th>Are VAs Fully Linked to VIs</th>
<th>VA Status</th>
<th><strong>VA Scheduled?</strong></th>
<th><strong>Is there a VA Plan &amp;/or a Procedure?</strong></th>
<th>Are there any Suspicious VI Links?</th>
<th>Schedule Days Remaining (if not completed)</th>
<th>V&amp;V Engineer / Owner of VA</th>
</tr>
</thead>
<tbody>
<tr>
<td>VA-x</td>
<td>25</td>
<td>Yes</td>
<td>Blank</td>
<td>08/10/09</td>
<td>No</td>
<td>Yes</td>
<td>10</td>
<td>Jack Jones</td>
</tr>
<tr>
<td>VA-y</td>
<td>20</td>
<td>Yes</td>
<td>Completed-NF</td>
<td>07/26/09</td>
<td>Yes</td>
<td>No</td>
<td>-5</td>
<td>Mary Jones</td>
</tr>
<tr>
<td>VA-z</td>
<td>100</td>
<td>Yes</td>
<td>Completed</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td></td>
<td>Susie Que</td>
</tr>
<tr>
<td>...</td>
<td>350</td>
<td>...</td>
<td>Blank</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td></td>
<td>Tom Smith</td>
</tr>
<tr>
<td>VA-n</td>
<td>55</td>
<td>Yes</td>
<td>Blank</td>
<td>08/20/09</td>
<td>Yes</td>
<td>Yes</td>
<td>20</td>
<td>Susie Smith</td>
</tr>
</tbody>
</table>

* VAs are organized in VAM under VAGs and sub-header VAGs, but tabulated separately here.

** Identifies if there is an http entry in the Plan and Procedure attribute.
DOORS Trace Tree Tool (T3)

JPL has parent-to-child requirements relationships where a parent has 1 to tens of children, and links between levels can be many-to-many. We have trouble seeing the forest for the trees and navigating requirements flow within DOORS.

• Primary Motivations
  – Provide JPL users with an alternative graphical presentation of requirement flow (links)
  – Allows navigation of requirements based on hierarchy or flow
  – Enables seamless navigation between modules following flow-down/links
  – Provides easy access via Web-based, platform independent interface

• Secondary Motivation - evolved with implementation
  – Provide an indication of timeliness of requirements flow-down
  – Provide an efficient way to checkout verification planning

• History
  – Conceived and developed by a JPL Software Systems Engineer (James Grimes) in 2006
  – Enthusiastically used by 8 JPL Flight Projects
Phaeton Trace Tree

Report Date: Wed Apr 27 11:54:20 PDT 2011

All links updated at this time. Requirement contents and attributes updated if object updated since last time report was run.

Explanation Caveat!

_ProjX/L1_MSC  L1 Reqs and Mission Success Criteria
_ProjX/L2_FG_IRD  Flight Ground Requirements
_ProjX/L2_ISS  ISS Interface
_ProjX/L2_LV  Launch Vehicle Interface
_ProjX/L2_PR  D-64670: Project Requirements

...
Project Map

Number of links/flowed-down requirements appear on edges
Trace Tree Index for ProjX/L3_FS

Report Date: Wed Apr 27 11:54:20 PDT 2011

All links updated at this time. Requirement contents and attributes updated if object updated since last time report was.

### Sequential Requirement Index

Requirements and headings only - no non-requirements

<table>
<thead>
<tr>
<th>ID</th>
<th>Requirement Text or Heading</th>
</tr>
</thead>
<tbody>
<tr>
<td>550</td>
<td>********** THE STATUS OF THE ECR CHANGES THE COLOR OF THE OBJECT TEXT TO RED GIVEN OBJECT WITHIN DOORS MUST BE DISPLAYED USING THE WAS/IS; VIEW TENTH</td>
</tr>
<tr>
<td>1</td>
<td>Introduction</td>
</tr>
<tr>
<td>2</td>
<td>1.1 Purpose and Scope</td>
</tr>
<tr>
<td>3</td>
<td>1.2 Change Control-Change Log: Auto-Status last run 11 November 2009</td>
</tr>
<tr>
<td>26</td>
<td>2 Design Architecture of The OPALS FS</td>
</tr>
<tr>
<td>41</td>
<td>2.1 Definition of Architecture</td>
</tr>
</tbody>
</table>

#### Concept of Operations

3 Requirements on ...... Flight System (FS)
**Requirement Page**

**Trace Tree with Titles (Short Text)**

- L1_MSC:44 Mission Success Criteria
- L2_PR:41 Mission Lifetime
- L3_FS:590 Uncontained Error Rate
- L4_CDH_PE:345
- VAM_-_DO_NOT_BASELINE:78

**Report date/time:** 2011-04-21 12:11:43
**Module baseline date/time:** 2011-04-13 09:39:32 (Object Text create/mod date/time not available)

---

**SHORT TEXT:** Uncontained Error Rate

This requirement is in section 3.1.1

**REQUIREMENT TEXT:**
The FS shall experience an uncontained soft errors

---

**ATTRIBUTES with values:**

**Change Status**

**Approved Change**

**Created By**

**Radosz Borsik**

**Attributes continue below**
Object Text Graphic

Back to Graphic Trace Tree without Text
Go to Graphic with [STDV] Verification Approach text (also big)

Trace Tree with Object Text

L1_MSC:14
The OPALS project shall deliver a flight system capable of  
..............................................  
..............................................

L2_PR:41
The OPALS Project shall operate  
..............................................  
..............................................

L3_FS:536
The FS shall experience an uncontained soft errors  
..............................................

L4_CDH_PE:345
The CDH/PE shall experience uncontained soft errors  
..............................................

VAM_-_DO_NOT_BASELINE:78
SEE Analysis

Attributes continue below
Verification Approach Graphic

L1_MSC:44
L2_PR:41
We will determine how many Demonstrations are required in order to obtain a satisfactory result. This number will then be coupled with

L3_FS:530

L4_CDH_PE:345
Analysis of controller components performed by radiation group..........................
..................................................................................................................
..................................................................................................................
..................................................................................................................
..................................................................................................................

VAM_-_DO_NOT_BASELINE:78

Attributes continue below
Typical DOORS T3 User Scenarios

• Quickly obtain the contents of a requirement with a known ID
  – Main page → Module page → Requirement number

• Scan a particular Project module for a specific requirement
  – Main page → Module page, then
    • Scroll up and down at web browser speeds
    • Use browser’s find capability (not as flexible as DOORS, but faster)

• Trace requirements flow-down starting at any requirement
  – Click on boxes in graph going up- or downstream in requirements flow
  – Go from there to text, attributes

• Obtain immediate visual indication of timeliness of flow-down
  – E.g., has upstream requirement X been updated more recently than my requirement? If yes, then it’s red. Actual date is shown on X’s page.
  – Is flow-down complete? Does the requirement have a parent?

• Provide supportive evidence during Project Reviews
  – Quickly show existence of flow-down
  – Quickly show V&V attribute, implementation status (if in attribute)
Development Tools Used

- **DXL** – DOORS eXtension Language, a DOORS proprietary C-like, object-oriented language available within the DOORS client
- **Perl** – a scripting language widely available on UNIX, Mac OS X, Linux, Windows
- **Graphviz** – open source Graph Visualization software developed at AT&T that includes the Dot language and dot program for drawing directed graphs
- **XML** and Perl/C-based XML parsing software – open source software
- **Java** for processing images
- **Standard UNIX utilities** such as date, rm, ls, rsync, etc.
- **SVN** – Subversion open-source version control tool
JPL’s DOORS Wish List

• Usability features: auto-fill, Excel-type formulas, simple on-screen filters
• Replace DXL with industry standard programming language
• Improve link visualization and navigation capabilities
• Improve multi-organizational collaboration capabilities
• Improve web/browser based client to make editing a reality.
• Integrations with other SysEng tools: Mechanical CAD, Electrical CAD.
• Standards based interchange with other tools.