

Jet Propulsion Laboratory uses IBM software to develop Curiosity

*Managing a massive volume of requirements for
Mars rover development, launch and operations*

Overview

The need

JPL needed a solution to capture technical product requirements and enable planning and tracking of verification and validation (V&V) activities for the Mars Science Laboratory (MSL) Curiosity rover.

The solution

In 1996, JPL adopted IBM® Rational® DOORS® software as its standard requirements tracing tool for large projects, including the MSL mission, and later began using it to plan and track V&V activities.

The benefit

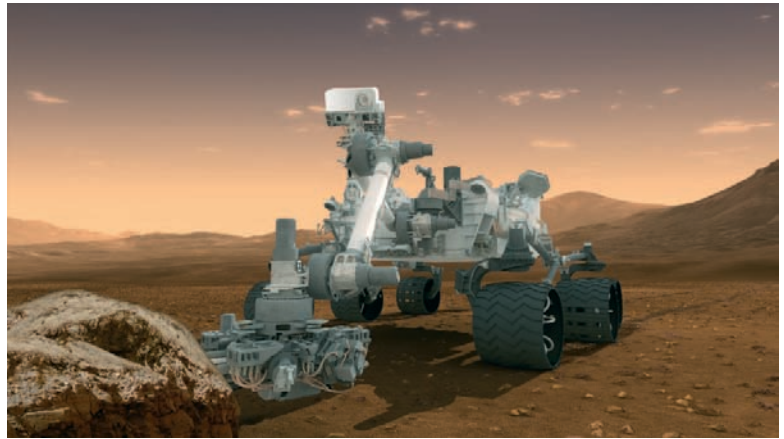
The solution enables collaboration between large teams of engineers, and reduces errors and rework. JPL estimates that it has saved the work of one full-time employee in V&V tasks.

Established in the 1930s, Jet Propulsion Laboratory (JPL) is a federally funded research and development facility managed by the California Institute of Technology for the National Aeronautics and Space Administration (NASA). Located in Pasadena, California, JPL conducts robotic space exploration missions in the fields of planetary exploration, Earth science and astrophysics, as well as research and development for NASA and other sponsors. In addition to the Mars program, other recent JPL missions include the Dawn spacecraft to orbit giant asteroid Vesta and dwarf planet Ceres in the asteroid belt; the Gravity Recovery and Interior Laboratory (GRAIL) mission to Earth's moon; the Juno spacecraft en route to Jupiter; and the Aquarius satellite, which is monitoring Earth ocean salinity.

Sending an entire science lab to Mars

In 2002, JPL began working on the Mars Science Laboratory (MSL) mission. As part of the NASA Mars Exploration Program, the mission included creating the Curiosity rover, which NASA designed to assess whether Mars had ever been capable of supporting life. The Curiosity rover is the latest in a long line of rovers designed by JPL, including the Mars Exploration Rovers Spirit and Opportunity, which landed on Mars in 2004, and Mars Pathfinder, which landed in 1997.





This artist's concept shows the NASA Mars Science Laboratory Curiosity rover, a mobile robot for investigating Mars' past or present ability to sustain microbial life.

JPL needed a requirements management solution to capture technical product requirements and perform verification and validation (V&V) activities for the MSL mission. In addition to managing the overall project, JPL designed and built the flight system, including the Curiosity rover, elements of the rover's suite of onboard science instruments, and the ground data system used to command the flight system, monitor its health and state and receive and process science data. JPL was also responsible for ground support equipment to enable testing of the rover.

Managing massive numbers of requirements

In 1996, JPL adopted IBM Rational DOORS software and it has become the organization's institutional requirements management tool for large projects, including the MSL mission. For this mission, JPL needed to capture five levels of requirements:

- Level 1: Program or science requirements, which were developed with the project sponsor, NASA
- Level 2: Project system requirements

Solution components

Software

- IBM® Rational® DOORS®
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- Level 3: System-level requirements for components such as the flight system, the ground system, and the launch vehicle
- Level 4: Requirements for subsystems of the flight system, including instruments of the payload, which in some cases outside partners, such as universities, deliver
- Level 5: Requirements for subassemblies, hardware components and software modules, which outside partners can also create

JPL used the Rational DOORS application to create the Level 1 through Level 4 requirements for the MSL mission, totaling 16,000 requirements with 11,000 links in 140 separate Rational DOORS modules or requirements documents. JPL writes a requirement at one level, and then performs design work to drive requirements at the next level. For example, the requirements owner at Level 2 will work with the requirements owner at Level 3 on the design, enabling the Level 3 owner to add requirement details and make allocation decisions. The design is documented in design documentation or models, and the requirements at the next level end up in the Rational DOORS application, linked back to the parent requirement one level up.

The Rational DOORS software provided collaboration for the hundreds of engineers who wrote and verified requirements, allowing different engineers to negotiate changes to the requirements and helping ensure that engineers entered sufficient detail for each requirement. Engineers also used attributes of the Rational DOORS software to provide contextual information to help improve the understanding and applicability of the requirements. Teams created Rational DOORS links between levels and allocated requirements down to the level at which they could be implemented and verified. After an engineer created a baseline requirement, a formal engineering change request was necessary to alter it, helping ensure that requirements were not inadvertently modified.

Performing vital V&V activities

JPL also used the Rational DOORS application to perform V&V activities, document verification plans and track verification statuses. JPL needed to carry out tests to prove that the rover was capable of performing its intended functions such as driving, taking samples and communicating results back to Earth.

The Rational DOORS application helped JPL manage the complex relationship between the 16,000 requirements and the verification activities for the requirements, which could have a many-to-many relationship. Using the module, JPL could assign engineers to different requirements for test planning, elaboration and analysis, and test execution. Engineers could then reference test artifacts, analyses and results from the requirements in Rational DOORS software.

After testing was complete, test engineers performed a review before officially approving the V&V activities. The Rational DOORS application's history capability made this approval process trackable and auditable, helping enable JPL to determine relevant information such as when each requirement was closed and who closed it. Rational DOORS software provides a centralized database that allowed JPL to create traceability from verification activities to artifacts, such as test reports and log files produced by testing systems, so auditors could trace right down to the raw data.

Gaining insight and efficiency

JPL management used Rational DOORS software to create burn-down charts, which track work that needs to be completed, to help make more-informed decisions about scheduling and assignments. Management also used the Rational product to create "horse-race charts," comparing the progress of different V&V teams. The charts showed the total number of V&V items per team along with the numbers of items that teams started, completed successfully and approved. This type of information was extremely valuable in keeping the project on track and helping management make informed decisions about where to apply resources.

Before JPL began using Rational DOORS software, it relied on a verification matrix in spreadsheet software to perform its V&V activities. However, this approach made it difficult to share information and keep track of version control. Further, there was no way to link requirements to the related verification activities. With Rational DOORS software, JPL staff is able to collaborate and link relevant activities and information, helping enable much greater traceability and efficiency. JPL estimates that Rational DOORS software saves the work of at least one full-time employee.

JPL also used Rational DOORS software on several recently launched missions including the Aquarius, GRAIL and Juno missions mentioned above, as well as:

- Nuclear Spectroscopic Telescope Array (NuSTAR), a mission to study the universe in high energy X-rays to better understand the dynamics of black holes and exploding stars
- Soil Moisture Active Passive (SMAP), an Earth satellite mission to better understand terrestrial water, carbon and energy cycles

JPL plans to use the Rational DOORS application while working on future projects, including:

- Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight), a lander that will measure seismic activity and heat flow on Mars to study the planet's early geological evolution
- Surface Water Ocean Topography (SWOT), an Earth satellite developed with French Space Agency partner CNES to develop a better understanding of the world's oceans and its terrestrial surface waters
- Low Density Supersonic Decelerator (LDSD), a technology demonstration mission that will pave the way for landing heavier payloads, including humans, on Mars.

For more information

To learn more about IBM Rational DOORS software, please contact your IBM representative or IBM Business Partner, or visit the following website: ibm.com/software/awdtools/doors



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