Robotics Ground Procedure Management and Requirements Testing

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Category: Computer Science/IT

I. Restore-L Mission Overview

The Restore-L Mission's goal is to perform in-space servicing of the Landsat 7 satellite. This servicing is required because the Landsat 7 satellite is almost out of the fuel needed to maintain a proper orbit. This will be the first effort by NASA to refuel a satellite that was not created to be refueled. This servicing includes performing an autonomous rendezvous, docking the Landsat 7 satellite on the Restore-L Payload, and performing tele-operated robotic operations that include the transfer of propellant. On the servicing payload there are two seven degrees of freedom robotic arms each equipped with a multi-function tool drive system and tool cameras.

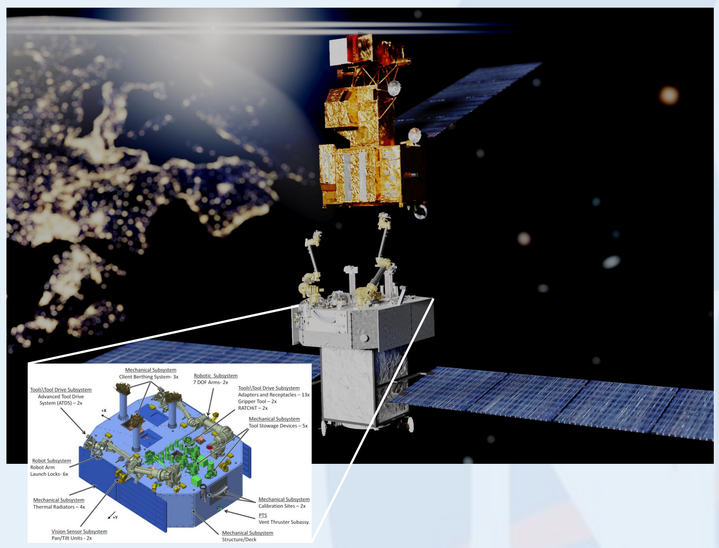


Figure 1. Artist's concept of Restore-L autonomous rendezvous and docking (AR&D) Inset: Detailed diagram of the Restore-L robotic payload.

II. Restore-L Robot Ground System Overview

The Restore-L Robot Ground System (Robot GS) is one of seven systems that make up the Restore-L Ground Element (RGE). This system is responsible for the command and control of the robot arms, tool drive system, and tool cameras. The Robot GS also includes video systems used during runtime operations and provides simulation support for planning and contingency operations.

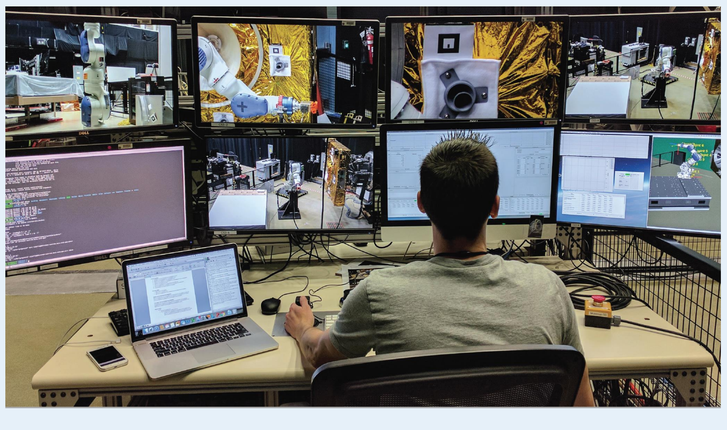


Figure 2. An operator at a robotic console controlling a Motoman robot arm.

III. Verification and Validation (V&V) of Requirements Overview

Product Verification demonstrates that an end-product complies with a regulation, requirement, specification, or imposed condition. Product validation confirms a verified end-product that has been integrated into the system fulfills its intended use and meets the needs of the customer and other identified stakeholders. There are 4 levels of requirements:

- Level 4 is closest and most relevant to the Robot GS, consisting of subsystem requirements. Factory Acceptance Testing (FAT) is used to verify end-to-end functionality for operational use.
- Levels 3.5 and 3 deal with system and element requirements. Site Acceptance Testing (SAT) in the Mission Operations Center and Ground Readiness Testing (GRT) are conducted to confirm satisfaction of these requirements.
- Level 2 requirements are verified by Mission Readiness Testing (MRT) and End-to-End Testing (ETE).

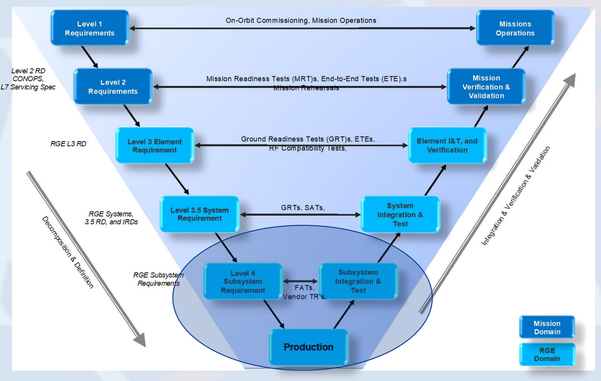


Figure 3. V&V Diagram with Requirement Levels.

IV. Media Wiki

MediaWiki is open-source software that is used for documentation of a number of things including robot procedures. It is well-known for powering Wikipedia. Its benefits include:

- Easy navigation with a visual editor
- Security control and accessibility through user management
- Creating templates with parameters,
- Built in search
- Ability to use plugins and extensions.

3.1 Augmented Jacobian with Weighted Damped Least Squares (WDLS) Controller [edit | edit source]

Use the following controller deployment class for this section of testing adjusted appropriately for the robot being tested:

```
CARTESIAN_POSITION_CONTROLLER_CLASS=robot::CartesianSIxMotionControllerMotoman rdt-deploy-moto50alpha-servicer-hw-b29green
```

The following tests should be run for all robots.

Step	Instruction	Pass	Notes
1.	Select "Tool configuration" in the Configuration drop down menu and verify that the Tool frame offset (transform_ET) is (x,y,z)=(0,0,0.17) *(The singularity status depends upon the tool offset, so the tests may fail if these are not set properly.)*	☐	
2.	Enter RESOLVED-RATE (needed to initialize bounds below)	☐	
3.	Open the Cartesian controller status panel and verify the following bounds for each robot: Pose (SIA10): Min Bound=0, Trans bound=0.15 Pose (SIA20): Min Bound=0, Trans bound=0.20 Pose (SIA50): MinBound=0, Trans bound=0.25 SEW (All robots): Min Bound=0.15, Trans bound=0.40 *(The singularity status depends upon these bounds, so the tests may fail if these are not set properly.)*	☐	
4.	Select Medium speed in the rate input panel	☐	
5.	Select Base frame in the rate input panel	☐	
	Single wrist singularity		
6.	Move the arm to the following joint pose using a joint-space, move-by-velocity at 10% velocity. All robots: 0, +20, 0, -100, 0, +30, 0	☐	
7.	Disable all hand controller axes except for Orientation-Y	☐	
8.	Enter RESOLVED-RATE	☐	
9.	Verify that the *Pose Singularity Status* in the Cartesian controller status panel is colored YELLOW (Dgrd)	☐	
10.	Pitch down on the joystick until the *SEW Singularity Status* turns RED and continue until it turns YELLOW	☐	

Figure 4. An example Procedure for a SAT of the ADP Software in MediaWiki format.

V. Robot Ground System Procedural Development

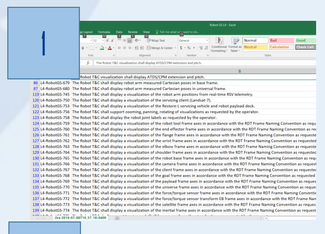
The goal of this project was to create procedures that will test the capabilities required by the Restore-L Robot Ground System. The procedures need to thoroughly test all Restore-L Robot Ground System requirements. The requirements pertained to the SSPD Robot Team Algorithm Development Platform (ADP) software, which is used to provide the telemetry and command (ADP GUI) and visualization (ADP VIZ) of the robot system.

VI. Method of Procedural Development

The level 4 V&V requirements are categorized by the specific part of the Robot GS they apply to. One test procedure can verify a number of requirements within a specific category. The method used for developing a procedure is:

- Group a number of requirements together that can most efficiently be tested together.
- Run the corresponding part of the ADP software (Either the Visualization or GUI) to what requirements need to be tested.
- Formulate a way to test the requirement, and take note of each step in doing so.
- Create a MediaWiki page with the procedural steps noted using the ADP software.

1



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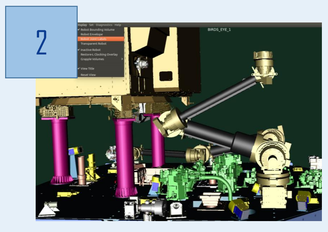

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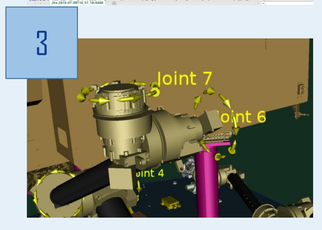

4

		Procedure Step	Succes
		Deploy rdt-deploy-restorearmm1-servicer-simrestorel,	
		Run rdt-visualization -x flight_restore_l_left	
		Use the mouse scroll wheel or press and hold the right mouse-button and then move the mouse either forwards or backwards to zoom in or zoom out.	
4		Press and hold the centerwheel on the mouse while you move the mouse around to pan around.	
5		Press and hold the left mouse-button and move the mouse around to rotate around.	
6		Verify that a visualization of the servicing client, Landsat-7 is displayed.	
7		Verify that a visualization of the Restore-L servicing vehicle and robot payload deck is shown.	
8		Turn on Robot Joint Labels in Display -> Robot Joint Labels	
9		Verify that the robot joint angles are displayed.	
10		Turn on the robot tool frame axis in Frame Axes -> Robot Tool Frame Axes -> Robot Measured Tool Frame Axes	
11		Verify that the robot tool frame axes is displayed.	
12		Turn on the End Effector Frames Axes in Frame Axes -> Robot End Effector Frame Axes	
13		Verify that the end effector frame axes is displayed.	
14		Turn on the flange frame axes in Frame Axes -> Flange Frame Axes	

Figure 5. Method of development steps

VII. Acknowledgment

We would like to thank Brian Roberts for providing us the opportunity to intern at NASA GSFC this summer. We would like to thank our mentor, Vuong Ly, for his guidance through our work along with all of SSPD. We also thank NASA employees who have supported and taught us during our time here including James Laporte, Zakiya Tomlinson, and Jillianne Shear.