California State University, Long Beach, Department of Electrical Engineering

EE 400D Verification and Validation Test Plan, Fall 2017

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Table of Contents

1 Introduction

This is Project Sojourners Fall 2017 Verification and Validation Test Plan

1.1 Purpose

The purpose of this document is to provide a comprehensive Verification and Validation (V&V) Test Plan of the Fall 2017 Sojourner, including the Project ConOps/Mission, Test Methodology, Verification and Validation Matricies, and Test Cases.

1.2 Project ConOps/Mission

The Sojourner is a 6 wheeled rover that is capable of autonomous travel on a Mars-like environment. For the mission a Mars-like world is defined to be a rocky surface that can reach the higher peaks of the temperature of Mars. To travel over this terrain, its mechanical system will utilize a rocker bogie suspension system and a differential gearbox. The rover will be powered by a battery/solar-panel charging module. A single operator will be able to control the robot in its mission and view the mission .

The Sojourner mission for Fall 2017 is to travel through a maze as defined by the customer. This Maze will be a 2D print with green lines to represent a maze hallway, and a black grid as guide markings for the rover to follow. The goal of the mission is for the rover to be able to take two different trips through the maze: one with remote assistance, and a second autonomous trip. The rover will be capable of making the autonomous trip through the maze simultaneously with other robots.

1.3 Document Overview

This document is organized as follows:

- Section 2 contains links to relevant and applicable project reference documents and presentations for this Test Plan.
- Section 3 contains a description of the Testing Methodology utilized in this Test Plan, including the Master Verification and Validation Matrix, a description of the 4 types of V&V testing performed, the Test Environment(s) description(s), and a Master Test Case List of all 6 Test Cases for this project.

2 Applicable Documents

This section contains a table of all relevant and applicable project reference documents and presentations for the Project Sojourner, Fall 2017 Verification and Validation Test Plan.

Document Name	Document Description	Document Link
PDD	Preliminary Design Document. Contains	http://arxterra.com/sojourner-preliminary-documentation-fall-2017/#toggle-id-2
PDR	Preliminary Design Review Presentation. Contains L1 and L2 Requirements, System Block Diagram, Resource Allocation Reports	http://arxterra.com/sojourner-preliminary-documentation-fall-2017/#toggle-id-2
NASA Systems Engineering Handbook (2007)	Document containing Test Methodologies in Section 3	http://www.acq.osd.mil/se/docs/NASA-SP-2007-6105-Rev-1-Final-31Dec2007.pdf

3 Testing Methodology

This section contains the Master Verification and Validation Matrix, as well as detailed descriptions of the various Test Methods and Test Cases utilized in this Test Plan.

3.1 Master Verification and Validation (V&V) Matrix

This matrix provides complete traceability of every requirement. Specifically, every requirement is mapped to its description, success criteria, V&V testing designation and method, and Test Case(s) where the requirement will be tested. Note that some overlap between Test Cases' requirements V&V is okay. **ALL REQUIREMENTS MUST BE MAPPED HERE AND ACCOUNTED FOR**

Requirement Number	**Requirement Text**	**V&V Success Criteria**	**V&V Designation** (Verification, Validation?)	**V&V Method** (Analysis, Demonstration, Inspection, Test?)	**Test Case(s) where Requirement is Tested**
C1	Sojourner shall be completed by Wednesday, December 13, 2017	Sojourner meets customers expectations by December 13th, 2017	Validation	Demonstration	TC04
C2	Sojourner will be controlled by a ArduinoMicro.	Sojourner is powered by the board and communicates with the Arxterra App	Validation	Inspection	TC04
C3	Sojourner will be a toy robot	Sojourner is a small robot with modular parts that will traverse a	Validation	Inspection	TC04

		maze intact.			
C4	The Sojourner will be controlled by the ARxRobot Android or iPhone Application	The ArxRobot application will send custom commands and telemetry to Sojourner as inputs/outputs	Validation	Demonstration	TC04
C5	Sojourner will use a solar panel as part of its power system	Sojourner power system will be rechargeable via a solar panel.	Validation	Inspection	TC04
C6	The design of Sojourner should be modular, being able to be assembled and disassembled within 20 minutes	Non-soldered parts will be able to be removed and reassembled.	Validation	Demonstration	TC04
C7	Project Sojourner shall be able to navigate a multi-colored maze with user-defined inputs	The commands the ArxRobot Application sends to Sojourner successfully assist it in completing a maze	Validation	Demonstration	TC02
C8	Sojourner shall be able to navigate said user-defined maze path autonomously	In playback mode, Sojourner remembers the user	Validation	Demonstration	TC03

		defined path			
C9	3D printing times shall be limited to a total of 6 hours, with no print taking more than 2 hours to complete	The total 3D printing time is less than 360 minutes	Validation	Inspection	TC05
C10	The Sojourner will avoid collisions with other robots	Sojourner won't crash into another toy robot	Validation	Demonstration	TC03
L1-1	The budget cost shall be less than $250.00	The sum of all the receipts is less than $250.00	Validation	Analysis	TC05
L1-2	Sojourner shall incorporate live video feed using a smartphone and periscope placed on top of Sojourner	The ArxRobot control panel shows the live video feed from the smartphone.	Verification	Inspection	TC02
L1-3	The Sojourner shall be a scaled down version of the Pathfinder Rover	Sojourner is smaller than the Pathfinder Rover	Verification	Inspection	TC01
L1-4	Project Sojourner will utilize a slip differential with dual rear motors using a differential gearbox	Slip differential to be used when a wheel loses contact with floor	Verification	Demonstration	TC02
L1-5	Sojourner should be able to travel on a Mars-like environment	Sojourner can travel over dips and bumps	Validation	Demonstration	TC06

L1-6	Project Sojourner will utilize an electronic differential	Electronic differential used in conjunctio n with L1-4	Verification	Demonstration	TC02
L1-7	Sojourner will use 6 wheels with a Rocker boogie suspension system	A Rocker boogie suspension is used with the chassis	Validation	Inspection	TC04
L2-1	The Sojourner shall use the IR Proximity sensor to detect other robots x inches in front	Sojourner will detect another toy robot in it's maze path.	Verification	Inspection / Demonstration	TC03
L2-2	The design shall have an area for a smartphone to be placed onto	The smartphon e is on top of Sojourner	Verification	Inspection	TC01
L2-3	The Sojourner will use 6 identical wheels for movement, with each wheel having its own motor.	All of Sojourner's wheels and motors are identical	Verification	Inspection	TC04
L2-4	The solar panel will be attached to the chassis. The solar panels will have no other components covering it for full sunlight acquisition.	Sojourner design incorporat es a solar panel	Verification	Inspection	TC01
L2-5	The Sojourner should have 2 separate sections incorporating the modular design. The chassis, motor, wheels, 3Dot board, and H-bridge should be in 1 module, while	The assembly and disassembl y is broken up into two sections.	Validation	Demonstration	TC04

	the solar panels and phone holder should make up the 2nd module.				
L2-6	The wheels shall be cleated , which assist in traversing terrain with soft sand and rocks. This allows for mobility in an environment similar to Mars	The wheels have a cleated pattern on the exterior	Validation	Inspection	TC01
L2-7	The Sojourner shall use 2 iR sensors to detect and follow the black lines using the line following algorithm.	While traveling the maze, Sojourner follows the black lines.	Verification	Inspection / Test / Demonstration	TC02
L2-8	The Sojourner shall have dimensions of 8.4cm(L) x 3.8cm (W) x 3.4cm (H)	The dimensions of Sojourner will be similar to that of Spring 2017	Verification	Inspection	TC01
L2-9	The Sojourner shall use the robot avoidance algorithm whenever a robot has entered the IR proximity sensor's detection zone	In the maze, Sojourner will activate the avoidance algorithm when another robot is detected	Validation	Demonstration	TC03
L2-10	The solar panel will recharge the 3.6V RCR123A battery on the 3DoT Board.	The board is powered by the RCR123A battery.	Verification	Test	TC04

3.2 Testing Types and Methods

This subsection contains the 4 types of Verification and Validation (V&V) testing, as derived from the NASA Systems Engineering Handbook referenced above in Section 2. Material is taken from Chapter 5 in the NASA Handbook, and replicated below.

Verification proves that a realized product for any system model within the system structure conforms to the build-to requirements (for software elements) or realize-to specifications and design descriptive documents (for hardware elements, manual procedures, or composite products of hardware, software, and manual procedures). In other words, Verification is requirements driven; verification shows proof of compliance with requirements; that the product can meet each "shall" statement as proven through performance of a test, analysis, inspection, or demonstration.

Validation is conducted under realistic conditions (or simulated conditions) on any end product for the purpose of determining the effectiveness and suitability of the product for use in mission operations by typical users; and the evaluation of the results of such tests. Testing is the detailed quantifying method of both verification and validation. However, testing is required to validate final end products to be produced and deployed. In other words, Validation is ConOps/Mission driven; validation shows that the product accomplishes the intended purpose in the intended environment; that product meets the expectations of the customer and other stakeholders as shown through performance of a test, analysis, inspection, or demonstration.

3.2.1 Verification by Analysis

The use of mathematical modeling and analytical techniques to predict the suitability of a design to stakeholder expectations based on calculated data or data derived from lower system structure end product verifications. Analysis is generally used when a prototype; engineering model; or fabricated, assembled, and integrated product is not available. Analysis includes the use of modeling and simulation as analytical tools. A model is a mathematical representation of reality. A simulation is the manipulation of a model.

3.2.2 Verification by Demonstration

Showing that the use of an end product achieves the individual specified requirement. It is generally a basic confirmation of performance capability, differentiated from testing by the lack of detailed data gathering. Demonstrations can involve the use of physical models or mockups; for example, a requirement that all controls shall be reachable by the pilot could be verified by having a pilot perform flight-related tasks in a cockpit mockup or simulator. A demonstration could also be the actual operation of the end product by highly qualified personnel, such as test pilots, who perform a one-time event that demonstrates a capability to operate at extreme limits of system performance, an operation not normally expected from a representative operational pilot.

3.2.3 Verification by Inspection

The visual examination of a realized end product. Inspection is generally used to verify physical design features or specific manufacturer identification. For example, if there is a requirement that the safety arming pin has a red flag with the words "Remove Before Flight"

stenciled on the flag in black letters, a visual inspection of the arming pin flag can be used to determine if this requirement was met.

3.2.4 Verification by Test

The use of an end product to obtain detailed data needed to verify performance, or provide sufficient information to verify performance through further analysis. Testing can be conducted on final end products, breadboards, brass boards or prototypes. Testing produces data at discrete points for each specified requirement under controlled conditions and is the most resource-intensive verification/validation technique. As the saying goes, "Test as you fly, and fly as you test." (See Subsection 5.3.2.5.).

3.2.5 Validation by Analysis

The use of mathematical modeling and analytical techniques to predict the suitability of a design to stakeholder expectations based on calculated data or data derived from lower system structure end product validations. It is generally used when a prototype; engineering model; or fabricated, assembled, and integrated product is not available. Analysis includes the use of both modeling and simulation.

3.2.6 Validation by Demonstration

The use of a realized end product to show that a set of stakeholder expectations can be achieved. It is generally used for a basic confirmation of performance capability and is differentiated from testing by the lack of detailed data gathering. Validation is done under realistic conditions for any end product within the system structure for the purpose of determining the effectiveness and suitability of the product for use in NASA missions or mission support by typical users and evaluating the results of such tests.

3.2.7 Validation by Inspection

The visual examination of a realized end product. It is generally used to validate physical design features or specific manufacturer identification.

3.2.8 Validation by Test

The use of a realized end product to obtain detailed data to validate performance or to provide sufficient information to validate performance through further analysis. Testing is the detailed quantifying method of both verification and validation but it is required in order to validate final end products to be produced and deployed.

3.3 Master Test Case List

A **Test Case** can be described as *a scenario containing a sequence of detailed test steps, in order to perform verification/validation testing on multiple requirements that are similar in nature.*

For example, if a group has multiple requirements regarding starting up their robot project, they can group all these requirements to be verified/validated in a single test case. Similarly, if a group has multiple requirements that can be verified/validated via inspection, they can group all of them together in a single test case.

The purpose of this subsection is to provide a High-Level overview of all Test Cases utilized in this Test Plan. Each item in this subsection will contain the following: Test Case Number and Name, High Level Scenario Description, and Test Environment Description.

The best way to approach Test Cases is to GROUP REQUIREMENTS THAT ARE SIMILAR IN NATURE FIRST, then write procedure steps for each Test Case.

3.3.1 TC01: Visual Inspection Before Mission Phase 1 & 2

Description: The visual inspections test case will contain Requirement Numbers C2, C3, C5, L1-3,L2-2,L2-4,L2-6, and L2-8. This test case will deal with most of the visual inspection V&V method. The inspections method can be conducted before Mission Phase 1 and Phase 2. These Requirement Numbers were grouped together because they can be inspected with the eye.

Test Environment: This test case will be conducted inside the EE400d classroom on the day of the final, Wednesday, December 13th, 2017.

3.3.2 TC02: Mission Phase 1 Demonstration

Description: The demonstration test case will contain Requirement Numbers C4, C7, L1-2, L1-4, L1-5, L1-6,and L2-7. The point of this test case is to verify the requirement numbers which are utilized during mission phase 1. These requirement numbers were grouped together because they can be can be verified/validated during the mission phase 1.

Test Environment: Test Case 02 will; be verified inside the EE400d classroom on the day of the final, Wednesday, December 13th, 2017.

3.3.3 TC03: Mission Phase 2 Demonstration

Description: The mission phase 2 demonstration test case will contain requirement numbers C8, C10, L2-1, and L2-9. The purpose of this test case is to verify and validate these requirement numbers during Phase 2 of navigating the maze. Phase 2 consists of the toy robot traversing the maze autonomously, ie. without user input. This is part 1 of the phase 2. Part 2 of phase 2 consists of more than 1 robot traversing the maze. This section will use the robot avoidance rules/algorithms. These requirements were grouped together because they are applicable during mission phase 2.

Test Environment: Test Case 03 will; be verified inside the EE400d classroom on the day of the final, Wednesday, December 13th, 2017.

3.3.4 TC04: Post Mission Phase 1 and Phase 2 Inspection

Description: The post mission phase 1 and phase 2 test case will contain requirement number C1, C6, L1-7, L2-3, L2-5, and L2-10. The point of this test case is verify the modular and charging aspect of the toy robot. These requirements were grouped together because they only can be verified once the mission phase 1 and phase 2 are completed.

Test Environment: Test Case 04 will be verified inside the EE400d classroom on the day of the final, Wednesday, December 13th, 2017.

3.3.5 TC05: Budget Test Case

Description: The budget case case will contain requirement numbers C9 and L1-1. The purpose of this test case is to verify that Project Sojourner is following alloted project budgets for a successful mission. These were grouped together because they are a critical aspect of the project. Without meeting these requirements, Project Sojourner will fail.

Test Environment: Test Case 05 will be verified inside the EE400d classroom on the day of the final, Wednesday, December 13th, 2017.

3.3.6 TC06: Movement Test Case

Description: The movement case will contain requirement L1-5. The purpose of this test case is to verify that Sojourner is able to travel of different mediums and environments. This requirement is important because it utilizes the rocker boogie suspension system by helping keep the chassis parallel to the earth when it drives over bumps or craters.

Test Environment: Test Case 06 will be verified inside the EE400d classroom on the day of the final, Wednesday, December 13th, 2017.

4 Test Procedures

This section contains details of every Test Case utilized for V&V of project requirements. Each Test Case subsection within this section will contain the following: Test Case number and name, detailed scenario description, Test Case Traceability Matrix, detailed success criteria, detailed Test Environment description, Test Assumptions/Preconditions, Detailed Test Procedure Steps, and a Pass/Fail Matrix of success criteria per Test Case.

4.1 TC-01: Visual Inspection Before Mission Phase 1 & 2

4.1.1 Detailed Description

The overall purpose of test case 01 is to visually inspect Project Sojourn to ensure it complies with the project mission and customer expectations. The requirements listed below were grouped together because they all could beL1-3 and L2-8 describe the scale of Sojourner and with octal examination and a ruler, the verification of these two requirements is simple. L2-2 and L2-4 are simply verified by examining the top of Sojourner and confirming that a smartphone can be placed on top and the mechanism which holds the smartphone is attached to the chassis. L2-6 is validated by confirming that the wheels have a cleated pattern to them.

4.1.2 Test Case Traceability and Pass/Fail Matrix

Requirement Number	**Requirement Text**	**V&V Success Criteria**	**V&V Designation** (Verification, Validation?)	**V&V Method** (Analysis, Demonstration, Inspection, Test?)	**Procedure Step(s) where Requirement is tested**	**Pass/Fail?**
L1-3	Sojourner shall be a scaled down version of the Pathfinder Rover	Sojourner is smaller than the pathfinder rover	Verification	Inspection	4	pass
L2-2	The design shall have an area for a smartphone to be place on to	A smartphone is on top of Sojourner	Verification	Inspection	1	pass
L2-4	The solar panel will be attached to the chassis. The solar panels will have no other components covering it for full sunlight acquistion.	Sojourner design incorporates a solar panel.	Validation	Inspection	2	
L2-6	The wheels shall be cleated , which assist in traversing terrain with soft sand and rocks. This allows for mobility in an environment	The wheels have a cleated pattern on the exterior	Validation	Inspection	3	pass

	similar to Mars					
L2-8 //updated //visuals inspections = wills	The Sojourner shall have dimensions of 8.4cm(L) x 3.8cm (W) x 3.4cm (H)	The dimensions of Sojourner will be similar to that of Spring 2017	Verification	Test / Inspection	4	pass

4.1.3 Detailed Success Criteria

To make TC-01 successful, a number of factors must be meet. The first factor which must be meet is simply Sojourner be a small toy robot, with dimensions a factor less than of a Pathfinder robot. This can be accomplished by measuring its length, width, and height. A simple comparison to the length, width , and height of the Pathfinder robot will confirm the requirement. The next factor in making TC-01 successful is done via visual inspection. A quick visual inspection should confirm there is a solar panel attached to the chassis and the wheels have a cleated pattern on there exterior. Once these factors are meet, TC-01 will be a success. This test case should not take more than a few minutes.

4.1.4 Test Environment

TC-01 will take place inside the Engineering and Computer Science building on CSULB, the third floor, room 16 on Wednesday, December 13th, 2017 by Professor Hill or Chris. Each test case requirement will be verified/validated on that day via the procedure steps.

4.1.5 Assumptions and Preconditions

- Sojourner is assembled with all it's parts and wired correctly.

4.1.6 Procedure Steps

Step Number	Step Description	Pass Criteria	Recorded Data	Requirement(s) Tested	Test Type	Test Method
1	Using both eyes, inspect visually that a	A area on top of Sojourner		L2-2	Verification	Inspection

	place for the smartphone is allocated.	design incorporates a smartphone holder	Visual data			
2	Using both eyes, inspect visually that the solar panel and it's holder is attached to the chassis	The solar panel is attached to the chassis.	Visual data	L2-4	Verification	Inspection
3	Using both eyes, inspect visually that the wheels of Sojourner are cleated	The wheels will have a cleated pattern	Visual Data	L2-6	Verification	Inspection
4	Using a standard ruler, measure the length, width, and height of the Sojourner in cm. The measurement will include the wheel length protrusions.	The measured dimensions of Sojourner will match the Solidworks model measurement of 14cm(L) x 13.5cm (W) x 10 cm (H)	Yes, the measured values from the ruler to compare them to the known values	L1-3, L2-8	Verification	Inspection

4.2 TC-02: Mission Phase 1 Demonstration

4.2.1 Detailed Description

The overall point of this test case is to validate and verify the requirements which will be used during the mission phase 1. Mission phase 1 consists of traversing a multi-colored maze with

user-defined commands using the ArxRobot application. The Robot will travel the maze by following the black lines which helps to determine its location , row and direction. When traveling the maze the robot will use it's slip and electronic differentials for turning and if a wheel loses contact with the ground. These requirements were grouped together because they are critical for the success of mission phase 1.

4.2.2 Test Case Traceability and Pass/Fail Matrix

Requirement Number	**Requirement Text**	**V&V Success Criteria**	**V&V Designation** (Verification, Validation?)	**V&V Method** (Analysis, Demonstration, Inspection, Test?)	**Procedure Step(s) where Requirement is tested**	**Pass/Fail?**
C4	The Sojourner will be controlled by the ARxRobot Android or iPhone Application	The ArxRobot application will send custom commands and telemetry to Sojourner as inputs/outputs	Validation	Demonstration	1,3,4	pass
C7	Project Sojourner shall be able to navigate a multi-colored maze with user-defined inputs	The commands the ArxRobot Application sends to Sojourner successfully assist it in completing a maze	Validation	Demonstration	2	tbd
L1-2	Sojourner shall incorporate live video feed using a	The ArxRobot control panel shows the	Verification	Inspection	1	

	smartphone and periscope placed on top of Sojourner	live video feed from the smartphone.				
L1-4	Project Sojourner will utilize a slip differential with dual rear motors using a differential gearbox	Slip differential to be used when a wheel loses contact with floor	Verification	Demonstration	5	
L1-6	Project Sojourner will utilize an electronic differential	Electronic differential used in conjunction with L1-4	Verification	Demonstration	5	
L2-7	The Sojourner shall use 2 IR sensors to detect and follow the black lines using the line following algorithm.	While traveling the maze, Sojourner follows the black lines.	Verification	Test / Demonstration	2.a	

4.2.3 Detailed Success Criteria

For this TC to be successful, several factors must be met. This factor can be validated during the final. When in phase 1, the robot will traverse the maze with user defined inputs. These user defined inputs will be saved in EEPROM so that they can be accessed during mission phase 2. As Sojourner traverses the maze, it will utalize its slip and electronic differential when making a turn or when a wheel loses contact with the ground. When it makes a turn, one set of wheels on either side of the chassis will rotate in the equal and opposite direction than the other set with a differential speed. The IR sensors will be used to help Sojourner stay within the maze and determine its location. This test case will be completed when Sojourner successfully exits the maze.

4.2.4 Test Environment

TC-02 will take place inside the Engineering and Computer Science building on CSULB, the third floor, room 16 on Wednesday, December 13th, 2017 by Professor Hill or Chris. Each test case requirement will be verified/validated on that day via the procedure steps.

4.2.5 Assumptions and Preconditions

- Sojourner is built and working, mechanically and electronically
- There is a proper connection between the ARxterra App and Sojourner

4.2.6 Procedure Steps

Step Number	Step Description	Pass Criteria	Recorded Data	Requirement(s) Tested	Test Type	Test Method
1	Sojourner is placed outside and maze and Robot is set up	Communication exists and live feed is working	(Write Yes/No, record number value, whatever you need to V&V Requirement)	C4, L1-2	Validation	Demonstration
2	Directional Pad is pressed on the Arxterra Application to move robot into the maze	Sojourner decodes the telemetry from Arxterra App	Yes Directional turns are saved in EEPROM.	C7	Validation	Demonstration
2.a.	Once inside the maze, IR sensors are used to detect and follow the black lines to help stay within the maze limits.	The black lines are being followed for maze navigation	Yes The color value is displayed	L2-7	Verification	Inspection / Test / Demonstration
3	A direction is chosen by the user	If the left direction hit on the	Yes,	C4	Validation	Demonstration

	and pressed on the directional pad.	d-pad, Sojourner makes a left	Directional turns are saved in EEPROM			
4	Sojourner takes the appropriate direction	Sojourner decodes the Telemetry	No	C7	Validation	Demonstration
5	If a turn is initiated, wheels will rotate at different speeds and directions to make the turn	When it turns, the wheels on either side of Sojourner moves in the opposite direction and the electronic differential compensates any error	Yes, RPM values are read for compensation purposes	L1-4 & L1-6	Verification & Verification	Demonstration & Demonstration

4.3 Tc-03: Mission Phase 2 Demonstration

4.3.1 Detailed Description

This test case deals with mission phase 2 part 1 and part 2. The requirements below are grouped together because they happen during the mission phase 2. Part 1 describes autonomous navigation. Autonomous navigation is done accessing the saved directional data from mission phase 1. After the robot navigates the maze, phase 2 will begin, which details what will happen when multiple robots are in the maze at the same time. However, due to time constraints, phase 2 part 2 will not be completed.

4.3.2 Test Case Traceability and Pass/Fail Matrix

Requirement Number	**Requirement Text**	**V&V Success Criteria**	**V&V Designation** (Verification, Validation?)	**V&V Method** (Analysis, Demonstration, Inspection, Test?)	**Procedure Step(s) where Requirement is tested**	**Pass/Fail?**
C8	Sojourner shall be able to navigate said user-defined maze path autonomously	In playback mode, Sojourner remembers the user defined path	Validation	Demonstration	2	Fail
C10	The Sojourner will avoid collisions with other robots	Sojourner won't crash into another toy robot	Validation	Demonstration	5	Fail
L2-1	The Sojourner shall use the IR Proximity sensor to detect other robots 6 inches in front	Sojourner will detect another toy robot in it's maze path.	Verification	Demonstration	4	Fail
L2-9	The Sojourner shall use the robot avoidance algorithm whenever a robot has entered the IR proximity sensor's detection zone	In the maze, Sojourner will activate the avoidance algorithm when another robot is detected	Validation	Demonstration	5	Fail

4.3.3 Detailed Success Criteria

For this test case to be successful, phase 1 must be completed first. This is important because phase 1 criteria is user defined inputs which are saved in EEPROM and then later accessed for autonomous navigation. Phase 2 success depends on being able to use remember and then follow the user defined path. Validation will only be done on the day of the final because the students do not know their maze path. Part 2 of phase 2 will be ignored because based on the current trajectory, phase 1 and 2 will not be completed.

4.3.4 Test Environment

TC-03 will take place inside the Engineering and Computer Science building at CSULB, on the third floor, room 16 on Wednesday, December 13th, 2017 by Professor Hill or Chris. Each test case requirement will be verified/validated on that day via the procedure steps.

4.3.5 Assumptions and Preconditions

- Project Sojourner is completed
- Project Sojourner is phase 1 ready

4.3.6 Procedure Steps

Step Number	Step Description	Pass Criteria	Recorded Data	Requirement(s) Tested	Test Type	Test Method
1	After mission phase 1, Sojourner is placed at the start of the maze	Sojourner begins at enterance of maze	No	none	none	none
2	Phase 2 is initiated from the ArxRobot App and Sojourner travels the maze autonomously	Sojourner follows path from phase 1 autonomously	No new data is being recorded	C8	Validation	Demonstration
3	Once the maze is cleared, part 2 of	Phase 1 part 1 is completed , and	No new data is being recorded	none	none	none

	Phase 2 is initated in which multiple robots are traveling on their phase 1 path	part 2 will begin				
4	Sojourner will travel on it's maze path and the IR proximity sensor will be used.	Phase 2 part 2 will contain mutiple robots and the proximity sensor will be used	Yes, when a robot is detected the proximity sensor will send back analog data. However, this specific phase will not be completed because no code was produced.	L2-1	Verification	Demonstration
5	After detection Robot Avoidance Rules/Strategy will be in play	Proximity sensor will detect a robot 6 inches in front of it. Sojourner will avoid the robot and avoid collision.	No, because no code was uploaded so this phase will most likely be skipped.	C10, L2-9	Validation / Validation	Demonstration / Demonstration

4.4 TC-04: Post Mission Phase 1 and Phase 2 Inspection

4.4.1 Detailed Description

This test case will deal with the inspections after mission phase 1 and phase 2 are completed. This will mainly deal with the disassembly and reassembly of Sojourner. The requirements below were grouped together because they either are connected with the disassembly and reassembly process or are requirements which can be meet in between the process. This test case will go over the process of disassembly and assembly. While doing this process, the test case will describe the procedures which will be done such as visual inspections and testings.

4.4.2 Test Case Traceability and Pass/Fail Matrix

Requirement Number	**Requirement Text**	**V&V Success Criteria**	**V&V Designation** (Verification, Validation?)	**V&V Method** (Analysis, Demonstration, Inspection, Test?)	**Procedure Step(s) where Requirement is tested**	**Pass/Fail?**
C1	Sojourner shall be completed by Wednesday, December 13, 2017	Sojourner meets customers expectations by December 13th, 2017	Validation	Demonstration	1	tbd
C2 // 3DoT board no micro	Sojourner will be controlled by a MicroArduino board.	Sojourner is powered by the board and communicates with the Arxterra App.	Validation	Inspection	6	tbd
C3	Sojourner will be a toy robot	Sojourner is a small robot with modular parts that will traverse a maze intact.	Validation	Inspection	10	tbd

C5	Sojourner will use a solar panel as part of its power system	Sojourner power system will be rechargeable via a solar panel.	Validation	Inspection	3	pass
C6	The design of Sojourner should be modular, being able to be assembled and disassembled within 20 minutes	Non-soldered parts will be able to be removed and reassembled.	Validation	Demonstration	9	tbd
L2-3	The Sojourner will use 6 identical wheels for movement, with each wheel having its own motor	All of Sojourner's wheels and motors are identical	Verification	Inspection	7	pass

L2-5	The Sojourner should have 2 separate sections incorporating the modular design. The chassis, motor, wheels, Arudino board, and H-bridge should be in 1 module, while the solar panels and phone holder should make up the 2nd module.	The assembly and disassembly is broken up into two sections.	Validation	Demonstration	3,4,5	tbd
L2-10	The solar panel will recharge the 3.6V RCR123A battery which powers the MicroArduio board.	The board is powered by the RCR123A battery.	Verification	Test	8	pass

4.4.3 Detailed Success Criteria

For this test case to be successful, many factors must be meet. The crux of this test case is the assembly and disassembly of Sojourner within 20 minutes. This process is broken in two sections, top section and bottom section. During the disassembly section, several requirements can be achieved. Requirements such as keeping in mind of a modular design, testing the solar panel's recharging capabilities of the battery, and having identical wheels with identical motors. After these requirements have been verified & validated, Sojourner will be reassembled.

4.4.4 Test Environment

TC-04 will take place inside the Engineering and Computer Science building at CSULB, on the third floor, room 16 on Wednesday, December 13th, 2017 by Professor Hill or Chris. Each test case requirement will be verified/validated on that day via the procedure steps.

4.4.5 Assumptions and Preconditions

- Mission phase 1 and phase 2 are completed
- Modular design was considered
- Assembly and disassembly is possible within 20 minutes

4.4.6 Procedure Steps

Step Number	Step Description	Pass Criteria	Recorded Data	Requirement(s) Tested	Test Type	Test Method
1	Mission Phase 1 & Phase 2 are completed & final phases of verification/ validations begins	Phase 1 and Phase 2 are completed	none	none	none	none
2	Begin to dissasemble Sojourner	Disassembly process begins	No new data is being recorded	none	none	none
3	Dissasembly process: phase 1 - Remove solar panel. Visually examine that it was connected to the	Dissasembly process should be done in two phases	No new data is being recorded	L2-5, C5	Validation	Demonstration

	Sojourner's power system.					
4	Remove the phone case holder	Phone case design should be modular	No new data is being added	L2-5	Validation	Demonstration
5	Dissasembly process: phase 2 - remove motors, wheels, Arduino board and H-bridge.	Phase 2 2 should include the mechanical and electronical parts	No new data is being added	L2-5	Validation	Demonstration
6	Visually inspect that after a successfulmission phase 1 & phase 2, Sojourner was controlled with a ArduinoMicro.	The ArduinoMicro shall control Sojourner	No new data is being added	C2	Validation	Inspection
7	Visually inspect Sojourner has 6 identical wheels with a motor for each attached to a rocker boogie system	All wheels and motors willl be identical	No new data is being added	L2-3, L1-7	Verification	Inspection

8	Measure rechargeable battery before assembly	Solar panel will recharge the battery after each mission phase	Yes, a blog post by Zach will be posted after finals. Preliminary findings indicate the battery is able to be recharged .	L2-10	Validation	Demonstration
9	After disassembly, reassembly Sojourner back together and note the total time	Total time should be less than 20 minutes	Yes, total time for assemble and disassembly will be recorded	C6	Validation	Demonstration
10	Sojourner is toy robot	Sojourner was able to travel the maze, be small in dimensions, and be modular	No new data was added	C3	Validation	Inspection / Test
11	Project Completed	Sojourner is completed and meets all of customers expectations	Project is completed	C1	Validation	Inspections / Tests / Analysis

4.5 Tc-05: Budgeting Test Case

4.5.1 Detailed Description

The overall point of this test case is to examine the budgeting of Project Sojourner. Budgeting is broken into two sections, 3D printing and cash budget, which is why these two were grouped together. To analyze this test case, simple procedures can be followed. Examining the paperwork, receipts invoices, and emails, from these two sections and comparing them to the customers expectations will provide an accurate picture of this test case.

4.5.2 Test Case Traceability and Pass/Fail Matrix

Requirement Number	**Requirement Text**	**V&V Success Criteria**	**V&V Designation** (Verification, Validation?)	**V&V Method** (Analysis, Demonstration, Inspection, Test?)	**Procedure Step(s) where Requirement is tested**	**Pass/Fail?**
C9	3D printing times shall be limited to a total of 6 hours, with no print taking more than 2 hours to complete	The total 3D printing time is less than 360 minutes	Validation	Analysis	1	Pass
L1-1	The budget cost shall be less than $250.00	The sum of all the receipts is less than $250.00	Validation	Analysis	2	Fail

4.5.3 Detailed Success Criteria

For this test case to be successful, several things must occur. Firstly, a budget of the total print times must be provided by the company or person producing the 3D printing. Next, a budget report must be provided as a base outline of the project's expedature. A more detailed report including all receipts should be provided to verify the accuracy of the budget report because there were no changes to the overall price from the budget report.

4.5.4 Test Environment

TC-05 will take place inside the Engineering and Computer Science building at CSULB, on the third floor, room 16 on Wednesday, December 13th, 2017 by Professor Hill or Chris. Each test case requirement will be verified/validated on that day via the procedure steps.

4.5.5 Assumptions and Preconditions

- 3D print times are provided
- All expenses have been accounted for
- Budget has been approved by the customer

4.5.6 Procedure Steps

Step Number	Step Description	Pass Criteria	Recorded Data	Requirement(s) Tested	Test Type	Test Method
1	Visually examine the 3D printing times documentation	Total printing times should be less than 6 hours	Yes, refer to final 3D printing times	C9	Validation	Analysis by inspection
2	Visually examine the project budget	Project budget shall be less than $250.00	Yes, refer to product budget in final blog post. Total budget was between $265-$280	Ll1-1	Validation	Analysis by inspection

4.6 Tc-06: Movement Test Case

4.6.1 Detailed Description

The overall point of this test code is to test any remaining requirements which did not fit into the other test cases. In this case, we had to verify that Sojourner can traverse on an environment which contains hard rocks, soft rocks, bumps, and divits. To summarize this test case, we would simply have Sojourner drive over a rock or a road bump and visually examine if the chassis remains level. If it remains level, then we know that it can travel on diverse environments and that it is functioning as expected.

4.6.2 Test Case Traceability and Pass/Fail Matrix

Requirement Number	**Requirement Text**	**V&V Success Criteria**	**V&V Designation** (Verification, Validation?)	**V&V Method** (Analysis, Demonstration, Inspection, Test?)	**Procedure Step(s) where Requirement is tested**	**Pass/Fail?**
L1-5	Sojourner should be able to travel on a Mars-like environment	Sojourner can travel over dips and bumps	Verification	Demonstration	2	Fail

4.6.3 Detailed Success Criteria

For this test case to be successful, Sojourner needs to simply drive over different environment. It can drive over rocks, inclines, bumps, craters and plain surfaces. What matter is that Sojourner's chassis remain level to the Earth in all scenarios.

4.6.4 Test Environment

TC-06 will take place inside the Engineering and Computer Science building at CSULB, on the third floor, room 16 on Wednesday, December 13th, 2017 by Professor Hill or Chris. Each test case requirement will be verified/validated on that day via the procedure steps.

4.6.5 Assumptions and Preconditions

- Project is completed including the testing and coding
- Electronic slip is functional

4.6.6 Procedure Steps

Step Number	**Pass Criteria**	**Recorded Data**	**Requirement(s) Tested**	**Test Type**	**Test Method**
1	A terrain of uneven ground is set up	none	none	none	none
2	Sojourner's chassis	Yes, Slip differential should read	L1-5	Verification	Demonstration

	should remain level when traveling the obstacle.	different RPMs' as it travels that obstacle.			

5 Appendices

This section will contain any addition documentation needed to verify/validate requirements. For example, if a project has a cost constraint requirement, include the cost breakdown spreadsheet below as a subsection and reference the appendix subsection in the related Test Step in the Test Procedure. If another group needs to verify something by hand via calculation, include the calculations as a subsection below and reference the appendix subsection in the related Test Step in the Test Procedure.