UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Engineering, Built Environment and Information Technology

Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie / Lefapha la Boetšenere, Tikologo ya Kago le Theknolotši ya Tshedimošo

A-Maze-Eng MARV

Qualification Test Procedures for Subsystem Specifications

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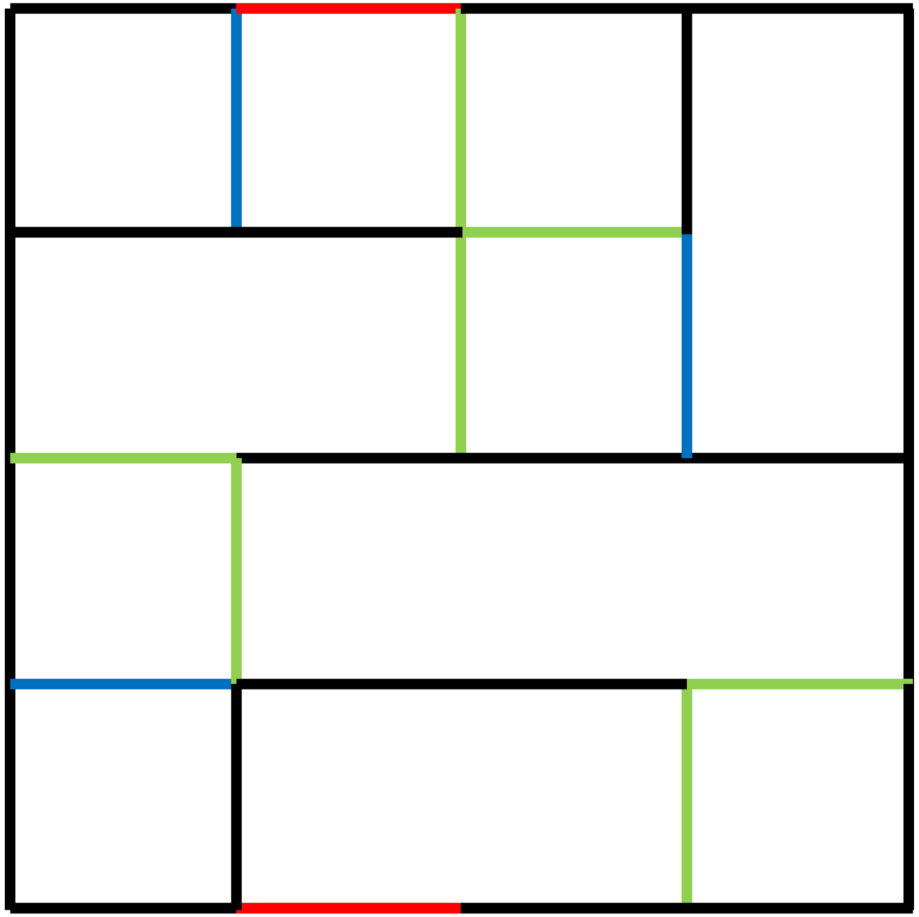

Contents

1. Introduction

The Qualification Test Procedures (QTPs) for each subsystem's specifications are set out in this document. Each subsystem has a table listing the test equipment required, the test environment and the test setup. This is followed by the QTP table stating for each test the specifications tested, the test procedure and the pass requirements. The QTPs are designed so that each subsystem is evaluated independently of the other two subsystems by connecting the subsystem to be tested to the HUB which will then emulate the other two subsystems according to the SCS State Diagram and Control Command Library within the practical guide. The QTPs will be conducted during the individual demonstrations as well as during the final demonstrations where systems are not fully integrated. However, due to time constraints, each subsystem will most probably only be required to undergo two of its QTPs. The evaluator will decide which two tests to complete.

The QTPs have been designed such the HUB will automatically give error messages at, for example, points within the state diagram where the subsystem being tested does not transmit the expected or correct data packets. This will assist students in debugging their subsystems and provide the evaluators with the means to determine which functions within the subsystem is operating to what extent. It is therefore imperative that students ensure that their subsystems are designed and implemented according to the specifications so that it can be tested as described in this document. In addition to this document, evaluators will also have the complete set of flow diagrams of each QTP as it is implemented within the HUB. Students can effectively test their subsystems without the HUB by transmitting the other subsystems' data packets via a terminal, or even by writing small python scripts that send data packets in accordance with SCS state diagram and control library. This is effectively the principle on which the HUB has been developed.

If a group delivers a complete integrated system capable of successfully navigating one of the 7 mazes at the final demonstration, it will of course imply that the subsystems are functional and hence rigorous qualification testing will not be required. However, after having demonstrated the integrated system on a maze, at least one QTP will be conducted per subsystem via the HUB to ensure the system adheres to the SCS design specifications. It is therefore very important that the USB communication ports of the subsystems are easily accessible to quickly connect all of the subsystems to the HUB.

2. State-and-Navigation Control (SNC) Subsystem Qualification Tests

Table 1 provides the test equipment, environment and setup for all the tests and Tables 2 and 3 the qualification tests and procedures that need to be performed to demonstrate that the SNC adheres to the relevant design specifications as mentioned in Sections 6b and 9b of the Practical Guide. The relevant design specifications must be met to ensure the SNC functions as intended within the system.

Table 1: Test equipment, environment and setup for all QTPs

Test Equipment	1. The SNC subsystem. 2. DC measuring equipment, such as a multi-meter. 3. Smartphone with "dB Sound Meter and Noise Detector – Decibel Level" app from Micro Inc installed to measure dB levels. 4. Personal computer or laptop (minimum screen height of 15 cm) with the HUB software installed.
Test Environment	1. Laboratory conditions (ABC or Heavy Machines lab).
Test Setup	1. Connect the power supply to the subsystem circuitry 2. Switch the system on and wait for the subsystem to complete its start-up sequence. 3. Connect the subsystem to the HUB through serial communication as will be outlined in the HUB User Manual. 4. Enter the following design parameters into the HUB GUI as defined in Appendix B of the practical guide: a. Inter sensor distances sd1, sd2, sd3 and sd4. b. Distance between the sensor array and wheel axis "A"

Table 2: Qualification Tests and Practical Demonstration Test Setup for the SNC excluding Specification 6 - Navigation Control.

QT Number	Specification The SNC must…	Test Procedure	Pass criteria
1 **Power Supply**	1. The subsystem must be able to function using one, or a combination of, the following input voltages, with a tolerable variation of 5 %: a. 3.3 V b. 5 V c. 9 V 2. The system may not draw more than 1 A from any of the three supply rails.	1. Connect Test Setup. 2. Verify the supply rail voltage of the subsystem to be 3.3V, 5V or 9V by measurement or inspection. 3. Activate the touch sensor (1st Touch) to transition into CAL state. 4. Measure the current drawn from supply rail. 5. Repeat the test for all supply rails used by the subsystem.	1. The supply rail values are 3.3V, 5V or 9V, to within 5% tolerance. 2. The current draw from any supply rail does not exceed 1 A.
2 **Touch sensor state transition and critical diagnostic display**	3. Adhere to the standard communications protocol as stipulated in the SCS. 4. Manage and communicate all state transitions as indicated in the practical guide Figure 3 and Table 1. 5. Await end-of-calibration (EoC) signals from the SS and MDPS within the CAL state before displaying all the critical system diagnostics and allowing a 2nd touch of the touch sensor to transition the system from the CAL to the MAZE state. 8. Receive and then display the following critical system diagnostic data using a web or smartphone application, an LCD screen or seven-segment displays (SSD), according to the display requirements as set out in the PEC documentation.	1. Connect the test setup. 2. On the HUB GUI, select SNC and execute QTP2. 3. Verify that the onboard display and HUB GUI indicates IDLE state. 4. Activate the touch sensor (1st Touch) to transition into CAL state. 5. Verify that the onboard display and HUB GUI indicates CAL state. 6. Verify that the SNC displays the Sensor Colours as transmitted from the HUB. 7. Activate 2nd Touch for transition into MAZE state. 8. Verify that the SNC displays all the critical diagnostics as transmitted from the HUB including MAZE state[1]. 9. Activate 3rd Touch to transition back into IDLE state. 10. Verify that the onboard display and HUB GUI indicates IDLE state.	1. The SNC must display only IDLE at startup. 2. The SNC correctly transitions to and indicates the CAL state after the 1st touch sensor activation. 3. The display correctly indicates the CAL state and correctly displays the following critical system diagnostics after calibration completion: i. Present system state. ii. Colour detected by each sensor. 4. The SNC correctly transitions to MAZE state after the 2nd touch activation and correctly displays all critical system diagnostics: i. Colour detected by each sensor. ii. Present system state. iii. MARV rotation angle [degrees]. iv. Tangential wheel speeds in [mm/s]. v. MARV distance covered in [mm]. vi. Incidence angle in degrees [degrees]. 5. The SNC transitions to and indicates only IDLE state after the 3rd touch activation.

[1] During tests, compare all HUB and SNC communication on the Hub GUI with the relevant QTP flow diagram to monitor the test execution. Appropriate error messages will be shown in the Hub GUI status window to indicate where in the process errors might have occurred. The Hub will also indicate when a test is complete.

QT Number	Specification The SNC must…	Test Procedure	Pass criteria
3 **Clap and Snap detection**	7. Detect a clap of hands and snap of fingers with a minimum volume of 70 dB.	1. Connect the test setup. 2. On the HUB GUI, select SNC and execute QTP3 3. Put the system into MAZE state. 4. Place the smartphone with the sound meter app as close as possible to the Clap/Snap sensor to monitor all dB levels. 5. Snap fingers below 70 dB. 6. Verify on the SNC display and HUB GUI that the system remains in MAZE state. 7. Snap fingers above 70 dB. 8. Verify on the SNC display and HUB GUI that the system transitioned into SOS state. 9. Clap hands below 70 dB. 10. Verify on the SNC display and HUB GUI that the system remains in SOS state. 11. Clap hands above 70 dB 12. Verify on the SNC display and HUB GUI that the system returned to MAZE state.	1. The SNC must remain in MAZE state for a finger snap below 70 dB. 2. The SNC must transition into the SOS state for a finger snap above 70 dB. 3. The SNC must remain in SOS state for a clap of hands below 70 dB. 4. The SNC must transition back into MAZE state upon a clap of hands above 70 dB.

Table 3: Qualification Tests for the SNC – Specification 6 Navigation Control. Specification numbers in the table correspond to the specification numbers in Section 9b of the practical guide.

QT Number	Specification	Test Procedure[2]	Pass criteria
1 **Traverse Green/Red at $\theta_i \leq 5°$**	3. The MARV must stop before changing direction or turning (rotating) 4. The MARV may not traverse (cross) a green or red line with an incidence angle of $\theta_i > 5°$. If the MARV encounters a green line at an angle of $5° < \theta_i < 45°$, it must reverse, apply steering correction, and re-attempt traversing the line.	1. Connect Test Setup. 2. Continue only if SNC QTP2 was successful. 3. On the HUB GUI, select NAVCON and execute QTP1. 4. Put the SNC into MAZE state via two touches of the touch sensor. 5. The HUB will automatically complete the rest of the QTP first emulating detection of GREEN at $5° < \theta_i < 45°$ followed by emulating RED detected at $\theta_i \leq 5°$ and indicate the status of the tests in the HUB GUI status window.	1. The MARV must stop before changing direction or rotating. 2. The MARV must cross RED or GREEN at $\theta_i \leq 5°$ when the line is encountered at $5° < \theta_i < 45°$. 3. The MARV must cross RED or GREEN without rotating when the line is encountered at $\theta_i \leq 5°$.
2 **Detecting Green/Red at $\theta_i > 45°$**	5. If in going forward the MARV detects a green or red line at an incidence angle $\theta_i > 45°$, the MARV must reverse and apply steering correction through a single rotation of ≤ 5° toward the line. This process (forward, detect, reverse, rotate) must repeat until $\theta_i < 45°$ at which point specification 4 must be adhered to.	1. Connect Test Setup. 2. Continue only if SNC QTP2 was successful. 3. On the HUB GUI, select NAVCON and execute QTP2. 4. Put the SNC into MAZE state. 5. The HUB will automatically complete the rest of the QTP emulating detecting GREEN on one side at $\theta_i > 45°$ such that more than one steering correction is required. 6. The HUB will then automatically repeat step 5 detecting RED on the other side.	1. Upon detecting GREEN or RED on the **left** at $\theta_i > 45°$, the MARV must apply multiple course corrections of ≤ 5° **toward** the line. 2. Upon detecting GREEN or RED on the **right** at $\theta_i > 45°$, the MARV must apply multiple course corrections of ≤ 5° **toward** the line.

[2] During all tests, compare all Hub and SNC communication on the Hub GUI with the relevant QTP flow diagram to monitor the test execution. Appropriate error messages will be shown in the Hub GUI status window to indicate where in the process errors might have occurred. The Hub will also indicate when a test is complete.

QT Number	Specification	Test Procedure	Pass criteria
3 **Detecting Blue/Black at $\theta_i < 45°$**	1b) Only two sensors are allowed to cross a black or blue line to determine the angle of incidence. 6. The following sequence must be applied when encountering a black or a blue line at an incidence angle of $\theta_i < 45°$ after the MARV has been driving forward. The MARV must: a) Reverse, b) Apply a $90° \pm \theta_i$ RIGHT turn to move forward parallel to the black/blue line on its left, c) Continue moving forward, d) If, after having turned right, the MARV detects a green line OR no line, it must keep on driving forward, e) If, after having turned right, the MARV, detects a blue OR a black line BEFORE detecting a green line, it must: i. Reverse; ii. Apply a 180° turn; iii. Drive forward.	1. Connect Test Setup. 2. Continue only if SNC QTP2 was successful. 3. On the HUB GUI, select NAVCON and execute QTP3. 4. Put the SNC into MAZE state. 5. The HUB will automatically complete the rest of the QTP emulating: a. a RIGHT turn (≤90°) on detecting BLUE/BLACK followed by GREEN and WHITE followed by another RIGHT turn (≤90°) on detecting BLUE/BLACK. b. crossing GREEN followed by a RIGHT turn (≥90°) on detecting BLUE/BLACK followed by a 180° turn on detecting BLUE/BLACK followed by WHITE as required by specification 6e.	**For part (a) a RIGHT turn ≤ 90°:** 1. Upon detecting BLUE/BLACK, the MARV must turn RIGHT such that the line is parallel to the MARV on the left. 2. The MARV must then drive forward and cross GREEN. 3. After GREEN, the MARV must again turn RIGHT upon detecting BLACK/BLUE and **not** turn 180°. **For part (b) a RIGHT turn ≥ 90°:** 4. Upon detecting BLUE/BLACK after a 2nd GREEN crossing, the MARV must turn RIGHT such that the line is parallel to the MARV on the left. 5. This will be followed by another BLACK/BLUE line where the MARV must turn 180° and then continue forward.
4 **Detecting Blue/Black at $\theta_i > 45°$**	7. If in going forward the MARV detects a black or blue line at an incidence angle $\theta_i > 45°$ the MARV must reverse and apply steering correction through a single rotation of ≤ 5°. This process (forward, reverse, rotate) must repeat until the MARV steers clear of the wall (black) or closed door (blue).	1. Connect Test Setup. 2. Continue only if SNC QTP2 was successful. 3. On the HUB GUI, select NAVCON and execute QTP4. 4. Put SNC into MAZE state. 5. The HUB will automatically complete the rest of the QTP emulating detecting BLACK or BLUE on the left at $\theta_i > 45°$ such that more than one steering correction is required. 6. Repeat of step 5 detecting BLUE or BLACK on the right.	1. Upon detecting BLACK/BLUE on the **left** at $\theta_i > 45°$, the MARV must apply multiple course corrections of ≤ 5° **away** from the line. 2. Upon detecting BLUE/BLACK on the **right** at $\theta_i > 45°$, the MARV must apply multiple course corrections of ≤ 5° **away** from the line.
5 **End-of-Maze**	8. If the MARV crosses red (exit), the maze is solved and the MARV transition into the IDLE state.	1. Connect Test Setup. 2. Continue only if SNC QTP2 was successful. 3. On the HUB GUI, select NAVCON and execute QTP5. 4. Put SNC into MAZE state. 5. The HUB will automatically complete the rest of the QTP emulating detecting and crossing RED.	1. Upon detecting RED the MARV must cross the line. 2. On receipt of the EoM from the eSS, the SNC must not transmit or transition into IDLE state.

3. Sensor (SS) Subsystem Qualification Tests

Table 4 provides the test equipment, environment and setup for all the tests and Table 5 the qualification tests and procedures that need to be performed to demonstrate that the subsystem adheres to the relevant design specifications as mentioned in Section 7b of the Practical Guide. The relevant design specifications must be met to ensure the Sensor subsystem functions as intended within the system.

Table 4: Test equipment, environment and setup for all QTPs

Test Equipment	1. The Sensor subsystem. 2. Stopwatch or Timer. 3. DC measuring equipment, such as a multi-meter. 4. Printed A4 sized protractor provided on the last page. 5. Ruler. 6. Personal computer or laptop (minimum screen height of 15 cm) with the HUB software installed. 7. Long USB cable between the computer and SS
Test Environment	1. Laboratory conditions (ABC or HEAVY MACHINES lab).
Test Setup	1. Apply the required supply rails to the subsystem. 2. Switch the system on and wait for the subsystem to complete its start-up sequence. 3. Connect the subsystem to the HUB through serial communication as will be outlined in the HUB User Manual. 4. Enter the following design parameters into the HUB GUI as defined in Appendix B of the practical guide: a. Inter-sensor distances sd1, sd2, sd3 and sd4.

Table 5: Qualification Tests for the Sensor Subsystem

QT Number	Specification	Test Procedure[3]	Pass criteria
1 Power Supply and Sensor Array	1. Be able to function using one, or a combination of, the following input voltages, with a tolerable variation of 5%: a. 3.3 V b. 5 V c. 9 V 2. The system may not draw more than 1 A from any of the three supply rails. 4. Have five (5) colour sensors in the sensor array. The sensors must be in a straight array, parallel to the wheel axis.	1. Connect Test Setup. 2. Verify the supply rail voltage of the subsystem to be 3.3V, 5V or 9V by measurement or inspection. 3. On the HUB GUI, select "Sensor" and then execute QTP1. 4. Measure the current drawn from the supply rail. 5. Repeat the test for all supply rails used by the subsystem. 6. Visually inspect the sensor array.	1. The supply rail values are 3.3V, 5V or 9V, to within 5% tolerance. 2. The current draw from any supply rail does not exceed 1 A. 3. There must be five sensors in a straight line parallel to the wheel axis.
2 Calibration	3. Communicate with the SNC or HUB using the standard communication protocol as stipulated in the SCS. 6. Communicate the colour being detected by each sensor to the SNC or HUB when the calibration is completed. 7. Visually depict the colour of each sensor in the array in real-time. 8. Implement the states and transition between operating states as set out in the SCS. 9. Calibrate within 60 seconds and send an end-of-calibration (EoC) signal to the SNC or HUB.	1. Connect Test Setup. 2. On the HUB GUI, select "Sensor" and then execute QTP2. 3. Verify on the HUB GUI that the SS is not transmitting data. 4. Click "Touch" on the eSNC[4] and start the timer simultaneously. 5. Stop the timer as soon as all 5 colours have been calibrated and the calibration readings have been received and displayed on the eSNC. 6. Place the sensor array on each of the four lines and on WHITE and visually verify that the SS displays all 5 colours correctly on its on-board display. 7. Click the "Touch" on the HUB GUI to transition from CAL into MAZE state. 8. The HUB will automatically verify that the SS transmitted the two MAZE state packages indicating the result in the status window.	1. The SS does not transmit data at start-up. 2. The SS displays and transmits the correct detected colours to the HUB after calibration. 3. The SS calibrates in under 60 seconds. 4. The SS successfully transitions from IDLE to CAL to MAZE states.

[3] During all tests, compare all Hub and SS communication on the Hub GUI with the relevant QTP flow diagram to monitor the test execution. Appropriate error messages will be shown in the Hub GUI status window to indicate where in the process errors might have occurred. The Hub will also indicate when a test is complete.

[4] eSNC = emulated SNC on the HUB GUI.

QT Number	Specification	Test Procedure	Pass criteria
3 **Colour Detection**	3. Communicate with the SNC or HUB using the standard communication protocol as stipulated in the SCS. 5. Be able to detect and classify the following colours as printed on the maze test block: White, Black, Red, Green, Blue. 7. Visually depict the colour of each sensor in the array in real-time.	1. Complete the execution of QTP2 which puts the SS in MAZE state and then execute QTP3 on the HUB GUI. 2. Place the sensor array in the centre of the test block at approximately 45° toward the blue and red lines facing the corner. 3. Slowly move the sensor array forward while visually confirming the change in colours from white-to-blue/red-to-white on the SS onboard display and HUB GUI as the array crosses the lines. 4. Repeat steps 2 and 3 with the array facing and crossing the red and green lines at 45° 5. Repeat steps 2 and 3 crossing the green and black lines at 45°. 6. Repeat steps 2 and 3 crossing the black and blue lines at 45°. 7. Click “Continue” to terminate the QTP.	1. The SS classifies white, blue, red, green or black correctly on the applicable sensors, both on the SS display and the HUB GUI, for each of the four directions.
4 **Incidence Angle**	3. Communicate with the SNC or HUB using the standard communication protocol as stipulated in the SCS. 5. Be able to detect and classify the following colours as printed on the maze test block: White, Black, Red, Green, Blue. 10. Determine the angle of incidence within a 5° accuracy and communicate the result to the SNC or HUB adhering to the formatting requirements as stipulated in the PEC documentation.	1. Complete the execution of QTP3. 2. Position the sensor array inside the Maze test block with the BLUE, BLACK or GREEN on the right at an incidence angle of $5° < \theta_i < 45°$. Use the printable A4 protractor provided. The evaluator will state which colour and at what angle at the evaluation. 3. Move the sensor array forward in a straight line and stop when the rightmost sensor (S5) detects the line. 4. On the HUB GUI, select “Sensor” and then execute QTP4. 5. Verify that the correct colours are displayed on the SS and the eSNC. 6. Mark the position of the sensor array on the test block. 7. Move the sensor array forward and stop when the second rightmost sensor (S4) detects the line. 8. Use the ruler to measure the distance ‘D’ the array moved forward from the position marked in step 6 to where S4 was detected. 9. Enter the measured distance ‘D’ into eMDPS[5] and click “Continue” on the HUB GUI. 10. Compare the θ_i communicated to the HUB with the actual θ_i of step 2 11. Repeat steps 2 & 3 with a different colour line on the left of the sensor array thus using the two leftmost sensors (S1 and S2) 12. Click “Continue” and repeat 5 to 10 for the new colour.	1. The SS measures and transmits an incidence angle within a 5° accuracy for $5° < \theta_i < 45°$ on the **right**. 2. The SS measures and transmits an incidence angle within a 5° accuracy for $5° < \theta_i < 45°$ on the **left**.

[5] eMDPS = emulated MDPS on the HUB GUI.

QT Number	Specification	Test Procedure	Pass criteria
5 **End-of-Maze, IDLE or SOS**	8. Implement the states and transition between operating states as set out in the SCS. 11. Communicate the end-of-maze condition to the SNC or HUB when all the sensors detect the colour Red. 12. Transmit no data to the SNC or HUB, while in IDLE or SOS state.	1. Complete the execution of QTP3. 2. Position the sensor array inside the test block facing the RED line at an angle of $\theta_i \approx 0°$. 3. On the HUB GUI, select "Sensor" and then execute QTP5. 4. The HUB will emulate a "ClapSnap" on the eSNC to transition into SOS. Verify on the HUB that the SS does not transmit in the SOS state. 5. Click "Continue" on the HUB GUI to transition back into MAZE. Verify on the HUB that SS is transmitting again. 6. Move the sensor array across the RED line. 7. Verify on the HUB that the SS communicates the End-of-Maze condition to the HUB when all sensors crosses or crossed RED. 8. If the SS does not successfully detect the EoM, click the "EOM" button to terminate the QTP on the HUB.	1. After the SOS state is communicated, the SS must not transmit data to the HUB. 2. After having transitioned back into the MAZE state, the SS must again transmit COLOUR and INCIDENCE data to the HUB. 3. When the SS detects and displays all 5 sensors as red, it must transmit the End-Of-Maze control byte to the HUB.

4. Motor Driver and Power Supply (MDPS) Subsystem Qualification Tests

Table 6 provides the test equipment, environment and setup for all the tests and Table 7 the qualification tests and procedures that need to be performed to demonstrate that the subsystem adheres to the relevant design specifications as mentioned in Section 8b of the Practical Guide. The relevant design specifications must be met to ensure the MDPS functions as intended within the system.

Table 6: Test equipment, environment and setup for all QTPs

Test Equipment	1. The MDPS subsystem. 2. DC measuring equipment, such as a multi-meter. 3. Load resistors to demonstrate 2 A drawn from each supply rail. Ensure that the resistors have a sufficient wattage rating. For example, a typical 0.25 W, 2.5 Ω resistance on the 5 V rail will result in 2 A, but what will the power dissipation in that resistor be? 4. Personal computer or laptop (minimum screen height of 15 cm) with the HUB software installed. 5. Long USB cable between the compute and MDPS so that it can move freely when connected to the computer. 6. Ruler or measuring tape. 7. Printed A4 sized protractor provided on the last page.
Test Environment	1. Laboratory conditions (ABC or HEAVY MACHINES lab).
Test Setup	1. Apply the required supply rails to the subsystem. Switch the system on and wait for the subsystem to complete its start-up sequence. 2. Connect the subsystem to the HUB through serial communication as will be outlined in the HUB User Manual. 3. Enter the following design parameters into the HUB GUI as defined in Appendix B of the practical guide: a. Inter-sensor distances sd1, sd2, sd3 and sd4. b. Distance between the sensor array and wheel axis “A” c. Designed v_{op} in mm/s which is the speed at which the MARV is designed to travel in the maze.

Table 7: Qualification Tests for the MDPS Subsystem

QT Number	Specification. The MDPS must:	Test Procedure	Pass criteria
1 **Energy**		QTP1 for the MDPS has been redacted in 2022	
2 **Power supply** **and** **End-of-Maze**	1. operate independently of wall socket power when in use. 2. output, externally, voltage levels of 3.3 V, 5 V and 9 V to within a 5 % accuracy under all load conditions, where the maximum external current drawn is 2 A for each rail while the motors are turning at nominal speed. 15. Stop and rotate 360° on detection of the End-of-Maze transmission from the SS.	1. Connect the test setup as described. 2. Disconnect all MDPS subsystem circuitry from the internal power supply. 3. Measure the voltage output from the 3.3 V or 5 V and 9 V supply rails under no-load conditions. 4. Reconnect the MDPS subsystem circuitry to the internal power supply. 5. On the HUB GUI, select "MDPS" and then execute QTP2. 6. The eSNC on the HUB will transmit c213-v_{op}-v_{op}-0 which must result in the designed forward operating speed $v_{op\_designed}$. Compare the v_{op} transmitted to the MDPS with the speeds received from the MDPS. 7. Click "End of Maze" in the eSS HUB GUI and confirm a Stop and 360° rotation. 8. Setup and measure the output voltage from the 3.3V or 5 V supply rail with a 2A load current. 9. Setup and measure the output voltage from the 9V supply rail with a 2A load current.	1. The 3.3V supply rail is in the output range of 3.135 – 3.465 V in both measurements. OR 2. The 5V supply rail is in the output range of 4.75 – 5.25 V in both measurements. 3. The 9V supply rail is in the output range of 8.55 – 9.45 V in both measurements. 4. The MDPS must stop and rotate 360° on receiving the SS's EoM transmission.
3 **Calibration and Communi-cation**	4. calibrate the tangential wheel speeds (v_{op}) in the CAL state within 1min. 7. ensure a speed to within 5% of the speed set by the SNC. 11. communicate with the SNC or HUB using the standard communication protocol as stipulated in the SCS. 14. report no data to the SNC or HUB in the IDLE state.	1. Connect the test setup as described. 2. Program the MDPS controller with a wheel speed of $\leq 0.8v_{op\_designed}$ OR $\geq 1.5v_{op\_designed}$ and enter this value into the HUB GUI. The evaluator will decide on the speed value in consultation with the student. $v_{op\_designed}$ refers to the speed at which the MARV is designed to travel in the maze. 3. On the HUB GUI, select "MDPS" and then execute QTP3. 4. The HUB will verify that no transmission is received from the MDPS in IDLE before automatically continuing to the CAL state.[6] 5. The HUB will verify that the MDPS calibrates the wheel speeds of both wheels to within 5% of the set v_{op}. 6. The HUB will verify that the MDPS continues to transmit a ≥ 0 battery level within the CAL loop as required by the SCS state diagram. 7. Repeat the test at $v_{op\_designed}$ and confirm visually and/or audibly that the MDPS calibrated at the higher or lower speed. The student will have to change v_{op} chosen in step 2 back to $v_{op\_designed}$ in the MDPS controller.	1. The MDPS must not transmit in IDLE state. 2. The MDPS must calibrate both wheel speeds to $v_{op} \pm 5\%$ in both test runs. 3. The MDPS must function and communicate as stipulated in the SCS state diagram. 4. It must be proven that the second test run executed at a higher or lower speed than the first.

[6] During this test, compare all Hub and MDPS communication on the Hub GUI with the relevant QTP flow diagram to monitor the test execution. Appropriate error messages will be shown in the Hub GUI status window to indicate where in the process errors might have occurred. The Hub will also indicate when a test is complete.

QT Number	Specification. The MDPS must:	Test Procedure	Pass criteria
4 Forward, Stop, Reverse, Communi-cation, SOS	5. enable all necessary movements of the MARV to adhere to all the navigation specifications in Section 9b. 6. be able to propel the MARV at a speed v_{op} of at least 30 mm/s. 7. ensure a speed to within 5% of the speed set by the SNC. 10. determine the distance travelled since the last stop with an error ≤ 5%. 12. communicate the following to the SNC or HUB, according to the display requirements in the PEC documentation: ● Tangential wheel speeds in [mm/s]. ● Distance travelled since last stop in [mm]. ● Last rotation angle of the MARV in degrees. 13. come to a complete halt in less than 2 seconds upon entering the SOS state.	1. Complete the execution of QTP3. 2. On the HUB GUI, select "MDPS" and then execute QTP4. 3. The HUB will execute the following three tests in a random order. a. An elementary Reverse and Stop instruction after a distance of between 60 and 100 mm, randomly chosen by the HUB, has been received from the MDPS. b. An elementary Forward and Stop instruction after a distance of between 120 and 200 mm, randomly chosen by the HUB, has been received from the MDPS. This test will evaluate the distance and speed accuracy of the MDPS. Measure the actual distance that the MDPS drove forward with a ruler and calculate the actual average speed of the MDPS using the time displayed by the HUB. Compare this to the average speed calculated and displayed by the HUB. c. A "Forward or Reverse – into and out of SOS – Forward" sequence of movements at distances of between 30 and 50 mm, randomly chosen by the HUB. 4. Before the start of each test, the status window will prompt the user to position the MARV accordingly and to then click "Continue".	1. The MDPS drives forward at a speed that is within 5% of the set point v_{op}. 2. **QTP4a**: The MDPS must reverse and stop after the distance indicated by the HUB with an error of ≤ 5%. 3. **QTP4b**: The MDPS must drive forward and stop after the distance indicated by the HUB with an error of ≤ 5%. 4. **QTP4b**: The average speed transmitted by the MDPS must be within 5% of the actual speed. 5. **QTP4c:** At the HUB's command, the MDPS must: ● Reverse or go forward as instructed ● go into SOS and stop within 2sec, ● transition back into MAZE, ● drive forward and ● stop again. 6. The MDPS must communicate all critical system diagnostics to the HUB throughout the process.
5 Rotation	5. enable all necessary movements of the MARV to adhere to all the navigation specifications in Section 9b. 8. rotate around the midpoint between the two wheels of the MARV (see Figure B.1a). 9. allow rotation of the MARV of between 5° and 360° with an error of ≤ 5%. NAVCON specification 2: The MARV must be able to perform the following distinct turn functions: ● turn 90° ± 5° RIGHT ● turn 180° ± 5° LEFT or RIGHT ● turn 360° ± 5° LEFT or RIGHT ● an incremental rotation of ≤ 5° RIGHT AND LEFT.	1. Complete the execution of QTP3. 2. On the HUB GUI, select "MDPS" and then execute QTP5. 3. The HUB will automatically instruct the following rotations in random order with the user required to click "Continue" before each rotation: ● turn 90° RIGHT ● turn 180° LEFT ● turn 180° RIGHT, ● turn 360° LEFT ● turn 360° RIGHT, ● a number of incremental rotations of ≤ 5° RIGHT ● a number of incremental rotations of ≤ 5° LEFT ● a random angle between 45° and 135° LEFT, ● a random angle between 45° and 135° RIGHT. Each rotation must be measured with the protractor provided on the last page.	1. The MDPS must execute all 9 rotations listed to within 5% accuracy. 2. The MDPS must rotate around the midpoint between the two wheels.

Appendix A: Important Revision Changes

2022-08-25

- Renumbering of MDPS's QTPs to correspond to that of the HUB.

2022-09-28

- SNC QTP2 Pass Criteria: Update of critical system diagnostic data that must displayed – corrected to correspond to table B.1 in the practical guide.
- MDPS QTP3 Test procedure: Specifically stated that a battery level of 0 must be transmitted as stipulated in the Practical Guide SCS control command library.
- Minor cosmetic changes.

2022-09-30

- Had to rewrite MDPS QTP3 test procedure because the old version effectively required the MDPS to read the designed speed from the HUB GUI which is not possible because the HUB never transmits the designed speed to the MDPS to calibrate at.

2022-10-06

- Revised NAVCON QTP3 test procedure and pass requirements to include a 2nd GREEN line crossing at the start of part B.

2022-10-25

- MDPS QTP2 – addition of End-of-Maze specification.
- NAVCON QTP5 – revision of End-of-Maze requirement and specification.

2022-10-31

- MDPS QTP4 and 5 Test procedure to be in line with the latest HUB version.

Appendix B: Protractor