System Test Plan & Test Results

P11211, P11212, P11213: Land Vehicle for Education
Spring 2011

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1. Preliminary Testing Plan

ES #	Engineering Specification	Verification Strategy	Pass/Fail Criteria	Data
General 1.0				
1.1	# of LVEs	Analyze	At least 10 mass produced LVEs	Count
1.1a	# of MSAs	Analyze	At least 30 mass produced MSAs	Count
1.2	Cost of Mass Produced LVEs	Analyze	Less than $5,000 deployment cost	Dollars
1.3	Cost for initial prototype	Analyze	Costs at most $500 to produce	Dollars
1.4	Educational	Test	At least 75% approval from faculty survey	Percent
1.5	Student machined parts	Demonstrate	At least 3 parts to be machined by students	Count
1.6	Hand Tools Required by students	Demonstrate	At most 5 hand tools required for construction	Count
Chassis 2.0				
2.1	Weight of Chassis	Test	Weighs at most 10 lbs	Pounds
2.2	Weight of Payload and MSA	Test	Weighs at most 5 lbs	Pounds
2.3	Speed of Fully Loaded LVE	Test	Maximum speed is greater than 0.5 mph	Mph
2.4	Turning Radius	Test	Less than 12 inches	Inches
2.5	Height Chassis	Analyze	Less than 8 inches	Inches
2.6	Base Area of Chassis	Analyze	Less than 144 square inches	Inches
~~2.7~~	~~Ability to travel up incline~~	~~Demonstrate~~	~~Can travel up a 15 degree incline~~	~~N/A~~
2.8	Drop Height	Test	Can be dropped from a minimum of 3 feet and still function as intended	Functions (yes/no)
Power 3.0				
3.1	Battery Life At Full Load	Test	Battery can power the LVE for 90 minutes	Minutes
3.2	Recharge Time for Full Battery	Test	Battery can be fully recharged in less than 4 hours	Hours
Safety 4.0				
4.1	Surface Temperature	Test	Surface temperature never exceeds 130 degrees F	Deg. F
4.2	Sharpness of Edges	Test	No edges or corners tear through more than 3 sheets of tissue paper	Count
Production 5.0				
5.1	Minimize Material Waste	Demonstrate	All material scraps weigh less than 1 lb	Pounds
5.2	Lead time for OTS parts	Demonstrate	All parts can be acquired within 2 weeks	Weeks
5.3	Time to construct LVE	Analyze	Mass produced LVEs can be constructed in less than 60 man hours	Hours
5.4	Machined Parts Per LVE	Demonstrate	Each LVE contains no more than 20 custom machined parts	Count
5.5	Custom Order Components	Demonstrate	The LVE contains no custom ordered parts	Count

2.1 Drop Height

Engineering Specification: 2.8

Background: The LVE was designed to be durable in order to withstand several years of use by Freshman Mechanical Engineering Students. The purpose of this test is to ensure that the LVE can withstand being knocked off of a table or desk and still continue to function as was originally intended.

Equipment Required:

- LVE and MSA Assembly (Appendix 1)
- LVE Controller
- Computer with the LVE program installed
- Yard Stick
- LVE Test Plan

Test:

1. Hold the yard stick vertically, with one end on the ground
2. Hold the LVE and MSA assembly at the top of the yard stick (3 feet above the ground) with the base facing down
3. Release the LVE and let it hit the ground
4. Repeat steps 2 and 3 with each of the remaining 5 sides facing down at the time of release and again with each of the 4 vertical corners facing down
5. Verify that all engineering specifications are still met by completing the remainder of the system test plan

Pass/Fail Criteria:

Pass: All engineering specifications are still met, as indicated by the completion of the test plan.

Fail: LVE no longer functions as intended or one or more engineering specifications are no longer met.

2.2 Educational

Engineering Specification: 1.4

Background: The primary purpose of the LVE and MSA is to educate Freshmen Mechanical Engineering Students with respect to the designing, modeling and machining of mechanical components. The MSA should build off of the student's preexisting knowledge from high school as well as the concepts that they will learn in the course that the LVE is being designed for. In order to determine whether or not this goal has been met, the LVE will be demonstrated to current Mechanical Engineering Faculty and a survey will be used to gather their opinions.

Equipment Required:

- LVE and MSA Assembly (Appendix 1)
- A minimum of 10 Mechanical Engineering Faculty
- Faculty Surveys (Appendix 2)

Test:

1. Distribute faculty survey
2. Demonstrate LVE capabilities for faculty
    a. Use of controller
    b. Chassis movements
    c. MSA movements)
3. Explain the student design portion of the project
    a. Linkage measurement calculations
    b. Linkage modeling in CAD
    c. Linkage manufacturing and assembly
4. Allow faculty time to fill out the survey
5. Collect and analyze survey results

Pass/Fail Criteria:

Pass: The LVE receives an average approval of at least 75%.

Fail: The LVE receives an average approval of less than 75%.

2.3 System Weight

Engineering Specification: 2.1, 2.2

Background: The weight of the overall system must not weigh more than specified in order to ensure that size of the motors and batteries are sufficient enough to support the LVE mission profile. This test will measure the weight of the entire assembly in order to verify that the Engineering Specification was met.

Equipment Required:

- LVE and MSA Assembly (Appendix 1)
- Foam Block (1 in^3)
- Digital Scale – able to measure in pounds to the nearest hundredth

Test:

1. Place LVE/MSA assembly and foam block on the scale
2. Wait for the scale to stop fluctuating
3. Record weight measurement

Pass/Fail Criteria:

Pass: Entire assembly weighs less than or equal to 15 lbs.

Fail: Entire assembly weighs more than 15 lbs.

2.4 LVE Speed

Engineering Specification: 2.3

Background: In order to ensure the functionality and impressiveness of the LVE, it should have a maximum speed equal to or greater than the specified value. This test will measure the speed of the LVE in order to verify that the Engineering Specification was met.

Equipment Required:

- LVE and MSA Assembly (Appendix 1)
- LVE Controller
- Computer with the LVE program installed
- Carpeted Hallway or Classroom (at least 15 yards long)
- Tape Measure
- Masking Tape
- Stop Watch

Test:

1. Place LVE assembly at one end of the hallway
2. Measure 2 yards from the location of the LVE
3. Place a piece of tape on the floor at this location
4. Measure 5 yards from the location of the tape
5. Place another piece of tape at the new location
6. Turn on the LVE
7. Accelerate the LVE
8. Begin the stop watch when the LVE passes over the first piece of tape
9. Stop the stop watch when the LVE passes over the second piece of tape
10. Decelerate and stop the LVE
11. Place the LVE back at the start and repeat steps 7-10 for 2 additional trials
12. Turn off the LVE
13. Remove and dispose of the tape
14. Calculate the speed of the LVE

    [v = (30 ft / X sec) * (1 mile / 5280 ft) * (3600 sec / 1 hour) = X mph]

Pass/Fail Criteria:

Pass: Maximum speed is equal to or greater than 0.5 mph.

Fail: LVE speed is less than 0.5 mph.

2.5 Turning Radius

Engineering Specification: 2.4

Background: In order to ensure the easy movement of the LVE, a maximum turning radius was specified. This will increase the usability and impressiveness of the LVE.

Equipment Required:

- LVE and MSA Assembly (Appendix 1)
- LVE Controller
- Computer with the LVE program installed
- Ruler / Yard Stick
- Masking Tape
- 3ft x 3ft section of paper
- Marker

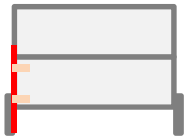


Figure 1a

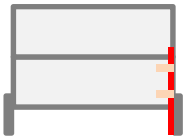


Figure 1b

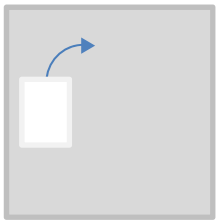


Figure 2a

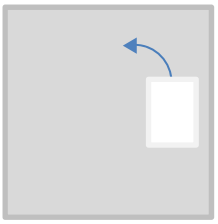


Figure 2b

Test:

1. Lay the paper on the floor
2. Tape the marker to the LVE as shown in Figure 1a, with the marker tip resting on the paper
3. Place LVE to the left side of the paper, facing away from the tester (Figure 2a)
4. Turn on the LVE on
5. Using the controller, turn the LVE in one complete circle to the right
6. Measure the radius of the resulting circle
7. Move the pen to the right side of the LVE as shown in Figure 1b
8. Move the LVE to the right side of the paper, facing away from the tester (Figure 2b)
9. Using the controller, turn the LVE in one complete circle to the left
10. Measure the radius of the resulting circle
11. Turn off the LVE
12. Remove and dispose of the tape and paper

Pass/Fail Criteria:

Pass: Radius does not exceed 12 in.

Fail: Radius exceeds 12 in.

2.6 Battery Life

Engineering Specification: 3.1

Background: The battery was sized to withstand a typical class session which would last approximately 90 minutes. This test will verify that capability.

Equipment Required:

- LVE and MSA Assembly (Appendix 1)
- Fully charged LVE battery
- LVE Controller
- Computer with the LVE program installed
- Foam Block
- Shelf (or Stack of Books)
- Voltmeter
- Typical College of Engineering Classroom (example: 09-2159)
- Mission Profile Charts: https://edge.rit.edu/content/P11211/public/System%20Mission%20Profile

Test:

1. Place the foam block on the shelf
2. Place the LVE on the opposite side of the room
3. Turn on the LVE
4. Start the stopwatch
5. Using the Mission Profile Charts and the LVE controller, run the LVE through one repetition of the mission profile
6. Repeat steps 4 – 7 until 90 minutes have expired
7. Measure the voltage of the battery using the voltmeter

Pass/Fail Criteria:

Pass: LVE battery voltage is greater than 7V at the end of 90 minutes.

Fail: LVE battery voltage is less than 7V at the end of 90 minutes.

2.7 Recharge Time

Engineering Specification: 3.2

Background: It is possible that the LVE will be used for several classes during the same day, for this reason it is necessary to minimize the time it takes to recharge the battery.

Equipment Required:

- LVE and MSA Assembly (Appendix 1)
- LVE Controller
- Computer with the LVE program installed
- Battery Charger
- Power Supply (Outlet)
- Stop Watch

Test:

1. Turn the LVE on
2. Run the LVE until the battery is fully drained (< 7V)
3. Plug the battery charger into a wall outlet, plug the other end into the LVE
4. Start the stop watch
5. When the stop watch reaches 10 minutes, stop the stop watch and unplug the charger from the LVE
6. Let the battery rest for 1 minutes
7. Measure battery voltage
8. If the battery voltage is less than 8V, repeat steps 5-9
9. When the battery reaches a charge of 8V, sum the ten minute intervals to determine the overall charge time

Pass/Fail Criteria:

Pass: The time to fully charge the battery does not exceed 4 hours.

Fail: After 4 hours, the battery is not fully charged.

2.8 Surface Temperature

Engineering Specification: 4.1

Background: In order to ensure student safety, the surface temperature of the LVE must not exceed the specified value.

Equipment Required:

- LVE and MSA Assembly (Appendix 1)
- LVE Controller
- Computer with the LVE program installed
- Mission Profile Charts: https://edge.rit.edu/content/P11211/public/System%20Mission%20Profile
- Thermocouple
- Data Acquisition System

Test:

1. Turn on the LVE
2. Run the LVE and MSA through the mission profile 3 times
3. Turn off the LVE
4. Using the Thermocouple and Data Acquisition System, measure* and record** the surface temperatures at various locations on the LVE and MSA (Appendix 3):
    a. Motors
    b. Servos
    c. Exposed cables/wires

Pass/Fail Criteria:

Pass: LVE surface temperature does not exceed 130 degrees Fahrenheit.

Fail: LVE surface temperature exceeds 130 degrees Fahrenheit.

* All measurements must be taken within 5 minutes of turning off the LVE.

** When using the Thermocouple and Data Acquisition System, allow the temperature to stop fluctuating before recording a value.

2.9 Sharp Edges

Engineering Specification: 4.2

Background: In order to ensure student safety, the LVE must contain no edges sharper that the specified criteria.

Equipment Required:

- LVE and MSA Assembly (Appendix 1)
- Single Ply Tissue (at least 10 6 in. sheets)

Test:

1. Leave the LVE completely assembled, as it would be used by the students
2. Hold 3 pieces of tissue paper (one on top of another) in one hand
3. Gently run the stack of tissue paper over all corners and edges
4. If a piece of tissue paper is torn, dispose of it and replace it so that the stack always contains 3 un-torn pieces
5. Make note of any corners that tear all three sheets of tissue paper

Pass/Fail Criteria:

Pass: No points on the LVE are sharp enough to tear through more than 3 sheets of tissue paper.

Fail: One or more points on the LVE are capable of tearing through 4 or more sheets of tissue paper.

3.1 Quantity of LVEs

Engineering Specification: 1.1

Background: In order to meet the needs of a semester of freshman engineers, a specified quantity of LVEs (chassis and controls) must be able to be produced within the mass production budget. The quantity of LVEs shall be great enough to allow each group of students within a class section to have their own LVE.

Analysis: A final bill of materials and cost summary for the mass production of LVEs can be found at: http://edge.rit.edu/content/P11211/public/LVE%20Budget

Pass/Fail Criteria:

Pass: 10 LVEs can be produced for less than $3,250.

Fail: The cost to produce 10 LVEs exceeds $3,250.

3.2 Quantity of MSAs

Engineering Specification: 1.1a

Background: In order to meet the needs of a semester of freshman engineers, a specified quantity of MSAs must be able to be produced within the mass production budget. The quantity of MSA shall be great enough to allow each group of students in a given semester to have their own MSA.

Analysis: A final bill of materials and cost summary for the mass production of LVEs can be found at: http://edge.rit.edu/content/P11211/public/LVE%20Budget

Pass/Fail Criteria:

Pass: 30 MSAs can be produced for less than $1,500.

Fail: The cost to produce 30 MSAs exceeds $1,500.

3.3 Mass Production Cost

Engineering Specification: 1.2

Background: Enough LVEs and MSAs to support a semester of students must be produced within the allotted budget.

Analysis: A final bill of materials and cost summary for the mass production of LVEs can be found at: http://edge.rit.edu/content/P11211/public/LVE%20Budget

Pass/Fail Criteria:

Pass: The mass production budget must not exceed $5,000.

Fail: The mass production budget exceeds $5,000.

3.4 Prototype Cost

Engineering Specification: 1.3

Background: The LVE and MSA assembly prototype must be produced within the allotted budget.

Analysis: A final bill of materials and cost summary for the LVE and MSA assembly prototype can be found at: http://edge.rit.edu/content/P11211/public/LVE%20Budget

Pass/Fail Criteria:

Pass: The LVE/MSA prototype cost does not exceed $500.

Fail: The LVE/MSA prototype exceeds $500.

3.5 Chassis Height

Engineering Specification: 2.5

Background: The LVE is intended to be compact, in order to reduce the storage space required for large quantities. This observation is to determine the height of the chassis.

Analysis: Use a ruler to measure the height of the chassis.

Pass/Fail Criteria:

Pass: The height of the chassis does not exceed 8 inches.

Fail: The height of the chassis exceeds 8 inches.

3.6 Chassis Base Area

Engineering Specification: 2.6

Background: The LVE is intended to be compact, in order to reduce the storage space required for large quantities. This observation is to determine the base area of the chassis.

Analysis: Use a ruler to measure the greatest length and width of the chassis base. Multiply the measurements to determine the overall area.

Pass/Fail Criteria:

Pass: The base area of the chassis does not exceed 144 square inches.

Fail: The base area of the chassis exceeds 144 square inches.

3.7 Time to Construct

Engineering Specification: 5.3

Background: The LVE must be designed to be easily manufactured by the RIT Mechanical Engineering Department. The purpose of this analysis is to determine the time it would take to produce a single LVE and MSA assembly.

Analysis: Obtain estimations of the time that each group spent on the construction of the LVE prototype. Troubleshooting time must be taken into account; therefore a 15% reduction of time should be used.

Team	Time to Construct	Adjusted Time (-15%)
Chassis		
Controls		
MSA		

Pass/Fail Criteria:

Pass: The total time to construct the LVE does not exceed 60 hours of manpower.

Fail: More than 60 hours of manpower were required to produce the LVE.

4.1 Quantity of Student Machined Parts

Engineering Specification: 1.5

Background: In order to meet educational requirements, the MSA must incorporate no fewer than the specified quantity of parts to be designed and machined by the students.

Observation: Observe the LVE and note all parts to be constructed by the students.

Pass/Fail Criteria:

Pass: The MSA incorporates at least 3 parts to be machined by students.

Fail: The MSA incorporates fewer than 3 parts to be machined by students.

4.2 Quantity of Hand Tools Required by Students

Engineering Specification: 1.6

Background: In order to reduce complexity of the MSA assembly, no more than the specified quantity of hand tools must be required by the students to construct the MSA.

Observation: Observe the student assembly process and note all hand tools required for the assembly.

Pass/Fail Criteria:

Pass: The MSA student construction requires at most 5 hand tools.

Fail: Students are required to use more than 5 hand tools to construct the MSA.

4.3 Waste Material

Engineering Specification: 5.1

Background: The LVE was designed to be manufactured with minimum material waste. The purpose of this observation is to ensure that this specification has been met.

Observation: Collect and weigh all waste materials from the construction of the LVE.

Pass/Fail Criteria:

Pass: Total waste materials weigh less than 1 lb.

Fail: The waste materials produced weigh more than 1 lb.

4.4 Lead Time for OTS Parts

Engineering Specification: 5.2

Background: The LVE must be designed to be easily and quickly manufactured by the RIT Mechanical Engineering Department. The purpose of this observation is to ensure that all parts required for the LVE construction can be obtained within a specified period of time.

Observation: Record the time from the date that the parts were ordered until they arrived.

Pass/Fail Criteria:

Pass: No parts took longer than 2 weeks from the date the order was placed to arrive.

Fail: One or more parts took longer than 2 weeks from the date the order was placed to arrive.

4.5 Machined Parts Per LVE

Engineering Specification: 5.4

Background: The LVE must be designed to be easily and quickly manufactured by the RIT Mechanical Engineering Department. The purpose of this observation is to ensure that the quantity of custom machined parts per LVE does not exceed that specified.

Observation: Observe the LVE and note all custom machined parts.

Pass/Fail Criteria:

Pass: No more than 20 custom machined parts are required to construct the LVE.

Fail: More than 20 custom machined parts are required to construct the LVE.

4.6 Custom Order Parts

Engineering Specification: 5.5

Background: The LVE must be designed to be easily and quickly manufactured by the RIT Mechanical Engineering Department. In order to ensure that parts can be obtained within a given time period, it was required that no custom order mechanical parts be required.

Observation: Observe the LVE and order receipts; note all custom ordered parts.

Pass/Fail Criteria:

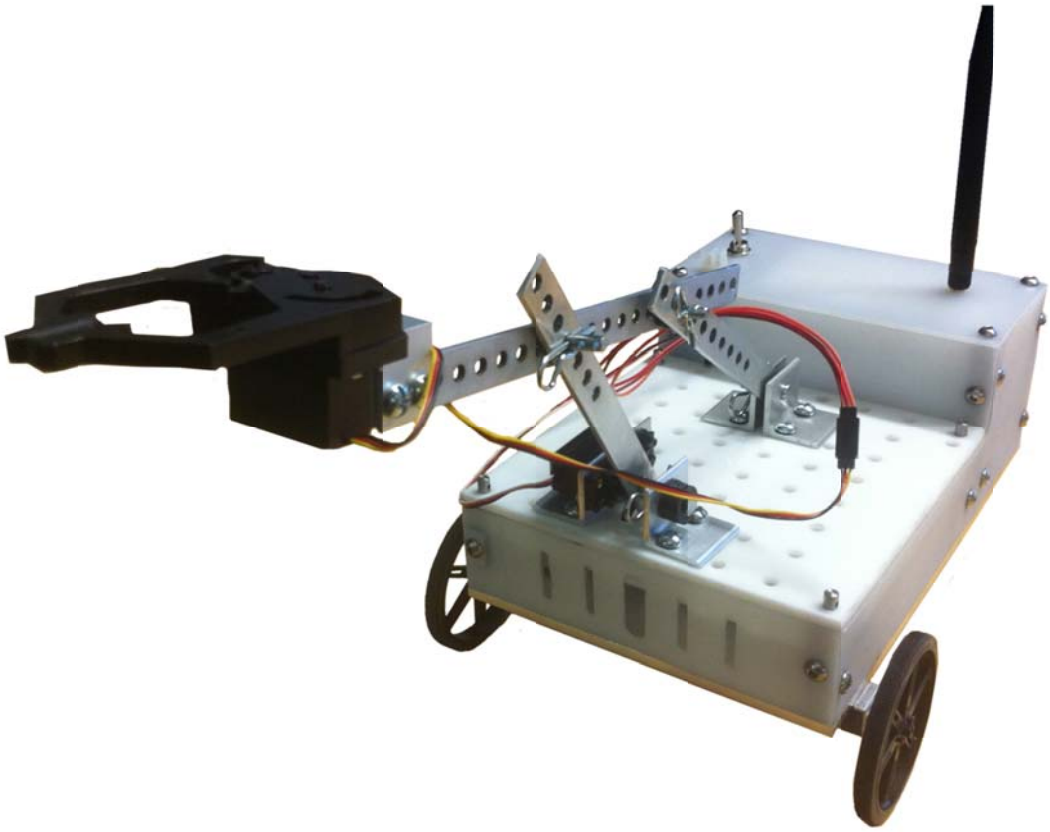
Pass: No custom ordered mechanical parts are required in the construction of the LVE.

Fail: One or more custom ordered mechanical parts are required in the construction of the LVE.

5. Results Summary

Test #	Test	Pass/Fail Criteria	Status	Actual Performance
2.1	Drop Height	Can be dropped from 3 feet and still function as intended	Fail	Motor gears broke upon a 1 ft drop
2.2	Educational	At least 75% approval from faculty survey	Pass	Average faculty approval is 80.43%
2.3	System Weight	Weighs at most 15 lbs	Pass	LVE assembly weighs 9.9 lbs
2.4	LVE Speed	Maximum speed is greater than 0.5 mph	Pass	Average system speed after 3 trials was 0.86 mph
2.5	Turning Radius	Less than 12 inches	Pass	Turning radius is 2.3 in
2.6	Battery Life	At least 90 minutes	Pass	After 90 minutes of continuous operation, 7.2V remained
2.7	Recharge Time	Less than 4 hours	Pass	Battery was fully charged in 70 minutes
2.8	Surface Temperature	Never exceeds 130 deg F	Pass	The highest Temperature (89 deg F) was measured at the drive motors
2.9	Sharp Edges	No edges or corners tear through more than 3 sheets of tissue	Pass	No more than 2 sheets were torn by any corner or edge
3.1	Quantity of LVEs	At least 10 mass produced LVEs	Pass	Mass production budget accounts for 10 LVEs
3.2	Quantity of MSAs	At least 30 mass produced MSAs	Pass	Mass production budget accounts for 30 MSAs
3.3	Mass Production Cost	Less than $5,000 deployment cost	Pass	Final Mass production budget estimates a cost of $4,541.39
3.4	Prototype Cost	Less than $500	Fail	Final cost is $511.69 (over budget due to shipping costs for the replacement motor)
3.5	Chassis Height	Less than 8 inches	Pass	Chassis height measures 7 in
3.6	Chassis Base Area	Less than 144 square inches	Pass	Chassis base area measures 125 square inches
3.7	Time to Construct	Less than 60 man hours	Pass	The LVE took approximately 30 hours to construct
4.1	Student Machined Parts	At least 3 student machined parts	Pass	There are 8 parts that can be made by the students
4.2	Hand Tools Required by Students	No more than 5 hand tools required	Pass	A maximum of 2 hand tools were required
4.3	Material Waste	Less than 1 lb of material waste	Fail	1.7 lbs of waste was produced
4.4	OTS Part Lead Time	Less than 2 weeks for parts to arrive	Fail	All parts arrived within 2 weeks except for the PBCs
4.5	Machined Parts per LVE	No more than 20 custom machined parts per LVE	Pass	The LVE contains 17 custom machined parts
4.6	Custom Order Components	No custom ordered mechanical parts	Pass	No mechanical components were custom ordered

6.1 Appendix 1 – LVE/MSA Assembly



6.2 Appendix 2 – Faculty Survey

- See attachment on the following page

Land Vehicle for Education (LVE): Faculty Survey

More information regarding the LVE can be found at the links below:

P11211: http://edge.rit.edu/content/P11211/public/Home
P11212: http://edge.rit.edu/content/P11212/public/Home
P11213: http://edge.rit.edu/content/P11213/public/Home

Please rate your opinions on the following questions:

	Bad			Good			Comments:
How would you rate the overall appearance of the MSA and LVE.	1	2	3	4	5	N/A	_____ _____
How would you rate the design goal of the MSA.	1	2	3	4	5	N/A	_____ _____
How would you rate the analysis required for MSA design.	1	2	3	4	5	N/A	_____ _____
How would you rate the difficulty in designing the MSA.	1	2	3	4	5	N/A	_____ _____
How would you rate the parts students will be designing and manufacturing.	1	2	3	4	5	N/A	_____ _____

Thank you for your participation!

The LVE Team