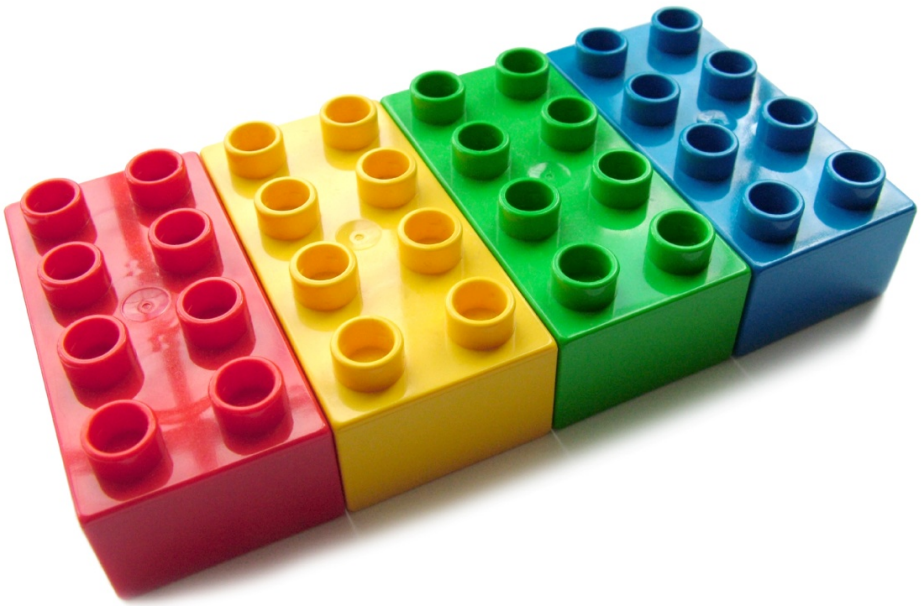


3. Test

The deadline for the Proof of Concept is looming near. The RACE Program must implement and test the design, making any necessary corrections and adjustment. Care must be taken to document test results as the Customer will review them at the next meeting.

Learning Points:

- Materials are costly. Make sure you consider this as you implement your design.
- Use the lessons learned from the previous modules and apply them to your design.
- As you build, there may be design problems that need to be addressed, and when you make changes, it is critical to maintain the design documentation.
- Testing often reveals design flaws.
- Keep in mind that in order to win the down-select your product needs to perform within the time limit, have minimal cost, meet the Customer's requirements and you have to deliver an engaging presentation.
- Document test results as you go, to ensure accuracy in your scientific data collection.

Customer Deliverables:

A Test Specification Document, which includes the requirements, what method will be used to validate each requirement, the description of how each requirement will be validated, and the actual results

- Detailed design of the chosen solution
- Updated Team Organizational Chart
- Role Assignments
- Schedule
- Plan Questions
- Brainstorm Ideas
- Risks
- Prototype
- Re-Design details
- Test Specification Document
- Test Results

Leadership Skills

Critical Thinking

- It is important to think things through thoroughly. Analyze the complete system. Don't sub-optimize by only addressing a piece of the puzzle.
- Resolve the root causes of the problem, not the symptoms.
- Consider the impact of each change to the system as a whole.

Root causes are the driving factors that are the undesirable effects. Symptoms should not be

Critical thinking results in sound decisions and well-developed programs. Leaders must consider the big picture to clearly appreciate how a change can affect the system as a whole.

Critical thinking involves analyzing the complete system. This includes getting to the root causes of the problem and resisting the temptation to apply a "band-aid" fix that temporarily masks the symptoms.

Decision Making/Problem Solving

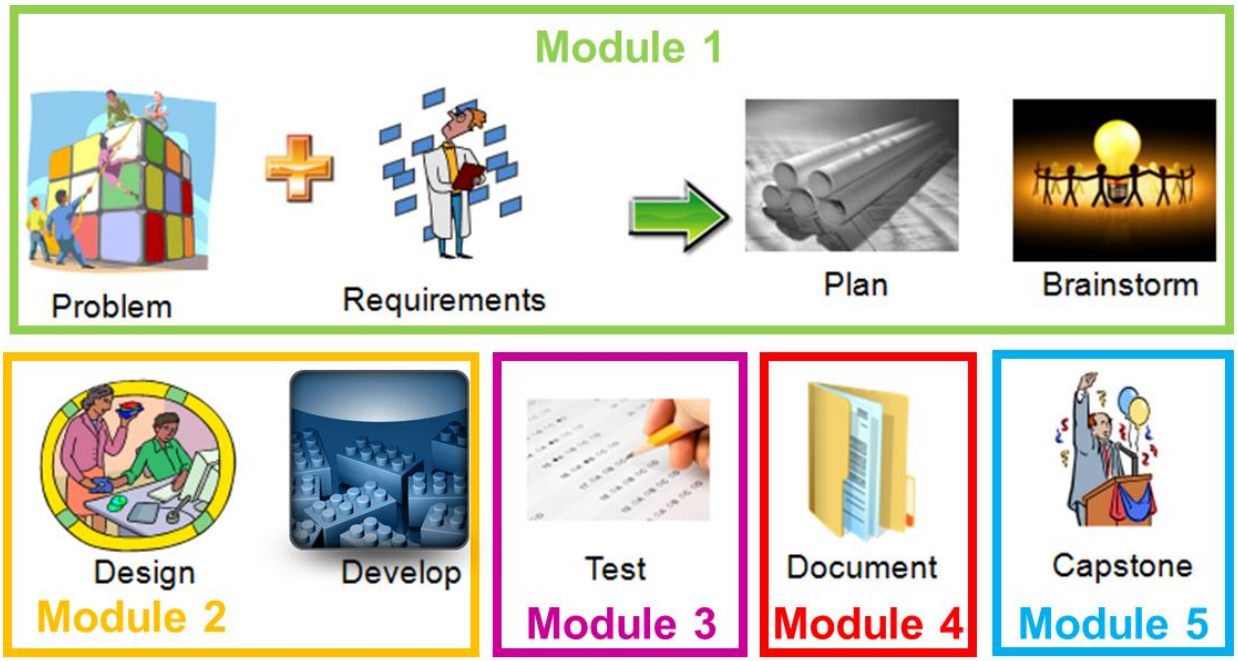
- There will be tradeoffs. Consider cost, schedule, functionality, and quality, etc. How can you make a quality product that will fit the budget and schedule? Use quantitative data to prioritize and drive decisions.

Decision-making requires considering cost, schedule and quality and the tradeoffs among them. Leaders need to understand what the team and the Customer can live with. In other words, leaders and their teams need to define what "good" looks like.

Decision-making and problem-solving skills are needed by a leader. These abilities include looking at the data and making the best decision with the data at hand. While making a decision, it is often acceptable to follow the 80 percent rule. The effort to get to the 80 percent solution can usually be done within a reasonable cost, schedule, and quality. To get to the 90 percent or 100 percent solution often significantly affects cost and schedule with little added value. At some point, the team will reach the point of diminishing returns. There are exceptions, especially when considering safety and human life-critical scenarios. It is important to understand your scope and Customer needs.

Engineering Lifecycle

In Module 3, the focus will be on testing the product. To ensure the product meets the Customer's needs, it must be tested against the requirements. Finally, the program will demonstrate the proof of concept to the Customer who will decide which company will be awarded the contract.



The Challenge

You have been assigned to your third project at Cogitate. The RACE (Rescue And reCon Enabler) team is challenged to build a delivery and rescue vehicle. The vehicle needs to be able to deliver supplies to isolated individuals as well as rescue injured people and carry them back to a safe location. This challenge will focus on the vehicle. Due to hostile environments, the vehicle must be able to withstand high impact forces. In the third phase of the program, the Customer is requesting a test plan and results demonstrating successful trial runs of the prototype.

Crash Test Dummies Activity

Objective

To build a vehicle prototype which transports and protects its passengers as they travel down an inclined ramp, across a level floor, and crash into a wall.

Technical Terms

Momentum is a property of a moving body related to its mass and motion. It equals the product of the body's mass and velocity. It is a property of a moving body that determines the length of time required to bring it to rest when under the action of a constant force or moment.

Energy is a fundamental entity of nature that is transferred between parts of a system in the production of physical change within the system. It is regarded as the capacity for doing work.

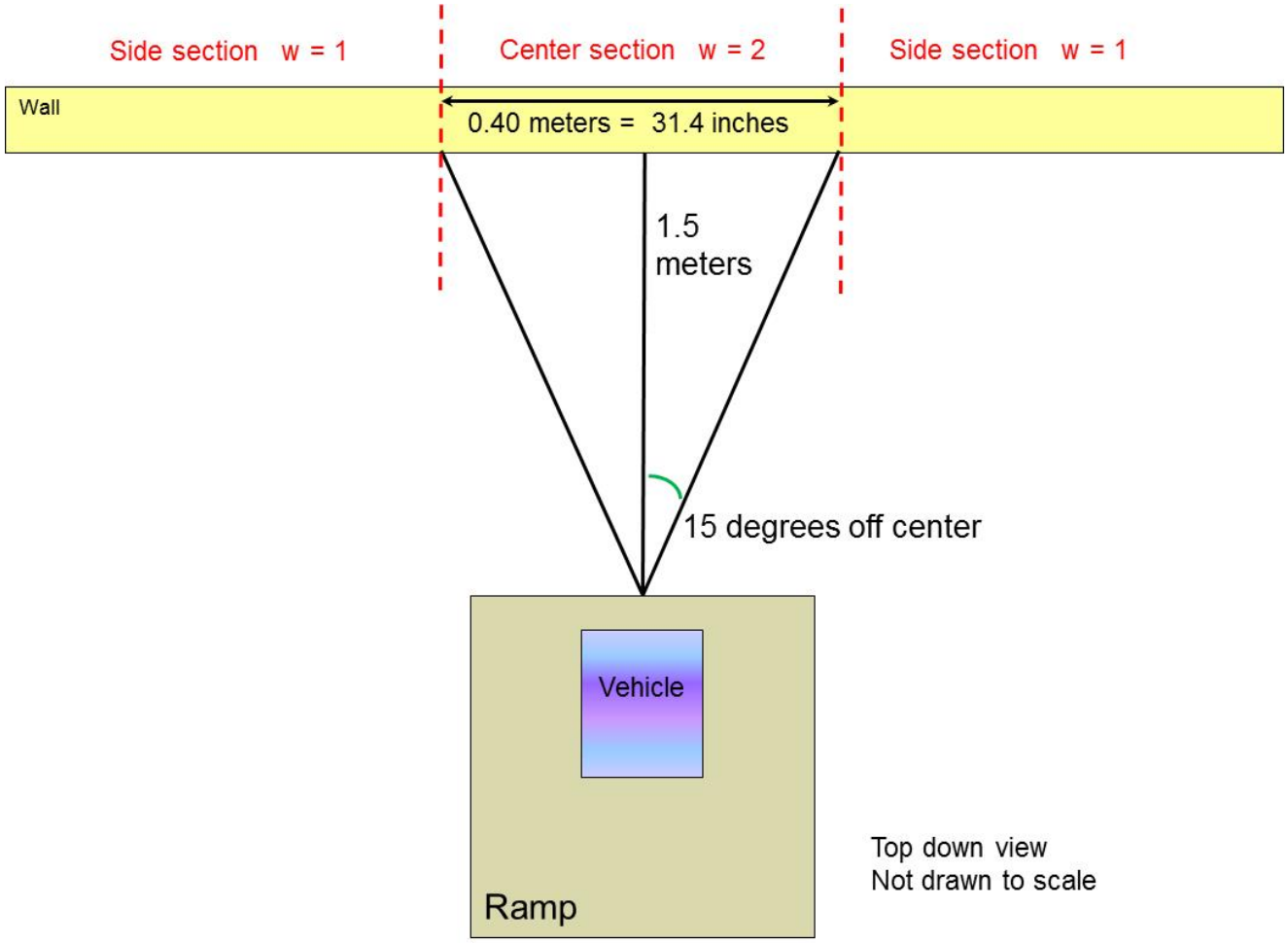
Impulse is the product of force, F, and the time, t, for which it acts. Impulse is a vector quantity since it is the result of integrating force over time. The units of impulse are kg m/s.
$J = F_{ave} (t_2-t_1)$

Requirements

1) Each team must construct one vehicle.
2) The vehicle shall be made from wood and/or paper, except for the wheels, axles, and connecting hardware.
3) Glue, staples, nails, or similar fasteners may be used in the construction for the purposes of holding the parts together.
4) The vehicle, including its passengers, shall be no more than 15 cm in height.
5) The length of the vehicle shall be less than 30 cm.
6) The width of the vehicle shall not exceed the length.
7) The vehicle prototype shall carry two large raw chicken eggs.
8) The top of the eggs shall be visible to the judges at all times during the testing.
9) The eggs shall be held in place by a 40 cm length piece of string provided by the judges which will act as a seatbelt.
10) The seatbelt shall not be directly fastened to the eggs by any means (including glue or tape)
11) The restraint system shall be designed such that when the seatbelt is removed, the passengers will immediately fall out of their seats when the car is inverted (meaning the seatbelt is the primary means of restraint).
12) The cost of the vehicle shall be recorded.

Event

1) The team will have no more than 5 minutes to get their vehicle and passengers ready for the test.
2) The car's length and mass (prior to the addition of the passengers) shall be measured and recorded.
3) The car shall be released from rest at the top of a 265cm x 35cm ramp that is inclined at 30 degrees to the horizontal. Walls that are 6cm in height will be located on each side of the ramp.
4) The car shall travel a distance of 1.5m along a level floor before it hits a solid wall.
5) The wall will be marked into three sections. The center section will have a value of w=2 and the end sections will have a value of w=1. The value depends on which part of the wall the car hits.
6) The speed (v) of the car will be determined on the level section of the floor just before the car strikes the wall.



The wall shall be marked with colored tape to indicate the side and center sections. If any part of the vehicle crosses over into the side sections, it will be counted as w=1. The vehicle should not deviate off the center point more than 15 degrees in either direction.

Scores

1) Score = $\frac{ewv}{m^2l^2}$

e is the egg coefficient (2 if both eggs are intact, 1 if either or both are cracked but not broken, and 0 if either is broken)
w is the wall value
v is the speed
m is the empty car mass
l is the car length (measured bumper to bumper)

The cost will also be reported.

Module 3 Rubric

Due	Due Date	High School – Module 3 Rubric	Pts
Before Mod 3 LASER Class	Jan. 14, 2015	Updated Team Organizational Chart	5
Before Mod 3 LASER Class	Jan. 14, 2015	Role Assignments	5
Before Mod 3 LASER Class	Jan. 14, 2015	Schedule	5
Before Mod 3 LASER Class	Jan. 14, 2015	Plan Questions	5
Before Mod 3 LASER Class	Jan. 14, 2015	Brainstorm Ideas	10
Before Mod 3 LASER Class	Jan. 14, 2015	Risks	10
Before Mod 3 LASER Class	Jan. 14, 2015	Detailed Design	10
Before Mod 3 LASER Class	Jan. 14, 2015	Prototype	20
During Mod 3 LASER class	Jan. 14, 2015	Discussion and Career Questions	10
During Mod 3 LASER class	Jan. 16, 2015	Test Specification Document	20
			100

Test Specification Document

The Test Specification Description is a critical document which defines the process for ensuring the product has been tested to verify the requirements and validate Customer expectations. This means, did we build it right, and did we build the right thing, respectively. Note that the list of requirements include requirements received directly from the Customer as well as requirements which have been derived internally through the design process. There are four different methods which can be used to verify the requirements:

1. **Test**: A formal and repeatable step-by-step procedure, where any two operators familiar with the Unit Under Test (UUT) performing the same test will achieve the same results, e.g., apply a specific voltage to an input pin and verifying the output on another pin.

2. **Demonstration**: A procedure that is also formal, but relies on events outside the control of the test conductor, e.g., using a radar to track a plane.

3. **Inspection**: A case where the pass/fail result can be determined by visually examining the UUT, e.g., determining paint color, looking at code, etc.

4. **Analysis**: A combination of any of the other methods where post-test activity is required to determine pass/fail conditions, e.g., doing mathematical computations on a set of recorded results.

It is important to maintain the Test Specification Description throughout the life of the project and product. Changes can be made to the design (and sometimes even the requirements!) late in the development cycle, and the product will need to be re-tested after each change.

Instructions: Using the Test Specification Document Enabler, fill in the template with the Requirement number, Requirement tested, a test description, and the method of test. During testing, the Results can be filled in.

TEST SPECIFICATION

Requirement Number	Requirement Tested	Test Description	Method of Test	Results
1	Each team must construct one vehicle	Visual verification of existance	Inspection	
2	The vehicle shall be made from wood and/or paper, with the exception of the wheels, axles, and connecting hardware			
3	Glue, staples, nails, or similar fasteners may be used in the construction for the purposes of holding the parts together.			

The Test Specification Document enabler is included in the Curriculum Enablers that will be provided by your teacher.

Discussion

1. What design flaws were revealed during implementation and test? How did you address them?

2. Discuss technical reasons that your team chose the design.

3. Once testing was complete, did the verification methods in the Test Description Document change or remain the same as the team's original assessment? If they changed, why?

4. How did the original assigned roles on the team evolve while working on this activity?

5. What lessons learned from previous modules were applied on this module?

Outbrief Instructions

In the outbrief, each team will have the opportunity to discuss their answer to one of the discussion questions. Remember what you learned in the pre-work about presentations.

As time allows, feedback will be provided on the outbrief.

Real Life Applications

Skills

Communication, teaming, innovation, critical thinking, decision-making, problem solving, design of experiments, and prototyping

Applications

Manager, Systems Engineer, Safety Engineer, Risk Manager, Mathematician, Physicist, Mechanical Engineer, Roller Coaster Designer, Imagineer, Astronauts, Race Car Drivers

Career–Summary Questions

1. I found that I have the following skills that helped me complete Module 3.

2. I discovered I have a gap in the following areas that can be a focus for future development.

3. List the aspects of Module 3 you enjoyed the most.

4. With the answer to Question 3 in mind, describe the types of career in which you might excel. **(Note, you are not limited to those listed above.)**

1.

References

1. Reprinted with permission from IEEE at http://tryengineering.org/ (The Sloan Career Cornerstone Center has provided engineering and engineering technology degree profiles to TryEngineering.)
2. Photos http://www.nasa.gov/home/index.html
3. Discussions Wikipedia
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