the

Engineering Design Process

in the

Production

of the

Perseverance Rover

A description of the engineering design process and a comparison of how NASA engineers and VEX VRC robotics teams approach its application; an explanation of how robotics is preparing students for life as a NASA engineer; a list of resources available to students of robotics interested in more research.

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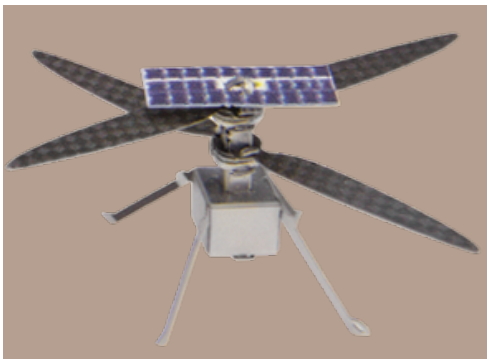
Introduction

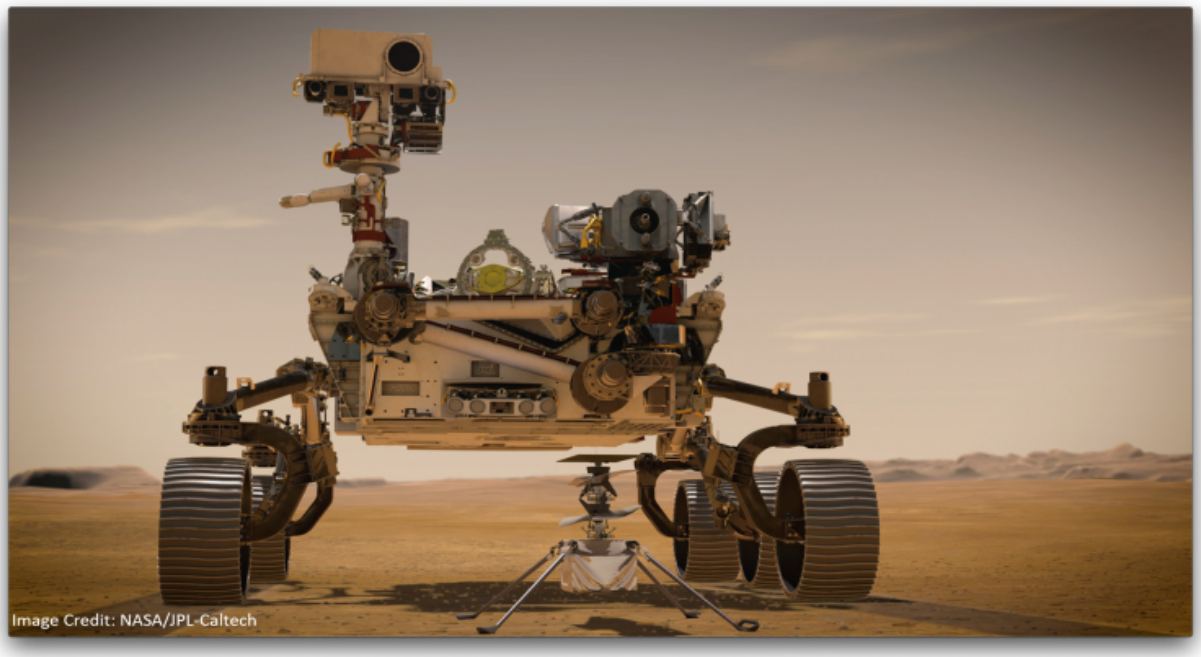
Since the launch of the Perseverance Rover Mission, I have been fascinated by the robotic and programming complexity of the Mars Perseverance Rover, nicknamed "Percy." This mission demonstrates the ideal connection between various engineering and computer science fields. Though the rovers are complex, sophisticated marvels of engineering, they have similar systems to the robots that VEX VRC students use daily. However, scientists use a more refined design process than VEX VRC students.

An engineering design process is a multi-step technique that is used to solve a problem and design a "build." "…it is a methodical approach to problem solving" (VEX Robotics). Engineering design processes can vary, depending on the objective of the project. "There is no single universally accepted design process… The process generally starts with a problem and ends with a solution, but the middle steps can vary" (VEX Robotics).

Basic VEX Robotics Design Process

1. UNDERSTAND – Define the problem.
2. EXPLORE – Do background research.
3. DEFINE – Determine solution specifications.
4. IDEATE – Generate concept solutions.
5. PROTOTYPE – Learn how the concepts work.
6. CHOOSE – Determine a final concept.
7. REFINE – Do detailed design.
8. PRESENT – Get feedback and approval.
9. IMPLEMENT – Implement the detailed solution.
10. TEST – Does the solution work?
11. ITERATE – Repeat. Improve.





A Comparison of Nasa and VEX Engineering Design Processes

The Mars missions have shown that science and robotics can play a key role in scientific discovery. Every mission starts at the drawing board and achieves success by following a specific process. Much like VEX, NASA has its own Engineering Design Process.

National Aeronautics & Space Administration
https://www.nasa.gov/sites/default/files/atoms/files/engineering_design_process_classroom_connections_508.pdf

Ask:

The first step is *identifying the problem*, or as NASA puts it, *ask*. Both VEX and NASA's design processes take this vital first step, without which engineers would be confused while trying to design and brainstorm. Without good knowledge of the problem, solutions cannot be identified.

Imagine:

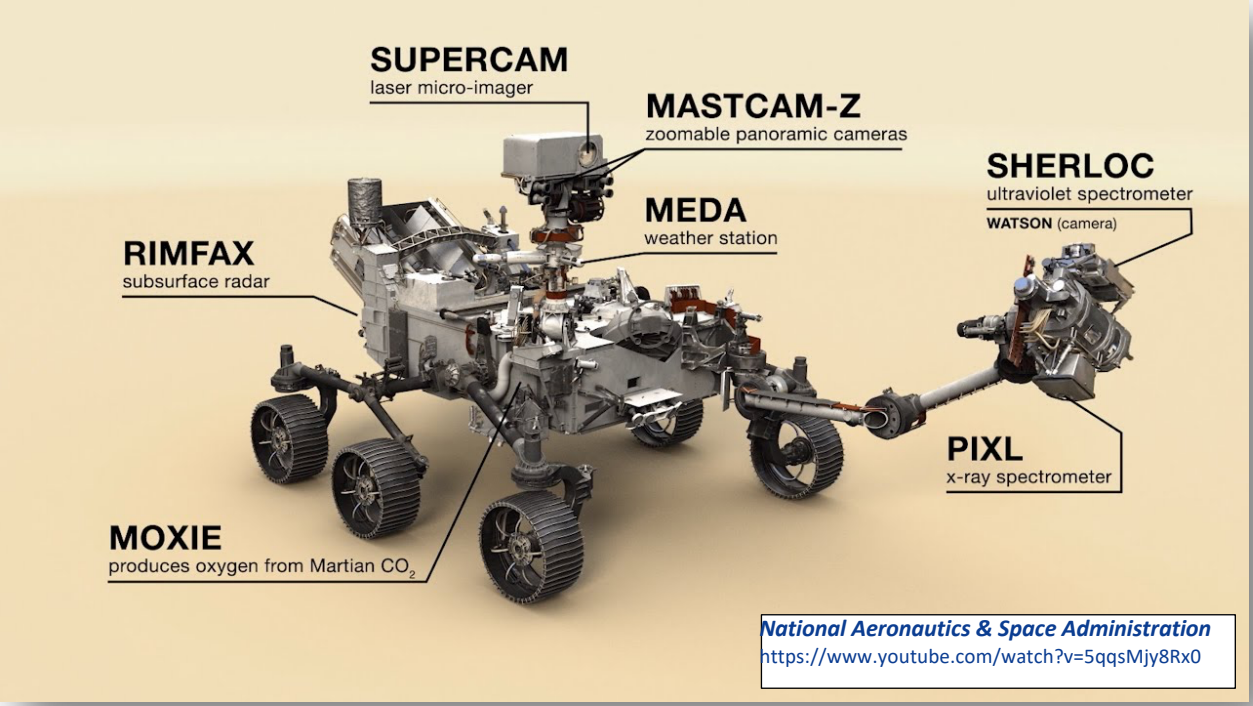
After becoming familiar with the problem, engineers must *brainstorm* or *imagine*. Building upon the first step, brainstorming involves generating as many solutions as possible. As experience with the project develops, the *problem* becomes more understandable and possible *solutions* are uncovered.

Both VEX and NASA engineers are encouraged to document *progress* and possible *roadblocks*. This helps in many different areas, such as having detailed descriptions of past ideas that may work when a previous prototype performs poorly.

Documenting struggles and problems is also an essential discipline for engineers. Being able to identify problems and know what went wrong is a hard-to-develop, but invaluable skill. Documentation helps engineers avoid repeating the same mistake. If the same mistake is repeated, having prior knowledge and documentation of the problem can shorten the time to implement a solution.

Plan:

Choosing and *planning* is the next step. Once brainstorming is complete, the team of engineers chooses a solid idea. Planning is required because before the build begins, it is always a better option to sketch a drawing and design the idea. The drawings include very detailed instructions about the parts used, occasionally including a scale. This is especially useful for aerospace engineers because most of the things being drawn are too large in real life.



Create:

This next step for both design processes is *building* or *creating*. For VEX VRC students this includes building a prototype and programming it. Since NASA's designs are so much bigger, it is normally better to make a smaller model of the design. For the Mars Rovers, it is possible to make a prototype because they are much smaller than rockets and planes.

Test:

Testing is the critical next step for NASA and robotics students. Without the testing phase, robotics students cannot know if the robot or subsystem functions as planned. Without testing, important design flaws can go undiscovered. NASA uses a similar step, and then they *evaluate* afterwards. This means that they use a rigorous decision matrix to assess the results of the tests.

Improve:

If the tests do not demonstrate what NASA wants, they continue to the *improvement* phase. In this step NASA engineers improve and, if needed, *redesign*. Even if tests produce the desired results, NASA will still move to the *improvement* step. THIS STEP IS NEVER SKIPPED. Even if everything *seems* perfect, there will always be potential opportunities for improvement!

Share:

The next step in NASA's engineering design processes is *share*. At this point, the build should be complete and able to function correctly. This step is focused on sharing the next rocket or rover with the world, a step which includes *using the build*. When the rocket shoots into space, NASA is sharing their accomplishment with the world and inviting everyone to experience their vision for the build.

VEX has a similar last stage called *Repeat the Design Process*. For a company like NASA and a program like VEX, problems never stop. This may seem bad at first, but these challenges are what make robotics fun. Knowing that there will be another challenge waiting for me is what gets my blood pumping. Without constant problems - or should we call them *opportunities*? - there would be no solutions.

How Has This Influenced Me?

Teamwork:

NASA does not build rovers independently. They develop strategic scientific and business partnerships and work as a team in every step of the design process. So it is with VEX robotics students. I have learned that I cannot grow as an engineer independently!

Imagination:

For NASA, the sky is NOT the limit! The opportunities are as vast and limitless as space itself. Similarly, VEX has expanded my understanding of the world, allowing me to imagine and create and brainstorm without limits.

Discipline:

VEX has challenged me to hone my understanding of engineering principles and to work within a clear framework for development. I've learned to focus my energies through rigorous testing, careful observation, thorough documentation, and repeated effort.

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