



NASA Robots: Robosimian and the Curiosity Rover

Matt Gildner

Robotics Engineer

Curiosity Lead Rover Planner / Driver

Jet Propulsion Laboratory, California Institute of Technology



NASA/JPL-Caltech/MSSS



Jet Propulsion Laboratory
California Institute of Technology

Introduction

Hi, I'm Matt



I started working with robotics in high school, where I competed in a underwater robot competition called MATE ROV.

**I continued having fun with robots in college
at the
Massachusetts Institute of Technology,
where I studied
Mechanical and Ocean Engineering**



Now I work at the
NASA Jet Propulsion Laboratory
(JPL)

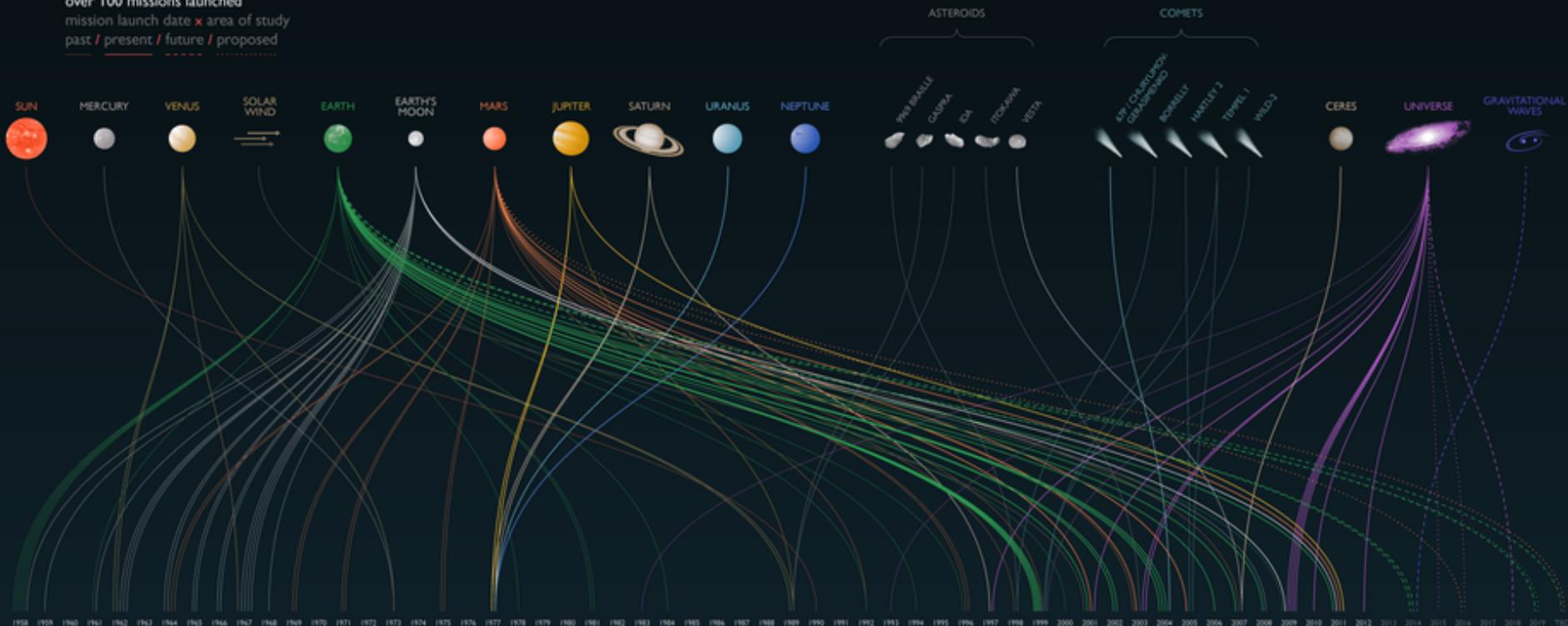
Pasadena, California

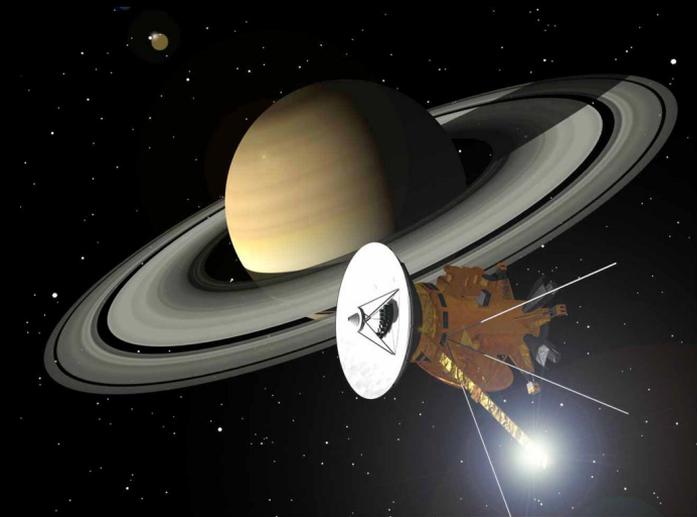
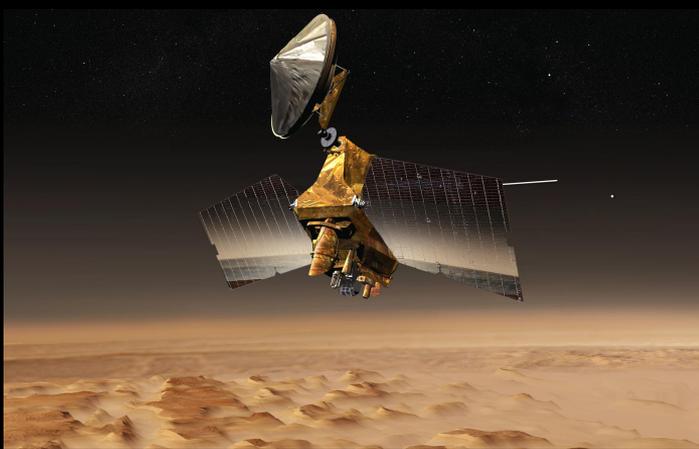


**At JPL it is our mission is to:
Design, Build, and Operate
Robotic Spacecraft
to Explore Earth and the Solar
System.**

JPL MISSION HISTORY

over 100 missions launched
mission launch date x area of study
past / present / future / proposed





**Today I'm going to talk about two very
special robots:
Robosimian
and the
Curiosity Rover**



NASA/JPL-Caltech/MSSS

How do you build a robot?

-

How do you operate a robot?

How do you build a robot?

The first step of building a robot is deciding what the robot will do and where it will operate.

At NASA we call that setting Requirements.

How do you build a robot?

Requirements are the instruction manual for building the robot.

- Where it will operate (Mars Surface, Asteroid, Moon)
- How long it will operate (5 days or 5 years)
- What temperatures it must handle (-100deg or 400deg)
- How heavy it can be (200lbs or 2000lbs)
- How steep of a hill it must climb (flat or steep)
- What instruments it must carry. (cameras or lasers)

How do you build a robot?

Why is Setting Requirements Important?

How do you build a robot?

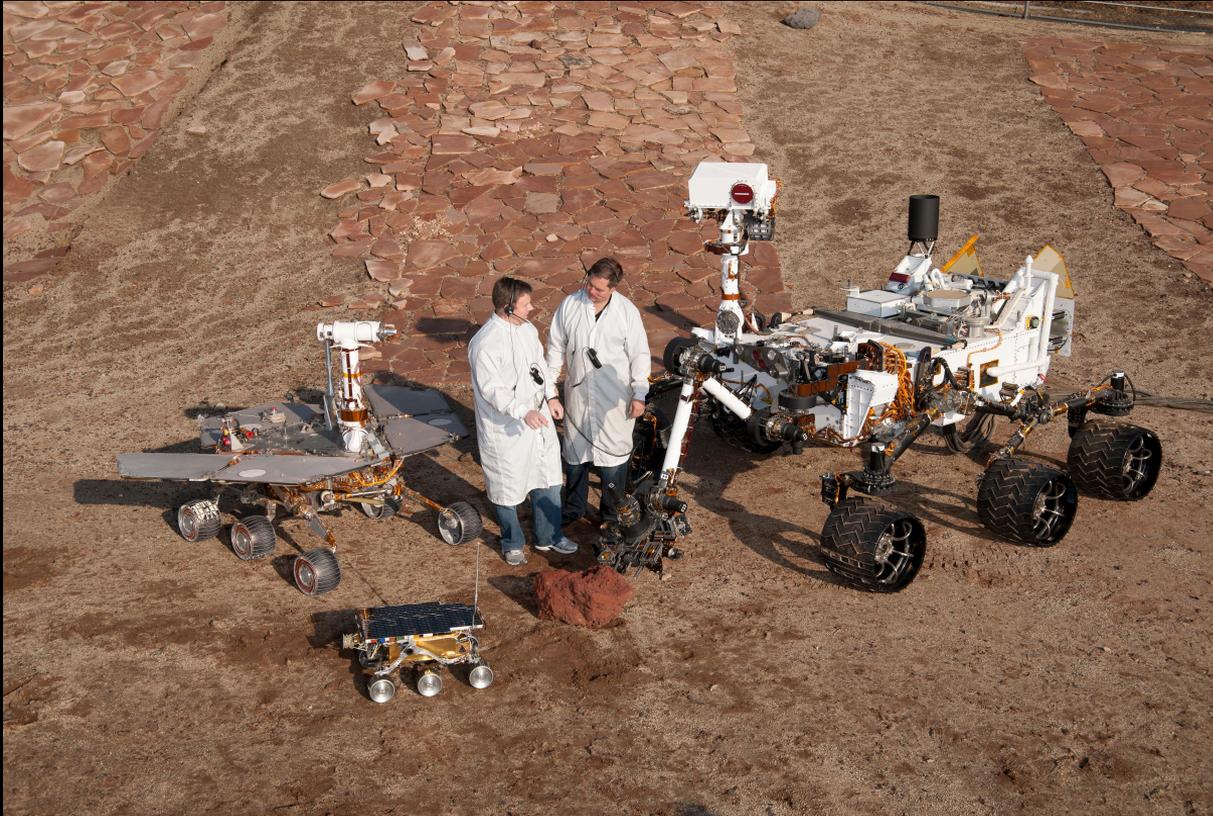
Why is Setting Requirements Important?

It's because sending robots to space is very hard and every tiny detail matters.

It helps the robot designers decide if they need to design a robot that is more like a **Mini-Van or **Sports Car** or **Submarine**.**

How do you build a robot?

Requirements: What's different about these robots?



How do you build a robot?

Requirements: What's different about these robots?



How do you build a robot?

Robosimian's Requirements: Based around a disaster scenario.

- Carry its own power
- Communicate to an operator wirelessly
- Move through obstacles
- Drive a ATV / Golf Cart
- Open a Door
- Cut a hole in a wall
- Turn a valve
- Climb stairs



How do you build a robot?

Curiosity's Requirements: Learn about how habitable Mars was

- Land by a jetpack crane
- Operate for 23 months
- Carry science instruments to analysis rocks and soil
- Drill 2 inches into the ground
- Survive in space on the way to Mars
- Survive -100 to 0 deg F on the surface of Mars
- Climb steep slopes
- Send back lots of images to Earth



How do you build a robot?

Most robots do not stay in one place.
When a robot needs to get around, it
uses its Mobility System.

How do you build a robot?

A Mobility System is all the parts of a robot that allow it move through its environment.

How do you build a robot?

Robosimian's Mobility System

Robosimian is very unique in that it can:

- Walk on 4 legs
- Drive on butt wheels
- Drive on 4 legs



How do you build a robot?

We designed its mobility system so it can travel over a wide range of obstacles using its limbs. Those limbs can then be used to grasp and manipulate objects as well. By serving double duty with its limbs, we were able to make Robosimian lighter than other robots.

How do you build a robot?

Robosimian's Mobility System: Walking

Remaining 2 (non-dominant) stance legs use look-up table solutions to set required local (x,y,z) wrt body.



How do you build a robot?

Robosimian's Mobility System: Driving on its Butt wheels



How do you build a robot?

Robosimian's Mobility System: Driving on its legs.

RoboSimian Matanuska Glacier Field Trial Highlights
June 5-13, 2019



How do you build a robot?

Curiosity's Mobility System:

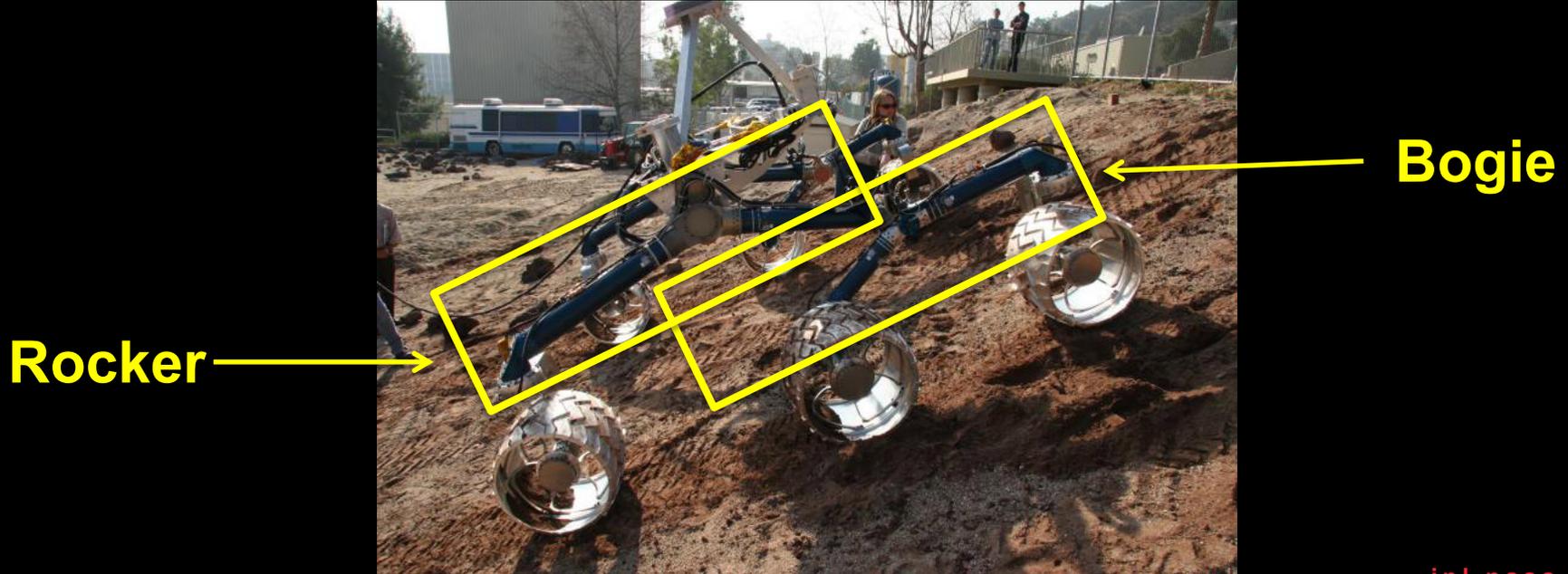
6x Wheeled Rover with a Rocker Bogie Suspension System



How do you build a robot?

Curiosity's Mobility System:

6x Wheeled Rover with a Rocker Bogie Suspension System



How do you build a robot?

Curiosity's Mobility System: Curiosity has 6x aluminum wheels that can handle going over sand, sharp rocks and the cold environment on Mars, unlike rubber wheels. Its suspension system keeps it very stable while operating its robotic arm.



How do you build a robot?



How do you build a robot?



How do you build a robot?

Most robots need the ability to see their environment, so that we can tell them where to go. That is done with a robot's

Perception System

How do you build a robot?

A Perception System is all the components used by a robot to see it's surroundings. Typically that includes:

- **Cameras**
- **Lights**
- **RADAR**
- **Laser Distance Sensors**
- **Proximity Sensors**

How do you build a robot?

Robots often need to see in 3D to avoid obstacles and better understand their environments. At JPL we use what are called “**Stereo Cameras**” to see in 3D. **Stereo Cameras** work just like pairs of human eyes.

Just like humans driving in cars, Robots do not like “blind spots”. So we often design our robots to have many cameras and/or cameras that can be moved around.

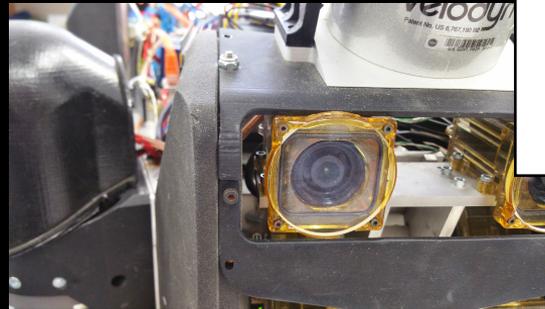
How do you build a robot?

Robosimian's Perception System

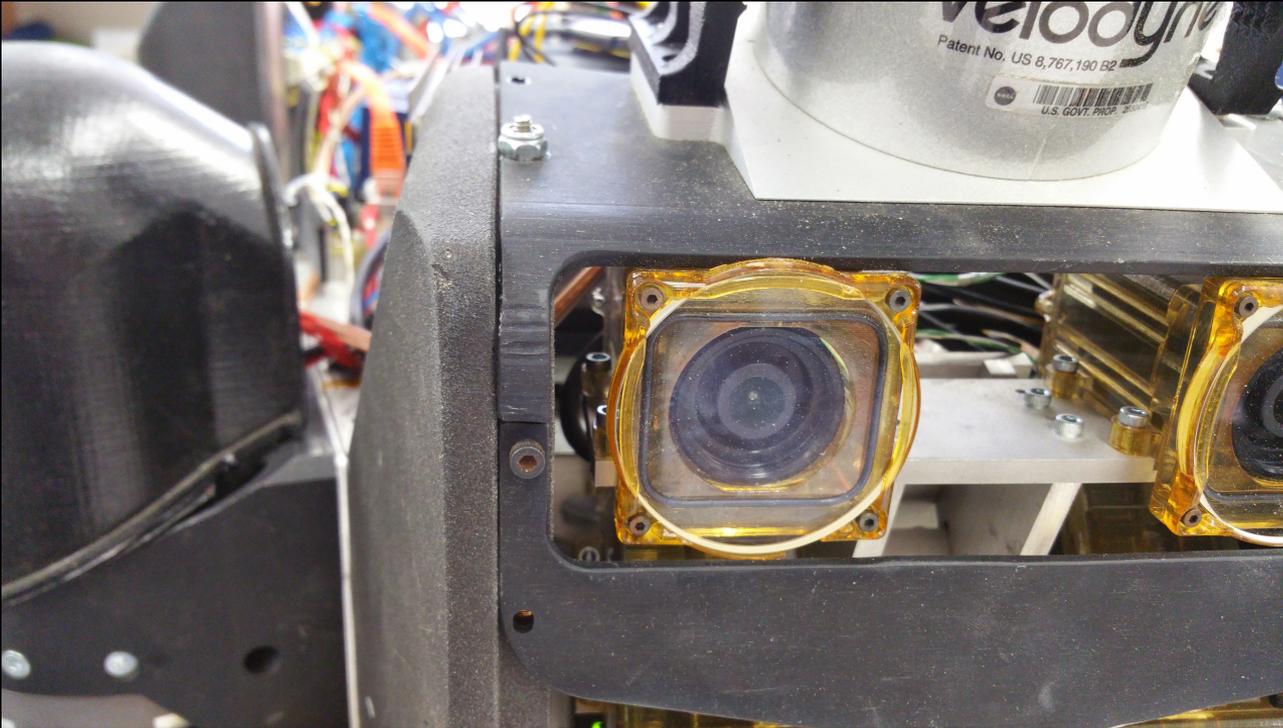
Robosimian has 7 pairs of “Stereo Cameras”. It also uses a spinning laser.

It's cameras are used to:

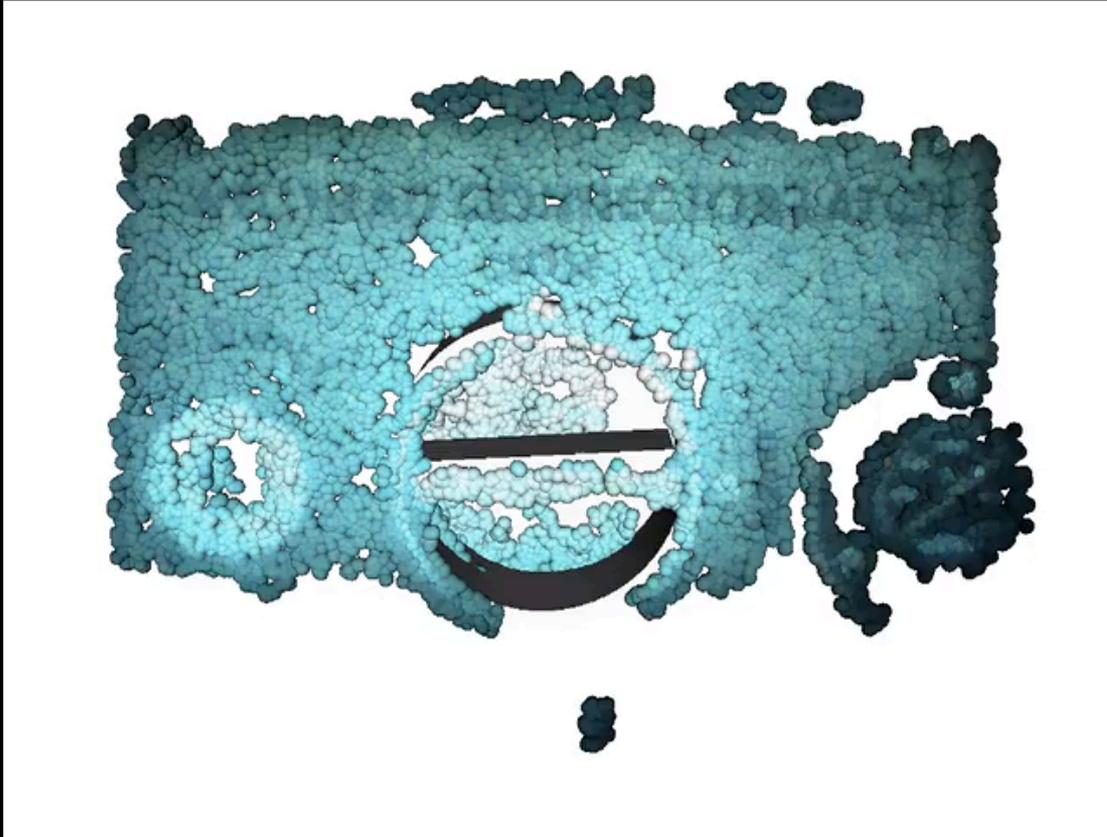
- Track its motion
- Detect obstacles
- Find targets



How do you build a robot?



How do you build a robot?



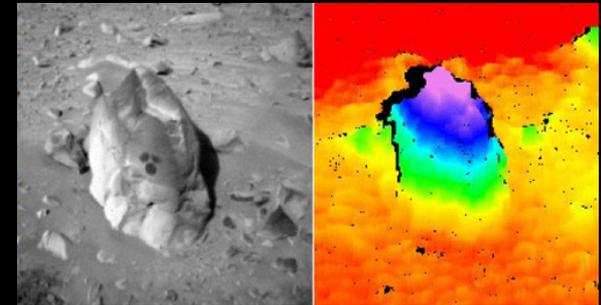
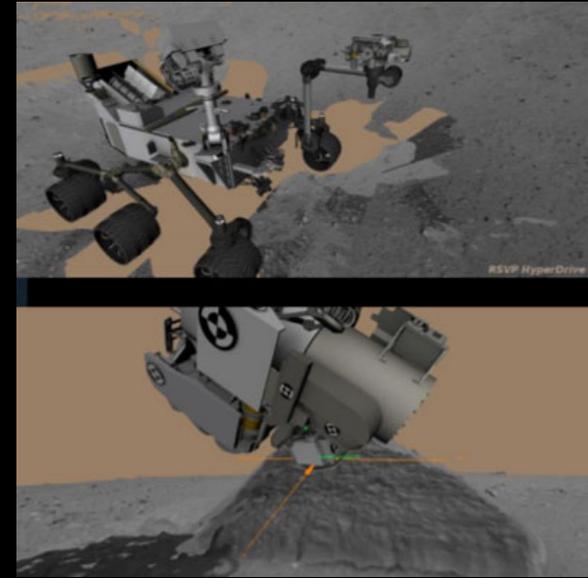
How do you build a robot?

Curiosity's Perception System

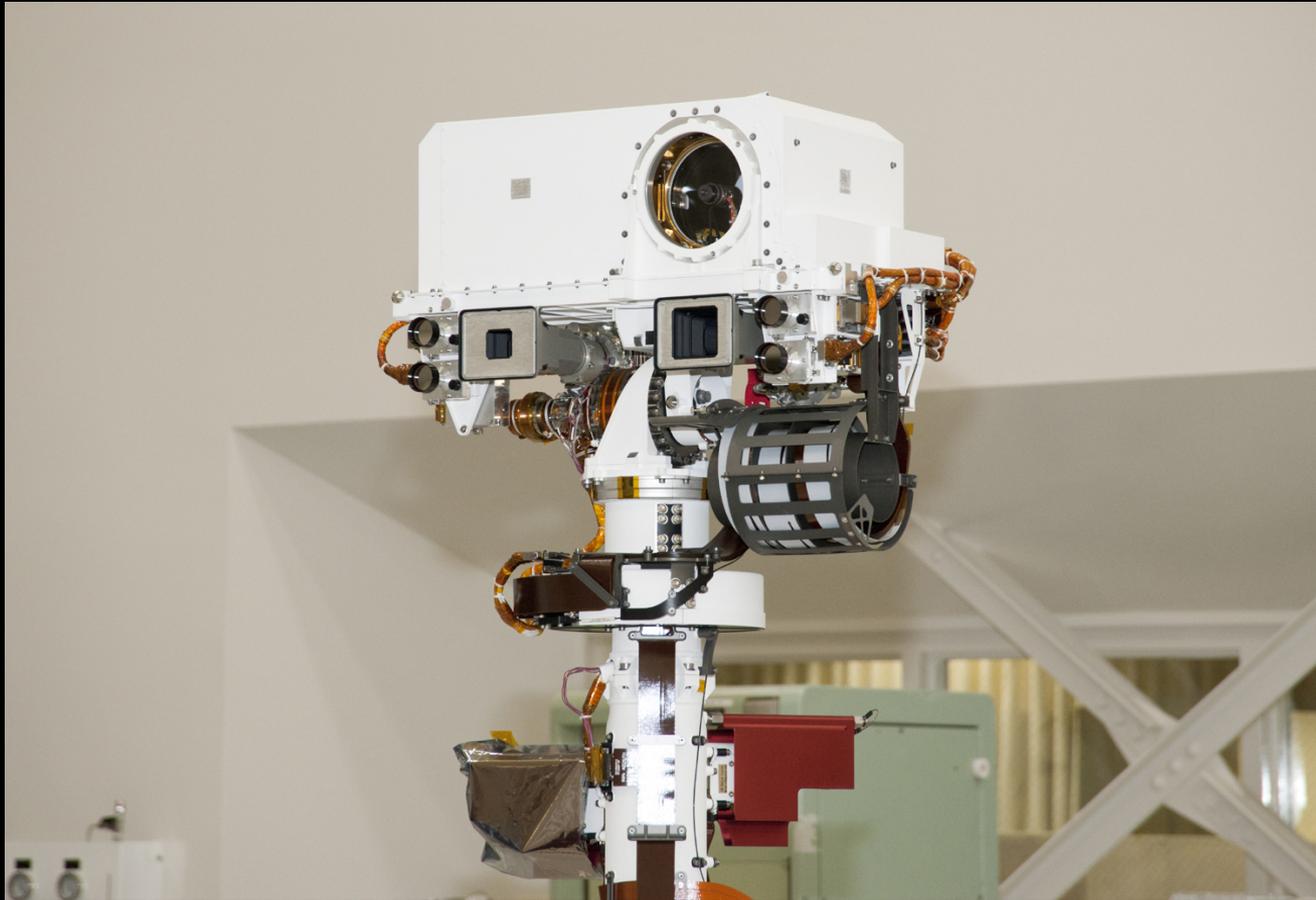
Curiosity has 6 pairs of “Stereo Cameras”. It also has 4 science cameras (one of which it uses to take Selfies)

It's cameras are used to:

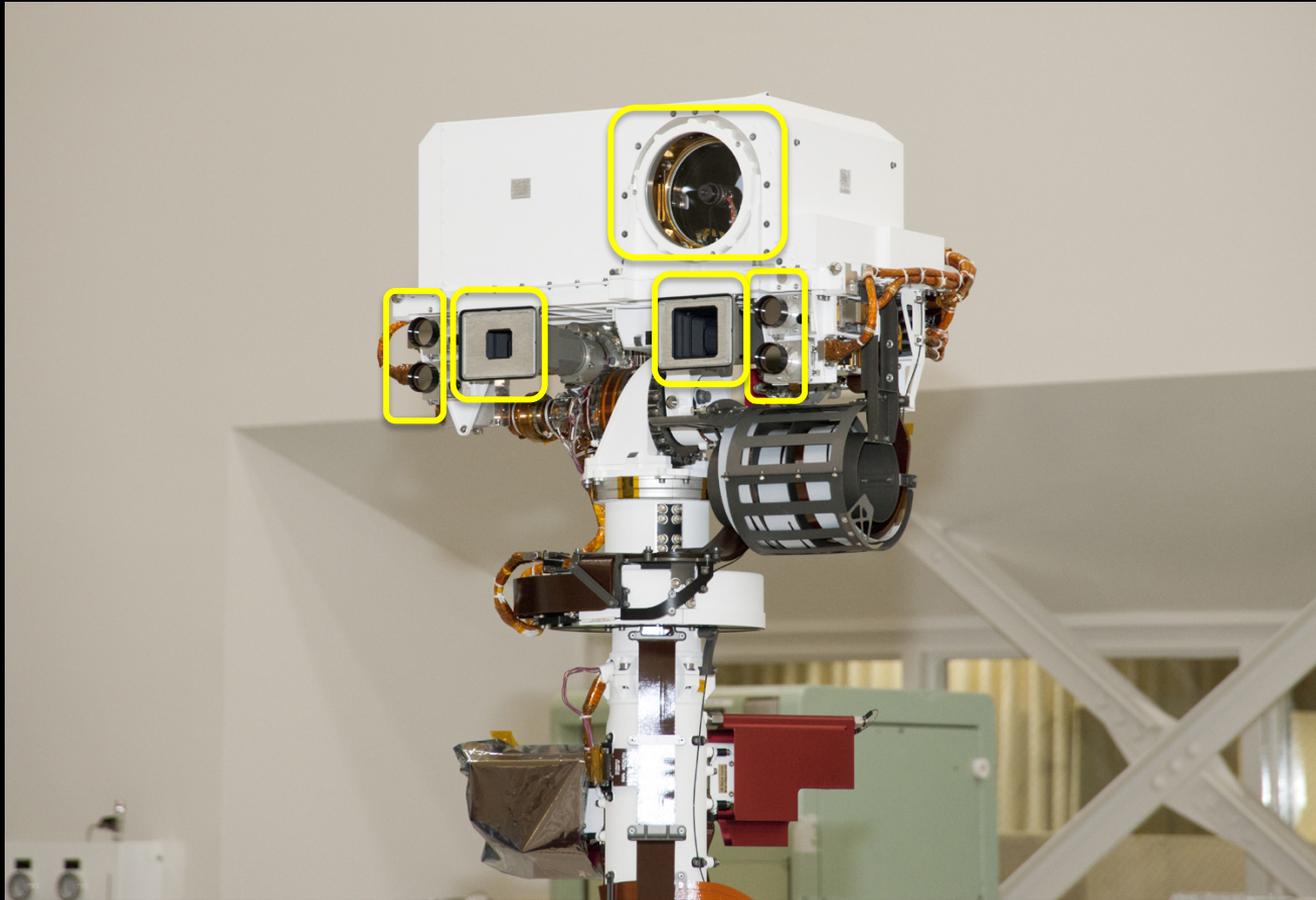
- Track its motion
- Detect obstacles
- Find targets



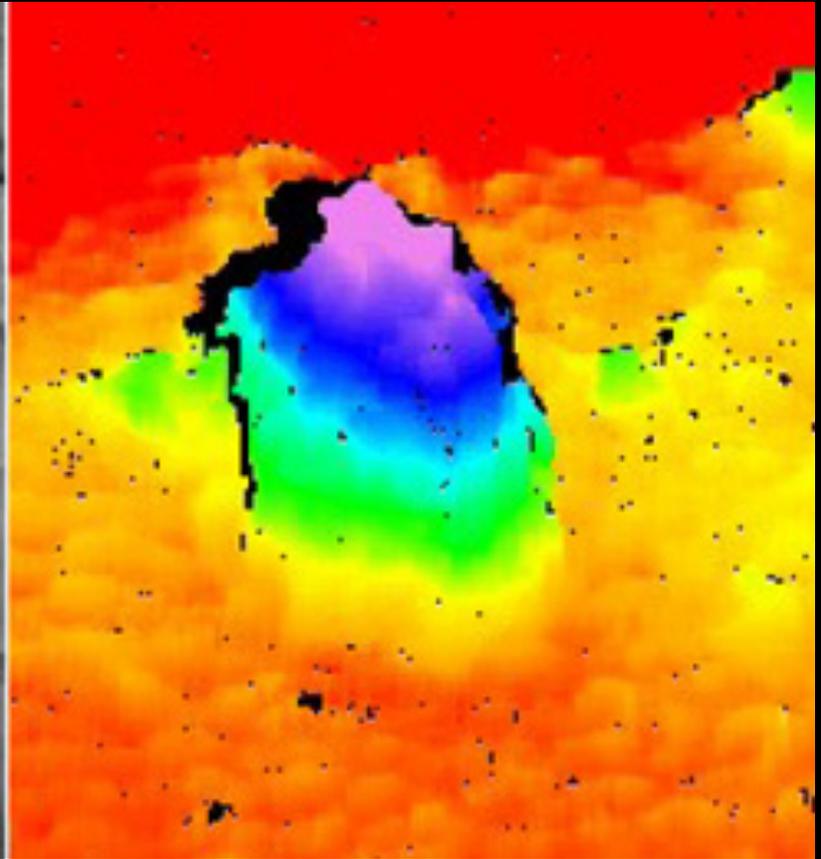
How do you build a robot?



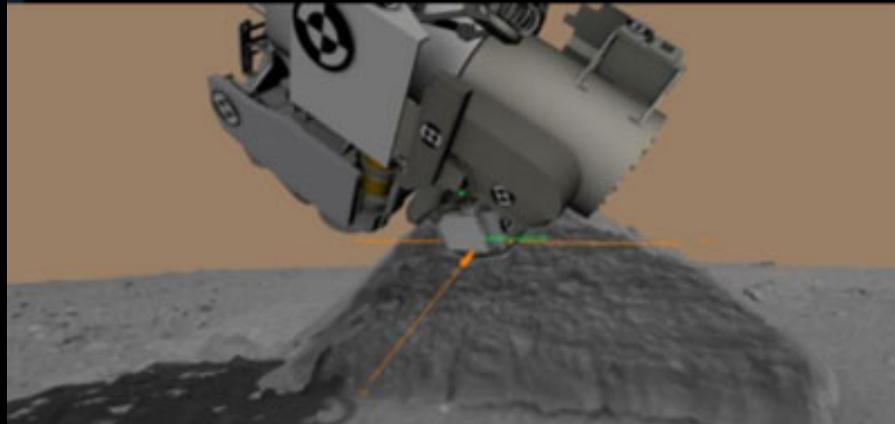
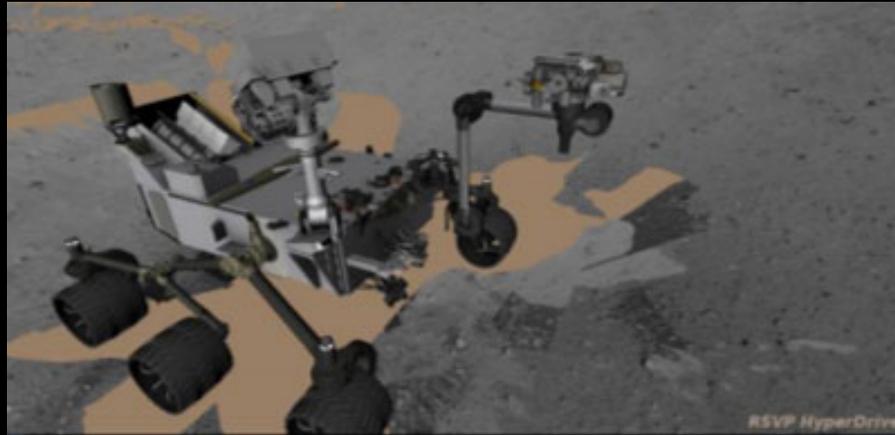
How do you build a robot?



How do you build a robot?



How do you build a robot?



OnSight

Virtual Visit to Mars



Jet Propulsion Laboratory
California Institute of Technology

How do you build a robot?

Robots that reach-out to touch their environment need a Manipulation System.

How do you build a robot?

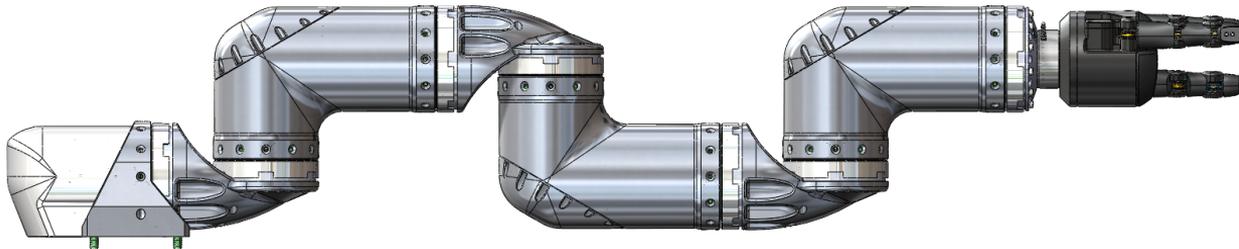
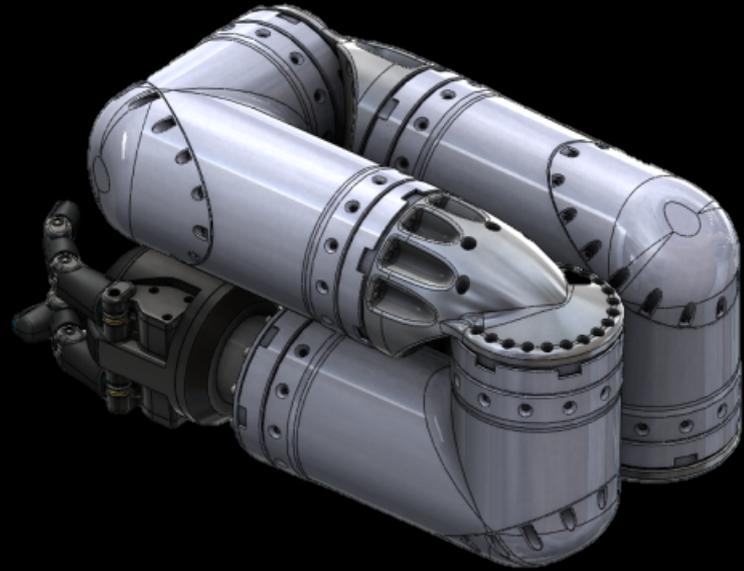
A Manipulation System consists of a robotic arm and end effectors or tools.

These tools include cameras, grippers, drills and cleaning brushes.

How do you build a robot?

Robosimian's Manipulation System

Robosimian is unique in that its manipulation system has 4x robotic arms. Each arm has 7 motors in it, which makes it very dexterous. The arm can be equipped with a gripper or wheels.



How do you build a robot?

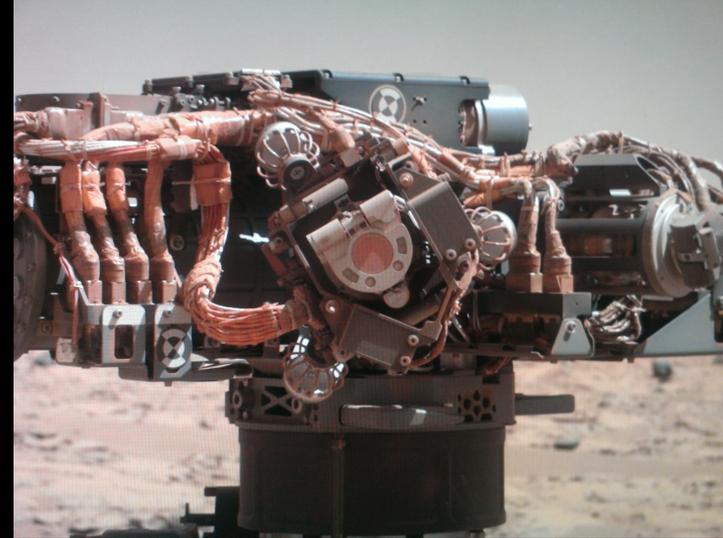
Robosimian's Manipulation System



How do you build a robot?

Curiosity's Manipulation System

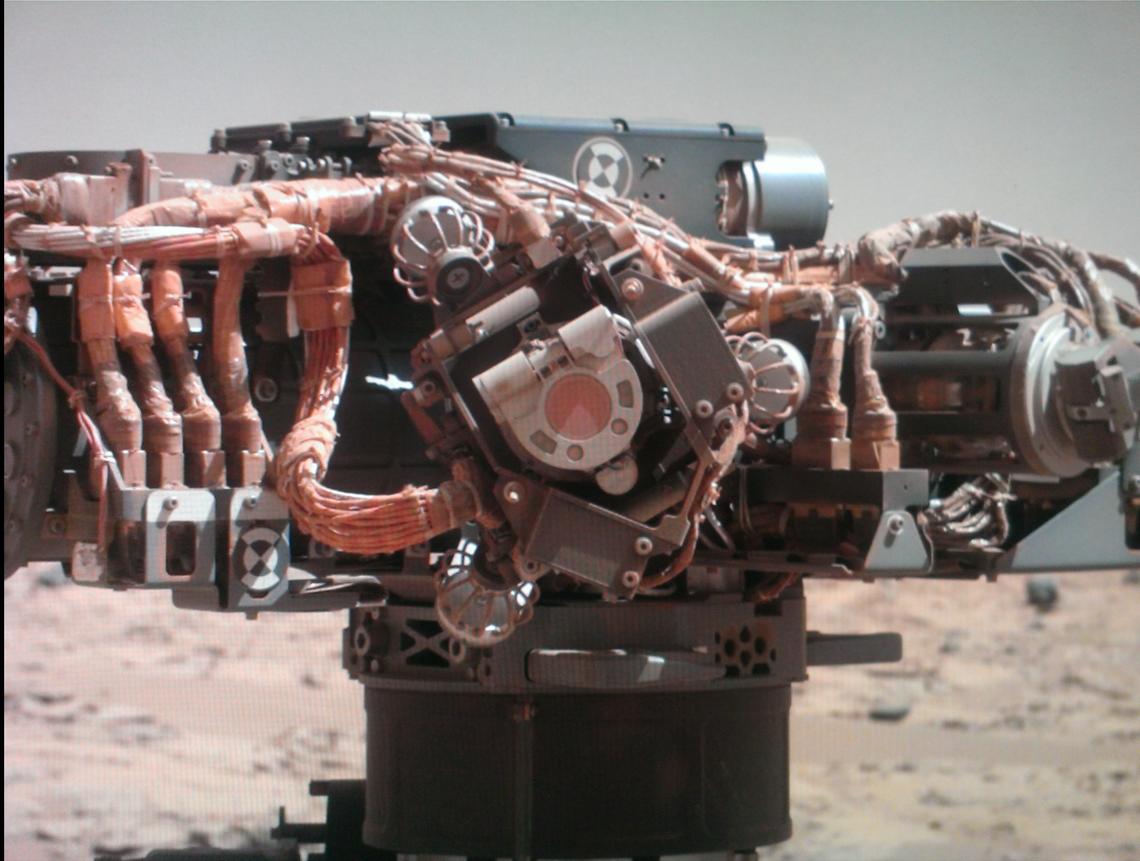
Curiosity is equipped with one robotic arm made up of 5 motors. At the end of the arm is a Turret containing 5 tools. The primary tool is a drill.



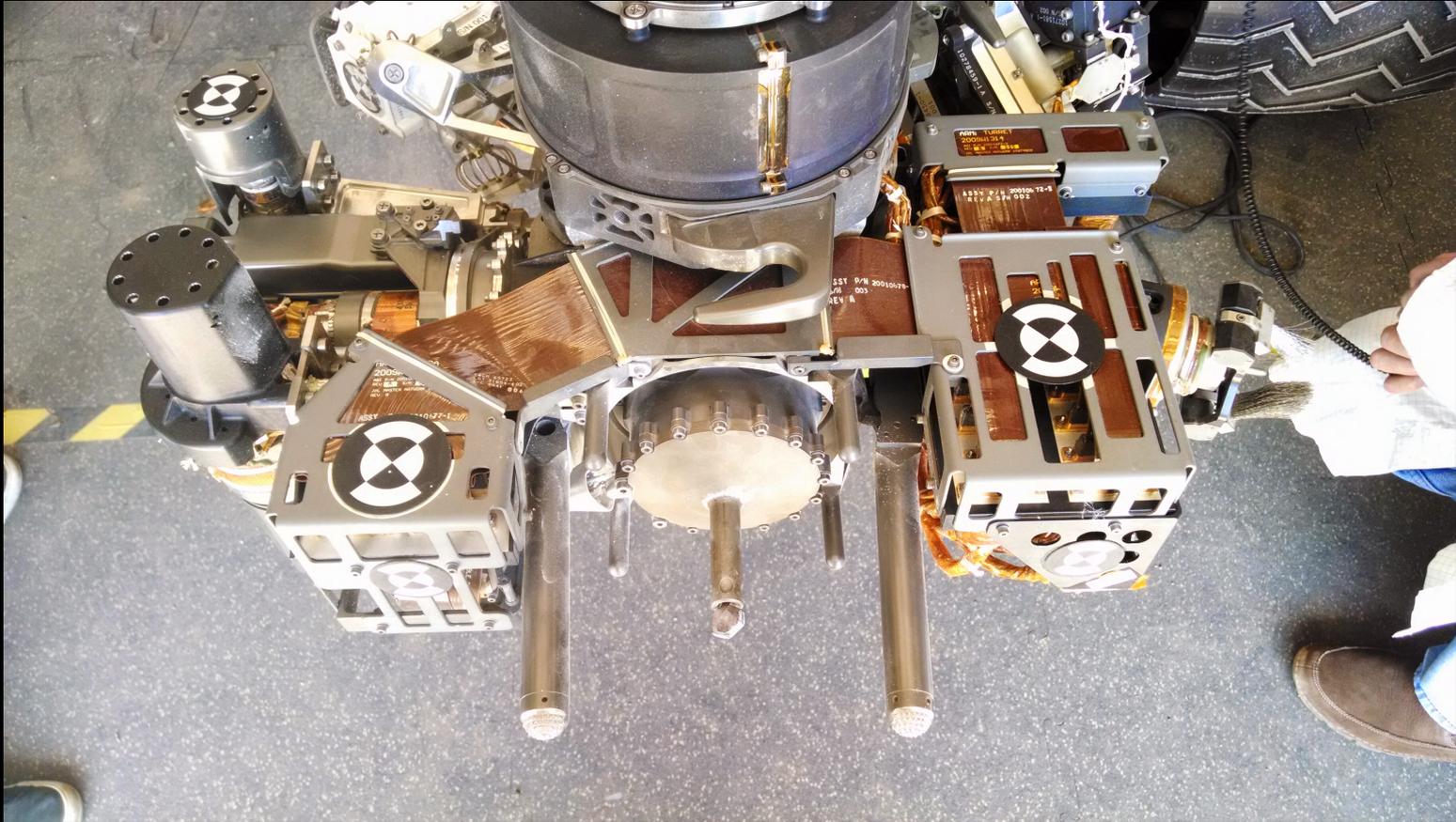
How do you build a robot?



How do you build a robot?



How do you build a robot?



How do you build a robot?

Curiosity's Manipulation System

Animation of
**Curiosity Rover's
Arm Movements**
for Taking a
Self-Portrait



How do you build a robot?

Curiosity's Manipulation System



How do you operate a robot?

**At JPL we operate robot's in space
that are millions of miles away.**

**I'm going to talk about how we do that
for the Curiosity Mars Rover.**

How do you operate a robot?

We send commands to Curiosity at the speed of light = 180,000 miles/ second. That's FAST. However, because Mars is so far away it still take 12min on average to send a message to Mars.

How do you operate a robot?

Sending data back and forth every 12mins would not be efficient, so instead we send a list of instructions to Curiosity every day and then wait to get data back.

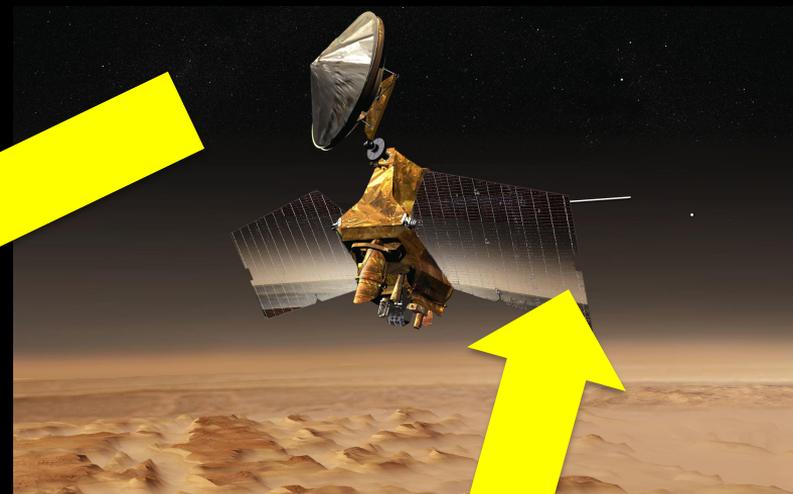
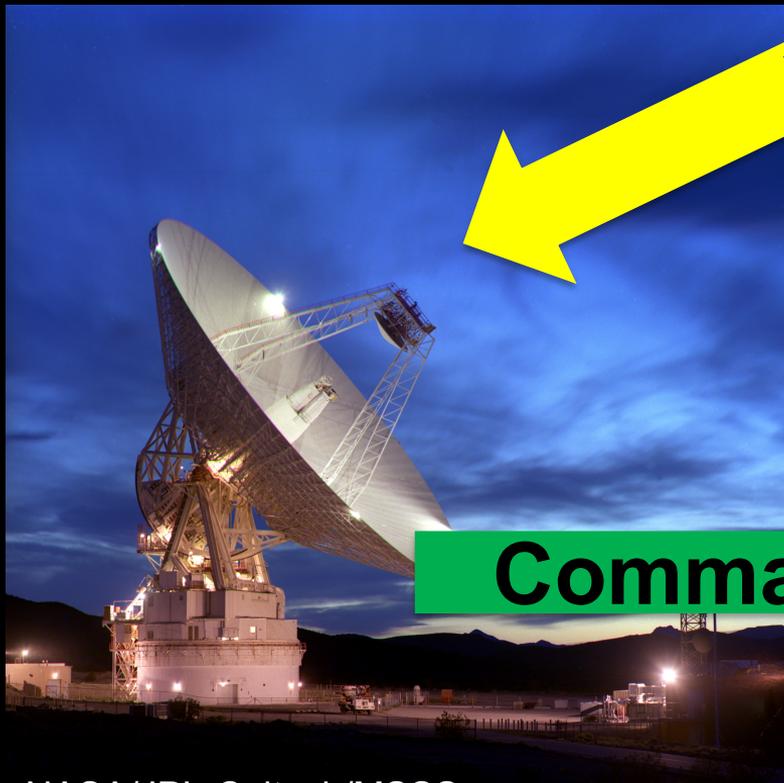
Instructions are sent directly to the rover from Earth. Data from the rover is first sent to Mars satellites and then beamed back to us.

How do you operate a robot?

Data

Commands

Data



How do you operate a robot?

This means we have to plan those instructions very carefully. We tell the rover when to wake up, when and where to drive, what rocks to drill, and when to phone home.

How do you operate a robot?

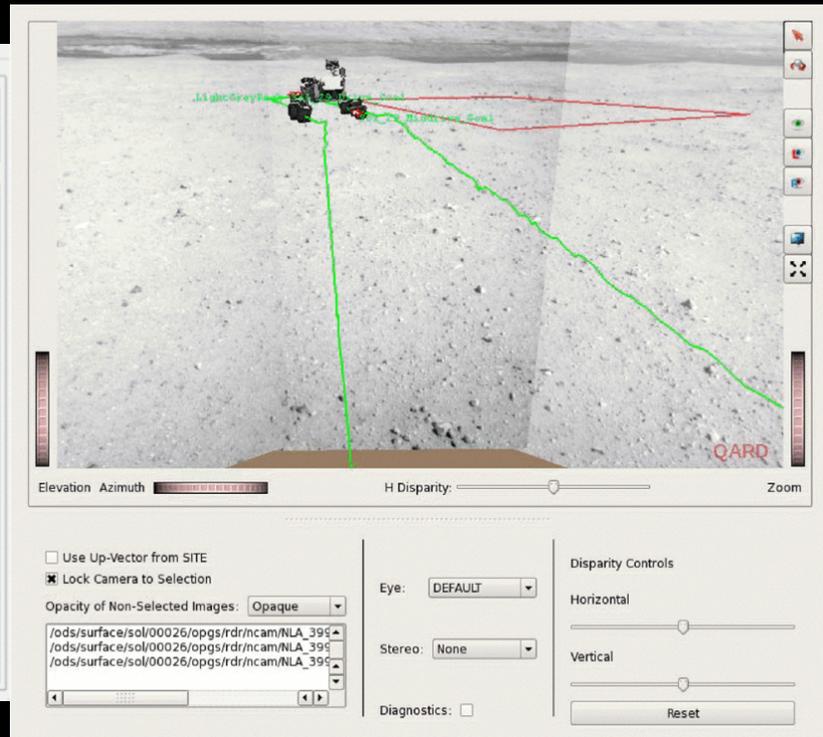
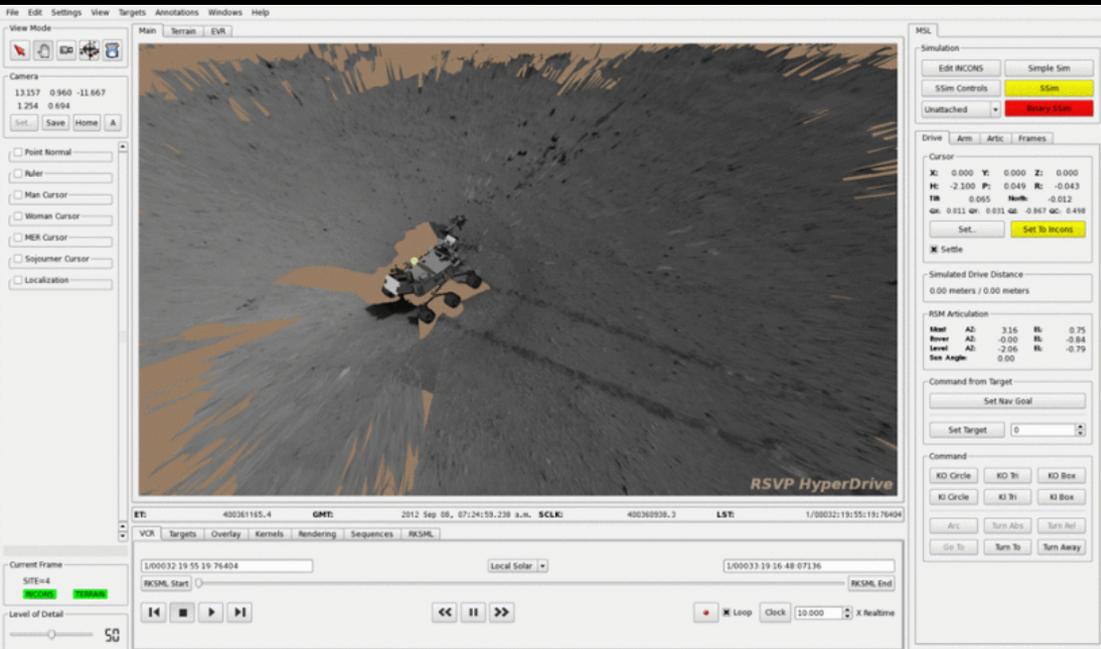
We develop these plans using computer programs that simulate what the rover will do. Using these simulation tools we can “drive” the rover.

These tools let us look at Mars and the rover in 3D and plan where we want it to go. It's kinda like playing a videogame.

Curiosity's First Test Drive

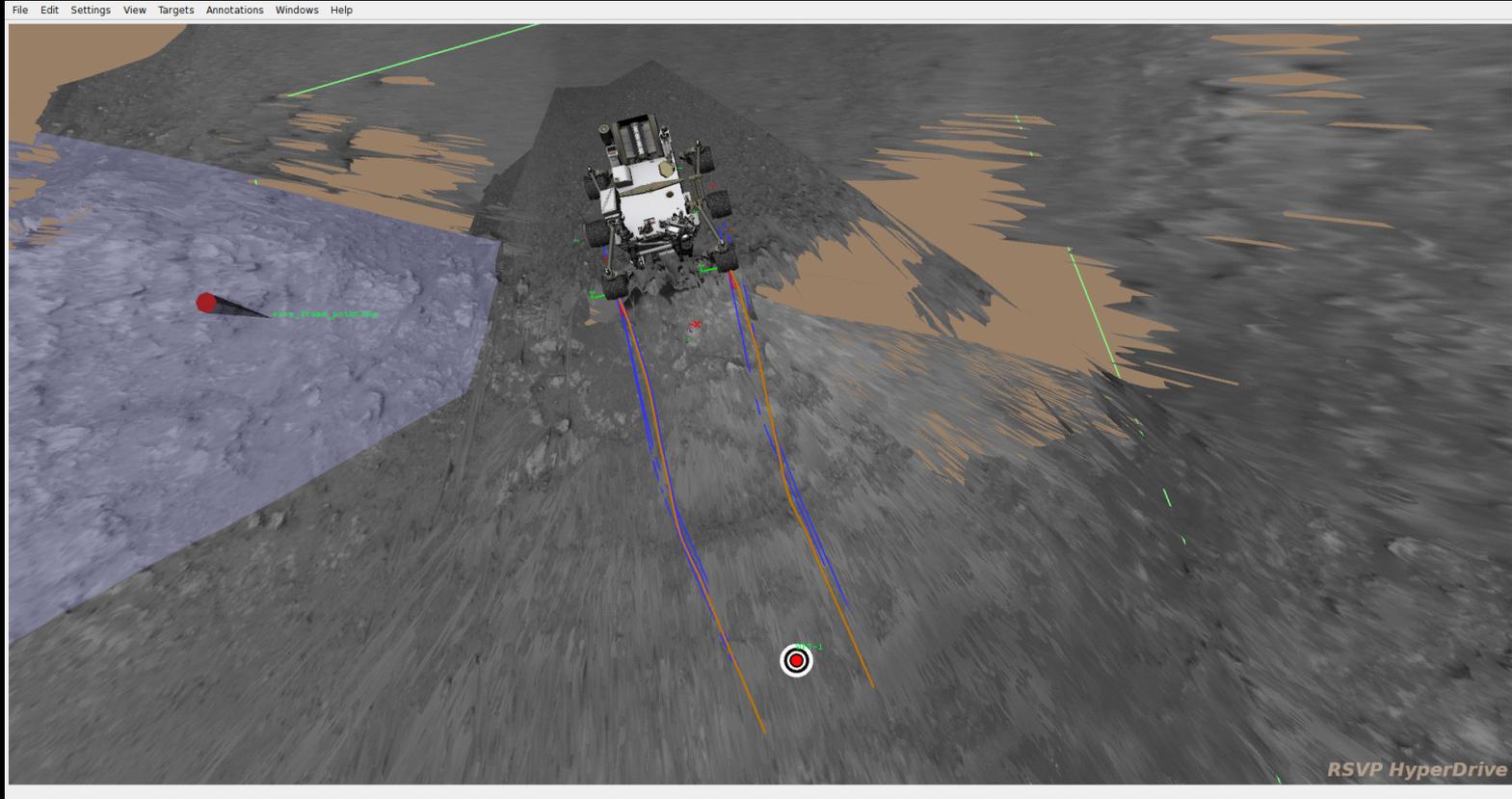


How do you operate a robot?

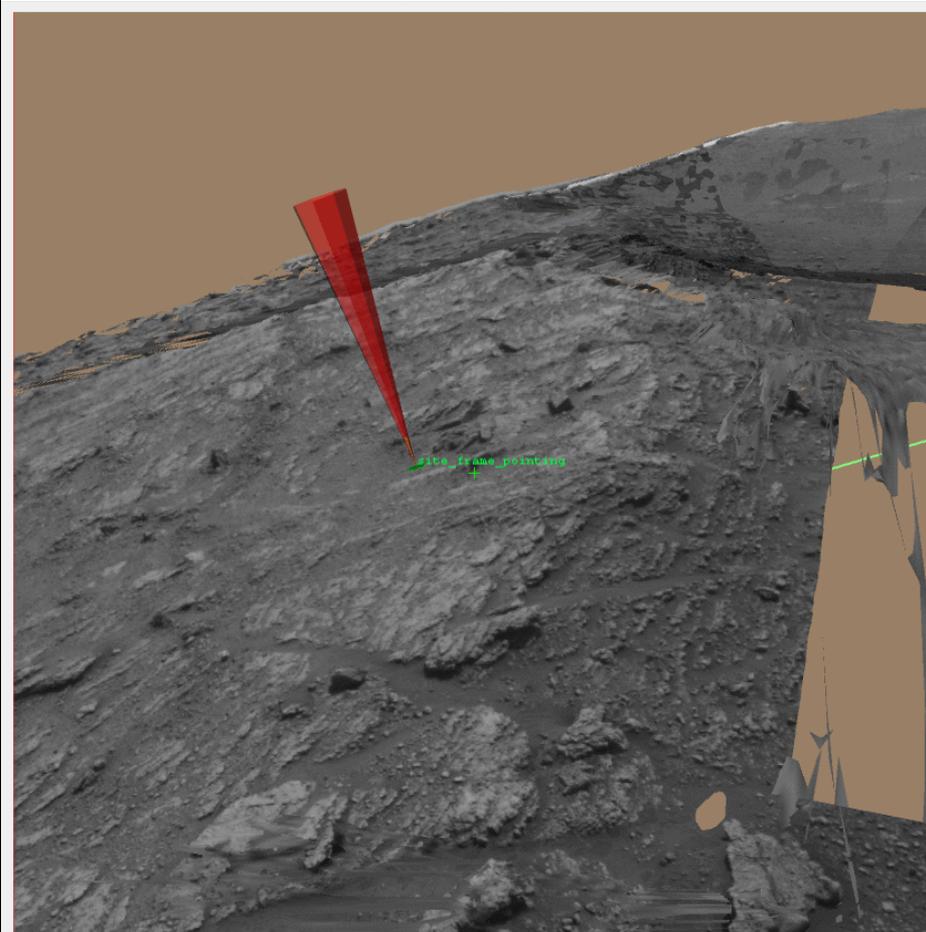


J. R. Wright, F. Hartman, S. Maxwell, B. Cooper and J. Yen, "Updates to the rover driving tools for Curiosity," 2013 8th International Conference on System of Systems Engineering, Maui, HI, 2013, pp. 147-152. jpl.nasa.gov

How do you operate a robot?



How do you operate a robot?





If you want to learn more about robotics in school you should focus on **Math**, **Geometry**, **Science**, **Chemistry** and English. Most importantly you should remain **Curious**, like our rover on Mars.

That means: **taking things apart**, **asking too many questions**, **reading A LOT**, and **building things** (*in the real world or Minecraft*).

Questions???



Jet Propulsion Laboratory
California Institute of Technology

jpl.nasa.gov

© 2019. California Institute of Technology.
Government sponsorship acknowledged.

This document has been reviewed and determined not to contain
export controlled technical data.