Mobile Manipulation Robotics in Uncertain Environments

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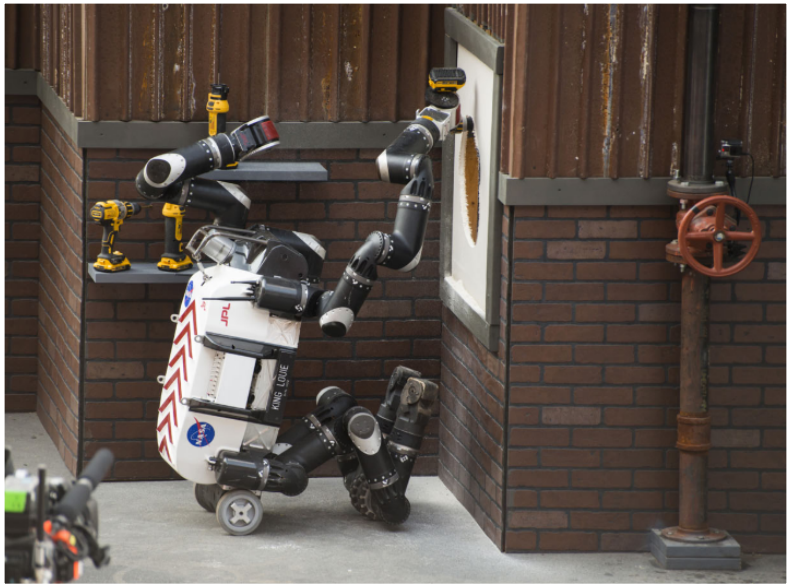
Overview

- Why mobile manipulation?
- Proven applications
  - Terrestrial
  - Extraterrestrial
- Key challenges
  - Power
  - Communications
  - Robust capabilities
- Looking ahead



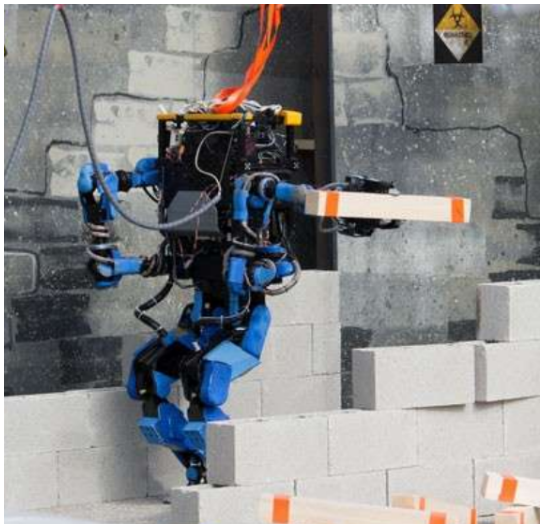
CW from top left:
https://www.jpl.nasa.gov/spaceimages/details.php?id=pia19326
http://time.com/5155273/boston-dynamics-spotmini-robot-dog/
https://newatlas.com/irobot-710-warrior/21396/#gallery
https://mars.nasa.gov/msl/blogs/index.cfm?FuseAction=ShowBlogs&BlogsID=283

DARPA Robotics Challenge - Overview

2013-2015

"The primary technical goal of the DRC is to develop human-supervised ground robots capable of executing complex tasks in dangerous, degraded, human-engineered environments." - https://www.darpa.mil/program/darpa-robotics-challenge

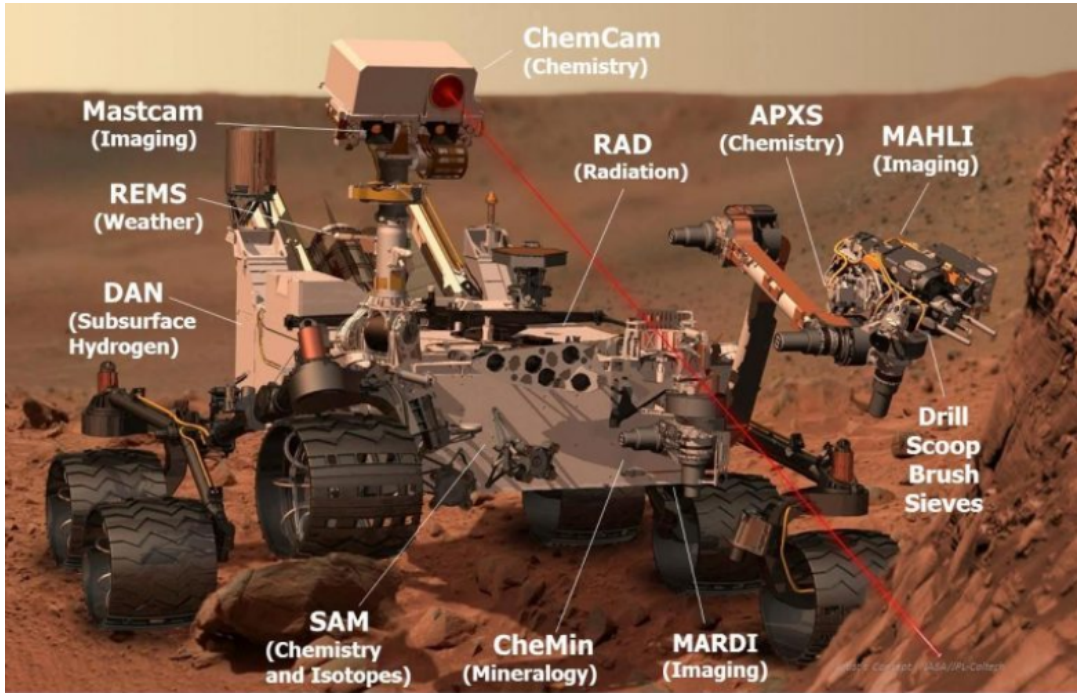
- Trials in 2013
  - 8 separate tasks
  - One half hour per task
- Finals in 2015
  - 8 tasks, sequential, one hour total
  - No tether

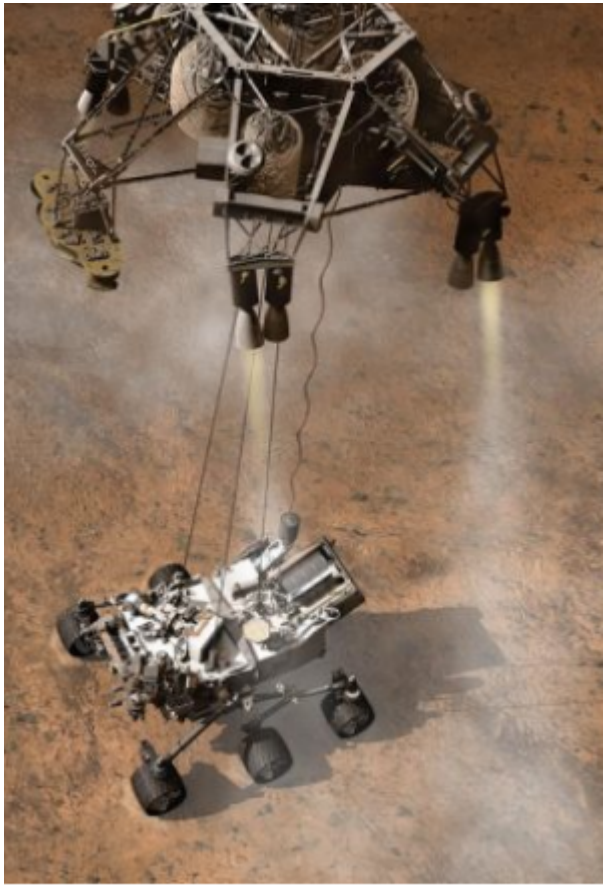


https://www.seeker.com/the-humanoid-robot-that-won-the-darpa-challenge-1768169752.html

https://www.youtube.com/watch?time_continue=78&v=nA_LmjKgd-E

Mars Science Laboratory (Curiosity)



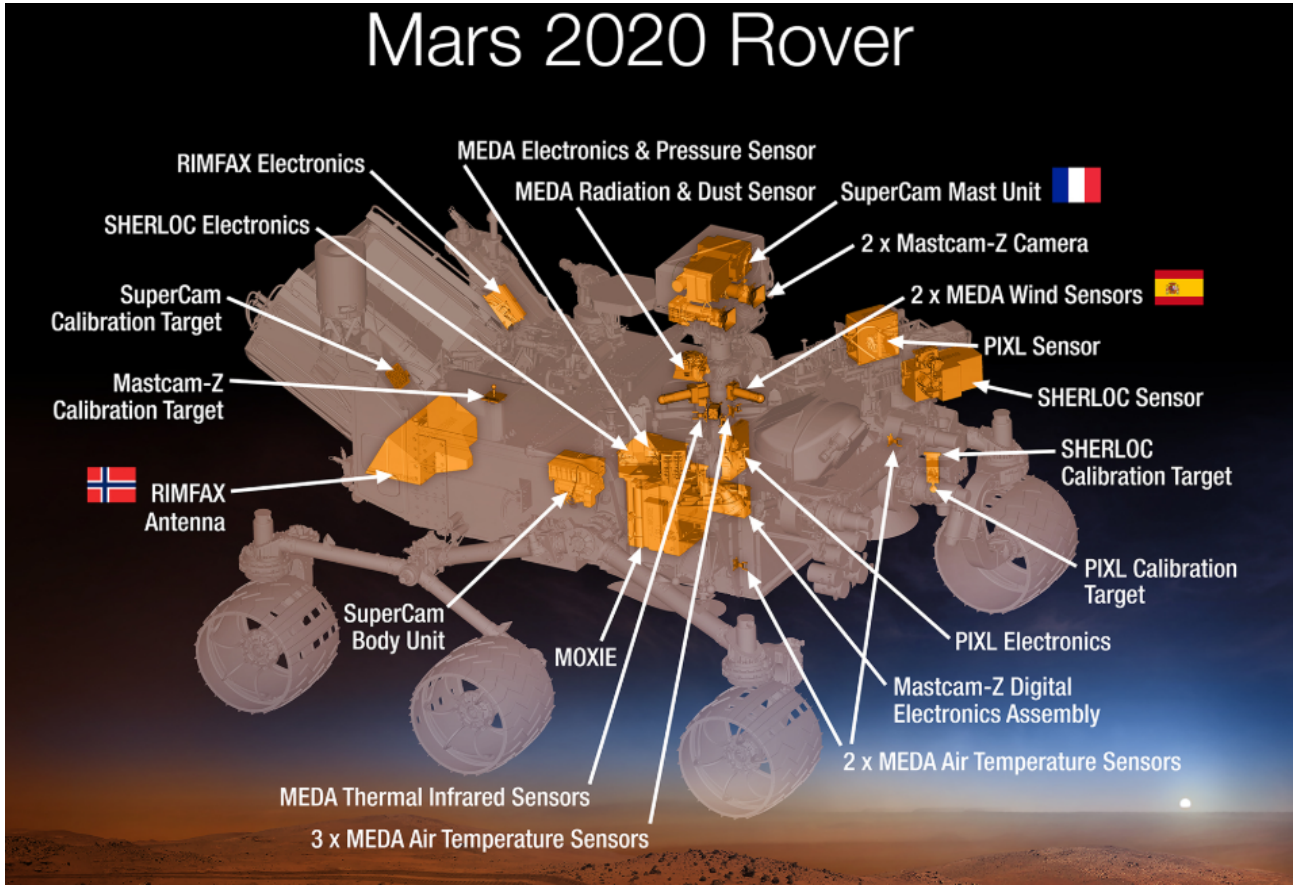


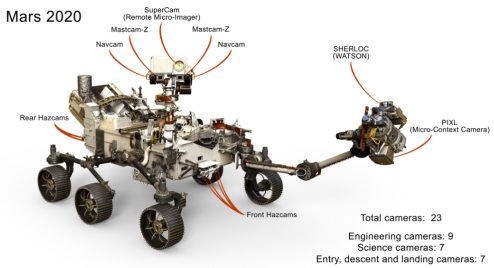
- Highly capable mobility platform and robotic arm
- Prime mission duration of about 23 Earth months
- Operational tempo – per day
  - Examine data from previous day
  - Write and review new sequences
  - Uplink new commands to spacecraft

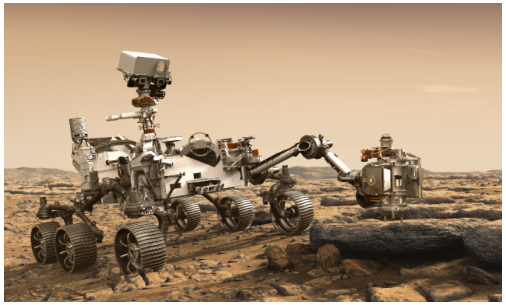
https://www.universetoday.com/132478/book-excerpt-incredible-stories-space-roving-mars-curiosity-part-1/

Mars 2020 Rover Mission

Improving upon state-of-the-art







https://mars.nasa.gov/mars2020/multimedia/images/

Key Challenges

What is driving mobile manipulation research

- Power

  How long would robot need to be operational?
- Communication

  What type of communication can be used in field?
- Robust Capability

  What capability is desired / required?

Power

- Three primary mobile power sources
  - Gasoline (*Boston Dynamics BigDog)*
    - High power density, finite run time, very noisy
  - Solar (*JPL Mars Exploration Rovers,*
    - Self-charging, imposes operational requirements, slow to charge
  - Battery
    - Quiet, finite run-time, heavy
- Most state-of-the-art mobile manipulation platforms (*Boston Dynamics Spot Mini, Kaist Hubo, JPL Robosimian…)* use batteries and can last **90-120 minutes** per charge
- Bomb disposal robots (e.g. iRobot PackBot) can last up to **8 hours**
- Tethering robot is an option, but cable management can be intractable

Communications

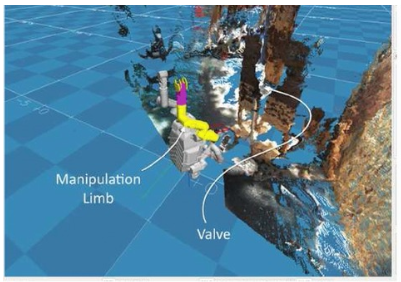
- Available communication directly influences robot design
  - DARPA Robotics Challenge degraded communications specifically for this reason
- Latency constraints/requirements directly influence command & control operations
  - If real-time robotic control is needed, operator must be nearly co-located

https://www.harris.com/solution/t7-multi-mission-robotic-system

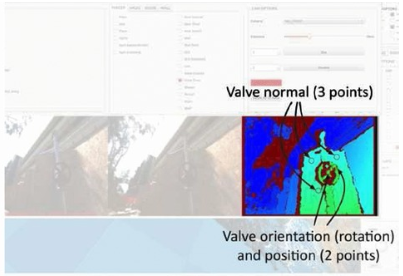
https://deepspace.jpl.nasa.gov/about/

Robust Capability

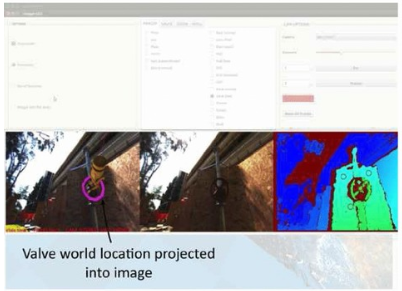
- Clear definition of desired capabilities
- Often drive the need for on-board autonomy. Without it…
  - Need high bandwidth link
  - Need highly trained operator
  - Potentially sub-optimal performance
- Sliding scale of autonomy
  - Let the robot do what it is good at
    - Complex motion
    - Repeatability
  - Leverage the human
    - Context
    - Intent



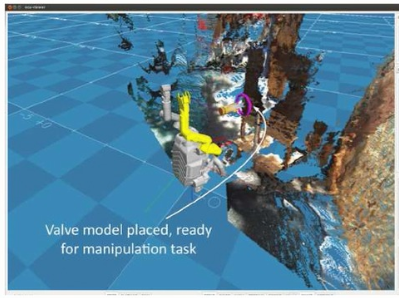
(a) Valve in 3d stereo maps



(b) Interactive perception window with stereo disparity



(c) Annotations on stereo disparity



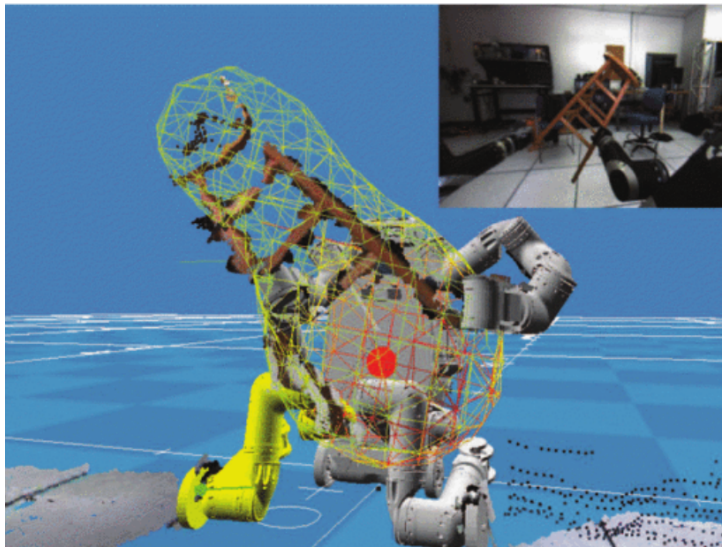
(d) Valve fit shown in 3d map view

Robust Capability - Autonomy

Autonomy is not a software problem. It is a robotics problem

- Dealing with the unknown
  - Example: learning center-of-mass properties of bulky objects

    https://www.youtube.com/watch?v=pmdjquZoJkE
- Consideration of hardware and software in parallel is required
  - Example: vision-less legged mobility https://www.youtube.com/watch?v=QZ1DaQgg3lE



Final Thoughts

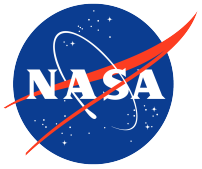
- There is no one-size-fits all for robotic solutions.
  - We have found starting with the problem to be solved and working backwards to the solution is optimal.
- High-volume testing, and demonstration of integrated software/hardware in a relevant environment is essential to make a system ready for the field.
  - “Test as you fly, fly as you test.”
- Some members of robotics community are focused on disaster response. Below are a couple prominent researchers:

  Robin Murphy, Texas A&M: http://faculty.cse.tamu.edu/murphy/

  Howie Choset, CMU: http://biorobotics.ri.cmu.edu/index.php
- Lots of progress over the last 4 years!

  DRC Finals, 2015: https://www.youtube.com/watch?v=g0TaYhjpOfo

  Boston Dynamics, 2018: https://www.youtube.com/watch?v=Ve9kWX_KXus



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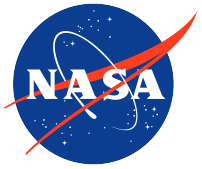

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