Exploring Space with Humans and Robots

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Complexity, Repair, and Servicing
Robotic Servicing?
SPHERES: ISS National Laboratory

VISION-BASED NAVIGATION

Upgraded Expansion Port

EXPANSION PORT

ELECTRO-MAGNETIC ACTUATION

TETHERED FORMATIONS

EXO-SPHERES

FLUID SLOSH
SPHERES: Zero Robotics

• A competition designed to allow Middle- and High-school students unprecedented access to the International Space Station

• Teams of students work to program the SPHERES satellite to win an MIT-designed game

• The teams go through multiple elimination rounds; the top teams see their code tested aboard the ISS

A “complementary” software Competition in the Fall, similar to the FIRST Robotics HW in Spring.
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So roughly speaking a crew of 6 would perform at least 100x the science of the robot for 100x the investment.
Typically, well-trained humans make discoveries that robots cannot, so the actual scientific return is even higher.

Humans can set up robotic equipment to function long after humans leave, and with human intervention, more complex robotic systems are possible.
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Assuming 40 days on the surface with a team of 6: \[40 \times 6 \times 0.6B/\text{day} = 144B,\] again showing that the cost /unit science is about the same.
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The reason we are currently sending robots rather than people is that we do not want to spend 100x the cost for 100x the science.
The instrumentation on Curiosity is roughly what MIT and other major universities and government laboratories had in the late 1960s to early 70s.

At some point a rover may have the capability to do more for less, but as we make the robots more sophisticated the cost goes up, and the pace of science slows down as, even though the science return goes up (from the better instrumentation).
Apollo 15 -- Green Rock -- 15425

Green Glass Clods -- 15425 - 15427
~ 500 grams

Green Glass Beads
40 – 250 microns
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The crux is that the human capability to operate the analysis and to rove is still so much greater than the robots that there is plenty of headroom for people to make more progress in greater detail, at a much higher pace...IF WE ARE WILLING TO SPEND THE MONEY REQUIRED TO ENABLE HUMAN EXPLORATION.
Foundations

• *Exploration* is the expansion of human experience.
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  “WHAT IS IT LIKE IN SPACE?”
Foundations

• *Exploration* is the expansion of human experience. “*What is it like in space?*”
• Explorers should share the experience of exploring as well as the environment being explored.
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  **VIRTUAL REALITY** tools should be part of every exploration mission.
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• *Exploration* is the expansion of human experience. "*What is it like in space?*"

• Explorers should share the experience of exploring as well as the environment being explored. *Virtual Reality*

• Our exploration of the universe expands in three stages:
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• Explorers should share the experience of exploring as well as the environment being explored. *Virtual Reality*
• Our exploration of the universe expands in three stages: *Direct, Remote, Passive*
Three Stages of Exploration

- Direct, with ability to interact with the local environment in real-time.
  
  Can include teleoperation, if sufficient feedback

- Remote (robotic), with speed-of-light impact on speed of interaction with the local environment

- Passive, with all knowledge of the environment comes from receiving radiation or particles.