# The Space Exploration Debate:
# Human vs. Robot

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## PURPOSE

"Who Should Explore Space?" has been a burning question since the first space missions. At first this question was a broad political issue, then a gender issue, and today with the advancements in technology it has become an issue of human versus robot. Therefore this paper's purpose is to summarize the major points of debate on human versus robotic space exploration, shown below, and provide a recommendation for future space missions.

| MAJOR POINTS OF THE HUMAN VS. ROBOT SPACE EXPLORATION DEBATE |
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| Mission Costs |
| Mission Overhead |
| Mission/Scientific Objective Accomplishment |
| Anomaly Resolution |
| Mission Support |

*Note: This paper focuses on the major debatable points created by the US/NASA human space flight experience/policies for conciseness but the concepts presented herein can be extrapolated to foreign and/or commercial and/or defense venues.*

**THE DEBATE**

*Mission Costs:*

Although the National Aeronautics & Space Administration (NASA) and space enthusiasts a like would prefer to ignore costs, everyone including NASA must work within it's budgetary limits.  Therefore when considering methods of space exploration for a mission cost is a major factor.  Currently, one human spaceflight (US shuttle) costs approximately $420 Million and one robotic mission approximately $262 Million (US - Pathfinder Mission)[Slakey 1999].  The cost savings attained by using a robotic devices (unmanned missions) over a human crew are significant but must be weighed against other mission requirements/ factors to formulate an answer to "Who Should Explore Space?" for a particular mission.


Space Flight Costs [Nelan 1998].

*Mission Overhead:*

Mission overhead as used herein implies those systems, processes and/or support that are not mission objective related. Each additional system, process, or support added to a space mission increases its complexity and thereby the potential for failure. The mission overhead required for human explorations includes all the life and health supprt equipment/supplies (See Shuttle example below), waste management systems, escape systems, and ground-based health support.

| **THE SPACE SHUTTLE ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM (ECLSS)** |
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| Air Revitalization System,<br>Water Coolant Loop Systems,<br>Atmosphere Revitalization Pressure Control System,<br>Active Thermal Control System,<br>Supply Water and Waste Water System,<br>Waste Collection System<br>Airlock Support System |

[NSTS 1988]

Conversely, robotic mission overhead (i.e., battery management systems, ground programming/control support) is far less complex because a mission or robotic device(s) is far more acceptable to lose or degrade than a human life. This difference affects a mission's overall cost, as shown above, and its reliability/success potential since higher complexity equates to higher risk and therefore must be weighed against other mission requirements/factors to formulate an answer to "Who Should Explore Space?" for a particular mission(s).

*Mission/Scientific Objective Accomplishment:*

In considering whether humans or robots are best for accomplishing a mission/scientific objective the following factors are the criteria to be assessed:

- Strength
- Endurance/Stamina
- Intuition/Intelligence

<u>Strength</u>. Whereas a human may have equal strength to a robot at launch the affects of microgravity on the human muscular/skeletal system is marked while a robot's capabilities remain constant. Humans in microgravity tend to lose bone mass and muscle (Type1 - Sustained Exertion Muscles) tone which would reduce their strength unless significant counter-measures (adds mission overhead) are employed [Jensen 1999]. Conversely, a robot may be designed with, as much strength as is required by the mission and this strength will remain unchanged unless the robot has a failure, the probability of which can be minimized through design. Therefore predictable strength upon arrival at a space exploration objective is assured by robotic usage and therefore must be weighed against other mission requirements/factors to formulate an answer to "Who Should Explore Space?" for a particular mission(s).

<u>Endurance/Stamina</u>. Endurance and stamina are related to two factors, which are physical capability and motivation. The affects of microgravity on human capabilities, as described above, would limit the endurance a human explorer may have even if highly motivated while his robotic counterpart would be unaffected. Secondly, robots have no sense of boredom or fatigue to affect their desire to perform a task repeatedly whereas humans do have a tendency toward boredom and fatigue from repeated

tasks. This capability to execute repeated tasks without fatigue or a lack of motivation can be directly seen daily in manufacturing plants on the Earth. Therefore mission requirements/objectives with high workloads and/or repeated task will serve to increase the importance of this factor while mission requirements/objectives with specialized tasking will serve to the importance of this factor when answering "Who Should Explore Space?" for a particular mission(s).

*Intuition/Intelligence.* Today's robotic systems only possess as much intelligence or knowledge as is programmed/loaded into them and can not independently formulate new knowledge. However, robots may be re-programmed from the ground with new information or operational criteria. Conversely, humans which gain intelligence and intuition from education and experience bring judgement to each task thereby providing the immediate flexibility that is sometimes needed in space exploration (i.e.; Skylab Deployments, Apollo 13). In addition, it has been argued that to transition from the reconnaissance missions of today to true field studies (studies with open-ended activities, revised and executed based on interpretations of findings) human intelligence is necessary at the exploration site [Spudis 1999]. This argument is supported by the fact that the space community still has many unanswered questions about Mars even though the Sojourner was such a success. Therefore mission requirements/objectives will determine how necessary intuition/intelligence is for a particular mission and provide another input to the "Who Should Explore Space?" decision process for a particular mission(s).

*Anomaly Resolution.* Anomaly or problem resolution by nature requires analysis, judgement, and knowledge to be successful. Human explorers have these required capabilities inherently while their counter-part robotic explorers are limited (i.e., self-repair, redundant system activation) unless aided by a ground-controller. Historically, there are two well-known examples where the human capability for anomaly resolution saved the mission and/or the crew and they are as follows:

1. Apollo - 13: This 1970 mission was to be the third lunar landing, however it was aborted due to an O2 tank rupture in the service module (SM). This rendered the command module (CM) without normal power or water. Water was conserved by the astronauts, but carbon dioxide had to be removed from the spacecraft before it put the astronauts in jeopardy. However, the square canisters to accomplish this from the CM would not fit in the round openings of the lunar module (LM). Therefore a modification was devised and implemented through human ingenuity on-board and on the ground with supplies on-board. Also with lack of power navigational instrumentation was replaced by human bore-sighting of the sun. [KSC 2000]

2. Sky Lab Deployments: During the launch and initialization of the SkyLab station its thermal shield was torn off, one of its solar panels was lost, and the other solar panel would not release. The human crew was able to install a new thermal shield and deploy the stuck solar array thereby saving the mission and the SkyLab program from this unexpected failure. [Spudis 1999]

Although robotics have made quantum technological leaps since these events the robots of today would most likely find it difficult or impossible to effect the same solutions even with ground control/intervention to such unexpected failures. However, there is robotic technology on the horizon that may integrate the human capabilities required for anomaly resolution into new designs [Spudis 1999]. Until then this factor will always weigh heavily when formulating an answer to "Who Should Explore Space?" for a particular mission(s).

*Mission Support:*

Although rather philosophical the concept of mission support plays a major role in the success of a mission. The most fantastic mission, whether human, robotic, science, commercial, or defense oriented, will not succeed without funding and funding only comes with mission support. Therefore in terms of "Who Should Explore Space?" public and/or philosophical beliefs can out weigh mission needs or technical rationale. This is because funding decisions are made outside the technical arena where personal advancement or re-election can be a higher priority than efficient space exploration. Currently, the latest surveys (1997) show a rise of ~19% in both the acceptance/support of robotic (77%) and human staffed (61%) missions to Mars by the public[Boyle 1997]. However, public opinion can be swayed quickly by one large loss (i.e., Challenger) and funding will be reallocated. Therefore it is not surprising that NASA has a policy of using 'robots for space exploration unless a human presence is absolutely essential and vital for the success of the mission.'[Boyle 1997] Therefore this factor will need to be weighed against other mission requirement/objectives when formulating an answer to "Who Should Explore Space?" for a particular mission while keeping an eye on future needs.

**CONCLUSIONS**

Based on the analyses of each of the debatable points for human versus robotic exploration shown above it is concluded that the "Who Should Explore Space?" question would have to be a mission specific analyses and decision. If this analysis and decision is not made on an individual mission basis mission costs and failures may rise while mission efficiency may fall.

## RECOMMENDATION

Therefore it is recommended that each mission be viewed individually for the most appropriate application of space tools be they human or robotic. Additionally, it is recommended that in the future each mission consider the collaboration of both human and robotic elements, as an answer to "Who Should Explore Space?". Such collaboration could be accomplished via dual-missions and/or telepresence.

> 'Telepresence -- the remote projection of human abilities into a machine … without the danger and logistical problems associated with human spaceflight. In telepresence the movements of a human operator on Earth are electronically transmitted to a robot that can reproduce the movements on another planet's surface. Visual and tactile information from the robot's sensors give the human operator the sensation of being present on the planet's surface, inside the robot.' [Spudis 1999]

Currently, this type of capability is under development by NASA via the Robonaut project at the Johnson Space Center [David 2000].

## RESOURCES USED

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