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Humans Versus Machine: Who Will Mine Space?

Tom James and Simon Roper

Humans versus machine? A question humankind has posed to itself since Charles Babbage invented the mechanical computer, The Babbage Engine. Since World Chess Champion Gary Kasporov played a computer named Deep Blue in 1997 and famously lost.[1]

Since their inception, the paradox that something humankind has created for his own convenience would make him obsolete has existed. Which is faster? Which is more accurate? Stronger? More durable? And now, which should mine space?

Currently, we have synthetic technologies, ramping achievements in the field of artificial intelligence (AI), all of which are creating an exponential curve in the field's further development. In basic forms, AI has already helped us out, thanks to Google's 'Home' and Amazon's 'Alexa', happily assisting millions in their homes.

So just who, what or whom, should harvest the dark, cold, atmosphere-less expanse that is space? A place humans cannot travel to, or through, without the help of this technological achievement. Human or machine or a synergy of both?

[1] *Time Magazine*, "Did Deep Blue Beat Kasparov Because of a System Glitch?", 17 February 2015, http://time.com/3705316/deep-blue-kasparov/

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History has proved that machines tend to do a better job all round, being devoid of emotion and any of the essential things humans need to function, such as oxygen, warmth, light, sleep, sustenance; they don't need oxygen, are mostly impenetrable to cold, don't need sleep and with a sustainable energy supply and some occasional maintenance, will last indefinitely.

Battery included and a software update when it's released. Job done? Well, the jury still remains out. Whilst appearing the obvious choice for space's exploration, colonization and production of mineable resources, can they really be programmed to make that all-important judgement call? Currently, as the definition of 'robot' stands, they are slaves to humanity and under our control.

And if not to be relied upon for cognitive thinking, can we develop a communications system fast enough to instruct from Earth? Is there a future where we have robots under local control of AI computer systems, or will humans also want to be, and need to be, around? Currently, our communications to probes and satellites are limited to radio waves. Future developments could see them impressively conducted at the speed of light using lasers. But will that be fast enough, the further they go?

In 1977, possibly one of the most audacious missions, the Voyager and its sibling Voyager 2 programmes proved that we would be in contact with two probes who slung-shot off in two different paths to "boldly go where no man has gone before" (quote: Gene Rodenberry's *Star Trek* franchise), and is not likely to go for some time. Maybe developments from NASA's Deep Space Network (DSN) team will answer this.[2]

DSN is a worldwide network of spacecraft communications facilities located in California in the US, Madrid in Spain and Canberra, Australia which support NASA's interplanetary spacecraft mission. It also performs radio and radar astronomy observations for the exploration of the system and supports selected Earth-orbiting mining missions. DSN is part of NASA's Jet Propulsion Lab (JPL). Similar networks are run by Europe, Russia, China, India and Japan.

Tracking vehicles in deep space is quite different from tracking missions in low-Earth orbit (LEO). Deep-space missions are visible for long periods of time from a large portion of the Earth's surface, and so require few stations (the DSN has only three main sites). These few stations, however, require huge antennas, ultra-sensitive receivers and powerful transmitters in order to transmit and receive over the vast distances involved.

[2] NASA, Jet Propulsion Lab, "Voyager Mission Overview", accessed 19 April 2018, https://voyager.jpl.nasa.gov/mission/

How to get further, faster then?

A spacecraft destined to explore a unique asteroid and also test new communication hardware that uses lasers instead of radio waves is the probe for NASA's 'Psyche Missions'. The Deep Space Optical Communications (DSOC) package on board utilizes photons (the fundamental particle of visible light) to transmit more data in a given amount of time.

The DSOC's goal is to increase spacecraft communications performance and efficiency by 10–100 times over conventional means, all without increasing the mission burden in mass, volume, power and/or spectrum. Using the advantages offered by laser communications is expected to revolutionize future space endeavours, a major objective of NASA's Space Technology Mission Directorate (STMD).

The DSOC project is developing key technologies that are being integrated into a deep-space worthy Flight Laser Transceiver (FLT), high-tech work that will advance this mode of communications to Technology Readiness Level (TRL) 6. Reaching a TRL 6 level equates to having technology that is a fully functional prototype or representational model.

"Things are shaping up reasonably and we have a considerable amount of test activity going on", says Abhijit Biswas, DSOC Project Technologist in Flight Communications Systems at JPL. "Delivery of DSOC for integration within the Psyche mission is expected in 2021 with the spacecraft launch to occur in 2022", he has explained in an article published by NASA.[3]

You can think of the DSOC flight laser transceiver on board Psyche as a telescope which is able to receive and transmit laser light in precisely timed photon bursts.

DSOC architecture is based on transmitting a laser beacon from Earth to assist line-of-sight stabilization to make possible the pointing back of a downlink laser beam. The laser on board the Psyche spacecraft, Biswas says, is based on a master-oscillator power amplifier that uses optical fibres.

The laser beacon to DSOC will be transmitted from JPL's Table Mountain Facility located near the town of Wrightwood, California in the Angeles National Forest. DSOC's beaming of data from space will be received at a large aperture ground telescope at Palomar Mountain Observatory in California.

Biswas anticipates operating DSOC perhaps 60 days after launch, given checkout of the Psyche spacecraft post-lift-off. The test-runs of the laser equipment will occur over distances of 0.1–2.5 astronomical units (AU) on the

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[3] NASA, Jet Propulsion Lab, "Deep Space Communications via Faraway Photons", 18 October 2018, https://www.jpl.nasa.gov/news/news.php?feature=6967

outward-bound probe. One AU is approximately 150 million kilometres, or the distance between the Earth and Sun.

At present, back on Earth, more conventional mining ventures have progressively utilized 'robotization' to increase and in part supplant people for cost and durability issues. Robots that require human connection are also used on our battlefields, in surgical settings, in heavy industry and in in-atmosphere flights.

As for the roads, while appearing to be a long way from regular day-to-day existence, Google's declaration to introduce marketable, driverless autos to consumers in the near future; and the race to create in-home robots, will make the human-computerization allotment issue omnipresent.

The dominating designing principle is to computerize as much as possible and limit the measure of human collaboration. This trend is based on the fact that developing technologies make robots more capable, removing any human complications. It's true to say that many engineers see the human as an aggravation in systems that can and ought to be eliminated.

There is a multitude of Earth inhabitants, 7.6 billion and swelling, including a booming world-wide white collar class, according to international population statistics.[4] We are going to require an increasing number of off-Earth assets if the development of humanity is to proceed. They're not all going to be available on the planet.

Innovation will help alleviate these inescapable asset crunches. However, unless we find new wellsprings of materials to use, humanity's advancement is bound to be choked if not prevented.

A standout among the most goal-oriented of these corporate elements brings us back to Planetary Resources. This Redmond, Washington-based organization expects to prospect and loot space rocks for crude materials to power future space attempts. So, amidst successful missions into space and announcements from governments and privateers to conquer it, the once mooted idea of a stellar-fuelled existence is creeping from sci-fi to science reality.

Planetary Resources was helped to establish itself by XPRIZE master Peter Diamandis, and incorporates Larry Page, Eric Schmidt and Galactic's Sir Richard Branson amongst its initial financial specialists. The primary objective of Planetary Resources is to ensure you have the things that you require when you get into space. Amongst plans from other participants like DSI, one of the essential assets Planetary Resources would like to mine from space is

[4] Worldometers, "current world population", accessed on 19 April 2018, http://www.worldometers.info/world-population/

water, initial prospecting of which suggests it to be in plentiful supply among the space rocks and comets zooming around us; and within perceivable reach from advancing technologies in development right now.

Water will be a critical in space for key reasons:

1. We obviously need to drink it to live.
2. Water particles can be gathered for oxygen to harvest for sustainable inhalation.
3. Water is comprised of hydrogen and oxygen iotas, which are the substance-building pieces expected to make rocket fuel to power space trips.
4. Water can be utilized as a shield against lethal astronomical radiation that pervades extraterrestrial situations.

Asteroids and other planetary entities are brimming with crude development materials such as iron, nickel and cobalt. That's why we need to get to space. So we need to stay positive.

In the Stanley Kubrick exemplary film *2001: A Space Odyssey*, a character is delineated taking a Pan Am space flight in transit to a goliath space station. That is the sort of delightful space positive thinking that gatherings of people had in 1968 when the film was first released.

Obviously, things didn't generally play out as expected when we reached the first year of the new millennium, 2001. There were no private space ships, space visitors or vast cosmopolitan urban areas in the sky. However, for reasons unknown, Kubrick's forecasts weren't really wrong—just off by a couple of decades. A visionary.

Fast forward from Kubrick's world to 2016 and we see that humankind is close to building the space environment that sci-fi has been predicting and guaranteeing for some time—and may be delivered just in the nick of time.

Robots are vital to our future. Robby the Robot could make anything, from jewels to dresses, all for people living in a different universe. Yet, he lived on the fictional Altair IV in the anecdotal film *Forbidden Planet*. Currently here on Earth, while we have made astounding achievements, launching several probes into our universe, humans to the Moon and a rover to Mars, here on Earth robots fill in as voice assistants, toys or vacuum cleaners in human family units.

Despite the fact that today's robots do not have Robby's refinement, they could be destined for greater things and will no doubt become very capable as human intermediaries for space investigation. Truth be told, robots and space go together, so well that should we question whether to question or closely monitor their involvement in space? They are simply a less expensive, more durable and less needy mechanical substitution for flesh and blood.

Ronald Arkin, chief of the Mobile Robot Laboratory at Georgia Institute of Technology, revealed to Space.com that researchers can simply repackage a robot to make it smaller and more impervious to its environs, yet they can't repackage people by any means.[5]

Robots are great adventurers since you don't need to manage emotionally supportive networks that people would require, plus they are less demanding to deal with and substantially more versatile for antagonistic situations than individuals.

Have Robots, Will Travel

The most recent focus for space robots has been Mars, where the ESA's Mars Express, the first planetary mission attempted by the agency, touched down in December 2003. The mission detailed high-resolution imaging and mineralogical mapping of the surface, radar sounding of the subsurface structure down to the permafrost, precise determination of the atmospheric circulation and composition, and study of the interaction of the atmosphere with the interplanetary medium.

Due to the valuable science return and the highly flexible mission profile, the Mars Express was granted six mission extensions, the latest lasting until the end of 2016. It concluded 14 years and six months after launch date, spending 14 years on and around the planet.

NASA's Mars Exploration Rover (MER) mission, a robotic space mission involving two Mars rovers, Spirit 1 and Opportunity, explored the red planet too. It all began in 2003 with the launch of the two rovers to map and explore the Martian surface and geology.

Both landed on Mars at separate locations in January 2004. Both rovers far outlived their planned missions of 90 Martian solar days. MER Spirit 1 was active until 2010, while MER Opportunity was still active in 2017 and holds the record for the longest distance driven by any off-Earth wheeled vehicle.

The mission's scientific objective was to search for and characterize a wide range of rocks and soils that hold clues to past water activity on Mars. The mission is part of NASA's Mars Exploration Program, which includes three

[5] Ronald Arkin, "Regents' Professor, Director of Mobile Robot Laboratory School of Interactive Computing, College of Computing, Georgia Tech", accessed on 19 April 2018, https://www.cc.gatech.edu/aimosaic/faculty/arkin/

previous successful landers: the two Viking programme landers in 1976 and the Mars Pathfinder probe in 1997.

Nozomi—Japanese for ‘wish’ or ‘hope’—'was another planned Mars orbiting probe. It did not reach Mars orbit due to electrical failures. The mission was terminated on 31 December 2003.

NASA sends robots into space where space explorers can’t yet go.[6] Their last robot to the Red Planet was the Pathfinder’s minimized, sun-powered, remote-controlled Sojourner unit, which arrived on 4 July 1997. The space office’s first Mars robots were the two Viking landers, launched in the mid-1970s. They contained a suite of logic instruments including a mechanical arm to gather Martian soil tests.[7]

Smaller, smarter, cheaper.

“Sojourner flew with what the general population would liken to the main PC”, said Paul Schenker, executive of JPL’s Applied Autonomy Research Center, which importantly and significantly utilized PC processors to deal with problems such as space radiation.[8]

Publically available PCs and cameras were key to allowing the MERs to distinguish and evade hindrances without waiting for instructions from Earth.

Astro-Helpers and Robonauts

Confidence is palpable among the science fraternity that advanced robots may go with planet-hopping space travellers to Mars or elsewhere, collaborators to us humans for base development and a range of different errands. The idea is you could send robots as a forerunner to set up residence and science bases before people arrive. When space explorers arrive, the robots can be utilized as colleagues and helpers.

NASA has officially made some progress with its Robonaut machine for the International Space Station (ISS). Space explorer Nancy Currie effectively gathered a metal truss with the assistance of two Robonauts—able robots that could play a part in future ISS development.

Machines are advancing towards becoming humankind’s future symbiont. This was showcased by the deployment of robots to assess and clean up the

[6] NASA Science, “Why do we send robots to space?”, last updated 26 September 2017, https://spaceplace.nasa.gov/space-robots/en/

[7] NASA Mars Exploration, Mars Pathfinder, Mission Rover Sojourner, accessed on 19 April 2018, https://mars.nasa.gov/programmissions/missions/past/pathfinder/

[8] Dr Dobbs the world of software development, “A Conversation with Glenn Reeves”, by Jack J. Woehr, 1 November 1999, http://www.drdobbs.com/a-conversation-with-glenn-reeves/184411097

nuclear disaster that befell Fukushima, Japan, where 'Scorpion' robots were used to try to assess the damage. Following a major earthquake, a 15-metre tsunami disabled the power supply and cooling of three Fukushima Daiichi reactors, causing the accident on 11 March 2011. All three cores largely melted in the first three days. Having been blocked by debris and their own limitations, aquatic 'Mini Sunfish' robots were utilized, piloted 300 kilometres away at tech-giant Toshiba's Yokohama Research Center. The Mini Sunfish were successful in identifying hazardous materials from the disaster.

Still, this shows to some extent the limitations we still have with our ground-based robots. So, in the interim, we mostly use 'unintelligent' robots to assemble the likes of cars, PC chips and other industry items that are generally repetitious in construction nature; and are relatively simple, featuring pre-determined parameters that rarely change.

But these automatons are advancing. The Roomba vacuum cleaner by iRobot, a global consumer company, will clean your floors for you in the event that you have US$200 to spare, while consumer tech-giant Sony offers the robot canine Aibo, a convenient robotic alternative to canine company. Another industrial Japanese heavyweight Honda has developed Asimo, a robot that has mastered the craft of balance, mobilizing like a biped, and speculations suggests one day it may be tasked as an assistant for disabled people.

All these devices get on with life and learn their environment, even user's facial expressions, to trigger their artificially generated responses. However, we still have many obstacles to overcome in the fields of self-governance and counterfeit consciousness.

And this is happening. World companies are spending billions to develop their robots, working towards to a fully working machine with AI, which governs itself accordingly and makes autonomous decisions. Could we eventually see American author Isaac Asimov's application of his 'Three Laws of Robotics' in his *I, Robot* short story collection, defined so as to protect humans from a renegade intelligent robot uprising.[9]

Moral issues brought up in Asimov's story are quite recently starting to be under consideration by the likes of NASA—an indicator that AI will rival humankind in terms of its consciousness, and be smarter, with an in-exhaustive capacity to learn and retain knowledge. NASA analysts are attempting to ascertain how much insight and autonomy their space robots ought to have. The trouble lies in figuring out how to evaluate precisely what mechanical

[9] Auburn University Alabama, "Isaac Asimov's 'Three Laws of Robotics'", last updated 2001, accessed on 19 April 2018, https://www.auburn.edu/~vestmon/robotics.html

processes are needed to do; and build AI systems that would permit correlation of knowledge over various stages.

Meanwhile, whilst the Russians and Americans may have concluded competition past Earth for now, another challenge for longevity of space stays has materialized, as this will be key to long-distance space travel. It's one that pits science and brains against circuits and chips.

To date robots have a great track record of achievements in deep space, in comparison to their somewhat more fragile creator's achievements (even thought they were incredible). As of yet, sci-fi fantasies such as cryogenic suspension, FTL (Faster Than Light) travel, warp drive or 'space-folding', which make life easier for 'biologicals' to travel in deep space, may stay on the cinema screen or pages of well-thumbed paperback books.

Robots have delved in the soil on Mars, flown in the air of Jupiter, cruised by the moons of Neptune, sling-shooting towards successful landings. The Voyager siblings are exploring on the boundaries of the close planetary system.

People, however, have been consigned generally to going round in circles over the surface of the planet. Other than the short Apollo mission triumphs on the Moon, around 250,000 miles away, people have never strayed more distant than 400 miles from the planet, not as much as a day's drive.

People Stay Close to Home for a Few Reasons

People stay close to home for a few reasons. Logistics; limitations of technology and propulsions systems; gravity; the need for supplies. All which culminate toward one simple factor: Cost.

NASA appears to have a difficult job on its hands according to the journal *Scientific American*. That job is convincing US taxpayers that space science is worth billions of US dollars each year. To achieve this goal, the agency conducts an extensive public relations effort that is similar to the marketing campaigns of America's biggest corporations.

NASA has learned a valuable lesson about marketing in the twenty-first century: To promote its programmes, it must provide entertaining visuals and stories with compelling human characters. For this reason, NASA issues a steady stream of press releases and images from its human spaceflight programme.

Every launch of the now-retired Space Shuttle was a media event. NASA presents its astronauts as ready-made heroes, even when their accomplishments in space are no longer ground-breaking. Perhaps the best example of

NASA's public relations prowess was the participation of John Glenn, the first American to orbit Earth, in the 1998 Space Shuttle mission 'STS-95'.

Glenn's return to space at the age of 77 made STS-95 the most avidly followed mission since the Apollo Moon landings. NASA claimed that Glenn went up for science. He served as a guinea pig in various medical experiments, but it was clear that the main benefit of Glenn's Space Shuttle ride was publicity, not scientific discovery, as the press reported.

The same miserable economics hold for the ISS, since during its development history the station underwent five major redesigns and fell 11 years behind schedule. NASA has spent over three times the US$8 billion that the original project was supposed to cost in its entirety. NASA had hoped that space-based manufacturing on the station would offset some of this expense. In theory, the microgravity environment could allow the production of certain pharmaceuticals and semiconductors that would have advantages over similar products made on Earth. But the high price of sending anything to the station has dissuaded most companies from even exploring the idea at this juncture.

No one throws a ticker-tape parade for a telescope. Human spaceflight provides the stories that NASA uses to sell its programmes to the public. And that's the main reason NASA was spending nearly a quarter of its budget to launch the space shuttle about 12 times every year.

Aside from generating less enthusiasm towards the mining and colonization of space, the fact remains that sending a human into space is extremely expensive. A single flight of the space shuttle cost about US$450 million in money-of-the-day. Robots and probes are vastly cheaper, despite being devoid of palpable personalities at present.

NASA is still conducting grade-A science in space, but it is being carried out by uncrewed probes rather than astronauts. In recent years, the 'Pathfinder' rover has scoured the surface of Mars, and the 'Galileo' spacecraft has surveyed Jupiter and its moons. The Hubble Space Telescope and other orbital observatories are bringing back pictures of the early moments of creation. But robots aren't heroes.

Generalizing, the cost of an orbital carry mission, for instance, varies between US$400 million and US$500 million. A satellite can achieve a circle around Earth for US$20 million. Uncrewed landers have touched down on Mars for a meagre US$250 million, although the more recent Mars Rover mission did hit US$2.5 billion. Yet, the evaluated sticker price for a human excursion to the Red Planet runs somewhere in the range of US$50–500 billion.

Also with an immense contribution to the success of humans in space are those issues of protection and safety. Sudden blasts of sunlight-based radiation can kill an unprotected spacewalker. Impacts with even the minutest of objects that litter the space surrounding our planets can puncture a ship. What's more, as the 1986 Challenger and the 2003 Columbia space shuttle accidents agonizingly show, dispatch and landing glitches can have fatal consequences.

And given that there is no gravity or resistance in space, Earth's sentient species has to address the issue of weightlessness, which over protracted months can truly debilitate human bones, muscles and vestibular systems. A roundtrip to Mars utilizing current rocket technology is tabled at present to take between six and eight months one-way. That's longer than astronauts currently stay on the ISS. Until we develop artificial gravity for long space journeys, at the moment if we ventured out to Mars we would potentially be partially blind and too weak to walk by the time we got there. These are all things NASA is researching on board the ISS.

So given the risk, the expense and the misfortunes, why send people into space?

Considering the known perils, justifying the billions of dollars spent on sending a couple of people into space as a beneficial venture to the billions of individuals on the ground takes some doing. Be it for research, science, survival of our species, even to develop a lucrative tourist market, which could lead to colonies, space is ultra-provocative for its mineral wealth.

So as scientists and analysts wrestle with a myriad of issues surrounding prolonged human activity in space, or even just getting them there, amid the developing role of crewed or uncrewed vehicles the present school of thought is as follows.

Asteroid Mining 101

As we are deducing, minerals can be mined from an asteroid or spent comet then used in space for construction materials or taken back to our planet. Most likely gases such as oxygen, water and hydrogen will be the first commodities we search for to support off-planet human colonies. But other rare earth or precious materials here on Earth can also be found off-planet in higher concentrations according to early deep-space surveys.

These deep-space commodities include gold, iridium, silver, osmium, palladium, platinum, rhenium, rhodium, ruthenium and tungsten, and useful back to Earth could be iron, cobalt, magnesium, molybdenum, nickel, aluminium and titanium for construction purposes.

Due to the high launch and transportation costs of spaceflight, inaccurate identification of asteroids suitable for mining, and in-situ ore extraction challenges, terrestrial mining remains the only tangible means of raw mineral acquisition today. However, because of the constantly decreasing cost of launching rockets from Earth (thanks to reusable rocket technologies perfected by SpaceX), it is quickly becoming a commercial reality and something Planetary Resources and Deep Space Resources companies are working hard to bring to a reality.

Some years ago the school of thought on mining and establishing colonies sided with machines first, then humans second, if at all, as it appears to be mining robots on larger planets (much impetuousness is present behind the development of these vehicles), which will be carried by the rockets planned by national institutions like NASA and privateers such as SpaceX.

Supporting Humans in Space

A little while back, plans surrounding the liberation of space decided that the least efficient way to get air, water and fuel into space is the way that we currently do it, as reported by the IEEE Spectrum portal in 2004. Packing as much of it as we can into rockets on Earth, and then firing them off into orbit to get supplies to the Moon, or Mars, is going to be ludicrously expensive and time-consuming. A much better solution is to extract everything that we need from wherever we are.

The process of robotic mining itself is well established on Earth, and NASA holds an annual Robotic Mining Competition (RMC) to help drive university-level research and innovation with robots competing to mine simulated Martian soil.

The most recent RMC competition, its Eighth Annual RMC awards ceremony in May 2017, held at the Kennedy Space Center Visitor Complex in Florida, saw teams compete to produce a winning solution to planet mining.

The 'Joe Kosmo Award for Excellence' saw a team from Alabama clinched first place. The whole initiative is designed to foster technology that can be used for NASA's trip to Mars. Joe Kosmo himself, a retired NASA engineer, has a background in robotic mining. "Before we go to Mars, we need to learn about it. We need to pre-stage supplies and equipment", said Kennedy Center Director Bob Cabana at the time of event. "There's a lot we can accomplish using robots".[10]

[10] NASA's John F. Kennedy Space Center, By Linda Herridge, "Robotic Miners Traverse the Martian Dirt for NASA's Robotic Mining Competition", 9 June 2017, https://www.nasa.gov/feature/robotic-miners-traverse-the-martian-dirt-for-nasas-robotic-mining-competition

In order to figure out the best way to mine, NASA has reportedly taken inspiration from some of the finest natural engineers on Earth that aren't beavers. Or termites. Our out-of-this-world mining hopes rest on the engineering prowess of the humble ant.

NASA's Swarmies robots, if they come to volition are designed and programmed to forage like ants. Each individual robot has basic hardware and follows a simple set of rules, so when it finds something interesting, the unit then communicates with other units to help exploit its find.[11] The current incarnation of this system only uses four robots, but it's been designed with scalability in mind, and it'll work for all different kinds of hardware. These small, relatively cheap robots can work together to efficiently perform much of the work that would take one big, expensive robot a very long time to execute.

Next, NASA will add some robots to the mix that actually do know how to get some work done. The plan is to incorporate 'RASSOR', "a concept robotic vehicle evaluating designs for a future craft that could work on another world", according to the space agency.

So in the near future of asteroid and planet mining, we can look to robotics as a solution to our needs. Advancing AI coupled with increasing speeds of Earth-to-robot communications should enable our creations to keep going to the places we haven't been before—this time not for exploration but for excavation.

Against all the benefits of machines going into space instead of humans, the question remains, would unmanned robotic missions be able to detect weird microscopic life-forms they are not programmed to recognize that might be lurking below the surface of Mars, or beneath the murky seas of Jupiter's jumbo moon, Europa? If you are just mining or doing specific tasks, then machines seem to be the better answer. See Table 4.1 for a comparison of attributes between machine robots and humans. For example, NASA currently operates more than 50 robotic spacecraft that are studying Earth and reaching throughout the solar system, from Mercury to Pluto and beyond. Another 40 unmanned NASA missions are in development, and space agencies in Europe, Russia, Japan, India and China are running or building their own robotic craft.[12]

What is not commonly known however is that many of NASA's leading scientists also champion human exploration as a worthy goal in its own right

[11] NASA Kennedy Space Center, by Steven Siceloff, 18 August 2014, "Meet The 'Swarmies' – Robotics Answer to Bugs", https://www.nasa.gov/content/meet-the-swarmies-robotics-answer-to-bugs

[12] NASA Goddard Space Center, Last updated 3 January 2018, "Goddard Missions – Present", https://www.nasa.gov/content/goddard-missions-present

Table 4.1 Comparison of attributes between machine robots and humans

Attribute	Machine	Human
Speed	Superior	Comparatively slow
Power output	Superior in level of consistency	Comparatively weak
Consistency	Ideal for consistent, repetitive action	Unreliable learning and fatigue are factors
Information capacity	Multichannel	Primarily single channel
Memory	Ideal for literal reproduction	Better for principles and strategies
Reasoning computation	Deductive, tedious to programme, fast	Inductive, easier to program, slow, accurate
Sensing	Good at quantitative assessment	Wide ranges, multifunction, judgement
Perceiving	Copes with variation poorly	Copes with variation better, susceptible to noise

Source: Tom James

and as a critically important part of space science in the twenty-first century. In *Scientific American*, Jim Bell, a stargazer and planetary researcher at Cornell University and creator of 'Postcards from Mars', notes that "you may believe that analysts like me who are included in mechanical space investigation would expel space explorer missions as expensive and pointless".[13] In spite of the fact that space human explorer missions are significantly more costly and dangerous than automated ones, they are fundamental to the accomplishment of NASA investigation programmes.

The heart of the open deliberation is this: automated machines will just do what they are modified to do; they are not customized to recognize unusual quality: the impossible, the obscure, the abnormal non-carbon life that we may have experienced on Mars; for instance with the two Viking vehicles, in 1976. Each conveyed hardware for inspecting the Martian soil and smaller than usual science research centres to test the specimens for indications of life. The results that these robotized labs radioed back to Earth were cryptic: the substance responses from the Martian soil were weird, not at all like anything seen on Earth. Be that as it may, they were likewise not at all like any responses that living life forms would create.

What are we searching for, precisely, when we scan for outsider life? That is the enormous question considered in another report from the National Research Council, 'The Limits of Organic Life in Planetary Systems'. For over

[13] Scientific American Magazine, Book Review, accessed 19 April 2018, "The Interstellar Age: Inside the Forty-Year Voyager Mission by Jim Bell", https://www.scientificamerican.com/article/book-review-the-interstellar-age/

five years, a board of trustees of researchers attempted to envision what life-as-we-don't-have any acquaintance with it may resemble. Their decision: Life may exist in non-carbon shapes totally unlike anything we see on Earth.

So for exploration at least, it seems humans may still have a job!