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Artificial Intelligence in Space

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ABSTRACT

AI in Space High-risk space missions require a delicate mix of daring thinking and meticulous engineering, particularly risk management. Incremental innovations, whether based on artificial intelligence or other technology, are accepted only when they provide a mission with substantial advantage. Even then, the dangers associated with a new capacity must be thoroughly recognised and actively withdrawn. And yet, whether by unmanned spacecraft or people, space travel is not for the week of heart or eyesight. Since 1998, artificial intelligence has made consistent progress in the area of space. Two manned spacecraft innovation trial RAX in 1999 and the ASE 2 on the Earth Observing One platform in 2003 and still operational today validated the appropriate use of artificial intelligence-based expertise in future human exploration. These skills will also assist NASA in redoubling its efforts to explore the Moon, Mars, and beyond via robotic and human exploration.

Keywords — Artificial Intelligence, Remote Agent Experiment, Robotic Space Craft, Planets, Application, AI management.

I. INTRODUCTION

Flight technology experiments are targeted endeavours that assist NASA in developing the equipment necessary to discover different regions in space. The tests assess the capabilities of new spacecraft while also analysing their potential and worth while minimising risks. Typically, the tests are carried on specialized spacecraft, but experiments can indeed be transmitted to lunar rovers that already completed their mission which is primary [1]. For example, in 1999, RAX distant agent was sent to Deep Space One DSO and managed the DS-1 expedition for several days. For the first time, AI flight software commanded a spaceship, and RAX was the groundbreaker actually, the flight breaker. An onboard model-based diagnosis, execution engine, planning system and recovery capacity were all incorporated. RAX met all of its experiment goals and showed the value and possibility of spacecraft autonomy. The Mars exploration rover's system of tactical planning, Mixed Initiative Activity Planning Generator, was developed as a result of this achievement [2]. MAPGEN coupled a descendant of RAX's planning technology using the editing system for JPL activity plan. RAX also left a legacy with the LS model design diagnostic engine [3], which is now being discussed for system-health management onboard NASA's upcoming human space exploration mission, the Crew Exploration Vehicle (CEV). The ASE programme exhibited independent tracking of volcano, floods, and freeze-thaw occurrences on Earth as a technical demonstration [4]. The experiment was sufficiently effective that mission related to EO-1 was decided to use for the ground and flight of ASE's operational capability in November 2004. This resulted in an annual cost reduction of over $1 million, which was a major factor in current three-year extended mission of EO-1. It includes the CASPER software planner, a powerful execution engine, and numerous instances of AI embedded technological event observation software, including as change detectors, recognizers, and classifiers. In 2004–2005, 2nd version of the Livingstone software was flown onboard EO-1, proving the diagnosis and monitoring of simulated malfunctions in the scientific equipment [5]. The Descent Image Motion Estimation Subsystem is another excellent AI application. The Landing system of Mars rovers includes a machine vision component called 7 DIMES. During the intensive time of fall, it tracked objects such as craters while estimating wind speed rates aboard and automatically firing propellers in order to repay for the winds which are shear.

II. APPLICATIONS OF A.I. IN SPACE RESEARCH IN THE FUTURE

These recent AI-based capability accomplishments have sparked discussion about their potential use in future space discoveries. By allowing embarked decision-making A.I. techniques aid satellites in identifying and reporting scientific phenomena. The spacecraft can respond to occurrences by examining them further in the highest aggressive implementation of such technologies. Dynamic settings' access, like comets, can potentially benefit from onboard decision-making [6, 7].

A. *Applications in Earth Science*

ASE has enabled the establishment of a sensor-web onboard EO-1 that connects autonomous decision-making nodes to research Earth scientific occurrences. EO-1 is integrated with other space-faring surveillance facilities as well as surface devices such as seismographs, tilt meters, and thermostats to monitor geological eruptions, storms, lagoon and snowfall. In the deployments of the ASE and EO-1 sensor webs, AI performed a number of roles, highlighting the potential of onboard decision-making to improve Earth science:

- Machine learning is used to create event detectors that follow scientific occurrences while also understanding noisy and incomplete data.

- Automated planning systems prioritise the highest-priority objectives for observational resources.
- Task execution systems deal with the execution irregularities that come with real-time systems.
- Future sensor-webs in other planetary orbits will benefit from the applications pioneered in Earth orbit [4, 8-10].

B. *Applications on Mars*

Recent discoveries have revealed that Mars is significantly more active than previously thought. Image processing software will be sent to Opportunity and Spirit rovers in July 2006, allowing on the ship evaluation of clouds and dust devils. [6] The rovers can now easily valuate these random events because to the new software, which allows them to downlink just the photos or image parts containing the targets of interest. Such research will help us learn more about the atmosphere of Mars. THEMIS, a Mars Odyssey Orbiter sensor, will aid in the detection and tracking of phenomena like include thermal anomalies generated by volcanic eruptions, climatic variables in the northern freeze - thaw, sandstorms, and cloud formations of water ice. [9] Other fascinating dynamic elements are dust devil streaks and black slope tails. Surface missions to research Mars geology might benefit from onboard decision-making. A rover that can identify when it goes from a lava flow to a water deposition location, for example, might allow for more efficient exploration of the Martian surface.

C. *Applications on other planets*

Consider taking a voyage to IO, one of the Jupiter's moons that are in our solar system, the most active volcano, in order to illustrate the benefits of onboard artificial intelligence and spacecraft independence. Despite the extensive research of Io conducted by NASA's Galileo spacecraft, numerous doubts remain concerning the particular nature of the planet's volcanic movements, such as the lava's composition spilling on the surface of the planet [2, 5]. Because of the high temperatures associated with lava eruptions, Io's interior composition and evolution models are restricted. Rare lava fountain events that show relatively extensive expanses of liquid lava at or near the temperature of the liquid lava's eruption are suitable for investigating lava temperature since they occur seldom. A star ship equipped with onboard decision-making might notice such an incident within seconds, even if it was a long distance away [6, 9]. It might then make use of such data to gather findings while close approach and to reset equipment in order to reduce detector saturation caused by the heat source [7]. The addition of extra instruments to study the eruption site and collect compositional data, such as high-resolution infrared spectra, might be part of a later inquiry.

Europa

For a proposed mission to Europa, one of Jupiter's moons, to exist, much alone explore, it would need a great deal of autonomy. After landing on the icy surface of Europa and breaking through the ice sheets, submersibles may next be released to investigate the ocean depths under the ice cover are all necessary processes to access the subterranean ocean on Europa's frozen surface. The thickness and nature of the ice cover, the emission necessary for piercing the sheets, and the sensor efficacy in the subsurface ocean would all be factors to consider for such a probe. Onboard autonomy has an enormous challenge in surviving the voyage, operating with limited contacts with Earth, and achieving research goals [4, 11].

Titan

The Cassini spacecraft discovered that Saturn's moon Titan has a rich and varied topography. Its gravity is very less (one-seventh that of the Earth) and voluminous airspace (4X times of the Blue planet) make it an attractive destination for astronauts, appealing location for airborne exploration. In this investigation, there are two main reasons for claiming autonomy [1]. First, because approximately two to two and a half hours is required for two-way light operation interactive operations are basically ruled out. If a balloon is drifting at 1 m/s and at height of 5 kilometres it can picture adequately. By the time the aerobat can transmit a message to Earth and get a feedback that will be outside the range of whatever thing prompted the signal [2]. Downlink bandwidth is the second concern. An aerobot with a point able antenna can transfer data directly to Earth at a few kilobits per second (when the Earth is above the horizon) [10]. An expedition in the North Pole in the 2015–2020 timescale) would've had a steady vision of Earth; on the other hand, a mission at lower altitudes would be visible to Earth only about a third to two - thirds. Generally, the aerobat would be maintained by a shuttle via a low-gain antennae and a UHF link [3, 11]. However, owing to Titan's orbital dynamics, the relay link will be known for just a few tens of minutes at a time, perhaps once or twice a day. This relay link is capable of transmitting hundreds of megabits per second and necessitates the separation of high-priority data for immediate transmission enabling lower-priority data to be buffered and down linked when a relay opportunity arises in the foreseeable future In most cases, a Titan aerobot would have the following instruments: The use of a subterranean radar sounder to detect underlying stratification, concealed fissures, and other anomalies in organic deposits; in situ measurements of temperature, humidity, and methane abundance; and other methods and a Titan aerobat with inbuilt decision-making might possibly examine dynamic phenomena like methane thunderstorms. cryovolcanic eruptions, or methane geysers. While such events would be dangerous to study, the findings would be of enormous scientific value. It's possible that a self-contained system might collect data from such an incident [11].

D. *Various other missions*

AI as well as on-board choice will be easily accessible applicable to missions to comets and other dynamic bodies. Approaching a comet necessitates circling a tiny entity in a hostile system. Geysers or plumes erupting from surfaces of different comet are both fascinating scientific phenomena and potential threats to the spacecraft. Mission capabilities include capturing these occurrences in detail, taking their samples, gathering and landing sample of subsurface. Landing and drilling for samples are both difficult tasks [2]. Uncertain surface hardness, for example, makes predicting the time or power necessary to drill to particular depths challenging. NASA astrophysics missions, such as ones designed to locate planets near other stars, will benefit from onboard decision-making. Another promising area for AI use is space weather. Several satellites operated by NASA and other organisations monitor the sun for different events, including coronal mass ejections. These occurrences have a significant impact on power grids, communications, and satellites close to the Earth surface, and a space weather sensor-web of equipment might detect and track them [10-11].

III. HUMAN SPACE EXPLORATION AND UTILIZATION OF AI

As part of NASA's current exploration strategy, a new spacecraft is being developed that will put an emphasis on human space exploration once again. Low-Earth orbit missions, returning humans to the moon, supporting a prolonged stay on the moon's surface, and eventually allowing humans to visit Mars are all goals of the CEV [2, 4, 8]. As a first step, it may seem like an odd choice to look at AI's future in the context of human endeavours. To put it another way, it's a crucial factor in the development of more intelligent spacecraft. Human spaceflight will undergo a number of important modifications when it advances beyond low Earth orbit. As missions get longer and more complicated, they'll require improved management of operations plans and crew scheduling in addition to other issues requiring task coordination [10-11].

IV. OPERATIONS AND CREW INTELLIGENCE

Ground operations staff plays a large role in traditional mission planning, such as crew scheduling. Additionally, the method is incompatible with both human nature and the purpose of human space travel. Employees aboard Skylab were outraged by the meticulous planning that had gone into the mission. Crew members have greater freedom to choose their own work schedules in today's International Space Station, thanks to the station's more flexible operations [3]. However, spaceflight operations are much too complex and risky to rely on haphazard decisions. It is difficult to change operations plans because of inter-linkages across processes, resource limitations, and onerous jobs. AI-based mission operations system has already demonstrated itself in the field of scientific operations designing. Through interactive systems, these technologies may assist crews, ground operations professionals, and others in managing operations plans. These tools allow the crew to securely coordinate plans' own timetable while working in conjunction with Earth-based mission operational objectives and constraints [3-4].

V. MANAGEMENT OF INTELLIGENT SYSTEMS

Due to the increasing complexity of human space travel, it will be impossible to maintain the level of specialised knowledge and people necessary to oversee and manage all systems from the ground. When humans leave low Earth orbit, crew and ground staff cooperation will be affected by light-speed latency and communication disruptions [4, 8]. As a result, crew members will be in charge of maintaining and monitoring their own systems. Artificial intelligence (AI)-based systems are an appealing choice to assist system management since the crew has other tasks and lacks in-depth knowledge of system operations. In intelligent process automation, a considerable human component augments AI-based control features such as state evaluation, decision-making, and execution [5].

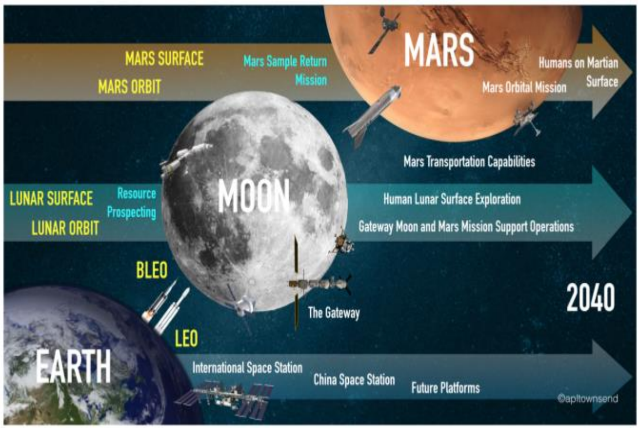

Figure 1. Space Exploration mission using AI [5]

To meet the requirements and wishes of the crew, AI software can give situational awareness, explanations, and information summaries. Take, for example, a spacecraft's power system. Production, like energy through solar panels, storage in batteries, load control, crucial system protection, distribution, and more are all part of power management. This task cannot and should not be done by the crew; instead, the specifics should be handled by automated control software. In nominal operations, this entails following a plan, tracking the system's status, projecting and making load management choices, and other activities [1-2]. The power system is clearly not controlled in isolation; other systems, such as those that use electricity, must work in tandem with power management. Furthermore, the angle of the spaceship will have a substantial influence on the solar panels' ability to generate power. Finally, the actions and demands of the crew have a significant impact on power management [4, 6]. Automated software must be able to identify the root cause of a problem and, if required, provide an initial and speedy response in this environment. Additionally, it's necessary to have a complete awareness of crew activities, including failure criticality and ground contact. Repairs and system modifications may be carried out by the software, in conjunction with the crew and perhaps ground control, in the event of an emergency [9]. AI-based management systems provide a strong argument for lunar exploration and development, despite the fact that present system operations may serve for near-term exploration and development in orbit around Earth.

VI. EXPLORATION BY HUMANS AND ROBOTS

The final human's objective presence in space to establish a permanent presence on celestial bodies throughout the solar system, beginning with the Moon and continuing on to Mars and beyond. Extensive study in space, moons, and Mars will be required to achieve these aims. However, human space explorers are capable and flexible, but they have a limited capacity and population [7]. From data-gathering scout rovers to in-situ resource use and habitat construction, the use of robotics in future investigations seems inevitable. Take a look at how things could develop on the surface of the moon in the future [8]. Some astronauts are stationed in a domain close to the lunar South Pole.

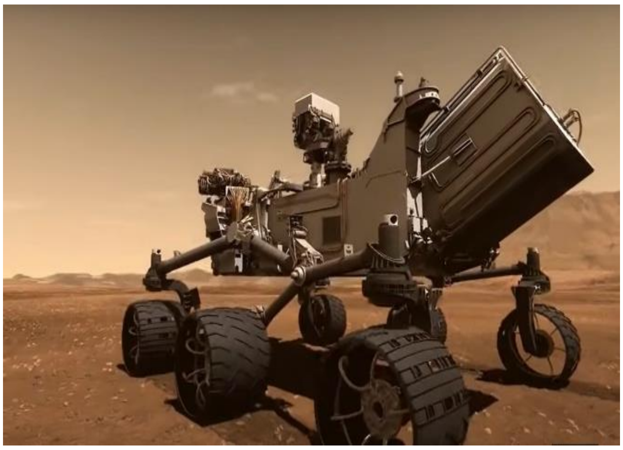

Figure 2. The robotic device to hover over the surface [8]

Both of these endeavours are important to them, as they want to develop their capacities while also learning more about the area. Because cosmic waves vulnerability and limits of lunar dust the crew's ability to function outside for lengthy periods of time, robotic devices are used to undertake tasks that do not need human involvement. Scouting the arctic region, obtaining data for research and technical operations, executing particular building and setup chores, and so on are all examples of these duties. Many of these robotic functions may be directed by the crew from within the habitat. When crew members walk outside, robotics will continue be used to help them complete their jobs [6]. Depending on the demands and circumstances, Humans or automated software may control the robotics. Cooperative human-robotic operations on earth and other planets, such as the Surface of Mars, will include some of the most demanding challenges in space travel for artificial intelligence [2]. AI applications have traditionally included the management of robots, such as rovers. Human-robot and interpersonal connection, location awareness for both robots and people, and much more dynamic situations are some of the additional issues that remote operations to assist human workers provide. NASA's commitment in space-based network systems has been spurred by the success of using relays on Mars to download information from Spirit and opportunity and also Sensor-web situations will become increasingly common. Mars Odyssey rovers shared almost all of their scientific data. The Mars Reconnaissance Orbiter was just launched by NASA to act as a relay for the Mars Lab rover mission. It is anticipated that the Mars Science Telecom Orbiter would act as a specialised networking platform on Mars. Space-based networking will increase the number of missions that use space platforms to accomplish their objectives [7]. While EO-1 has shown what can be done with sensor webs on the ground, situations on Mars where a event's finding starts on an orbiting platform and is followed up on by ground assets are not out of the question. Such conditions limit the platform's capacity to survive. With time, the ability of space assets to participate in different coordination arrangements enabled by space networks grows increasingly versatile. The fact that Spirit and Opportunity are expected to live longer than originally thought is a plus in this regard [9]. Systematic space platform feeds A.I. research in areas like distributed designing and controlling, as well as distributed fault management [12-13]. It's possible that space platforms, if they can endure over 10, would be capable to improve the mission goals over years and ultimately complete tasks that go beyond what they were initially designed to do for. There must be more study in rationality, reasoning, genetic systems, and other machine intelligence technologies in order to meet these aims [10].

VII. CONCLUSION

Artificial intelligence (AI) is playing an increasingly important role in space exploration, as explained in this article, from the scheduling of spaceship operations to the creation of AI-based assistants. Because to this tremendous advancement in Artificial Intelligence; it can show the first picture of the black hole. The concerns of privacy and upkeep must still be given attention, though. NASA is already planning space missions that might use a network of autonomous spacecraft to fly intelligent agents in space. In order to accomplish difficult scientific tasks, these armadas might go to various locations, discuss their results, and divide the labour between them. Distributed AI approaches are anticipated to be used for modelling, routing, resource development, networked fault detection, and coordination of the constellation's components.

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