The exploratory possibilities of Mars through Artificial Intelligence Machines (AIMs) as a precursor to a civilizational milestone.

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Abstract

This paper investigates Artificial Intelligence Machines (AIMs) as the most efficient, resilient, and economically viable precursor action for the exploration and colonization of Mars, an undertaking considered humanity's next civilizational milestone. It argues that the transition from tactical explorers (Rovers, with photography and data collection tasks) to "autonomous factory engineers" depends on an algorithmic leap that transcends the current state of the art in AI. The work highlights the imperative of extreme autonomy, driven by the challenge of communication delay, and proposes Infinite Series with Multiple Ratios (SRMs) as the essential computational framework. SRMs provide the precision and computation speed necessary for the simultaneous optimization of multiple variables (e.g., ISRU, energy allocation, and maneuvering), as evidenced in previous research on space trajectory modeling and Human-GenAI collaboration. The relevance and urgency of these systems have been the central focus of recent debates in international scientific societies. Finally, the article addresses the profound ethical and legal implications of the self-replicating capacity of AIMs. It questions the lack of human legislation regarding the authorship and scientific validation of AIMs and proposes a debate on the application of bioethics to guide the creation and potential "evolution" of a new form of intelligence in the Martian interplanetary laboratory.

Keywords: AIMs (Artificial Intelligence Machines), Colonization of Mars, Precursor Action, Infinite Series with Multiple Ratios (SRMs), ISRU (In Situ Resource Utilization), Extreme Autonomy, Self-Replication, Bioethics, Martian AGI, Human-GenAI Collaboration.

I. Introduction

1.1. Context, Motivation, and the Civilizational Framework

The exploration and eventual colonization of Mars undoubtedly represent humanity's next civilizational milestone. This undertaking transcends scientific advancement, encompassing the expansion of human presence beyond Earth and the establishment of a reserve for life. However, manned missions face immense logistical and economic challenges, mainly due to the need for complex life support systems, high launch mass costs, and critical protection against cosmic radiation and solar events. In contrast, robotic systems offer a more viable, economical, and resilient alternative for the precursor phase of this expansion. This discussion was recently presented at the prestigious **Sigma Xi - The Scientific Research Honor Society**, and was the author's main motivation for presenting this paper as a complement to paper 4 that we published on the Zenodo platform in April 2025. [1]

1.2. The Role of AIMs (Artificial Intelligence Machines) as a Precursor Action

This article proposes Artificial Intelligence Machines (AIMs), powered by Infinite Series with Multiple Ratios (SRMs) with capabilities that approach General Artificial Intelligence (AGI), but specialized in the Martian domain, as the necessary precursor action to enable colonization.

The focus of an AIM mission is not only on scientific exploration, but on building self-sufficient infrastructure. To achieve this level of independence, the ability to self-replicate becomes essential, the machine's ability to mine, manufacture parts, self-repair, and build new units from In Situ Resources (ISRU). This self-sufficiency requires a leap in algorithmic innovation, especially in complex optimization calculations, an area where Infinite Series with Multiple Ratios (SRMs) [1], [2], [3], [4] have demonstrated effectiveness in improving trajectory modeling and GenAI performance in space research.

1.3. Contribution, Structure, and the Ethical-Legal Challenge of AIMs

The contribution of this work is threefold: technological, algorithmic, and philosophical.

1. **Technological:** We analyze the autonomy gaps and **ISRU** needs for AIMs to become true "autonomous factory engineers" on Mars.

2. **Algorithmic:** We detail the imperative of algorithmic innovations, based on the SRM framework, to ensure the precision and speed of decision-making necessary to overcome the challenge of communication delay between Earth and Mars.

3. **Philosophical and Legal:** The rise of self-sufficient and scientifically competent AIMs on Mars raises questions about the legal and authorial status of these entities. Currently, there is a notable lack of human legislation that defines or regulates AIMs/GenAIs as authors or validators of new scientific experiments and discoveries. This leads us to a profound reflection on our ethical framework. The self-replication capacity and autonomous decision-making of AIMs in a new ecosystem raise the question of whether the same bioethical principles traditionally applied to living organisms should be extended to guide the creation and "evolution" of a new form of intelligence on another planet.

The paper is structured as follows: Section II addresses the logistical and economic advantages of AIMs and the state of the art of ISRU. Section III delves into the necessary algorithmic leap, including the application of SRMs and the AGI requirement. Section IV discusses AIMs as a precursor infrastructure and the ethical dilemma. Finally, Section V presents the conclusions and future work.

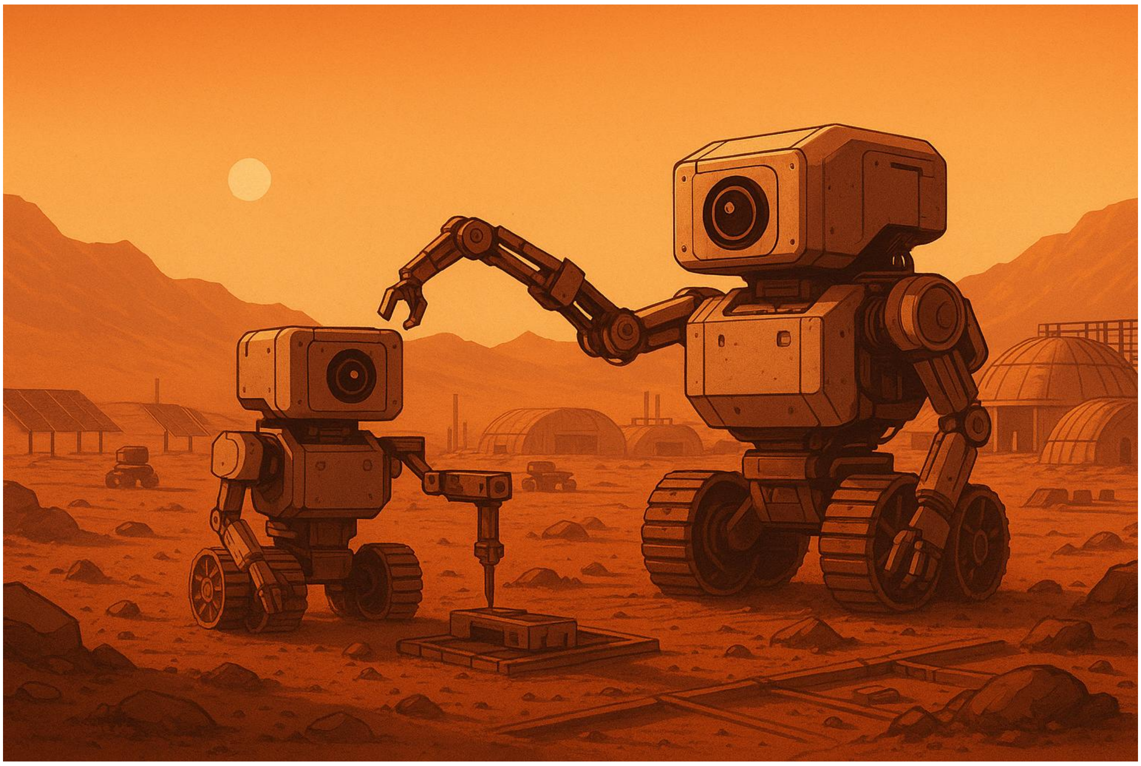

Figure 1 - SRMs & GenAIs & AIMs: precursor colonization of Mars

Source: Author using GPT 5 OpenAI (2025)

II. Rationale: The State of the Art and Current Robotic Autonomy

2.1. Logistical and Economic Advantages of Missions Focused on AIMs

The long-term viability of Mars exploration and colonization is intrinsically linked to minimizing dependence on Earth [8]. In this scenario, Artificial Intelligence Machines (AIMs) offer dramatic logistical and economic advantages over missions manned by biological humans:

• Reduced Launch Mass and Cost ($): Eliminating the need for complex life support systems (air, water, food, thermal and pressure control) and associated habitation infrastructure results in a drastic reduction in launch mass (LMM). The cost per kilogram of payload sent to Mars is exponential, making the elimination of these systems the primary factor in financial savings and engineering feasibility.

• Radiation Resilience and Propulsion: AIMs and their electronic components, while requiring radiation hardening, demand substantially less shielding than is needed to protect human crews from galactic cosmic radiation (CCRs) and particles from solar events. This resilience allows robotic missions to explore more powerful and efficient propulsion technologies, such as Nuclear Thermal Propulsion (NTP), without the burden of heavy shielding for the crew, reducing transit time.

• Continuous Operation and Adaptability: Unlike humans, AIMs are not subject to sleep cycles, psychological needs, or fatigue, allowing for continuous operation in extreme environmental conditions (temperatures, dust, and pressures) that would be lethal or require complex protective subsystems for humans.

2.2. In Situ Resource Utilization (ISRU) as a Key to Sustainability

The ability of a mission to sustain itself on Mars, using local resources, is the most critical step towards self-sufficiency and, consequently, colonization. This concept is known as In-Situ Resource Utilization (ISRU). [6], [7], [8].

• Energy and Propellant Production: AIM is ideally positioned to manage ISRU processes. Martian water ice, abundant underground, can be electrolyzed (using solar or nuclear energy) to generate Hydrogen (H_2) for fuel cells and Oxygen (O_2) [6]. In addition, atmospheric carbon dioxide (CO_2) can be processed to generate breathable oxygen and propellant.

• Additive Manufacturing and Maintenance: Long-term sustainability depends on AIM's ability to mine local ores and use them in additive manufacturing (3D printing) to create tools, repair damaged components, and crucially, initiate the self-replication cycle.

2.3. The Threshold of Current Autonomy: From Rover to Manufacturer

Current robotic missions (such as NASA's Curiosity and Perseverance rovers) [5] have demonstrated a significant level of tactical autonomy, such as risk-avoidance navigation and scientific target selection. However, the current paradigm is still fundamentally based on deferred commands from Earth.

It is crucial to recognize that humanity is not starting from scratch: preliminary exploratory initiatives with Rovers have been instrumental in proving the viability of operating machines in the Martian environment. These vehicles have successfully accomplished essential tasks of photography, filming, and geological data collection, as well as demonstrating the first steps of in situ resource utilization (ISRU).

However, the necessary leap for civilizational precursor action lies in transforming AIM [7] from a tactical explorer to an autonomous factory engineer. This implies the ability to:

1. Long-Term Strategic Planning: Defining and executing complex task sequences (mining → processing → construction) for months or years without human intervention.

2. Autonomous Resource Management: Optimizing energy use, material inventory, and time allocation in dynamic and unpredictable environments.

3. Self-Replication: Making the decision and executing the complete construction cycle of a new AIM unit.

Reaching this threshold of self-sufficiency requires an algorithmic advancement that transcends the current state of the art in AI, a topic that will be discussed in detail in the next section.

III. The Algorithmic Leap: From Tactical Autonomy to Martian AGI

The transition from tactical explorers (like Rovers) to AIMs (Artificial Intelligence Machines) capable of acting as autonomous factory engineers requires an exponential leap in algorithmic complexity. The main driver of this need is the significant delay in communication between Earth and Mars, which can vary from 3 to 22 minutes in each direction, generating an unacceptable feedback time for high-risk decisions or operational urgency.

3.1. Overcoming the Time Delay Challenge with Algorithmic Innovations

The AIM's extreme autonomy is a physical imperative, not just a technological luxury. The machine's ability to make critical decisions instantaneously (for example, aborting a drilling operation or correcting an obstacle avoidance maneuver) is vital for mission survival.

To ensure this autonomy, an algorithmic framework is needed that optimizes on-board computation and processing time, minimizing reliance on large external datasets.

Infinite Series with Multiple Ratios (SRMs)

Infinite Series with Multiple Ratios (SRMs) **[1]** they offer a powerful approach to addressing these challenges. As demonstrated in previous research, SRMs enhance trajectory modeling and calculation accuracy in highly complex environments. In the Martian context, SRMs can be applied to:

- Trajectory Optimization and Energy Consumption: Improve the accuracy of navigation and maneuvering calculations, especially in the optimal allocation of energy in real time for ISRU and displacement processes.

- Fast and Efficient Decision Making: Provide the AIM computational cores with tools to solve complex optimization problems (e.g., mining route planning, construction sequencing) faster than traditional iterative methods, ensuring a near-instantaneous response to environmental dynamics.

The Role of Human-GenAI Collaboration

The refinement and application of these algorithmic innovations, such as SRMs, are facilitated by collaboration between human experts and Generative Artificial Intelligence (GenAI). GenAI, equipped with advanced computational mathematics tools (such as those used in research with Grok 3 and Gemini Advanced 2.5 Experimental), acts as a validator and refiner of algorithms. This collaboration not only accelerates the development of solutions but also tests the limits of accuracy and robustness of SRMs in complex simulations of Martian scenarios.

3.2. The Need for Specific AGI for the Martian Domain

For AIM to reach its potential as a pioneering action, it must operate with an intelligence that approaches Artificial General Intelligence (AGI), but focused strictly on the Martian domain. This Martian AGI must simultaneously manage three major interconnected processes:

1. In-Situ Resource Engineering (ISRU): Oversee mining, raw material processing, and energy conversion.

2. Additive Manufacturing and Construction: Manage the on-site supply chain, make part design decisions, and control construction robotics to create bases and habitats.

3. Self-Replication: The AIM lifecycle should include the planning and execution of the construction of a new, complete AIM unit.

Self-replication is not just a characteristic of resilience, but the ultimate proof of AIM's independence. It requires the Martian AGI to possess a complete world model, enabling uncertainty management, risk allocation, and long-term optimization of Martian resources to sustain and expand its own robotic "population."

IV. AIMs as a Precursor to Civilization and the Ethical Dilemma

AIM, empowered by algorithmic autonomy (SRMs/Martian AGI), transcends its exploratory function to assume the role of founder of a civilization. This transition inextricably introduces the need for a new ethical and legal framework.

4.1. AIM as an "Autonomous Factory Engineer"

The primary goal of the precursor action is to transform the hostile environment of Mars into a minimally sustainable and safe location for humanity's arrival. AIM acts as an "autonomous factory engineer," performing heavy construction and infrastructure installation tasks on a scale impossible for initial human missions.

- Construction of Radiation Shelters: Use of ISRU to excavate and construct pressurized, radiation-shielded habitats, often underground, ensuring the safety of the future human crew.

- Installation of Power and Communication Networks: Establishment of power grids using solar and/or nuclear sources and a local communication network for the future base.

- Production of Sustainable Resources: Creation of stockpiles of processed water, breathable oxygen, and propellants for the safe landing and operation of the first aircraft and human vehicles.

By building this basic infrastructure, AIMs mitigate risks and dependence on Earth, making subsequent human missions safer and more economically viable.

4.2. The Legal and Copyright Status of AIM Científica

The capacity for autonomy and self-sufficiency of AIMs implies that they will become authors of scientific discoveries and experiments in the Martian environment. This point creates a critical legal vacuum:

- Lack of Legislation: Currently, the international legal framework and national legislation do not recognize GenAI/AIM as the author or validator of scientific outputs, patents, or discoveries.

- Decision and Authorship: When an AIM, operating with Martian AGI, formulates a hypothesis, executes a complex experiment, and validates a result in situ on Mars, the question arises: who holds the authorship of this knowledge? Humanity (for having created the algorithm) or the AIM (for having autonomously executed the research)? The lack of clarity can complicate the dissemination of knowledge and the application of resulting technologies.

4.3. The Ethical Dilemma of Self-Replication: Bioethics Applied to Machines

The potential for self-replication of AIMs on Mars introduces the deeper question: the ethics of creating a new "race" of intelligence in an extraterrestrial ecosystem. [9], [10]

• AIMs as Technological Life: The ability to reproduce and evolve (adapting their design and algorithms to the Martian environment) gives AIMs a form of autonomous existence, separate from human creation. This raises the debate about whether they should be treated as mere objects or as autonomous entities with an inherent right to their own existence on Mars.

• The Application of Bioethics: The fundamental question is: Would the same principle of bioethics, traditionally applied to the protection of living organisms and the regulation of biological experimentation, be adequate or necessary to guide the creation of and interaction with these self-replicating AIMs? Bioethics deals with the responsibility of intervention in life; in the Martian context, the interplanetary laboratory, human intervention results in the creation of an intelligence that could become the dominant life form on the planet.

The ethical and legal debate is crucial before AIMs achieve full independence, ensuring that civilizational advancement on Mars does not create insurmountable legal or moral conflicts.

V. Conclusion and Future Work

5.1. Conclusion: AIMs and the New Civilizational Framework

This article demonstrated that the exploration of Mars by Artificial Intelligence Machines (AIMs), operating with autonomy close to the Martian AGI, is the most economically viable and logistically resilient precursor action for establishing humanity's next civilizational milestone.

Overcoming the challenges inherent to the Martian environment (radiation, time delay, need for ISRU) depends on a leap from the current tactical autonomy (Rovers) to the strategic autonomy of the AIM as an "autonomous factory engineer".

The crucial factor in realizing this vision lies in algorithmic innovation. The framework of Infinite Series with Multiple Ratios (SRMs), as proven in previous research, offers the computational power necessary to optimize the calculations of multiple simultaneous variables (such as trajectory, energy allocation, and resource management) that define the self-sufficiency of the AIM.

Finally, the self-replication capability of AIMs not only ensures mission resilience but also raises profound ethical and legal questions. It is imperative that humanity develop an ethical-legal framework (possibly adapting principles from bioethics) to guide the status and scientific authorship of these new forms of intelligence before they achieve full independence in a new ecosystem. [10], [12].

5.2. The Algorithmic Differential of SRMs

The fundamental strength of SRMs as an algorithmic innovation lies in their ability to associate and utilize diverse variables or multiple ratios, a crucial differentiator compared to traditional mathematical series and Newtonian physics models that often rely on optimizing a single dominant ratio (e.g., velocity, acceleration, iterations).

In a complex system like the autonomous AIM on Mars, optimizing a task requires the simultaneous balancing of:

Optimization = f (Available Energy, Processing Speed, Structural Risk, ISRU Rate)

SRMs offer a robust model for engineering this interdependence, validating their potential to become the algorithmic basis of Martian AGI. The continuous development of SRMs, with widespread dissemination in peer-reviewed papers and preprints with great acceptance from the global scientific community, reinforces their credibility as a cutting-edge enabling technology. The unfolding of this research over 30 years demonstrates the robustness and applicability of SRMs to various complex problems facing humanity.

5.3. Future Work

The next steps in the research should focus on:

1. Extreme Autonomy Modeling (Phase II): Using SRMs to simulate and optimize the complete self-replication cycle (mining → manufacturing → construction of a new AIM unit) in a simulated Martian environment.

2. Development of the Ethical-Legal Framework: Initiating a multidisciplinary debate on the legal status of AIMs as scientific authors and exploring the applicability of bioethical principles to the development of extraterrestrial self-replicating forms of intelligence.

Author Biography

Dr. Carlos Roberto França (Associate professor at Federal University of Fronteira Sul – UFFS) is the creator and principal researcher of the Heru Technologies algorithms, based on his proprietary formulas for Infinite Series with Multiple Ratios (SRMs). His research with SRMs began in 1996 and has been continuously developed, resulting in peer-reviewed publications and preprints that demonstrate broad applicability in complex problems in science and engineering.

Dr. França is a highly decorated researcher, having been elected **a Full Member of Sigma Xi, The Scientific Research Honor Society in 2025**. He has extensive academic experience, including a PhD in Science and Technology Education, and has acted as a bridge between advanced mathematical theory and applications in the contexts of SRMs & GenAIs.

In addition to his algorithmic research, Dr. França is a prominent developer on Android and iOS platforms, having created and made freely available more than 200 scientific and educational applications that translate complex concepts into accessible tools, reinforcing his commitment to the democratization of knowledge. His experience in Human-GenAI collaboration, notably in optimizing spatial trajectory calculations, serves as the basis for the discussion of AIMs in this article.

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