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Empirical Research Paper

Tackling sustainable development goals through new space

Stewart R. Clegg [a,*], Miguel Pina e Cunha [b], Aníbal López [c,g], Emir Sirage [d], Arménio Rego [e,f]

[a] The University of Sydney, School of Project Management and John Grill Institute for Project Leadership, 21 Ross St Forest Lodge, NSW, 2037, Australia
[b] New University of Lisbon Nova School of Business and Economics, R. da Holanda 1, 2775-405, Carcavelos, Portugal
[c] New University of Lisbon Nova School of Business and Economics Library, R. da Holanda 1, 2775-405, Carcavelos, Portugal
[d] AIR Centre, Canada de Belém sn, 9700-702, Terra Chã, Portugal
[e] Universidade Católica Portuguesa, Católica Porto Business School, Portugal
[f] Business Research Unit, Instituto Universitário de Lisboa (ISCTE-IUL), Lisboa, Portugal
[g] Lisboa University – ISEG, Lisbon School of Economics and Management, Management Department, ADVANCE/CSG, Portugal

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ABSTRACT

Achieving the UN's Sustainable Development Goals (SDGs) constitutes a formidable challenge. Existing solutions may be insufficient to respond to the scale and scope of the endeavour. The 17 SDGs are not discrete but interconnected, sustained by 169 targets. Their cross-level effects require the adoption of a panarchical view of data. New Space projects, still unfamiliar to many managers and organizations, provide such data related to grand challenges capable of addressing the paradoxes that arise from the interaction of a system of systems of multiple scales of spatiality, temporality and social organization. To address these requires project managing developing capabilities that can connect everyday interventions in terrestrial economy and society with high level data findings from Geospatial Information Systems. We contribute to the SDG debate through the articulation of three streams of literature that may radically revise the way wicked problems are addressed: panarchy, paradox, and New Space.

1. Introduction

In an earlier paper in this journal, Whyte et al. (2022) suggested the need to develop a new agenda for project leadership, which they dubbed socialized leadership, focused on researching three interrelated areas. These areas were changing technologies, increased organizational complexity and ecological concerns. In this paper we develop the agenda for researching these interrelated areas further, by considering the latest developments in what is referred to as 'New Space'. New Space is characterized by increasingly private/commercial participation activities in the space sector. Peeters (2018) offers the following definition of New Space as "Private companies, which act independent of governmental space policies and funding, target equity funding and promote affordable access to space and novel space applications."

The significance of these new developments is not just technological. Aspects of these commercial endeavours in space link with the pursuit of the United Nations (UN) Sustainable Development Goals on Earth. The goals were first specified in 2015, when the UN adopted a set of ambitious Sustainable Development Goals (SDGs) in the framework of the 2030 Agenda for Sustainable Development (https://sdgs.un.org/goals). These grand challenging goals aim to address, over fifteen years, the world's most pressing challenges, such as ending poverty, ensuring prosperity for all and protecting the planet. The grand challenges confronting the Anthropocene (Heikkurinen et al., 2021), promulgated in the SDGs, have recently been reconfigured to accommodate the contribution of space science, technology and data (UNCTAD, 2021).

The significance of our contribution is in focusing on the benefits of multiple conversations between diverse disciplines, in a transdisciplinary exercise, about the organization of New Space and its implications for life on Earth. We aim to respond to this challenge by contributing to the literature on grand challenges at the intersection of diverse literatures. There are separate literatures on New Space, project leadership and change that need to be connected in relation to the need for a radical revision of sustainability theory as a lens for social action (Jarzabkowski et al., 2021). The consideration of the role of New Space solutions and the panarchical level is part of the radically revised orientation required. In terms of the latter, many of the sustainable development goals can be tackled by using complex space-based

* Corresponding author.
E-mail addresses: stewart.clegg@sydney.edu.au (S.R. Clegg), miguel.cunha@novasbe.pt (M.P. Cunha), anibal.lopez@novasbe.pt (A. López), emir.sirage@aircentre.org (E. Sirage), arego@ucp.pt (A. Rego).

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low-orbit satellite technology capable of providing pinpoint geo-spatial data mapping and data on terrestrial changes in climate and ecology; however, these technologies must communicate data in ways that end-users can make sense of and apply in practice, especially for those traditional custodians of the land in indigenous communities, often remote from sophisticated metropolitan devices, knowledge and ways of thought. Space projects can be game changers, 'transition projects' (Sharma and Bansal, 2020) or 'vanguard projects' (Gasparro et al., 2022), that can use emerging New Space technologies developed to allow commercial activities in the space sector to orient to the SDGs and their management indigenously.

Multiple connections are required for dynamically complex and lengthy networks. Where science in space meets indigenous knowledge on Earth, the likelihood is that structural holes (Burt, 1992, 1994) in networks will need to be bridged. Structural holes can indicate the presence of persistent tensions in bridging; tensions that can sometimes be paradoxical (Gaim et al., 2022a,b; Cunha et al., 2021), especially in connecting different conceptions of time and space (Van der Byl and Slawinski, 2015). Bridging requires assemblages of collective actions, action nets, connected to one another because they are necessary to accomplish a goal that lies outside the present order (Czarniawska, 2004; Lindberg and Czarniawska, 2006). SDGs require actions nets, especially where structural holes exist between the relations of power and knowledge (Clegg, 2023) that are to be conjoined in sustainability projects. These issues of New Space and SDGs have barely begun to be addressed by writers on project management (Harridon et al., 2021).

We will explore an important theoretical gap connecting the space, sustainability and project literatures by asking *what is the potential role of New Space technologies in achieving SDGs and how might panarchical project leadership create actions nets to bridge structural holes in power and knowledge*? We will proceed to address the research question by structuring the article in three core sections. We will briefly introduce the literatures on New Space and SDGs that we draw on and to which we contribute. We will discuss the need to consider the panarchical nature of projects tackling SDGs, the paradoxical tensions they raise and how the structural holes of relational power and knowledge that define these tensions need to be bridged by action nets. First, we discuss the meaning of New Space to elucidate its contours and promise. Next, we briefly outline how action nets can link SDGs and the affordances of New Space. We go on to consider some paradoxical features in developing action nets that can bridge structural holes in power and knowledge in relation to sustainability. There have been many discussions of sustainability in recent years in project management (for instance, Sabini and Alderman, 2021) but surprisingly few studies have embraced a panarchical inter-organizational, systems-level approach to SDGs (Carmine and De Marchi, 2023). SDGs articulate multiple levels of analysis requiring a cross-level view because effective solutions for one level can have problematic effects at other levels. Where multiple connections and interests exist between participants in a process, it opens the possibility of contradictions that imply finding integrative solutions to complex problems, the focus of paradox thinking (Smith and Lewis, 2022) in management. Where these paradoxes relate to bridging the dense technical knowledge of New Space data in such a way that it can contribute to indigenous practices of care for country, then the value of socialized leadership becomes evident.

1.1. New space and SDGs

The United Nations recognized that "space science, technology and data have the potential to contribute in direct or indirect ways to all of the Sustainable Development Goals" (UNCTAD, 2021, p. 1). UNCTAD's (2021) report enunciates the importance of New Space technologies for achieving SDGs and its targets but shows that conceptual development of the project management and organization required is less developed. The space sector is commonly divided in two segments (OECD, 2014) – upstream and downstream – each with its collection of organizations serving the needs of distinct groups and market niches. The upstream segment entails fundamental and applied research with related support activities, comprising manufacturers of space hardware and the suppliers of launch services (Brennan et al., 2018). The downstream segment deals with space operations for terrestrial use and produces services which rely on satellite technology (e.g., Earth observation data, satellite broadcasting, telecommunications). It is the latter area, New Space (Paikowsky, 2017), that constitutes the concern of this paper in relation to the achievement of sustainability.

New Space refers to an ecology of relatively new commercial aerospace companies working independently of governments and their institutional contractors, funded by risk capital to develop faster, better, cheaper and easier spaceflight technologies, with the designers and advocates of associated programs forming an essential part of the ecosystem (Davidian, 2020a,b; Weinzierl et al., 2022). New Space promises radical technological innovation, especially through hardware cheapening and miniaturization afforded by wider access to open satellite data (Vidmar, 2020). Organizationally, New Space projects comprise flat and open organizations using agile approaches to project management in developing the hardware (Campos and Ferguson, 2021). The technological miniaturization of satellites and their diminishing fixed price, which is no longer costed on a plus price model, allows project management that is "more inclined to take risks, to perform technological demonstrations while in service" (Miranda et al., 2019; Garzaniti et al., 2019). The space launch vehicles used are small, vertically integrated devices, produced fast and entrepreneurially (see Thomas, 2021). Increasingly, however, replicable modularity in New Space projects design and speed in their iteration enables projects to be delivered fast in a replicable, agile, and modular manner, enhancing the chances of success while minimizing the costs of failure through accelerating opportunities for learning.

The agility of private ventures and the rapid experimentation permitted by their business models not only decreases the costs of space mission projects but also accelerates the creation and development of new technological solutions for sustainability on Earth (Gustetic et al., 2019). New Space transforms traditional state-based exploration projects to include projects with a commercial space exploitation focus. Privately ventured innovative projects have now become, in certain sub-sectors, the main suppliers of resources to state players. By accepting the regulations, rules and expectations enacted by governments, private projects gained market legitimacy, an essential resource for leveraging commercial interests and fostering venture growth (Zimmerman and Zeitz, 2002).

New Space technologies allow decision-makers at various levels to obtain information at a scale that may be critical to address grand challenges (for an illustrative list of possibilities see the appendix) that have not been systematically considered to date. The emergence of low-orbit commercial satellites, the data they daily map and the application of that data to specific grand challenges on Earth is not only a matter of a space-project workflow starting from assembly, integration, testing and flight but also involves data reception, processing, distribution and, most importantly, practice. Increasingly, converging boundaries must be crossed and conjoined between technology and sustainability (George and Schillebeeckx, 2021; Rejeb et al., 2022). The technological affordances of developments in New Space facilitate this convergence. Convergence requires the connectivity of five major domains of technology. These are space access, remote sensing, satellite data access and analytics, habitats and space stations, as well as beyond low Earth orbit (Weinzierl, 2018). Tackling *sustainability* challenges implies timely and reliable access to environmental data and information obtained at different scales that is made applicable in practice by non-technologists on Earth.

Remotely sensed Earth observations (EO) obtained from satellites are sources of information useful in practice, providing opportunities to measure and track deforestation, sustainably managed natural resources, as well as prevent or mitigate the effects of catastrophes and predict and respond to climate change (Estoque, 2020). Increasing availability of EO data and processing, via the integration of space and digital technologies, allows collection and interpretation of information over time (Giuliani et al., 2020), in some cases, in near-real time. These resources provide scientists and decision-makers with multi-level evidence of problems and urgent needs. As we will argue, these have to be translated into various forms of terrestrial practice and knowledge.

New Space technologies are essential to support SDGs (e.g., Anderson et al., 2017). Being able to visualize, monitor and forecast natural and human activity on the planet has direct and meaningful consequences in terms of measuring impacts on key indices of planetary and localized sustainability. As an example, the International Space Station (ISS) has been used to monitor global climate, ecological and environmental change, as well as natural disasters via a unique complement of crew-operated and automated Earth observation platforms (ISS National Laboratory, March 2020). Non-space industry, such as agriculture (e.g., smart farming) is using satellite data for crop management with reduced consumption of resources, such as water. New Space geospatial data is pushing the digitalization of commoditized sectors, therefore advancing innovations in technological areas such as cloud computing, big data and artificial intelligence.

New Space's contribution to SDGs includes the potential to provide demographic, statistical and environmental data to monitor and measure SDGs targets and indicators (UNOOSA, 2018). Space technology has become an integral tool in the successful achievement of SDGs (Anderson et al., 2017) and the United Nations (UN) has recognized its potential for sustainable development of the planet since the early days of international space law (Verspieren, 2019). The recent UNCTAD report emphasizes how space technologies matter for several aspects related to SDGs, such as food and agriculture, health applications, access to telecommunications in sparsely populated rural or remote areas, disaster risk reduction and humanitarian crises, natural resources and environment management as well as reduction of poverty. Space technologies, by virtue of the data and information they can harvest, can create transformative new solutions to the problems posed by the achievement of the SDGs, as elaborated in the context of the United Nations Office for Outer Space Affairs (UNOOSA; unoosa.org).

The challenges emanating from how New Space contributes to achieving SGDs are more than technological; they involve multiple actors collaborating at different levels and across disciplinary projects, representing a significant challenge (Urton and Murray, 2021). By their very nature, grand challenges demand more than single-level incremental approaches; they require considerable organizational complexity requiring the adoption of a grand scale perspective (Anderson et al., 2017). Such a perspective must increasingly be able to address dynamic systems of systems (Sankaran et al., 2020). Examples of such systems have been labelled as super-high tech (Shenhar, 1993) or as super global projects (Krichevsky, 2018). These not only present inherent technical and innovation challenges but also demand a capacity to manage panarchically. The term "panarchical" was coined as an antithesis to the word hierarchical. A panarchy is "a *nested* set of adaptive cycles operating at discrete scales" (Holling, 2001, our emphasis). These systems, at different scales, are disjointed in time and in connections across space; they have scale regimes characterized as complex systems (Garmestani et al., 2009). Panarchy, as we use the concept, is a conceptual model encompassing complex systems of people, nature and technologies. In these complex systems. while people are actors, nature and technology are also vital actants, each acting on the others. Panarchy is dynamically organized and structured, as Allen et al. (2014) suggest, connecting adaptive cycles at small scales to adaptive cycles at large scales.

The connective tissue linking actors, actants and action in New Space ventures, is data gathered at large scale through New Space technologies to inform adaptive cycles of nature on Earth. To meet terrestrial SDGs sustainability on Earth requires a panarchical exercise in organizational complexity linking human activity to data derived from low orbit satellites about changing Earth conditions. Major ambitions, such as the EU's Green Deal or the UN Paris agreement (https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement) require innovative approaches and demand considerable technological and coactive capacity. Digital data derived from New Space technologies (Weinzierl, 2018) create the conditions for smart farming or agriculture 4.0 to be performed by actors on Earth as a response to the sustainability goals in the SDGs. Digital data affordances enable human actors to interact anthropocentrically in a positive way to the challenges of climate change on Earth by using data derived from space.

For these beneficial outcomes to be achieved, field workers must be able to work with digital data. For farmers and agricultural scientists to work with New Space data there is a need for projects that connect the two realms of knowledge of agriculture on Earth and data derived from space. To connect the two realms of knowledge, that terrestrially grounded in and on the Earth, with knowledge gleaned from data collected in space, panarchy must be able to connect extra-terrestrial technologies with user experiences that are, literally, on the ground. To some extent this is being achieved in what Sekine (2021, p. 49) has identified as a "limited number of elite farms [that] operate agriculture employing new technologies such as Internet of Things (IoT) and Artificial Intelligence (AI) and exporting their products to international markets" (Sekine, 2021, p. 49). Digital data makes possible precision agriculture that combines agronomic sciences, sustainability, automation and the New Space industries (Gardezi and Stock, 2021; Medici et al., 2021). Perhaps more significantly, if the SDGs are to be achieved, then partnerships will have to be created, particularly in relation to sustaining Earth and its indigenous peoples. Different kinds of leadership than those to be found in the agribusiness sphere will be required if these relations are to be forged.

Managing sustainability projects related to New Space requires the development of organizational complexity that can connect the most sophisticated technologies with mundane practices of sustainability on the ground. Project managing such a stretch of potentially paradoxical relations between practices embedded in and on the Earth and those that sustain space orbiting satellites indicates a new direction for project management (e.g., Gaim et al., 2022a,b; Ika and Munro, 2022) that will invite scholars to reconsider the meaning of factors such as system complexity, scale, and risk (Green and Dikmen, 2022). Actors creating New Space technologies not only need to project manage the space mission; they must also be attuned to specific actors and projects on Earth that are situated at the heart of the grand challenges. Making these connections is "complicated by the multitude of actors with different strategies and skills, spread out along a fragmented value chain" (Ferretti et al., 2016) with whom connections need to be made. The chain stretches from internationally regional institutions to specific field sites of NGOs. For instance, the Global Land Ice Measurements from Space monitors the world's glaciers. As an example of their importance, over 1.9 million people rely on meltwater from Himalayan glaciers, spread across eight countries, from Afghanistan to Myanmar (Ritchie, 2021; Ahmed et al., 2021).

Monitoring data from space is one thing; implementing action in concrete projects in politically contested terrestrial spaces to achieve transboundary water management requires projects of a substantially different order. Space actants and the data derived from them, to be of material benefit, must form an action net (Lindberg and Czarniawska, 2006) with organizational actors on Earth. Such action nets will involve inter-organizationally related acting in temporary and loosely coupled relations in which the key objective is translation, in Latours' (1986) sense. Data must be translated into boundary objects (Star and Griesemer, 1989) connecting different realms and their different meanings in different social worlds managed to be exchangeable one to the other. Processes of translation are rife with tensions.

1.2. Action nets linking SDGs and the affordances of new space

Grand challenges imply multiparty collaborations across levels (local, regional, national, global). It is because different types of knowledge and a variety of interests are invoked, that such scale and scope can introduce tensions and contradictions. Sustainability agreements, for example, often generate governmental tensions between development goals and how achievement of the grand challenges of sustainability are to be delivered (Hahn et al., 2018; Jennings and Hoffman, 2021; Landrum, 2018; Schad and Smith, 2019). Any boundary spanning projects can confront project leaders with tensions between opposing elements, denoting the potential presence of paradoxes (Berti et al., 2021).

Electric, or e-vehicles, provide an example of tensions in practice. For instance, e-vehicles are clearly more sustainable in everyday use than are carbon-fuelled vehicles. However, the full tally of sustainability does not include only everyday use; it also includes end of life recycling (Orsatto et al., 2002).[1] Typically, the sustainability problems being addressed by SDGs are both micro and macro in their causes and consequences. Sustainability factors, such as water pollution and depleted fish stocks imply the consideration of information that may be accessible only by satellites and other new types of sensors (air, in-situ and others) (Klemas, 2013). Also, Earth Observation can play a critical role in the assessment and mapping of processes such as land degradation (Giuliani et al., 2020), fishing (Klemas, 2013), forest fires (Laneve et al., 2006; Verhegghen et al., 2016) and other processes with important consequences for the protection of the planet. Data enabled by space technologies adds analytics and insight for application to on the ground infrastructure. Information thus obtained may be important to reinvent the way industries operate, promoting domains such as precision agriculture (Cunha et al., 2022; Mulla, 2013), new mobility solutions (Enge et al., 2015) as well as increased levels of efficiency in the use of resources such as food, water, energy and time (Jacobson, 2020).

Enormous differentials of power and knowledge characterize the application of New Space technologies. End users can range from the most sophisticated scientific agriculturalists employed by global chains in the food system (Sage, 2012) to indigenous and traditional custodians of land colonized by white settlers. For instance, precision agriculture enabled by New Space technologies may advantage those already well-resourced while simultaneously marginalizing those without resources, in what Sage (2012, p. 205) has termed a ‘Faustian bargain’: “the provision of cheap food while turning a blind eye to its consequence”. Precision agriculture is an example of what the Royal Society (2009) has termed sustainable intensification, “a largely incremental, technology-driven and adaptive strand” (Sage, 2012, p. 204) of a prevailing technological paradigm. Agriculture is located within a food system comprising all those activities related to the production, processing, distribution, sale, preparation and consumption of food with complex relationships between different components (Sage, 2012). The food system feeds a global market in which there is demand for “a historically unprecedented abundance of cheap and convenient food choices for consumers in rich, middle-income and wealthy pockets of poor countries” (Sage, 2012, p. 205). By using space exploration, it can exploit the cultivation of nature more efficiently, through precision agriculture. Precision agriculture is the point at which extra-terrestrial systems meet terrestrial systems premised on contract production of agri-commodities in an unsustainably ecologically exploitative system oriented, especially, to livestock production of meat for global, not local, markets. New Space technologies may benefit the goals of managing both poverty and ecology but intervention in one may have negative impacts on the other.

Linking disparate elements into a co-active action net involves nested, embedded and ‘knotted’ tensions (Lindberg and Czarniawska, 2006), cutting across levels (e.g., individual vs collective), with different time horizons (e.g., short vs long term) and emergent unpredictable effects. Action nets can knot together networks that bridge structural holes in power and knowledge. Jarzabkowski et al. (2022) write of paradox knots where multiple co-occurring tensions may amplify attempts at bridging tensions. To knot an actor network coactively is essential to producing positive effects but the challenges in doing so are ample. Illustratively, the project of reducing poverty (SDG1) knots with many other SDGs, such as how the livelihoods of impoverished communities interact with local developments that have an impact on biodiversity and projects for its management and preservation.

With Ika and Munro (2022, p. 2) grand challenge projects can be characterised by “issues that are complex” and that “entail radical uncertainty”. They do not respect disciplinary boundaries (Ferraro et al., 2015) and in practice require coordinated and collaborative project work (George et al., 2016) as temporary initiatives addressing “wicked problems” that are “hard to describe, have many interrelated causes, no criteria for evaluating potential solutions, where actions to address the problem tend to cause more unanticipated problems and where defining the problem itself is as difficult as identifying potential solutions” (Clegg et al., 2022). Hence, “grand challenge projects are likely to be a messy mix of emergent problems, unintended consequences, cacophonous stakeholders voicing contradictory demands, changing technologies, evolving knowledge, and new and untried business models” (Ika and Munro, 2022, p. 3); in a word they are likely to be *paradoxical*, rich in persistent contradictions and competing demands. They are also grand in scale, hence difficult to grasp and to understand.

Williams et al. (2021) have noted the potential paradoxes involved in discussion of sustainability issues across scales. Paradox theory, as an overarching theoretical framework for understanding contradictions (Berti et al., 2021), can be applied to explain and manage system dynamics produced at the panarchical level, encompassing micro and macroscales (Kennedy et al., 2021). The tensions raised by sustainability (Hahn et al., 2014) are amplified by the scale and complexity of SDGs and their targets. Given the order of ambition and the temporal scales involved, the articulation of the macro (governments, international agreements or initiatives, global food systems) and the micro (local communities and actors) is necessary. The megaprojects literature (Wiewiora and Desouza, 2022) probably comes closest to elaborating a panarchical-paradoxical view of SDGs.

1.3. Paradoxes of putting new space into sustainability practice

Projects involving New Space technologies articulate multiple stakeholders across various sectors and scales, delivering novel and complex solutions that often require decision-makers to deal with persisting tensions to balance conflicting demands at different levels. Scholars have considered the existence of four main types of paradoxe: paradoxes of learning, belonging, organizing and performing (Smith and Lewis, 2022). We discuss four critical New Space SDG challenges corresponding to these paradoxes: simultaneity of exploration-exploitation (as a learning tension), multidisciplinary collaboration and translation difficulties (a paradox of belonging to different disciplinary domains), zooming in and out (organizing at different levels), and the conflict of logics and business models (contrasting views of performance and effectiveness).

1.4. Simultaneity of exploration-exploitation and project management learning

After an era of space exploration, there has emerged an important element of exploitation (March, 1991), with new start-ups using

[1] A reminder of the importance of this has recently come with an announcement by sustainable e-vehicle car company Polestar CEO Thomas Ingenlath. Recently, he was reported as saying “car companies alone should not be responsible for recycling vehicles and their components” (Butler, 2022), a statement that sounds paradoxical because sustainability must address not only the carbon footprint of a vehicle in use but also its ultimate disposal in a circular economy (Geissdoerfer et al., 2017). Who else other than manufacturers should be responsible for end-of-life recycling? Purchasers?.

commercial concepts such as the lean approach to devise competitive market solutions rather than projects led by national agencies. The past of space exploration, premised on long range planning, is now being complemented with successful attempts at agile commercial exploitation. The recent Axiom Mission ax-1, launched on April 8, 2022, from the Kennedy Space Centre in Florida, controlled from Axiom's Mission Control Centre MCC-A in Houston, Texas, is a prime example of exploitation rather than exploration. Axiom Space was founded in 2016 with the goal of creating the world's first commercial space station. The Ax-1 mission is the first part of a plan by Axiom Space to produce this space station, in a project in which the space station will be constructed onboard the International Space Station (ISS). Initially, a habitation module (Axiom Hub One) to be launched in 2024 will be built. The module will integrate with others in a complex that could subsequently grow to five pressurized modules with a large observation window, facilitating the company's activities in Low Earth orbit (Axiom Space, 2020). The use of modular replicability enables project learning by creating a feedback loop to improve the delivery of one module after another. Project organizational learning occurs through feedback, something that is rarely useful when projects are one-off, as are most megaprojects, for whom project uniqueness is often a shield against learning. As Flyvbjerg (2021) notes, modular replicability is more adequate and agile than long-range planning. Replicability is conducive to experimentation with successive modules and the faster the iterations, the more is learnt and the more efficient the exploitation of innovations.

Many different forms of mission are projected for Axiom, amongst which are Earth observation activities contributing to analysis of the impact of climate change, urbanization, and other factors on the ecology and human habitation of North America. What is of interest for socialized leadership in these projects is the way that their action net extends from New Space into coactive partnership with indigenous peoples managing land of which they are the traditional owners. An example is a Royal Canadian Geographical Society program into the environmental health and sustainability of the Great Lakes and their ecosystem promotes conservation, restoration, protection, and reconciliation of the water and the land with the Indigenous peoples of the watershed. The exploration involved using the Ax-1 mission to collect pinpoint terrestrial data and to share the knowledge gained with indigenous leaders. On October 19, 2022, the RGS hosted a talk between a Mission participant, philanthropist Mark Pathy, with indigenous leaders (https://www.facebook.com/RCGS.SGRC/). Such action nets are essential to achieving both exploration and exploitation: the exploration occurs in space, while the exploitation of knowledge learned can only take place through the actions of the traditional custodians of the land and water. This is an example of adopting both-and thinking (Smith and Lewis, 2022) that is characteristic of successfully managing organizational paradoxes (Gaim et al., 2022a,b): both the exploration and the exploitation are being project managed in an action net connecting end users with the explorers. Socialized leadership on this scale needs to connect panarchically from the scientific heights of orbital technologies and the data they collect to the grounded practices of the traditional custodians of the land in the pursuit of sustainability. Between traditional indigenous knowledge and that of space technology there is a substantial structural hole (Burt, 2004) that action nets must attempt to bridge.

1.5. Multidisciplinary collaboration and difficulties with translation

While space exploration projects are technologically complex, their application on Earth requires translation across many assemblages of actors and their networks. For instance, satellite data *per se*, to be useful, requires the involvement of other stakeholders in the process (e.g., managers, big data analytics) in which highly technical discourses must be translated into terms that users can understand, respond to and apply. Important difficulties for translation are posed by the intersection of the three domains of space, sustainability, and business, creating a need for a common language spanning and interlinking domains with different ways of thinking as well as diverse histories and traditions (Sharma and Bansal, 2020).

Each domain brings different thought worlds, very different ways of thinking, as well as distinct bases of knowledge, with their corresponding vocabularies. Hofer et al.'s (2020) study indicated that people working in Earth observation and geographic information processes struggle to translate state-of-the-art projects in the industry into skills and business concepts. The authors stressed that "both parties [academics and industry] need to work in symbiosis and agree on a vocabulary of the domain (…) but also in terms of application fields" (Hofer et al., 2020, pp. 599–600; parenthesis added). These three domains require multidisciplinary forms of collaboration that cojoin and translate different vocabularies and knowledge repertoires into a mutually comprehensible language. Given that transdisciplinary encounters of this type are not necessarily smooth, integrating technical, business and sustainability project dimensions raises important challenges.

Some Engineering schools, such as the Lassonde School of Engineering at York University, Canada, are developing project-based learning that builds capabilities for coupling New Space projects and sustainability challenges. Students are designing, building, launching and operating a CubeSat mission in collaboration with remote indigenous communities in northern Canada to change power dynamics around water quality, giving communities direct control of data to measure their water quality and quantities (Newland et al., 2022). The example of socialized leadership in this instance seeks to bridge a structural hole, this time between remote indigenous people and university technology students, to create power relations in a coactive action net connecting traditional indigenous knowledge and practices with scientific data generated orbitally by satellite.

1.6. Zooming in and out

New Space technologies bring new possibilities for zooming out to obtain a synoptic view of the Earth. Yet the potential of those technologies needs to be articulated with first-hand, local knowledge. Addressing SDGs implies a combination of micro and macro views, when also addressing the underlying targets. Such articulation may be difficult to achieve but is of critical importance to bring together the benefits of technology with a deep understanding of local social conditions. Erikson's study (2018) illustrates the combination of big data zooming out and an ethnographic focus zooming in. Zooming will be multi-focal, combining big data, anthropological approaches, with an appreciation of engineering and environmental practices, to achieve sensitivity in interpreting cross-level effects. Tensions between different bodies of knowledge with their respective traditions, namely engineering and anthropology, require the integration of technical solutions and cultural embeddedness (Workman et al., 2021), confronting project leaders with the need to cultivate a multidisciplinary approach to projects. The development of a panarchical view to bridge the structural holes between the subjects of engineering and anthropology demands co-involvement of different forms of knowledge and a sensitivity to cross-level effects.

Zooming in is the weak link in the chain. The monitoring and performance evaluation of concepts and measures are crucial to managing behavioural changes in resource management. As Volk et al. (2022) note, citing Voskamp et al. (2021), Dar et al. (2021) and Ataman and Tuncer (2022), satellite-based Geographic Information Systems used for sustainable urban resource management have to consider the complex relation of many factors, including local ecosystems and community goals. Scientifically sophisticated tools need to be able to translate geospatial data into terms, practices and systems and/or services of sustainability that make sense to people lacking a sophisticated grasp of the sciences involved in their interpretation. In zooming in, what is crucial is translation capable of creating requisite local action nets that can extend scientific findings into the practice of everyday life.

The structural hole creating a divide in this instance is the lack of mutual knowledge. The divide is between space technologies and indigenous knowing that has largely been translated orally down through the generations and, where it has been recorded, has been largely done by anthropological ethnography. The question is twofold: can the engineering subjects speak and be understood by the anthropological subjects; can the anthropological subjects speak and be understood by the engineering subjects? As E.M Forster (2000) stated, the issue is to "only connect". Only connecting is at the heart of a panarchical organizational complexity that must reach from the firmament to the fundamentals of life on Earth.

1.7. Conflict of logics and project business models

A major obstacle to the development of a dynamic space industry is the amount of time that derives from stringent safety protocols, the huge complexity of procurement contracts (typically based on 'waterfall' project management models; see Clegg et al., 2021), a tendency to prioritize contracting by large established companies, often having bureaucratic structures and lengthy processes (MacCormack, 2004). For instance, one of the pillars of the European Space Agency (ESA) programs is that ESA is founded on geographical returns, investing in each Member State an amount broadly equivalent to each country's contribution through industrial contracts for space programs. To the extent that private ventures accept European institutional regulations and rules to enter the market, in the long run this bureaucratization might be at the expense of the value added by New Space industry, which is its agility.

Private ventures typically employ highly qualified engineers essential to developing high-quality technology that lack essential project coordination and management skills important to perform daily managerial activities. To remedy this, a business roadmap for project management of New Space technology in the European Union has recently been developed that eschews strict project management protocols and instead draws on strategic management to develop an approach that is more risk-taking and faster in developing industrial and technological capabilities, stakeholder, investor and talent management, acceleration of time-to-market technologies and a common EU policy (Rodriguez-Donaire et al., 2022).

Agile approaches, based on low-cost experimentation and open collaboration principles, are ways to develop cost-efficient solutions in niche areas, as well as to test new ideas and possibilities, as are opportunities for "seeding" the market by offering prizes, creating venture funds and knowledge clearinghouses, initiatives focused on small-medium enterprises as well as university-based research/prototyping team projects. Private missions need to develop ways of working around state institutional mechanisms' regulatory control of entrepreneurial energies (Davidian, 2020a,b; Peeters, 2003). In these instances, the action nets seek to connect the empty spaces, the structural holes, in institutional networks that seeding the market can connect. Socialized leadership in this instance consists precisely of devising bridging strategies that can connect actors that hitherto have not formed an action net.

In summary, the adoption of New Space technologies, however promising, involves a number of tensions that need to be addressed. For each of these four tensions, the crucial capability is the formation of action nets that build coactive relations between different forms of power/knowledge to create socialized leadership that bridges structural holes from both sides.

2. Discussion and implications

2.1. Discussion

While it is being increasingly recognized that project managers need to navigate multiple tensions inherent to projects (Farid and Waldorff, 2022), we have taken the debate one step further and considered that the scale and scope of tackling SDGs, when addressed by the contributions of New Space technologies, are so massive that they require integrated efforts at a panarchical level of collaboration. These will be supported by information about the "big picture" (Anderson et al., 2017, p. 83) or a synoptic view of Earth, in combination with local, ground-based infrastructures and knowledges. The advantage of New Space technologies to acquire and mobilize data in a way that will promote new uses of resources and new sustainable solutions and services must be grounded, literally. We need to bring consideration of New Space down to Earth, connecting extra-terrestrial and terrestrial systems in pursuit of the SDGs and its targets as an exercise constituting new competences in panarchical thinking that can envisage and enact action nets reaching and translating across scales, bridging structural holes.

SDGs are an example of a "poorly understood complex phenomena" (Sætre and Van de Ven, 2021, p. 32), which we have discussed in relation to an equally major conceptual domain, New Space. Advancing scientific knowledge of poorly understood phenomena is an effort that depends on the interactions of disciplinary communities. Our contribution provides an introductory attempt to call attention to the benefits of multiple conversations between diverse disciplines, in a transdisciplinary exercise, about the organization of New Space and its implications for sustaining Earth and its peoples. Our ideas are aimed at questioning and creating awareness about the potential of this articulation by facilitating conversation between different scientific disciplines, while acknowledging the difficulties involved in executing megaprojects (Ninan et al., 2021). These difficulties should not discourage us from exploring changes in project leadership (Whyte et al., 2022).

Work on sustainability tends to be inductive (Eisenhardt et al., 2016) and often focused on the micro-level (Preuss et al., 2021; for an exception see Heikkurinen et al., 2021). Future research may carefully investigate modularity and scalability and how action nets are constituted that connect panarchically across structural holes of power/knowledge. Various methodological approaches need to be used to study grand challenges and researchers defend the need to employ unconventional approaches, combining scales and research paradigms (Kistruck and Shantz, 2021), which we have done in this paper. The combination of scales is fundamental to developing understanding of coevolutionary dynamics across levels (Grewatsch et al., 2023).

2.2. Implications

The implications of our discussion to project leadership are threefold. First, we consider the importance of a space strategy, second the application of this to the specific case of SDGs, and third the importance of educating the workforce so that space is not viewed as something extraneous to companies. Regarding managers, especially senior managers, our discussion can be read as an invitation for executives in different industries to consider the space sector and its respective affordances as a new source of information and intervention. The space sector is no longer reserved for space companies but can be a source of solutions to be applied downstream, on Earth. In this sense, our discussion can be read as an invitation for executives to gain familiarity with the space sector. As noted by Weinzierl et al. (2022), companies need to have a space strategy for their core businesses. This is new and suggests that, in terms of space, large companies need a digital strategy. This leads to:

Working hypothesis 1: companies whose leaders are aware of space sector solutions develop more innovative strategies (broadly speaking).

Second, we invite leaders to think about SDGs as involving more than incremental fine tuning of existing operations. Tackling major problems cannot be pursued with current approaches. Therefore, thinking about new ways of addressing major problems must generate new solutions. The space sector is composing a portfolio of solutions that may be considered for obtaining better information to solve sustainability related problems. Some of these novel solutions have been used in war theatres in Ukraine and can be adopted for peaceful ends, including better use of our limited natural resources as well as to protect and regenerate ecosystems, to confront problems such as wildfires better and to respond to human needs, for example to use drones to transport medicines to unreachable areas.

Working hypothesis 2: companies whose leaders are aware of space sector solutions develop more innovative SDG approaches (strictly speaking).

The adoption of New Space solutions although potentially beneficial will raise doubts and resistance. Given resistance to change and the lack of information that still prevails regarding the space sector, which is still often viewed as non-relevant to other sectors, this is to be expected. For this reason, leaders will need to educate key people regarding the space sector. Projects that enable key actors to gain familiarity with the theme as well as to explore new possibilities may be considered. Lessons from digital transformation may also be useful. Of course, the two fields are significantly distinct but they both involve an element of transformation. This leads to our third working hypothesis:

Working hypothesis 3: Companies with space-educated workforces will be more open to adopt New Space-based solutions for SDG related challenges.

3. Conclusion

Leading projects in a changing world involves a combination of societal, technological, and environmental concerns (Whyte et al., 2022). We have addressed the uses of rapidly changing space technologies that engage considerable organizational complexity on a scale that we have characterized as panarchical. We have done this to address how ecological challenges can be tackled on Earth, concentrating especially on action nets bridging structural holes of power and knowledge. Some of these exist intra-organizationally, as organizational capabilities become attuned to the uses of New Space data that have not been considered previously. For panarchical project leadership, the challenge consists in the acquisition of competencies at the interface of New Space's technologically unapplied potential and its application to terrestrial problems. New competencies will need development, including a sensitivity to power/knowledge disparities and a facility in developing action nets. A major structural hole will be between some of the least powerful, indigenous peoples, and the custodians of extremely esoteric scientific knowledge embedded in space science. The challenge for theory and practice is considerable and the opportunities for learning great.

Declaration of competing interest

There is no conflict of interest.

Data availability

No data was used for the research described in the article.

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Appendix. New Space, SDGs: A paradox view (source: unoosa.org, with adaptations)

Goal	New Space contributions
1: No poverty	New Space technological solutions may contribute to poverty reduction in several ways: education, smart and sustainable agriculture. Mapping populated areas and their access to basic services (UNOOSA). Illustrative works: Schi et al. (2020); Zhao et al. (2019). Illustrative panarchical paradoxical challenges: Populations may resist technologies even if these technologies will potentially be beneficial.
2: Zero hunger	Space applications can be used to improve management of agriculture (smart farming for specific crops in export intensive countries) and impacting the availability of food. Illustrative work: Kogan et al. (2019). Illustrative panarchical paradoxical challenges: Technological possibilities must be combined with political conditions.
3: Good wealth and well-being	Space technologies have allowed the development of new products such as rechargeable cardiac pacemakers (Goodrich et al., 1987) as well as the production of new pharmaceutical solutions in space (Goodrich et al., 1989). The use of drones is also promising to deliver medicines to remote areas. Development and optimization of early warning systems for disasters prevention, risk reduction relating to the management of global health crisis. Illustrative work: Balasingam (2017). Illustrative panarchical paradoxical challenges: Telemedicine should not substitute but rather complement human contact and even traditional forms of medicine (which may increase resistance).
4: Quality education	As seen during the Covid-19 pandemic, remote access to education is a challenge in more isolated areas. The availability of internet coverage (free and reliable) in many areas of developed and developing countries is a human right (mainly for children) and is only possible with satellite-based internet, now in Low Earth Orbits. Illustrative work: Boylan et al. (2000). Paradoxical panarchical challenges: Standard contents may be diffused globally without acknowledging local knowledge.
5: Gender equality	The Office for Outer Space Affairs seeks to "bring the benefits of space to humankind. The Office for Outer Space Affairs is committed to ensuring that those benefits reach women and girls, and that women and girls play an active and equal role in space science, technology, innovation and exploration." (https://www.unoosa.org/oosa/en/ourwork/topics/spaceforwomen/index.html) Illustrative panarchical paradoxical challenges: Training in space disciplines, if male-dominated, may aggravate gender imbalance
6: Clean water and sanitation	The management of clean water implies the use of satellite remote sensing (Schaeffer et al., 2013) to monitor the restoration of water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes. Illustrative work: Klemas (2013). Illustrative panarchical paradoxical challenges: Extraction mentality coexists with restoration.
7: Affordable and clean energy	New, clean energy solutions (land solar power plants, off-shore wind energy plants, etc.) can be monitored by Space-enabled technologies, in combination with in-situ sensors, to better manage the energy yields to sustain populations and prevent the disruption of critical industry value-chains.

(*continued on next page*)

(*continued*)

Goal	New Space contributions
	Illustrative work: Stokes and Seto (2019). Illustrative panarchical paradoxical challenges: Incumbents may lobby in favour of the status quo.
8: Decent work and economic growth	The convergence of New Space and digitalization may be a source of economic growth and job enrichment. Automation of simple repetitive tasks may liberate people to do more creative work as reflected in jobs market trends on the US. Illustrative work: Deming (2017). Paradoxical challenges: decent work may coexist with massive job loss resulting from technological advances including in New Space.
9: Industry, innovation, and infrastructure	New Space combined with digitalization are components of a fourth industrial revolution (industry 4.0), in progress. This revolution may bring new impetus to economic growth. Illustrative work: Carou (2021). Illustrative panarchical paradoxical challenges: Revolutionary practices coexisting with traditional management logics.
10: Reduced inequalities	New Space may contribute to reduce inequalities by giving people access to education by connecting people in isolated areas; remote participation in democratic processes. Illustrative work: Boylan et al. (2000). Illustrative panarchical paradoxical challenges: New Space technologies may liberate but also favour panoptical control.
11: Sustainable cities and communities	The development of new forms of urban planning, mobility, settlement and transportation must be done combined with several external factors. Due to climate change, one of the most challenging problems affecting our coastal communities is the increase of floods to extreme natural hazards. Therefore, space-ocean based entrepreneurs and the scientific community are developing near-real time applications to forecast, prevent and monitor these events. Illustrative work: Wang et al. (2020). Illustrative panarchical paradoxical challenges: Mobility technologies may become control tools.
12: Responsible consumption and production	Responsible consumption can be supported by tracing of the product life cycle since its origins. This can be useful for several applications including use of forced labour as well as sourcing of materials from protected areas. Illustrative work: Whitcraft et al. (2019). Illustrative panarchical paradoxical challenges: Business case mentality prevails above sustainability
13: Climate action	For example, the EU Earth Observation programme - Copernicus (a constellation of Earth Observation satellites) has a Climate Change Service (C3S) that continuously monitor Earth's Climate and its evolution by providing key Essential Climate variables (temperature, sea-ice, CO_2). There are other international climate monitoring programs from other space-faring nations. Illustrative work: UNCTAD (2021). Illustrative panarchical paradoxical challenges: Political divergence may neutralize the gains of New Space technologies.
14: Life below water	Monitoring of oceans is fundamental to tackle oceanic pollution, microplastics, toxic algae (Gobler et al., 2017). The study of oceanic impact on human health is also important (National Research Council, 1999). Illustrative work: Papadimitriou et al. (2019). Illustrative panarchical paradoxical challenges: Sustainable fishing and traceability coexist with illegal fishing and false labelling.
15: Life on land	Processes central to the sustainability of life on land such as deforestation and soil degradation critically depend on the use of space-enabled data to ensure platforms, e.g., Natura2000, have the latest information on the status of protected hotspots in land. Illustrative work: Forkuor et al. (2020). Illustrative panarchical paradoxical challenges: Sustainable farming coexists with intensive agriculture
16: Peace, justice, and strong institutions	Space, understood as a global commons, can be a source of global collaboration. This brings important legal as well as political challenges. It is paramount to recognize the importance of New Space and the commercially driven space activities as a sustainable and critical ecosystem to produce the solutions to the array of challenges we face on earth in the coming decades. Illustrative work: Steer (2017). Illustrative panarchical paradoxical challenge: Institutional actors' disagreement of lack of enforcement.
17: Partnerships for the goals	All the above goals have important implications in terms of partnerships, involving communities, corporations, nation states and international organizations. Partnerships such as the Consumer Goods Forum and the Tropical Forest Alliance constitute illustrative examples (Polman and Bhattacharya, 2016). Illustrative work: Mintzberg et al. (2018). Illustrative panarchical paradoxical challenges: The commercial use of space poses important coopetitive challenges between firms and states.

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