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MULTI-PLANETARY INFRASTRUCTURES AND HYBRID EXPLORATIONS

An analysis of the structures of epistemic enrolment in online discourses on space missions

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Abstract

This paper explores the *sociotechnical imaginaries* involved in the construction of technoscientific knowledge as it is conveyed by space science institutions through websites and social media. The study focuses on the discourses by which Nasa promotes the Artemis programme, aimed at achieving a new human landing on the Moon. The study is based on a mixed-methods perspective that combines the *social world framework* and social network analysis to examine the relational structures at play in the discourses disseminated by Nasa through several online spaces observed between March and November 2024. Using a methodological protocol developed to study epistemic structures, we analyse the discursive assemblage constituted of knowledge claims on space missions and the (heterogeneous) actors discursively enrolled to sustain those claims. Through this analytical framework, we reconstruct the epistemic structures underlying Nasa's discourse on Artemis and the intertwining of technoscientific elements and sociotechnical imaginaries relevant to these structures.

Keywords

Nasa, space missions, online discourse, social network analysis

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1. INTRODUCTION

«Earth is the cradle of humanity, but one cannot live in a cradle forever». With these words, in 1911, the Russian-born scientist and mathematician Konstantin Tsiolkovsky opened what later became the field of study of astronautics and human spaceflight[1]. Two centuries later, after humans have landed on the Moon and robotic machines have reached the surface of Mars, the world's major space agencies and scientific institutions are still hard at work trying to turn Tsiolkovsky's visionary imaginaries of human life beyond the limits of our planetary system into imaginaries of the possible – or, in other words, into reality.

Space missions are an elective field to investigate how imaginaries are embedded in the construction processes of technoscientific knowledge and, more specifically, the relationship between images, imagination and imaginaries in such epistemic processes. Given its nature, research on space missions plans crewed travels to places (almost entirely) unexplored by humans, and therefore, based on the technoscientific knowledge acquired so far, the same research can only *imagine* human life beyond Earth – or can, at least, try to perform a *placemaking* endeavour (Messeri, 2016). Accordingly, *techno-imagination* (Maestrutti, 2011) is a constitutive and determining element of research on space missions, in which diverse skills converge. The boundaries between images and imagination in space mission research dissolve in the creation of imaginaries that elaborate and plan crewed space travels and the occupation of outer space, hence proposing forms of «humanization of the universe» (Dickens and Ormrod, 2007: 2) as well as forms of anticipation of the future and, at the same time, a construction of expectations and visions about the future (Konrad et al., 2016).

Science and Technology Studies (STS) have developed a range of conceptual and methodological frameworks for understanding the performative force of *imaginaries*. In this contribution, we thus adopt the theoretical and methodological tools provided by this field of studies to understand how scientific institutions construct and enrol imaginaries on space missions are aimed not only at communicating the research's objectives but also at legitimising space science.

The analysis focuses on the online spaces run by the National Aeronautics and Space Administration (Nasa) to promote the Artemis campaign, the programme developed by this agency in collaboration with US and international public and private partners, aimed at achieving a new human landing on the Moon (and then on Mars). We explore the *sociotechnical imaginaries*

[1] Indeed, Tsiolkovsky is acknowledged as both «the world's first rocket scientist» and «the first space scientist» (Scharmen, 2021: 14)

(Jasanoff and Kim, 2009; 2015) involved in the processes of technoscientific knowledge construction performed by space science institutions to disseminate their work via their own websites and social media channels. The notion of sociotechnical imaginaries is familiar to scholars working on outer space from an STS perspective (e.g. Tutton, 2021; Cirac-Claveras, 2022; Rementeria, 2023; Klimburg-Witjes, 2024; Young and Docherty, 2024). In fact, the sociotechnical imaginaries of outer space largely relate to the promises of science for the future. Hence, it is worth looking at how these imaginaries are depicted in space science to shape future visions and expectations concerned with space missions (Borup et al., 2006; Konrad et al., 2016; Van Lente; 1993; Tutton, 2018; Rementeria, 2023).

The present study poses the following questions: Which actors are enrolled into the narratives of space scientists implicated in the construction of a performative future? What are the enrolment strategies implemented by scientific institutions in the construction of imaginaries of humans in space embedded in these forms of scientific knowledge? To answer these research questions, we assume the *sociology of associations* (Callon, 1984; Latour, 2005) as the theoretical framework for analysing technoscientific knowledge, and rely on its empirical translation through a methodological protocol developed for the study of the epistemic structures of knowledge refused by science (Picardi et al., 2024)[2], by which we analyse the corpus of knowledge on space missions promoted by Nasa in online environments, understood as a discursive assemblage constituted of both knowledge claims on space missions and the heterogeneous actors enrolled to sustain these knowledge claims.

The concept of *enrolment* is derived from Latour (1987; 2005) and adapted to our context to mean the discursive involvement of a plurality of heterogeneous actors – both human, such as stakeholders, concerned people, Nasa representatives, etc., and non-human, like technological devices, spacecraft, planets, biochemical elements, and so on – in the framing and promotion of the relevant activities. It should be noted that, in line with the perspective of the sociology of associations, attention is paid to all aspects of technoscientific activities and domains of interest, including its political, cultural, and economic implications.

The analysis is framed within a mixed-methods perspective that combines the *social world framework* (Clarke and Star, 2008) and Social Network Analysis (SNA) to examine the relational structures at play in the enrolment of actors in support of the claims disseminated by Nasa's online

[2] More specifically, the protocol has been applied to the study of "refused knowledge communities", i.e. communities promoting «a body of knowledge partially or totally refused by institutional and scientific authorities» (Crabu et al., 2024: 10).

spaces. Through this analytical framework, we reconstruct the epistemic structures underlying Nasa's online discourse and the intertwining of technoscientific elements and sociotechnical imaginaries in the identified structures.

The findings of this study show that, on the one hand, Nasa sets forth different sociotechnical imaginaries centred on the increasing advancement of technologies (including AI) to emphasise the future undertaking of lunar exploration and the exploitation of lunar resources. On the other hand, the human factor is central to narratives related to the crew modules developed by Nasa, such as the Orion Spacecraft or Gateway. The network analysis permits us to explore the configuration of these narratives and to highlight how they are distinct and yet interrelated through the ties between claims and actors, which keep the whole epistemic structure connected and consistent.

2. INVESTIGATING SOCIOTECHNICAL IMAGINARIES OF OUTER SPACE THROUGH THE SOCIAL WORLD FRAMEWORK

In this section, after a brief review of STS literature on sociotechnical imaginaries, we illustrate the theoretical and methodological framework employed in this study to explore how imaginaries are involved in the construction of the technoscience of space missions and, more specifically, how Nasa embeds visions of human life in space in the technoscientific knowledge disseminated through the online spaces devoted to promoting the Artemis programme.

In recent years, the concept of sociotechnical imaginary has informed a growing STS body of work focused on the analysis of how broad narratives orient pathways to the future, legitimating ones, and foreclosing others (McNeil et al., 2016; Konrad, 2016; Felt, 2015; Jasanoff and Kim, 2009; 2015; Levidow and Papaioannou, 2013; Taylor-Alexander, 2014). Following the theoretical perspective tracked by *Dreamscapes of Modernity* (Jasanoff and Kim, 2015), we borrow the concept of *sociotechnical imaginaries*, defined as «collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of life and social order attainable through, and supportive of, advances in science and technologies» (Jasanoff, 2015: 4).

Some STS scholars have concentrated their reflections on *expectations* and *visions* related to imaginaries. Konrad et al. (2016: 466) define *expectations* «as statements about future conditions or developments that imply assumptions about how likely these are supposed to be and that travel in a community or public space». As Van Lente (1993) suggests, expectations have agency in the representation (and creation) of the future; they advise, show

direction, and create obligations (Van Lente, 1993: 191). In this sense, «expectations are performative» (Tutton, 2018: 521) and constitutive in recruiting allies, «in defining roles and in building mutually binding obligations and agendas» (Borup et al., 2006: 289). Such promises and concerns mobilise and legitimise the activities of scientists, innovators, policymakers, companies and other societal actors, with future expectations that can align with or contest each other (Konrad, 2006; Meyer, 2019; Pfotenhauer and Jasanoff, 2017; Rementeria, 2023).

On the other hand, *visions* relay a wider picture of future societies in which new social orders, governance structures, cultures and values are redrafted. While expectations concern future developments in specific technological contexts, visions forward fuller portraits of an alternative world, presenting (coherent) packages of potential future states (Konrad et al., 2016; Berkhout, 2006; Eames et al., 2006).

Consequently, both expectations and visions work well with the notion of sociotechnical imaginaries, as well as with those of «sociotechnical futures» (Konrad and Böhle, 2019; Meyer, 2019), and «sociotechnical future scenarios» (e.g. Neresini et al., 2020). Most importantly, sociotechnical imaginaries and sociotechnical futures have proven to be well suited for the study of outer space activities (Tutton, 2018; 2021; Cirac-Claveras, 2022; Rementeria, 2023; Klimburg-Witjes, 2024; Young and Docherty, 2024).

To investigate expectations and visions embedded in the sociotechnical imaginaries concerned with Nasa's Artemis campaign, we mainly refer to the conceptual framework of the *social world perspective* proposed by Clarke and Star (2008). To this aim, we introduce below a set of definitions for *sensitising concepts* (Blumer, 1969) that we have utilised to develop the analysis, namely those concepts which «merely suggest directions along which to look», instead of providing «prescriptions of what to see», as is the case with «definitive concepts» (Blumer, 1969: 148).

Relying on the definition of social worlds as *universes of discourse* (Strauss, 1978), we focus on the dissemination of knowledge on space missions performed in the online spaces run by Nasa, conceiving of them as «shared discursive spaces» (Clarke and Star, 2008: 113) in which expectations and visions of the future are conveyed and elaborated to engage the larger publics' attention and interest.

According to the social world framework, Nasa scientists and the authors of the contents displayed in the relevant online spaces are considered as the *entrepreneurs* (Clarke and Star, 2008: 118; see Becker, 1963) of the relevant technoscientific knowledge. In using the term *entrepreneurs* we refer to those who are committed to promote the perspective of Nasa towards future missions via these online spaces, although we do not consider them in terms of

the active role they play as agents, limiting our attention to the outcome of the entrepreneurs' activity. Nonetheless, as a sensitising concept, that of entrepreneur leads us to look at online spaces as cues to understanding the various ways in which Nasa commits itself to provide Artemis with a sound and captivating discursive framing.

In this respect, drawing on Latour's early work on the making of technoscience (Latour, 1987; see also Callon and Law, 1982; Latour, 2005), by *enrolment* we mean the process through which the promoters of technoscientific knowledge attempt to frame the contents and the ends of such knowledge and its products, in order to make them relevant to others' interests and concerns, including the fabrication of imaginaries apt to foster such relevance. In the context of the present inquiry, this means to construct knowledge that necessitates the involvement of a plurality of human and non-human (i.e. heterogeneous) actors in the discourse to be legitimised, with the objective of reinforcing that knowledge itself.

Hence, in our context, enrolling other actors does not mean to directly involve them in the construction of scientific facts, but to consider them in the discursive framing of the facts as part of that process of construction. Therefore, as for the human actors considered in the discourse analysed in this paper, these are *implicated actor*s, i.e. «actors silenced or only discursively present – constructed by others for their own purposes» (Clarke and Star, 2008: 119). In addition, the focus is only on the second type of implicated actors defined by Clarke and Star as those who are «*not* physically present in a given social world but solely discursively constructed and discursively present» (*ibidem*)[3]. Consequently, these actors are neither actively involved in negotiating self-representations in social worlds nor considered for what they argue, although they can play a determinant role in enrolment processes aimed at conferring legitimation to given forms of knowledge.

Non-human actors enrolled in discourse are, instead, all those objects, imageries, and ideas that can help to give meaning and pertinence to the claims – namely to make the latter *interesting* for other people, such as concerned actors, stakeholders, and the general public (a strategy that can be often recognised in the development of technoscientific ideas and products; see Latour, 1987).

As this process covers many aspects of technoscientific activities, ranging from the design and production of technological devices employed in space missions to the formal participation of public and private institutions in the undertaking of space programmes – all these aspects being vital for the

[3] *Implicated actors*, *universes of discourse* and *entrepreneurs* are included in "The Social Worlds/Arenas Framework Conceptual Toolbox for Science Studies" provided by Clarke and Star (2008: 118).

realisation of those activities and their acknowledgement at different societal levels – we consider the whole enrolment process as *epistemic enrolment*.

We define the cognitive elements stated in Nasa's online spaces as *knowledge claims*, i.e. statements that convey key ideas regarding what Nasa's Artemis is meant to undertake, what it is aimed at and to whom the programme addresses its values and proposed activities and projects (both actual and envisaged). These are the constituting segments of the corpus of knowledge proposed in these spaces. The content disseminated through Nasa online spaces is thus conceived of as an assemblage of such knowledge claims and actors – as we have defined them above – discursively enrolled to sustain them.

The result of the assemblage of knowledge claims and enrolled actors is what we call *epistemic structures* (Picardi et al., 2024), in that they result from the construction – and the *hardening* – of technoscientific facts through the networks of association (Latour, 1987; 2005) that are formed by the constituting elements of knowledge and the social worlds within which knowledge is disseminated. This implies that such epistemic structures encompass the diverse dimensions – political, socio-cultural, economic – that are inherent to the construction of technoscientific facts, and that the knowledge claims and actors considered pertain to these dimensions, either at the level of a local work team or at level of global politics.

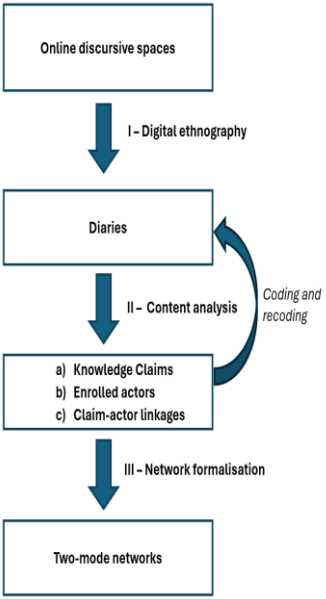
Finally, we define an *epistemic enrolment space* (Picardi et al., 2024: 142) as «the set of discursive structures that guide, focus and delimit» the processes by which knowledge is attributed credibility, relevance and legitimacy. Therefore, the aim of the analyses presented in this article is to highlight and interpret the epistemic structures that can be traced in the epistemic enrolment space of Nasa's Artemis programme, of which the online spaces that provide the material for these analyses constitute an empirical manifestation.

In the following sections, deploying this analytical toolkit, we shall provide an analysis of the data gathered from observing several online spaces by which Nasa promotes the Artemis space programme and proposes expectations and visions of future missions – which, as we will show, are intended to go beyond the sole achievements of space programmes. The epistemic structures that will be highlighted via the ensuing analysis will enable the identification of specific sociotechnical imaginaries within such communication endeavours. The methodological strategy presented in the subsequent section will be employed to this end.

3. METHODOLOGICAL STRATEGY

The methodological strategy we adopt in this work (see Picardi et al., 2024) seeks to furnish an analytical procedure aimed at identifying the networks of relations underlying the discursive universes under study, using tools from both qualitative research and SNA. This strategy is pursued through different steps displayed in Figure 1.

Figure 1. The steps of the analytical process



The first step of the analysis took the form of a digital ethnography (Hine, 2015; Marcus, 1995) carried out between March and November 2024. During this period, several Nasa online spaces, such as social network sites and institutional webpages (both the types of online space pertaining to different divisions of Nasa) aimed at promoting the Artemis campaign, were observed (Table 1). In this timespan, we collected the textual and iconographic contents disseminated in these spaces, as well as the observations and reflections that these contents contained, recording all the materials in ethnographic diaries. It must be specified that this observation concerned publicly available content and did not involve any type of interaction between the researchers and the subjects involved, i.e. neither the entrepreneurs nor the users of these

online spaces who left comments to the posts analysed. These comments were not collected or analysed either. Consequently, the empirical material consists only of the content of social media posts and webpage articles.

Subsequently, these ethnographic diaries were analysed to identify the claims and actors enrolled to support these claims. The claims were then obtained by recognising the essential knowledge elements contained in the discursive material collected. To identify the actors enrolled in support of such claims, we used the tool of content analysis (Lieblich et al., 1998) and the sensitising concepts described above (see Section 2), particularly those of universe of discourse and social worlds (Strauss, 1978; Clarke and Star, 2008). The interpretative work embedded in this strategy implies that the resulting networks should be understood as *qualitative networks* and as heuristic tools that help us highlight epistemic structures strictly connected to the theoretical lenses used in this analysis.

The enrolled actors have been classified into a number of categories defined according to the following criteria: a) the sector of activity (e.g. economy, politics, technoscience – and their subsectors or subspecialties), with regard to either terrestrial or space-related domains; b) the area of outer space on which discourses are focused (e.g. the Moon or Mars and their characteristics); c) the distinction between Nasa and other space agencies; d) the distinction between these latter and the private companies that participate in Nasa activities; e) the internal organization of Nasa offices, divisions and facilities.

3.1 Network-analytic strategy

In SNA, a tradition of studies revolves around the interplay between networks and meanings (e.g. Mützel, 2009; Fuhse and Mützel, 2011; Mohr, 1998). We partly refer to this tradition in gathering data and interpreting results from a quantitative and qualitative angle. This paper deals with a way of analysing meaning structures (Mohr, 1998) in the discourses observed online, which relies upon a qualitative content analysis deployed to «map out the structure of meanings within narratives» (Mohr, 1998: 358). As shown in the bottom box of Figure 1, these structures are represented in the form of two-mode networks made of claims and actors (the two modes of the network), with connections running only between modes, such that each claim is linked to one or more actors, and vice-versa. This means, in addition, that claims are connected if they share at least one actor, and vice-versa[4].

[4] This strategy could be partly in line with Carley's *map analysis* of discourses. According to Carley (1993: 78), the term *map analysis* refers "to a broad class of procedures in which the focus

In reconstructing the claim-actor matrix, we have tried to preserve the meaning of any single word or phrase to the extent that it would unequivocally represent a specific thing or concept. Changes in the wording of enrolled actors have been made in harmony with the way entrepreneurs aim to convey specific meanings. When this way is not peculiar to a given actor, the wording is changed for the sake of homogeneity. On the same note, if a given phrase is different in some respect from other akin phrases, but it is known that the actor would mean the same thing or idea with it, the phrase's wording is harmonized with the other ones of the same kind. Broadly speaking, we avoided generalization and/or homogenization of words and phrases to keep the relevant meaning intact. Modifiers are retained when the meaning of the wording would be different otherwise.

Claims are different in terms of generality/specificity when this helps distinguish the original information in its core meaning, which may or may not be general/specific. Moreover, different contents of a claim can be both present in a sentence as well as separated and thus forming two or more sentences. We maintained this difference as well. The above choices all refer to the need to remain faithful to the original empirical material. Identical wording also applies to those originally different phrases having similar meanings.

We then analyse visually and statistically the two-mode network of claims and actors via the *Gephi 0.10.1* software. We use basic SNA metrics to support our interpretations, specifically degree and betweenness centralities for two-mode networks (Brandes, 2001; Faust, 1997). Integral to our use of *Gephi* is the application of a community detection procedure to the network data, using the Louvain algorithm (Blondel et al., 2008). This method helps us to highlight the community structure of the network by seeking to optimise the modularity of the partitions, i.e. a measure of the quality of these partitions. In this way, we attempt to better understand the patterns of connections between the different claims and actors. In the following, we shall refer to each partition resulting from this procedure mainly as "community" rather than "modularity class" (the term used in the *Gephi* modularity routine, see Figure 5).

is on networks consisting of connected concepts rather than counts of concepts". For the sake of the present work, in brief, a map "is a network of concepts formed from statements. Two statements are linked, if they share one concept" (Carley, 1997: 540). As we explicitly use SNA within an STS framework, it is also worth mentioning other studies that deal with the matter, such as Venturini et al. (2019), and Cambrosio et al. (2020), among others. Text analysis and text mining in combination with SNA is also a relevant perspective in STS (see Venturini and Guido, 2012; Neresini et al. 2020).

4. RESULTS

4.1. Nasa's Artemis programme

Artemis is a space exploration programme developed by Nasa in collaboration with US and international partners such as Esa, Jaxa and the Canadian Space Agency (Csa), aimed to achieve a new human landing on the Moon – more than fifty years after the end of the Apollo programme – in order to lay the groundwork for a long-term human presence on the lunar surface and, at the same time, to prepare for a human landing on Mars.

The Artemis programme consists of a series of space missions, each centred on launching a booster of Nasa's lunar rocket, the Space Launch System (SLS), used as a transporter for the Orion Spacecraft. During Artemis I, carried out in 2022, SLS sent the Orion Spacecraft 1.4 million miles beyond the Moon, only to return; this first mission was uncrewed and preparatory to the following ones. Next on Nasa's timeline is Artemis II, which aims to carry a crew of four astronauts on a 10-day flight to test human deep space exploration capabilities.

Through the following analysis, we aim to highlight the extent to which Artemis narratives are multifaceted, as they constitute complex assemblages of elements from different domains of knowledge and activity, either scientific, political, economic or cultural.

4.2. The network of Artemis' discourse

The network under investigation is made of 80 claims and 665 actors. As for the claims that are most central in the graph, these are connected to a high number of actors because of the discursive frame within which they appear and due to the relevant enrolling strategy[5]. Three claims with the highest degree are C17, C35 and C36. Claim C17 announces the integration of an additional nation in the Artemis Accords, which at the time of data collection included 43 countries. Since degree values indicate the number of enrolled

[5] It should be noted that the degree distribution of claims and actors is markedly dispersed, as shown in Table 4. This is due to the high variability of degree values in consequence of the enrolment of actors to support the claims. Less than 3% of the actors are tied to 10 or more claims. Empirically, these actors are "important" in the discourse as they are called upon more frequently, but this also means that their role is central in maintaining the relevant epistemic structure (as also expressed by betweenness centralities). The most part of the enrolled actors does not play such a role. As for the claims, 15% of them are tied to 50 actors or more. This can be interpreted as the extent to which highly central claims shape the foci of the discourse and, thus, gather many actors around them. Such data structure is consistent with the kind of process investigated and the coding procedure utilised, which does not affect the reliability of the results.

actors associated with a claim, the high degree value associated with this claim shows the relevance of the political dimension of Nasa's project that mobilises a high number of heterogeneous actors in supporting the Artemis Accords, indicated by the numerous blue nodes linked to claim C17 (see Figure 4). Among these nodes there are political actors, either actual (e.g. a given country) or symbolic (e.g. the American flag), and actors belonging to the category of "Value of humanity", which are invoked to legitimise the political dimension of space missions.

Indeed, considering actor attributes (Figure 4), enrolling political entities turns out to be different from enrolling technologies, with the former being mostly located on the left-hand side of the graph, while the latter are mostly placed on the right-hand side. For instance, claim C17 and the actors associated with it form a distinct community (i.e. community 11, see Figure 5), while, on the right-hand side, claims C28, C30, C31, C35, C36 form a bunch of nodes that belong to community 2 (see below) and refer to the deployment of technological advancements as well as to the challenges and expectations regarding new lunar areas to be explored (e.g. C30 - "Moon's permanently shadowed regions could help reveal the origin of water throughout our solar system", C35 - "New Nasa science and technology instruments will be heading to the Moon in 2027", and C36 - "The Moon's South Pole is a challenging but scientifically interesting site"). This area of the graph represents what Nasa sets forth as the core business of the Artemis mission in its next steps to start exploring the lunar surface, and specifically the lunar South Pole.

The actors "lunar surface" and "lunar South Pole" are the first two in the ranking by degree scores, enrolled to sustain a large number of claims in the relevant discourse, which is virtually reflected in their degree centrality. These are also non-human actors that gain centrality in the network as they act as drivers of future exploration, either human-made or automated.

Indeed, in this context, the discourse about Nasa's Artemis programme depicts an imagined future in which technology – and autonomous technology in particular – will open avenues for brilliant scientific achievements. Furthermore, enrolling knowledge about lunar geography – in conjunction with the act of naming lunar sites of interest for future exploration – constitutes an instance of the colonisation of extraterrestrial territories. It is worth noting, however, that the five claims mentioned above are connected to a single actor of the category "Astronauts and space crews", which means that the human factor – represented by the "crew" as an implicated actor – seems to be set aside or at least minimised in the narratives of technologically advanced exploration[6]. This assemblage of non-human actors concerning

[6] Indeed, astronauts and space crews are mostly present in community 10, which is embedded in

mainly technological devices and lunar geography, with a weak enrolment of human actors or discursive entities related to humanity (such as "the benefit of all"), is captured by the composition of community 2, the second largest in the network (Figure 5), which is located on the right-hand side of the graph.

Interestingly, community 2 also includes the actor "water", namely one of the most important resources that scientists are seeking on the Moon. Yet, another resource that is sought to be extracted from the lunar surface is "oxygen", which, as an actor in this network, belongs to community 9, along with claim C84 ("Researchers are working to enable human life on the Moon"). As for the enrolled actors, this latter community is all the more concerned with artificial intelligence (AI) and robotics, namely the automated technologies that will pave the way for establishing human settlements on the Moon.

The third most central actor in terms of degree centrality score is "Orion Spacecraft", with 20 claims associated with it. Orion was already the protagonist of recent achievements of Nasa for an uncrewed Artemis I mission. Now, and in the discourses that we observed, it conveys a more "humanised" vision of space activities, along with "Gateway" (degree = 14), "humanity's first space station around the Moon" (claim C52). The actor "Orion Spacecraft" is linked to different claims than those expressing progress in the sole technological mastering of lunar exploration. Rather, here it seems that a *crewed* exploration of the Moon is the point, as is the case with claim C66 – which is also linked to the actor "discovery" – and C67, which concerns "the possible places on the Moon's surface where Artemis III astronauts could land" (both C66 and C67 are connected to "the benefit of all"), along with the idea that "space belongs to everyone" (claim C10) and recalling the legacy of past exploration achievements (C26), like those of the Apollo programme.

Interestingly, linked to Orion are also claims C3, "Artemis IV astronauts will be the first to live and work aboard a lunar-orbiting space station", and C4, "Nasa and its partners are working to explore our Moon safely". The human venture is, here, at the core of an imaginary that depicts not only the giant technological leaps in gaining knowledge of the Moon's characteristics, but also on how this endeavour will be experienced by the crews, with an inevitable link to "long-term exploration" as the actor that connects this area of the graph and the relevant discourse to claims C35 and C36 (see above).

Space humanisation also pertains to the narratives concerning Gateway. The latter is a distinct enrolled actor and the constitutive element of several claims (e.g. C51, C52, C53, C54, C55, and others; see Table 3). Claim C55

the core of the graph, with close connections to communities 2 and 6 (see Figure 5, and below in the text).

asserts that aboard Gateway "astronauts will prepare missions to investigate the lunar South Pole region", which denotes a connection between the ambitions of the next crewed steps with Artemis and the hard, everyday work that astronauts are now doing to be trained for the future missions. This narrative can be said to paint a "Nasa workshop" imaginary, in which the expectations of future missions are anchored to a prospective humanisation of the Moon.

The latter theme might also happen to be interrelated with the actual human endeavour made aboard the "International Space Station" (ISS) an actor having a peculiar location in the graph (Figure 2): it is tied to claim C45 ("Nasa fosters international cooperation"), which, in turn, connects the ISS to the rest of the graph, along with Claim C59 ("Nasa helps research on climate on Earth"). Indeed, the dyad ISS-C59 looks peripheral with respect to the main network, with C59 being associated with half of the 10 actors belonging to the category "Earth and earthly environment" (which includes the actor "Earth" that can be found in the core of the network, besides Moon-related actors and claims). The distance between these nodes and the rest of the network can lead to the following interpretation.

Earthly environment as an actor category does not appeal much to the discursive material with which we are dealing. This discourse seems, instead, more focused on the potential of human and/or technological efforts to reach other planetary surfaces. Further, considering this relational pattern, the ISS appears to be more "earthbound" (Latour, 2017) than other actors in this network (particularly among those of the same type, i.e. "Spacecraft and space facilities").

Both Orion and Gateway are part of community 4, the largest one, which holds a sparser pattern of connections than that of community 2 (Figure 5). Community 4 includes 20 claims, some of which pertain to Gateway, while others seem more explicitly to propose a far-reaching vision of humans in space, as is the case with claim C71 ("Gateway is going to allow Nasa to do many years of scientific study in a place where humans have never worked and lived long-term"), attempting to make the human adventure on the Moon – and subsequently on Mars – much closer to reality but also safe enough for astronauts.

Community 6 – which lies between communities 4 and 2 (Figure 5) – is again centred on the combination of future-oriented and actual/practical concerns, but with a slightly different strategy than the one informing the assemblage of community 4. In community 6, the diversity and equity causes are enrolled (e.g. through actors like "first person of colour", or "first woman")[7]

[7] An edit on this point is required due to the current political situation in the US (as of April 2025), where the Diversity, Equity, and Inclusion (DEI) policy has been banned by President

as well as the technical peculiarities of spacecraft, including Nasa partners like SpaceX.

And what about the actor "Mars"? It follows "Orion Spacecraft" in the degree centrality ranking and it is the third most central as for betweenness centrality (following "lunar South Pole" and "lunar surface"). As an actor, Mars belongs to community 14, in which the technology already used to study the Red Planet is at the core of several claims concerned with Nasa's Farside Seismic Suite (C11, C12, C15 and C16), a set of instruments that will be employed to obtain seismic data from the Moon, leveraging the technology that enabled the detection of marsquakes. In fact, community 14 is centred mainly on the Moon and lunar geography, with few actors (4 out of 56) concerning Mars and Martian geography, the latter category being, instead, mostly present in community 5, which is more centred on Mars exploration through the Perseverance rover, which provides the wider public with images of the planet – the production of which places visualisation technologies at the core of the social organization of space scientists' work (Vertesi, 2012).

Therefore, Mars appears to be part of a narrative that foregrounds the enhancement of knowledge about the lunar surface – with an eye to mastering such knowledge for lunar exploration and the possibility of exploiting lunar resources (e.g. oxygen and water) – and the future human landing on the Moon. As an actor, the Red Planet is placed between the two main Moon-related actors (Figure 3), while the knowledge acquired on its characteristics takes place in a peripheral area of the graph (community 5, on the upper-right side).

Trump's directives in the beginning of his current term (https://www.whitehouse.gov/presidential-actions/2025/01/ending-radical-and-wasteful-government-dei-programs-and-preferencing/, accessed 9 April 2025). Consequently, the claims and actors we included in our analysis that were related to DEI programmes may have disappeared from the content of the agency's media outlets, accompanying the decision of Nasa to drop «its longstanding public commitment to land the first woman and person of color on the moon» (https://www.theguardian.com/us-news/2025/mar/21/nasa-drops-plan-first-woman-moon, accessed 9 April 2025).

Figure 2. Two-mode networks of claims and actors relevant to Nasa's Artemis programme (March-November 2024), with node sizes proportional to degree centralities (orange and blue nodes represent claims and actors, respectively)

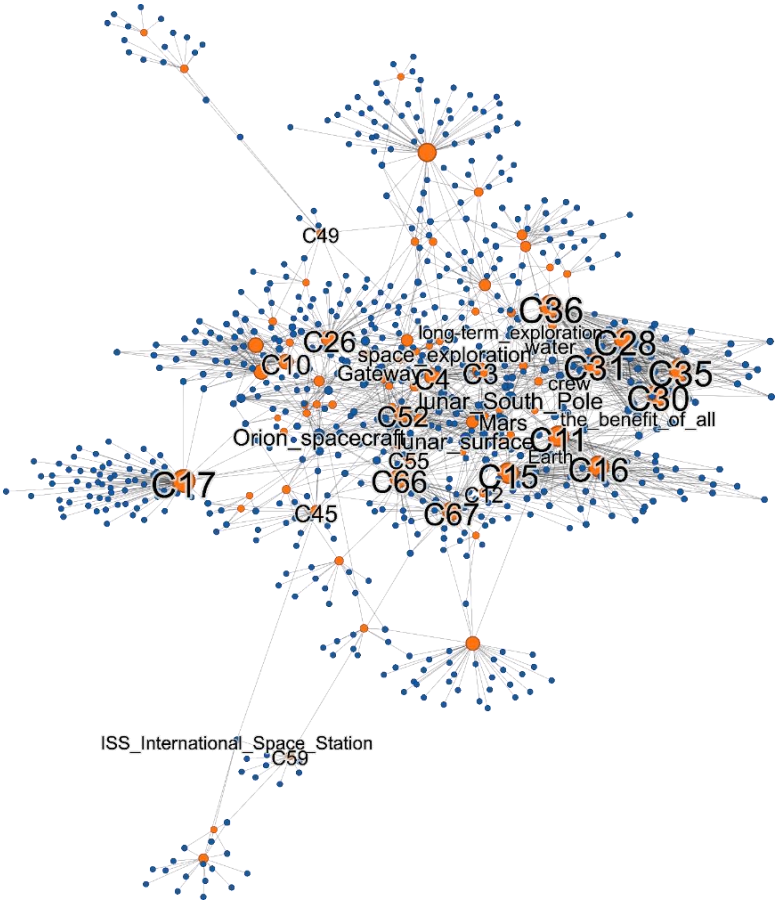


Figure 3. Two-mode networks of claims and actors relevant to Nasa's Artemis programme (March-November 2024), with node sizes proportional to betweenness centralities (orange and blue nodes represent claims and actors, respectively)

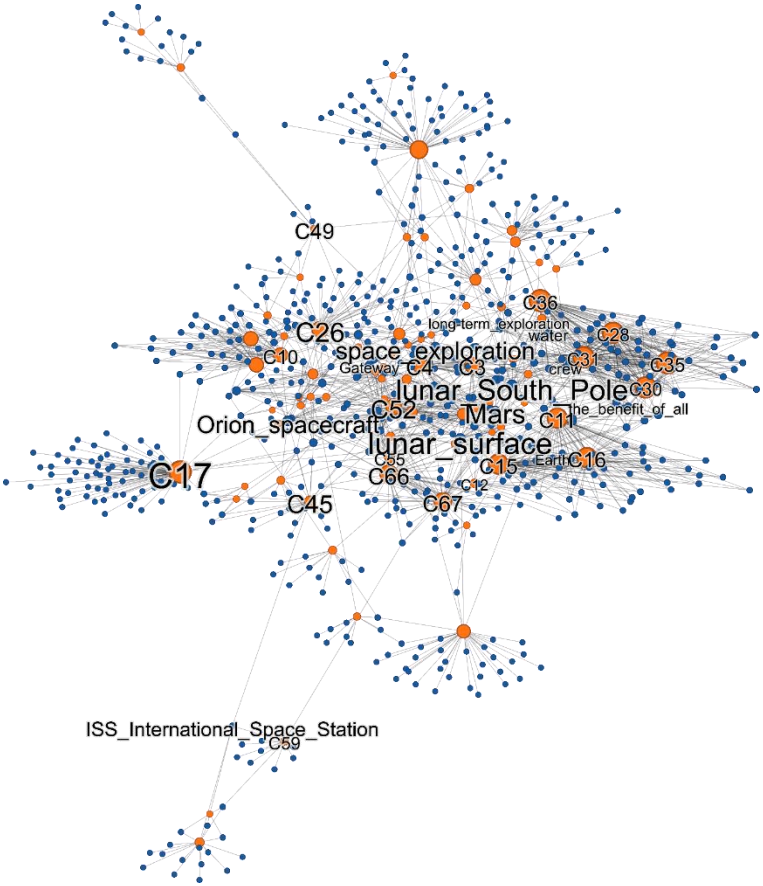


Figure 4. Two-mode networks of claims and actors relevant to Nasa's Artemis programme (March-November 2024), with node sizes proportional to betweenness centralities and colours denoting actor attributes (grey nodes represent claims)

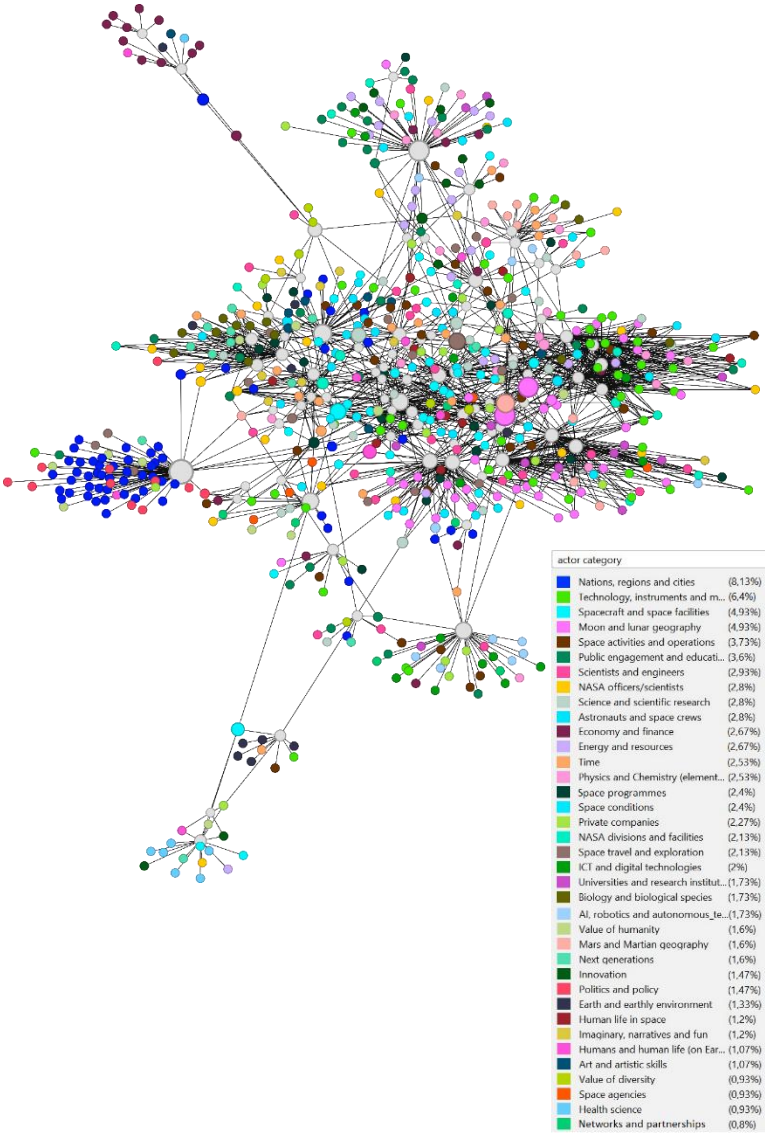
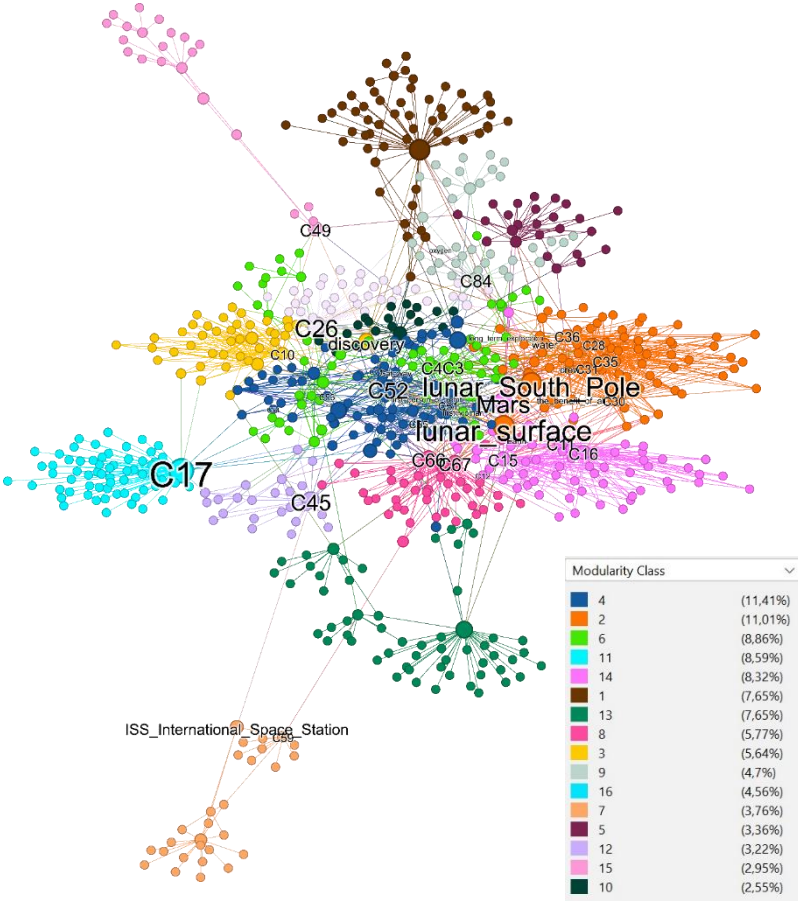


Figure 5. Two-mode networks of claims and actors relevant to Nasa's Artemis programme (March-November 2024), with colours denoting modularity classes



5. DISCUSSION AND CONCLUSIONS

In this article, a study of the sociotechnical imaginaries (Jasanoff and Kim, 2015) pertaining to Nasa's Artemis programme, aimed at landing astronauts on the Moon more than five decades after the end of the Apollo programme, was presented. The focus was on the discursive online spaces run by Nasa to promote the Artemis campaign, relying on the social world framework (Clarke and Star, 2008) and providing a network analysis of the content displayed on webpages and social media channels relevant to the Artemis programme. Such empirical endeavour is based on a mixed-method strategy derived from a methodological protocol devoted to the analysis of scientific knowledge and rooted in Science and Technology Studies (STS). This strategy led us to assemble a network made of knowledge claims and the human and non-human actors discursively enrolled as allies to sustain and legitimise them.

The concept of enrolment is derived from Latour (1987; 2005) and adapted to our context so that we could investigate how the communication about the Artemis programme relies on associations between key ideas about this programme and the plurality of other ideas, concerns, objects, categories of people called upon to foster Nasa's perspective regarding future missions beyond Earth. In so doing, we were able to highlight the epistemic structures relevant to discourse around the Artemis campaign.

The network structure described in the previous section represents the epistemic enrolment space purporting the sociotechnical imaginaries of outer space relevant to Nasa's Artemis programme. The analysis of these structures explored how different actors are discursively engaged in the shaping of these sociotechnical imaginaries. In this section, we discuss these findings and describe expectations and visions of the future proposed as desirable in such imaginaries, together with the forms of life and social order embedded in the scenarios of current and future space missions.

The community structure of the network of claims and actors pertaining to the observed epistemic enrolment space allows us to identify a *multiplicity of sociotechnical imaginaries of outer space* that combine visions of *multi-planetary life* and expectations of *multi-planetary infrastructures* and *hybrid (human and non-human) exploration of outer space*.

One of the main visions promoted in the observed online spaces is that human life in outer space might be a concrete possibility: multi-planetary life is the «grand challenge» (Konrad et al., 2016) that underlies Nasa's Artemis narratives. Humans are not, however, meant to abandon Earth, but rather to expand the frontiers of the territories of human habitation – i.e., the humanisation of space (Dickens and Ormrod, 2007). In the discursive universe with

which this work is concerned, the Moon is the first outpost for outer space exploration, the springboard for expeditions to Mars and beyond, namely the *places* where human life will soon be possible (Messeri, 2016).

As the Deputy Associate Administrator for the Exploration Systems Development Mission Directorate at Nasa, Cathy Koerner, says in an interview for the Nasa website in July 2023:

> We're really trying to do [sic] is create a blueprint for exploration beyond Earth. So exploration to any destination in the future, if we do this right, we should be able to say, 'we want to go explore this moon of this planet, or this other planet' [...]. We create a capability. And then, it's the, 'if you build it, they will come' kind of mentality[8].

Multi-planetary life futures are permeated by technological infrastructures spread across our planet, on its surface and orbit, on the Moon (and its orbit), and in outer space more broadly. The Space Launch System (SLS), Orion Spacecraft, Exploration Ground Systems, Gateway, Extravehicular Activity and Human Surface Mobility Program (EHP), and Human Landing System (HLS) are Nasa's Artemis core sub-programmes for human and non-human transportation in space, which will enable exploration activities beyond the Moon and eventually on Mars. This complex sociotechnical architecture draws *multi-planetary infrastructures* that inform the outer space imaginaries of *hybrid (human and non-human) exploration*.

Terrestrial launch bases communicate with lunar bases, where a complex technological architecture connects the paths between Earth and outer space. Through the technological and digital infrastructures that are expected to be built on the Moon, it will be possible to conduct scientific experiments, as well as to obtain resources aimed at supporting human life in outer space, such as oxygen, water, and energy. These infrastructures will be equipped with sophisticated hardware and autonomous technologies. AI, robots and automation technologies have recently entered the imagination of space missions to perform activities that are risky for humans, such as entering the "dark side of the Moon" where automated devices will build pipelines to carry the oxygen that is expected to be found in lunar resources, at the Moon's South Pole (and in collaboration with private companies).

On the lunar surface, robot astronauts are gradually joining human astronauts where «[A]utonomous systems allow spacecraft, rovers, and robots to operate without relying on constant contact with astronauts or mission

[8] Podcast "Houston we have a podcast 14 July 2023" (https://www.nasa.gov/podcasts/houston-we-have-a-podcast/ep-297-moon-to-mars-architecture/), accessed 2 April 2025.

control» (Nasa website, 8 October 2024)[9]. In the sociotechnical imaginaries depicted in the discourse about Nasa's Artemis programme, the future scenarios of a completely automated colonisation of other planets (Campa et al., 2019), made possible by advancements in the use of autonomous technology, would coexist with those of human exploration of space.

As described in the previous section, constructing such infrastructures in multi-planetary imaginaries (Tutton, 2018) requires the enrolment of a large network of partners that participate in the construction of sociotechnical imaginaries of outer space. The analysis of the epistemic enrolment space has shown the role of nations enrolled in the Artemis project through the Artemis Accords – the Multilateral Agreement of International Cooperation of the Artemis Lunar Program. Formally, Artemis and the Artemis Accords in particular claim that space exploration will be of interest to global partners, but the US leadership does not remain in question.

Through coalition building, the Artemis Accords aims to engage other countries in the construction of the sociotechnical imaginaries of outer space thus proposed. Indeed, following Sheila Jasanoff (2015: 4), it can be said that only when Nasa's vision «comes to be communally adopted, however, does it rise to the status of an imaginary». Obviously, this is why the more nations join Artemis, the more credible it becomes as a (global) scientific undertaking. As an entrepreneur (Clarke and Star, 2008) in the online discursive space we have investigated, Nasa enrols many partners in the Artemis venture, including the reference to humanity as a concept on which the principle of communitarianism is based. In other words, for Nasa, *Artemis is humanity's next giant leap, and an international coalition is helping to make it a reality.*

Furthermore, in such discursive spaces, we recognise a latent tension between the Mertonian *ethos* of *universalism* and *communitarianism* (Merton, 1973), invoked by "the benefit of all" to legitimise the Artemis programme, and the involvement of large private corporations in the construction of sociotechnical imaginaries of space missions and in the more general development of the new space economy. This tension is expressed for example in the removal of the extractivist and commercial motivations of the new space economy implicit in the analysed discursive spaces.

According to the first *Handbook on Measuring the Space Economy*, the latter is defined as «the full range of activities and the use of resources that create and provide value and benefits to human beings in the course of exploring, understanding, managing and utilising space» (OECD, 2012). Space missions are not only a growing technoscientific sector aimed at expanding knowledge on outer space, but they are also conceived as a vital enabler of

[9] https://www.nasa.gov/directorates/stmd/student-lunar-autonomy-challenge/, accessed 2 April 2025.

growth in the economic sector.

Some analysts believe that the space industry could become the next trillion-dollar industry by 2040; this explains the huge private investment in space ventures attracted by possibilities of development of commercial activities worldwide (such as the ones based on SmallSats/CubeSats) and in fields like micro-launchers and space flights. Nevertheless, notwithstanding its pertinence, the economic dimension of the Artemis mission in the analysed online spaces remains beneath the radar, while the construction of future imaginaries of life in space is mainly called upon with respect to human values. The Artemis programme boasts the distinction of bringing the first woman and the first man of colour to the Moon, making the narratives on "Diversity, Equity, and Inclusion" (DEI) one of the pillars on which the epistemic enrolment space aimed at legitimising space missions is built – at least during the period of our observation (see below).

Nevertheless, *humanity* in these discursive spaces appears as a neutral and abstract concept, which does not clarify which actors will concretely benefit from the future "enclosures" (Polanyi, 1944) and the exploitation of extraterrestrial territories, which, notwithstanding Donald Trump's 2020 statements claiming the right to use extraterrestrial space[10], still constitute *global commons according to the 1967 United Nations Outer Space Treaty.* Finally, it should be noted that the web-ethnography conducted for this study covered the period preceding Donald Trump's victory in the 2024 presidential election. One of the initial actions undertaken under this mandate was the removal of the DEI policies in scientific programmes (see above, footnote 7). Consequently, in recent months, a rapid transformation of the argumentative frames that Nasa mobilises to legitimise its actions and sociotechnical imaginaries has been observed. The focus and analysis of these transformations may be the subject of future research.

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[10] https://trumpwhitehouse.archives.gov/presidential-actions/executive-order-encouraging-international-support-recovery-use-space-resources/.

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APPENDIX: DATA TABLES

Table 1 Online spaces related to Nasa's Artemis programme

Online space name
Nasa (website)
Nasa Artemis
Nasa Mars
Nasa Moon
Nasa Technology
Nasa's Gateway Program
Nasa's Orion Spacecraft
Nasa's Gateway
Nasa's Gateway Program
Nasa's Johnson Space Center
Nasa's Marshall Space Flight Center
Nasa's Space Launch System

*Except for the Nasa website, all spaces are denoted by the name of the relevant Facebook page

Table 2. Actor categories

Actor category	%
Nations, regions and cities	9.17
Technology, instruments and machinery	7.22
Spacecraft and space facilities	5.56
Moon and lunar geography	5.56
Space activities and operations	4.21
Public engagement and education	4.06
Scientists and engineers	3.31
Science and scientific research	3.16
Astronauts and space crews	3.16
Nasa officers/scientists	3.16
Time	2.86
Energy and resources	3.01
Economy and finance	3.01
Physics and Chemistry (elements and concepts)	2.86
Space programs	2.71
Space conditions	2.71
Private companies	2.56
Space travel and exploration	2.41
Nasa divisions and facilities	2.41
ICT and digital technologies	2.11
Biology and biological species	1.95
Next generations	1.80
Mars and Martian geography	1.80
Universities and research institutions	1.80
Value of humanity	1.80
AI, robotics and autonomous technologies	1.65
Politics and policy	1.65
Innovation	1.65
Earth and earthly environment	1.50
Human life in space	1.35
Imaginary, art, narratives	1.35
Art and artistic skills	1.20
Humans and human life (on Earth)	1.20
Space agencies	1.05
Value of diversity	1.05
Health science	1.05
Networks and partnerships	0.90

Table 3 Claim codes and description

Claim Code	Claim
C1	Caitlyn Durham a role model of women who make difference at Nasa
C2	The launch director Charlie Blackwell-Thompson thanks JoAnn Morgan for being a role model for women in Nasa
C3	Artemis IV astronauts will be the first to live and work aboard a lunar-orbiting space station
C4	Nasa and its partners are working to explore our Moon safely
C5	Industry partners make possible the Space Launch System
C6	The Artemis campaign includes increasingly complex missions
C7	A new era of Moon trees will one day stand tall in communities across America
C8	Nasa is bringing the spirit of exploration back down to Earth
C9	Seeds that journeyed during Artemis I were germinated and grown into seedlings and are now ready to be planted
C10	Space belongs to everyone
C11	Nasa Farside Seismic Suite will gather the agency's first seismic data from the Moon in nearly 50 years
C12	Nasa's Farside Seismic Suite (FSS) will answer a lingering question about fewer moonquakes on the far side of the Moon
C15	The technology behind the two seismometers that make up Nasa's Farside Seismic Suite was used to detect more than a thousand Red Planet quakes
C16	Nasa's Farside Seismic Suite, the most sensitive instrument ever built to measure quakes on other worlds is getting closer to its journey to the Moon
C17	Armenia has joined 42 other nations that have committed into Artemis Accords
C18	1,000 tiles protect the Orion Spacecraft from the heat of re-entry from the Moon
C19	Nasa has celebrated the 55th anniversary of Apollo11
C20	Nasa has transported the core stage of Nasa's Space Launch System to Nasa's Kennedy Space Center for the Artemis II mission
C21	Nasa scientists have designed the route for Perseverance to ensure that it goes to areas with the potential for interesting scientific samples

Claim Code	Claim
C22	Now it's time to look to the future
C23	Nasa's Perseverance Mars Rover has found a rock that could be one of the signs of ancient microbial life that may have once existed on the Red Planet
C24	Nasa school projects involve students in testing flight simulators on the lunar surface
C25	The Perseverance Mars Rover is beginning its 5th science campaign
C26	Nasa's Johnson Space Center has selected the defining moments of space exploration
C27	On Aug. 21, the first piece of hardware manufactured at Nasa's Marshall Space Flight Center for Nasa's SLS (Space Launch System) rocket that will launch a crewed Artemis mission was moved for shipment
C28	A new set of Nasa science experiments and technology demonstrations will arrive at the lunar South Pole in 2027
C29	Commercial Lunar Payload Services initiative will help Nasa conduct science and continue working toward a long-term human presence on the Moon
C30	Moon's permanently shadowed regions could help reveal the origin of water throughout our solar system
C31	Nasa Awards Intuitive Machines Lunar South Pole Research Delivery
C32	Nasa will explore more of the Moon than ever before
C33	The instruments on flights developed by Commercial Lunar Payload Services could advance our exploration efforts on the Moon and help us with continued exploration of Mars
C34	The instruments on flights developed by Commercial Lunar Payload Services will help us achieve multiple scientific objectives and understand the Moon's environment
C35	New Nasa science and technology instruments will be heading to the Moon in 2027
C36	The Moon's South Pole is a challenging but scientifically interesting site
C37	A pressurized rover will enable astronauts to travel farther and conduct science in geographically diverse areas
C38	Breakthrough power transmission and energy storage technologies developed in the Watts on the Moon Challenge could

Claim Code	Claim
	advance the nation's lunar exploration goals
C40	Collaborations provide opportunities for Nasa and other countries to work together to integrate and fly technology and experiments as part of Artemis
C41	Nasa is increasing access to space for the international community and enabling its partners to expand scientific and technological knowledge
C42	Power transmission and energy storage technologies developed in the Watts on the Moon Challenge could have implications for improving power systems on Earth
C43	Power transmission and energy storage technologies developed in the Watts on the Moon Challenge seek to improve our ability to explore and make discoveries in space
C44	The energy solutions developed by Watts on the Moon Challenge support Nasa's recently ranked civil space shortfalls
C45	Nasa fosters international cooperation
C46	Nasa is working to fly satellites that will study the effect of the space environment on electrical components
C47	High-fidelity virtual simulations allow Nasa to anticipate and improve how systems, both software and hardware, will function in the physical world
C48	To embark on long-duration missions on the Moon with Nasa's Artemis programme, we're going to need cutting edge software that can accomplish pre-defined tasks without help from humans
C49	Nasa will land the first woman and first person of colour on the Moon
C51	Gateway is a safe and functional artifact for Nasa's Artemis crews
C52	Gateway will be humanity's first space station around the Moon
C53	Gateway will chart a path for the first human missions to Mars
C54	Gateway will return humans to the Moon
C55	In the Gateway space station astronauts will prepare missions to investigate the lunar South Pole region
C56	Teams from Nasa and Esa tested a mock-up for the Gateway lunar space station
C57	Artemis II astronauts put Orion to the test

Claim Code	Claim
C58	The Nasa's Artemis II crew recently practiced opening and closing an Orion crew module side hatch to ensure they can safely enter and exit the spacecraft in the event of an emergency
C59	Nasa helps research on climate on Earth
C60	Nasa invests in cutting-edge technologies to help maintain America's competitive advantage
C61	Nasa space inventions will find practical uses on Earth
C62	Nasa strengthens the US economy
C63	Nasa's Moon to Mars endeavours generated economic output and jobs
C64	Research in space helps improve health on Earth
C65	Nasa missions inspire future generations
C66	Artemis will return humanity to the Moon
C67	Nasa is working to define the possible places on the Moon's surface where Artemis III astronauts could land
C68	Artemis II will be the first mission to send humans to the Moon since 1972
C69	Artemis III will be the first landing in the lunar South Pole region
C70	Artemis IV mission in 2028 will be the first lunar mission to include an orbiting space station
C71	Gateway is going to allow Nasa to do many years of scientific study in a place where humans have never worked and lived long-term
C72	Gateway is set to advance science in deep space, bringing groundbreaking research opportunities to lunar orbit
C73	Gateway sounds so science fiction, but it's real
C74	Gateway will return humans to the Moon
C75	Halo will host science experiments to understand how to protect astronauts and hardware during deep space travels to places like Mars
C76	In a few years Gateway is going to be around the Moon
C77	Nasa is building Gateway for a 15-year lifespan or more
C78	An exciting new era of space exploration is coming

Claim Code	Claim
C79	Artemis campaign will pave the way for the first crewed mission to Mars
C80	Gateway will support a new era of lunar exploration and deep space discovery
C81	Gateway will support human spaceflight
C82	Gateway's first two modules will launch to lunar orbit ahead of Artemis IV
C83	The lunar space station will serve as a central hub where crew spacecraft and supply modules dock and prepare for missions to the Moon's surface.
C84	Researchers are working to enable human life on the Moon

Table 4. Degree centrality (descriptive statistics)

	Degree centrality	
	Claims	Actors
Mean	21,6	2,6
Median	11	2
Mode	6	1
St. dev.	20,6	2,6
Min	4	1
Max	71	23
N	80	665