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An International Perspective on Planetary Protection Policies (Presentation)

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An International Perspective on Planetary Protection Policies

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Abstract

The Committee on Space Research (COSPAR) guidelines provide an international standard for planetary protection, but are not legally binding for any one nation. Therefore, it is the purview of individual nations to determine how to identify and implement planetary protection policies to meet the guidelines. The COSPAR Panel on Planetary Protection facilitates this process. With a number of nations planning missions to Mars and proposing Mars sample return in the coming years, it is increasingly necessary to understand how different space actors are approaching planetary protection policies. This study examines nations as case studies for planetary protection compliance, including Europe, Russia, China, Japan, and the United Arab Emirates. This report draws on a literature review and interviews with planetary protection experts, national representatives, and COSPAR representatives to compare planetary protection policies internationally and identify any proposed changes in the near future.
Keywords: planetary protection, COSPAR, sample return, Mars, international, policy

Acronyms/Abbreviations
ASI – Italian Space Agency
CNES – National Center for Space Studies (France)
CNSA – China National Space Administration
COSPAR – Committee on Space Research
DLR – German Aerospace Center
DSN – Deep Space Network
EMM – Emirates Mars Mission
ESA – European Space Agency
IMBP – Institute on Biomedical Problems
ISS – International Space Station
JAXA – Japan Aerospace Exploration Agency
JPL – Jet Propulsion Lab
JUICE – Jupiter Icy Moons Explorer
LASP – Laboratory for Atmospheric and Space Physics
LEO – Low Earth orbit
LIFE – Living Interplanetary Flight Experiment
MAV – Mars Ascent Vehicle
MBRSC – Mohammed bin Rashid Space Center
MMX – Mars Moons Exploration
MOMA – Mars Organic Molecule Analyze
NASA National Aeronautics and Space Administration
OST – Outer Space Treaty
PPIRB – Planetary Protection Independent Review Board
PPO – Planetary Protection Office
PPP – Planetary Protection Panel
RAS – Russian Academy of Sciences
S&MA – Safety and Mission Assurance
STPI – Science and Technology Policy Institute
UAE – United Arab Emirates
UAESA – United Arab Emirates Space Agency

1. Introduction

This study was motivated by the recent increase in the number of upcoming missions to Mars, including some with sample return. Planetary protection, the practice of avoiding the harmful contamination of celestial bodies from Earth life, and also avoiding adverse effects to the Earth environment from extra-terrestrial life, is a major consideration for these missions.

Guidelines for ensuring planetary protection are published by the Committee on Space Research (COSPAR) and provide an international standard, but they are not legally binding. These guidelines categorize missions based on their activities and target destination, and are rooted in the Outer Space Treaty. It is in the purview of each individual nation or space agency to determine how to identify and implement planetary protection policies.

This is a follow-on to a study that the Science and Technology Policy Institute (STPI) completed in 2019 that took an in-depth look at planetary protection policies in the United States. The aim of this study was to learn more about how other countries approach planetary protection.

The case studies summarized below represent a sampling of countries undertaking planetary exploration. Each is planning to send spacecraft to

Mars, with some also planning to conduct sample return missions. These five case studies are not exhaustive. For example, India is also planning to send an orbiter to Mars, but there is relatively little information available about its planetary protection policies or practices. The private sector in other countries is also involved in space science and exploration. For example, in 2019, Israel's non-profit company SpaceIL sent a lander to the Moon. Its adherence to COSPAR planetary protection policies was unclear—the lander was carrying life without the knowledge of SpaceIL, SpaceX (the launch provider), or even the regulatory authorities in Israel [1].

For purposes of this study, it is helpful to note the difference between planetary protection policies and practices. Policies are generally adopted or prescribed by one or more central decision-making authorities, while practices are the means of implementing those policies. In the case of planetary protection, a national policy might involve the decision whether to adopt COSPAR recommendations for various categories of space exploration missions. The planetary protection practices would include the specific manufacturing processes and sterilization techniques used in the development and launch of those missions. In general, STPI was able to find relevant information on national planetary protection policies for each country, but less information on planetary protection practices in some of the countries studied, most notably, China and Russia.

2. Europe

Europe provides a unique case study of planetary protection policies and practices because its space exploration capabilities combine those of national space agencies (e.g., France's National Center for Space Studies [CNES], the German Aerospace Center [DLR], and the Italian Space Agency [ASI]) and the international European Space Agency (ESA), with 22 member states.

ESA represents the interests of its member states, all of whom are signatories of the Outer Space Treaty (OST).[1] Therefore, ESA writes its policies to abide by the articles and principles outlined in the treaty, including Article IX and its implications for planetary protection.

2.1 Planetary Exploration Plans

ESA has conducted a number of missions that necessitated planetary protection considerations, the most involved of which are the ExoMars robotic exploration missions. In 2016, ESA sent the ExoMars Trace Gas Orbiter into Martian orbit, and had to satisfy the probability impact constraint, showing that the orbiter had a 1 in 100 chance of impacting Mars within the first 20 years. This mission also included the Schiaparelli lander, for which ESA built a new cleanroom in Italy. They conducted microbial heat reduction and completed approximately 3,000 microbiological tests throughout the development of the spacecraft [2]. The lander crashed upon impact of the Martian surface. ESA is now planning to continue the ExoMars program with the Rosalind Franklin rover.

2.2 Planned Outgoing Missions

ESA has three planned outgoing missions with planetary protection considerations. The first is the ExoMars Rosalind Franklin rover mission to Mars, which is a life-seeking mission (Category IVb). This mission is being completed in collaboration with Roscosmos in Russia, which will provide a Martian surface platform. NASA has also provided expertise for ExoMars—most notably for the development of the Mars Organic Molecule Analyzer (MOMA) instrument, designed to examine organic molecules. On March 12, 2020, ESA delayed the mission to 2022 due to issues with the parachutes and electronics [3].

The second relevant mission is the Jupiter Icy Moons Explorer (JUICE) mission. This mission is Category III for Europa and Category II for Ganymede, and is expected to launch in 2022 [4]. The goal of this mission is to investigate the evolution of the Jovian system, particularly focused on the emergence of potentially habitable worlds (i.e., the icy moons) around a gas giant.

The third and final relevant mission is the outgoing leg of the Mars sample return campaign, which will be Category III.

2.3 Planned Return Missions

ESA will be collaborating with the United States to plan and execute a Mars sample return mission. The first step of this mission began with the launch of NASA's Mars 2020 mission on July 30, 2020. This mission is sending the Perseverance rover to Mars, and is planning to select samples for subsequent return to Earth. Then, a NASA Sample Return Lander with an ESA Sample Fetch Rover will retrieve these samples. A Mars Ascent Vehicle (MAV) will launch the container into Mars orbit. In Martian orbit, the ESA Earth Return Orbiter will collect the samples in a biocontainment capsule before returning to Earth and landing in Utah [5]. (See Figure 1 for a depiction of the mission architecture).

Because of the risk of returning extant Martian life, the mission will be a Category V restricted Earth return requiring extensive protections. This joint

[1] ESA Convention, Article II

sample return campaign requires a cohesive policy framework between the United States and the ESA—for example, to facilitate the return of samples from a European spacecraft to the United States' landing site in Utah. A policy framework for such a mission does not currently exist.

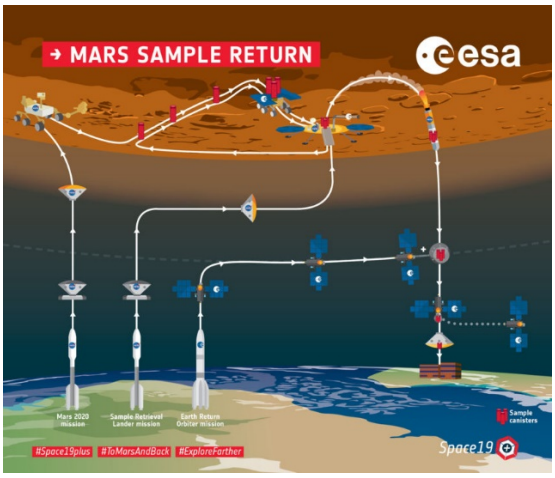

Figure 1. Architecture of Mars Sample Return. Source: ESA

2.4 National/Regional Planetary Protection Policy and Practices

The ESA Planetary Protection Policy is based directly on the COSPAR Planetary Protection Policy [6]. The European Planetary Protection Requirements, both at ESA and European Cooperation for Space Standardization (ECSS) levels, are in line with the COSPAR planetary protection implementation requirements (with some additional elements to ensure that requirements are clear and verifiable). ESA is well represented on the COSPAR Planetary Protection Panel (PPP) and has often played a leadership role. The current chair of the COSPAR PPP is European, as are both vice-chairs, one of whom is the ESA Planetary Protection Officer. Members of the COSPAR panel also include agency representatives from Italy, the United Kingdom, Germany, and France. European scientists are also individual members of the panel [interview with ESA expert]. To the best of our knowledge, European countries all follow COSPAR's planetary protection guidelines.

The European Planetary Protection Requirements, based on the COSPAR planetary protection guidelines, are reviewed approximately every 2 years, historically during the biannual COSPAR Scientific Assembly (interview with ESA expert). Potential updates to the requirements are discussed between space agencies, and if all agencies agree on the need for updates, it is recorded and discussed at the COSPAR level. The last time they were reviewed was in July 2018 at the 42nd COSPAR Scientific Assembly in Pasadena, California. The requirements will likely be reviewed next at the 43rd Scientific Assembly in January 2021.

ESA does promulgate its own implementation procedures of the COSPAR policy as standards. Changes to these practices are discussed between individual space agencies and their industry partners. According to interviewees, there have been no recent discussions about updating the implementation of the European policies, analogous to the 2019 update to the NASA Planetary Protection Independent Review Board (PPIRB) recommendations in the United States. Internationally, these ESA planetary protection standards are perceived to be the best formulated [interviews].

3. Russia

In the Russian Federation, the main hub for space activities is the Roscosmos State Corporation for Space Activities (Roscosmos), which is a national state corporation. Roscosmos assumed these responsibilities after the Federal Space Agency Roscosmos merged with the United Rocket and Space Corporation in 2015 to form a nationalized Russian space industry [7, 8]. The Institute on Biomedical Problems (IMBP), which is a part of the Russian Academy of Sciences, addresses most of the biological concerns of the Russian space program.

PAO S.P. Korolev Rocket and Space Corporation Energia (RSC Energia) is the primary manufacturer of spacecraft and space station components for Roscosmos. In addition, there are dozens of subsidiaries and partners who collaborate with Roscosmos on Russian space initiatives. Notable examples include: NPO Lavochkin, a spacecraft developer and manufacturer; the Central Research Institute of Machine Building (TsNIIMash), a space and defense research agency focusing on propulsion and satellite systems; and Proton-PM, a heavy machinery and engine manufacturer. The Russian Academy of Sciences (RAS) also plays a prominent role in space activities by providing proposals, designing instruments, and lending expertise for missions.

3.1 Planetary Exploration Plans

Since the dissolution of the Soviet Union, there has only been one attempted Russian mission with planetary protection considerations, Phobos-Grunt. This mission planned to go to Phobos, one of the Martian moons. It intended to be the first spacecraft to return a macroscopic sample from an extraterrestrial body in over 30 years [9]. The orbiter portion of this mission was Category III. At the end of assembly, Russian researchers noted that the microbial

contamination did not exceed 500 bacterial spores per sq. m and with a bioburden not exceeding 5x105 spores, which is a lower threshold than requested by COSPAR guidelines [10]. This was achieved by sterilizing and assembling the craft in a class eight clean room, in accordance with GOST ISO 14644-1-2002 [11]. The descent module was Category V for unrestricted Earth return, and again, the procedures for the lander supposedly followed COSPAR guidelines.

Beyond the Russian lander and orbiter, Phobos-Grunt also included a Chinese orbiter, Yinghuo-1, and a payload from the Planetary Society, an American space exploration and advocacy organization[11, 12]. The Planetary Society's payload, Living Interplanetary Flight Experiment (LIFE), contained samples of Earth-based life meant to fly to Phobos and then return to Earth. These samples included *Deinococcus radiodurians*, an extremely durable bacterium; tardigrades; three species of archaea, single-celled prokaryotic organisms; yeast; plant seeds; and a soil sample from the Negev Desert [12]. These samples, most of which were freeze-dried and rendered inert, were placed in individual vials, which were placed into a titanium disc. According to NASA's Planetary Protection Office (PPO) at the time, the LIFE payload satisfied planetary protection requirements due to the conditions on Phobos, and under the condition that Roscosmos would provide detailed confirmation that the mission reached its target. However, the planetary protection procedures for this mission were ultimately a moot point, as after launch Phobos-Grunt failed while still in Earth orbit due to a programming error and the spacecraft was destroyed upon re-entry [13].

3.2 Planned Outgoing Missions

Currently, the ESA and Roscosmos are planning a Martian mission, ExoMars Rosalind Franklin, which is slated for launch in 2022 after over a decade of delays [14]. Roscosmos will be the primary manufacturer for the lander—named Kazachok or "Little Cossack"—and ESA will be the primary manufacturer of the rover Rosalind Franklin. In a public interview, Gerhard Kminek, ESA's Planetary Protection Officer, noted that the ExoMars mission "has stringent planetary protection requirements" that are being carefully followed [15]. However, information could not be gathered on the implementation practices Russia has used to follow these planetary protection requirements.

Roscosmos has three lunar missions planned for the next decade: Luna 25 in 2021, Luna 26 in 2024, and Luna 27 in 2025. Luna 25 and Luna 27 will land on the lunar South Pole to prospect and drill for water ice. Luna 26 is an orbiter that will survey the surface for resources, particularly water ice [16]. If these missions contain an organic inventory, they fall into Category II and do not have stringent planetary protection requirements. If these missions do not contain organics, they fall into Category I.

In the mid-2020s, Russia is planning to launch an orbiter, lander, and surface station to Venus, called Venera-D [17]. The orbiter is intended to operate for at least 3 years, and the lander will operate for just a few hours on the planet's surface [18]. The orbiter will collect data on the Venusian atmosphere, including composition, dynamics, and structure. The lander will also collect atmospheric information on its descent, but upon landing, will focus on the composition of the surface. There have been some reports that NASA or other international space agencies will collaborate on these missions; however, this has not been confirmed beyond news articles and a single NASA Jet Propulsion Laboratory (JPL) press release from 2017—so the nature and extent of the collaboration are unclear [19, 20]. This mission falls into Category II and is subject to the planetary protection requirements that correspond to this designation.

3.3 Planned Return Missions

Russia has indicated plans for a Mars sample return mission called Mars-Grunt, but these plans have been pushed back until after their involvement in the ExoMars landing [21].

3.4 National/Regional Planetary Protection Policies and Practices

It is prohibited in Russia to create harmful contamination of outer space that leads to undesirable changes to the environment under Article 4(2) of the Law of the Russian Federation about Space Activities [22]. The text translates to "Space activities are carried out in accordance to the following principles: ensuring the safety of space activities and environmental protection."[2] This article also establishes the licensing regime of Russian space activities. In addition, Article

[2] Original text: Космоческая деятельность осуществляется в со ответствии со следующими принципами:... обеспечения безопасности космической деятельности и охраны окржающей среды.

Закон РФ от 20 августа 1993 г. Н 5663-1 "О Космеческой деятельности" [The Law of the Russian Federation of August 20, 1993 N-5663-I "On Space Activities"]. http://base.garant.ru/136323002004003003003003003003003003003003003003003003003003003003003003003003003003003003003036

5(H) of Resolution 104 of the Government of the Russian Federation on the Statute on Licensing Space Operation of February 2, 1996 mandates that licensing applicants must confirm that their mission meets safety standards, including environmental.[3] The direct text, according to the United Nations Office for Outer Space Affairs, is "to obtain a license, the applicant shall submit to the Russian Space Agency [now Roscosmos]…documents confirming the safety of space operations (including ecological, fire and explosion safety) and reliability of space equipment [23]."[4]

While these two statutes establish the baseline for planetary protection standards, Russia does not have, in its national space law, a specific planetary protection policy or program [email correspondence with Russian space and planetary protection experts]. However, they do report to follow COSPAR regulations, and are long-standing members of the organization [24, 25]. More specifically, the Russian Academy of Science's Council on Space is the primary agency in Russia addressing planetary protection, and within the Council on Space, the Experts Working Team on Planetary Protection is charged with the regulation of such activity in Russia [26, interview]. The Experts Working Team on Planetary Protection acts as the intermediary between COSPAR, the various Institutes of the Academy of Sciences, Roscosmos, and the Federal Medical Biological Agency. The major players within the Experts Working Team are Institute of Biomedical Problems of the RAS (IMBP); Space Research Institute of RAS (IKI); Vernadsky Institute of the RAS; Federal Medical-Biological Agency; Lavochkin Association; and the Central Research Institute of Machine Building (TsNIIMASH). In particular, an interviewee noted that IMBP focuses on these issues and sends delegates to COSPAR [interview]. As far as STPI could ascertain from interviews, Russia has no plans to change their planetary protection policies in the near future.

The Russian Academy of Science's Institute of Biomedical Problems (RAS IBMP) has been conducting "bio-risk" experiments on the International Space Station (ISS) to better understand the effects of spaceflight on certain forms of life—higher order plants, microorganisms, lower crustaceans, etc.—to understand the survival limits and whether such life forms could survive longer-duration missions in space [27]. These bio-risk experiments found these organisms could survive and reproduce after 31 months on the exterior of the ISS, which is similar to the expected duration of a voyage to Mars. As to the effect these experiments may have on planetary protection requirements, all that was stated was that the ability of these organisms to survive harsh conditions "must be taken into consideration when developing and validating planetary quarantine methods" [27].

4. China

China's space program began as part of a Cold War defense program, sending its first satellite, Dong Fang Hong (The East is Red), into Low Earth Orbit (LEO) in April 1970 [28]. Since that time, China has launched more than 357 space objects and pursued a number of scientific and exploration missions with planetary protection implications [29].

4.1 Planetary Exploration Plans

As discussed in the Russia case study, Yinghuo 1 (Category III) was a Chinese orbital satellite for Martian surface surveillance and testing deep space navigation, launched with the Russian Phobos-Grunt mission in 2011 [30]. The mission failed in the secondary firing stage, leaving Yinghuo 1 in LEO. One interviewee from another national space agency, who was then involved in COSPAR, indicated that China was not very cooperative on the Yinghuo 1 mission in adopting the categorizations proposed by the international scientific community through COSPAR [interview]. Other previous missions include Chang'e missions 3 and 4 (Category II), both of which put landers on the Moon, sampling lunar soils and conducting biological experiments on the surface of the Moon.

4.2 Planned Outgoing Missions

China aims to expand its space exploration capabilities by launching a Mars rover in the 2020–2022 timeframe, carrying out orbiting and roving exploration [31, 32]. Since the rover was launched on

[3] Ibid.

[4] Постановление от 2 февраля 1996 ф И 104 "Об Утверждении Положения о лицензировании космеческой деятельнотси" [Decree of 2 February 1996 no. 104 "On the Approval of the Regulation on the Licensing of Space Activities."] Russian Federation, February 2, 1996. http://www.consultant.ru/document/cons_doc_LAW_9145/

Original text: "Для получения лицензии заявитель представляет в Российское Космическое агентство:... документы, подтверждающие безопасность космической деятельности (в том числе экологическую безопасность и пожаровзрывобезопасность) и надежность космической техники."

schedule in July 2020, a landing module could enter the Martian atmosphere in early 2021 [33]. The rover would carry high and medium resolution cameras in addition to a spectrometer to analyze Martian geology [33]. The Mars mission will advance Chinese orbiting, roving, and sample return technical capabilities for future missions [32].

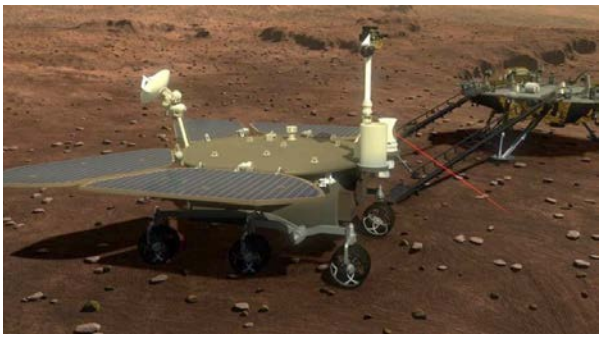

Figure 2. 2020 CNSA Mars Rover. Source: SpaceNews

4.3 Planned Return Missions

Chang'e 5 will be the first Chinese lunar sample return mission, bringing 2 kg of lunar regolith back to Earth [34]. The return sample will go to the Inner Mongolia Autonomous Region for testing and research, transported in a sealed container [35]. Pending the success of Chang'e 5, China has planned another sample return mission with Chang'e 6 in the 2023-2024 timeframe. Initial plans for Chang'e 6 include 20 kg of payload reserves selected from Chinese colleges, universities, private enterprises, and foreign scientific research institutions for lunar sampling and other lunar research [36].

China is also conducting technology studies for a Mars sample return but does not expect to return Martian samples until sometime around 2030. While on the Martian surface, the mission plans to study soil and atmospheric conditions, searching for water ice and habitability characteristics [37]. China is working to increase its technological capabilities to be compliant with planetary protection standards for their Mars sample return [378.

4.4 National/Regional Planetary Protection Policy and Practices

China is a signatory of the OST and joined COSPAR in 1993. China has created CN-COSPAR to "promote the development of China's space science cause and improve the level of Chinese space research [39]." The Chinese Panel on Planetary Protection is led by General Secretary Wu Ji, director of the National Space Science Center and Vice President of COSPAR. The panel consists of roughly 50 committee members and 12 executive committee members [39].

China does not appear to have national space laws at the time this case study was written [40, 29]. International agreements, in order to have legal standing in China, must be passed through statutes from the Standing Committee and the National People's Congress, or reflected in departmental rulings. To our knowledge, there are no departmental regulations concerning planetary protection. However, at the November 2017 CN-COSPAR meeting, Vice President of the Chinese Academies of Sciences and Chairman of CN-COSPAR Xiangli Bin indicated:

"Starting in 2018, space science mission data was made public through a large number of publications, using the COSPAR stage to carry out good communication and learning, playing a role in COSPAR, the largest international space research academic organization." [41]

Chinese researchers from government and private entities—including the China Astronaut Training Center, Aerospace Shenzhou Biotechnology Group Co., Ltd., Beijing Space Biotechnology Research Center, China Aerospace Science and Technology Corporation Space Bioengineering Research Center, China Academy of Space Technology, and the Beijing Spacecraft Overall Design Department—have all noted that planetary protection should be a priority for China to become a major spacefaring nation [42, 43]. Online, the Chinese National Space Administration (CNSA) published the NASA PPIRB statements, indicating that state and commercial entities operating in space should "keep up with the times" developing planetary protection policies that reflect the current state of technology [44]. Interviews confirmed that the dynamic between China and COSPAR has changed since the Yinghuo mission, changing for the better [interview]. Based on publicly available information and interviews, China does not appear to be considering changes to their planetary protection practices that would be in conflict with COSPAR guidelines.

China's views on space parallel its ambitious economic and political goals on Earth. According to Lt. Gen. Zhang Yulin of the Central Military Commission, China has long-term goals to reach cislunar space for solar power and resource exploitation, among other things, using this space to expand exploration capabilities [45]. The Chinese scientific community understands the value of complying with international standards in order to be seen as a great spacefaring nation; however, it remains to be seen to what extent China will provide timely and complete registration of space objects to adhere to international agreements [29].

5. Japan

The Japan Aerospace Exploration Agency (JAXA) runs Japan's aerospace and space activities. It was founded in 2003, combining several pre-existing space and aerospace agencies. The majority of JAXA's work focuses on Earth-orbiting activities, but Hayabusa and Hayabusa-2 sample return missions have established JAXA as a major player in the international planetary protection community. JAXA sets and implements its own planetary protection policy, follows COSPAR planetary protection policies, and coordinates with the international community.

5.1 Exploration Plans

Japan has conducted several missions with planetary protection implications, most notably two sample return missions, Hayabusa and Hayabusa-2. Both missions from small bodies were categorized as unrestricted Earth return, as confirmed by the international community, including COSPAR. In addition to the sample return missions, JAXA's first planetary protection activity was a Mars orbiter, NOZOMI, launched in 1998. Hayabusa-2's piggyback spacecraft Procyon also followed COSPAR's planetary protection policy in 2014.

5.2 Planned Outgoing Missions

JAXA has several planned outgoing robotic, scientific missions. These include several to small solar system bodies such as DESTINY+ (2022) and Comet Interceptor (2028). JAXA is also planning a lunar lander (SLIM) for launch in 2021 to be followed by more lunar exploration activities [46]. Only one planned mission rises above Category II: the sample return missions named the Martian Moons Exploration (MMX), which has an outgoing rating of Category III.

5.3 Planned Return Missions

JAXA is planning a Martian Moon observation and sample return mission expected for launch in 2024. MMX will bring back 10 grams of soil from the Martian Moon Phobos, returning it to Earth in 2029. NASA, ESA, and CNES are participating in the project and will provide scientific instruments.

MMX is categorized as an unrestricted Earth return mission and was recently approved by COSPAR [47]. To obtain an unrestricted status as the first mission to Phobos, JAXA had to show that the probability of a viable organism being returned from the celestial body was very low—less than one in a million. To do so, JAXA modeled the probability of a viable organism transferred from Mars to Phobos as the result of a meteorite impact. JAXA concluded the most likely sampling probability value was 10-8, warranting an unrestricted status [48]. That conclusion was confirmed by a joint study of the U.S. National Academies and the European Science Foundation [49].

5.4 National/Regional Planetary Protection Policy and Practices

Japan is a signatory of the OST but does not have national planetary protection provisions nor any legislation to protect the environment while conducting space activities [50]. JAXA independently directs and implements its planetary protection policies in coordination with COSPAR and the international community.

The JAXA planetary protection organization comprises a standard-setting working group, a research group, and a planetary protection review board (see Figure 3). The planetary protection organization resides within JAXA's Department of Safety and Mission Assurance (S&MA). COSPAR standards have been implemented as agency policy and standards. In 2018, JAXA established its own planetary protection policy and "organizationally committed to steadily complying with the COSPAR planetary protection policy [50]."

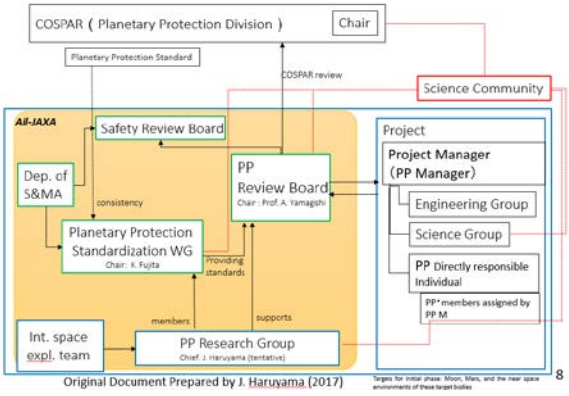

Figure 3. JAXA Planetary Protection Structure. Source: Yano, Hajime. 2018. "Planetary Protection Management at JAXA." Presentation at the PPOS Planetary Protection Tutorial 101, June 12-13, 2018 in Pasadena, CA, USA.

Prior to 2018, each project organization within JAXA or its predecessor organizations handled its own planetary protection protocols in order to directly satisfy the COSPAR Planetary Protection policy. Although several missions required planetary protection consideration (NOZOMI, Hayabusa, Hayabusa-2 and Procyon), small teams within the project independently implemented requirements and recommendations set by COSPAR Planetary Protection Panel, namely orbital calculations of impact probability to Mars and proposals of planetary

protection categorizations to COSPAR. As described by a JAXA press brief:

"obligations under the COSPAR planetary protection policy were implemented by individual projects by adopting standards in compliance with the COSPAR planetary protection policy and associated requirements, and by forming an international agreement at the COSPAR planetary protection panel [51]."

At the time of this report, JAXA decided to establish agency-wide planetary protection policy "in consideration of an increase in space-exploration missions and in response to recently implemented space activity laws [52]." The newly created policy and office were created in time for and to support the MMX mission.

According to interviews, the top-level planetary protection policy is in full compliance with COSPAR planetary protection policy. The underlying standards and thus the underlying practice are based on ESA standards, with small changes to compensate for different organizational and project management structures.[5] ESA's standards were seen as simpler and more up-to-date than those from NASA, as well as more appropriate for a smaller space agency like JAXA.

JAXA's planetary protection policy only applies to JAXA missions, and there is no explicit national policy or law to deal with private sector missions or those sponsored by other components of Japan's government. According to interviews, Japan's cabinet offices have limited knowledge of planetary protection, and typically consult with JAXA to determine mission compliance with treaty obligations. Except for the United Arab Emirates' (UAE) Hope mission, no non-JAXA missions launched or planned in Japan have had significant planetary protection implications. The Emirates Mars Mission (see below) was launched from Japan in July 2020 on the now privatized H-IIA Mitsubishi Heavy Industries launcher. Because the United States participated in the planetary protection review for the UAE mission (Category III) and COSPAR approved it, a JAXA planetary protection review is reportedly not required [interviews with JAXA scientist].

JAXA has remained informed of the changes to planetary protection policy recently proposed by the NASA PPIRB. JAXA does not yet have an official position on any proposed changes, but the personal opinion of one interviewee is that the lower categorizations of the Moon and Mars (especially for commercial entities) are welcome changes so long as more at-risk portions of the celestial bodies are still better protected.[6] However, the interviewee indicated that sending humans to Mars, whether sponsored privately or by a state actor, could pose an unavoidable loss to future science.[7]

An interviewee related that because all outgoing missions have been Category III or less, the cost of planetary protection for each mission has been small. However, they are finding that as JAXA examines missions to Mars, the cost is rising. MMX, as a Category III outgoing mission, may be the first iteration of this increase. As an important example, the interviewee related that JAXA's competition proposal for a landed mission to Mars was recently not selected due to high cost, in part arising out of planetary protection requirements. JAXA used NASA's experience and data to estimate the cost of cleaning a Martian lander. In spite of this, according to interviewees JAXA has no plans change their planetary protection policy independent of advances made at and through COSPAR.

6. United Arab Emirates

The UAE is a relative newcomer to the space industry. The country has two space agencies: The United Arab Emirates Space Agency (UAESA), a government agency based in Abu Dhabi, and the Mohammed bin Rashid Space Centre (MBRSC), a government entity of Dubai. These agencies were established in 2014 and 2006, respectively. Since then, the UAE has made quick strides in establishing itself as a major player in space, and in 2019 sent its first astronaut to the International Space Station [53]. The UAE is sending a spacecraft into Mars orbit.

6.1 Planetary Exploration Plans

Prior to 2020, the UAE had not conducted any space missions with significant planetary protection implications. It has one ongoing orbiter mission to Mars and its practices are based on the COSPAR planetary protection policies.

6.2 Planned Outgoing Missions

The UAE is currently working on the Emirates Mars Mission (EMM), the main component of which is the Hope spacecraft. This mission is funded by the UAESA and was built and operated by the MBRSC. The Hope spacecraft was launched from Japan on July

[5] The policy and standards are currently only available in Japanese.

[6] The interviewee also noted that ESA, on the other hand, will likely want to keep more stringent policies.

[7] The United States, including several of its private companies has planned human missions to Mars." Because you cannot clean humans or keep them fully contained, it is unavoidable that a human on Mars would leave behind microorganisms.

19, 2020 on a private launch provided by Mitsubishi Heavy Industries. It will stay in Mars orbit and its goal is to collect weather and climate information from the Martian atmosphere [54]. This is a Category III mission.

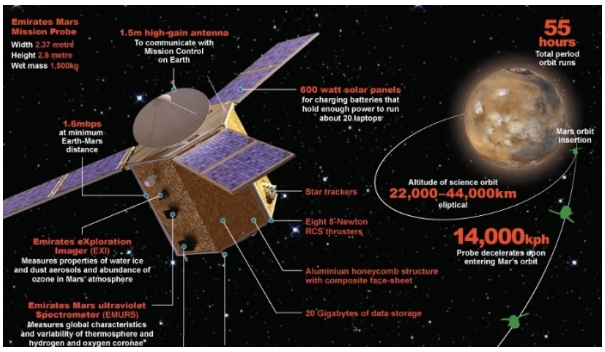

Figure 4. Emirates Mars Mission Hope Probe Source: Sarwat, Nasir. 2020. "UAE's mission to Mars on schedule for launch despite Covid-19." *The National*. https://www.thenational.ae/uae/science/uae-s-mission-to-mars-on-schedule-for-launch-despite-covid-19-1.993686

To successfully execute the mission, the UAE collaborated with teams from U.S. universities, rather than building its own space infrastructure. Its main collaborator is the Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado, Boulder [55].

6.3 Planned Return Missions

The UAE currently has no plans for return missions.

6.4 National/Regional Planetary Protection Policies and Practices

The UAE has no national or regional planetary protection policies, nor an office of planetary protection. According to interviewees, there are no plans to change this. The UAE has ratified the OST, and their national space policy states that "[a] safe, sustainable, and stable space environment, free from impediments to access and utilization, is a vital national interest [56]." The UAE does not have a representative on the COSPAR Planetary Protection Panel; however, an interviewee participating in COSPAR indicated that an invitation has been extended or will soon be, and that UAE contributions would be welcome.

When LASP was helping to design EMM, it had to develop its own planetary protection practices. It was the responsibility of the mission designers to ensure that the Hope spacecraft was sufficiently sterilized to meet the treaty obligations under Article IX of the OST. LASP collaborated directly with COSPAR to ensure that its planetary protection practices abided by the COSPAR guidelines, and used the ESA planetary protection policies as a reference [interview with EMM expert]. The EMM mission required planetary protection approval from JAXA, the launch provider, and NASA, for use of the Deep Space Network (DSN). Working with COSPAR to determine planetary protection implementation plans gave the mission credibility with the NASA PPO and JAXA.

When asked about challenges implementing the planetary protection requirements, a representative from the Hope mission said that the major challenge was interacting with NASA to get planetary protection approval because the mission plans to use the DSN. For example, during mission planning, the NASA planetary protection officer changed, which precipitated a change in planetary protection requirements. This contributed to delayed mission approval from NASA. The mission did not receive approval until a year after it would have been possible to make any changes. Fortunately, all changes required by the new PPO were addressed through further reporting [interview with EMM expert].

7. Summary of Findings

7.1 All countries examined as part of this study appear to adhere to COSPAR guidelines and none is planning major policy changes

In STPI's review of the planetary protection policies of the five countries and regions, we found that all claim and appear to adhere to COSPAR's planetary protection guidelines. To the best of our knowledge, none of these countries is currently considering any major changes to their national planetary protection policies or practices. A number of the country-level experts we spoke to reported that they are aware of the recommendations of the NASA PPIRB. No analogous study appears to have been conducted elsewhere.

7.2 Difficult to ascertain level of adherence of some countries

For some countries, such as China and Russia, it was difficult to ascertain their level of adherence to the published guidelines. However, both have ratified the Outer Space Treaty (OST) and are members of COSPAR. They have therefore signaled their overall willingness to commit to and develop planetary protect policies and practices that conform to the COSPAR planetary protection guidelines. However, domestic space activities in these countries are more challenging to research and would necessitate additional time to be reviewed. Public information on and evaluations of

their programs are not readily available. It is therefore much more difficult to ascertain their level of adherence to and compliance with internationally accepted planetary protection practices.

7.3 No relevant policies or regulations for the private sector

With the exception of Russia, none of the countries studied has explicitly developed planetary protection policies or regulations specifically applicable to the emerging private space sector.

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An International Perspective on Planetary Protection Policies

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Motivation and Scope

- Increased number of upcoming missions to Mars, including some with proposed sample return.
- COSPAR guidelines provide an international standard for planetary protection, but are not legally binding for any one nation.
- It is the purview of individual nations to determine how to identify and implement planetary protection policies.
- Follow-on to a STPI study about planetary protection policies in the U.S. We wanted to know more about how other countries approach planetary protection.
- Conducted case studies on Europe, Russia, China, Japan, and the United Arab Emirates.

Methodology

- Examined the literature, news articles, and publicly available information about planned missions and planetary protection practices.
- Conducted interviews with subject matter experts from each country or region.
- For each case study, determined the relevant planetary protection stakeholders, any planned outgoing or return missions with planetary protection concerns, and their national/regions planetary protection policy and practices.

Europe

Stakeholders

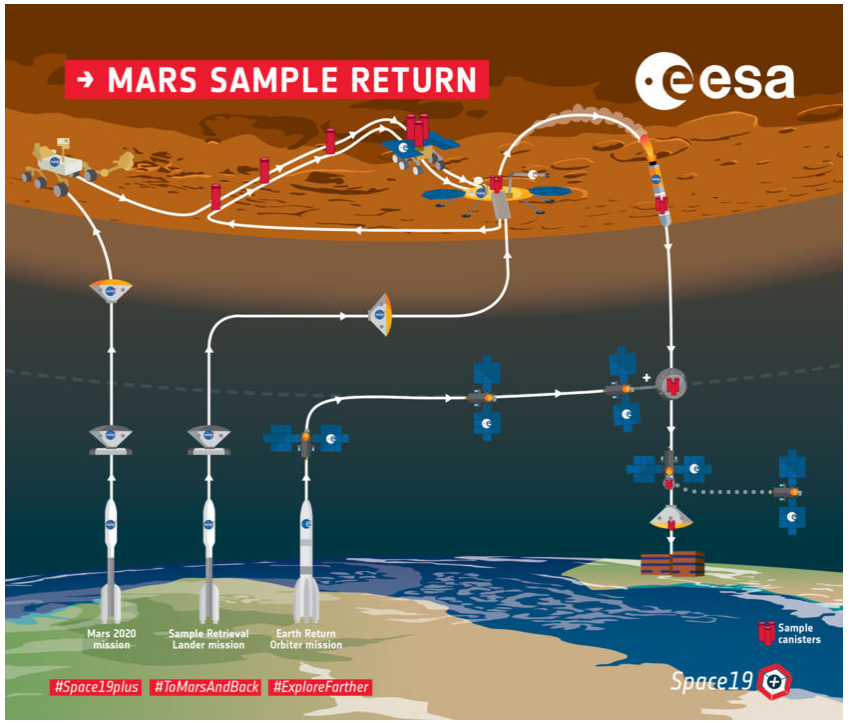
- Unique case study it combines the national space agencies and the international European Space Agency (ESA).

Upcoming Planetary Exploration Plans

- Planned Missions: ExoMars Rosalind Franklin (2022), Jupiter Icy Moons Explorer (JUICE) (2022), Mars Sample Return (in collaboration with NASA).

Planetary Protection Policy and Practices

- ESA policy is based directly on COSPAR, and is well-represented on the COSPAR Planetary Protection Panel.
- European Planetary Protection Requirements, both at ESA and European Cooperation for Space Standardization (ECSS) levels, are in line with the COSPAR implementation requirements. They are reviewed approximately every two years, and were last updated in 2018.
- No discussions to update ESA implementation policies.



Architecture of Mars Sample Return
Source: ESA

Russia

Stakeholders

- Major stakeholders are the Roscosmos State Corporation for Space Activities (Roscosmos) and the Russian Academy of Sciences Institute on Biomedical Problems (IMBP).

Past and Upcoming Planetary Exploration Plans

- Only one previous Russian mission with planetary protection considerations, Phobos-Grunt, which failed in Earth orbit. This mission planned to go to Phobos (Category III), but included a payload from the Planetary Society with samples of Earth life.
- Now collaborating with ESA on the ExoMars Rosalind Franklin, and will be the primary manufacture of the lander.
- Plans for a return mission called Mars-Grunt, but these plans have been pushed back until after ExoMars.

Planetary Protection Policy

- Article 4(2) of the Law of the Russian Federation about Space Activities prohibits the harmful contamination of outer space. Furthermore, licensing applicants must confirm that their mission meets safety standards, including environmental ones.

China

Stakeholders

- Signatory of the Outer Space Treaty, member of COSPAR since 1993, and created CN-COSPAR and a Chinese Panel on Planetary Protection which is led by Wu Ji, the director of the National Space Science Center and Vice President of COSPAR.
- Researchers from Chinese government and private entities have indicated that planetary protection should be a priority for China to become a major spacefaring nation, and interviewees indicated that the relationship between China and COSPAR has improved since the Yinghuo 1 mission.

Past and Upcoming Planetary Exploration Plans

- Yinghuo 1 orbiter launched with Phobos-Grunt in 2011, but was left in LEO. One interviewee noted that China was not cooperative in adopting the COSPAR categories for this mission.
- Planning a Mars sample return mission for sometime around 2030.

Planetary Protection Policies

- China is working to increase its technical capabilities to be complaint with planetary protection.
- Based on publicly available information and interviews, China does not appear to be considering changes to their planetary protection practices that would be in conflict with COSPAR guidelines.

Japan

Stakeholders

- The Japan Aerospace Exploration Agency (JAXA) sets and implements its own planetary protection policy, follows COSPAR planetary protection policies, and coordinates with the international community. Japan is a signatory of the OST.

Past and Upcoming Planetary Exploration Plans

- Japan has conducted several missions with planetary protection implications, most notably two sample return missions, Hayabusa and Hayabusa-2.
- The Martian Moons Exploration (MMX) sample return from Phobos (Category III) mission is the only planned mission greater than Category II.
  - This mission is unrestricted Earth return, for which JAXA had to prove a less than 1 in a million chance of a viable organism being returned to Earth. That conclusion was confirmed by a joint study of the U.S. National Academies and the European Science Foundation.

Planetary Protection Policy

- Created a new Agency-wide planetary protection policy to support MMX, based on ESA standards.

United Arab Emirates

Stakeholders

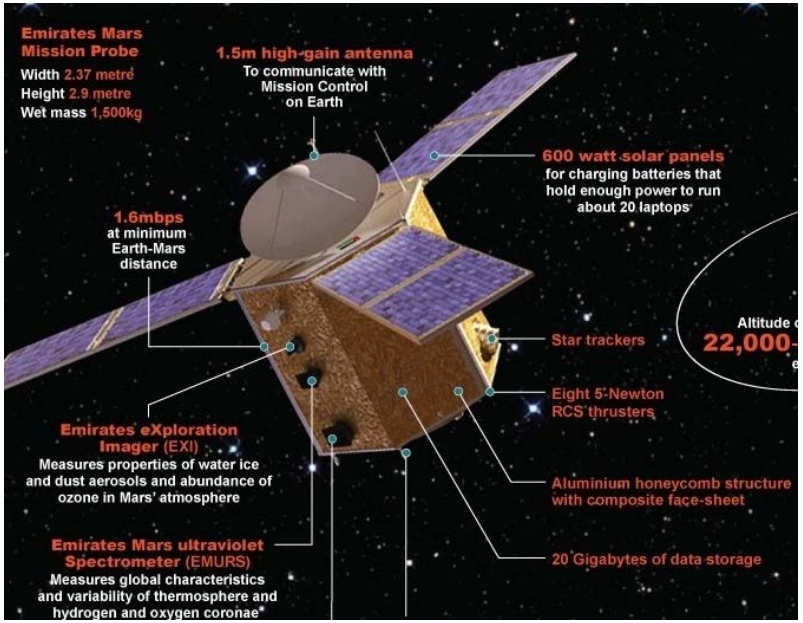
- Two space agencies: The United Arab Emirates Space Agency (UAESA), a government agency based in Abu Dhabi, and the Mohammed bin Rashid Space Centre (MBRSC), a government entity of Dubai.

Upcoming Planetary Exploration Plans

- Emirates Mars Mission (EMM), the main component of which is the Hope spacecraft.
- Collaborated with teams from U.S. universities, rather than building its own space infrastructure. Its main collaborator is the Laboratory for Atmospheric and Space Physics (LASP) at the University of Colorado, Boulder.

Planetary Protection Policy

- LASP developed its own PP guidelines, collaborating directly with COSPAR and using ESA policies as a reference.
- Challenge: Received approval from NASA a year too late to make any changes (but none were needed).



Emirates Mars Mission Hope Probe
Source: Sarwat, Nasir. 2020. "UAE's mission to Mars on schedule for launch despite Covid-19." *The National*.

Summary

- All countries or regions examined for this study appear to adhere to COSPAR guidelines.
- None are planning major changes to their planetary protection policies.
- It is difficult to ascertain the level of adherence of some countries.
- With the exception of Russia, there are no relevant policies or regulations for the emerging private space sector.

Thank you!

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

The Committee on Space Research (COSPAR) guidelines provide an international standard for planetary protection, but are not legally binding for any one nation. Therefore, it is the purview of individual nations to determine how to identify and implement planetary protection policies to meet the guidelines. The COSPAR Panel on Planetary Protection facilitates this process. With a number of nations planning missions to Mars and proposing Mars sample return in the coming years, it is increasingly necessary to understand how different space actors are approaching planetary protection policies. This study examines nations as case studies for planetary protection compliance, including Europe, Russia, China, Japan, and the United Arab Emirates. This report draws on a literature review and interviews with planetary protection experts, national representatives, and COSPAR representatives to compare planetary protection policies internationally and identify any proposed changes in the near future.

15. SUBJECT TERMS

COSPAR; international; Mars; planetary protection; policy; sample return

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