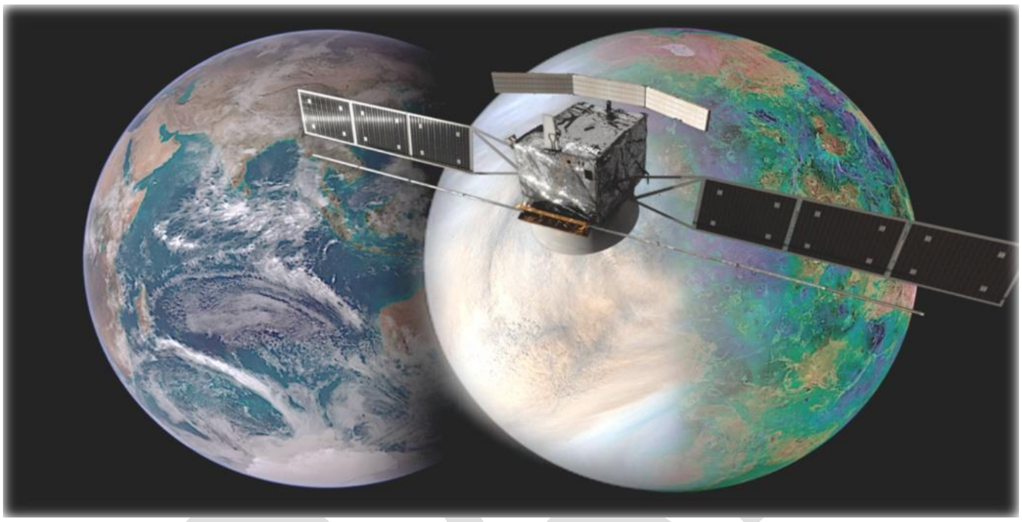
Study on the employability in Planetary Geosciences (2020-2030)



Credits: ESA/JAXA/Damia Bouic/VR2Planets

"Artist's impression of the evolution of Venus through an Earth-like phase to what we see today. Venus is the most Earth-like telluric planet, in size, composition and distance to its star, yet at some point in planetary history there was a bifurcation between the two: Earth has been continually habitable since the end of its formation, whereas Venus became inhabitable, providing a natural laboratory to study the evolution of habitability."

Study conducted by the University of Nantes and its international Partners in the framework of the Erasmus+ Strategic Partnership GeoPlaNet-SP (ref 2020-1-FR01-KA203-079773).

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Introduction

The spectacular progress of space exploration during the last 30 years has allowed the **development of Planetary Geosciences**, which are characterized by a fertile and increasing involvement at the international level, of specialists of the Earth (geologists, geophysicists, geochemists) in understanding evolutionary processes of other planets. Planetary Geosciences is an interdisciplinary science which combines expertise in observation, experimentation and modelling and is a development axis of the industry of the future, through the preparation of future exploration missions requiring advanced science in space technology and information processing with major spin-offs beyond the space domain.

The training in Planetary Geosciences suffers from a lack of structuration, at least at the European level and very few elements of statistics are available so far to identify and estimate the needs of training in this strategic sector. Compared to other disciplines which necessitate a quick response in adapting training to the fast-evolving market, **the very long timescale of a space exploration mission can be used efficiently to develop ambitious education programmes specifically designed to train young scientists to analyse and interpret the future data in relation to the scientific objectives of the missions**.

The aim of this report is to identify the needs associated to these missions. This analysis is conducted by GeoPlaNet Strategic Partnership, as (IO 2 of project 2020-1-FR01-KA203-079773) and led by the Laboratoire de Planétologie et Géodynamique of the University of Nantes. All the institutes of the partnership have already developed their own education programmes based on their involvement in space missions and are working on the **preparation of a Joint Master Programme in Planetary Geosciences**, combining their expertise, which could be propelled by a successful application to an Erasmus Mundus Joint Master Programme funded by the European Commission. **This study will serve to determine the academic needs of the future Earth and Planetary exploration programs that will allow the Partnership to design the most relevant joint training programme in Planetary Geosciences.**

Objectives

This review aims at identifying:

→ **the upcoming scientific challenges associated to planned space missions for the coming 10 years**

→ **the needed scientific expertise and skills of the future workers in Planetary Geosciences**

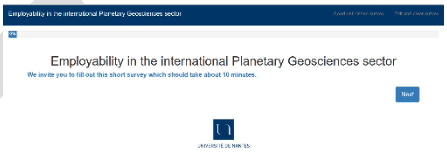
→ **the job opportunities and careers of the students trained in Planetary Geosciences**

1. Presentation of the study

This study was based on the following sources of information:

1.1. A survey on the employability in the international Planetary Geosciences domain

Considering that there was **currently no existing statistics and analysis at EU level on the employability and career prospects in the space exploration sector,** the consortium conducted **a qualitative survey aiming at getting an overview of the career opportunities as well as the needs of industrial and research fields (skills, competences and profiles) foreseen in Planetary Geosciences** for the next 10 years. The survey has been conducted within the Erasmus + Geoplanet Strategic Partnership among ESA, NASA as well as academic and research field stake holders in Planetary Geosciences in Europe and worldwide through the consortium GeoPlaNet. Together, the GeoPlaNet Consortium is involved in all major Earth and planetary missions and the data collected in this survey may therefore be considered as a representative sample of the global market in planetology.



The survey is still available on this link:
https://questionnaires.univ-nantes.fr/index.php/788137?lang=en

Survey about employability in international Planetary Geosciences:

I - The geopolitical aspect of research in planetary geosciences

1 - In your opinion, which organisations/companies/nations/etc have the greatest influence on research in planetary geosciences and on space exploration in general? In the world / in Europe?

2 - What is the involvement of your institution and your country in ongoing space missions and missions planned in the next 10 years?

II - Statistics in Planetary Science

Where can we find the employment statistics for Earth and planetary geosciences graduates and/or qualitative information on which jobs/employment sectors they go into?

III - Challenges in planetary geosciences

In your opinion, what are the major axes of exploration and technical challenges in the next 30 years in planetary geosciences?

IV – Skills requirements

Who are / will be the major employers in planetary geoscience (can be private/academic/state) and what skills portfolio is / will be required for new employees?

V – Private sector

1 - In your opinion what are the most influential companies in the private planetary science sector? Where are they located? What are their specialities? Market, figures, recruitment data, profiles sought?

2 - What are the existing collaborations between private companies and academic institutions?

We received to this exploratory investigation feedback from 10 institutes from the GeoPlaNet Consortium, sampling 9 countries: Laboratoire de Planétologie et Géodynamique (Université de Nantes, FR), University of Coimbra (PT), University of Porto (PT), JPL-Jet Propulsion Laboratory (USA), Observatoire Royal de Belgique, International Research School in Planetary Science (IT), Université de Berne (CH), CUNI-Charles University (CZ), Agricultural University of Athens (GR), Open University (UK).

1.2. The analysis of the European Space Agency (ESA) white papers and of the political strategies of the European Institutions (Council of Europe, European Commission) with regard to Space:

> **The ESA** published its white papers in 2019, detailing the long-term planning of the ESA Science Programme (https://www.cosmos.esa.int/web/voyage-2050/white-papers).
> **Council of Europe**: *"Why an EU Space policy?"* https://www.consilium.europa.eu/en/policies/eu-space-programme/
> **European Commission** about EU space policy: https://ec.europa.eu/growth/sectors/space. About EU investment in space: https://europa.eu/rapid/press-release_IP-18-4022_fr.html

1.3 Identification of Earth and Planetary missions in operations/post-operations and ongoing/forthcoming space missions from the main space agencies websites

> **European Space Agency (Europe)** about Science & Exploration missions (Sun, Solar System, Astrophysics and fundamental physics) in operations or post-operations, in implementation and cosmic vision program (2015-2025):
https://www.esa.int/Science_Exploration/Space_Science/Mission_navigator

> **NASA (United States)** about Solar System exploration active missions :
https://science.nasa.gov/missions
and programs https://science.nasa.gov/solar-system/programs

> **JAXA (Japan)** about international space exploration program:
https://www.exploration.jaxa.jp/e/program/index.html

> **National Space Science Center, Chinese Academy od Science** : http://english.nssc.cas.cn and **China National Space Administrat**ion : http://www.cnsa.gov.cn/english/index.html

> **Indian Space Research Organisation** about spacecraft :
https://www.isro.gov.in/spacecraft/space-science-exploration

> **DLR** about new missions ans projects **:** https://www.dlr.de/EN/research/space/missions-and-projects.html

> **CNES** about project library sort by https://cnes.fr/en/fiches_mission_alpha

> **Roscosmos**

> **ASI**

> **KARI**

> **UKSA**

> **CSA**

> **ISAB**

1.4 Employment statistics (FR, IT, PT) and qualitative data on employment of graduates in Planetary Geosciences disciplines

> **Europlanet industry database**: https://www.europlanet-society.org/europlanet-society/european-space-industry-database/
> **Portugal Space Agency** https://ptspace.pt
> **Employment outlook in the field of Geosciences by 2020** (Issued by French ministry of Research and HE): https://uncloud.univ-nantes.fr/index.php/s/G3JtE39x34kMwwK"
> **Report on the employability of Erasmus students** by the French Observatoire national de l'impact Erasmus: « Développement de l'employabilité et des aptitudes citoyennes au cours d'une mobilité Erasmus + », https://agence.erasmusplus.fr/wp-content/uploads/2019/12/2547_observatoire-4.pdf
> **Data about student & staff mobility, employment of graduates (following careers of students) of the universities of Coimbra, Porto, Chieti-Pescara and Nantes**

2. Outcomes

2.1 Overview of geopolitical stakes in Planetary Geosciences

Space exploration has always been a **highly competitive zone of strategic political influence and potential economical profit** for states and private companies. Currently the **most influential nations in Planetary Geosciences and space exploration** (and their space agencies) in the world are: **USA (NASA), Russia (RSA), China (CNSA), Japan (JAXA), the international ESA, Germany (DLR), France (CNES), England (UK Space Agency), Italy (ASI) and India (ISRO).**

The beginning of the 21st century has been marked by the development of ambitious space exploration programmes by **new actors such as India and China** and more recently the Emirates (UAE). But **at this specific moment, USA has the greatest influence in the world by far**. Within its FY21 $21.3 billion, NASA allocates $2.7 billion to Planetary Science to run its ambitious programme that includes flagship missions to Mars and Europa, and smaller missions selected through the Discovery and New Frontiers programs. The NASA laboratory leading Planetary Science exploration is the Jet Propulsion Laboratory (JPL) located in Pasadena (California) that, among other achievements, successfully landed rovers on the surface of Mars. Through its Planetary Science programme, NASA spends more than $200 million for research to be performed in US universities.

One characteristic of the Solar System Exploration is that instruments on a given mission are provided by national agencies in collaboration with their research laboratories. The national agency provides the funding of the instrument and delegates the development of this instrument to a research laboratory. For example, the recently selected ESA mission EnVision will have its main instruments provided by Italy, Germany, France, and the US. On the NASA VERITAS mission, some instruments are provided by Germany and Italy. The instruments onboard the NASA InSight mission were provided by the UK, France, and Germany. And the list of missions and instruments is very long. It is therefore important to train the younger generation of scientists who will take over from the previous generation and will check that the performances of the instruments provide the high-quality data required to answer the science questions they are supposed to address. The typical cost of an instrument is between 10 and 100 M$. This money is awarded by a national agency to a laboratory.

Another aspect is the trend to involve private companies in Solar System Exploration. For example, NASA relies on private companies such as Blue Origin and Space X to develop lunar landers. Such landers will carry science instruments that will be provided by national agencies. Recently, NASA awarded three grants to three different US laboratories to develop instruments that will be embarked on these landers. It is very likely that with the involvement of European countries in the Moon initiative (Artemis program), similar opportunities will exist for European laboratories.

Europe also hosts strong influential companies such as Thales Alenia (FR-IT); Airbus, Ariane Group and Sodern (FR), Swedish Space Corporation (Sweden), Logica (space and defence systems) and E2v (for detectors) UK. A few smaller SMEs such as ACRI-ST are coming into the field. *(source: Europlanet industry database).* In **Russia, Roscosmos** is a state company and sole shareholder of all industrial companies in the Russian space sector.

The coming decades will see an **increasing enthusiasm for private companies in the race for space**, not only **in the technological development such as today but also in the resource exploitation.** Some companies in the US and also in Europe (e. g., Asteroid Mining Company) are planning asteroid mining missions and were able to capture significant investments. Tesla is one example and there will be many companies ready to invest in this field as soon as technologies will become cheaper.

According to the new president of the CNES (the French National Center for Space Studies), “the **sector has a major economic impact, with a big leverage effect and the spatial share in the GDP will explode”**. The new stake is **Internet by satellite** in which players of the “New Space” are rushing (SpaceX, OneWeb*). (source: Le Monde, “L’espace, zone d’influence et de profits”, 24 April 2021)*.

Currently, in **Europe, ESA is the most influential actor in the field**, as well as several companies active in technological development. The **main European nations involved in Planetary Geosciences and space exploration are Germany, France, England and Italy.**

National agencies with their strategies and decisions strongly determine the success of the national planetary science community. Through their dialogue with national agencies, many actors, such as ESSC (European Space Sciences Committee), **Europlanet** and from industry, Eurospace and Airbus, as well as large labs such as DLR, Max-Planck (Germany) contribute to this success.

In this context, **Europe will be part of the game as a result of the *European Commission’s* plan to allocate an envelope of 16 billions euros "to stimulate the space leadership of the European Union for year 2021-2027". This funding is mainly focused on Galileo and EGNOS navigation systems, Copernicus programme of Earth observation and Earth communication satellites**. The Earth observation programme aims to provide accurate data in order to better understand our environment and climate. In complement to Earth observation, comparative planetology offers the most suitable way to deeply understand the phenomena occurring on the Earth, by analyzing their analogues on other planets. On such topics, Europe has a strong know how and technology to export by training scientists from countries newly involved in space missions. *(Source: see reference links quoted in 1.2)*.

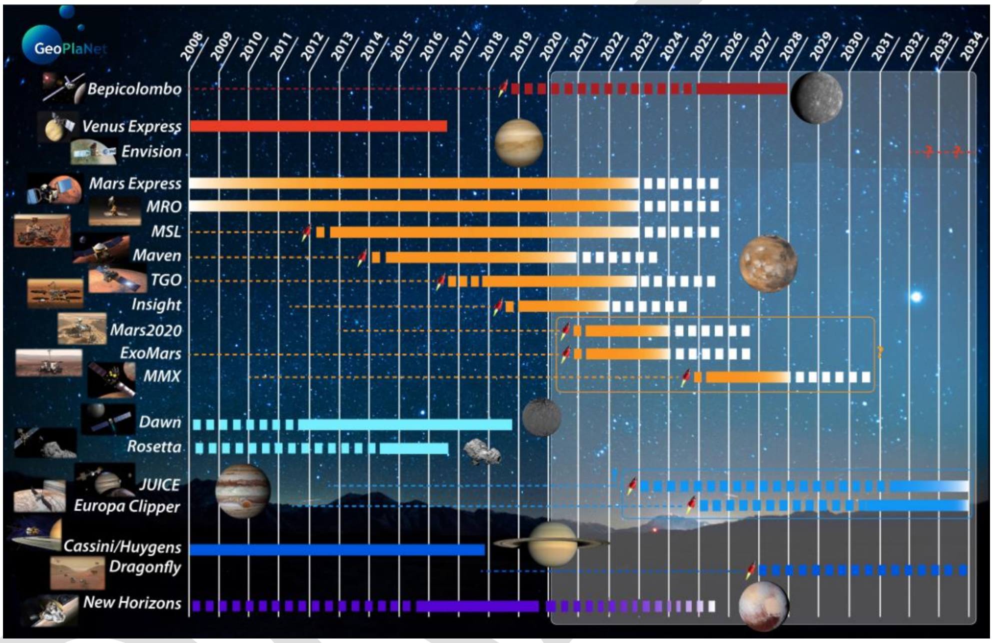
2.2. Axes of exploration and specific skills

In combination with the analysis of ESA white papers (Voyage 2050) and of the political strategies of the European institutions with regards to space, the survey highlights that:

2.2.1 Axes of exploration

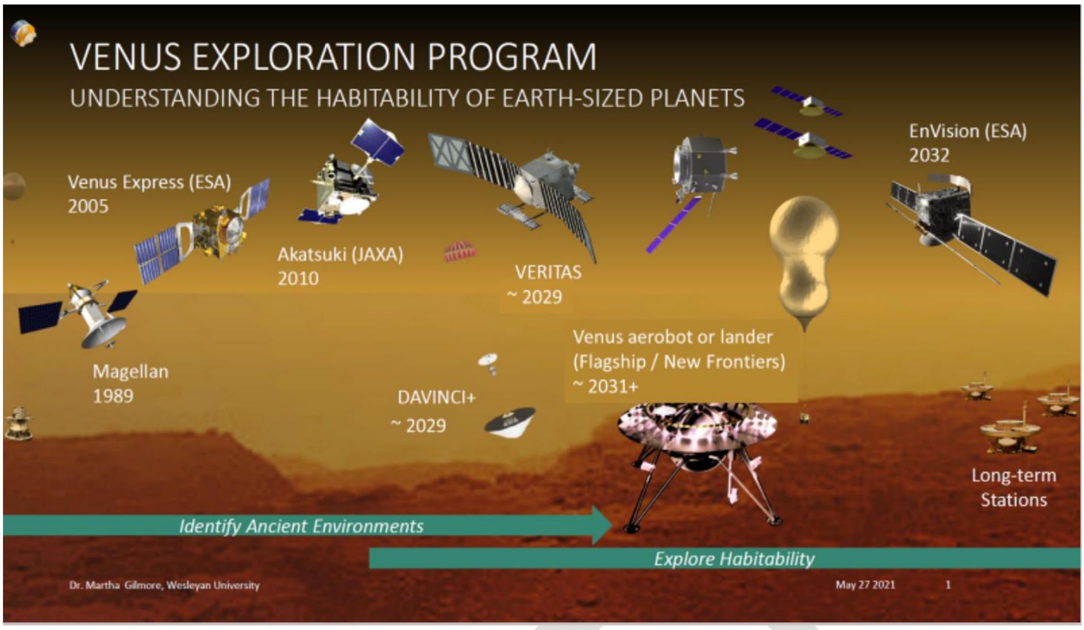
ESA’s white papers are good indicators of future axes of exploration for the next decade. From 2019, of the 20 white papers devoted to the solar system exploration, 6 were about Giant Planets moons, 3 were about Mars, 3 about Uranus and Neptune and 2 about Venus. Seven white papers concerned additionally the exoplanets characterization. The GeoPlaNet Consortium was very well represented in

these White Papers as 35% of the Solar System exploration papers were led by GeoPlaNet institutes, whereas 60% of them include collaboration from at least 2 GeoPlaNet members.
Even if not all the members of the consortium work on the manufacture of the instruments, our expertise allows us to contribute to the definition and monitoring of these instruments, to the argumentation of the scientific objectives of the missions and to the project management, and thus to contribute to the definition of the major space programmes. The involvement of the consortium members is thus from the preparation of the missions well before the launch (for example, work on the JUICE mission to Jupiter began about 15 years ago for a mission that will launch next year) and extends to the operations and data analysis phases, which can last well after the mission has ended, as shown in fig XXXX.



Main missions in which the GeoPlaNet consortium is involved as principal Investigator, co-Investigator or Team Members, half of which are European missions

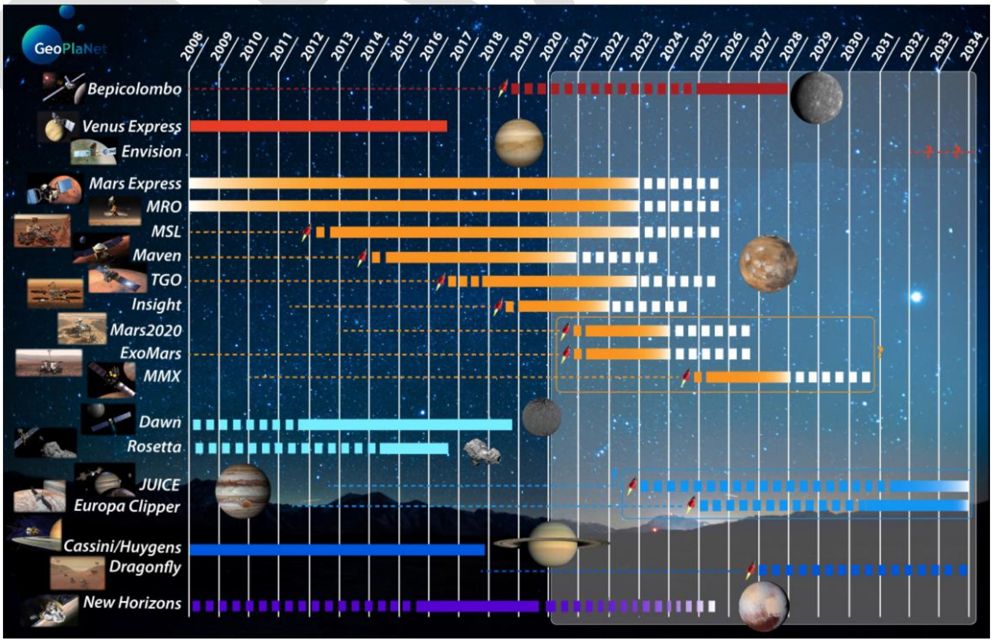
The identification of the **moons of Giant Planets, Mars and Venus** as priority targets for the future exploration of the solar system can also be acknowledged by the number of space missions devoted to them in the planned missions from ESA and NASA. The scientific interest of these axes has been recognized by ESA in June 2021 by identifying moons of the giant planets and temperate exoplanets as two of the three future themes for its large-class science missions for the timeframe 2035-2050 (Voyage 2050 Programme).



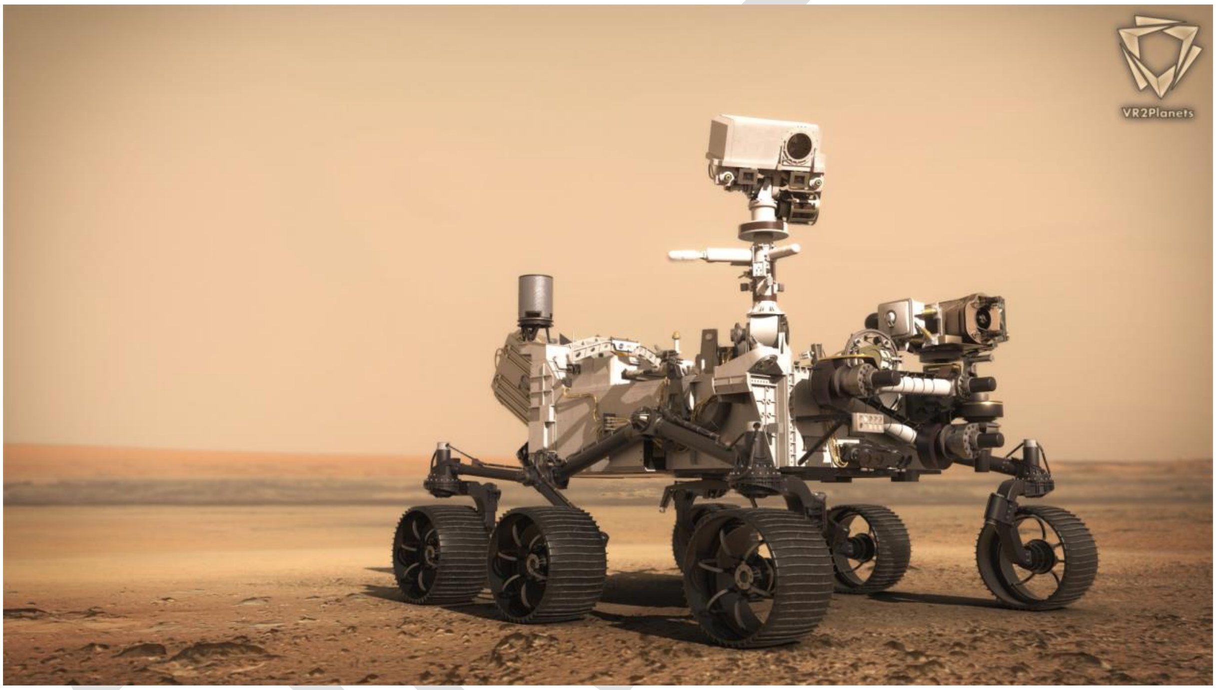
History of the exploration of Venus and that highlights the growing interest for such planet with 4 missions planned in the 2029-2032 period.

Technology now allows safe landing of rovers and instrumented platforms on planetary surfaces. Thus, space exploration now increasingly combines observations from orbits with **in situ investigations**. The perspective to **analyse return samples** from Mars, Asteroids or the Moon offers moreover the fascinating perspective to benefit from the additional expertise of scientists deeply involved in laboratory measurements. If remote sensing remains a powerful tool to characterize planetary surfaces, in-situ investigations require now a complementary expertise from the Earth Science community (geochemistry, geophysics, geology) to obtain **a full picture and understanding of surface, subsurface and interior processes**.

The following Table and Figure present an overview of these missions:



This table highlights that:
- the next decade will be extremely fruitful for the exploration of planets and moons of the Solar System, with a total number of TBC missions planned for ESA and NASA. This very large number is unique in the history of space exploration and does not include missions from Russia, India, China, which currently also develop ambitious space exploration programs. This strongly supports the growing strategic and scientific interest for space exploration for all nations,
- the diversity of targets, missions' scenarios, actors, or scientific instruments will require top-level scientists trained to work in a multidisciplinary and international collaboration,
- the GeoPlaNet Consortium is deeply involved in these missions with TBC PI and TBC CO-I responsabilities offers a very valuable education by research environment to train students to address the future scientific challenges of Earth and Planetary exploration programs.



Rover Perseverence landed on Mars in February 2021. Credits: VR2Planets.

2.2.2 Specific skills

Three types of specific skills were emphasised in the survey:

1) Strategic and project management skills required to develop ambitious programmes to explore and exploit planetary resources in an international and collaborative effort**.**

2) Data science: from the development of new softwares to numerical modelling, along with the **creation of new innovative numerical tools** such as machine learning techniques or virtual reality,

3) Space engineering and technology, from instrument design to the creation of new propulsion systems.

2.3 Employment opportunities of students in Planetary Geosciences

Planetary Geosciences, as multidisciplinary science, offers multiple employment opportunities.

Planetary Geosciences is not limited to space missions and studies of the planets. Master students often come with a Bachelor degree in maths, chemistry, physics, geology or engineering and can choose to go for jobs that refer with their initial study choices in sectors of Earth sciences. A French Ministry of Higher Education and Research (MESRI) prospective in 2020 has highlighted the **growing**

demand in the world for expertise in exploration and sustainable exploitation of natural resources.

(Employment outlook in the field of Geosciences by 2020 (Issued by French ministry of Research and HE): https://uncloud.univ-nantes.fr/index.php/s/G3JtE39x34kMwwK)

Students in planetary science become experts in using up to date technologies (e.g., remote sensing, computing facilities, analytical equipments, synthesis of materials, ...), handling and analysis of huge amounts of data (e.g. signal processing, computing skills, innovative mathematical and numerical methods, ...). All these skills are also highly valuable in the industry, even outside the spatial domain.

The employment opportunity types after a Master in Planetary Geosciences are as followed:

<table>
<tr><td>Activity sectors</td><td>Higher education, Public/private research institutes, International companies related or not to geosciences</td></tr>
<tr><td>Positions available</td><td>Researcher, Professor in academia and in industry; R&D engineer in industry; Experts in numerical modelling, lab experiments, physics, chemistry and geology; Project manager, consultant in various companies</td></tr>
<tr><td>Employers</td><td>Academic careers:
Master followed by a PhD and Post doc prior to getting a teacher/researcher position in HEIs or national public research institutes. Research engineers in public research labs in geosciences /planetary sciences. Our survey has demonstrated that about, 20% of PhDs in the field will have long-term possibilities in academia.

National or International Space Institution agencies:
ESA, NASA, Centre National d’Etudes Spatiales (CNES), Agenzia Spatiale Italiana (ASI), Portugal Space Agency
Public Industrial and Commercial Establishment or Scientific and Technological Public Institute for geosciences:
> Examples in Italy:
- CNR: Consiglio Nazionale delle Ricerche
- ISPRA: Istituto Superiore per la Protezione e la Ricerca Ambientale
- INGV: Istituto Nazionale di Geofisica e Vulcanologia
- INAF: Istituto Nazionale di Astrofisica

> In Portugal, in Geosciences and GIS:
- LNEG (National Laboratory of Energy and Geology, https://www.lneg.pt/en/homepage/)
- IPMA (The Portuguese Institute for Sea and Atmosphere, https://www.ipma.pt/en/oipma/)
- Direção Geral do Território (DGT, https://www.dgterritorio.gov.pt/)

> In France:
- BRGM: Bureau de recherches géologiques et minières
- Université Gustave Eiffel
- IRD: Institut de recherche pour le développement
IRSTEA: L'Institut national de recherche en sciences et technologies pour l'environnement et l'agriculture
- IFREMER, Institut français de recherche pour l'exploitation de la mer
- EDF: Electricité de France

Engineering consultant offices: requiring specific expertise in mapping, geology, data analysis.

Private companies: with strong R&D activities, can fund PhDs and offer jobs. They will have a growing importance in the view of resource exploration and exploitation in the coming decades. (source: survey, Ministère de l’Enseignement Supérieur, de la Recherche et de l’innovation (MESRI) prospective). Recent actualities with SpaceX have demonstrated the success of the public/private collaboration in the space sector, highlighting the potential of private sector to contribute to the development of space exploitation by designing rockets, spacecrafts softwares or applying space technology on Earth utilities.</td></tr>
</table>

Several points to improve in relation to employability were also identified:

1. Planetary Geosciences has become a highly competitive and rapidly evolving market. Employers need very well trained workforce (with both hard & soft skills) and express the difficulty to find multidisciplinarity in their recruits 'academic background.
2. The cooperation between academia and the private sector is still very limited. Some private companies exchange knowledge and data with research institutes. Some local companies host licence and master internships to develop technology and software for space. But the connections are still not as strong and interactive as they could be. The common problems "remain of differing goals, timescales and culture" (*survey*).

3. Conclusion

The combination of the different sources of information of this report have highlighted that :

- there is a g**rowing demand in the world for expertise in exploration and sustainable exploitation of natural resources**

- the forthcoming decade will be extremely fruitful for Earth and Planetary exploration programs in Europe and world-wide with more than TBC ESA and NASA missions planned,

- these missions will require the expertise of many scientisits trained to work in an international and multidisciplinary collaborative effort to gain a maximum return from these missions,

- skills on identification of natural resources, data science, from numerical modelling to machine learning or VR, and knowledge of space engineering and technology will be very valuable in this context

A Master programme based on complementary education on geology, from field activity to numerical mapping, numerical data analysis and instrumentation for space, along with VR activities a research internship in an international environment seems particularly relevant to train the young scientists that will be involved in the future exploration programs and take over the strong scientific heritage in Earth and planetary sciences.