Comparison of planet detectors of Opportunity and Juno

Jinghan Cheng*

Mellon College of Science, Carnegie Mellon University, Pittsburgh, the United States.

*Corresponding author: jinghanc@andrew.cmu.edu

Abstract. Generally, the planet detectors offer a unique insight for planet detection in astrophysics. This paper focuses on the planetary probes by first introducing the origin of humans' exploration of the Solar System ever since the Space Race in the Cold War era. The main topic is about the three different types of probes ever launched (i.e., lander, orbiter, and flybys). Two probes, Mars rover Opportunity and Jovian orbiter Juno, are chosen to represent a typical probe in its category. Both are explained from the perspectives of its structures and crucial scientific discoveries. The comparison method is employed between the two probes as well. The results are then used for proposes on future possible probes, which the experiences gained from past missions that are organized will be valuable to consider. These results shed light on guiding further exploration of planet detections.

Keywords: Planetary probes; Opportunity; Juno; Solar System.

1. Introduction

Ever since mankind discovered that there are other planets beside Earth in the Solar System, countless measures have been taken into consideration to explore them. First naked eye and then telescopes are employed to observe the planets from afar, giving researchers basic understanding of how they look like (e.g., the colors and their relative sizes), so as to wonder how are they different from the Earth. Yet just seeing the surface of things is clearly not a characteristic of the always curious *Homo Sapiens*, the desire of reaching the planets proves to be greater than the obstacles of technological barriers. Beginning with the launch of *Sputnik* 1 in 1957, human capabilities of exploring the Solar System have increased dramatically, thanks in part to the Space Race between the US and the USSR, which, in fact, competed with each other for launching more missions to other planets and their moons [1].

An example of this is the exploration of the planet Venus. The first successful flyby mission was conducted by NASA's *Mariner* 2 in 1962. Five years later in 1967, USSR successfully launched *Venera* 4, the first atmospheric probe to Venus. That is followed by one day later by NASA's *Mariner* 5, another flyby mission. In 1970, the *Venera* 7 became the first lander on Venus. Unmanned probes have become the most important way of helping astronomers understand the Solar System. By far, all the eight large planets in our Solar System have been reached by probes, just a little more than half a century have passed since the first attempt to reach Space.

Past literatures have focused on in-depth studies of individual planet probes. Boris Ragent et al. have comprehensively analyzed results of Jupiter's atmosphere conducted by the NASA 1995 *Galileo* Mission, specifically the results of the nephelometer experiment conducted by the probe carried in the mission [2]. In their article, Donald Hassler et al. have included measurement of radiation resulted from the RAD on the *Curiosity* Mars rover, which is important information when considering manned missions to the surface of Mars [3]. Yet what is noteworthy is that besides reports on already launched probes, there are many that concentrated on proposed ones for the future. The Ice Giants of Uranus and Neptune are relatively less known to humans compared to the other planets, partly because they are so far away from Earth and partly of their extreme conditions. That is not a problem for Sushil Atreya and her co-authors in proposing a probe that will detect the abundance of noble gases in the atmosphere of Ice Giants [4]. As for Alberto G. Fairen along with co-authors suggested an innovative facility (the Complex Molecules Detector (CMOLD)) in biochemical detection, which will serve as compelling evidence for existence of life in Mars and the oceans in the icy moons [5].

This paper will introduce the basis for planetary probes. The Section two will give some basic descriptions for the probes. The Section 3 will focus on the Mars rover *Opportunity* and the Section 4 will explore the Jupiter detector *Juno*. These two well-known probes are chosen because they represent different types of planetary probes and they are typical in different categories, respectively. Thus, the Section 5 will include the comparison of the two probes. In addition, suggestions about future missions will be proposed at the end of the essay, utilizing the experiences gained from past missions.

2. Basic Description of Planetary Probes

There are basically three types of planetary probes in present. The exact type launched usually depends on the types of destined planets. They shared some basic common characteristics like antennas to transmit messages back to Earth and also a reliable power source. The main difference appears in their function. For terrestrial planets (e.g., Mars and Venus), the existence of a solid surface makes it possible for the probe to land on it, and sometimes a rover, most notably the Mars rovers, to explore the composition of the ground and other data. This is often the first step before manned missions and the probes usually carried the most numbers of sensors and detectors.

Another choice is probing at the orbit of the planet, in circumstance which the planet has a too harsh environment or there is no solid surface, e.g., the Gas Giants and the Ice Giants. In some cases, the orbit probe will send entry probes into the atmosphere which it then did scientific measurements during descend, e.g., the *Galileo* mission as shown in Figure 1. The composition of the atmosphere is usually the main goal of the mission.

The third option is to flyby a planet and take photographs along the way. This gives the opportunity to visit several planets in one journey but none is explored as comprehensively compared to that of the two other methods. The focus of flybys is to carry enough fuel for extensive journeys and famous examples include the *Voyager* 1 and 2, which have already left the Solar System and entered the outer space. One of the key methods for planetary travel is known as gravity assist [6]. Lastly, it is noteworthy to mention that although the Moon have been explored by all the three types of probes, it is technically still a moon of Earth and therefore its probes cannot be included in the categories of planet probes. It is also the case for application to the probes that are aimed to explore the dwarf planets, the comets, and those in the Asteroid Belt.

Fig. 1 A skectch of the *Galileo* [7].

3. Mars Rover of Opportunity

Opportunity is, at present, perhaps the most famous and successful Mars rover. It is launched from Cape Canaveral in Florida by Delta 7925H rocket on July 8, 2003, landed on Mars on January 25, 2004, and operated until 2018. *Opportunity*, along with its twin rover *Spirit*, represented the MER. *Opportunity* is a six-wheeled, solar-powered robot standing 1.5 meters high, 2.3 meters wide, and 1.6 meters long and weighing 180 kilograms. It is designed to last about 90 days and to roam a distance of 1 kilometer. However, according to NASA, it had actually operated for 14 years and nearly 45.16 kilometers, or 28.06 miles, an unprecendented record and still remains the longest distance traveled on a celestial object beside Earth [8]. The rover was mainly powered by its solar panels during the day [9]. The cameras are located at the top of the probe, as shown in Fig. 2 [10]. The scientific instruments are located in an arm, convenient for measurements. The main body is mostly taken up by the solar panels and the dynamic systems that powers the rover.

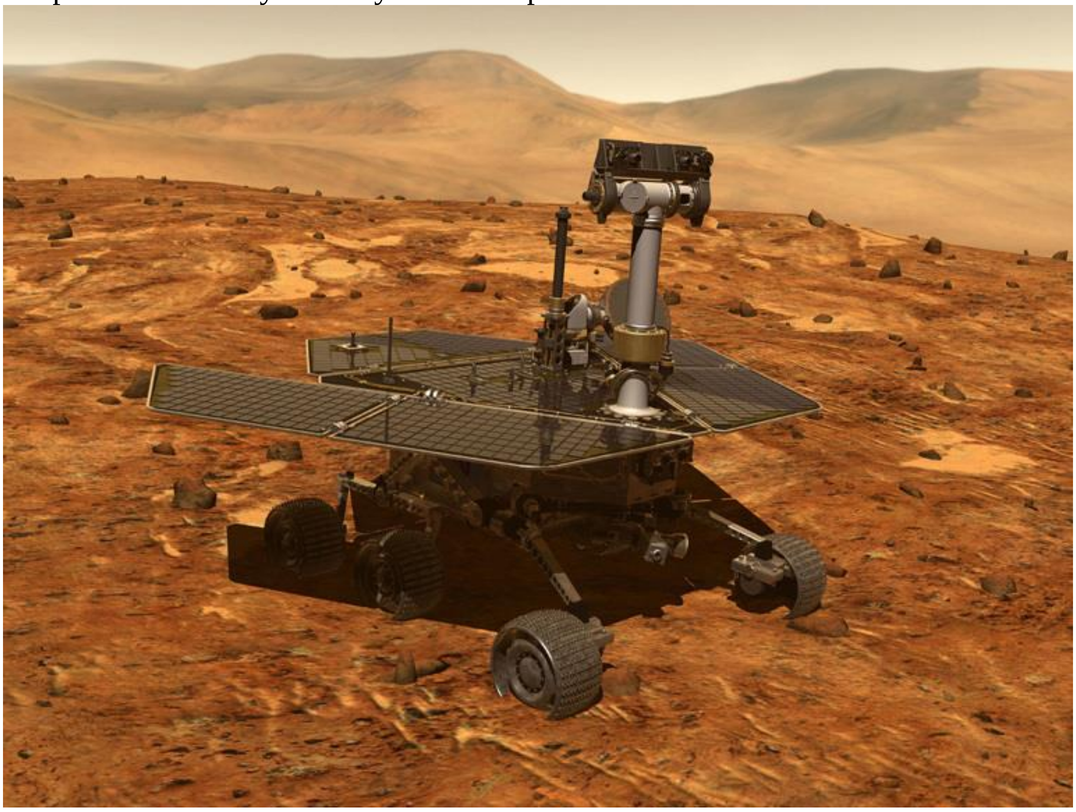

Fig. 2 A sketch of Opportunity [10].

The main goal of *Opportunnity* is simple, to find remians of ancient water on Mars, and it had acheived stunning results for that goal. One of the most significant results is the close up view of blueberry-shape hemitate, a kind of mineral that often forms in the presence of liquid water on Earth, on its way through the Meridiani Planum, not long after it had landed [11, 12].

4. Jupiter detector Juno

Juno is the second probe launched to orbit Jupiter, the largest planet in the Solar System, after the *Galileo* Mission. It is named after the Roman Goddess that is wife to Jupiter [13]. *Juno* was launched by the Atlas V rocket at Cape Canaveral in Florida on 5 August 2011. The spacecraft's main body measures 11.5 feet (3.5 meters) tall and 11.5 feet in diameter, with three large solar panels to provide energy for operation. *Juno* also spins which helps to stabilize and make it easy to control and follows a highly elliptical polar orbit that avoids most of Jupiter's high-radiation regions [14]. Some of the scientific instruments carried include, as shown in the Figure 3 [15-17].

Jupiter is the oldest planet in the Solar System, which may include secrets that can unveil the dawn of creation. Understanding this massive planet will not only help to understand a celestial object but also help to understand the origin of the world. With the instruments aforementioned, Juno has investigated deep about Jupiter's thick and turbulent atmosphere. The Jupiter's Great Red Spot is famous for its large size and it has been swirling for centuries. More appealing, *Juno* has founded that

Jupiter may not have a solid core as previously thought but rather spread out across nearly half the planet’s diameter. *Juno* is currently still orbiting around Jupiter and no doubt she, just like her namesake, will reveal more secrets from Jupiter.

Fig. 3 *Juno* spacecraft and its science instruments.

5. Comparison

Opportunity and *Juno* are quite similar in many ways. First, they are destined to study a planet beside Earth in the Solar System in unmanned missions and to transmit data back to Earth. They have used past experience, the *Sojourner* rover for *Opportunity* and *Galileo* for *Juno*, to help them succeed in their missions.

Yet the two probes are also very different. Essentially, they represent two totallly different types of probes. They have diffferent structures and objectives. *Opportunity* is a rover, which means that it is meant to study the solid surface of Mars, to find the soil composition and evidence of water. Its main body is simliar to that of a vehicle. *Juno*, on the other hand, is a orbit detector, since Jupitor has no solid surface to land on. It has a more traditional appearence of a satelilte. Its aim is to invesitage the Jovian atmosphereic content and the shape and intensity of the magnetic field. Despite their differences, both probes have achieved remarkable results and have played a vital role in help people understand better about the Solar System and they will be remembered as the pioneers for future human space exploration.

6. Limitations & Future prospects

This research has only focused on two types of probes, out of the three types aforementioned. Interplanetary probes that are aimed to flyby planets (e.g., *Voyager* 1 and 2) are prerequisites for interstellar travel are barely mentioned. However, this does not imply that they are less important than the other types. For future missions, one can safely assume that they will increase in complexity compared to that of past projects.

To be specific, it is possible that a probe could travel inside Jupiter's atmosphere, an extension of the *Galileo* project. The probe could be mobile on its own, with self-propulsion rockets while also having enough protection from Jupiter's extremely high pressure and magnetic field long enough for extensive investigations. In addition, the distant objects in the Kepler Belt, the edge of the Solar System, have a chance of been reached by future probes carrying enough fuel and utilizing the gravity assist of planets, like what their ancestors have done.

7. Conclusion

In conclusion, this paper discusses planetary probes from the perspective of their types and functions. To be specific, two probes, *Opportunity* and *Juno*, are chosen because they are typical in their respective categories. Besides, some of their most important mission results are mentioned in addition to their overall structures and the scientific instruments. Moreover, the two probes are compared for their common properties and differences. Nevertheless, the paper has not mention other kinds of probes such as those for interplanetary travel. In the future, probes will be more sophisticated and missions more complex so as to provide more answers for people. Overall, these results offer a guideline for possible planning by organizing past experiences.

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