JAPAN'S FUTURE PLANS FOR MISSIONS TO PRIMITIVE BODIES: HAYABUSA-2, HAYABUSA-MK2, AND MARCO POLO. M. Yoshikawa[1], H. Yano[1], and J. Kawaguchi[1], Hayabusa-2 Pre-project Team, Small Body Exploration WG. [1]JSPEC, JAXA, Kanagawa, Japan (makoto@isas.jaxa.jp).

Introduction: The small bodies (or primitive bodies) of the solar system, such as asteroids and comets, are important objects from various reasons. Firstly, they are important from science, because they have the information of the early solar system. By investigating such small objects, we will understand the origin and evolution of the solar system. Moreover we may understand the origin of the life. Secondly, they are important from the point of spaceguard. Now we know there are many small objects around the orbit of the earth, so collisions with the small bodies must take place in the future. Therefore we should know the properties of these objects to avoid collision. Thirdly, they are important from the point of resources. In the future world, if the humankind is active in the interplanetary space, small bodies will be utilized as natural resources. So it is worth much to investigate such possibilities beforehand. Finally, small bodies has been recognized as good targets for manned missions after the moon but before Mars.

The importance of small bodies in the solar system has been well understood in Japan for many years, and actually the first planetary mission of Japan was the exploration of Comet Halley. After about 20 years from then, the spacecraft, Hayabusa, arrived at a very tiny asteroid, Itokawa. Still Hayabusa mission is going on, but we are planning future missions to primitive bodies. In this paper, we will summarize what we are planning. We hope that many people will be interested in our plans and join our exciting missions.

Strategy: There are a lot of asteroids and comets discovered up to now. For example, there are more than 380,000 asteroids discovered up to now. But we can send only a few spacecraft to such small bodies in our life. Therefore, the target selection is quite important. Asteroid Itokawa, which is the target of Hayabusa, was an S-type asteroid, which is abundant in the inner region of the solar system. The fact that the first target was S-type asteroid is in a sense a coincidence, because we did not select this asteroid from the point of the taxonomy type. It was selected because we can perform sample return mission for this asteroid. Anyway, the exploration of Itokawa gave us a lot of new information, which will be important for the study of the solar system.

The next target should be C-type asteroids, because C-type asteroid is also major group in the main asteroid belt. They are abundant in the middle or outer part of the main belt. The C-type asteroids are interesting because we think that they have much more organic matter than S-type asteroids. And then, D/P-type asteroids or dormant comets will be very interesting and important to know the nature of the solar system. For the missions to such new targets, we have been studying missions called Hyabusa-2 and Hayabusa-Mk2. This is the exploration of primitive bodies in program. Recently Hayabusa-Mk2 was upgraded to "Marco Polo" by collaboration with the European researchers. In the following, we will introduce each mission quickly.

Hayabusa: As already mentioned, Hayabusa is the spacecraft for the asteroid sample return mission of Japan. It revealed a lot of strange nature of a very small-sized asteroid, Itokawa. We were surprised to see that the surface was covered with many boulders instead of craters. We learned a lot of scientific things about small S-type asteroid. From the technological point of view, we have had many experiences and learned a lot about exploration of small asteroid. Because of the trouble after the second touchdown, Hayabusa is still on the way back to the Earth. The careful operations for Hayabusa are now continued and it will come back to the earth in June 2010.

Fig.1 Image of Hayabusa mission. The image of Itokawa is real photograph taken by Hayabusa.

Fig.2 Artistic image of Hayabusa-2. The appearance of the spacecraft is almost same as Hayabusa, but a flat high gain antenna is uesed.

Fig.3 Artistic image of Marco Polo. There are mother spacecraft, a large lander, and small lander.

Hayabusa-2: The spacecraft of Hayabusa-2 is basically a replica of Hayabusa, so the appearance is almost the same as Hayabusa. The only difference from Hayabusa is the high gain antenna, which will be flat antenna, not a dish (parabolic) antenna like Hayabusa. Of course, we modify several points where there were problems in Hayabusa. But the model is almost same, so we can save time to manufacture it. The current target is Asteroid 1999 JU3. This is a small near earth asteroid and it is C-type. We have good opportunities to observe this asteroid in 2007 and early 2008, so now we have a lot of data about 1999 JU3. We hope that we can launch it in 2011 or 2012, but there is budgetary problem and we are discussing about collaborations with USA and Italy.

Hayabusa-Mk2: We are considering another sample return mission, which we call "Hayabusa-Mk2." In fact, we started the study of this mission much before the study of Hayabusa-2. Hayabusa-Mk2 is not the copy of Hayabusa, but it is much-advanced mission both in the sampling and the remote sensing. For example, we will challenge sampling with preserving depth profile and getting much more detailed data of the sampling sight. The current target is Wilson-Harrington, which is a dormant comet.

Marco Polo: From 2006, we had many discussions with the researchers of Europe and we agreed to make a joint mission to a primitive body. We proposed our mission to the ESA's program, Cosmic Vision in 2007. The mission name is "Marco Polo." This mission was passed the first selection in ESA and now it is under the assessment study phase. The baseline of the mission is as follows: The mother spacecraft will be provided by JAXA, because JAXA has heritage of Hayabusa. In fact, the mother spacecraft is based on what we considered as Hayabusa-Mk2. As for ESA side, they provide lander and launcher. The lander is a rather large one. ESA has heritage of the lander of Rosetta mission. One of the targets is Wilson-Harrington and the launch window is in 2018.

International Collaborations: We believe that the exploration of asteroids will provide us a lot of new discoveries. We are happy to discuss about the international collaborations for missions to small bodies in the solar system, because there are lots of them and we can know their real nature after we explore at least several of them. So we need several missions at least. We do hope that we can execute missions to the primitive bodies in the solar system in near future.