DATA ARCHIVES AND STANDARDS FOR JAPANESE PLANETARY MISSIONS. Y. Yamamoto[1,2], Y. Ishihara[1], and S. Murakami[1], [1]Japan Aerospace Exploration Agency (3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa 252-5210, JAPAN). [2]SOKENDAI, The Graduate University for Advanced Studies, School of Physical Science, Space and Aeronautical Science (3-1-1 Yoshinodai, Chuo-ku, Sagamihara, Kanagawa 252-5210, JAPAN).

Introduction: Considering the long-term preservation of data, it is important to follow standards. Although the history of planetary explorations in Japan is over 30 years, standardization of data archives has just begun(Table 1). In the 1990s, Japanese planetary exploration programs did not notice the importance of data archiving. Recently discussions of data archives become active, and long-term preservation is one of the topics in the planetary exploration programs. There are several standards to be followed making planetary data archives.

Archiving standards: Japan Aerospace Exploration Agency (JAXA) has applied the Planetary Data System (PDS)[1] as a standard to the data archives of planetary explorations. The PDS is not just a format definition, it is the system as its name. It specifies directory structure and essential files to be provided.

The missions launched before 2011 uses PDS version 3 (PDS3), and after the Hayabusa2 mission, JAXA is going to use newly developed PDS version 4 (PDS4). The PDS4 incorporates recent Information Technologies, and it is superior to PDS3 regarding metadata verification and data updating mechanism. However, the conversion from PDS3 to PDS4 is under consideration because it requires too many resources.

Ancillary data standards: SPICE[2] is used to archive ancillary data such as trajectory, attitude, coordinates, shape model, etc. The first use of SPICE in Japan was the original Hayabusa mission. Through the experience of the past planetary missions and strong support of the JPL NAIF team, JAXA continuously accumulates knowledge on SPICE.

JAXA developed software to convert from the original format to SPICE format not to depend on a specific person. The software is included in an automated pipeline. It converts from a time conversion table to SPICE SCLK format, and from quaternions in the raw CCSDS space packets to SPICE CK format.

Coordinate and Cartographic standards: It requires prior adjustment of the coordinate standards. Also, projection rules should be determined in advance if possible.

An example is the SELENE(Kaguya) mission. It uses the mean Earth/polar axis (ME) reference system, and a reference sphere of a radius is 1737.4 km. There was a discussion to select a coordinate, and it decided to match with the Lunar Reconnaissance Orbiter (LRO) standards[3].

Table 1 Data of Japanese planetary explorers

Name	Launch	Target	Archives
Sakigake Suisei	Jan.1985	Comet Halley	DARTS PDS/SBN
Hagoromo Hiten	Jan. 1990	Moon	-
Nozomi	Jul. 1998	Mars	-
Hayabusa	May 2003	Asteroid Itokawa	DARTS PDS/SBN
Kaguya	Sep. 2007	Moon	DARTS
Akatsuki	May 2010	Venus	DARTS PDS/Atmos.
Hayabusa2	Dec. 2012	Asteroid Ryugu	DARTS PDS/SBN
BepiColombo (MMO/MPO)	Oct. 2018 (Scheduled)	Mercury	DARTS PSA

For another example, there was an undefined coordinate system during a mission. The asteroid 25143 Itokawa was a target of the original Hayabusa mission. The definition of the coordinate was referred in Fujiwara et al. in 2006[4], and IAU officially approved the orientation parameters in 2007[5]. In this case, the precise values obtained by the original Hayabusa project affected the IAU definition.

Internal organization for PDS: For JAXA without many planetary probes, it is hard to organize specialized units of data archives for planetary explorations. Therefore, each project must build a data archive on a project basis. This structure works very well if the standard is not that complicated. Unfortu-natally, the planetary data archive is no longer simple already. The PDS is sophisticated for the long-term preservation and instrument team must understand abundant documents. It is required to prepare experts internally beyond missions to make a high-quality data archive continuously.

External support for PDS: While data standards are in place, securing resources to follow them is difficult. External support is essential to make archives high quality.

Indeed, developing PDS4 archives entailed many difficulties in Japan because JAXA has just acquired knowhow on the PDS3 standards. To confront this problem, the existence of the International Planetary Data Alliance (IPDA) was quite meaningful. There are

PDS4 related members in IPDA and JAXA was able to issue a question or a request to the PDS4 via IPDA.

Also, the contracts between NASA and JAXA, or ESA and JAXA are helpful. The memorandum of understanding (MOU) between agencies described the cooperation for data archives, and the framework beyond agencies was established.

Data status of Japanese planetary missions: JAXA opens scientific data obtained by spacecraft from the DARTS website[6].

Sakigake datasets were recently recreated to fill the coverage by the historical data recovery program in Japan. Originally, there was no data in DARTS, but newly archived datasets were released from DARTS in 2017. The format is a simple ASCII format, and still not in PDS3 format. We consider submitting this dataset to PDS Small Body Node(SBN) after PDS3 conversion.

The original Hayabusa was fully supported by MOU between NASA and JAXA to create archives in PDS3 format. Therefore, the data is currently released both from NASA's PDS website and JAXA's DARTS website.

The data archives of SELENE (Kaguya) mission was constructed in the original format similar to PDS3. They were converted from the original format to PDS3 over several years, and it was a very challenging task because the project was already finished and the cooperation of other agencies was minimum.

Archiving of data sets of Akatsuki (also known as Venus Climate Orbiter, VCO) are ongoing (in Nov. 2017). The SPICE kernels dataset had already been passed the review by PDS NAIF node, and is archived in DARTS and is mirrored by NAIF. The other datasets that mainly includes images acquired by the cam-eras onboard Akatsuki are currently under review by PDS Atmospheres Node.

Hayabusa2 is the first mission to implement PDS4 archives in the Japanese missions. To follow the new standards PDS4, the cooperation of NASA PDS and IPDA are essential. Training programs and talks to the actual developers of PDS4 are also available for the implementation.

Conclusion: Even with sophisticated design, it is difficult to implement. The data archive field of planetary exploration already requires experts. International cooperation is indispensable to enhance the quality of data archives.

References: [1] NASA The Planetary Data System (PDS) https://pds.nasa.gov,2017. [2] JPL NAIF https://naif.jpl.nasa.gov/naif/,2017. [3] LRO Project White paper Version 4 (2008) [4] Fujiwara A. (2006) *Science*, 312, 1330-1334. [5] Seidelmann P. K. (2007) *Celestial Mechanics and Dynamical Astr.*, 98-155. [6] JAXA/ISAS Data Archives and Transmission System (DARTS) http://darts.isas.jaxa.jp/, 2017.