ON-ORBIT POTENTIAL MEASUREMENT OF H-II TRANSFER VEHICLE-5

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ABSTRACT

JAXA developed KASPER module to measure the potential of HTV-5 and plasma environment around HTV-5. Atotie-mini module on HTV-4 has similar function, however Atotie-mini module does not have the sensor to measure the plasma environment. KASPER has the electrovoltmeter and plasma current monitor. Therefore, we can check the relationship between plasma environment and potential of HTV. In addition, KASPER has two kinds of debris monitor to demonstrate in the orbit. In this report, the results of potential and plasma current measurement are discussed.

HTV-5 launched at August 2015. KASPER worked through the entire operation period of HTV-5. At the earlier operation period, the potential of HTV-5 corresponded to our estimation. Several unexpected events were observed through entire operation period.

> The potential was rapidly changed at the night.

> The potential was increased before ISS capture.

1. INTRODUCTION

It is necessary to measure the potential of HTV to evaluate following matters.

- The influence for the potential when HTV docks to ISS
- The plasma interaction for solar array of HTV
- The influence for the EVA

JAXA develop Atotie-mini module to demonstrate sensors which measures the potential of HTV. Atotie-mini is installed on HTV-4, and operated at operation period of HTV-4 on 2013 [1,2,3].

The experiment result of Atotie-mini shows the following result[2].

- Demonstration of measurement of potential of HTV by using Electrovoltmeter TREK-3G. The data comparison with the conventional potentiometer “SCM” shows us TREK-3G correctly measures the potential of HTV.
- The potential of HTV in solo-flight phase is approximately 40V at day, approximately 0V at night.
- During ISS attached phase, the potential of HTV is equal to the potential of ISS. We confirmed the result from the data obtained by SEDA AP which is operating at JAXA module in ISS.

Because of internal electrical circuit, the data of Atotie-mini contains non-negligible error. In addition, the data is not enough at docking phase, because communication resource for Atotie-mini is limited.

Because of above reason, we develop KASPER module for HTV-5. KASPER is the acronym of Kounotori Advanced Space Environment Equipment. Fig.1-1 shows KASPER module. Table.1-1 is the list of sensors. Because accuracy of TREK-3G is confirmed in Atotie-mini, we use only TREK-3G for potential measurement. We added plasma current sensor, LP, to measure the ambient plasma environment. The detail of sensors for potential measurement is shown in Chapter.2. The purpose of KASPER module is not only potential measurement but also demonstration of debris sensors. Therefore, KASPER module has two kinds of debris sensors. The result of demonstration of debris sensors is beyond the scope of this report. We focus on the result of potential measurement of HTV-5.

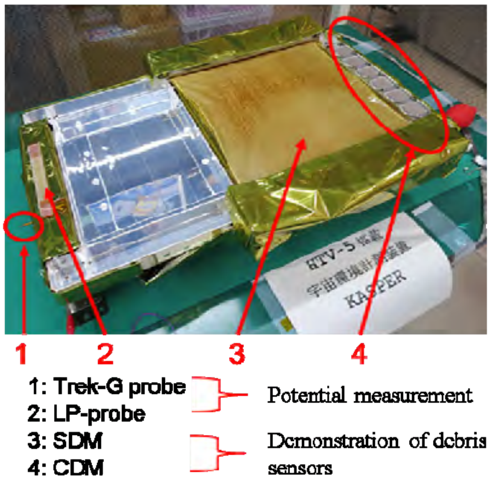

Fig.1-1 KASPER module

Table.1-1 List of sensors

No.	Sensor name	Image	Function
1	Trek-3G		･Charged potential measurement ･1 sensor
2	LP		･Plasma density measurment surrounding HTV ･1 sensor
3	SDM (Film type debris monitor)		･Monitor debris over 100um in diameter (about 100um~several mm) ･Sensor pattern area: Approximately 35cmx35cm ･1film
4	CDM (piezo-ceramic element type debris monitor)		･Monitor micro debris less than 100um in diameter, and over 100pg･km/sec. ･Size:40mm x 40mm ･6pcs

2. KASPER MODULE

The detail of measurement mechanism of TREK-3G is shown in Ref.3. Because LP is subordinate sensor of TREK-3G, we briefly describe TREK-3G. Fig.2-1 illustrates TREK-3G probe. It is coaxial cable with the tip coated by insulator. The electrical circuit of TREK-3G measures the potential difference between surface of insulation coating and reference potential of TREK-3G. Here, the reference potential of TREK-3G is the chassis of HTV. In low earth orbit, the surface potential of insulation material is equal to the potential of space. Therefore, TREK-3G is possible to measure the potential of HTV. The measurement range of potential against ambient plasma is designed in the range of -150V to 50V.

LP is the plasma current sensor. We use the data to estimate the plasma density. To perform the plasma diagnostics, it is necessary to sweep the bias voltage of probe against ambient plasma. However, because the communication resource for KASPER module is limited, it is impossible for us to obtain voltage-current characteristics. In order to estimate the plasma density, we need saturation current and electron temperature. Our requirement for the accuracy of plasma density is not high, therefore, we assume the electron temperature as 0.3eV. Based on this assumption, we need to measure saturation current.

In order to measure saturation current to estimate the plasma density, we need to fix the bias voltage of LP probe against the potential of ambient plasma. The idea is illustrated on Fig.2-2. In case of negative charging of HTV, we need to bias the LP probe to positive voltage to keep the potential of LP probe against the ambient plasma at constant voltage. In case of positive charging of HTV, the LP probe should be biased to negative voltage. In case of KASPER module, we set the constant voltage at 50V.

The size of LP probe is designed to measure the plasma current in the range of 1.17×10^{-5}A to 1.17×10^{-3}A. The plasma current range corresponds to the plasma density in the range of $7.5\times10^{9}\mathrm{m}^{-3}$ to $3.0\times10^{11}\mathrm{m}^{-3}$.

KASPER module is attached on the propulsion module of HTV-5 as shown in Fig.2-3. Depends on the attitude of HTV-5, the positional relation between KASPER module and the ambient plasma changes. In case of Yaw-90’ and Yaw180’, KASPER module is on ram side of HTV.

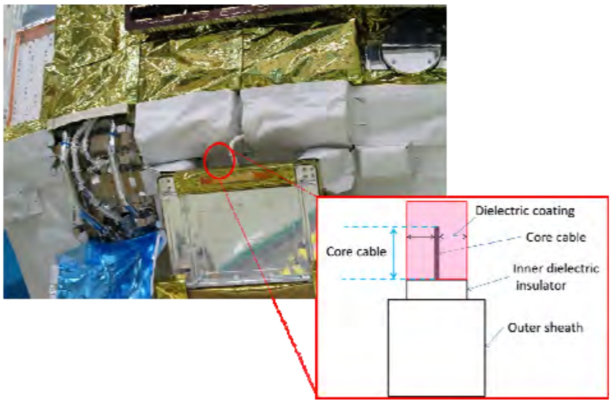

Fig.2-1 TREK-3G probe

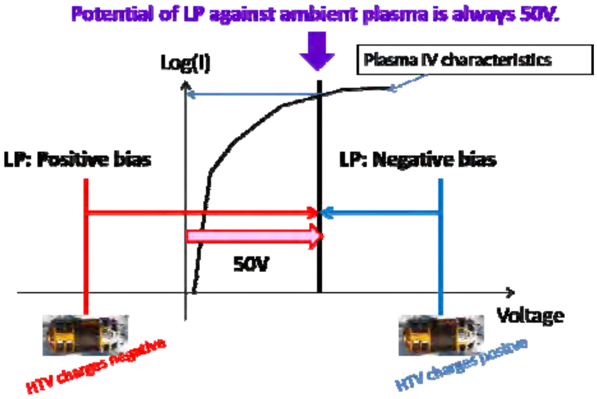

Fig.2-2 Mechanism of LP of KASPER module

Fig.2-3 The position of KASPER module on HTV-5

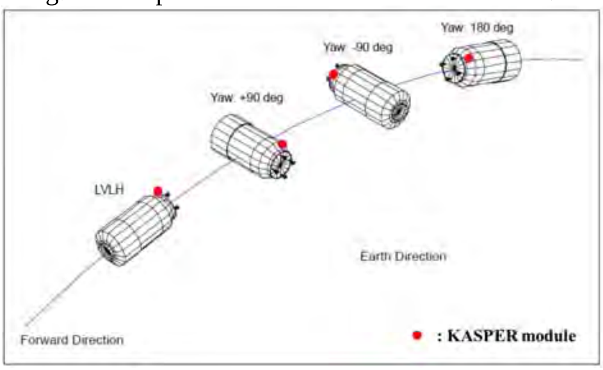

Fig.2-4 The relationship between the position of KASPER module and the attitude of HTV-5

3. FLIGHT DATA

HTV-5 is launched at 19 August 2016. HTV-5 automatically sends the command to start KASPER module. HTV-5 is attached to ISS at 24 August. HTV-5 is on ISS for one month. At 28 September, HTV-5 is released from ISS. HTV-5 re-entry at 29 September.

The plasma data of SEDA AP on JEM allows us to verify the measurement technique of LP at ISS attached phase. We show the result of ISS attached phase at Chapter 3.1. The result of solo-flight phase is discussed in Chapter 3.2.

3.1. ISS attached phase

Figure.3.1-1 shows the potential of HTV at 2 September. The maximum potential in the day ranges 15V to 25V. In case of night, the potential is below 5V. The result is same as Atotie-mini as reported in Ref.3. This fact shows TREK-3G of KASPER module is correctly working.

In Fig.3.1-2, we can compare the plasma density obtained by KASPER module and SEDA AP on JEM. The data shows us the KASPER module correctly measures low density plasma environment.

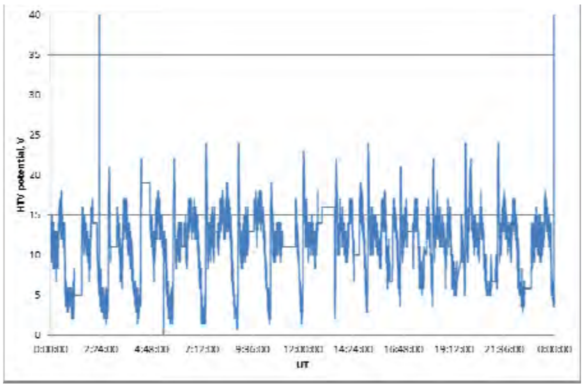

Fig.3.1-1 Potential of HTV at ISS attached phase, 2 September

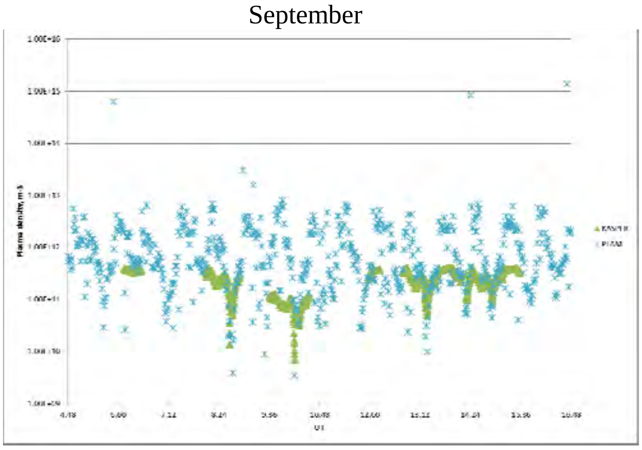

Fig.3.1-2 Plasma density measured by KASPER module and SEDA AP on JEM

3.2. Solo-flight phase

Figures.3.2-1, -2, -3, -4 show the potential of HTV during solo-flight phase. The upper graph shows not only potential of HTV but also solar array output current. We can identify night and day from the solar array output current. The lower graph shows the attitude of HTV. Because the attitude of HTV affects the potential as reported in Refs.3 and 4, we show the attitude in the figures.

After starting KASPER module at 19 September, the trend is same as Atotie-mini until the end of 5 cycles. After 5cycles, the potential rapidly increases at the night. The value of increase is 10V to 50V. After increasing of potential at the night, the potential slightly decreases with the time as it is shown in Fig.3.2-2. It should be noticed that the event of rapid increase of potential event occurs when the attitude of HTV is LVLH. In case of Yaw90', the potential is slightly decreasing. Figures.3.2-1, -2, -3, -4 show this fact.

Figure.3.2-4 shows the data before and after rendezvous operation. The event of rapid increase of potential occurs before rendezvous operation. However, once ISS catch HTV, the potential trend is changed. The event of rapid increase of potential does not occurs during ISS attached phase. Therefore, cause of rapid increase event depends on the HTV.

As it is well known the potential of spacecraft in low earth orbit depends on the generation voltage of solar array. Therefore, the potential should be approximately 0V at the night because no solar array generates the power. The event of rapid increase of potential is against the general charging mechanism in low earth orbit.

As the first step, we list the possible cause of this event.

Case1
Cause: HTV itself
Reason: HTV has 120V bus. If there is exposed electrode, the potential might reach approximately 120V.
Brief evaluation: we cannot find any exposed electrode of 120V bus on the design sheet. In addition, the maximum potential temporarily exceeds 120V at 24 August.

Case2
Cause: Influence of thruster
Reason: The thruster of HTV is chemical thruster. Therefore, it basically does not affect the potential of HTV. However, we checked the relation.
Evaluation: We checked all thruster event during HTV operation period. And, no thruster event does not correlate with the event of rapid increase of potential.

Case3
Cause: Change from Atotie-mini

Reason: There are several change of design from Atotie-mini. In the change of design, there might be the cause of the event. We check the design of KASPER in detail.
Evaluation: The electrical circuit of KASPER module is isolated from HTV bus. It electrical circuit cannot affect the potential of HTV.

Case4
Cause: Influence of LP
Brief reason: LP corrects electron. Although, LP probe repeats ON/OFF with 0.5Hz. If 1sec off time is not enough to collect ion, it is possible.
Brief evaluation: After releasing from ISS, LP is temporally switched off. However, the event still occurs. The off time might not be enough. Therefore, it is difficult to deny this cause.

Case5
Cause of event: Plasma environment
Reason: High energy electron can cause the event.
Evaluation: HTV does not flight through the polar region. HTV cannot meet the high energy electron.

As it is written in above, we do not have conclusion of the cause of event. We need more investigation to make clear the cause of event.

4. SUMMARY

We develop KASPER module to measure the potential of HTV and ambient plasma. In the ISS attached phase, the potential of HTV is same as ISS. The fact is same as Atotie-mini as reported before. The plasma current probe allows us to estimate the plasma density. The plasma characteristics data obtained by SEDA AP is used to check the estimated plasma density of KASPER module.

In the solo-flight phase, the potential behaviour of HTV is complicated. The potential sometimes rapidly increase in the night. The mechanism of rapid increase of potential is still unknown. We need more investigation.

5. ACKNOWLEDGMENT

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6. REFERENCES

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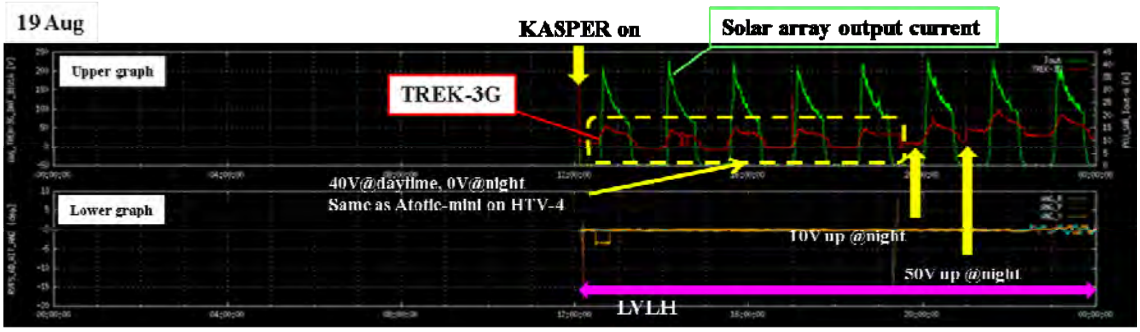

Figure.3.2-1 The data at 19 August, KASPER module is started: Upper graph shows solar array output current (Green line) and potential of HTV (Red line), lower graph shows attitude of HTV

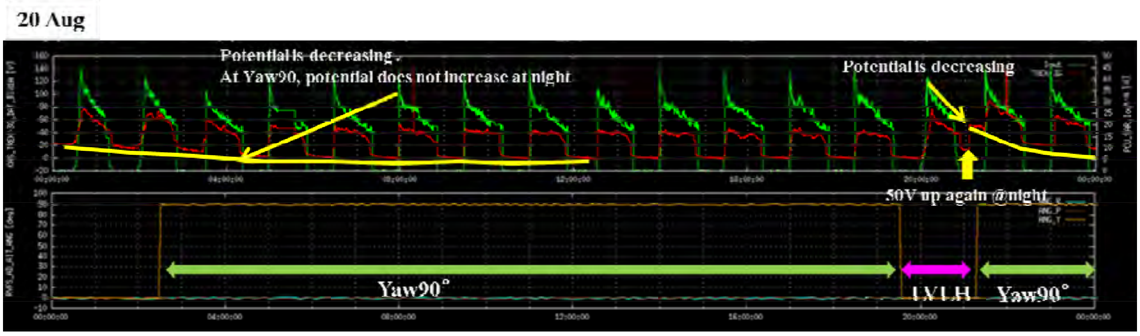

Fig.3.2-2 The data at 20 August: Upper graph shows solar array output current (Green line) and potential of HTV (Red line), lower graph shows attitude of HTV

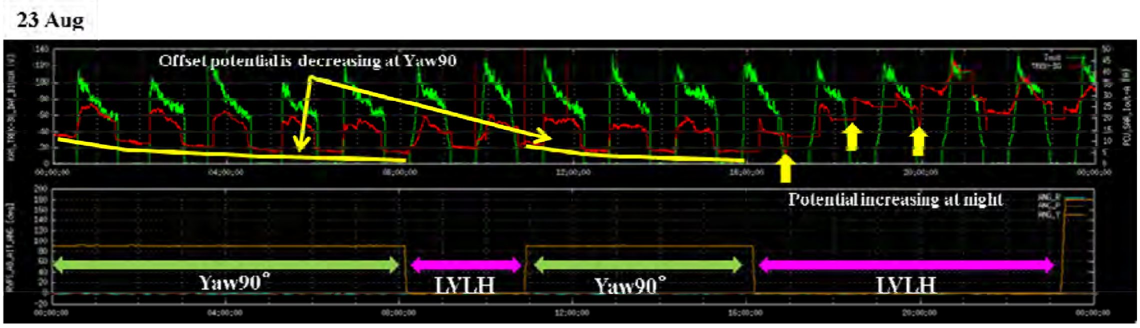

Fig.3.2-3 The data at 23 August: Upper graph shows solar array output current (Green line) and potential of HTV (Red line), lower graph shows attitude of HTV

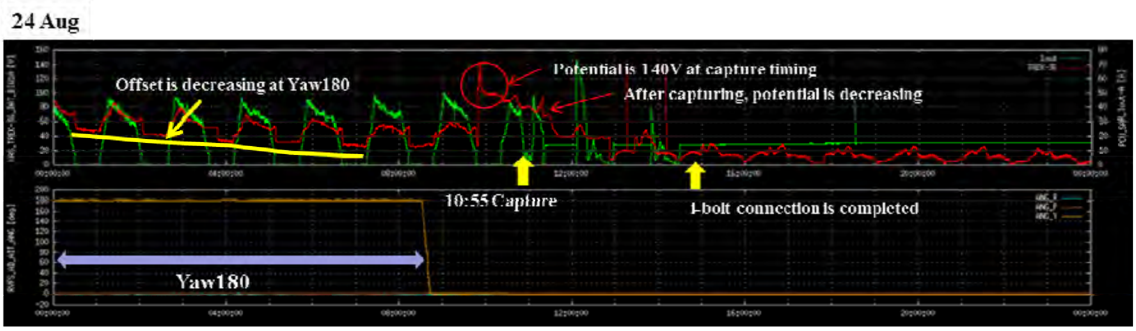

Fig.3.2-4 The data at 24 August, Solo-flight phase to ISS attached phase: Upper graph shows solar array output current (Green line) and potential of HTV (Red line), lower graph shows attitude of HTV