PARM
Conceptual Design Review

University of Tokyo / JAXA
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May 24, 2017
CoDR Presentation Contents

• Section 1: Mission Overview
  • Mission Statement
  • Mission Objectives
  • Theory and Concepts
  • Concept of Operations
  • Expected Results

• Section 2: Design Overview
  • Science Design
  • Engineering Design
  • Functional Block Diagram
  • Payload Layout (sketches)
  • RockSat-XN User’s Guide Compliance

Science part from Hosokawa

Instrument part from Asamura
CoDR Presentation Contents

• Section 3: Management
  • Team Organization
  • Schedule
  • Budget
  • Mentors (Faculty, industry)
  • Risks/Worries
  • Contact and Availability Matrices

• Section 4: Conclusions
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Science part from Hosokawa

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Instrument part from Asamura
The PARM mission will transit a region of Pulsating Aurora (PsA) with instruments that provide high-time resolution observations:

To understand:
the loss of the Earth’s radiation belts due to precipitation of high-energy magnetospheric electrons through the wave-particle interaction during PsA

To imply:
the impact of high-energy electrons on the Earth’s atmosphere, in particular, the possible change of ion chemistry including ozone (O\textsubscript{3}) due to precipitation of MeV electrons during PsA
Mission Overview: Mission Statement

• What is **Pulsating Aurora (PsA)**?
  Diffuse aurora which changes its luminosity quasi-periodically. Pulsating frequency ranges from a few to a few tens of sec.

• PsA is caused by **periodic precipitation of tens of keV electrons** from the magnetosphere along the magnetic field line.

Observations of PsA in the Scandinavian sector
Mission Overview: Mission Statement

- Recently, ionization at ~70 km altitude during PsA was discovered, which infers precipitation of very high-energy (sub-relativistic) electrons of radiation belt origin during PsA.

Radar observations of the electron density during PsA

Miyoshi et al. [2015]

PsA

Contribute to the loss of the radiation belts?
• If the radiation belt electrons precipitate deep into the middle atmosphere, significant ionization takes place
• As a result, destruction of $O_3$ can be expected

The impact of high-energy electrons on the Earth’s middle atmosphere
Mission Overview: Mission Statement

Who will this benefit/what will your data be used for?

PARM will contribute:

1. To the understanding of the loss of the Earth’s radiation belts due to precipitation of high-energy magnetospheric electrons through the wave-particle interaction during PsA

2. To the understanding of the impact of high-energy electrons on the Earth’s atmosphere, in particular, the possible change of ion chemistry including ozone ($O_3$) due to precipitation of MeV electrons during PsA
Mission Overview: Mission Statement

Why this mission should fly on this rocket

There are two strong reasons:

• High time resolution optical instruments (>100 fps) are operative in Scandinavia by Japanese scientists including graduate students for PsA observations

• Japanese ARASE satellite launched in December 2016 will also be operative during the planned launch window of G-CHASER for radiation belt observation at magnetosphere
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Science part from Hosokawa

Instrument part from Asamura
We aim at understanding:

Relationship between the loss of high-energy electrons in the Earth’s radiation belts and PsA

The mission objectives are:

• To observe the incoming PsA electrons in a wide energy range from a few tens of keV to a few MeV by onboard particle detectors

• To observe the temporal/spatial variations of PsA by an onboard optical instrument which is essential for studying PsA

Then we imply:

The impact of high-energy radiation belt electrons on the Earth’s atmosphere associated with PsA
Mission Overview: Mission Objectives

Planned instruments:

1. Two electron detectors (HEP and MED) which seamlessly cover the high-energy part of PsA electrons from 20 keV to 2 MeV

Observations of PsA electrons by REIMEI satellite

Miyoshi et al. [2015]
Mission Overview: Mission Objectives

Planned instruments:

1. Two electron detectors (HEP and MED) which seamlessly cover the high-energy part of PsA electrons from 20 keV to 2 MeV

Observations of PsA electrons by REIMEI satellite

Miyoshi et al. [2015]
Mission Overview: Mission Objectives

Planned instruments:

1. Two electron detectors (HEP and MED) which seamlessly cover the high-energy part of PsA electrons from 20 keV to 2 MeV.

- Energy covered by HEP
- Energy covered by MED

Observations of PsA electrons by REIMEI satellite
Miyoshi et al. [2015]
Mission Overview: Mission Objectives

Planned instruments:

2. An optical instrument (wide-FOV camera: AIC) which can identify the spatial distribution of PsA from space.
Mission Overview: Mission Objectives

What do you expect to discover or prove?

We expect to discover:

- Simultaneous precipitation of high-energy (sub-relativistic) electrons during PsA

If we discover this signature by using data from the experiment we will be able to prove/imply:

- Simultaneous precipitation of MeV electrons of radiation belts during intervals of PsA
- Possible destruction of ozone due to the radiation belt electrons
What are the minimum success criteria?

Minimum Success:
• Identification of temporal variations of precipitating electrons and optical emissions (Note that good weather condition at Andøya is not always necessary).

Nominal Success:
• Identification of temporal modulations of precipitating electrons in a wide energy range from tens keV to MeV energy during PsA

Extra Success:
• Identification of inverse energy dispersion that is a definitive evidence for the electron precipitation in the wide energy range
• Identification of the minimum altitude of PsA
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Science part from Hosokawa

Instrument part from Asamura
Mission Overview: Theory and Concepts

- It has been widely believed that periodic electron precipitation during PsA is caused by the **cyclotron resonance** between **chorus waves** and ambient electrons:

Nishimura et al. [2010, Science]
Mission Overview: Theory and Concepts

- The resonance energy of the **cyclotron resonance**:

\[ E_R = \frac{B^2}{2\mu_0 N} \frac{w_{ce}}{w} \left(1 - \frac{w}{w_{ce}}\right)^3 \]

- \( E_R \) increases when the **chorus wave** propagates closer to the Earth

- Higher-energy electrons (sub-relativistic) precipitate at the same time during intervals of PsA
Recent computer simulation has predicted that inverse energy dispersion should be observed when electrons whose energy ranges from a few keV to a few MeV precipitate at the same time.

Expected energy dispersion of precipitating electrons at the rocket altitude

Saito, Miyoshi, Seki [2012]

Travel time from the Magnetosphere
Mission Overview: Theory and Concepts

• Recent computer simulation has predicted that inverse energy dispersion should be observed when electrons whose energy ranges from a few keV to a few MeV precipitate at the same time.

Saito, Miyoshi, Seki [2012, JGR]
What are the minimum success criteria?

Minimum Success:
• Identification of temporal variations of precipitating electrons and optical emissions (Note that good weather condition at Andøya is not always necessary).

Nominal Success:
• Identification of temporal modulations of precipitating electrons in a wide energy range from tens keV to MeV energy during PsA

Extra Success:
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Science part from Hosokawa
Instrument part from Asamura
Mission Overview: Concept of Operations

Start of HEP / MED
Right after the open of nose cone at ~70 km alt.

Precipitating electrons
Along the magnetic field-line

Emission layer of PsA
(ranges from 95 to 105 km)

The Arase satellite measures magnetosphere

Field-of-view of AIC

Magnetic field lines

Ground-based supporting all-sky aurora camera
Requirement from Science Side: Launch Conditions

It would be better to identify PsA clearly from the ground by using all-sky camera at Andøya at the time of launch:

To meet this launch criteria, we expect the following possible launch conditions which will be discussed with the project manager:

1. **New moon periods** to prevent contamination from moonlight (New moon in Jan 2019 is “Jan 4 – Jan 11”)
2. **Active geomagnetic condition** (just after aurora substorm)
3. **Morning side**, which is a hotspot of PsA
4. **Good weather conditions**, i.e., clear sky, to observe PsA optically at one of our ground-based optical observation sites (clear sky is not always necessary at Andøya)
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Science part from Hosokawa

Instrument part from Asamura
Mission Overview: Expected Results

*What do you expect to discover or prove?*

We expect to discover:

- Simultaneous precipitation of high-energy (sub-relativistic) electrons during PsA

If we discover this signature by using data from the rocket we will be able to prove/imply:

- Simultaneous precipitation of MeV electrons of radiation belts during intervals of PsA
- Possible destruction of ozone due to the radiation belt electrons
Mission Overview: Expected Results

*What your data might look like*

We expect to observe **inverse energy dispersion**, which is a sign of simultaneous occurrence of cyclotron resonance in wide area along the magnetic field line.

![Graph showing energy coverage of HEP and MED](image)

Energy coverage of **HEP**

Energy coverage of **MED**

Saito, Miyoshi, Seki [2012, JGR]
Mission Overview: Expected Results

What your data might look like

We expect to observe inverse energy dispersion, which is a sign of simultaneous occurrence of cyclotron resonance in wide area along the magnetic field line.

If observed, we are able to prove that:

Effective loss of radiation belt electrons occur during PsA which has a potential to affect the ion chemistry in the atmosphere.
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Science part from Hosokawa

Instrument part from Asamura
Design Overview: Engineering Design

- PARM consists of 3 instruments: HEP, AIC, and MED
- They are controlled by COMMON electronics unit which has electrical interfaces to the Wallops system

![Diagram showing the connections between HEP, AIC, MED, COMMON-E (PWR and DH), and Wallops system.]
HEP

HEP observes precipitating electrons with energies 0.7 to 2MeV.

- SSD (Solid-State-Detector) is used for \(~\text{MeV}\) electron detection. SSD can measure energy of incident electrons for each detection event.
- 8 SSDs are stacked, since stopping range of \(~\text{MeV}\) electrons is long (2mm Al equivalent length for 1MeV).
- Maximum count rate of 10kHz can be achieved, which is enough for the required time resolution, 50-100ms (typical time-scale of the electron micro bursts).
# Design Overview: Engineering Design

## HEP

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>&lt; 9W Including DCDC efficiency</td>
</tr>
<tr>
<td>Mass</td>
<td>3kg</td>
</tr>
<tr>
<td>Timer signal</td>
<td>1 required For HVPS ON (TE-R)</td>
</tr>
<tr>
<td>F/S connector (*1, *2)</td>
<td>Yes Safety: HV output is reduced with low level (sensor power off at HV on is ok) Flight: HV output is normal level (Reset control is required before sensor power off)</td>
</tr>
<tr>
<td>C/O connector (*1)</td>
<td>Yes For reset control and checkout.</td>
</tr>
<tr>
<td>Data</td>
<td>via RS232 Communication between common electronics and Wallops system</td>
</tr>
<tr>
<td>Onboard software</td>
<td>No FPGA is utilized for sensor control and data handling.</td>
</tr>
<tr>
<td>Non-flight item</td>
<td>Yes Aperture cover</td>
</tr>
</tbody>
</table>

(*1) These connectors shall be accessible from outside when the nose fairing is unmounted (on the ground).

(*2) If the nose fairing is closed and the Flight connector is mated, Timer signal (TE- *) shall be masked on the ground. Of course be unmasked during flight.
Design Overview: Engineering Design

HEP

Utilization of heritage elements

ARASE HEP: SSSD 8 stack + preamp (700-2000keV electrons)
  HVPS (300V)
  FPGA sensor control and command / data handling

ARASE XEP: SSD 4 stack + preamp
  (300-20000keV, with GSO (scintillator))

Major technology dependencies

SSD + preamp: key element for detection of high-energy electrons
HVPS: 300V

ARASE HEP test model
Design Overview: Functional Block Diagram

Parm

HEP

- SSD x3
- Temp
- MPX
- A/D
- D/A
- HVPS (300V)
- FET SW

DISCR CONTROL

CAL GENERATOR

FPGA

HV safety

F/S connector

Cont

C/O connector

RAM

C/O Box
(Non-flight item)

Wallops Power & Tim

GSE-1

GSE-2

TE-R1/TE-R2/TE-1/TE-2/TE-3

RS232

AIC

COMMON ELEC.

Power block

FPGA

Level converter

MED

RockSat-XN

CoDR
Design Overview: Engineering Design

**AIC**

<table>
<thead>
<tr>
<th><strong>Weight</strong></th>
<th>3 kg</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power</strong></td>
<td>10 W</td>
</tr>
<tr>
<td><strong>Size</strong></td>
<td>70 x 70 x 120 (1camera)+ Electronics(150x150x40)</td>
</tr>
<tr>
<td><strong>FOV</strong></td>
<td>90 (azimuthal) x 180 (vertical) deg. FOV center is perpendicular to axis</td>
</tr>
<tr>
<td><strong>Wavelength</strong></td>
<td>O2 762 nm (or O 557.7nm)</td>
</tr>
<tr>
<td><strong>Frame rate</strong></td>
<td>10 fps (can be reduced to 4 fps for example)</td>
</tr>
</tbody>
</table>
| **Detector** | Watec-CCD + video capture  
WAT-910HX CCD camera  
½ inch (6.45 x 4.84 cm) CCD  
pixels: 768 x 494  
binning: 384 x 30-pix. binning(2x16 bins)  
8 bit/bin |
| **Data rate** | 2.56 kbps |

AIC
Design Overview: Functional Block Diagram

AIC

AIC-cam

CCD

Electronics

video

control

12V

power

ADC

Binning

FPGA or CPU

DC/DC

5V power

28V

CHECKOUT

BOX (non flight)

Common electronics

TLM

power
Design Overview: Payload Layout

AIC

AIC-cam
Weight 1kg

Box
150 x 150 x 40
1 board

AIC-Electronics
Weight 2kg

Φ=305mm

120

~136 km alt.
FOV150 x 180 deg

~100 km alt.
Pulsating aurora

RockSat-XN
CoDR
Utilization of heritage elements

- AIC CCD camera is based on a commercial camera, but it has the heritage for several space satellite missions, such as Raijin, Raijin-2, etc.
- Sakano has experienced the developments of optical instruments for space and ground, such as the Reimei (INDEX) satellite, Kaguya, Akatsuki, and ground-based spectrometers at Svalvard and Alakska.
- Collaborating ISAS/JAXA team members have experienced a lot of space missions as well as rockets.

Major technology dependencies

- Rocket interface electronics is newly developed using FPGA (or CPU) that control CCD camera electronics, ADC and data processing including pixel-binning to produce telemetry data. DC/DC converter is also involved in the interface electronics.
MED measures precipitating electrons with energies 20 to 100 keV

- APDs (Avalnche photodiodes) are used for energy detection
- 5-9 (TBD) APDs are arrayed in order to cover (roughly) 2-pi steradian FOV
- Incident plane is coated by Al for rejecting EUV and protons
# Design Overview: Engineering Design

## MED

<table>
<thead>
<tr>
<th>Specification</th>
<th>Specification Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>&lt; 9W Including DCDC efficiency</td>
</tr>
<tr>
<td>Mass</td>
<td>3kg</td>
</tr>
<tr>
<td>Timer signal</td>
<td>1 required For HVPS ON (TE-2)</td>
</tr>
<tr>
<td>F/S connector (*1)</td>
<td>Yes Safety: HV output is reduced with low level (sensor power off at HV on is ok)</td>
</tr>
<tr>
<td></td>
<td>Flight: HV output is normal level (Reset control is required before sensor power off)</td>
</tr>
<tr>
<td>C/O connector (*1, *2)</td>
<td>Yes For reset control and checkout.</td>
</tr>
<tr>
<td>Data</td>
<td>via RS232 Between COMMON-E and Wallops system (RS422 between MED and COMMON-E)</td>
</tr>
<tr>
<td>Onboard software</td>
<td>No FPGA is utilized for sensor control and data handling.</td>
</tr>
<tr>
<td>Non-flight item</td>
<td>Yes Aperture cover</td>
</tr>
</tbody>
</table>

(*1) This connector shall be accessible from outside when the nose fairing is unmounted (on the ground).

(*2) If the nose fairing is closed and the Flight connector is mated, Timer signal (TE- *) shall be masked on the ground. Of course be unmasked during flight.
Design Overview: Engineering Design

MED

Utilization of heritage elements
ARASE MEPe:
APD + charge amp + shaping amp + pulse height detection
HVPS (300V)
FPGA sensor control and command / data handling

Major technology dependencies
APD + pulse height detection:
key element for detection of medium-energy electrons
HVPS: 300V
Design Overview: Functional Block Diagram

MED

- APD board
  - APD
  - Temp. sensor
- Analog board
  - CSA
  - Shaper
  - Lower discr.
  - P/H
- FPGA board
  - ADC
- HV board incl.
  LVPS (DC/DC)

FPGA board
- ADC

Analog board
- CSA
- Shaper
- Lower discr.
- P/H

HV board incl.
LVPS (DC/DC)

CoDR
COMMON-E

COMMON-E is an electronics unit where:

All the PARM electrical interfaces to the Wallops system are included. Power / timer signals are applied to the instruments through COMMON-E. TLM data are collected and sent via COMMON-E.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>&lt; 5W</td>
<td>Including DCDC efficiency</td>
</tr>
<tr>
<td>Mass</td>
<td>1kg</td>
<td></td>
</tr>
<tr>
<td>Timer signal</td>
<td>1 required</td>
<td>For sequence timer start (TE-1)</td>
</tr>
<tr>
<td>C/O connector (*1)</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Data</td>
<td>RS232</td>
<td></td>
</tr>
<tr>
<td>Onboard software</td>
<td>No</td>
<td>FPGA is utilized for sensor control and data handling.</td>
</tr>
</tbody>
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Instrument part from Asamura
Design Overview: Payload Layout

Unit: mm
Design Overview: Payload Layout

Outer envelope of RockSat-XN Experiment Design Space

- AIC-E
- HEP
- MED
- FOV (AIC)
- FOV (HEP)
- FOV (MED)
- COMMON-E
- deck
Design Overview: Payload Layout

- AIC
- HEP
- MED
Design Overview: Payload Layout

**Conceptual design**

PARM envelope fits inside of “middle mount” option of “full” experiment space

*Unit: mm*
Design Overview: Payload Layout

Notches on the deck may be requested to avoid interference of FOVs.
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Science part from Hosokawa

Instrument part from Asamura
## User Guide Compliance: Summary

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Status/Reason (if needed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center of gravity in 1&quot; plane of plate?</td>
<td>TBC</td>
</tr>
<tr>
<td>Weight 30.0+/- 1.0 (15.0 +/- 0.5) lbs?</td>
<td>~10 kg</td>
</tr>
<tr>
<td>Max Height &lt; 10.75&quot; (5.13&quot;)</td>
<td>Yes, 270 mm (10.63&quot;)</td>
</tr>
<tr>
<td>Bottom of deck has flush mount hardware?</td>
<td>Yes</td>
</tr>
<tr>
<td>Within Keep-Out Zone</td>
<td>Yes</td>
</tr>
<tr>
<td>Using &lt; 10 A/D Lines</td>
<td>No</td>
</tr>
<tr>
<td>Using/Understand Parallel Line</td>
<td>No</td>
</tr>
<tr>
<td>Using/Understand Asynchronous Line</td>
<td>Yes, at 19200 baud (but prefer to have higher rate)</td>
</tr>
<tr>
<td>Using X GSE Line(s)</td>
<td>Yes, GSE-1 and GSE-2</td>
</tr>
<tr>
<td>Using X Non-Redundant PWR Lines (TE-1, TE-2, TE-3)</td>
<td>Yes, TE-1 and TE-2</td>
</tr>
<tr>
<td>Using X Redundant Power Lines (TE-R)</td>
<td>Yes, TE-R</td>
</tr>
<tr>
<td>Using &lt; 1 Ah (.5 Ah for half payload)</td>
<td>Yes, 0.4Ah</td>
</tr>
<tr>
<td>Using &lt;= 28 V</td>
<td>Yes (300V)</td>
</tr>
<tr>
<td>Using RF (If yes, list frequency and TX Power)</td>
<td>No</td>
</tr>
<tr>
<td>Using deployable?</td>
<td>No</td>
</tr>
<tr>
<td>Using ITAR and/or Export Controlled hardware</td>
<td>TBC</td>
</tr>
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• Section 4: Conclusions
Management

Team organization chart:

- **PI** Asamura
  - **Supervisor** Fujii
    - Science Miyoshi
    - HEP Mitani Hasegawa Namekawa
    - AIC Sakano
    - MED Kasahara
    - COMMON-E Asamura
    - Ground observation Hosokawa
Management

Schedule:

• September 2017
  • PDR

• November
  • Design fix (electronics, chassis)

• December – March
  • Fabrication

• April – May
  • Unit test (sensor performance, environment tests)

• June
  • Integration test at Wallops
Other Issues:

- **Monetary Budget**
  We have a fund from Japanese Government which covers until 2019.3.

- **Team Mentors**
  Consultation with JAXA staff is available

- **Contact Matrix**
  See Excel file in welcome package

- **Team Availability (MDT) Matrix**
  See Excel file in welcome package
Request:

Required downlink bit rate of PARM is:

**HEP:**
6.2 kbps = 7 count x (8 energy (num of SSDs) x 8bit + 1 time indicator x 24bit) / 0.1s

**MED:**
6.4 kbps = 16 energy bin x 5 detectors x 8bit (counter depth) / 0.1s

**AIC:**
2.6 kbps = 2 x16 bins x 8 bit / 0.1s (rocket spin rate is assumed as 1Hz)

These are the minimum bitrate required. We prefer to have higher rate in order to get better counting statistics and/or spatial resolution of auroral images.

Time-scale of the microburst of high-energy electrons: ~100ms
Time-scale of pulsating auroral emission: several seconds
Risks and worries:

What are your biggest worries or potential failure points with your conceptual design?

1. Interference of FOVs. FOV of HEP should be upward. Can HEP be mounted on the top-plate with no obstacles within HEP FOV? For AIC and MED, notches on the deck may be necessary.

2. It is not clear how we get attitude information. Is an attitude magnetometer onboard as a rocket system instrument?

3. Data rate: We would like to have higher rate in order to get better counting statistics.

Items identified should be completely mitigated through your design effort and fully addressed by CDR.
Conclusion

Address why your mission deserves to fly

We aim at understanding the loss of radiation belt and its impact on the chemistry of middle atmosphere by observing the energy of precipitating electrons during PsA. The particle detectors developed by ourselves can provide high time resolution observations of electrons in a wide energy range. Moreover, the optical imager provides comprehensive view of PsA. We believe that our instruments contribute to detailed understanding of the loss processes of energetic electrons in the plasma sheet and radiation belts, and then provide fundamental knowledge on the modification of the middle atmosphere by the energetic electron precipitations.

Next steps for your team to get to PDR

• Check the FOVs available
• Update drawings/sketches/layout of the deck
• Begin requirement flow down process for system and subsystems
Questions from PARM team (1/2):

We would like to know following points:

1. Field-of-view (FOV) of HEP should be upward. Can HEP be mounted on the top-plate with no obstacles within HEP FOV?
2. Size / shape / thickness of the deck. We need this information in order to consider FOVs. We may request to make notches on the deck.
3. Can we use threads on the deck to mount the instruments? Since we will use almost the entire deck, we can make fit check of the instruments in Japan by using dummy deck plate.
4. Can we request specific spin rate, for example, 0.5Hz during the observation? We do not need precise control of spin rate, but need actual spin rate and attitude data after the flight operation.
5. Timing of nose fairing jettison. Can it be jettisoned around altitude of 70km at upleg of the rocket trajectory?
Questions from PARM team (2/2):

6. How can we get following information?

   ○ **Time of observation**
     It is necessary to add a time stamp on the data stream for data analysis. Are there any timing signals come from the Wallops system? If not, can we get precise time of timer signal activation as a flight result?
   ○ **Rocket attitude**
     Is an attitude magnetometer onboard as a rocket system (Wallops?) instrument? If so, can we receive its data after the flight operation? If not, can we receive the attitude data?
   ○ **Rocket trajectory**
     We expect that time series of rocket position and velocity will be provided to the instrument teams after flight.

7. Are there any rooms to increase the data rate of PARM to the ground?