Final report on Engineering model development of 6U Cube Sat observing atmospheric and space electricity for the earthquake prediction

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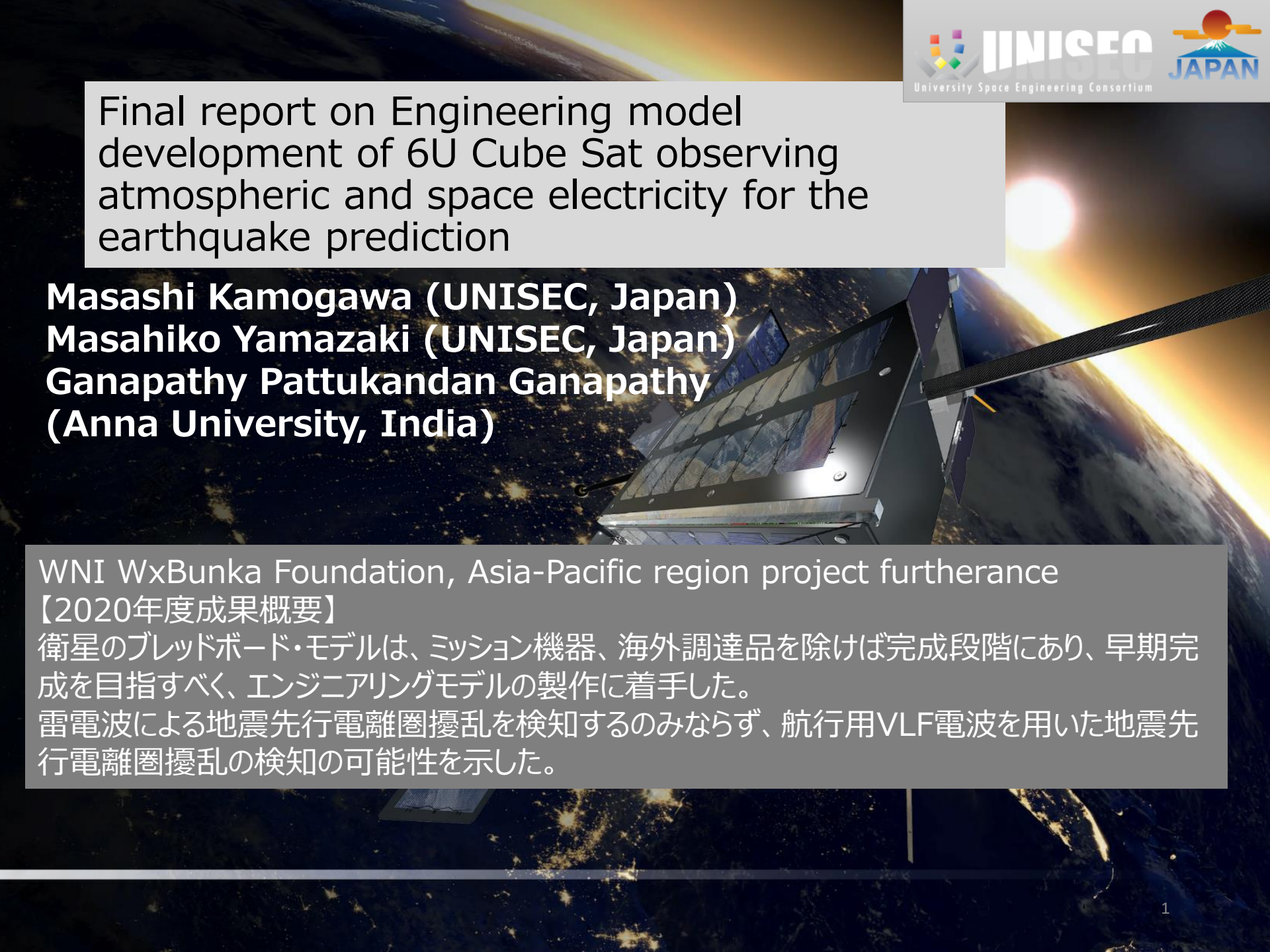
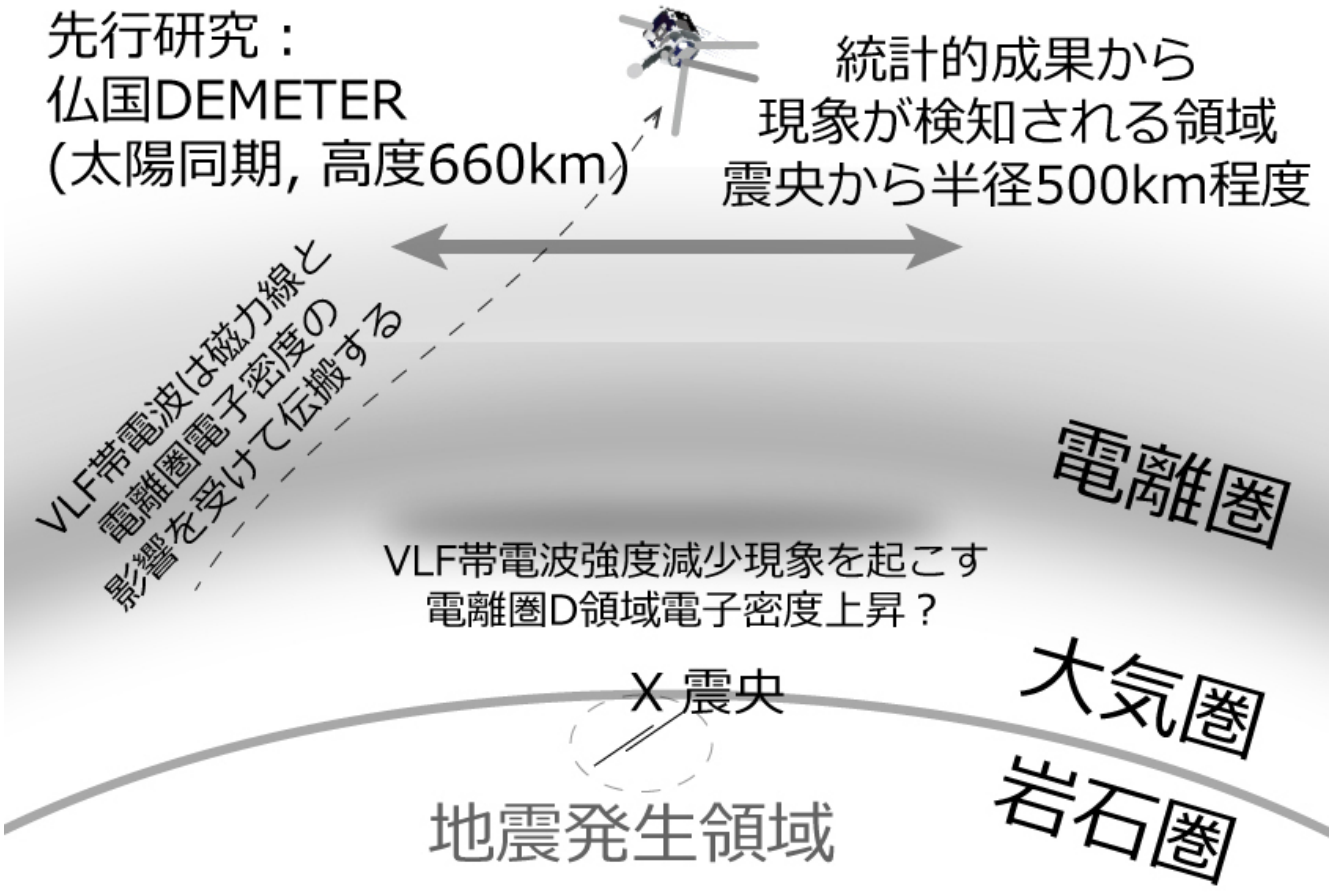


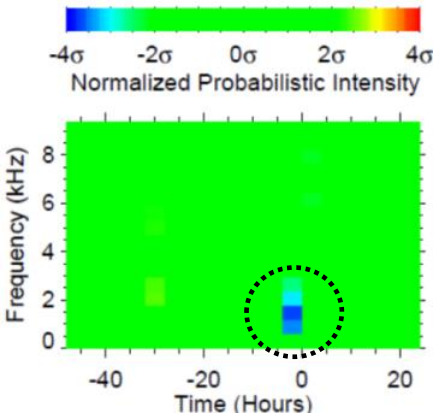
WNI WxBunka Foundation, Asia-Pacific region project furtherance

【2020年度成果概要】
衛星のブレッドボード・モデルは、ミッション機器、海外調達品を除けば完成段階にあり、早期完成を目指すべく、エンジニアリングモデルの製作に着手した。
雷電波による地震先行電離圏擾乱を検知するのみならず、航行用VLF電波を用いた地震先行電離圏擾乱の検知の可能性を示した。

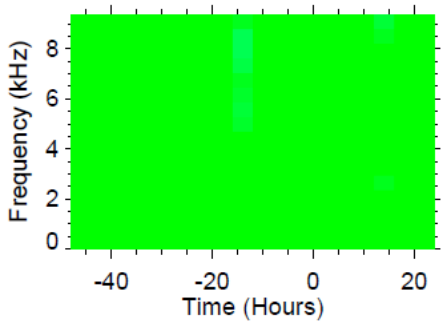
Observation of EQ precursor using CubeSat

- **Ionospheric D-region electron enhancements** are the most plausible precursor because of high spatio-temporal observation.
- This precursor investigation contributes to the EQ prediction study, accompanying the **seismic/geodetic and geochemical precursors**, because the **satellite observation facilitates their validation**.





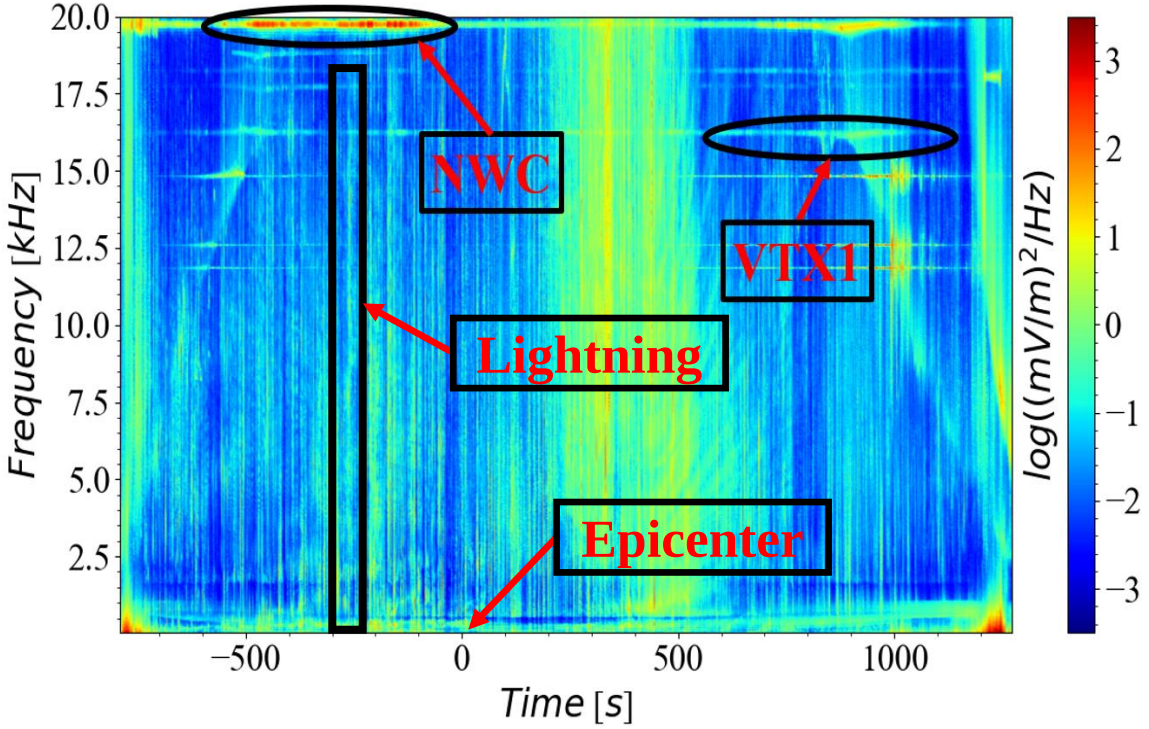
Case of Real EQs



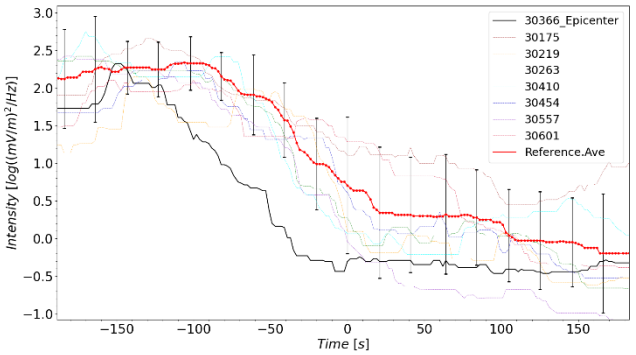
Case of Randomly-generated EQs (Nemec et al, GRL, 2008)

Additional DEMETER analysis for mission design.

- In addition to the analysis on lightning-origin EM waves, the VLF transmitter EM waves is analysis to monitor the D-region ionospheric electron density enhancement.
- EQ-related electric-field intensity depression was clearly found.



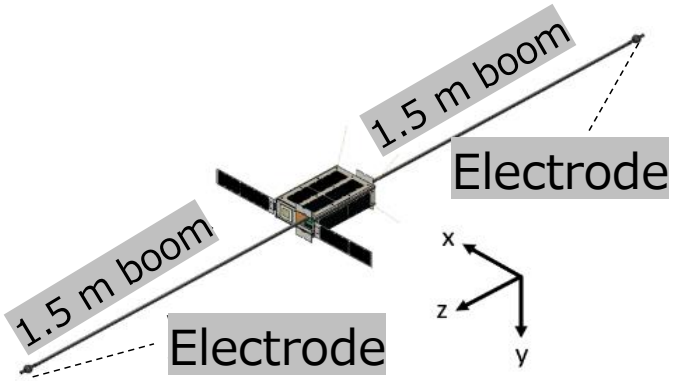
Time-series of VLF electric-field spectrum observed by the DEMETER in the EQ-related orbit.
The time equal to zero indicates the closest to the future epicenter.

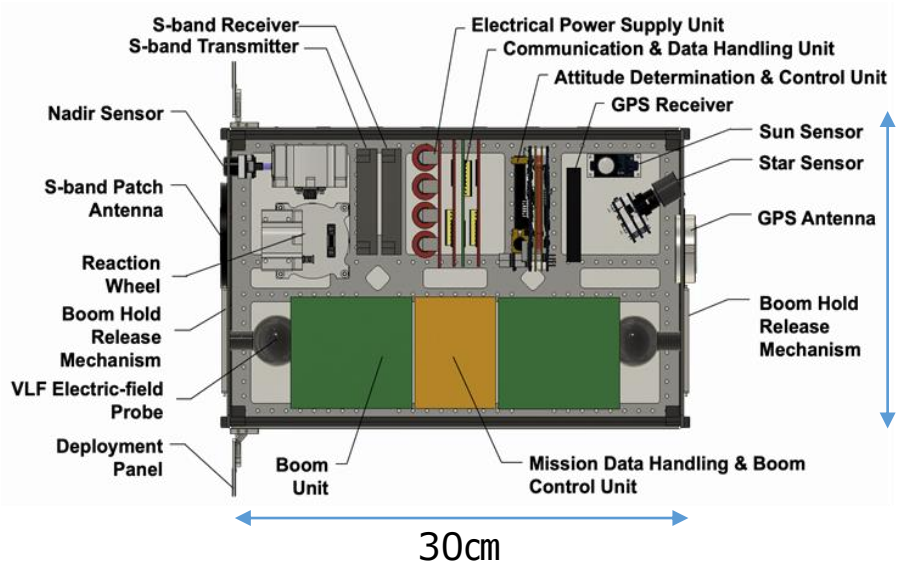


Time-series of electric field data at 19.8 kHz (NWC) on EQ and 7 control orbits.

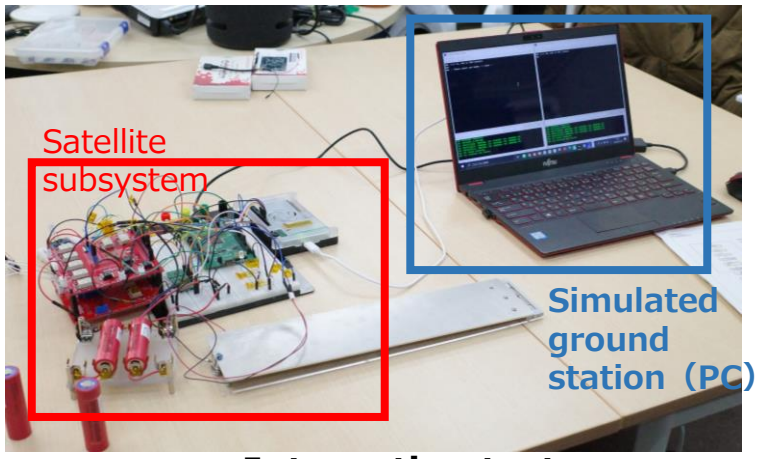
Current status of engineering model of Prelude

- Integration test for engineering model was conducted **except** booms, electric probes, VLF receiver and electron emitters.





- Validation of initial operation and phase.
  - Subsystem control using command
  - Microcomputer operations for EPS and CDH
  - Power supply and block controls
  - Dyneema wire parts and solar panel extension.
  - HK data acquisition, store, and transfer.



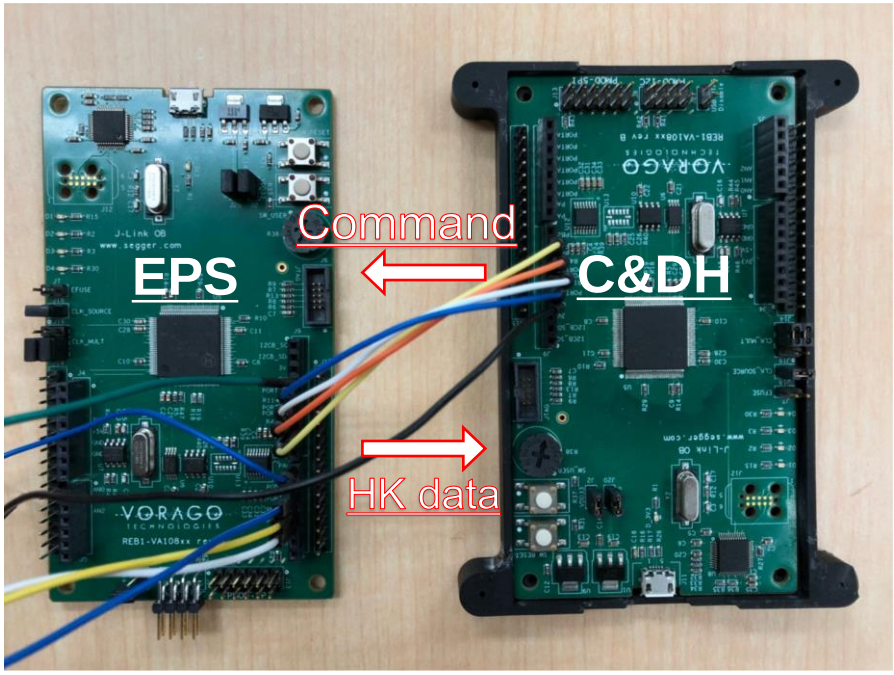
Integration test

Command and Data Handling（C&DH）

- Validation of HK data acquisition (SPI communication) and command for subsystems was conducted using VA10820 microcomputer (radiation resistance).

- *Next step for Engineering model*

1. Data store of HK and GPS data into flash memory.
2. Health monitor function for each subsystem using WDT.
3. Confirmation of UART communication.
4. Writing program in the FRAM memory.
5. Command format for
   1) Providing GPS timestamp for ADC and mission components.
   2) Providing EQ time



Communication（COM）

- From mission analysis, the downlink data amount, the communication requirement, communication protocol were designed.
- The transmitter and received and antenna were selected.
- Nighttime sensing（DL data amount: 63.5[MByte/day], Required communication period; t>63.5 [**s**])
- Nighttime sensing（DL data amount: 88.5[MByte/day], Required communication period; t>88.5 [**s**])
- Possible communication period (more than margin 3)
  - Candidate A station: 158.7 [s]
  - Candidate B station: 703.9 [s]
  - Candidate C station: 703.8 [s]

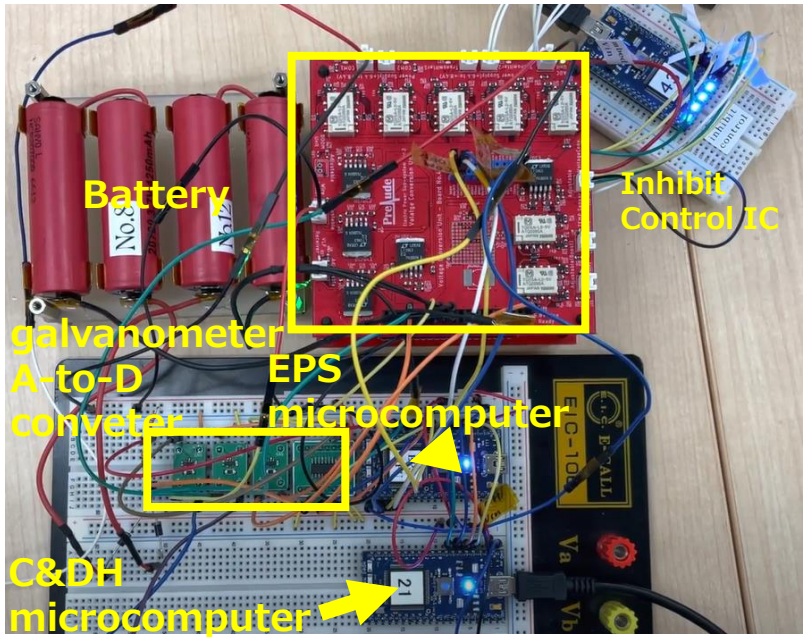
- *Next step for Engineering model*
  - Development of transmitter/receiver communication interface board..

Communication protocol
for satellite and ground stations.

Electric Power Subsystem（EPS）

We confirmed as follows:

- Inhibit controller activating the inhibit switch provided the electric power for satellite subsystems a certain period after detecting the satellite release.
- MPU simulating C&DH microcomputer provided the electric power for each subsystem through the command.
- Power consumption for each system and battery voltage was measured.

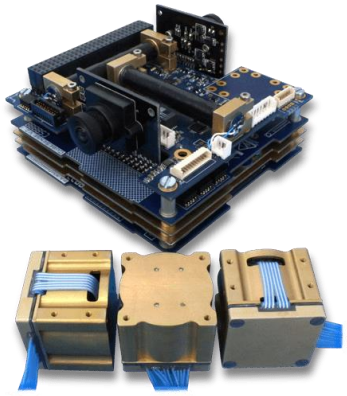


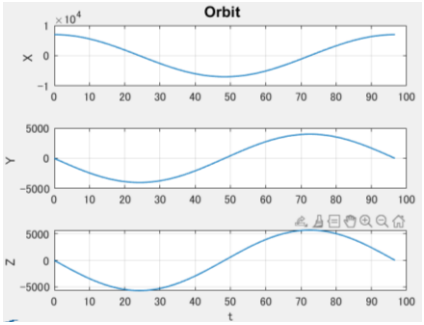
- *Next step for Engineering model*

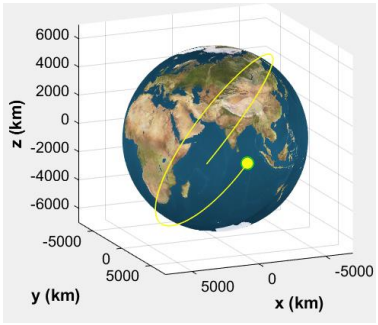
  The following functions will be developed.
  - Charge control and battery protection.
  - Power supply stop due to over current.
  - Heater control for battery temperature.
  - Melting Dyneema wire for the boom system.

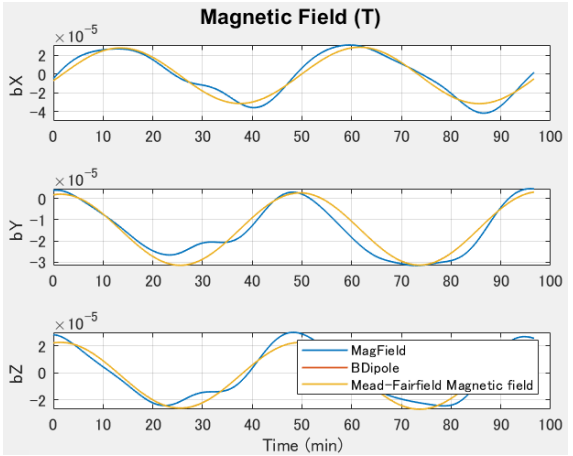
Attitude Determination and Control System (ADC)

- In the Bread Board Model (BBM), dummy component was used for the integration test.
- After CubeADCS developed by South African company was received, we started the test..
- Numerical simulation of attitude control for the geocentric direction and geomagnetic environment was conducted.





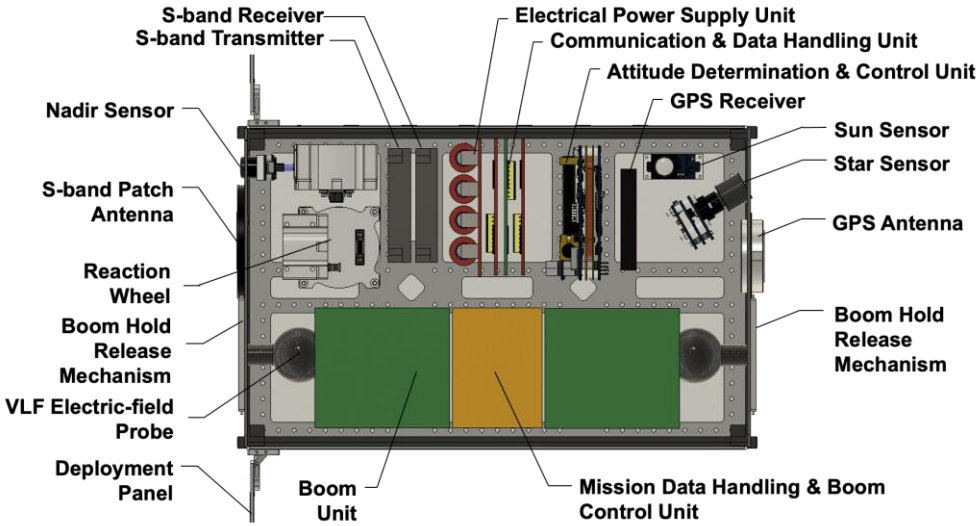


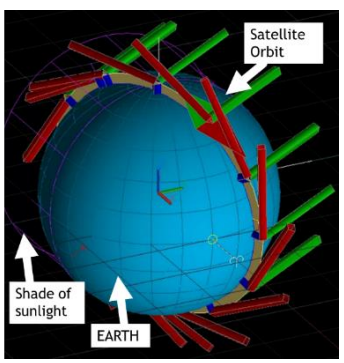


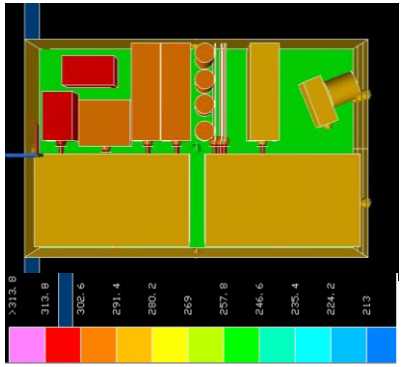
- *Next step for Engineering model*
  - Construction of HILS environment

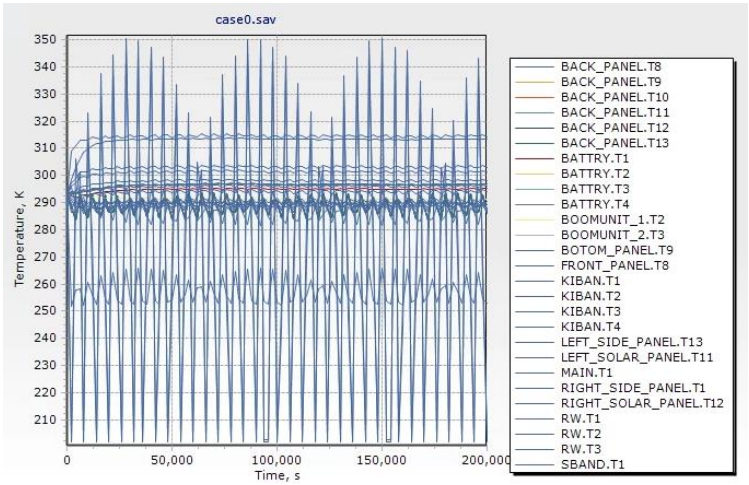
The Spacecraft Structure and Thermal Design Considerations

- SC structure was designed. Each component was placed.
- Using simulation “Thermal Desktop”, the thermal design was confirmed.









- *Next step for Engineering model*
  - Construction of HILS environment to evaluate attitude control system.