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Global Water Level Monitoring for Disaster Mitigation Using Data Collection Function of Micro-satellites

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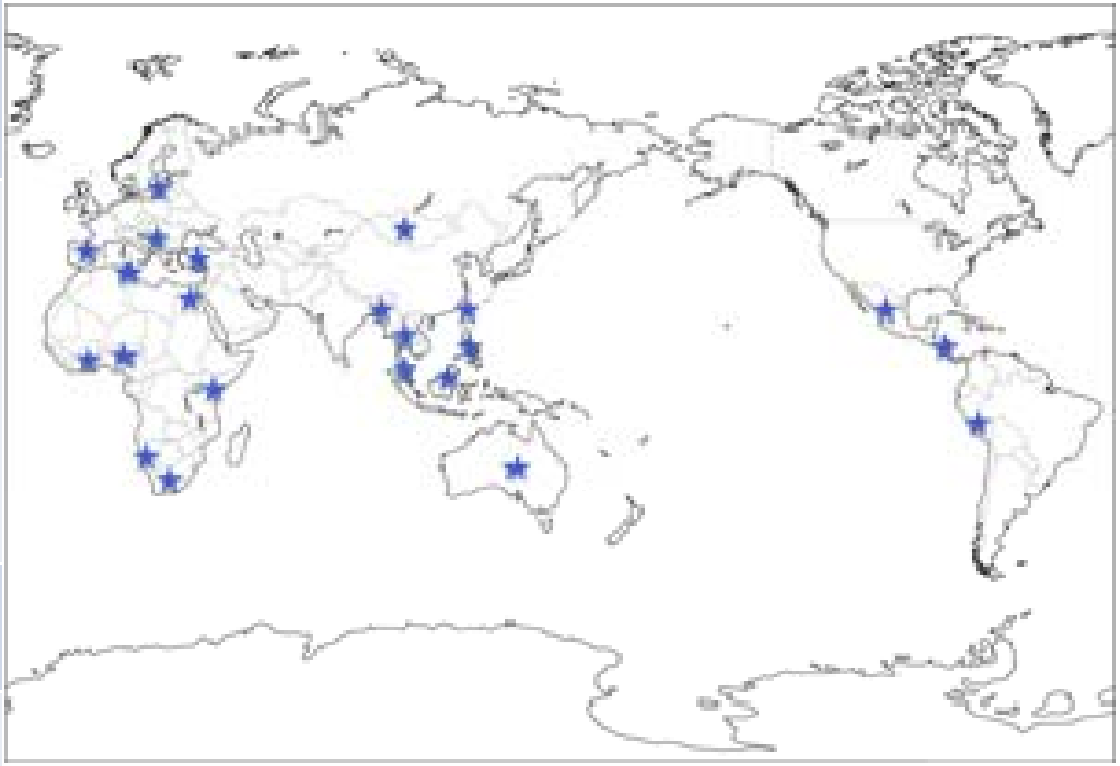
Background: Flood and Drought

Mission

- We aim to establish global water level monitoring network with Hodoyoshi "Store and Forward" (S&F) communication function and an affordable ground sensor (Target cost: <$600).
- After the pilot program is completed, further development to improve S&F communication network with cubesat-size satellite constellation and to increase versatility of ground sensor will be executed. (Future plan)
- This project will be an international co-operation project.

Strong Global Demand

Area	Countries
Africa	South Africa, Egypt, Tunisia, Nigeria, Kenya, Namibia, Ghana
Asia	Mongolia, Malaysia, Philippines, Bangladesh, Brunei, Taiwan, Thailand, Turkey
Latin America	Peru, Guatemala, Mexico
Europe	Slovenia, Spain, Lithuania
Oceania	Australia

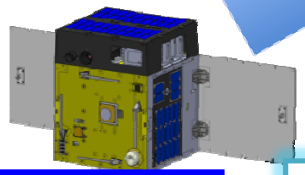


Concept of Global Network for On-Ground Sensors with Nano/Micro Satellites (Application: Water Level Monitoring)

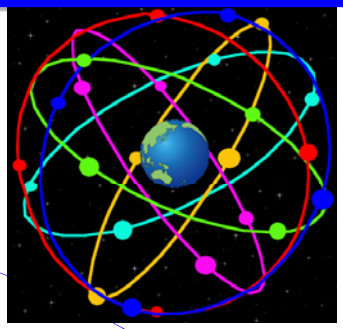
Global network for water level monitoring

Water level monitoring sensor system with low cost sensor will be developed

Hodoyoshi satellites #3 & #4



S&F satellite constellation



Store and Forward Communication

Water level monitoring sensor systems installed in many places in the world send data to satellites

Collect and store water level data

Satellites send collected data to a ground station

Ground Station

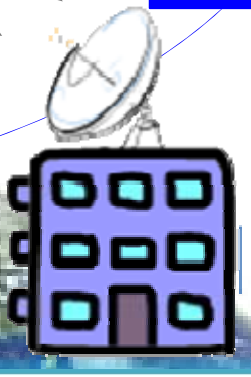
End users who need to monitor water level in the world

inundation

flood

drought

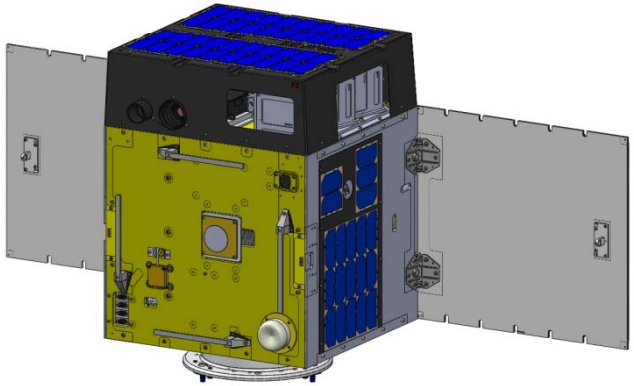
Internet



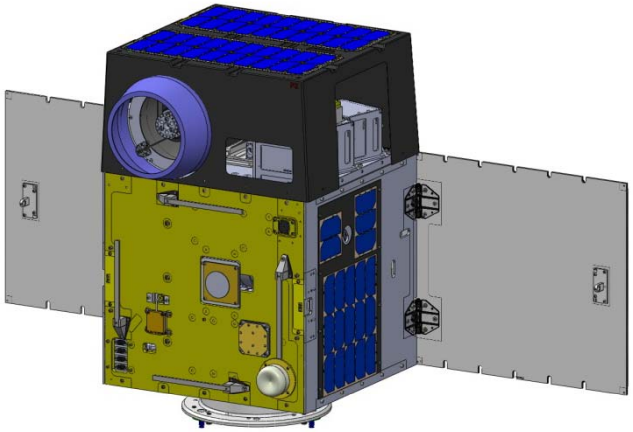
Automatic Analysis and distribution of data of water level

Space Segment: HODOYOSHI-3 & 4

Hodoyoshi-3



Hodoyoshi-4



	Hodoyoshi-3	Hodoyoshi-4
Size	0.5×0.5×H0.65m	0.5×0.6×H0.7m
Weight	60kg	66kg
Orbit	SSO. 600km, LTAN 10am～11am	
ACS	Earth pointing, 3 axis stabilization	
Power	Power generation: max 100W Power consumption: average 50 W Bus voltage: 28V, 5V Battery: 5.8AH Li-Ion	
Commu-nication	H/K and Command: S-band uplink:4 kbps, downlink:4/32/64 kbps Mission data downlink: X-band 10Mbps (100Mbps to be tested on Hodoyoshi-4)	
Orbit control	H_2O_2 propulsion	Ion-thruster (Isp: 1100s)
Missions	Mid-resolution optical camera GSD:40m & 200m	High-resolution optical camera GSD:5m
	Store & Forward Hosted payloads (10cm cube x 2) Hetero-constellation experiment	

“Store and Forward” Receiver

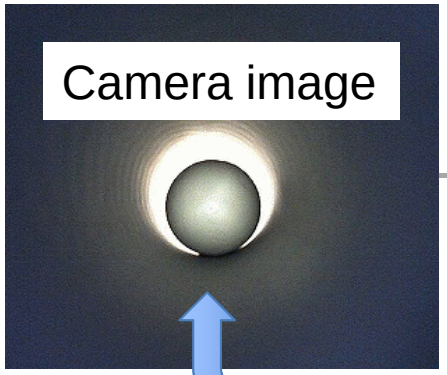
Function and Spec	
UHF frequency	401.5 MHz
High speed A/D conversion	
Sampling frequency	10 kHz or 40 kHz
Sampling time	1 sec or 10 sec
Modulation (Data transmission)	BPSK
Data storage capacity	Up to 16 Gbits (nonvolatile memories)
Digital data transfer speed	Up to 10 Mbps (Target)
Power supply	Unregulated power bus between +16 V and +36 V
Power consumption	Up to 5 W (Target)
Size	150 mm x 150 mm x 35 mm (excluding fitting mount)
Development status	FM integration and testing

Characteristics:
- No on-board demodulation
- High-speed A/D conversion of received signals.

Water Level Monitoring Sensor Requirement

Observation Range	5
Resolution	0.01
Unit	Meter
Required data bits	9
Observation Frequency per day	24
Sensor availability	Under development
Target sensor cost	<$100
Note	Observe water level change in short term and long term.

Water Level Monitoring Sensor（1）

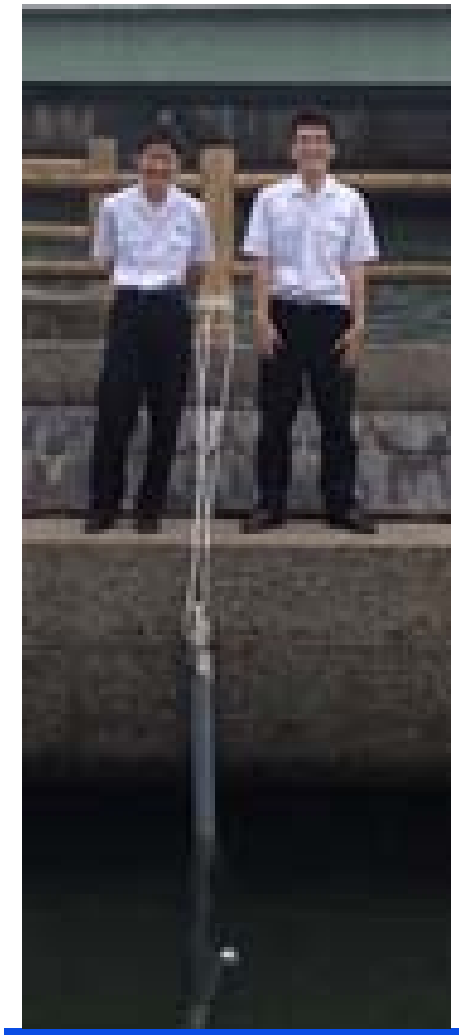


Original Concept (Abiki-kun)

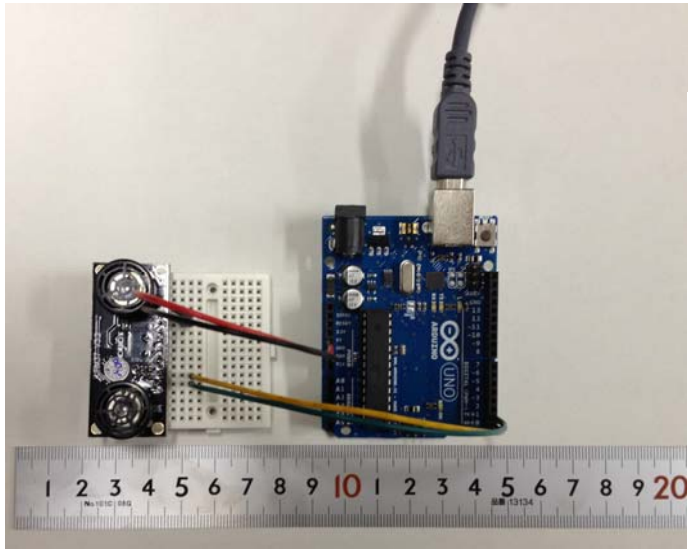
Camera
Installation device
Float
Water surface
Installation device
PVC Tube
River side
Longer than 2 m
Bus system
Sensor system
Enlarged view
Transmitter
GPS
CPU
Memory
Batteries
Solar cells

Water Level Monitoring Sensor (2)

Current Design: Abiki-kun R

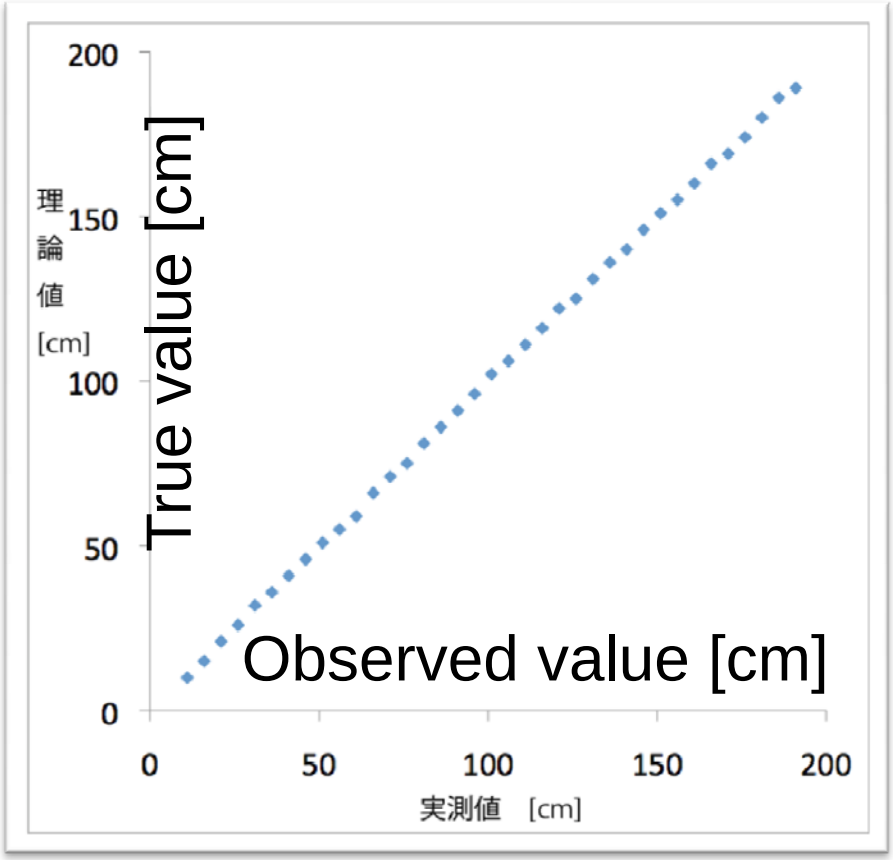


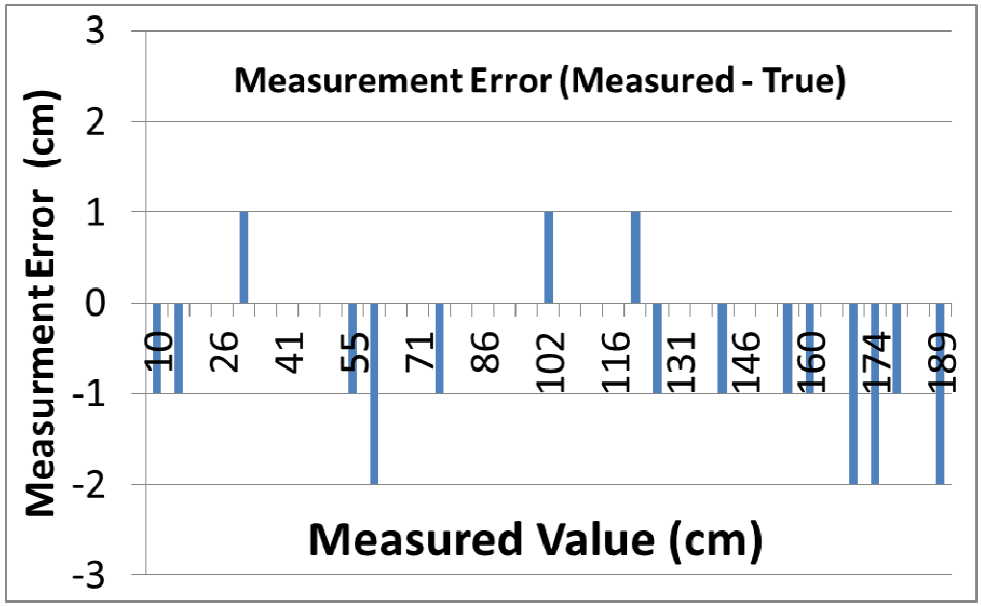
Sensor: URM37 V3.2 Ultrasonic Sensor
Voltage: 5 V
Current: less than 20 mA
Observation range: 4 cm – 5 m
Interface: TTL or RS232



Water Level Monitoring Sensor (3)

Current Design: Abiki-kun R





Measurement Error;

- Average: -0.4 cm
- Sigma: 0.8 cm

Source: Water level monitoring by an ultrasonic distance measuring sensor (Analysis of distance measuring unit for Abiki-kun R), Nagasaki Nishi High School, Earth Science Club

Water Level Monitoring Sensor (4)

Three different configuration were tested.

Configuration	With a 2m vinyl chloride tube	With a float	Measurement method	System feasibility	Note
Original	Yes	Yes	Camera	No	Too much resources required.
Abiki-kun R # 1	Yes	Yes	Ultrasound	Yes	Measurement error is relatively small
Abiki-kun R # 2	Yes	No	Ultrasound	Yes	Measurement stability might be degradated by waves.
Abiki-kun R # 3	No	No	Ultrasound	Yes	Measurement stability might be degradated by waves.

Source: Water level monitoring by an ultrasonic distance measuring sensor (Analysis of distance measuring unit for Abiki-kun R), Nagasaki Nishi High School, Earth Science Club

Store and Forward Transmitter

	Spec
Frequency	401.5 MHz
Modulation	ASK+BPSK Recognition: 9-bit ASK signal
Bandwidth	Less than 30 kHz
Speed	300 bps
Transmission power	1 W nominal Low power mode (1 µW, 10 mW , 100 mW)
Power consumption	During data transmission: 5 W Stand-by mode: 50 mW Sleep mode: 1 mW
Size	150 mm × 80 mm × 30 mm
Weight	Less than 200g

Store and Forward Transmitter Specifications

Development status:

- A prototype transmitter is being manufactured.
- Field testing will be performed by the end of this year.

Data Transmission（1）

- Data Transmission mode: 1 sec/10 sec
- Data Transmission speed: 300 bps
- Signal recognition and info. header : 0.1 sec
- Transmittable data size per one data tranmission attempt
  - 1 sec mode: **270 bits** (0.9 second for data)
  - 10 sec mode: **2970 bits** (9.9 seconds for data)

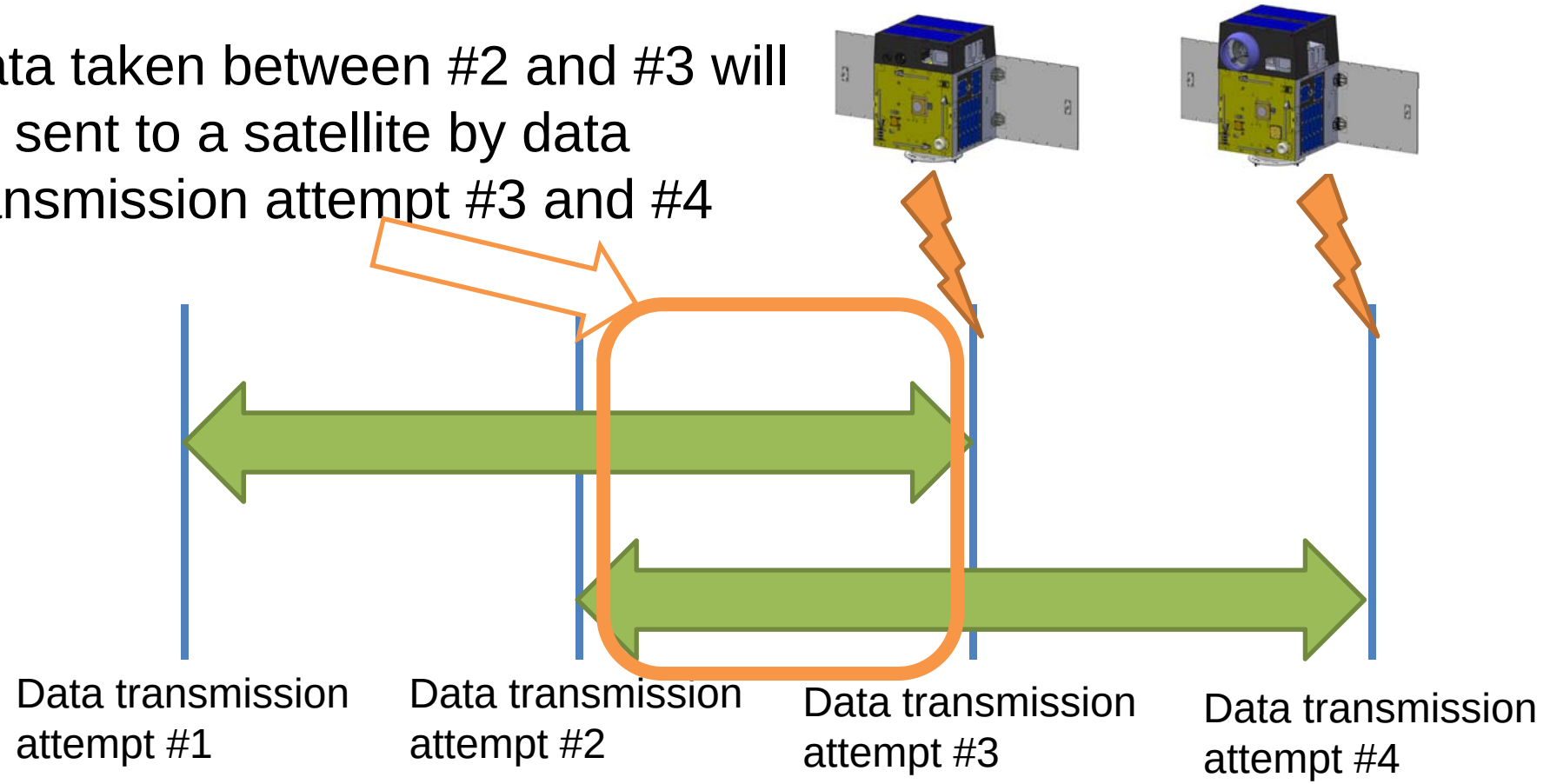
Data Transmission (2)

- Estimation of Hodoyoshi satellite AOS/LOS, and timing of data transmission
  - A sensor keeps orbital elements of Hodoyoshi satellite and estimate AOS/LOS time.
  - Orbital elements become inaccurate over time
  - Multiple data transmission attempt between AOS and LOS. (2-4 times, once every minute)

Data Transmission (3)

- Observation data will be sent twice to prevent data transmission failure.

Data taken between #2 and #3 will be sent to a satellite by data transmission attempt #3 and #4



Link Budget Analysis

- 1 W transmission power is enough.
  - Communication distance: 1,000 Km (600 km altitude, 30 deg elevation angle)
  - Frequency: 400 MHz
  - Gain for antennas (dipole): -10 (ground) and 0 (satellite) dBi

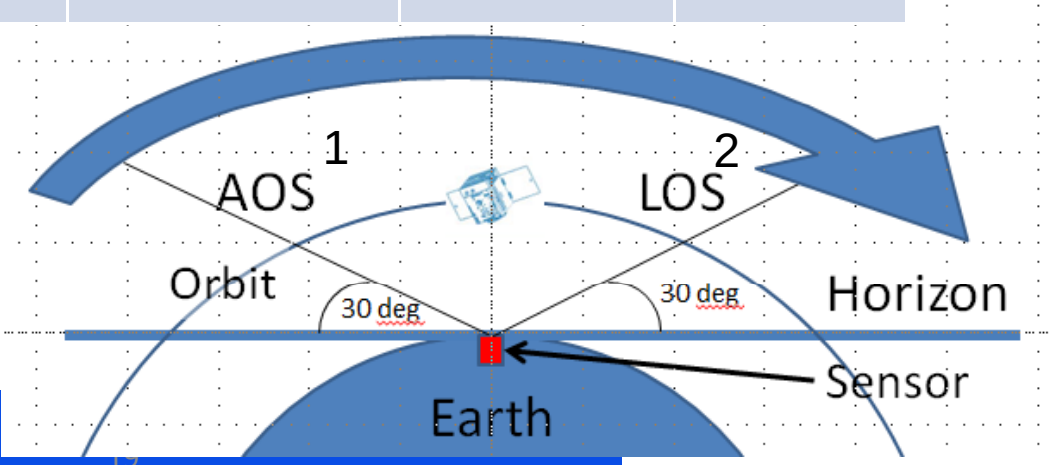
Item	Value	Unit	Note
Transmitted power	30	dBm	1W
Received C/No	43	dB	
Required C/No	36	dB	
Link margin	7	dB	

- Reference: Store & Forward on-board satellite communication receiver for Hodoyoshi 3rd and 4th satellites, NE-G120004, April 23rd 2012, Next generation Space system Technology Research Association

Communication Link Analysis (1)

Pass	Day	AOS[1] Time (UTCG)	LOS[2] Time (UTCG)	Max Elevation (Deg)	Mean Range (km)	Duration (min:sec)
#1	1	8:28:40	8:32:16	52.5	930	3:36
#2	1	19:14:48	19:18:11	47.7	959	3:21
#3	2	8:41:12	8:43:37	36.6	1032	2:25
#4	2	19:26:27	19:30:27	69.8	908	4:00
#5	3	19:38:23	19:42:29	81.4	889	4:06
#6	4	19:50:34	19:54:17	55.7	914	3:43
#7	5	07:41:38	07:43:50	35.2	1046	2:12

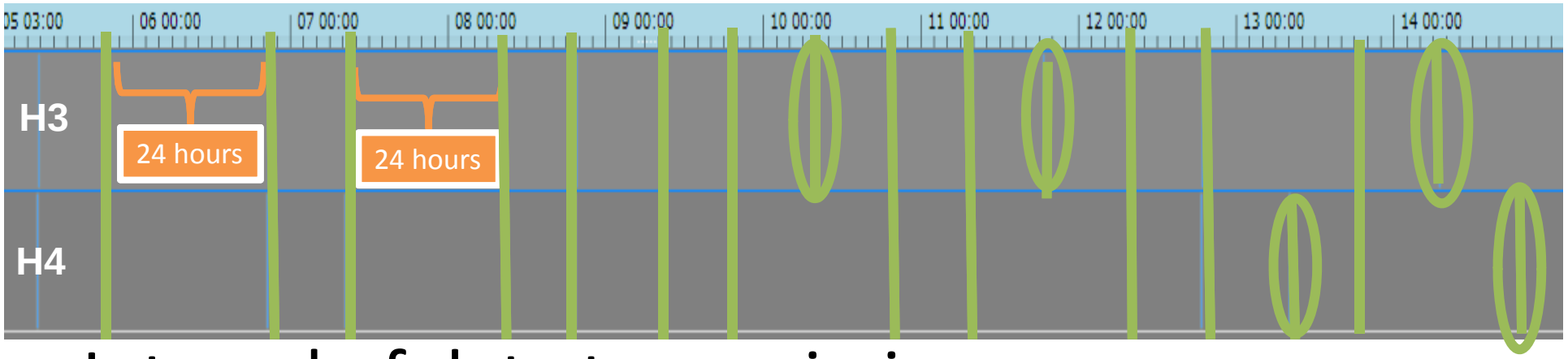
Data transmission timing from a sensor located in Egypt to the Hodoyoshi satellite with 30-deg elevation constraint



Communication Link Analysis (2)

Satellite	Semi-major Axis (km)	Inclination (Deg)	Eccentricity
Hodoyoshi 3	7022 (644)	97.978	0.0035
Hodoyoshi 4	7014 (636)	97.980	0.0024

Timing of Hodoyoshi satellites flying over a sensor in Egypt

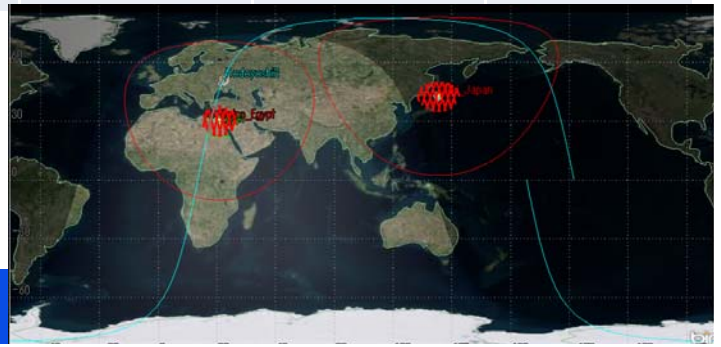


- Interval of data transmission:
  - Typical: 11 or 13 hours
  - Worst case: 24 hours

Communication Link Analysis (3)

	Ground Sensor in Egypt				→	Ground Station in Japan			
	Day	AOS Time (UTCG)	LOS Time (UTCG)	Duration (min:sec)	**Latency (hour:min)**	Day	AOS Time (UTCG)	LOS Time (UTCG)	Duration (min:sec)
#1	1	8:28:40	8:32:16	3:36	**2:43**	1	11:15:40	11:16:41	1:01
#2	1	19:14:48	19:18:11	3:21	**5:16**	2	00:33:46	00:37:26	3:40
#3	2	8:41:12	8:43:37	2:25	**2:43**	2	11:26:38	11:29:35.	2:58
#4	2	19:26:27	19:30:27	4:00	**5:15**	3	00:45:35	00:49:39	4:04
#5	3	19:38:23	19:42:29	4:06	**5:15**	4	00:57:33	01:01:41	4:07
#6	4	19:50:34	19:54:17	3:43	**5:15**	5	01:09:41	01:13:31	3:50
#7	5	07:41:38	07:43:50	2:12	**4:18**	5	12:01:59	12:06:05	4:06

Maximum data latency is less than 6 hours.



Organization

UNISEC
University Space Engineering Consortium

自主創造 日本大学 NIHON UNIVERSITY

慶應義塾 SDM System Design and Management

首都大学東京 TOKYO METROPOLITAN UNIVERSITY

東京大学 THE UNIVERSITY OF TOKYO

国立大学法人 九州工業大学

Manufacturers

In corporation with Hodoyoshi Project (Cabinet Office FIRST Program, PI: Prof. Nakasuka)

超小型衛星センター NANO-SATELLITE CENTER

NESTRA Next generation Space system Technology Research Association

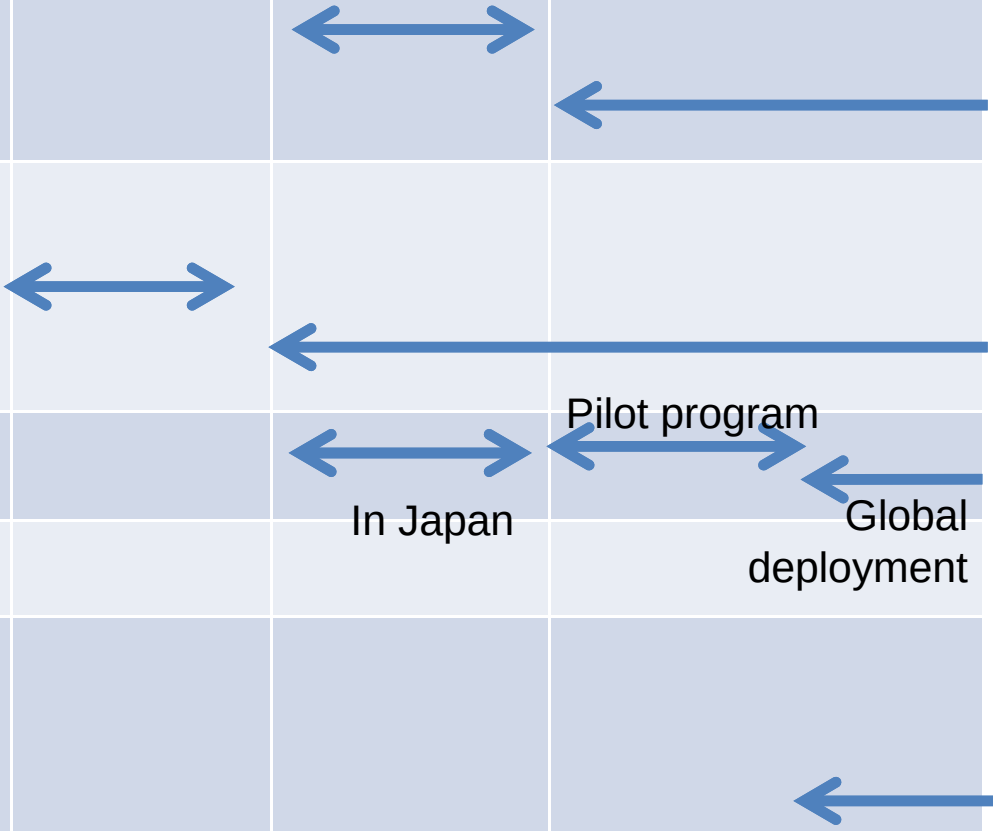
Nagasaki Nishi High School: Water level observation sensor

Future plan

- Development of S&F satellite constellation
  - Cubesats
  - Different algorithm to accommodate large number of sensors
  - International cooperation
- Development of universal on-ground observation sensor
  - Radiation monitoring, tracking of wild animals, tracing stolen objects, etc.

Schedule

	2013FY	2014FY	2015FY-
(1) Water level monitoring sensor Development Manufacture			
(2) Sensor bus system Development Manufacture			
(3) Water level monitoring activity			
(4) Future plan • Development of S&F satellite constellation • Development of Universal on-ground observation system			



Conclusion

- Our “Global Water Level Monitoring for Disaster Mitigation Using Data Collection Function of Micro-satellite” is a very unique mission and it can positively impact global society, especially after the cubesat-size S&F satellite constellation is deployed.
- Since Hodoyoshi 3rd and 4th satellites are almost ready for launch, the technical feasibility is high and the technical risk involved is considered minimal.
- The future plan calls for the multinational collaboration. The harmonized effort by the international teams is crucial to achieve the common and ambitious goals to contribute global society.

Thank you for your attention

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