Pre-3rd Mission Idea Contest Workshop

Utilizing Nano Satellites for Water Monitoring for Nile River

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USER: Ashraf Nabil Rashwan, Cairo University, Egypt
DEVELOPER: Ayumu Tokaji, University of Tokyo/Keio University, Japan

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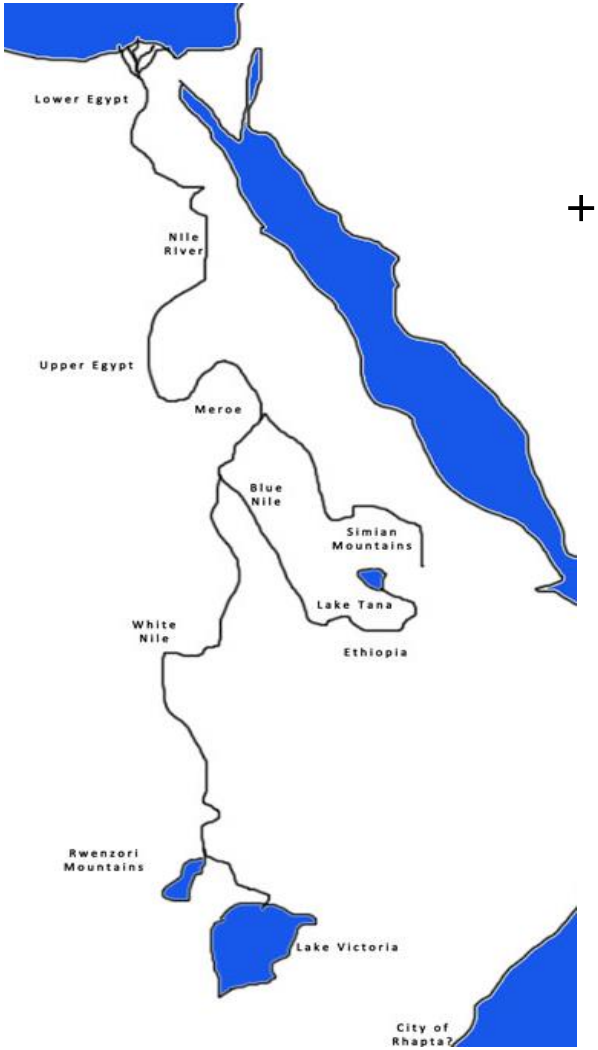
Background: Flood and Drought

Background: Water Pollution

Mission Statement

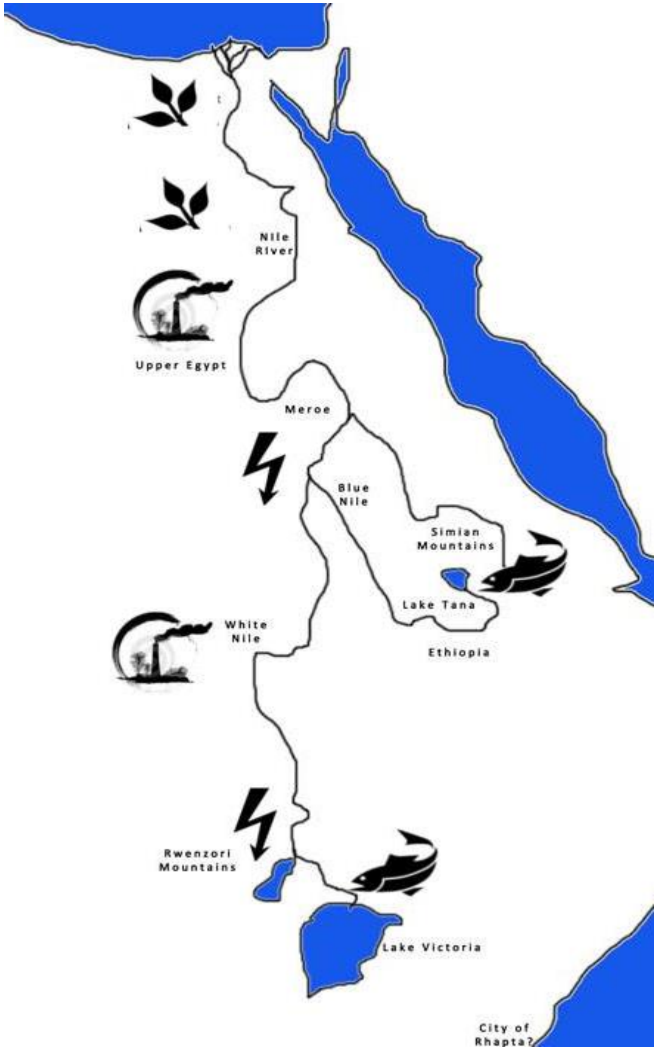
- We aim to establish network for water resource monitoring for Nile river with Hodoyoshi "Store and Forward" (S&F) communication function and an affordable ground sensor (Target total system cost: <$600).
- Water resource management for Nile river basin will be conducted first.
- After the completion of Nile river project,
  - Water resource monitoring system will be deployed world wide.
  - further development to improve S&F communication network with cubesat-size satellite constellation and to increase versatility of ground sensor will be executed.
  - This project will be an international co-operation project.

Remapping Nile River



+ Data from Satellites

Locations of:
1- Electricity
2- Fisheries
3- Agriculture
4- Pollution



Mission Overview（1）

- Water level
- Acidity (pH)
- Clarity (turbidity)
- Oxygen(DO)
- Temperature

Mission Overview（2）

- Sensor selection and the number of sensor will be determined based on:
  - Sensor availability
  - Costs
  - Locations of urgent need
  - Suggestion of MWRI/NWRC/NRI.

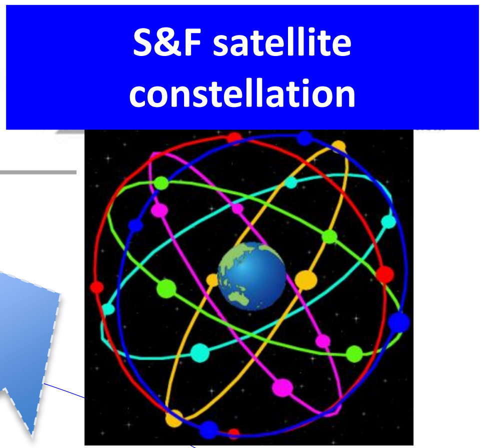
Mission Example: Water Level Monitoring

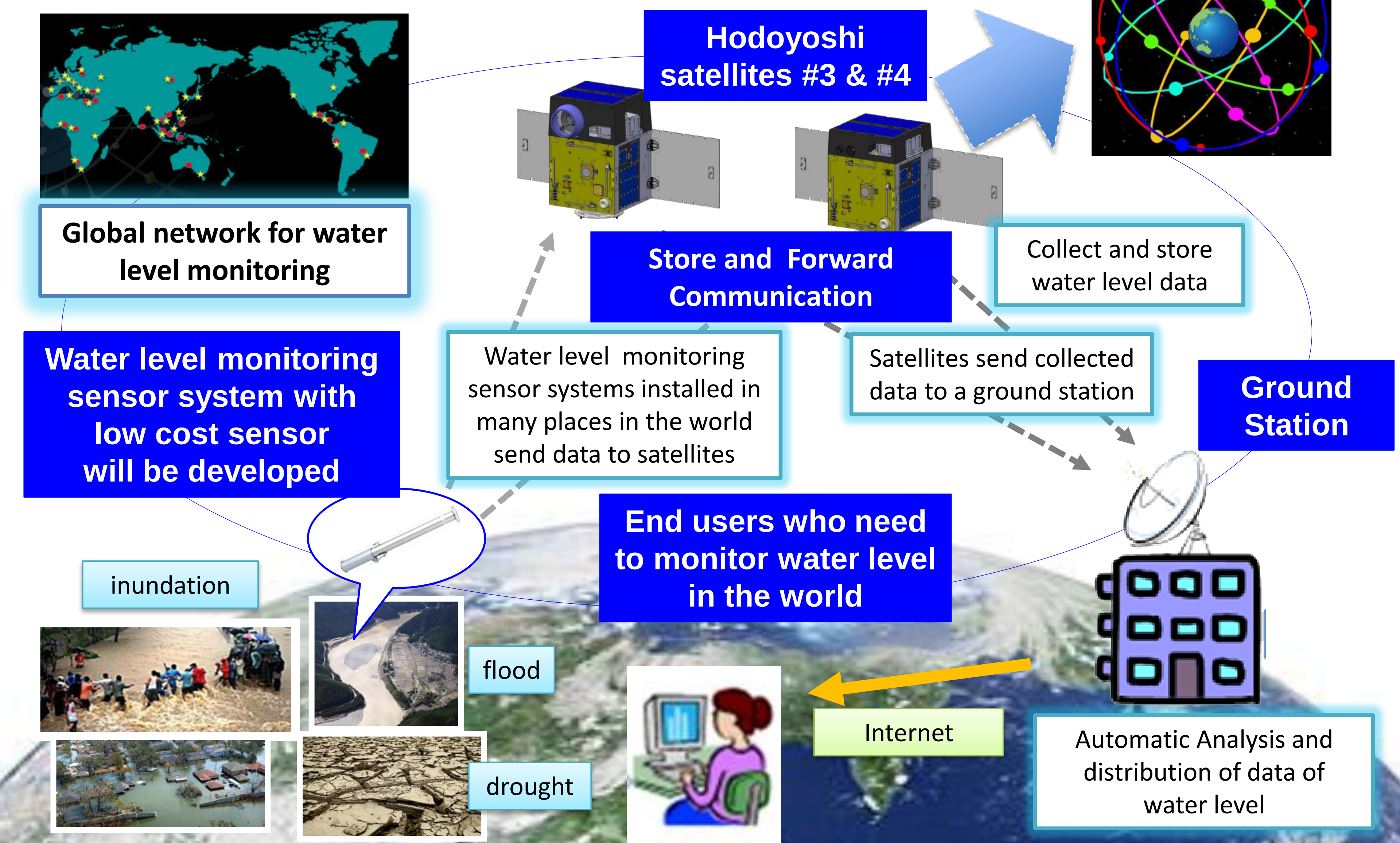
Observation Range	5
Resolution	0.01
Unit	Meter
Required data bits	9
Observation Frequency per day	24
# of sensors for Nile river coverage	TBD
Sensor availability	Under development
Target sensor cost	<$100
Note	Observe water level change in short term and long term.

Success Criteria

- Minimum success
  - At least one sensor data from one location is successfully received by a Hodoyoshi satellite and forwarded to a ground station for 6 months.
- Full success
  - All sensor data from one location are successfully received by a Hodoyoshi satellite and forwarded to a ground station for 2 years.
- Extra success
  - All sensor data from multiple locations are successfully received by a Hodoyoshi satellite and forwarded to a ground station for 2 years.

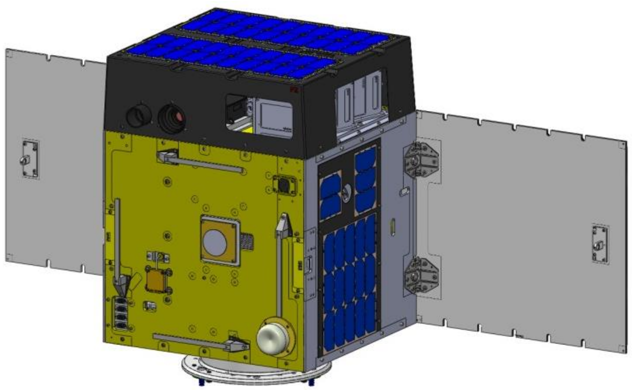
Concept of Global Network for On-Ground Sensors with Nano/Micro Satellites (Application: Water Level Monitoring)



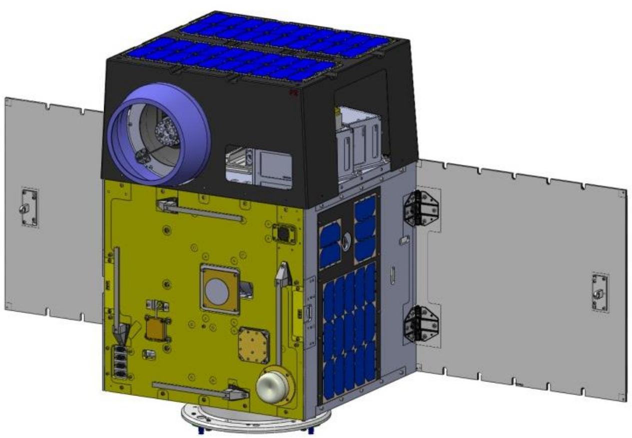


Space Segment: HODOYOSHI-3 & 4

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

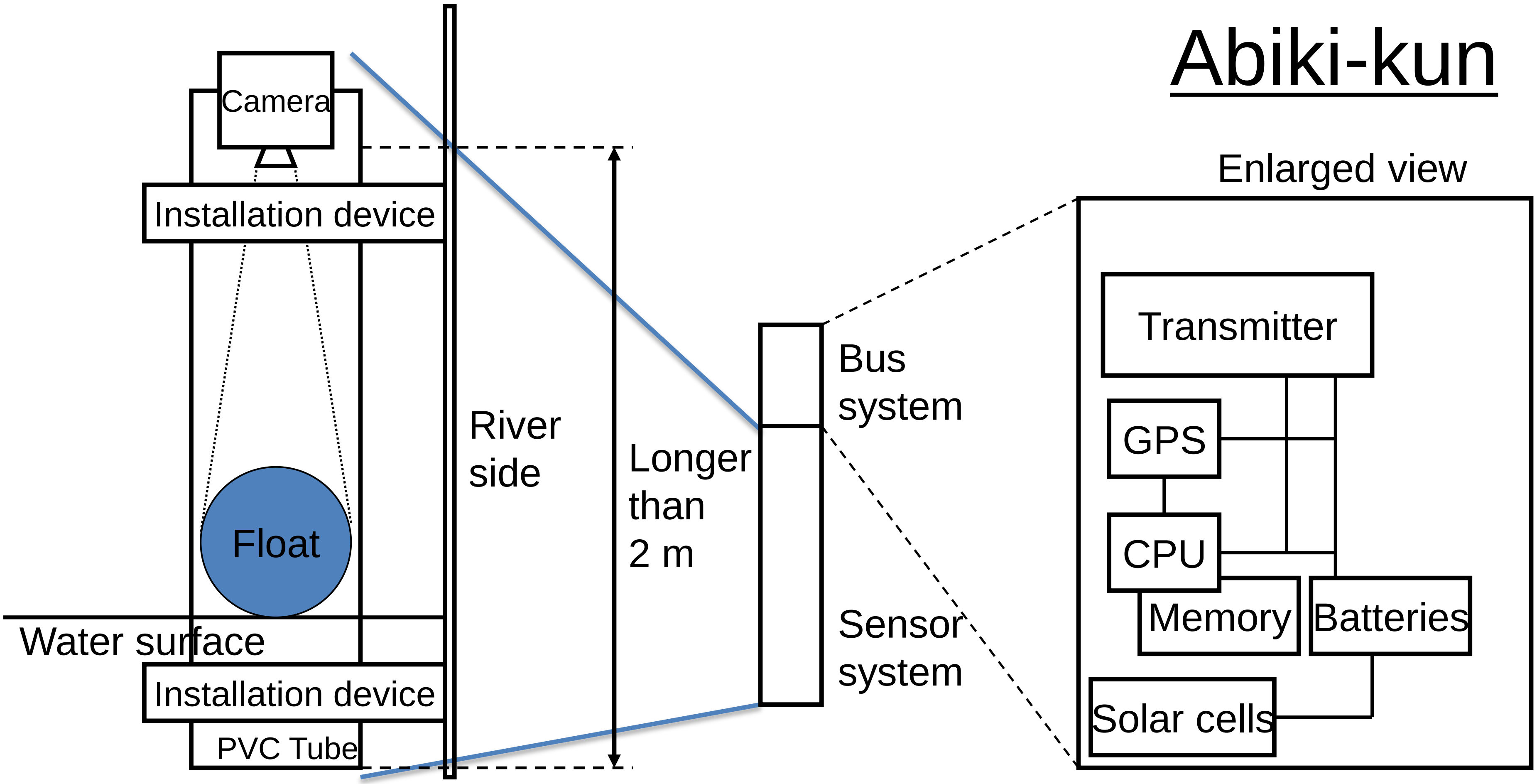
Function and Spec	
UHF frequency	400 MHz
High speed A/D conversion	
Sampling frequency	10 kHz or 40 kHz
Sampling time	1 sec or 10 sec
Modulation (Data transmission)	BPSK
Data storage capacity	Up to 16 Gbits (nonvolatile memories)
Digital data transfer speed	Up to 10 Mbps (Target)
Power supply	Unregulated 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 Resource Monitoring Sensor（1）

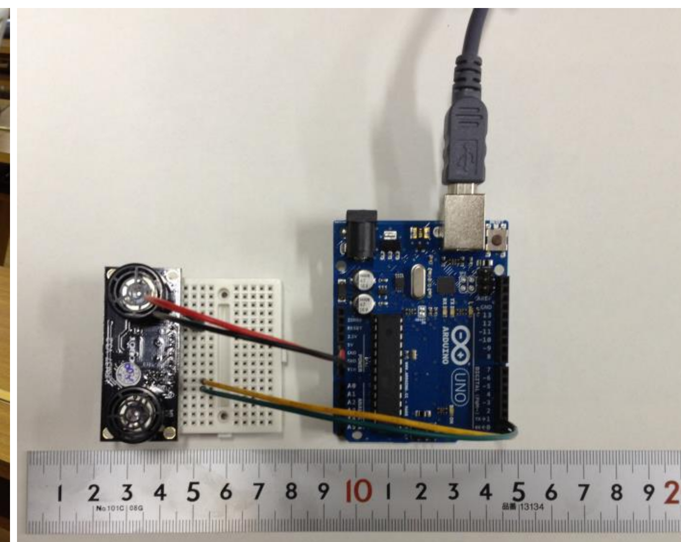
Original Concept (Water level monitoring)



Water Level Monitoring Sensor (2)

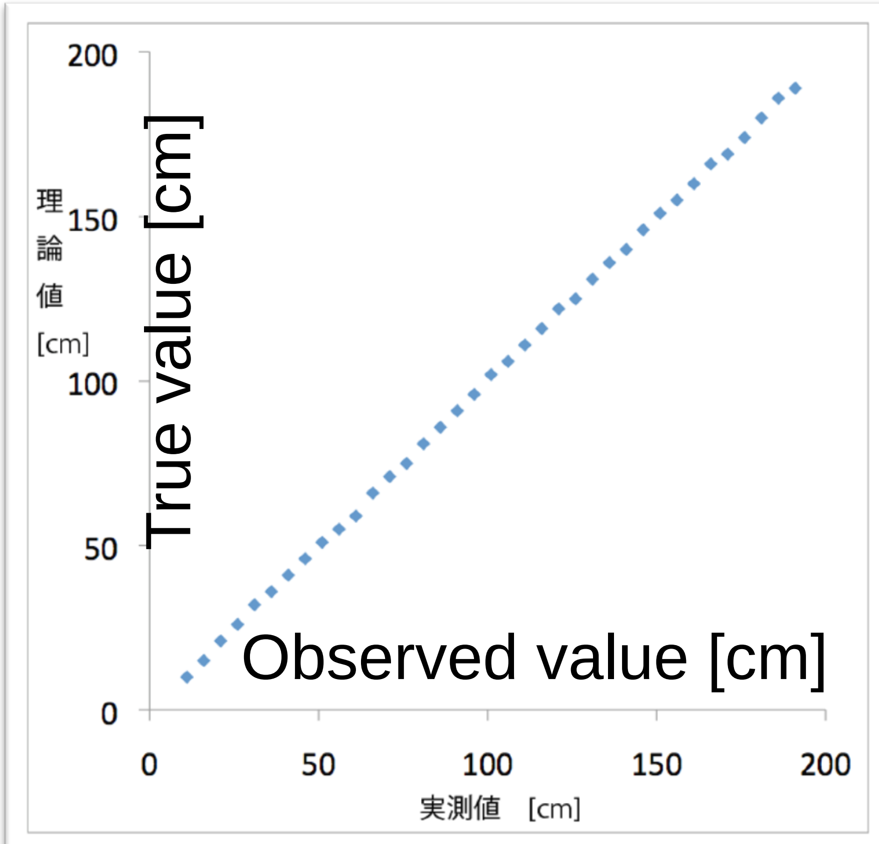
Current Design: Abiki-kun R

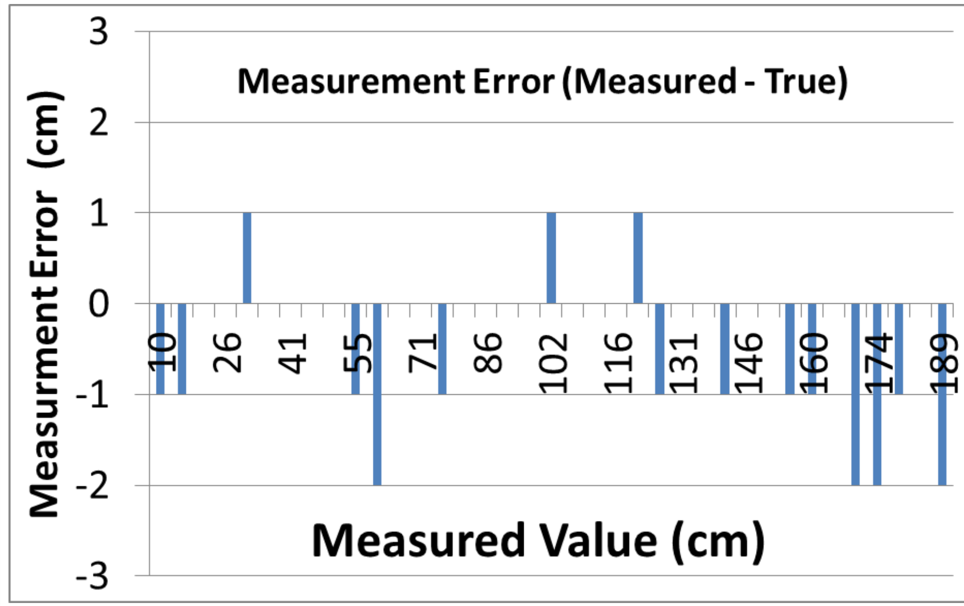
Sensor: URM37 V3.2 Ultrasonic Sensor
Voltage: 5 V
Current: less than 20 mA
Observation range: 4 cm – 5 m
Interface: TTL or RS232



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 (3)

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	400 MHz
Modulation	ASK+BPSK
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

Development status:

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

Store and Forward Transmitter Specifications

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)

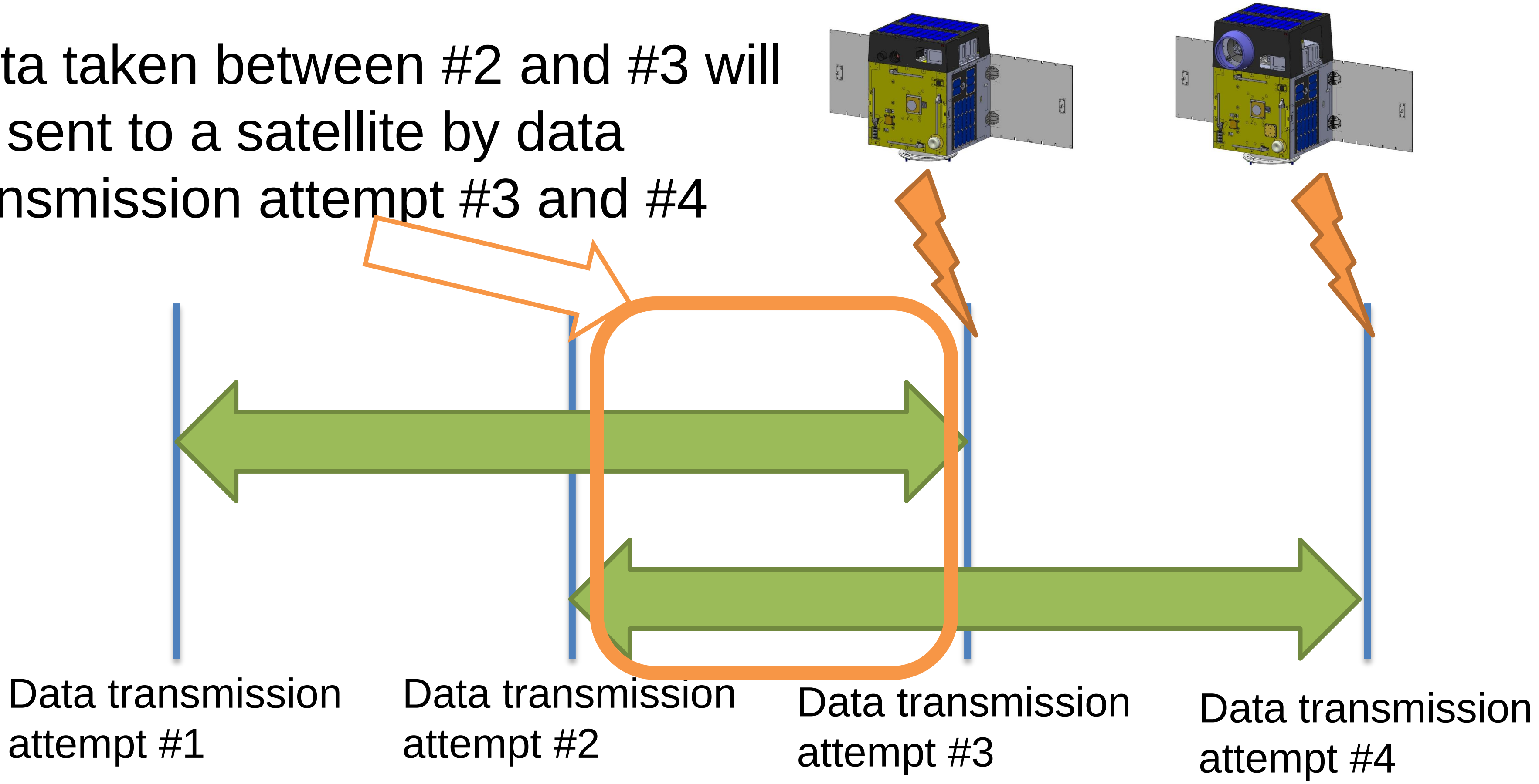
Data Transmission（2）

- 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



Data Transmission (4)

- Estimation of Hodoyoshi satellite AOS/LOS, and timing of data transmission (Continued)
  – All sensor are alloted time slot for data transmission to avoid crosstalk of radio waves (FATDMA: Fixed Access Time Division Multiple Access)
    - 10 sec mode: up to 5 sensors (12 sec time slot)
    - 1 sec mode: up to 50 sensors (1.2 sec time slot)
  – There are more than 50 sensors in the area where their transmitted radio waves can reach at the same time, additional satellites which has S&F capability are required. (Future plan)

Link Budget Analysis

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

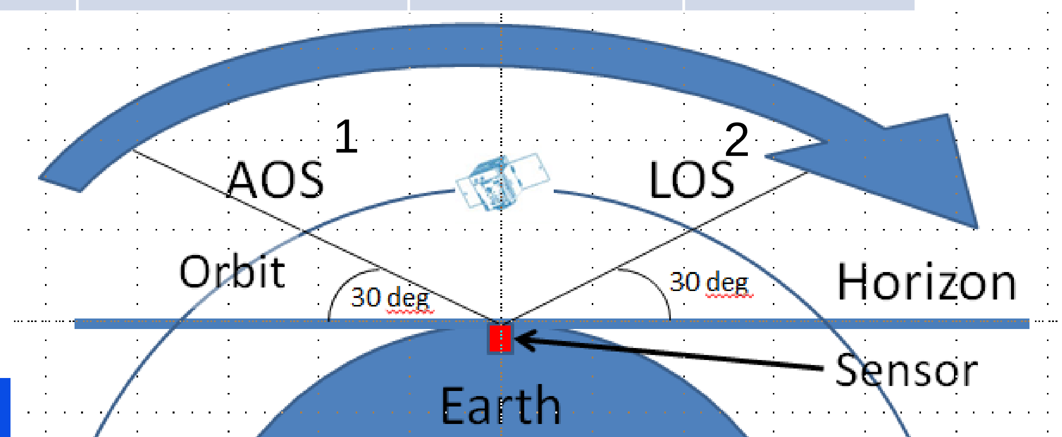
- 1 W transmission power is enough.
  - Communication distance: 1,000 Km (600 km altitude, 30 deg elevation angle)
  - Frequency: 400 MHz
  - Gain for antennas (dipole): -10 (ground) and 0 (satellite) dBi

- 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

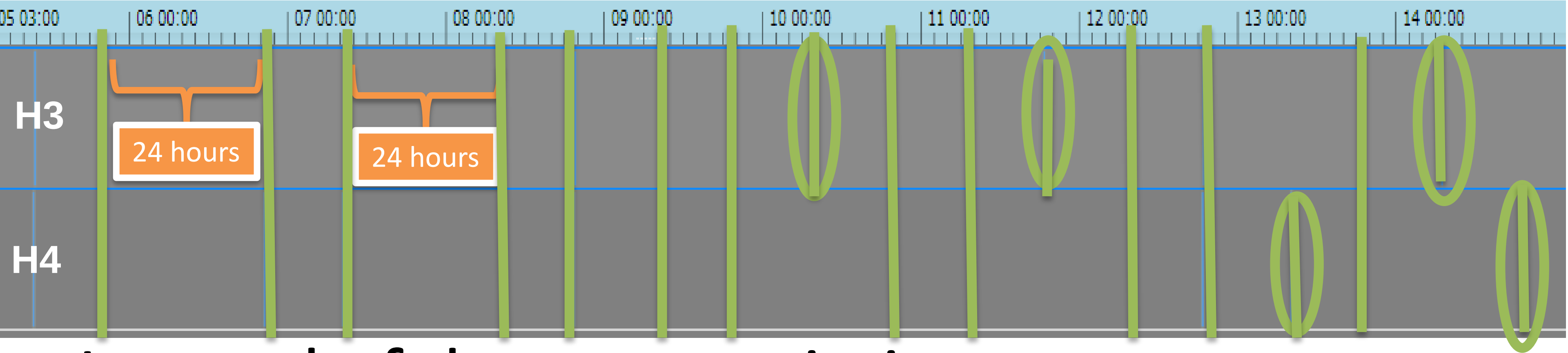
Data transmission timing from a sensor located in Egypt to the Hodoyoshi satellite with 30-deg elevation constraint



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

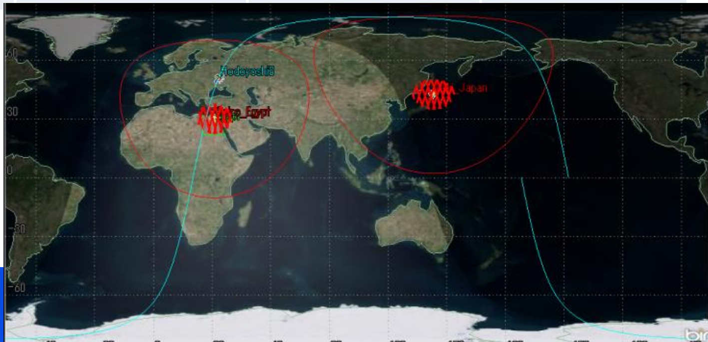


- Interval of data transmission:
  - Typical: 11 or 13 hours
  - Worst case: 24 hours

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.



Technical risks（1）

- Launch failure of Hodoyoshi 3rd and 4th
  - Hodoyoshi 2nd satellite can be used as back-up. (Launch date for Hodoyoshi 2nd is not fixed yet.)
  - In case of no available satellites, Limited observation activities will be performed with ground-base network
- Development failure: Space segment
  - Hodoyoshi 3rd and 4th satellites are currently in the phase of FM integration and testing without delay.
- Development failure: Ground segment
  - A prototype transmitter is being manufactured, and field test will be performed by the end of this year.

Technical risks（2）

- Development failure: Ground segment
  - Water resource observation sensor
    - Strict resource limitation
      - Power
      - Size
      - Data size
      - Cost
      - Maintenance/Calibration free

    - To minimize development risk, The most promising sensors based on priority, technology readiness level (TRL), cost, and availability will be adopted for this project.

Technical risks（3）

- One or more sensors not working properly or losing.
  - Replace only the sensor which is not working, not a whole system
  - Replaceable sensor design like PC accessories

Sustainability of the project

- International user community for water resource management will be organized.
  - Egypt: MWRI/NWRC/NRI
  - Japan: Japan Meteorological Agency
  - UNISEC Global

Organizations（1）

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

Organizations in Egypt

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 Sensor

Organizations in Egypt (1)

Government agency:

وزارة الموارد المائية والرى

جمهورية مصر العربية

Ministry of Water Resources and Irrigation

Arab Republic of Egypt

المركز القومي لبحوث المياه

National Water Research Center

NWRC

NARSS

National Authority for Remote Sensing and Space Sciences

Organizations in Egypt (2)

Research center:

Dr. Abdelazim M. Negm

Prof. Mohamed Khalil
Prof. Ayman Kassem
Mr. Ahraf Nabil Rashwan

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 resource monitoring sensor Development Manufacture			
(2) Sensor bus system Development Manufacture			
(3) Water resource monitoring activity		In Japan	Egypt Global deployment
(4) Future plan • Development of S&F satellite constellation • Development of Universal on-ground observation system			

Conclusion

- Our “Utilizing Nano Satellites for Water Monitoring for Nile River” 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 including Japan and Egypt is crucial to achieve the common and ambitious goals to contribute global society.

Thank you for your attention

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