Title: Utilizing Nano Satellites for Water Monitoring for Nile River

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1. Need

Water resource surveillance including water levels, such as of rivers, lakes, or seas, are crucial in predicting and monitoring for disasters including tsunami, flood, drought, and pollution. Many countries at various level of development have suffered from these disasters every year. However, there is no satellite-based affordable global monitoring system with continuous and automated data collection capability at low cost without risk to human observers.

2. Mission Objectives

Mission objectives are listed below.
1: Establish water resource monitoring network for Nile River to serve Egyptian society.
2: Deploy water resource monitoring network worldwide.
3: Form an internationally collaborated community for sharing data and disaster mitigation efforts
4: Develop versatile ground sensor network system for other monitoring needs
5: Develop store and forward (S&F) satellite constellation to improve S&F communication capability

3. Concept of Operations

Concept of operations is shown in Figure 1. Details of key mission elements are listed below.

- Space segment: Hodoyoshi satellite #3 and #4, and S&F communication system (Table 1)
- Ground segment: X-bank downlink ground station at Taikicho, Hokkaido, Japan (Figure 7)
- Ground sensor segment: Low cost and low power consumption sensor system with UHF transmitter (Figure 2)
- User segment: Organizations / Scientists / researchers who install/operate the ground sensor, and use the date for water resource management

Relationship between each segment is summarized in Figure 3.

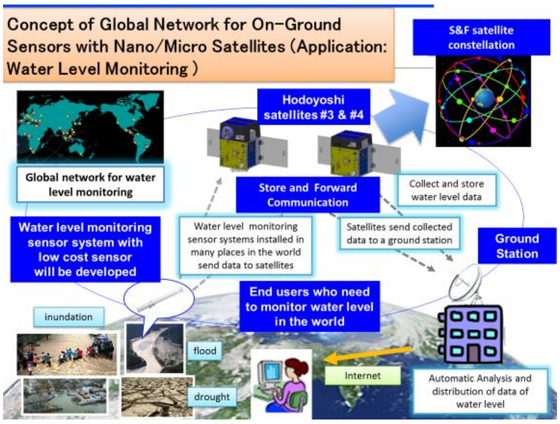
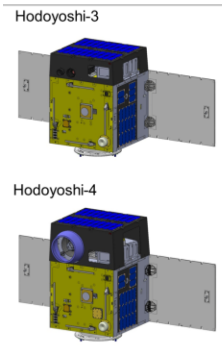


Figure 1: Concept of operations

Table 1: Specification of Hodoyoshi satellites

Space Segment: HODOYOSHI-3 & 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	

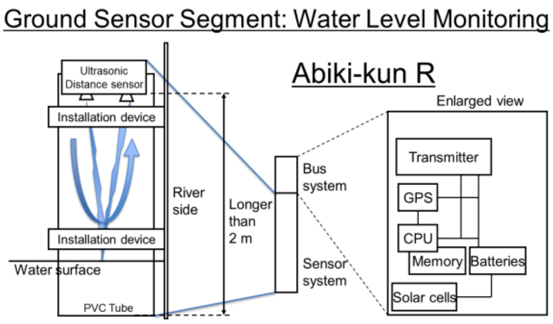


Figure 2: Ground sensor system with Abiki-kun R

4. Key Performance Parameters

Key performance parameters for this project are listed below.

- Low power consumption: Ground sensor system needs be operated independently without power supply from outside. Therefore, power consumption should be as low as possible. In addition, when power consumption becomes smaller, requirements for power subsystem including solar panels, secondary batteries can be modest. As a result, ground sensor system as a whole can be simpler, smaller, and cheaper.

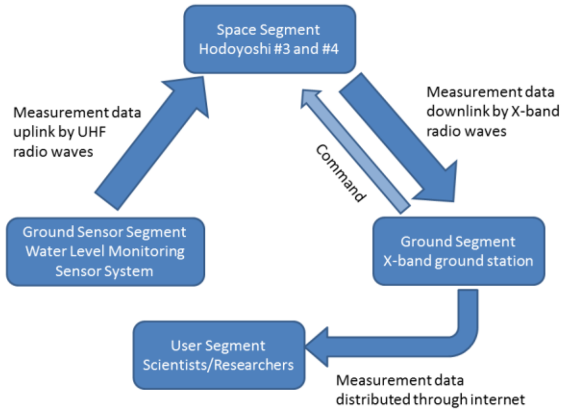


Figure 3: Relationship between each segment

- Low cost ground sensor system: The more ground sensor systems are used globally, the more they benefit the society. Therefore, achieving low cost can make it easier for developing countries to install and operate the system and utilize measurement data for disaster damage mitigation.
- Interval of data transmission from a ground sensor to a Hodoyoshi satellite: Due to capability limitation of S&F communication, continuous data communication link between a ground sensor and a Hodoyoshi satellite cannot be achieved. However, twice-a-day data transmission from a ground sensor to a Hodoyoshi satellite can be achieved, and it is good enough for the most part of water resource monitoring activities (Table 2).
- Data latency: Due to the number of ground stations and their location, data latency is relatively large. Fortunately, for water resource monitoring mission in Egypt, 3-5 hours data latency is acceptable (Table 2).
- Data transmission speed from a ground sensor to a Hodoyoshi satellite: Data transmission speed for S&F communication is 300 bps, and 270 bits of data for 1-sec, and 2970 bits of data for 10-sec data transmission mode can be sent to a satellite for each data transmission opportunity. Due to characteristics of water resource monitoring (intermittent and less frequent measurement), 10-sec data transmission mode has enough capability and can be used for this project.

5. Space Segment Description

Key specifications for Hodoyoshi #3 and #4 satellites are shown in Table 1, "Concept of Operations" section. Diagram for hodoyoshi S&F communication system is shown in Figure 4, and specification of S&F communication receiver is summarized in Table 3. Hodoyoshi #3 and #4 satellites are now in orbit and S&F communication system is now operable.

Table 2: AOS/LOS time for uplink/downlink

	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

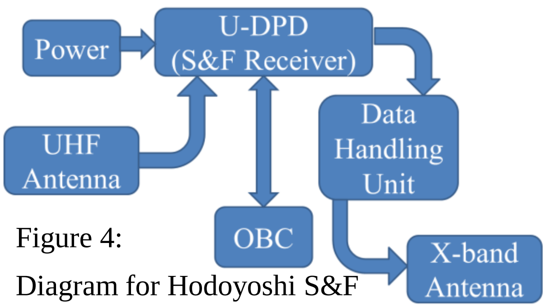


Figure 4: Diagram for Hodoyoshi S&F communication system

6. Orbit/Constellation Description

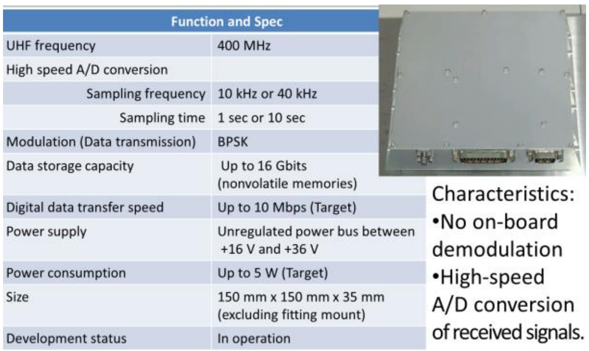
Hodoyoshi 3 and 4 satellites orbit information is summarized in Table 4. Both Hodoyoshi satellites have propulsion system, but relative position is not controlled. Therefore, relative position between two

Hodoyoshi satellites will change over time. Ground sensor is assumed to send measurement data to Hodoyoshi satellites whose elevation angle is larger than 30 deg. (Figure 5.)

Table 4: Hodoyoshi 3 and 4 orbit information

Sate-llite	Semi-major axis (km)	Inclin-ation (Deg)	Eccent-ricity	LTAN
#3	7022 (644)	97.978	0.0035	10:30:00
#4	7014 (636)	97.980	0.0024	

Table 3: Specification of S&F 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	In operation

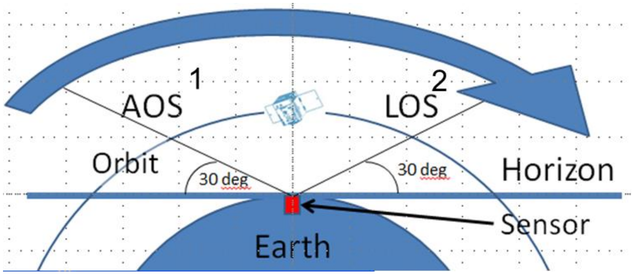


Figure 5: Geometrical configuration

When a ground sensor (uplink) is located in Egypt along the Nile River, and a ground station (downlink) at Taiki-cho, Hokkaido is used (Please refer to Figure 7.), AOS and LOS time for uplink and downlink is summarized in Table 2. Timing of Hodoyoshi satellites flying over a sensor in Egypt is shown in Figure 6. Based on communication link analysis, a sensor in Egypt can send measurement data to a satellite every 11-13 hours typically, and up to 24 hours in the worst case.

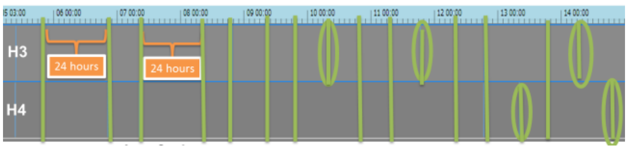


Figure 6: Timing of Hodoyoshi satellites flying over a sensor in Egypt

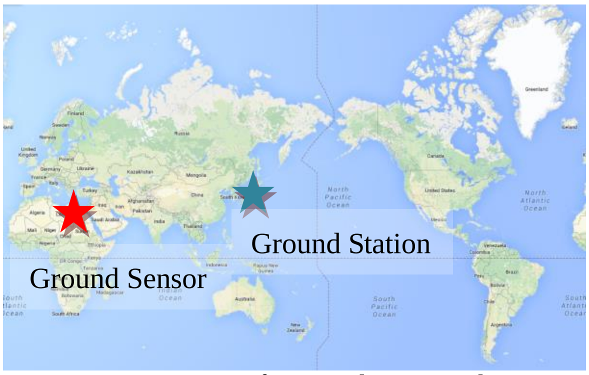


Figure 7: Location of a ground sensor and station

7. Implementation Plan

Participated organizations and their responsibilities are summarized in Figure 8 and Figure 9. Top-level project schedule is shown in Table 5.

Figure 8: Egyptian organizations

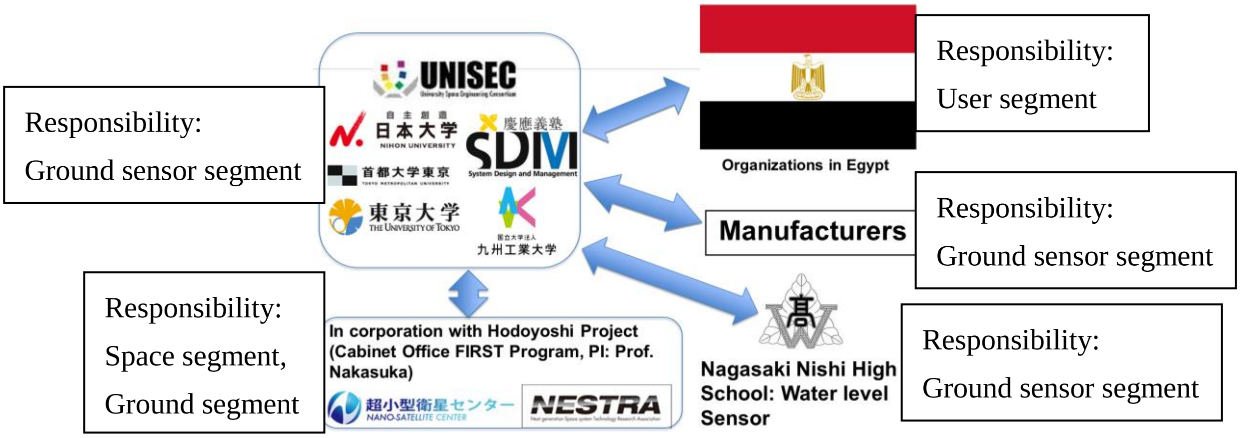


Figure 9: Organizations for project implementation

Table 5: Top-level project schedule

	2014 Q2	2014 Q3	2014 Q4	2015	2016
Hodoyoshi 3 and 4 satellites Development Launch Operation	~June, 2014	June 20, 2014			
Water resource management sensor Development Manufacture					
Sensor bus system Development Manufacture		System for ground test with Xbee	System for ground test with S&F transmitter		
Monitoring activities ● Activities in Japan System test with Xbee transmitter System test with S&F transmitter ● International activities Monitoring activities in Egypt Global deployment			**Monitoring activity results will be presented during MIC3**		
Future plan:					
Development of S&F satellite constellation				Conceptual Design	
Development of versatile on-ground observation system					
MIC3 (3^{rd} Mission Idea Contest)					

Facilities and infrastructures to be used are listed below.

- Space segment: Hodoyoshi 3 and 4
- Ground segment:
    - X-band antenna in Taiki-cho, Hokkaido, Japan and back up antennas in Japan
    - Operation center: Univ. of Tokyo

The top five project risks are listed below.

1: Failure to develop low cost and low power consumption ground sensor system

2: Hodoyoshi 3 and 4 satellite malfunctions

3: Lack of funding to develop and operate satellites and ground sensor system

4: Poor public security and political turmoil in Egypt

Estimation of total life cycle cost is summarized in Table 6. About 6.6 million USD is necessary for this project, however, Japanese government have provided 6 million USD for Hodoyoshi project. Therefore, only about 0.6 million USD are required to implement this project.

Table 6: Estimation of total life cycle cost

Item	Est. Cost (1,000 USD)	Note
Hodoyoshi #3 and #4 satellites: Life cycle cost	6,000	3M USD each
Ground sensor system: Development / manufacturing	250	80 ground sensors
Monitoring activities	200	In Japan and Egypt
PR activities	16	Website
Project management	140	UNISEC
Total life cycle cost	6,606	6M USD: Hodoyoshi project

References

1. Concept for Global Network of Water Level Data Collection Using Satellites, 57th Space Sciences and Technology Conference, 3O07, October 2013, Tottori, Ayumu Tokaji, Shinichi Nakasuka, et al
2. Global Water Level Monitoring for Disaster Mitigation Using Data Collection Function of Micro-satellites, 5th Nano-satellite Symposium, Tokyo, Japan, November 2013, Ayumu Tokaji, Shinichi Nakasuka , Yasuyuki Miyazaki, Hironori Sahara, Rei Kawashima, Kei-ichi Okuyama, Takashi Kondo, Masayasu Matsui, Takeshi Matsumoto, and Naomi Kurahara
3. Utilizing Nano Satellites for water monitoring for Nile River, Pre 3rd Mission Idea Contest, November 23, 2013, Takeda Hall, University of Tokyo, Japan, Ayumu Tokaji and Ashraf Nabil Rashwan
4. Outline of Mission and Development of Hodoyoshi Micro Satellites, Korehiro MAEDA, Naomi KURAHARA, and Shinichi NAKASUKA, IEICE Technical Report, SANE2011-67(2011-10)