Universidad Nacional de Ingeniería – Lima – Perú
Prepared by : Research Team “2” 2011

Title: Global water pollution monitoring using a nanosatellite constellation (WAPOSAT)

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Need

Lakes and rivers in Peru lack of pollution detection mechanisms for protecting them from excessive metal sediment and other substances affecting the Physico-Chemistry water characteristics (caused by industrial activities e.g. mining, hydroelectric, or others). Thus, it is important to install sensors connected to satellite systems to provide information to authorities in a near real time, when certain materials in the water affect pH, oxygen concentration, and others.

Objectives

1. **Retrieve water pollution (by metal sediment) information from sensors distributed over Per uvian lakes and rivers .**
2. **Send the retrieved data from sensors to ground stations and then to satellites (forming a constellation).**
3. **Distribute the data from the satellite constellation to every monitoring center.**

Concept of Operations

The mission consists of sensors distributed over Peruvian lakes and rivers, which register data from polluted water every 30 min

utes. The sensors send the retrieved information, as shown in Fig. 1, through Earth communication systems, to satellites forming a constellation using an store-forward communication mechanism.

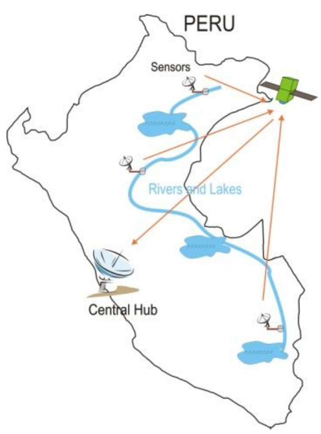

Figure 1. Mission concept. Data from polluted water is sent to a Central Hub in Lima through satellites.

Drawings of components do not necessarily match with real ones.

There will be two kinds of ground segment. The first one is composed by a ground station (Central Hub) in Lima, managed by people in the project, including transceivers, antenna rotors, antennas and Internet connection. The other kind is composed by 50 ground communication systems attached to the sensors. They include a transceiver, a fixed antenna, batteries and solar panels for autonomous operation. A preliminary analysis with 6 ground stations was already carried out [1].

Key Performance Parameters

Orbit Height: 1000 km. At this LEO height, very good coverage is obtained (further details in the Orbit section).

Effective transmission rate: 1200 baud, proposing a NanoCom UHF Half-Duplex Transceiver for each satellite. Frequencies: 432 – 438 MHz, Output Power: 200mW – 600mW. Modulation: FM + MSK.

Power System: a NanoPower P30U Power Supply is proposed, together with two quad-battery pack for extra energy capacity. Up to 30 W supplies.

Space Segment Description

Satellites used: Double Cubesats (10cmx10cmx20cm).

Number of satellites: 40

Mass of satellites: less than 5 kg

Link Budget : The system estimate a link margin of 0.7 dB for the downlink (worst case) and 9.5 dB for the uplink. The data rate is 1200 bps and a BER=10^{-5}.

Orbit/Constellation Description

There will be 40 satellites in a constellation, 4 satellite planes (45 degrees between each plane). The expected orbit inclination is 98.5º. Each plane will have 10 equally-spaced satellites. The Earth surface coverage will be total, as shown in Fig. 3, although sometimes there are time gaps of a few minutes, considering a 10º ground station elevation mask angle.

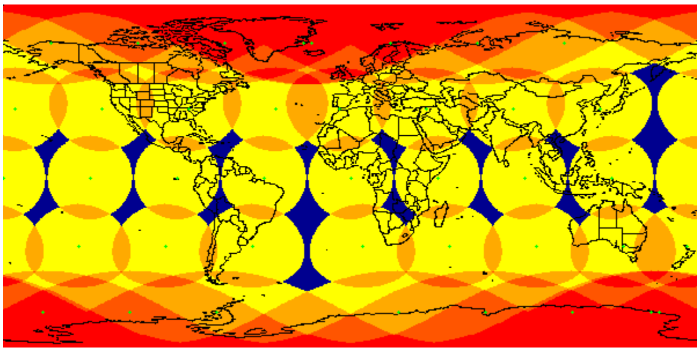

Figure 3. Mission coverage.

Implementation Plan

Budget:

Satellite cost (components from ISIS Company [2]).

Amount	Product	Cost
1	2-Unit Cubesat Structure (ISIS)	4 300 US$
1	NanoCom UHF Half-duplex transceiver (ISIS)	10 000 US$
1	NanoPower P30U Power Supply (ISIS)	4 600 US$
2	NanoPower Quad – Battery Pack (ISIS)	4 200 US$
1	2-Unit Cubesat Side Solar Panel (ISIS)	4 400 US$
1	Cubesat Magnetorquer (ISIS)	1 600 US$
1	Thermal system (estimated)	2 000 US$
1	Dipole Deployable Antenna System (ISIS)	6 300 US$
1	NanoMind A712 – OnBoard Computer (ISIS)	6 600 US$
	TOTAL PRICE	44 000 US$
	+ Estimated Assembling Cost	25%
	TOTAL ESTIMATED PRICE FOR 2U CUBESAT	***55 000 US$***

Project Cost (excluding launch)

Amount	Item	Cost
40	Double Cubesats (estimated price above)	2 200 000 US$
50	AMSS System	1 000 000 US$
50	Ground Communication Systems for Sensors (estimated)	1 000 000 US$
1	Ground Station for Lima	45 000 US$
	Labor (20 persons for 2 years)	350 000 US$
	TOTAL ESTIMATED EXPENSES	**4 595 000 US$**

Water pollution monitoring is an important issue that can be addressed using a net of automated multi-sensor systems running remotely in rural areas. Peru is a country that has one of the biggest rivers and water reserves worldwide, linked to the Amazonas rain forest and its monitoring is extremely important to preserve the rain forest and all the bio-diversity contained in it.

Water pollution is mainly due to chemical and biological contaminants, and there are several tests to monitor them. Standard biological tests depend mainly from bacteria incubation, and usually take around 18hours to be performed. Chemical tests use several techniques; nevertheless electrochemical methods have a good performance in both sensitivity and performing time. We have identified heavy metals, Arsenic, Cadmium, and Lead to be the more risky contaminants and its presence have to be monitored. The monitoring systems have to be autonomous, work in harsh environments, they shall measure the contaminants continuously and they have to be interconnected to a main station for data treatment and statistics. This integral automated multi-sensor system shall be used for government authorities, in Peru by the Ministry of the Environment, for taking decisions.

We have experience in developing automated systems based on electrochemical methods to monitor contaminants in water [4,5], and also in nanosatellites and cubesat constellations [6,3,1]. We propose the development of an integrated system composed by a net of autonomous multi-sensor systems united with a nanosatellite constellation, to ubiquitous water pollution monitoring. In a first attempt we will monitor water pollution in rivers in Peru, but because the simplicity of the autonomous multi-sensor system, and the background of the nanosatellite constellation the project can be easily scalable worldwide.

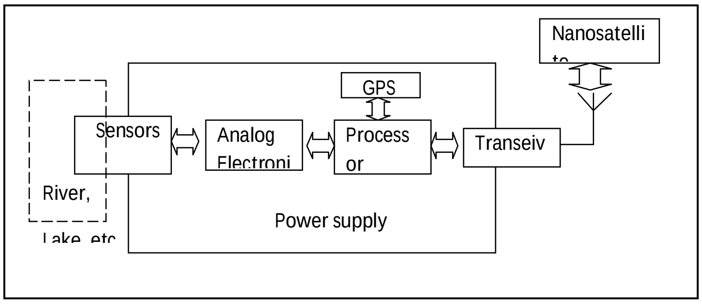

Figure 3. Autonomus multi-sensor system (AMSS) diagram.

Each autonomous (Figure 3) multi-sensor system (AMSS) is based on selective ion electrodes connected to an electronic interface based on a microprocessor and analog electronics that take the signal from the electrodes and perform the measurement. Due the system is going to be located in rural areas, a robust design is going to be made including power-supply that is going to base in solar energy. The data is saved on a memory including the AMSS position. The processor search if there is connection with any of the constellation nanosatellites, if there is connection, the data is send to the nanosatellite, then the data is retrieved to a base station in Peru, or any base station located worldwide. Thus the computed information can be acceded by final user, government authorities.

The sustainability of the project is ensured since there is the international commitment for the environmental preservation. This commitment is being implemented by intergovernment organizations in laws and regulations that have to be accomplished by the states. Therefore this integral system is proposed as a tool for governments around the world for taking decisions under technical, scientific and transparent bases.

Facilities to be used:

1. Physics Engineering, Chemistry, Computer and programming, Electronics and Communications Laboratories (National University of Engineering).

Potential Risks: assuming that we start developing the project:

1. Funds not available at the right time
2. The transceiver does not connect properly with the satellite (solution: increment power).

3. The solar power is not enough to supply transceiver consumption (solution: adjustments)

4. Acts of vandalism on the sensor stations (start again)

5. Political risk - In order to avoid that information could be used badly, the information should be distributed only to identified government authorities: Ministry of Medio Ambiente, Ministry of Energía y Minas, Autoridad Nacional de Aguas.

Table 1: Tentative schedule.

Task	First Year												Second Year												3rd Year	4th Year	5th Year
Nano-satellite modules design	■	■	■																								
AMSS design	■	■	■																								
Satellite implementation				■	■	■	■	■	■	■	■	■															
AMSS implementation				■	■	■	■	■	■	■	■	■															
Integration and Testing													■	■	■	■											
Satellites implementation (Flight model)																	■	■	■	■	■	■					
Fligth model Tests																							■	■			
Launch																									■		
Operation of constellation																									■	■	■
Disposal																											■

References

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[6] Bedon, H.; Negron, C.; Llantoy.; J; Miguel, C.; Asma, C.; , “Preliminary Internetworking Simulation of the QB50 Cubesat Constellation,” Latin-American Conference on Communications, 2010 IEEE, September 2010.