Near Earth Objects detection Network Project Overview

Primary Point of Contact (POC): Marco Agnan
POC email: marco.agnan@gmail.com
Co-authors: Jordan Vannitsen, Ernest Huang, Oussema Sleimi, Jim Lin, Teddy Chang, Jyh-Ching Juang
Organization : National Cheng Kung University, Taiwan
(X) We apply for Student Prize.
( ) Please keep our idea confidential if we are not selected as finalist/semi-finalist.

Need

Collisions between Earth and other bodies have played an important role in the biological and climatological development of the Earth. Cretaceous–Paleogene event proves that collisions may have significant impact on biological evolution, as a result of mass extinctions brought on by global climate change. The Low (but non-negligible) probability associated to ***extremely high consequence of asteroid collisions*** makes studies of this topic worthwhile (ESA and NASA show concern since few years by the establishment of dedicated NEO programs).

The ***vulnerability of our planet to sudden devastation*** is moreover the root cause of a high popular interest from the public. One symptom is the presence of killer asteroids in some science fiction movies (Deep Impact, Armageddon,…) or in the internet culture.

There is several examples of small/medium asteroid collisions in recent history:

- *6 June 2002 over the Mediterranean Sea:* energy ≈ 26 kilotons of TNT (One Nagasaki Atomic Bomb)
- *7 October 2008 in Sudan:* energy ≈ 2 kilotons of TNT (first predicted collision)
- *8 October 2009 in Indonesia:* energy released ≈ 50 kilotons of TNT (Two Nagasaki Atomic Bombs)
- *15 february 2013 in Russia:* energy release ≈ 90 kilotons of TNT
- what about the next one ? when ? where ? how powerful ?

All the asteroids above were smaller than 50m in diameter.

A Near Earth Objects is a comet or an asteroid whose orbit bring it into proximity with Earth. However, ***The smallest objects are not reliably detectable using ground-based telescopes*** because of atmospheric interference and manpower considerations (1). Even the small NEO can be harmful, since chances of dying from an Asteroid/Comet impact are superior to the chances of dying from a venomous bite or sting (2) (1 in 40,000 and 1 in 100,000).

Modern scientific methodologies associated with low financial risk of new nanosatellite technologies allow us now to develop a ***space-based network of instruments to monitor potentially threatening Near Earth Objects.***

Mission Objective

Humanitarian

While in the past CubeSats were only associated to educational goals, they are now also associated with high scientific payback for a very low financial risk. ***The main objective of the NEON Project is to participate to the space situational awareness by NEO detection, providing early valuable informations for eventual mitigations.*** Only few existing missions are currently monitoring NEO (WISE, Hubble… none at first dedicated to NEO detection). NEON will image the more interesting part of the sky with nearly real time reactivity.

Scientific

Besides providing early informations to mitigate collisions, the NEO detection will provide a high amount of information about the solar system. Indeed, ***studying asteroids & comets is a perfect way to know more about the origins of our solar system.*** Moreover, the NEON project will participate to the global effort to better understand our direct space environment.

Educational

Each CubeSat will be developed by a partner institution (see Concept of Operations) and can be a student project. Worldwide institutions can participate for a low needed budget (see Implementation Plan) as long as the scientific payload is included and the specifications respected. ***The NEON Project is the perfect way to educate aerospace engineering students through an international project with a high scientific payback.***

International collaboration

The space-related challenges are now carried out by international partnership (ISS, Cassini-Huygens,…). The low financial risk (see Implementation Plan) allow developing countries (even those without space program) to participate to the NEON project. ***A devastating impact with Earth of a NEO would affect the whole World. As all the countries are concerned, an international collaboration is thus a very logic solution.***

Concept of Operations

Space Segment

The NEON project will ***use the CubeSat standard***, allowing to buy ***Components Off-The-Shelf.*** Typical NEON Nanosatellite shall be 3U (10x10x30cm, 4kg) CubeSat caring a visible imager to detect NEO.

Launch

Space segment units are delivered to the principal investigator institution in charge for the launch. The NEON Project aim is to put ***every CubeSats of the network on an Inclined Low Earth Orbit (inclination between -5° and 50° to detect incoming objects, altitude = 900-1000 km).*** The deployment device will put every “watchers” on the reference orbits, launched at the same time. The total mass to launch should be < 1 tons.

Operations

Communication with Ground Station will only be through ***beacon function,*** to allow signal detection even with small ground segments (radio amateur community). Onboard data processing is therefore mandatory (using FPGA or LEON CPU, few minutes needed), to transmit only the date, latitude & longitude of observed object (T,L,l). When a NEO is detected, the beacon signal is sent then detected by ground segment. Competent authorities (NASA, ESA…) are then notified and perform confirmation with ground observation. ***Delay between picture and notification should be less than 30 minutes.***

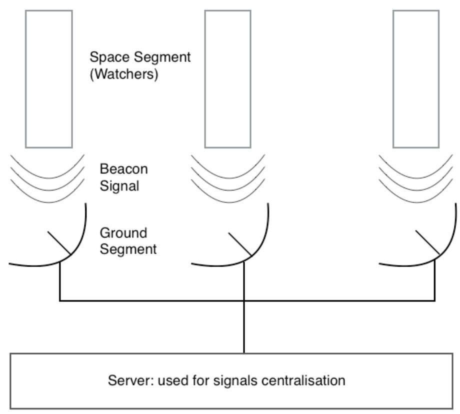

figure 1 - concept of operations illustration

Each watcher take picture of the sky and compare it to referenced sky objects (by data processing). If something observed is not in the onboard data, then the beacon alert is sent.

Ground Segment

Every “watcher” beacon signal can be freely observed by universities or radio amateurs, but the ground segment tracking and data processing shall be as automated as possible with the participation of every partner institutions (data centralization on the internet for outreach purpose).

Decommissioning

To avoid unwanted detection of artificial objects in Low Earth Orbit and to allow a good lifespan, the NEON network will be at 900-1000km of altitude. This is the highest altitude feasible due to the 25 years decommissioning limit, using passive atmospheric drag to de orbit. New technologies are already available (3).

Key Performance Parameters

The NEON Project require high performance on specific parameters listed below:

1. ***Payload performance:*** the instrument need a sensibility to high magnitudes in order to detect small asteroids (50-100m, to be confirmed) at a reasonable distance with a small integration time (few ms). The Payload also need a field of view adapted (approximately 5°, Field of view ≈ 25 deg^2, to be confirmed) and a high resolution.
2. ***Simultaneously observed part of the sky:*** this parameter depend on the Field Of View of the payload and the amount of "watchers" (minimum = 90).
3. ***Orbit inclination:*** Combined with the simultaneously observed part of the sky, the orbit inclination will define the total observed part of the sky. Observe between -30° and +30° around ecliptic plan ensure the scientific payback (between -5° and 50° around celestial equator).

Space Segment Description

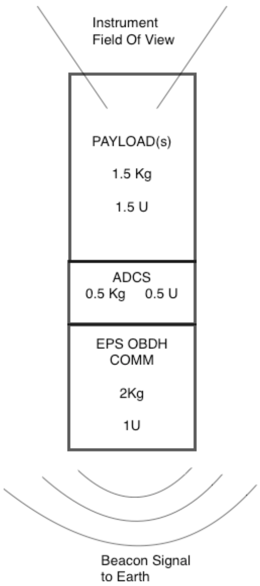

figure 2 - a "watcher" 3U CubeSat overview

This is the technical description of one "watcher" (3U CubeSat, 10x10x30cm, 4kg) of the network:

- *Payload:* A specification of needs shall be done to define the field of view, the resolution, the mass, the power and imaging frequency. The allocated volume and mass (margin included) seems sufficient according to preliminary studies.

- *Attitude Determination & Control System:* The only attitude requirement of the satellite is that it must conserve the beacon signal pointed at Earth and the instrument field of view pointed at interplanetary medium. Existing Off-The-Shelf solutions (Magnetorquers, reaction wheels…) with sufficient capability are already available.

- *Electrical Power Supply:* Each 3U sides of the CubeSat shall be covered with solar panels, to ensure the power supply (approximately 7W). No deployment device seems to be needed. Several batteries will store power for use during eclipses.

- *Communication:* No data transmission will be possible in nominal mode, so informations about ***detected NEO's will be only a date, latitude & longitude in morse code through beacon function*** to ground station.

- *OnBoard Data Handling:* Each "watcher" will ***process the payload data to determine if NEO is detected in the field of view***. Two technical solutions are under consideration : space-based FPGA or LEON CPU.

- *Thermal:* The thermal control is passive. Subsystems location and attitude control will be done accordingly.

- *Software:* The System Logic will be the responsibility of the participating university. The Data Processing Unit (aka DPU) will be developed by the PI institution. The Housekeeping data shall be stored into FLASH memory and will be transmitted if commanded by ground segment.

- *Structure:* Each "watchers" structure shall be a 3 Unit CubeSat with certified technology readiness level.

Orbit/Constellation Description

Unlike numerous startups projects aiming to image Earth in LEO, the NEON project goal is to image space in order to detect NEO. ***The network will be uniformly distributed along 12 orbits (pearl string configurations) with different inclinations*** as described on figure 3:

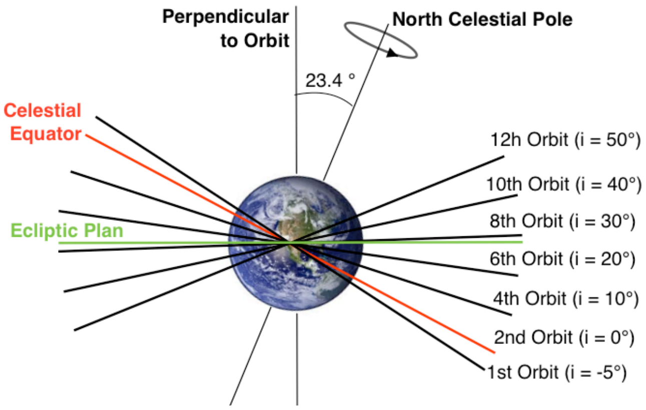

figure 3 - orbits distribution along the Celestial Equator: -5°, 0°, 5°, 10°, 15°, 20°, 25°, 30°, 35°, 40°, 45°, 50°

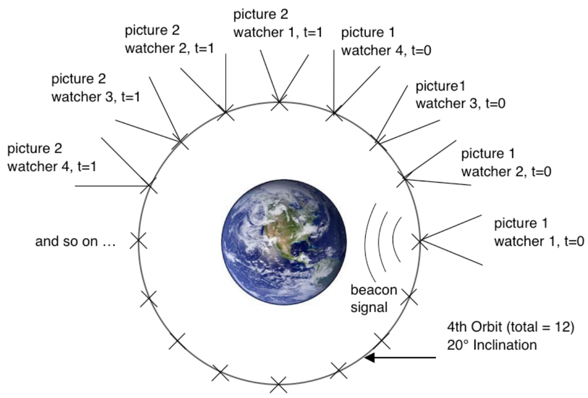

figure 4 - Sky repartition example between 4 different watchers on the 4th orbit (i = 20°)

Each "watcher" is responsible for the monitoring of 10 parts of the sky (preliminary value), and compare detected objects and references to detect if something new appears. Data processing duration will also determine the number of parts of the sky monitored by each satellite. At least 7 "watchers" shall fill each orbit, and figure 4 describe how each pearl string configuration will work (example with only 4 watchers). ***The minimal number of "watchers" is 90 according to preliminary studies,*** with a field of view of approximately 25 deg^2. A superior number is therefore acceptable for redundancy reasons.

Implementation Plan

Leadership & Costs:

One defined institution shall be the principal investigator of the project. This role include:

- *Define the specification of needs of "watchers" and transmit it to every participating universities.*
- *Define the specification of needs of "ground stations" and transmit it to every partner institutions.*
- *Design, test, integrate and transport the payloads and DPU to every participating universities.*
- *Design, test, integrate and transport the network deployment device.*
- *Program the launch.*
- *Coordinate the design, test and integration of every "watchers".*
- *Acceptance test of all the watchers integrated in the deployment system.*

The preliminary estimated budget for the PI institution is < 20 M$ (labor excluded).

Partnership & Costs:

Each partner institutions around the world will be in charge of the design, test and integration of one "watcher" (Payload excluded) as a student project (Flight Model is estimated < 100,000 US$). ***The low needed budget can even allow countries without satellite activities to participate, or involve international organizations such as UNOOSA (United Nations Office for Outer Space Affairs) into this project concerning the safety of every countries on Earth.***

Methodology:

The NEON Project stands as a methodology prototype as well. Due to the need to make several teams of students work remotely together, the AGILE principles (4)(coming from the software industry) will inspire the project management. ***The tools to design a CubeSat, the production cycles and the dialogue among the teams will be adapted*** as a combination of the space project methods (V cycle, reviews..), the AGILE methods (early functional deliveries, short release cycles, metaphors, individual-centered and collaborative tools) and the concurrent design tools (Concurrent Design Facility at the European Space Agency and at CNES, the French agency).

Schedule:

Conceptual Design (feasibility studies, specification of needs)	Dec. 2014
Announcement of opportunity to find partners	Jan. 2015
Frozen list of partners	Jun. 2015
Engineering Models deadline (Design, Test, Integration)	Jun. 2016
Flight Models deadline (Design, Test, Integration)	Jun. 2017
Network Launch	Dec. 2018
Operation	2019 - 2021
Decommissioning	Dec. 2021

The AGILE Management methodology allow a high flexibility on the schedule described above. Needed facilities and infrastructures are the responsibility of the partner institutions and international collaboration allows those who don't have needed infrastructure to find some with other partners help.

Top 5 Risks:

1. **Funding:** CubeSat projects (especially educational) are considered as high technical risk projects, turning the project unattractive for funding. **Considered Mitigation:** The high scientific, engineering and educational impact of the project compensate the technical risk. Moreover, the financial exposure is reduced for the partners (i.e participating countries, <100,000$ for one Flight Model). Moreover, international organizations can fund the project.

2. **Global Coordination:** the expected high number of partners can turn the project into a complex organization. **Considered Mitigation:** the AGILE Methodology is particularly suitable for this kind of projects. Moreover, the principal investigator institution shall constitute a permanent team for engineering support and coordination.

3. ***"Watchers" full autonomy:*** The space segment autonomy may make it more vulnerable to software or hardware malfunction. ***Considered Mitigation:*** No "watchers" control are considered in nominal operations. Degraded modes will however be consolidated and to send commands to the "watchers" will be possible.

4. ***Sufficient number of partners to cover a large part of the sky:*** if the number of partners is under a value (90 watchers needed, preliminary result), the project will lose scientific interest. ***Considered Mitigation:*** Analogously to the funding risk, the low financial risk may attract universities from the entire world, allowing some countries to launch their very first own satellite, associated with low technical risk, or allowing other countries to maintain valuable know how in space related high technologies.

5. ***Response Time:*** The delay between observation and notifying must be short enough to ensure humanitarian interest. ***Considered Mitigation:*** every significant parameters must be controlled: Onboard processing period, Beacon transmission delay, Ground segment reception delay and finally competent authorities notification: Delay should be short enough to allow the application of NEO impact mitigation methods.

References

(1) Asteroid Detection and Monitoring Using A Satellite-borne Visible Scanner A.Shaffer J. McHugh 1993
(2) Reprinted from Clark Chapman and David Morrison, Nature, Vol. 367, page 39 (1994).
(3) "The Terminator Tether™: A Low-Mass System for End-of-Life Deorbit of LEO Spacecraft," R.L. Forward, R.P. Hoyt, C. Uphoff, *Tether Technical Interchange Meeting*, Huntsville, AL Sept 10 1997.
(4) "The Paving Stones: initial feed-back on an attempt to apply the AGILE principles for the development of a CubeSat space mission to Mars", B. Segret, SPIE 2014