Space Science and Technology Institute

Title: Global orbital monitoring of nuclear facilities decommissioning - NUCLFADESAT

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Need

Thousands of ageing nuclear facilities[5],[6],[7],[8],[21] worldwide (still exploiting uranium mines[19],[20], widely using transport means[24],[25],[26], inspiring various contamination[12],[13], creating nuclear waste[22] and underground storage[23],[31] installations, reprocessing problems[16],[21] with water[15] and atmospheric[14],[16],[17],[18] pollution, provoking incidents[11],[12],[13],[17],[18] and etc.) demands attention for their safe decommissioning[1],[9],[10],[25] today as well as many decades later for newly built facilities[5]. There is a strong need for world society to optimize, monitor[30], protect[2],[3],[4], control and secure global permanent decommissioning which still remains far from completion[11],[29]. An adequate multipurpose[27] and systemic micro-, nano-, pico-, even femto-satellite[28],[29],[30] constellation's publicly open tracking[24] and monitoring[28],[29],[30] with regular and constant for that aims launches into LEO (or GEO depending on future signal transmission technologies) lies among possible, reliable[33] and transparent solutions (for instance, like Helioviewer[32]). The proposed sustainable NUCLFADESAT constellation mission will contribute safer[1] and healthier environment to Global community in near and far future and secure it out of nuclear debris in land, water, air and underground created by many decades of human activity in the Earth.

Notice: the presented idea for the 1st round of contest is more intended to present importance of mission itself rather than its detail technical description.

Mission Objectives

The primary goal of NUCLFADESAT constellation is to start (at least) Environmental Earth's nuclear-free safety monitoring for today and future generations of humankind and wildlife on broad timescales based on remote high and ultra-high precision scanning and tracking from space. The 5 objectives are as following:

1) **Support of Nuclear fuel cycle monitoring from Space** (more than *100* uranium mines in different stages in more than 25 countries; *440* nuclear power reactors operating in 30 countries; more than *60* power reactors are currently being constructed in 15 countries notably China, South Korea and Russia; thousands of nuclear based facilities worldwide). Primary goal is remote imaging (for instance Satellite Imaging Corporation) based on geographical coordinate data of facilities, realized and tested on smaller satellites.

2) **Support of Nuclear pollution monitoring from Space** (incl. emergency cases) (Krypton-85 leakage from about 25 nuclear reprocessing sites; Concentrations of krypton-85 due to high reprocessing activities are much higher on the Nothern Hemisphere than on Southern where nuclear reprocessing is absent). The goal is safe and clean atmosphere and water.

3) **Support of Nuclear decommissioning monitoring from Space** (80 commercial power reactors,

45 experimental or prototype reactors, over 250 research reactors and a number of fuel cycle facilities have been retired from operation; Early nuclear plants were designed for a life of about 30 years and newer plants - for a 40 to 60 year operating life). The goal is transparent (out of smuggling) and safe dismantling.

4) **Support of Nuclear-transportation monitoring from Space** (about 20 million consignments of all sizes containing radioactive materials are routinely transported worldwide annually on public roads, railways and ships. Since 1971 there have been more than 20000 shipments of used fuel and high-level wastes (*over* 80 000 tonnes) over many million kilometres). The goal is to enable safe (out of smuggling) transportation of nuclear materials.

5) **Support of Nuclear waste storage monitoring from Space** The goal is permanently (thousands of years) monitor areas of deep repository from possible future leakages of containments (noble gases, contaminated by radionuclide underground water).

Concept of Operations

The Moore's law will bring more compact and reliable satellites (possibly the cloud of femtosatellites) which would serve for NUCLFADESAT constellation mission. After some consequent tests of all NUCLFADESAT constellation's components in all it stages there is an economical sense to launch normal satellite into Geostationary orbit for monitoring (see objectives hereinabove) area covering America, Europe, Asia and Australia continents. Launching the group of satellites per few stages is of great necessity for monitoring nuclear industry in a whole, for nuclear transportation tracking, for obtaining "lost" radioactive materials, for decommissioning control, for air and water pollution monitoring. Due to many decades lasting nuclear decommissioning in the world, the concept of NUCLFADESAT constellation mission is economically and technically viable, improves the necessity of periodic launches of constellation at the same time allowing further and permanent equipment modernization due to fast upcoming technical progress. Possible scenario could consist of few stages.

First stage. Launch of nano-satellite for global testing of the trajectory, making imagery and sending information to dedicated net of ground stations (according to geographical coordinate data of all nuclear facilities in the world) ;

Second stage. Launch of two nano-satellites - first is acting in the same way as in the first stage, second nano-satellite is for thermal (IR) measurement of casks for low radiation waste and all water reservoirs used in nuclear industry; First satellite is sending job processing and targeting commands for second nano-satellite_

Third stage. Launch of at least two nano-satellites (depending on speed and coverage area) - one is acting in the same way as in the first stage, next or more of them are for testing global tracing of nuclear material transportation between all nuclear industry objects; First satellite is sending job processing and targeting commands for remaining nano-satellites;

Fourth stage. Launch of at least four nano-satellites - one is acting in the same way as in the first stage, second nano-satellite is for monitoring dangerous and cancerous noble gases

(krypton-85), third nano-satellite is thermal (IR) measurement of casks for low radiation waste and all water reservoirs used in nuclear industry; next or more of them are for testing global tracing of nuclear material transportation between all nuclear industry objects; First satellite is sending job processing and targeting commands for remaining nano-satellites;

Fifth stage. According to results achieved it could be a sense to launch satellite in Geo stationary orbit working for 25 years (due to Space debris requirements) with further replacements (at least 3 times per century); At the same time the NUCLFADESAT constellation might work being periodically launched and might have the communication with base-satellite situated in GEO;

Test (intermediary) stages. Short-lasting launches of future generations of NUCLFADESAT based on nano-, pico-, femto-satellites (depending on future miniaturization of technologies);

Importance for business: for instance, elimination of radioactively contaminated scrap from world market will lower economic loses in case of misusing contamined material and save a health of industry workers and industry product consumers; permanent orders for production and modernization of NUCLFADESAT constellation modules;

Communication - TBD (after 1st round of Mission Idea Contest). Notice: inside constellation via Bluetooth, outside constellation via S-band;;

Ground segment: some already existed in nuclear industry monitoring and communication equipment installed by IAEA[28],[29] could be incorporated in todays and future NUCLFADESAT constellation activities;

Components – TBD (after 1st round of Mission Idea Contest).

Key Performance Parameters

The NUCLFADESAT constellation might seek the following performance parameters:

- Remote measurement of low energy Gamma rays – sensitivity of approx. ground detectors;
- Large amount of data in constellation modules – up to ~1TB;
- High Image quality for broad range of objects (vehicles, scrap and etc.) - ~ 0,5m resolution;
- High communication rate between constellation and ground stations – 2,4 GHz (or higher).

An information of great value for selecting performance parameters is presented in LITE, ISR-2 and LANDSAT. The great variety of scientific equipment for possible adoption by technological miniaturization and installation in NUCLFADESAT constellation modules could be obtained in the book "Earth Science Satellite Remote Sensing. Science and Instruments". Exact figures of performance parameters and measuring equipment of NUCLFADESAT mission TBD after 1st round of Mission Idea Contest.

Space Segment Description

Outside image – TBD (after 1st round of Mission Idea Contest);

Inside component list – TBD (after 1st round of Mission Idea Contest);

Detailed project performance parameters – TBD (after 1st round of Mission Idea Contest);

Notice: de-orbiting from LEO could be realized by Solar blades or Solar sails.

Orbit/Constellation Description

NUCLFADESAT constellation mission will be the first network of satellites devoted for safer and cleaner Earth environment due to its dependence on nuclear industry debris. The constellation might consist of the following nano-satellites:

- nano-satellite covering geographical coordinates of all nuclear facilities in the world;
- thermal (IR) nano-satellite measuring areas of casks for low radiation waste and all water reservoirs used in and around nuclear industry;
- nano-satellite for global tracing of nuclear material transportation between all nuclear industry objects;
- nano-satellite for monitoring dangerous and cancerous noble gases (krypton-85);
- satellite (later if necessary) in Geo stationary orbit able to fullfil mission objectives and at the same time able to work synchronous with periodically launch future generations of NUCLFADESAT constellations based on nano-, pico-, femto-satellites.

Project (ambition) product with public access: **EarthNuclearViewer** (multispectral gamma, beta, X-ray, thermal scanning of atmosphere layers as well ground and water surface coverage). Viewer similar to Earth's topographical map, weather satellite imagery, composite image, colour composite or the global distribution of water vapour.

Orbits: all orbits LEO (500-800km)

Implementation Plan

Our organization in the Mission could act only as Undertaker. As domestic partners could be invited "Konstravimo biuras" (CAD drawings), "Arginta" (unitary metal construction work), "Ekspla" (scientific laser company), Kaunas University of Technology (piezomechanics), Institute of Physics (LIDAR), "ArcusNovus" (satellite communication);

Project implementation phases – TBD (after 1st round of Mission Idea Contest);

Project costs – TBC (after 1st round of Mission Idea Contest);

Project development schedule, infrastructure – TBD (after 1st round of Mission Idea Contest);

Project sustainability is guaranteed against the long lasting nuclear decommissioning process.

Project organization – TBD (after 1st round of Mission Idea Contest). Personally being as EU FP7 Space National Contact Point as well as partner of project COSMOS, I have ability participate by organizing consortium via all NCP's from Europe countries;

Companies WeatherNews, Ltd., Surrey Satellite Technology Ltd. must be incorporated and lead the Project;

Project risks: 1) absence of global political will for total orbital nuclear decommissioning monitoring; 2) lack of industry support (for instance steel and foundry); 3) absence of specific devices for remote orbital scanning of low level γ ray from contaminated scrap; 4) lack of specific devices for remote scanning of krypton-85 levels in atmosphere due to nebulosity; 5) absence of technology level or technological possibilities for installing very specific devices into the shape of nano-, pico-satellites.

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