THE SAIL SAILS ART SPACE MISSION

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The Sail Sails ("Avelaleva" in Portuguese) is an art space mission. As such is the first one of this type in Latin America. It is an idea from José Wagner Garcia who is an experienced artist using space with his experiment operated by the brazilian astronaut, Marcos Pontes, in the International Space Station - ISS in his Centennial mission in 2006. The mission combines art and advanced technology as it will use a very small satellite, of the type "cubesat", with 10x20x30 cm. dimensions.

The art is accomplished by the sunlight reflected in the satellite so that people on Earth can see it at naked eye. However, for that, a lot of advanced technology has to be incorporated in the satellite. The reflectance is achieved with the use of a "mirror" composed of a very thin material, that unfolds with the satellite already in space. The technology atractiveness of this design is that it can also be used as a propulsion sail to cubesats, making it achieve orbits that woud not be possible to achieve without a propulsion system in the cubesat. The solar wind "blows" the sail as the wind does with a boat in the sea. This is a very new concept to increase capacity of the cubesats. The mission thus has a double purpose. To perform art in space and also to advance the cubesat technology for further applications. The project in the technology aspect has an international cooperation of cubesats companies interested in solar sail propulsion with brazilian engineers with experience both in larger satellites as well as in specifying, design, develop, launch and operate successfull space missions using cubesats. The mission analysis, a key point for both objectives of the mission (angular control of the cubesat, orbit analysis, sun-satellite line of view, mission lifetime, ground operation etc) will also be performed by the space engineering side of the project. Brazil, through its National Institute for Space Research - INPE, has the required insfrastructure for testing the cubesat in an unique environment, including a thermal vacuum chamber that can test the opening of the sail, which emulates the space envoronment in vacuum and varying the temperature as is the case from minus 80 degrees Celsius to over 60 degrees Celsius. This testing capability, emulating the space environment while the sail unfolds, greatly increase the reliability of the mission performance. The launch will be from the International Space Station (ISS) at a 400 km. height. ISS is one of the main cubesat launchers at the present days and probably will increase this participation as, at this height, it doesn´t originate debris in space after the satellite lifetime, since it reentries the Earth atmosphere after a short period.

"Sail sails" will be operated by existent ground stations for cubesats in Santa Maria,
RS and São José dos Campos, SP, owned by INPE. However, as it will operate in VHS/UHF amateur radio frequency, any amateur radio station in the world will be able to get its signal and check its health. But the ultimate Earth stations for the mission will be the people eyes and delight.

1. Introduction

In order to understand the origin and development of Sky Art and Space Art, we must launch a brief introduction to the artistic movements of the early 20th century. At the turn of the 19th century to the 20th century, with the apogee of historical vanguards, one of the main roles of the arts was to deconstruct the classical concept of representation (the figure and landscape), and also allowing other technical means of the time to take the place of the tradicional supports. The poetic and anarchic irreverence of the Dadaist manifesto, the beginning of the cubism of geometric revolution, and the minimalist abstraction of Suprematism, made these movements a water splitter with the past and prepared our senses for the never-unimaginable future.

With the onset of computer machines and the cybernetic revolution after the second half of the twentieth century, inspired by the concepts of revolutionary scientist Robert Winner, pioneering artists take ownership of the beginning of computational technologies to make art. Gyorgy Kepes, artist, teacher, author, theorist and partner of the great Hungarian artist Moholy-Nagy, founded the new Chicago Bauhaus in the 1940s. Between the years of 1946 and 1947 Gyorgy Kepes taught at MIT and in 1967 was invited to found the CAVS - Center for Advanced Visual Studies. In this center there was the greatest concentration of high-tech artists from all over the world who experienced the technological state of the American Institute. Born in this scenario German artist and thinker Otto Piene, was the first to introduce the concept of Sky Art. He made large inflatable sculptures that cut through the skies and used the "blue like a big écran”. New technological artists began later to point out the expansion of the new concept of “celestial deep blue” at the orbital Earth dimensions.

At the beginning of the 80's, artists began to adhere to the use of space technologies in their artistic work: stratospheric balloons and rocket launches, remote orbital sensing images, experiments on the Space Suttle (Get Away Special). In the early 1980s, a select group of artists such as Joe Davis, Tom Van Sant, Pierre Comte and José Wagner Garcia (Ref. 1) began the poetic journey in proposing artificial satellites for artistic purposes. The difficulties and costs to place an artefact in space of the time, prevented that we could watch sculptures orbiting the skies of the whole planet. With the advent of the cubesats this possibilities seem to have come to a more realistic and feasible scenario.

2. The Mission

The mission objective is to reflect the sun light through a reflectance surface deployed from a 3U cubesat, such that people on Earth can see it at naked eye. This artistic objective is supported by the technological interest of agregating the cubesats with propulsion capability that may take it to other orbits than LEO (Ref. 2). This propulsion principle uses the solar wind to blow a sail in space as the wind does with a boat in the sea. With this method there is no need for fuel and tanks, since the propellant is available at large in space. There are technological difficulties to fold and hold the sail into a 1U part of a 3U cubesat where then 2U is used for the cubesat platform. The sail then unfolds (Ref. 3) acting as a propulsion component of the cubesat. This unfolding is critical and has to be performed simultaneous and coordinately into an estimated area (in this specific mission) of 16 to 25 m^2. The launching of the cubesat is expected to be from the ISS due to future costs restrictions at a 400 km height. This low altitude is benefical for the reflectance and then the artistic objectives of the mission but not for the propulsion of the cubesat with the solar wind. In fact it is the opposite since the large area of dragging at this altitude will shortened the reentry period of the cubesat. However this is tolerable since the main technological objective of the mission is to serve as a proof of concept for such deployment by a brazilian cubesat project that can be used in the future in other orbits. The first studies for the mission will have to find the optimal attitude in order to maximize the solar reflectance and minimize dragging in the opposite direction of the solar wind during full orbit.

Two INPE cubesat stations in Brazil will operate the mission and the platform health data. TMTC will use radio amateur UHF/VHF frequencies so any amateur radio station can track the platform data.

3. The State of the Art

IKAROS

The first solar sail for interplanetary propulsion was launched in May, 2010 by the Japan Aerospace Exploration Agency (JAXA) named IKAROS (Interplanetary Kite-craft Accelerated by Radiation of the Sun) and it was successful in solar sail flight (Figure 1), with nominal opening of the sail, which is a critical step and reached a speed of 100 m/s after six month of the sail deployment (Ref. 4), with a 200 m^2 (14x14 m) polyimide experimental solar sail 0.0075 mm thick and a mass of 10 g/m^2. IKAROS was launched toward Venus and traveled in this direction for 6 months and then began a three years journey to the far side of the Sun.

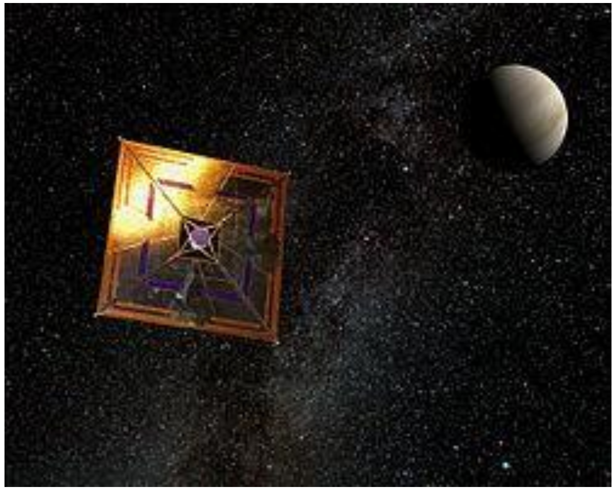

Figure 1 - Typical IKAROS square sail configuration
(https://en.wikipedia.org/wiki/Solar_sail#IKAROS_2010)

NanoSail-D

Before IKAROS, NASA through Marshall Space Flight Center and Ames Research Center launched a solar sail mission called NanoSail-D (Figure 2) to test sail deployment technologies as a simple and passive means of deorbiting dead satellites and space debris. The purpose then was not for solar propulsion although the sail design and opening mechanisms are similar. NanoSail-D was lost in a Falcon-1 launch fail on August 2008. A second and successful launch was performed on November 2010 with the deployment of the sail afterwards in LEO with NanoSail-D2 stowed in a 4.5kg. satellite (FASTSAT) and a 100 m^2 light catching square sail. It flew for 240 days collecting data from the sail as a deorbit device.

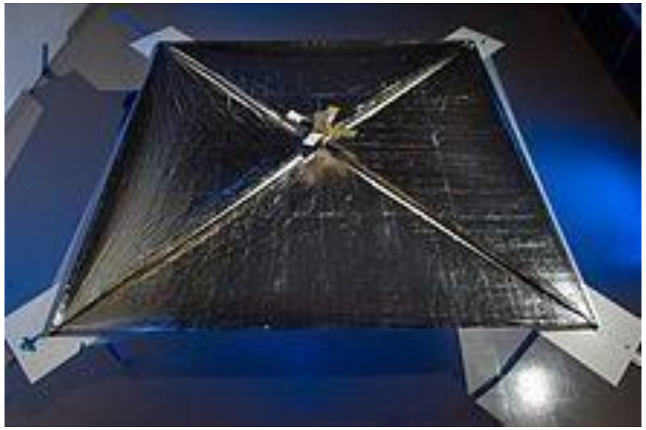

Figure 2 - NanosatSail-D experimental solar sail
(https://en.wikipedia.org/wiki/Solar_sail#NanoSail-D_2010)

LightSail

In June 2005, the Planetary Society with the Cosmos Studios Company and the Russian Academy of Science launched a prototype sail called Cosmos 1 from a submarine with a Volna rocket that failed to deliver it at the proper orbit. The purpose of the mission was to deploy a solar sail to gradually raise the satellite orbit for a mission duration of one month. On a follow on mission the Planetary Society launched LightSail-1 on May 2015 with a 32 m^2 sail made of mylar. It hasn´t deployed fully but just partially, still the mission performance was sufficient to encourage the development of LightSail-2 (Ref. 5), to be launched at the beginning of 2019 in a 3U cubesat (Figure 3) and that will serve as a test bed to NASA NEA (Near Earth Asteroid) mission.

NEA Scout

The Near Earth Asteroid NASA mission (NEA Scout) is a joint mission by NASA MSFC and JPL with a 6U cubesat deploying a 83 m^2 aluminized polyimide solar sail aiming at encoutering near Earth asteroids. NASA has selected NEA Scout to launch as a secondary payload on the EM-1 in the first flight of the SLS heavy lift launch vehicle (Ref. 6).

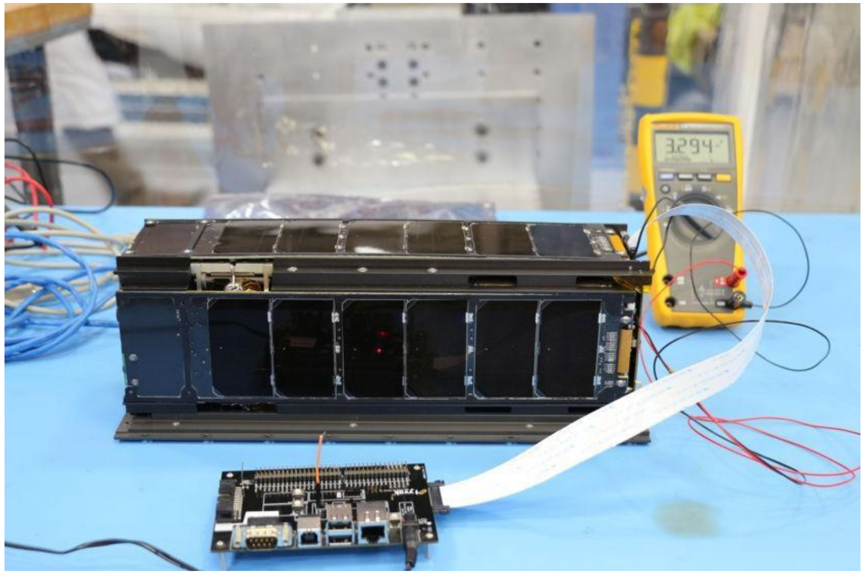

Figure 3 - Light Sail 2 3U cubesat power monitoring
(http://www.planetary.org/blogs/jason-davis/lightsail-2-launch-nov30.html)

Those were solar sail mission solely with scientific and technological purposes. There are others under developments. Lately, the solar sails are also being seen as a mean to provide art in space that with the existence now of cubesats may turn these artistic objectives economically feasible and incorporating new developments for space science and technology as well. Three examples are shown.

Mayak

Mayak (light house in Russian) was launched in July 2018 for the deployment of a reflective sail to be among the brightest objects in the night sky. It was launched in a 3U cubesat with 73 other cubesats by a Soyuz 2-1A launcher. The reflective sail constitute of four triangular reflectors each one with a 3.9 m^2 area with a reflective coefficient of 95% (Figure 4). The Mayak project claimed the satellite could reach an optical magnitude of -10, surpassing the brightness of the ISS and Iridium satellite flares (Ref. 6). Mayak has not carried any telemetry equipment and planned to be identified by its brighness and faster orbit decay in coparison with the other cubesats launched simultaneously. The reflective light was not seen from the ground consistently with different reports stating different and confusing results.

The most accepted result for the mission at the present time is that Mayak failed to deploy its reflectance surface. This conclusion is based on the time the other cubesats decayed when compared with Mayak that are relatively closed, despite the larger dragging area if the sail had been deployed (Ref. 7).

Figure 4 - Initial brightness prediction by the Mayak team (https://spaceflight101.com/soyuz-kanopus-v-ik/mayak-lighthouse-in-the-sky-fails-todeploy-solar-reflector/)

Orbital Reflector

Orbital reflector (Ref. 8) is a space art project by artist Trevor Paglen, to launch a reflective non functional satellite into LEO. It is a sculpture constructed of a lightweight material similar to Mylar. It is housed in a cubesat. At an orbit height of about 350 miles, the cubesat opens and releases the sculpture, which self-inflates like a balloon. Sunlight reflects onto the sculpture making it visible from Earth with the naked eye — like a slowly moving artificial star as bright as a star. Global Western is an aerospace firm working with the artist and the Nevada Museum of Art to design and manufacture Orbital Reflector. Spaceflight is the company to arrange for the launch on board a SpaceX Falcon 9 rocket.

Artificial moon

This is a project conducted in China with launched planned for 2020 (Ref. 9). It is an "illuminated satellite" and developed by Chengdu Aerospace Science and Technology Microelectronics System Research Institute Co., Ltd. The company claims the brightness reflected will be eight times stronger of the real Moon and may replace street lights. The satellite will be able to light an area with a diameter of 10 to 80 kilometers, while the precise illumination range can be controlled within a few dozen meters. Testing of the illumination satellite have been performed for years now. The light of the satellite is similar to a dusk-like glow.

4. Present Stage of the Project

The Sail Sails Mission project was submitted to the São Paulo State Foundation for Research Support - FAPESP within its Small Companies Innovation Program - PIPE (proc. nr. 2018/08624-7) and it is now under final analysis for the requested grant. In this Phase I the project team will study the feasibility of constructing an engineering model in Phase II. The proposal submitted to FAPESP has atracted the interest of CRON System and

Technology Ltd., a brazilian company working with cubesats development and its applications. CRON is a member of the proposal. Also, the dutch cubesat company, ISIS Innovative Solutions in Space has shown interest in participate in the project. ISIS has participate before in the DOS - DeOrbitalSail project in Europe where a sail is used to de-orbit the satellite, similar to NanoSail-D project form NASA. A member of this late project is also participating in the Sail Sails Mission, which makes it an international mission.

Once Phase I is granted, the feasibility studies will concentrated in orbit and attitude control analysis and in an optimization model to minimize drag, launching from the ISS, as a function of the attitude and maximum solar reflectance. The mission in its technological aspects does not expect to raise the orbit of the cubesats but rather serve as a technological demonstration of the sail deployment process to be used in further non LEO missions

For the development of the engineering model in Phase II these feasibilities studies will be used to reach other investor that may be interest in the project and its artistics and cultural aspects.

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