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NEE-01 PEGASUS: THE FIRST ECUADORIAN SATELLITE

Abstract

On April 2010 the Ecuadorian Civilian Space Agency - EXA started the project PEGASUS, the building of the very first Ecuadorian satellite. This project was undertaken by Ecuadorian personnel only, funded by the EXA and the local industry, launch operations and testing facility development funds are provided by the Ecuadorian Defense Ministry, while space operations are to be conducted jointly between EXA and Ecuadorian Air Force personnel.

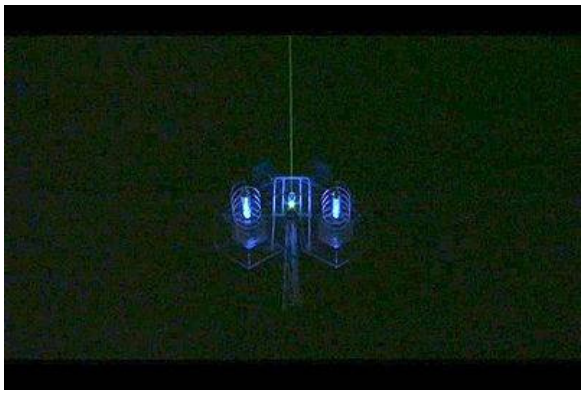
The satellite was designed as a 1U cubesat; primary objective is to serve as technology and capability demonstrator while secondary objective is to serve the elementary schools of Ecuador with a space-based learning tool platform which will inspire the next generation of domestic engineers. Launch is schedule on board a Russian launch vehicle for a 450 to 550 km orbit, 98 degrees inclination, sun synchronous, for the second half of year 2012.

Primary mission is to transmit a continuous, real time video feed from orbit, while displaying on-screen telemetry and an audio beacon carrying both human voice and digital data signal, secondary mission is to test various techniques, devices and capabilities, like the SEAM/NEMEA Space Environment Attenuation Manifold that allows the spacecraft COTS electronics to survive the harsh space conditions, the testing of a very high energy density power supply management system, coupled with the use of 2 ultrathin deployable multi panel solar arrays, an unpowered, self deploying antenna system based on the use of shape memory alloys, a high power, micro booster for low noise amplification of the satellite's transceiver, an internal thermal distribution system based on carbon nanotubes and many other innovative techniques, all product of in house development.

Introduction: EXA is the Ecuadorian Civilian Space Agency, a civilian NGO created in 2007, in charge of the administration and execution of the Ecuadorian Civilian Space Program – ECSP.

As a part of the ECSP, a ground station had to be built from scratch, as a first step toward developing national satellite building capability.

This was project HERMES, started in 2009, which rendered a ground station not only able to efficiently work satellites from HF to K band, but also became the first internet to orbit gateway, enabling the nation to acquire many capabilities such as space traffic monitoring and even the capability to relay live scientific satellite signals to any point in the world.



The MINOTAUR array during night operation

One remarkable program is the A SATELLITE IN CLASSROOM program, based on the DELTA operation mode of the HERMES-A/MINOTAUR array, which enable school kids to receive live scientific satellite signals to their classrooms and decode them in real time, taking education to a new highs in the country.

The HERMES-A Ground station has rendered best than expect results and it is also a powerful laboratory that allow us to experiment and learn for ourselves about satellite technology from firsthand experience. And also serves other international institutions abroad like the JAXA, The Michigan State University, the Graz Technical University, the Swiss EPFL and it is sometimes used for national security purposes when monitoring possible spacecraft collisions on its range of 6000kms, like the event of February 5 2010 between a Iridium 33 debris and the EPFL SwissCube.

Once the HERMES-A/MINOTAUR G/S gateway was complete, on April 2010 the EXA Directorate approved a project proposed by Cmdr. Ronnie Nader, Space Operations Director, the building of the first Ecuadorian satellite, the project was named Project PEGASUS and with that we moved on to the next phase of the ECSP.

NEE-01 is the Ecuadorian registry number meaning 'Ecuadorian Space Ship – 01' in Spanish, so the spacecraft was christened **NEE-01 PEGASUS**

Project was to be financed entirely by the EXA and the local industry, specifically QUICORNAC, who provided half the funding needed, total budget was of US$30.000 for the research and building phase, as usual in EXA projects, all personnel was working in 'pro-bono' mode, the funding was solely dedicated to hardware, tools, books and facilities.

Team was led by Cmdr. Ronnie Nader and composed by Sidney Drouet, Manuel Uriguen, Hector Carrion, Ricardo Allu and Gonzalo Naranjo

Restrictions: The following restrictions were imposed to the project:

-All the technology was to be created by the EXA.
-The building had to be made solely in the country.
-The mission design had to be made by the EXA.
-The least amount of money had to be used.
-At least one breakthrough had to be achieved by the project.
-It had to be a 'future-enabling technology' experiment.
-It had to have an educational mission.

This restrictions were imposed in order to validate the project as a real Ecuadorian satellite, as the Directorate considered the examples of other nations that achieved this historical advance on their own terms finding their own solutions and by doing so, their societies rightfully earned their place in human history as pioneers, so in the face of those bold and noble examples, we Ecuadorians wanted to honor the values that lead those valiant engineers and make true our own motto that says: "Name is earn, not given"

Objectives: The NEE-01 PEGASUS has the following objectives:

TECHNOLOGY DEMONSTRATOR: We will demonstrate the use of new technologies and approaches that can be the basis for a national satellite building industry at a very low cost.

SCIENTIFIC RESEARCH: By collecting data about basic LEO environment and space navigation that will allows us to step in to the next levels.

EDUCATION: The NEE-01 PEGASUS will be put to the service of the Ecuadorian schools and the common people.

CAPABILITY DEMONSTRATION: We need to show our countrymen our capability as a society to step into new levels of civilization.

INSPIRATION: We want to lead by example and inspire our countrymen to achieve progress by their own hand, by building instead of buying as a means for empowering our identity as a technology-creation capable society.

Primary Mission: National Satellite Technology Test

-To survive the space environment and transmit telemetry for at least a year.

-Transmit real time, live video from orbit and OSD telemetry

-To test the space environment attenuation capabilities of the SEAM/NEMEA shield.

-To test the passive release/deploy nanomorphodynamics technology of the multipanel ultrathin solar arrays

-To test the high energy generation/storage matrix technology

-To test the hyper amplification matrix ARGOS-MINOTAUR

Secondary Mission: Education from Space

-To serve as elementary education space based platform

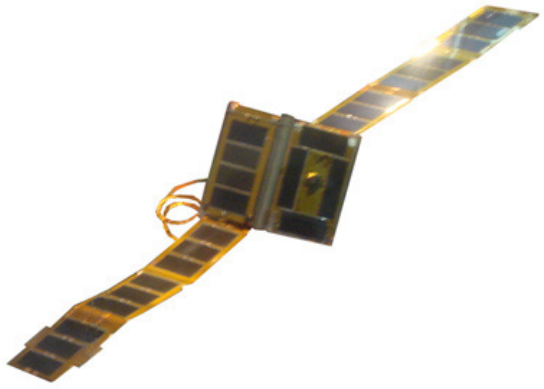
-To serve as undergraduate education space based platform

-To demonstrate the benefits of an educational satellite

-To inspire and awake the science and technology vocation in our youth.

-To transmit the Ecuadorian National Anthem from space.

Design: The NEE-01 PEGASUS was designed as a 1U cubesat form factor, however, as soon as the design was complete, a grave limitation was made evident: the lack of space for enough solar cells, so we decided to add a pair of multi panel solar arrays or 'wings' to supply this deficiency.



The NEE-01 PEGASUS in orbital flight configuration with its 2 DSA Multipanel solar wings deployed

Characteristics:
-Mass: less than 1.3Kg

-Dimensions: 10x10x75 cm (wings deployed)

-Less than 3W TX power

-ISM transmission/reception frequency

Orbital parameters will be:

-H=450 to 500km

-I = 98 degrees

-P = 95 minutes

One of the DSA solar arrays with its 99.98% pure titanium scaffolds and the SEAM/NEMEA shield

Equipment and Modules: The following is the list of modules that composes the payload of the spacecraft:

CYCLOPS: This module handles the radio transmission, the real time video and the OSD telemetry, the camera has 720 lines of resolution and IR sensitivity of 0.0001 Lux, the video has no discernible delay.

NEREID: This is the module responsible for transmitting the national anthem and the educational mission data; it has an onboard memory of 2GB

PMSS: This the spacecraft navigation system, which uses the EMF to stabilize its position in 1 axis, using 4 linear arrays of magnets and inertial-magnetic dampers

SEAM/NEMEA: Its mission is to moderate the S/C temperature, to block the Alpha, Beta, X, Gamma and GCR within the limits of the possible, without producing Bremsstrahlung radiation

DSA: It handles the unfold and release of the multipanel solar arrays, made if 99.98% pure Titanium and 1.5mm thickness, they reach 27cm once fully deployed and are activated by the heat of the sun, using nanomorphodynamic techniques and memory metals

EPS: It has 32 cells distributed in 2 arrays for a total of 28.8 amps or 107 Watts.

ADS: The Antenna Deployment System is based on memory metals and it is deployed using the heat of the sun in a gentle way to avoid any unwanted rotation.

NTDS: The thermal distribution system uses the internal heat to equalize the temperature inside the S/C, it is made of a thin layer of multiwall carbon nanotubes over a heat reflecting shield to route the heat properly and use it during the eclipse phase of the orbit.

The process of working the raw Aluminum structure donated by Prof. Twiggs.

Educational Mission: As per the project restrictions, the satellite had to have an educational mission, something that gave the most number of people down in earth something valuable in terms of new knowledge, so it was decided that the best we could do was to use the spectacular capability of real time video from space to tempt the common people's curiosity and offer it as a prize for developing investigative skills.

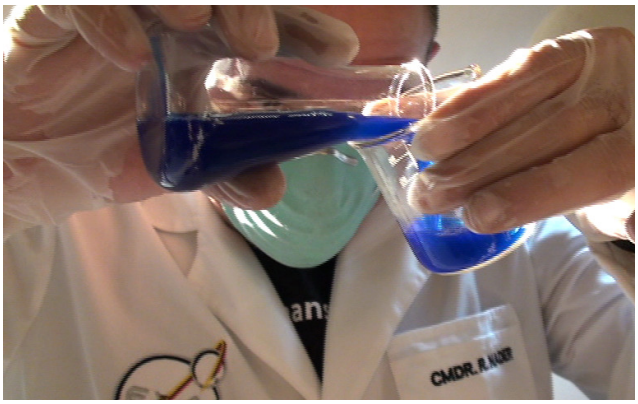
Each time the satellite is in range of our ground station it will send a pre-programmed question about technology or science directly to Facebook and Twitter via the HERMES gateway. Any person will be able to answer these questions on the EXA website and if the question is answered properly the website will connect them to the live video feed of the satellite, opening in full screen, without delay

Our intention is to tempt the people to investigate the answers to this technical and scientific questions, as we consider that the knowledge best retained is the one which is needed to achieve a goal, a practical knowledge, even if this knowledge is a pure theoretical one, it is enveloped by a need spawned by the curiosity of seeing a real time video from space. In short, we are prompting the people to auto educate themselves, teased by curiosity.

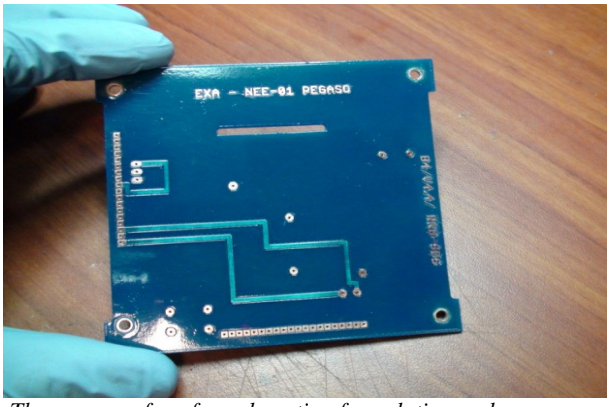
Building: The NEE-01 has been built on the EXA facilities during a year by Sidney Drouet, Manuel Uriguen, Héctor Carrión, Ricardo Allú, Gonzalo Naranjo y Ronnie Nader, it has passed more than 700 hours of tests Its hull is made of 50% Aluminum and 50% Titanium, the design, test, build and integration was made locally, down to the printed circuit level.

We imported the raw materials and worked them to final product; we also imported some components like the battery cells, the solar cells and the basic electronics components like chips, condensers, etc.

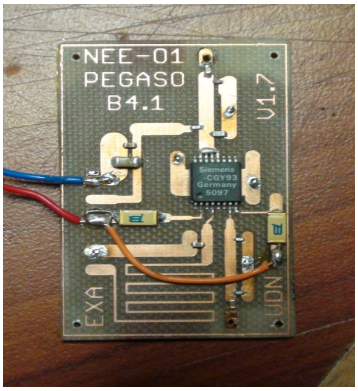
The design and building of the electronics was made locally, from milling our own PCBs out of blank FR4-06 sheets, down to formulating our own conformal coating and the manual soldering of sub millimetric electronic components.



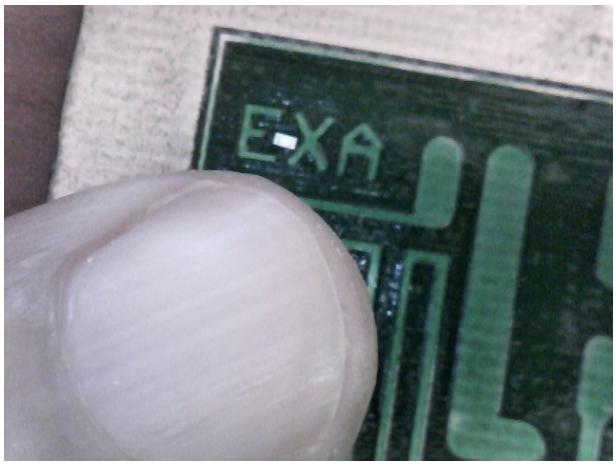
The process of conformal coating formulation and application



The process of conformal coating formulation and application and one of its results



Detail of the TX amplification test daughterboard built by EXA personnel.



Detail of a 1pF condenser integrated into the TX amplificator, soldered manually

We built our own Space Environment Simulation Chamber (SESCA) in order to test every component and the final integrated product to be compliant with the LSP/LV test specifications

The Space Environment Simulation Chamber- SESCA

SESCA has an 1/8 of cubic meter volume capacity, and it has interchangeable modules for generating up to 200C degrees luminal heat and -120C cold at the same time, also has one manipulator module, it was designed to support pressures down to 2.0E -7 mBar

Operations: All space operations will be performed using the SFCC HERMES, from there the signal could be distributed via Internet, these operations will be automatic but we will be able to take manual control at any time.

Launch: We have invited the Ecuadorian Air Force (FAE) to participate in the project on the phase of launch and operations, using a Dnepr LV for Q3/2012., FAE will also participate in the development of the launch certification testing laboratories

The launch is being coordinated by ISIS on behalf of IKSC Kosmotras, the owner of the LV.

The FAE and the EXA will operate the satellite jointly, sharing the technological and scientific benefits of the mission as a first step towards establishing a national satellite program; the main idea is that, together, civilian society and estate will sum up resources, experience and knowledge in order to achieve higher goals for the nation. Within this concept we secure a future of scientific and technological development.

Image of the NEE-01 PEGASUS during its maiden presentation on April 4, 2011

Image of the NEE-01 PEGASUS video transmissions with the OSD telemetry

Breakthroughs: To our best knowledge, the NEE-01 PEGASUS is the first pico satellite to:

Use an MLI to regulate space environment

To have the most quantity of titanium as a hull component (50%).

To dedicate a mission entirely to elementary education

To be able to interact with 2 social networks directly, at the same time.

Include a live video system for transmitting from orbit in real time.

Use nanotechnology to regulate the spacecraft temperature

Use the thinnest multi-panel solar arrays, with only 1.5 mm thickness

Include the biggest electrical power capacity installed, with 32 batteries and 28.8 Amps

The NEE-01 PEGASUS transmitting live video during a thermal vacuum testing.

Notes: On May 17, 2011 The National Congress awarded the Ecuadorian Civilian Space Agency – EXA with the VICENTE ROCAFUERTE National Medal to Scientific Merit, the highest national decoration in this field, for its outstanding and longstanding labor in designing and developing the Ecuadorian Civilian Space Program and specially the first Ecuadorian satellite.

Acknowledgments: The EXA Directorate and the team that built the NEE-01 PEGASUS want to thank our main sponsor, QUICORNAC for its faith and financial support that allowed us to complete this historical project successfully. We also want to thank Prof Robert Twiggs who candidly donated the T6061 aluminum raw structures that we later cut to build the mechanical frame of the satellite.

We also acknowledge the inspiration brought to us by reading the many versions of the Sputnik history and most specially the gallant history of the Amateur Satellite Program.

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