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HERMES Delta: The use of the DELTA operation mode of the HERMES-A/MINOTAUR Internet-to-Orbit gateway to turn a laptop in to a virtual EO ground station

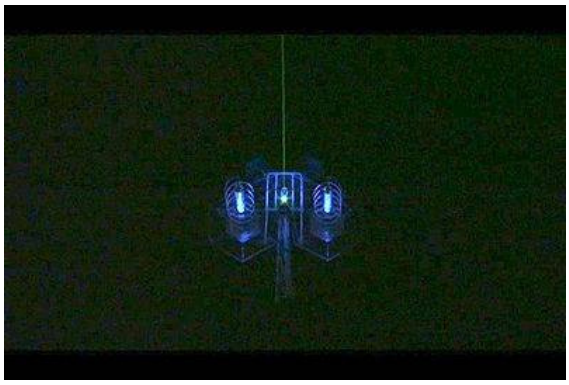
Abstract

The Delta operation mode of the HERMES-A/MINOTAUR Internet-to-Orbit gateway built and operated by the Ecuadorian Civilian Space Agency (EXA) as part of the Ecuadorian Civilian Space Program (ECSP) allows the real time routing of Earth observation satellite signals over the internet, this capability allowsto turn a laptop computer with an internet connection in a full virtual ground station capable of receiving and processing pure APT and HRPT signals from orbiting EO satellites like the NOAA constellation.
Signal transmission methods and bandwidth saving policies will be discussed and so the structure of the gateway station, also automated APT and HRPT signal-to-image processing tools accessible to the common user. The potential use for climate change online monitoring and disaster prevention and/or early warning will be discussed too. If possible, a live demonstration during the presentation could be done, depending on the satellite passes scheduling at the time of the presentation
Actual users of the HERMES Delta system includes the Ecuadorian Air Force as well as 3 schools and one University in Ecuador. A major point is the novel use of this new technology for space education from the ground level, the A SATELLITE IN CLASSROOM program will be outlined, and actual case studies will be presented.

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, 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.

HERMES-A Internet to Orbit gateway: An Internet to orbit gateway (I2O) is a machine that acts as a connector between computers or devices connected to the Internet and computer systems orbiting the earth, like satellites or even manned spacecrafts. Such connection is made when the I2O establishes a stable link between the spacecraft and a computer or a network of computers on the Internet, such link can be control signals, audio frequency, or even visible spectrum signals.

Project HERMES is the first of this kind of devices to become operative. The HERMES-A/MINOTAUR Space Flight Control Center became operative on June 6 2009 and was operated by representatives of 34 countries on the UNOOSA Symposium of Small Satellites for Sustainable Development in Graz, Austria on September 10, 2009. Project HERMES is an initiative of the Ecuadorian Civilian Space Agency and has a maximum coverage of 22,000 km, HERMES-A/MINOTAUR is not only capable of data transmission but voice also.

Compliant with the OSI model, HERMES has no Terminal Node Controller (TNC), its main job is to convert protocols from one network in the ground (internet) to another network or device in orbit by routing and translating the radio or laser waves to a protocol that can be understand for user-end TNCs, it also has full remote ground station operation capabilities, but in modes like Delta, no control interface is needed. HERMES will serve transport, session and presentation layers, application layer will remain on the user side.

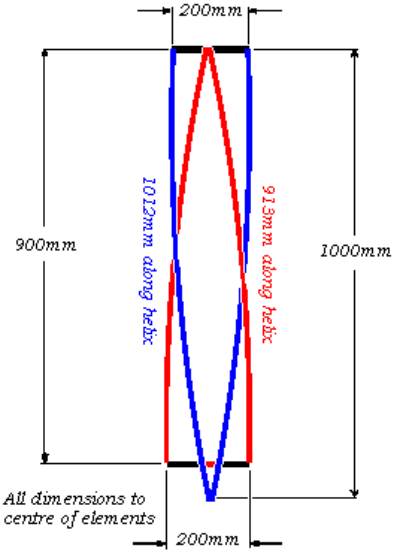
Operation Modes: The HERMES-A/MINOTAUR gateway can operate in 4 modes, digital and analogical:

- MODE A (Alpha): Reception of data from orbit and relay trough Internet
- MODE B (Beta) : Uplink/downlink full duplex connection between computers on the Internet and orbiting spacecrafts
- MODE C (Gamma): Half duplex voice conversation between any computer on the Internet and manned spacecrafts

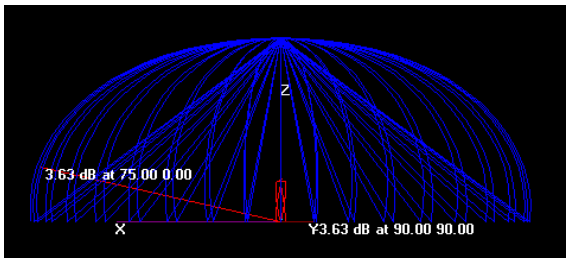
- MODE D (Delta): Automated APT/HRPT signal relay from weather satellites to any computer on the Internet

The MINOTAUR antenna array is the primary sensor, it is a 36 feet tall dual polarity, variable frequency resonator operating from 1.2 Mhz to 2.4 Ghz, having a +140dB gain, while the GORGON-B is the secondary array operating in VHF narrow band.

GORGON-B is a tall-narrow Quadrifilar Helical Antenna (TN-QHA), which serves exclusively the DELTA operation mode, it can be combined with the MINOTAUR array automatically to enable HRPT signal reception



GORGON-B schematics



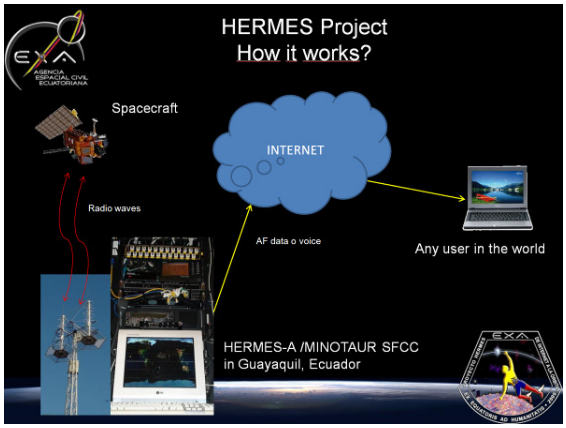
GORGON-B radiation patterns

How to turn a laptop into an EO Ground Station?: With the implementation of the DELTA mode capability, the HERMES gateway automatically tracks and links with the passing APT/HRPT satellites within range, which is about 3000km of radius centered on the coordinates for Guayaquil, Ecuador, then it sends the Audio Frequency (AF) in real time to the internet using TCP port 264.

Any computer on the Internet, that has previously been registered into the gateway's security matrix and that has an small and free program called VRS, for audio reception trough port 264 can receive this AF and it will be played in its sound card immediately

This AF signal is enough to feed any weather satellite decoding program for image processing in real time, thus turning any computer, even a laptop, into a fully qualified Earth Observation ground station.

The HERMES Delta gateway takes care of all the tracking, Doppler shifting and linking tasks, freeing the user to focus in the scientific data incoming from port 264 into his/her weather satellite decoding program

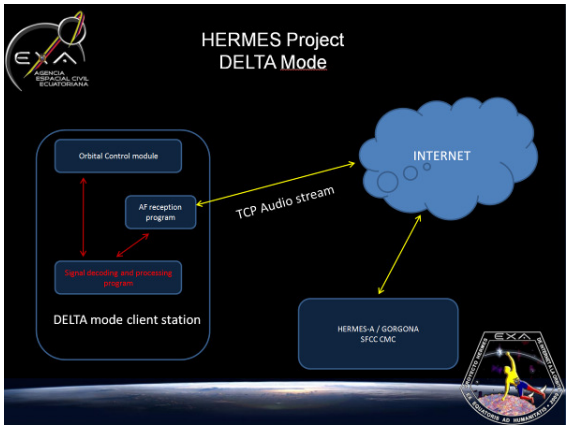


The Doppler shifting is managed internally in the decoding radio receiver by a series of linked PLL management circuits with a bandwidth of 250khz, this way the signal is stable enough to be interpreted by the software on the user end without fading or distortions, also, the gain of the array guarantees a strong signal even -1 over horizon as many users sometimes experience.

To the end user, he/she only has to start 2 programs: the VRS for receiving the signal and the weather satellite imaging/decoding program, like the WXtoImage, which is a free program in its basic

version and it is freely downloadable at the WXtoImage website which URL is detailed in the References section.

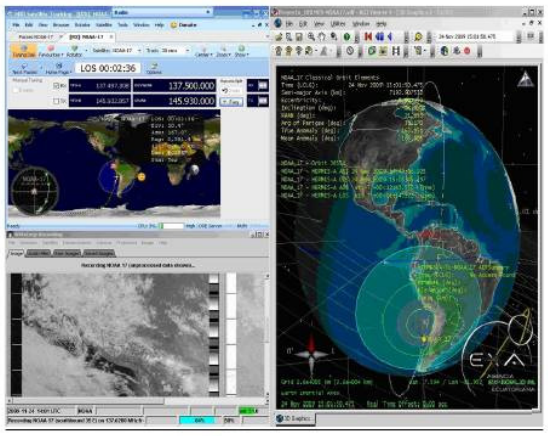
Programs like this can be left to their own devices and automatically download the TLE data from free sites like www.celestrak.com and calculate the satellite passes for themselves, once a satellite is in range, the program will just open the audio feed from the HERMES Delta serve and start processing the AF data as the satellite sends it, after the satellite pass has concluded, the program will start the imaging processing tasks, selecting up to 28 different enhancements, accordingly to the user preferences



Delta mode client side structure

Active satellites: Any satellite transmitting in APT can be routed by the HERMES Delta server, currently, the satellites most worked are the whole NOAA K/L/M/N constellation

The EXA provides some users with a very useful 3D simulation of the whole NOAA constellation, updated in real time and based on the Satellite Tool Kit – STK software as seen in the image bellow:


The HERMES Virtual Ground Station 3D STK client interface

Bandwidth management: HERMES Delta works by sending a 44Khz sampling audio stream over an internet channel, the challenge here was to make this stream lightweight enough to avoid network latency delays that will surely affect the mapping capabilities of the decoding software in the user end, as this has to be perfectly synchronized to the same time server HERMES is using (time.nist.gov), if not, maps on the images appear moved or shifted out of position and georeferenced data is not reliable.

The Bandwidth management is the task of the HERMES Audio Streaming Gateway, inside the main server, the ASG needs a high throughput upload internet connection to be able to deliver to its full capability, the HERMES/GORGON SFCC-CMC facility has such a connection, so all the users are well served, even when they are using public roaming internet like 3G access and a laptop they can access the satellite data even on the road.

Results: Using software like WxtoImage, many users have achieved pristine and very detailed images of the NOAA constellation and even movies can be made, as well as 3D images and movies

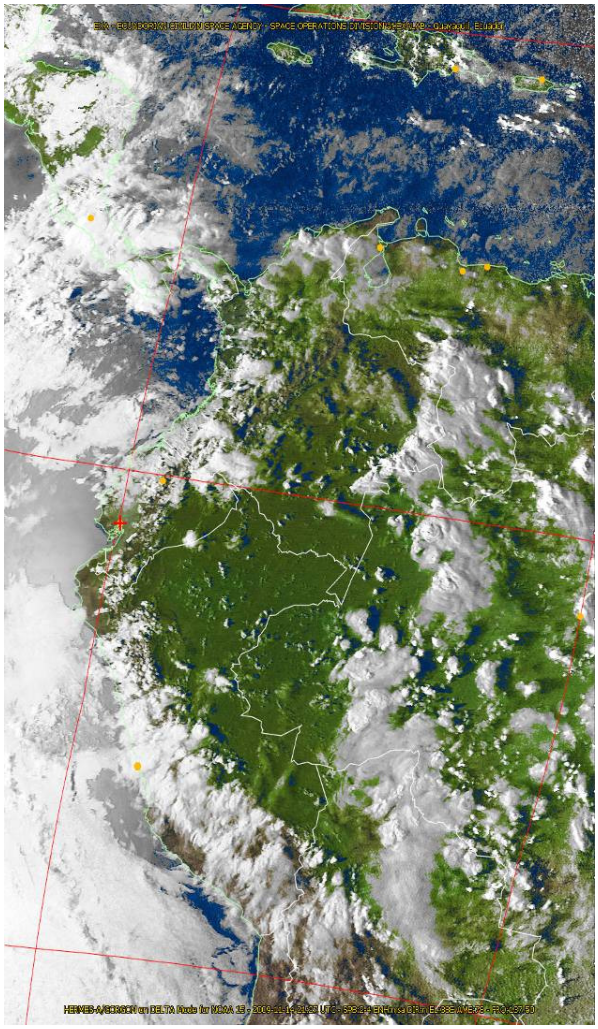
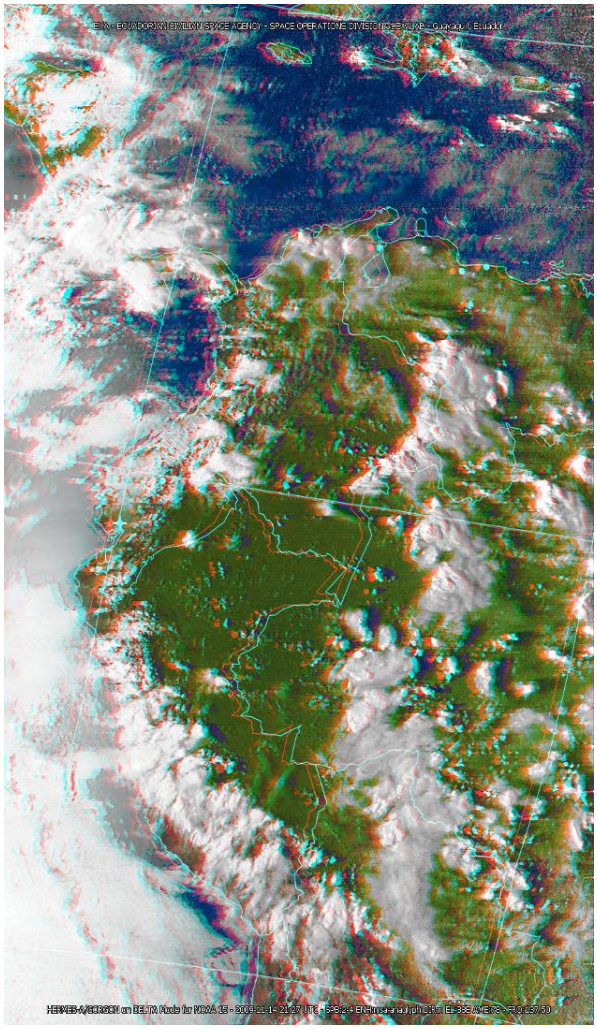


Image of South America retrieved and processed in a Sony VAIO laptop with 3G cellular modem.



3D anaglyph image of South America, you need red-blue anaglyph lenses to see it properly

3D images can be generate by the software and they can be printed, viewed on any display or projected using no special hardware; they only need the standard, cardboard made red-blue anaglyph lenses available almost everywhere.

Early this year, the Tungurahua volcano erupted and spewed an ash cloud that could be seen and felt up to 200kms away, scientists around the country and the world had immediate access to this event using the HERMES Delta gateway

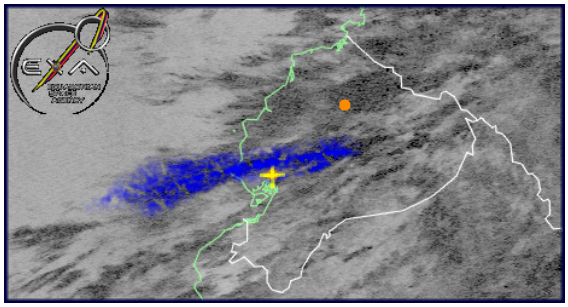
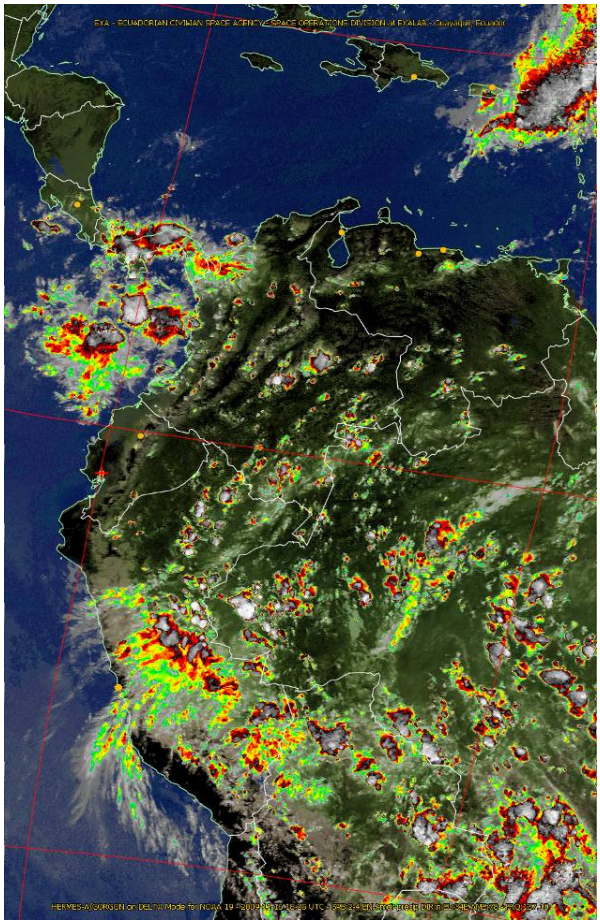
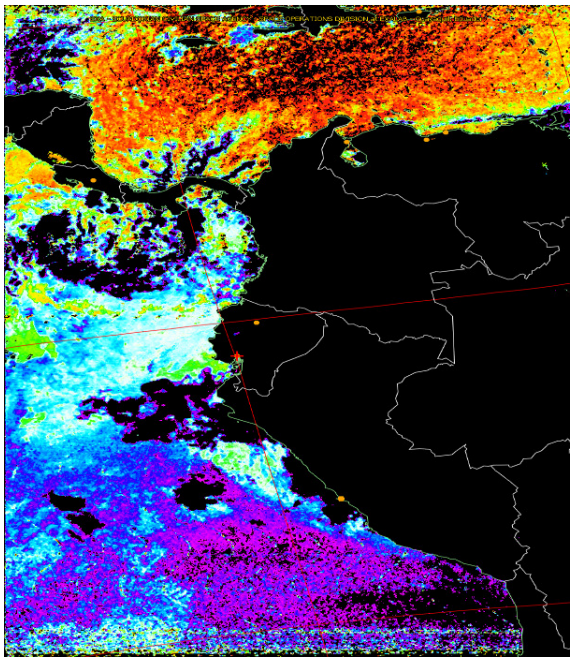


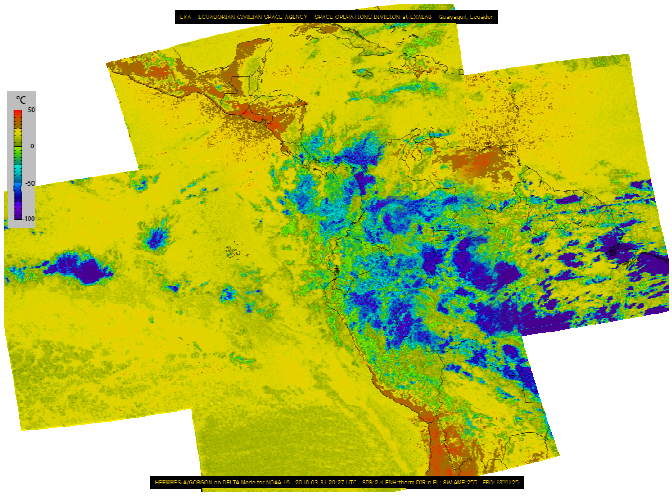
Image of ash cloud spewed by the Tungurahua volcano early this year and processed using the same Sony VAIO laptop with 3G cellular modem, only a few hours later than the event happened.



Precipitation enhancement image of South America



Sea temperature enhancement image of South America



Thermal enhancement composite image of the NOAA-15, NOAA-18 and NOAA-19 satellites, showing the full near 6000kms range of the HERMES Delta GS

A satellite in the classroom: Due to the very simplified interface and automated functioning of the end user interface, an idea was born to put this technical and scientific capabilities in the hands of naturally curious children as a tool to bolster the interest in science and technology early in the life of the children, in fact, the program will make a synergic marriage between education, space sciences and environmental consciousness to build a powerful tool that will help our children to grasp the challenges of the future.

That is how, on November 19 2009, EXA presents the A SATELLITE IN CLASSROOM program, based on the Delta operation mode of the HERMES-A/MINOTAUR gateway, the first program in the world that puts a real satellite in the classrooms of elementary schools, making possible for the first time that school children can download images from weather satellites in real time. The Academia Cotopaxi in Quito and the Ecomundo in Guayaquil becomes the first schools in the world to be able to work satellites in their classrooms in a daily basis.

2nd grade children capturing a NOAA-18 satellite image by themselves in real time, thanks to the A SATELLITE IN CLASSROOM program

Conclusions: The capability of getting information from weather satellites as soon, easy and almost anywhere as possible is a key capability for entities charged with the disaster management and mitigation responsibilities, as well as for the active weather scientist and why not even for the children, to learn about their world from a privileged point of view

HERMES Delta has been told to inspire many of this kids to follow science and engineering careers, but only time will tell if we were able to touch their lives with our work.

Acknowledgments: The EXA team that built the HERMES gateway wants to thank our many users for they feedback, especially to Dr. Ghulam Jaffer at Graz Technical University, Dr. Andrew Klesh, now at JAXA and to Mrs. Margot Solberg at Academia Cotopaxi.

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