RevMexAA (Serie de Conferencias), **43**, 5–8 (2013)

ASTROMETRIC POSITIONING OF THE VENEZUELAN SATELLITE VENESAT-1 "PASAVEN"

S. Otero,[1] C. Abad,[2] and R. Hernández[1]

RESUMEN

En este trabajo informamos de la colaboración entre dos instituciones venezolanas, la Agencia Bolivariana para Actividades Espaciales (ABAE) y el Centro de Investigaciones de Astronomía (CIDA), con el propósito de hacer uso de la Astrometría para el seguimiento del satélite geoestacionario venezolano *VENESAT1* a partir de observaciones ópticas. Para ello, dos pequeños observatorios han sido instalados junto a las estaciones terrenas de seguimiento que el ABAE posee en Venezuela, esperando que en un corto espacio de tiempo den los resultados deseados. Asimismo, es nuestro interés extender esta aplicación a futuros satélites venezolanos, e incluso a la búsqueda y determinación de trayectorias de basura espacial geoestacionaria.

ABSTRACT

By means of this document we inform regarding the collaboration between the Venezuelan institutions, Bolivarian Agency for Space Activities (ABAE) and the Astronomy Research Center (CIDA) with the purpose of using astrometry for the tracking of the Venezuelan Geostationary Satellite *Venesat1* by means of optical observation. For this purpose two small astronomical observatories shall be installed on the space tracking ground stations owned by the ABAE in Venezuela and we hope that in a short term they shall be producing the expected results, and also that these observations may be extended to future Venezuelan satellites and to the determination of the geostationary space debris trajectories.

Key Words: astrometry — space vehicles

1. GENERAL

Since long time ago, the geostationary ring has become a space of enormous strategic and commercial interest that must be regulated and protected. In this sense, satellites included in it follow a series of norms that are necessary for a good use of such space, among them that of the confinement in an operating window, created and passed by an international commission.

Likewise, the interest for the knowledge of the behavior of the so called space debris is growing, due to the danger that it represents for the space missions and even more in the above mentioned geostationary space, because a little distraction may cause a serious accident that limits the use of this area.

In this sense, everything that helps to a better knowledge of the trajectory of a body that is placed in space, whether catalogued as satellite or space debris, is welcomed, the automation and reliability of this effort being highly appreciated.

Astrometry is used to learn the positions of bodies in space, and the accumulation of positions over time allows us to determine their movement. With the appearance of detectors, such as CCD, the development of this area has been surprising. Bodies without their own light, of weak magnitude, variable and dependent of the parallactic angle with respect to the body that illuminates them may be observed with short exposure times. Astrometry easily achieves precisions around a tenth of arcsecond. At the distance of the geostationary belt this is equivalent to about twenty meters, especially in orientation, the parallax precision being dependent on the baseline used to calculate it.

Under these introductory premises, the PASAVEN Project is born as a product of a staff exchange visit of the Bolivarian Agency for Space Activities (ABAE) to the Astronomy Research Center (CIDA). ABAE and CIDA are institutions attached to *Ministerio del Poder Popular para la Ciencia, Tecnología e Innovación de Venezuela*. On that visit, areas where the exchange might enrich both institutions were identified. For that event the CIDA participated on the PASAGE project, led by the Real Observatorio de la Armada (ROA) to perform tracking of the *Hispasat 1C-1D*

[1]Agencia Bolivariana para las Actividades Espaciales (ABAE), Base Aérea Generalísimo Francisco de Miranda, Complejo Tecnológico Simón Rodríguez, Caracas, Venezuela (sotero@abae.gob.ve).

[2]Centro de investigaciones de Astronomía (CIDA), Avda. Alberto Carnevalli, Edif. CIDA, La Hechicera, Mérida, Venezuela.

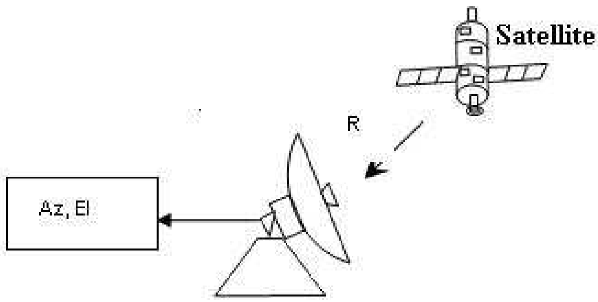

Fig. 1. Diagram of the parameters defining the station-satellite vector position obtained by the interferometric tracking of the Venesat1 satellite from the Venezuelan ground control stations.

and *Spainsat* satellites, among others (Montojo et al. 2011). The project turned out to be viable and attractive; consequently, an optical tracking network for the Venesat1 was established in Venezuela. The purpose of the optical tracking system is not to replace the tracking system with the radio frequency systems with which the Venesat1 normally operates, but to profit from the advantages that the optical system offers in terms of precision.

Venesat1 geostationary satellite was put into orbit on October 29, 2008 and provides telecommunications services for almost the whole American continent. Its nominal operating point is longitude 78°W. Since it is subjected to disturbing forces (for example: the distribution of the mass of the Earth is not homogeneous, the gravitational potential is not homogeneous either, as well as the gravitational attraction forces exerted by the sun and the moon) that tend to modify the orbital position of the satellites, either over the fundamental plane (earth's equator) or outside of it (inclination with respect to the equator). Given these circumstances, it is necessary to periodically perform orbit corrections to return the vehicle to its nominal working position. For the in-orbit operations, it is necessary to precisely determine the satellite's position in space; this calculation uses the Azimuth (Az) and Elevation (El) parameters of the tracking antenna and the modulus of the radio vector (R) from the mission control center (Guárico-Venezuela) to the satellite (Figure 1), and then applying the interferometry technique, that is, measuring the phase difference between tones transmitted to the satellite and later sent back to the Earth, the distance to *Venesat1* may be calculated. These parameters are processed by means of a flight dynamics software in order to perform analysis of the mission orbitals.

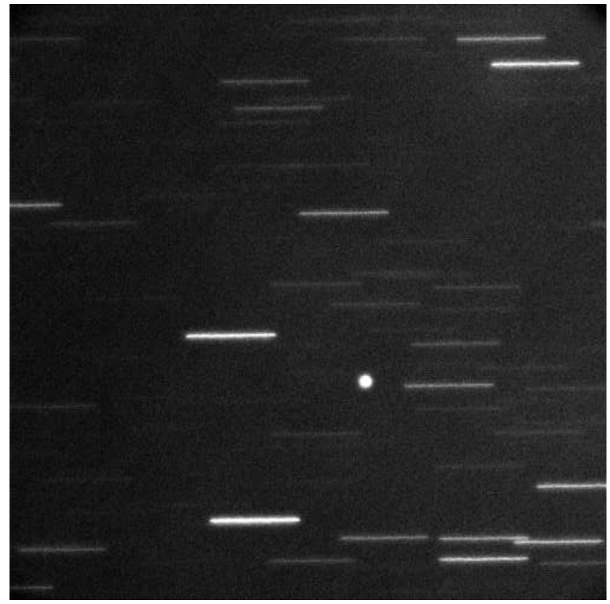

Fig. 2. First image captured from the Venezuelan Geostationary Satellite Venesat1 on the night of February 10, 2009, using the Double Astrograph telescope of the OAN (National Astronomical Observatory) in Venezuela. The dot image is the satellite, while the tracks correspond to the stars detected, that appear on the observation field of the camera CCD being used, at the moment of the exposure.

To improve precision, the backup station located in the Bolívar state is used. The distance between the two stations is about 1000 km. In conditions with a single tracking station, the calculated position error is less than 7 km, and the semi-major axis (transitory elements) error is less than 500 meters. Under conditions of double tracking station, the calculated position error is less than 3 km, and the semi-major axis (transitory elements) error is less than 200 m. The main goal of PASAVEN is to obtain much more precise ephemerides that allow in a first phase to determine with higher accuracy the satellite's position and in a second phase to use parallax techniques for the determination of the distance, and as a consequence, a tracking system totally independent from the nominal one shall be available.

2. PASAVEN PROJECT

The first observations of the Simón Bolívar – *Venesat1*– Satellite were performed at the OAN, Venezuelan National Astronomical Observatory, using one of the astrographs of the Double Astrograph (0.5 m) installed on that observatory. It was the main telescope used for the PASAGE project. The first picture of satellite (Figure 2) was obtained

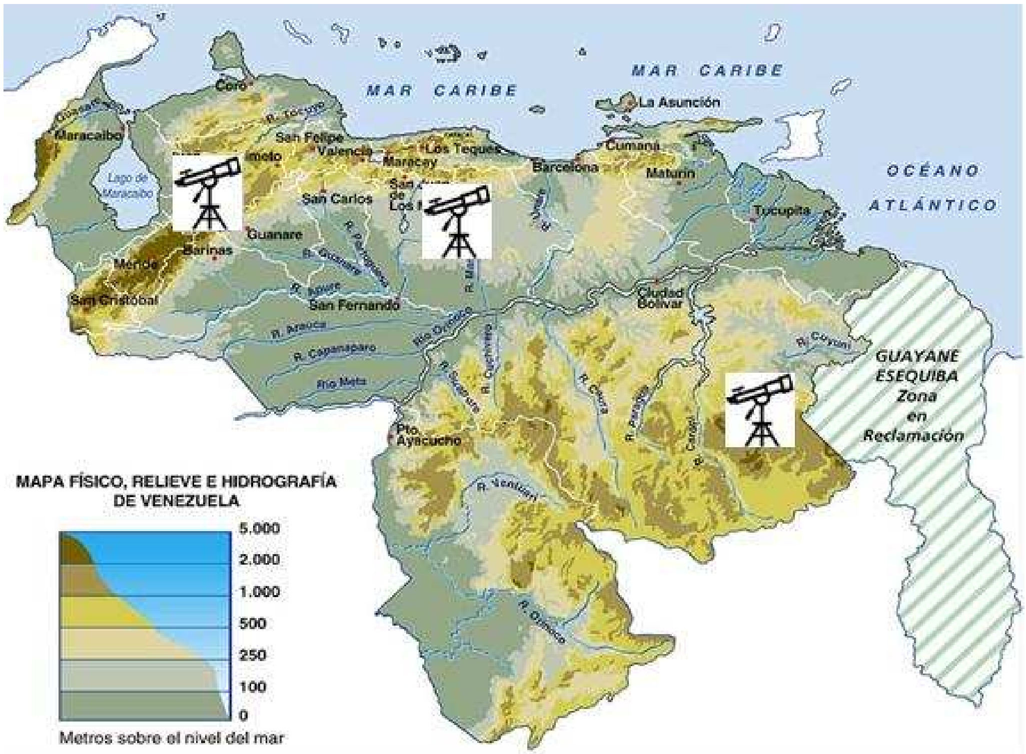

Fig. 3. Map of Venezuela, with the astrometric control centers of the PASAVEN Project schematically located. The map gives us an idea of the relative position between the triangle vertices and their separations (aprox. 400, 700 and 1300 km).

on the night of February 10, 2009. The observation technique is based on placing, during the whole night, the telescope and therefore also its coupled detector, and to perform periodic exposures, with a short exposure time, so that any movement of the satellite is reflected on the composition of the series. The stars appearing on each one of the exposures shall serve as a reference to the astrometric position of the satellite, as well as to determine the stability of the telescope-detector position and the observation conditions. The quality of the astrometric reduction of the observations is associated to the determination of the star position over the exposure and the time associated to that position. Since the images of the stars are strokes, it is necessary to use astrometric specialized techniques. In our case, we use the "tepui function" (Abad et al. 2004) for the positioning of the satellite over the exposure and the reduction techniques described by Stock (1981) and Abad (1993) including the possible overlapping between exposures.

The tracking network consists of placing telescopes and CCD detectors coupled to them, that for convenience shall be installed on our mission control centers, ground control center of Bamari, Guárico state and ground control center of Luepa, Bolívar state, since it is preferable that the time reference is the same as the one used by the main system. A double astrograph from the National Astronomical Observatory "OAN" is also used that would serve as a reference and that was used on the PASAGE project with very good results. The following map of Venezuela (Figure 3) may give an idea of this distribution.

The project is already in progress, since the telescopes and detectors that shall serve as observation instruments were already purchased. For this, 2 Celestron, CGE PRO 1400 EDGEHD telescopes and 2 CCD, 3k×3k, FLI ProLine PL09000 cameras were purchased. Part of the equipment has been already installed and tested in Luepa's station.

3. PRESENT AND FUTURE

The introduction of astrometry as a supporting element to the tracking of geostationary satellites is the beginning of a broader relationship due to the potential that the astrometry implies. On the one hand, there is the incorporation of the quality

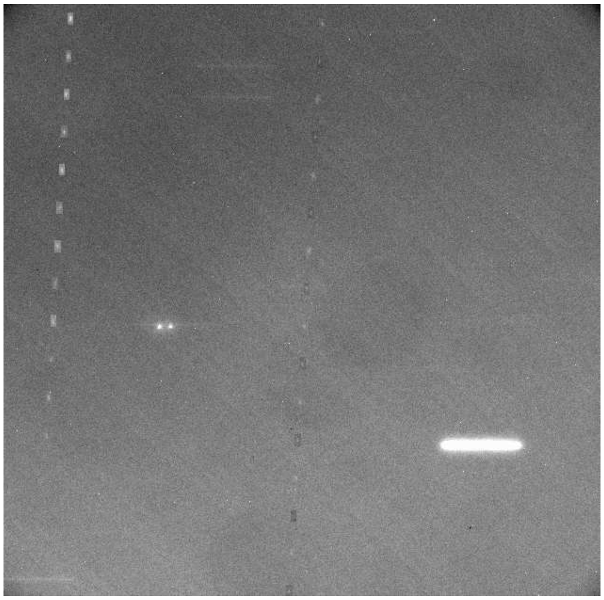

Fig. 4. Composition of the movement of the Argentine satellite Nahuel-1A and the Venezuelan Venesat1, both geostationary satellites, while the first one passes by the window of the second one, obtained from the observations corresponding to the nights of May 27 and 28, 2010. In the intermission there were maneuvers of the Venezuelan satellite and for this reason it appears like a double dot.

and precision in the positioning over the celestial sphere of the satellite. The precision in the station-satellite distance must match the precision obtained by telemetry since the triangle of the 3 observation points contains sides with distances between 400 km and 1500 km. But on the other hand, it opens the doors to the use of such astrometric observations to other future Venezuelan satellites, as it has already been verified with the passage of the Argentine satellite Nahuel-1A, in transit by the Venesat1 window, since it was repositioned in the year 2010. A composition of exposures of this event is shown in the Figure 4. And finally, the use of this equipment for the study of the space debris and especially the geostationary debris is possible.

We hope that this project brings a series of benefits for the Venezuelan institutions directly involved on it, as well as for the country, similar to some of those below described:

– To increment the security and to help in the decision-making for satellital repositioning maneuvers, taking advantage of the astronomical observational data and its consequent ephemeris.

– To obtain an independing calibration system for the tracking antenna of the radio frequency system.

– To develop the area of astrodynamics, offering an opportunity for students in physics, mathematics and engineering.

– To experiment with the observation and study of geoestationary space debris.

– Small observatories could be an important educational attractions for the people who live near them.

REFERENCES

Abad, C. 1993, A&AS, 98, 1
Abad, C., et al. 2004, A&A, 416, 811
Montojo, F. J., López Moratalla, T., & Abad, C. 2011, Adv. Space Res., 47, 1043
Stock, J. 1981, RevMexAA, 6, 115