APOD mission status and observe APOD by VLBI

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Introduction

On Sept. 20, 2015, the Chinese CZ-6 test rocket was launched successfully from TaiYuan Satellite Launch Center, and 20 satellites was sent simultaneously into a circular, near-polar and 520 Km altitude orbit. Among these 20 satellites, four CubSats, named with APOD (Atmospheric density detection and Precise Orbit Determination), are projected for atmospheric density in-situ detection and derivation via precise orbit. The APOD satellites, manufactured by DFH Co., carries a number of instruments including density detector, dual-frequency GNSS (GPS/BD) receiver, SLR reflector and S/X band VLBI beacon. The mission aims to detect atmospheric density below 520 Km. The ground segment is run by BACC for payload operation as well as science data receiving, processing, archiving and distribution. Currently, one of the APOD satellites and payload validation had finished, and the preliminary results are presented as follows. The precision of orbit determination is about 10cm by both overlap method and (about 10cm) by compared with SLR observation, and the derived atmospheric density from this precise orbit determination matches well with in-situ detection. We have constructed the distribution system of these data on AFDL's website.

Since three space geodetic techniques (i.e. GNSS, SLR, and VLBI) are co-located on APOD satellite, the observations can be used for combination and validation in order to detect the systematic differences. Furthermore the observations of APOD satellite by VLBI radio telescopes can be used in an ideal fashion to link the dynamical reference frames of the satellite with terrestrial and, most importantly, to the celestial reference frame as defined by the positions of quasars. From a VLBI observational point of view, APOD satellite is rather challenging since mutual visibility depends on the altitude of APOD satellite and the separation of the radio telescopes. And the APOD satellite travel through the field of view very fast. The possibility of observing APOD satellite by IVS VLBI radio telescopes will be analyzed, considering continental-size VLBI observing networks and the small telescopes with sufficient speed.

APOD configuration

- 1 Nano-satellite: 15kg, 360mm*360mm*360mm
- 3 identical Pico-Satellites: 5kg, 220mm*220mm*220mm

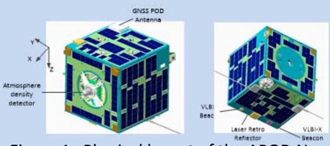


Figure 1 Physical layout of the APOD Nano-sat with the location of scientific instruments (Left: Front side view; Right: Bottom side view).

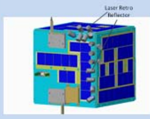


Figure 2 Bottom side view of APOD Pico-sat with location of Laser Retro-Reflector instruments.

APOD orbit	Nano-sat	Pico-sat
Semi-major Axis/Km	470	530
Inclination/°	97.49	
Local Time of Descend Node	6:30	6:10

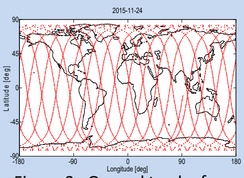


Figure 3 Ground track of APOD Nano-sat in 24 hours.

APOD payload system

		Nano-satellite	Pico-satellite
GNSS Receiver	Mode	GPS/BDS	
	GPS Frequency/MHz	L1:1575.42, L2:1227.60	
	BDS Frequency/MHz	B1:1561.098, B3:1250.618	
	Sampling Rate/s	8	
VLBI Beacon	S-Band Frequency/MHz	$f_{carrier} = 2262.01$ $f_{s\_dor1} = 2256.87$ $f_{s\_dor2} = 2260.98$ $f_{s\_dor3} = 2263.04$ $f_{s\_dor4} = 2267.15$	-
	X-Band Frequency/MHz	$f_{carrier} = 8424.02$ $f_{X\_dor1} = 8404.87$ $f_{X\_dor2} = 8420.19$ $f_{X\_dor3} = 8427.85$ $f_{X\_dor4} = 8431.66$	-
Atmosphere Density Detector	Detection Range/km	120 - 550	-
	Pressure Measure Range/Pa	$1.0^{-6} \sim 1.0^{-2}$	-
	Temperature Range/℃	-20 ~ 60	-
	Sampling Rate/s	1	-
Laser Retro Reflector	Type	Pyramid	Mounted on bottom surface dispersedly
	Number of cube corner prisms	9	11

APOD orbit determination

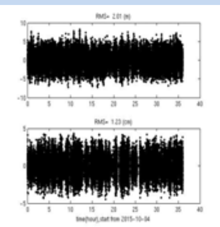


Figure 4 Residuals of orbit determination for Nano-sat, with GPS pseudo-range observations (top) and carrier phase (bottom) observations, respectively.

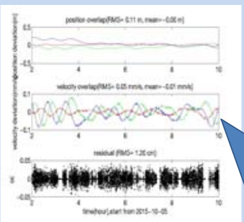


Figure 5 Overlap comparisons of Nano-sat.

The rms of pseudo-range and carrier phase observations is about 2m and 1.5cm,respectively. The precision of APOD Nano-sat orbit is about 10cm by virtue of overlap comparisons.

Comparison of neutral densities between In-situ detection and retrieved from APOD precise orbit

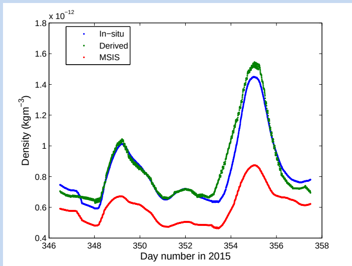
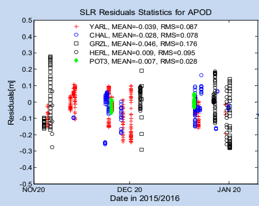


Figure 6 Comparison of neutral densities .

APOD SLR observations

Until now, APOD Nano-sat has been tracked by 13 SLR stations all over the world

Figure 7 Network of SLR stations for the APOD observations.



APOD Nano-sat has obtained ~1000 Normal Points. These date are utilized for validating GPS-based precise orbit

Figure 8 O-C of SLR observations for APOD Nano-sat.

APOD VLBI observations

➢ with CEI

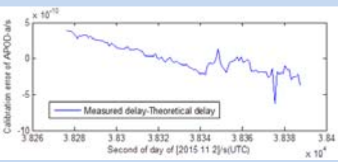


Figure 9 O-C of VLBI observations for APOD Nano-sat.

➢ with IVS stations (simulations)

Maximal azimuth rate for APOD Nano-sat is 5 deg/s.

Maximal elevation rate for APOD Nano-sat is 1 deg/s.

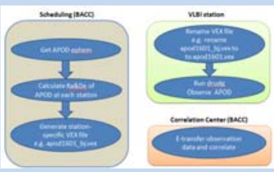
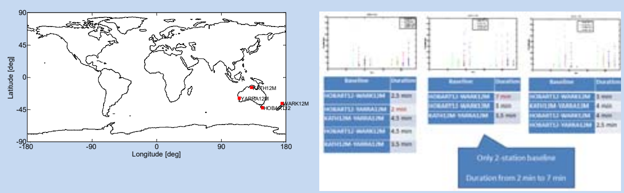
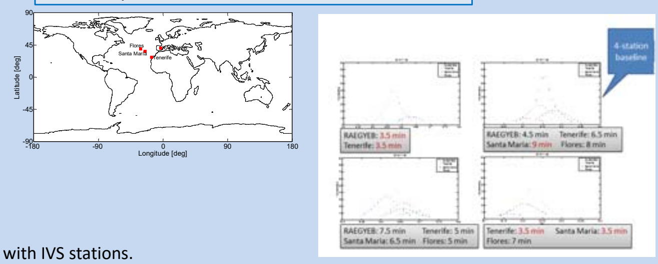


Figure 10 Scheme of VLBI observations for APOD Nano-sat with IVS stations.

◆ Visibility of APOD Nano-sat with Australian and New Zealand VLBI antennas



◆ Visibility of APOD Nano-sat with RAEGE VLBI network



◆ Other possibilities

For the persons, who have interests in APOD, You are welcome to contact with authors.

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