TAOS Orbit Determination Results Using Global Positioning Satellites

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ABSTRACT

Orbit determination results for the Air Force Phillips Laboratory's Technology for Autonomous Operational Survivability (TAOS) satellite using a Rockwell AST V Global Positioning System (GPS) receiver are presented in this paper. Under a cooperative effort, GPS orbit determination technology developed at the Jet Propulsion Laboratory (JPL) has been transferred to the U.S. Air Force. JPL's post processing differential GPS software, MIRAGE [1] was modified to perform precise orbit determination for the TAOS satellite. Three-dimensional orbit comparisons of less than five meters have been achieved with overlapping orbit determination spans. Orbit determination results are also compared with those of the Air Force's Satellite Control Network.

The TAOS program, sponsored by the U.S. Air Force's Space Test Program and Phillip's Laboratory, is operated by Detachment 2, Space and Missile Systems Center, Test Planning and Operations Division (Det 2, SMC/TD), Onizuka Air Force Base, Sunnyvale, California. It was launched on 13 March 1994 into a 560 km circular orbit and 105 degree inclination. Elements of TAOS/GPS orbit determination system are shown in Figure 1.

The TAOS/GPS receiver is not capable of removing the effects of Selective Availability (SA) or tracking the encrypted P-code (i.e., Y-code) [2]. However, the SA effects do not diminish the orbit solutions since the MIRAGE software employs a differential technique that effectively removes SA effects.

During Anti-Spoofing (AS) operation of the GPS constellation, only single frequency CA-code pseudorange and delta range measurements are available from the GPS receiver on-board TAOS. Therefore, the ionospheric calibration based on the linear combination of the TAOS dual frequency pseudorange measurements is unavailable. The GPS receivers used at the ground sites have an advanced hardware design that allows for the dual frequency ionospheric calibration **[3-4].**

Since the delta range observations of the TAOS receiver do not provide high precision information, compared to the ground station carrier phase measurements, no TAOS delta range measurements were processed initially. Further Studies will evaluate the usefulness of the delta range,

Baseline Solution Scenario

Initially, the GPS satellite orbits are determined using only ground station observations. With the GPS orbits fixed, combined solutions using the TAOS pseudorange and ground station pseudorange and carrier phase measurements are performed, The estimated parameters are: TAOS position and velocity, clocks for TAOS and GPS space vehicles and all but one ground receiver. Data arc lengths of 10 hours were selected with a five hour overlapping segment, Differential processing is performed by aligning the data times and intervals from the ground and TAOS receivers. Table 1 lists the rates and relative weights.

Table 1.- Data Rates and Processing Weights

Data Type	Processing Rate	Weight {meters]
TAOS Pseudorange	2.5 min. (decimated)	10
Ground Pseudorange	2.5 min. (decimated)	40
Ground Carrier Phase	2.5 min. (decimated)	.03

Results

Currently, we have results from two 10 hour orbit arcs with a common five hour overlap. TAOS pseudorange observation residuals for one of the 10 hour arcs are show in Figure 2 with an RMS of approximately 4.7 meters. Orbit comparisons during the five hour overlapping period yield 3.2 meter three-dimensional precision (Figure 3). Due to receiver on-orbit performance it was impossible to perform longer orbit fits with the initial periods of good data.

Summary

This paper documents results of a cooperative effort to transfer technology developed under NASA contract at the Jet Propulsion Laboratory to the U.S. Air Force. Precision spacecraft orbit determination using post-processing differential GPS software called MIRAGE was modified to support the TAOS satellite. Orbit overlap comparisons show five meter precision using reduced accuracy CA-code data from the TAOS GPS receiver. Sub-meter accuracies could be obtained, as demonstrated by TOPEX/Poseidon [1 ,5], by including P-code, delta range, and/or continuous carrier phase observations.

Acknowledgements

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References

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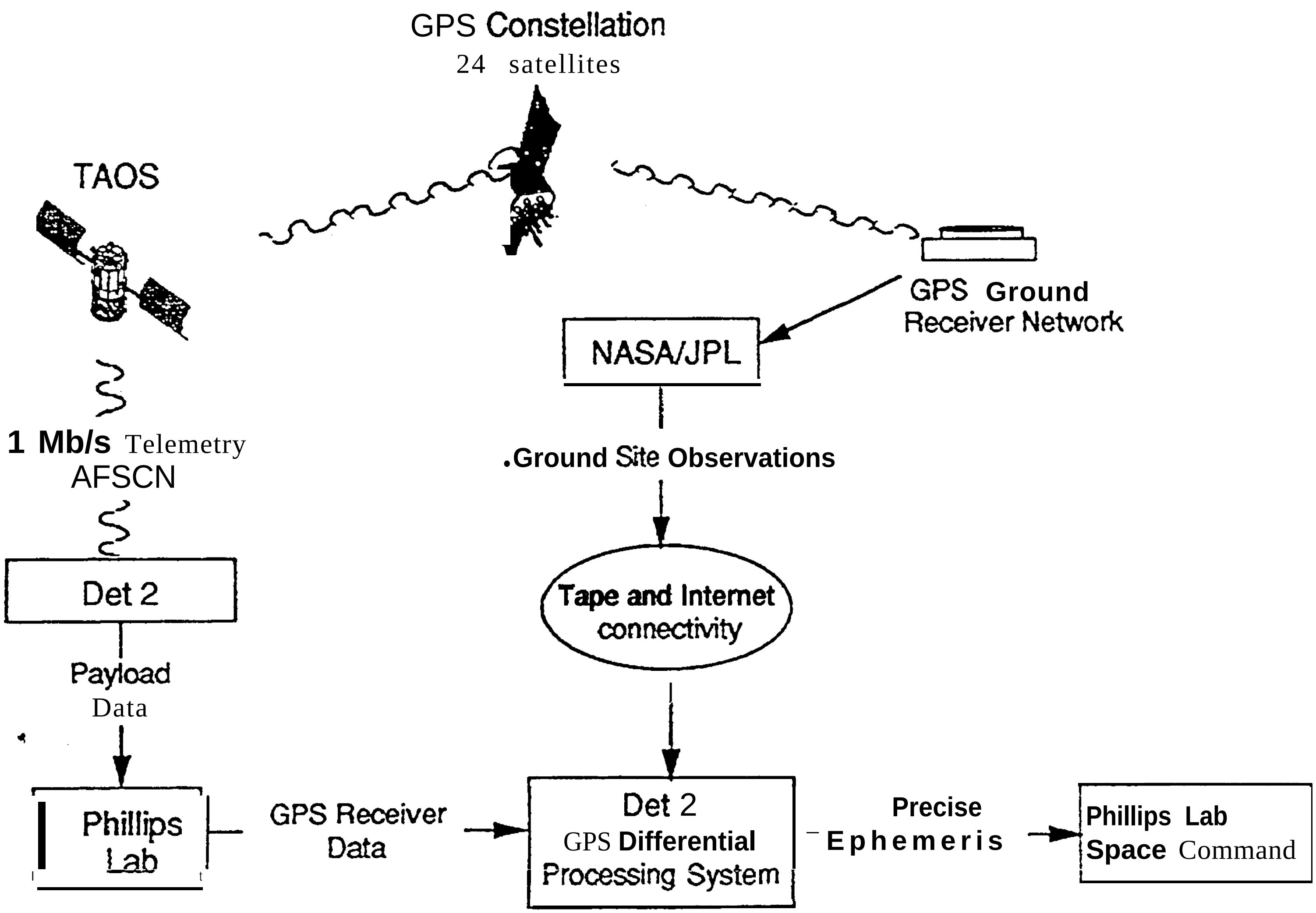

Figure 1. - Elements of TAOS/GPS Orbit Determination System

Figure Z„ - TAOS/GPS PSEUDORAN GE RESIDUALS (2.5 minute rate)

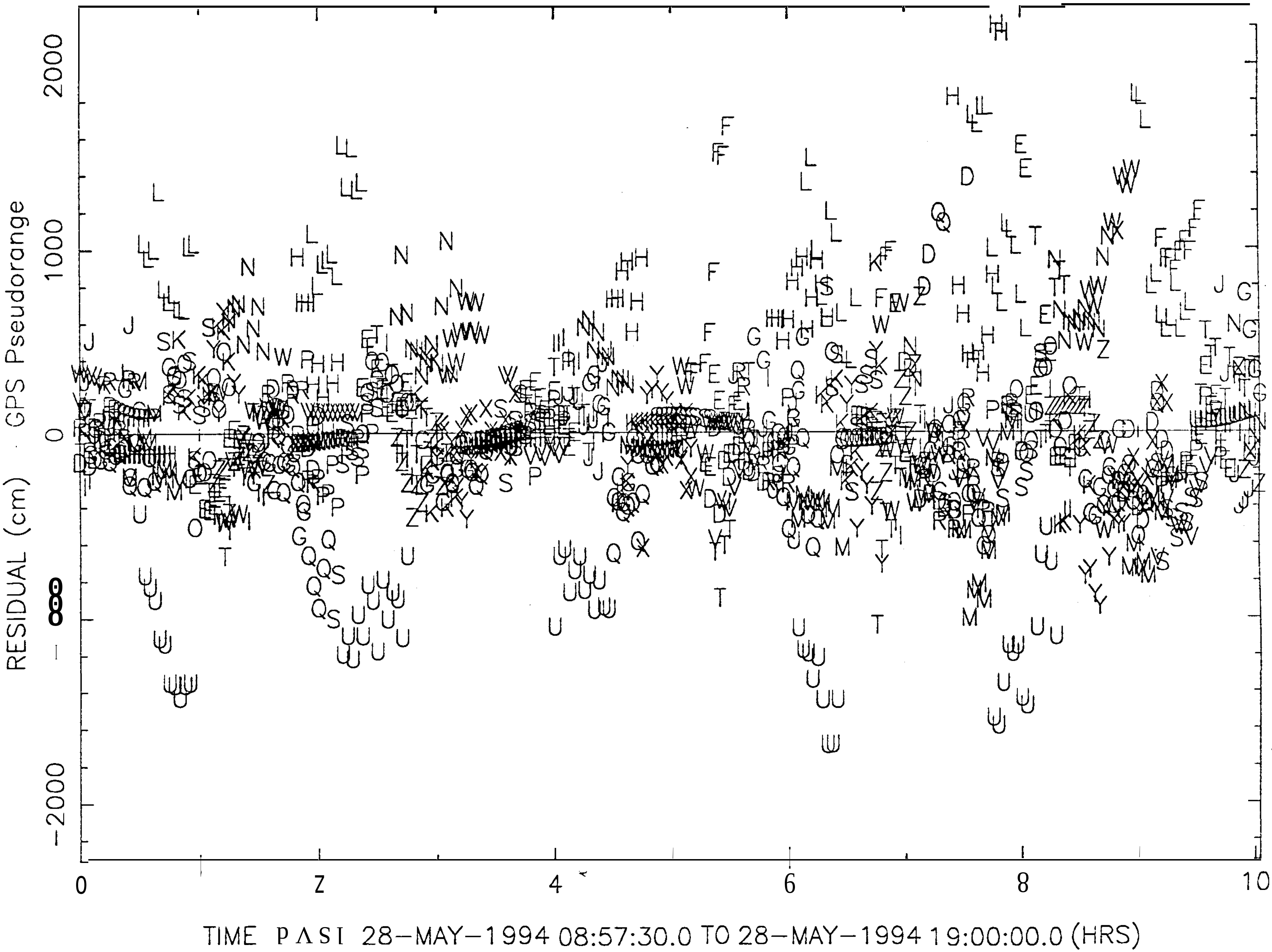

Figure 3. - TAOS Orbit Overlap Differences