PNT as a Service (PNTaaS): Providing a resilient Back-Up to GPS by Leveraging Broadband Satellite Constellations and Ground Infrastructure

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***Abstract*—To address the loss of GPS position and timing information, alternative solutions that do not rely on GPS satellite constellation are needed. The PNTaaS solution developed by NAVSYS allows existing broadband SATCOM satellites to be used as signals of opportunity (SoOP) to bound inertial and clock errors and allow Assured PNT devices to maintain accurate positioning and timing in long-term GPS outages. By partnering with operators of global commercial SATCOM service providers, the PNTaaS technology provides a cost-effective capability to provide a global back-up PNT solution.**

In this paper, the open architecture PNTaaS solution is described, which provides data services to deliver timing and signal information from multiple broadband satellite constellations. Test results are presented from a Software Defined Radio using these services to provide Time of Arrival (TOA) updates to an inertial and clock A-PNT device. The benefits of using SoOP operating in both geostationary (GEO) and non-geostationary satellite orbits (NGSO) is shown through a combination of simulation and test results to demonstrate the ability to provide a precision back-up PNT capability which can operate in the absence of GPS

Keywords—PNTaaS, GPS loss, Signals of Opportunity (SoOP), Assured Positioning Navigation and Timing (A-PNT)

I. Introduction

Threats in military operating domains are becoming more sophisticated and are increasing the risk to maintaining military superiority. In contested environments, adversaries are denying GPS, thereby challenging critical PNT data. These threats are not only progressing to make GPS unavailable regionally, but emerging threats could cause extended GPS outages. As shown in Fig. 1, various solutions exist to support operations in the various threat severities. In operations where GPS is available or challenged, secure military GPS signals coupled with advanced antennas provide some level of protection (Threat level 1-2). During GPS outages, Assured Positioning Navigation and Timing (A-PNT) devices allow operation for short periods of time (Threat level 3) but their errors grow significantly in the absence of aiding.

To combat these threats, the US DoD is investigating open system architecture systems that can provide mission critical PNT data across all threat severities. These Assured PNT devices use a modular approach to allow an inertial and clock device to be aided from a combination of different aiding sources. As outlined in Fig. 2, NAVSYS' open architecture inertial and clock solution, InterNav[1], allows for tight coupling of external navigation aiding sources to sustain Assured PNT operations under GPS outages.

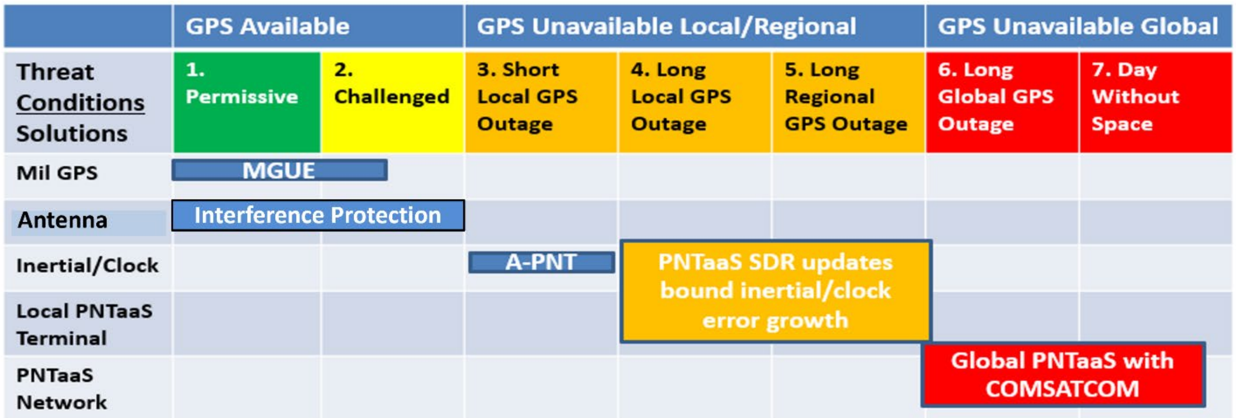

Fig. 1 GPS Risk Levels and Solutions.

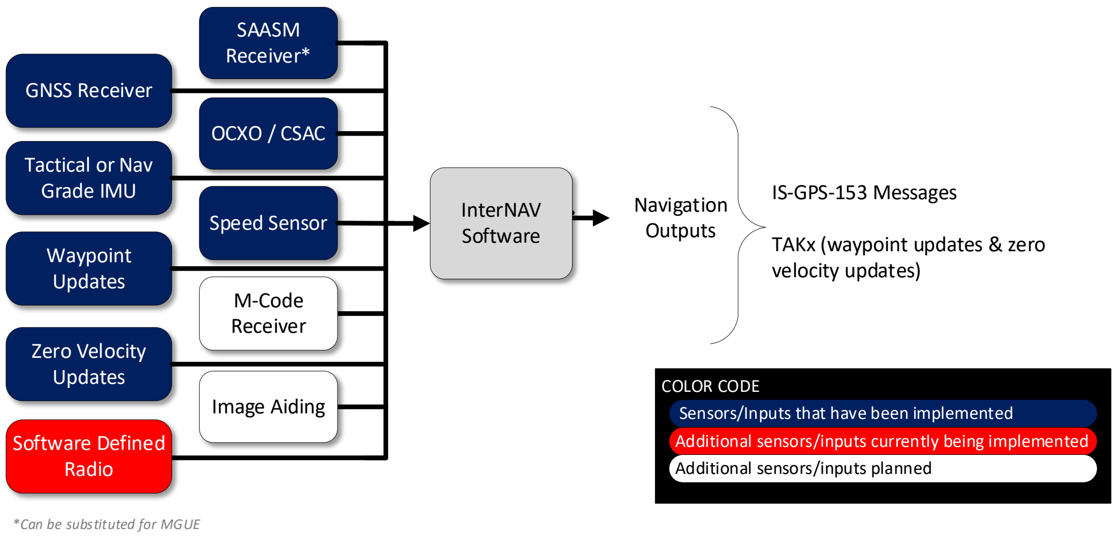

Fig. 2 A-PNT Hub using NAVSYS InterNav Open Architecture Software

By including a Software Defined Radio (SDR) with an inertial and clock A-PNT device, observations can be made from alternative navigation sources that can operate on different frequencies to the GPS signals to provide resilience in a contested environment. PNT as a Service (PNTaaS) allows users to subscribe to data services through an open architecture to enable existing commercial SATCOM signals to be used as Signals of Opportunity (SoOP) for PNT.

II. COMMERCIAL BROADBAND SATELLITE COMMUNICATIONS

A risk to the current Global Navigation Satellite Systems (GNSS) is that they all operate at fixed frequencies in L-band. While there is limited spectrum available for Radionavigation Satellite Systems (RNSS)[2] (see Fig. 3) there are many more frequency allocations in the 3-30 GHz range for satellite communication services (see Fig. 4). As of January 2023, the Federal Communications Commission (FCC) listed 194 approved geostationary (GEO) satellites for broadcast, fixed and mobile satellite services[3]. They also listed 43 approved Non Geostationary Satellite Orbit (NGSO) systems. The largest of these are the proliferated LEO systems with reported launches in the FCC report of 4,408 satellites from SpaceX (Call Sign S2983/3018), 720 satellites from OneWeb (Call Sign S2963), 117 satellites from Telesat (Call Sign S2976), 66 satellites from Iridium (Call Sign S2110), and 42 satellites from O3B (Call Sign S2935), with thousands more launches planned.

In the early 1990s, NAVSYS demonstrated that a conventional commercial GEO communication satellite could be used for navigation[4]. This technology became the foundation for the Wide Area Augmentation System (WAAS) deployed by the FAA and international partners. This showed that SATCOM transponders had the power and bandwidth needed to support precision navigation. The PNTaaS technology developed by NAVSYS now enables any broadband SATCOM to be leveraged as a Signal of Opportunity (SoOP) for PNT. A list of some of the available SoOP operating in different SATCOM bands are shown in Table 1.

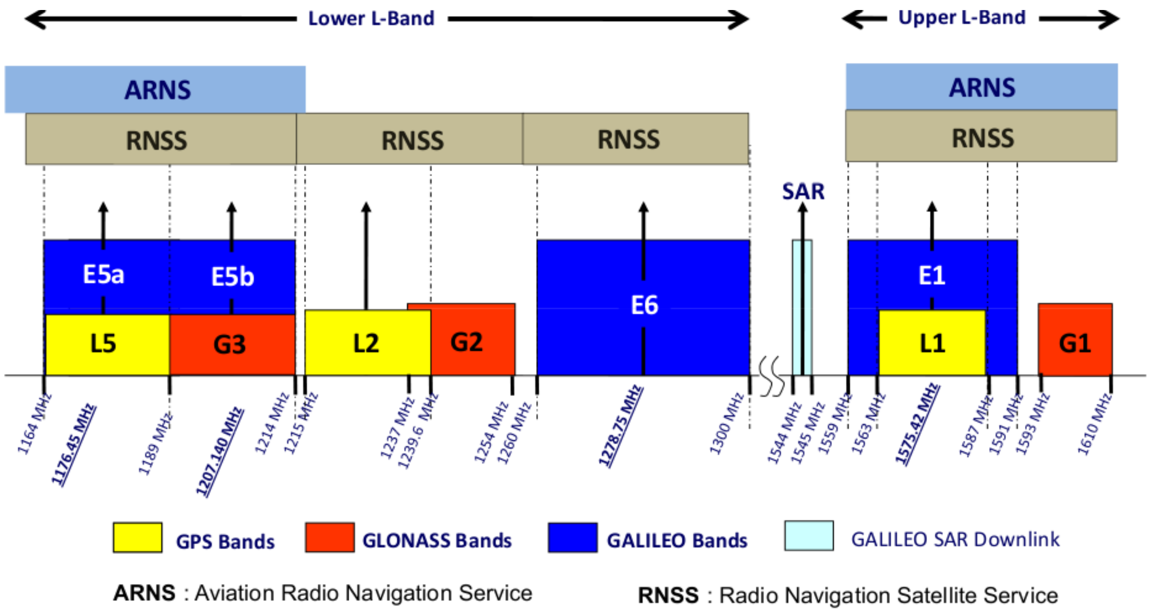

Fig. 3 Radio Navigation Satellite Service Bands[5]

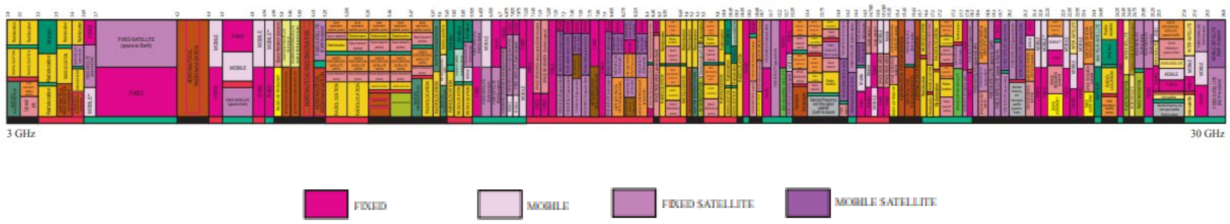

Fig. 4 Frequency Allocations for Fixed and Mobile Communication Services (3-30 GHz)

Table 1 Examples of Alternative Signals of Opportunity (SoOP) for Global Coverage

Band	Freq	SoOP	Orbit
L	1 – 2 GHz	GNSS, Iridium Inmarsat	MEO GEO
S	2 – 4 GHz	GlobalStar TDRS COSMIC-2	MEO GEO LEO
C	4 – 8 GHz	Xona Intelsat, Telesat, SES, etc.	LEO GEO
X	8 – 12 GHz	WGS, Skynet	GEO
Ku	10.7–12.7 GHz 12 – 18 GHz	OneWeb, SpaceX DBS, Viasat	LEO GEO
Ka	17.8-18.6 GHz	Telesat, Kuiper, O3B ViaSat, Telesat	LEO GEO

III. PNT AS A SERVICE ARCHITECTURE

The PNT as a Service (PNTaaS) system architecture is shown in Fig. 5. This architecture is designed to be able to leverage any broadband SATCOM as a Signal of Opportunity (SoOP) by leveraging a PNTaaS Monitor Station that tracks the SATCOM broadcast and publishes PNTaaS data that includes signal content and timing information. Using an Internet of Things (IoT) protocol, end users can subscribe to the PNTaaS Cloud and select which SoOP they can use based on their location, frequency ability of their SDR, and any interference that is affecting them locally.

The PNTaaS operation is shown in Fig. 7. The PNTaaS Cloud Server is designed to subscribe to SoOP data from the network of monitor and reference sites. By compiling observations from multiple locations, a list of available SoOP and also associated precise location information (ephemeris) is published. The published SoOP list includes a unique SoOP identifier with signal characteristics such as frequency, bandwidth and any known modulation or pilot tone content. The PNTaaS server also publishes a time slot and sequence interval at which the SoOP Snapshot will be published by a SoOP Monitor Station.

At the PNTaaS Monitor Station, a high gain antenna is used to observe the SATCOM broadcast. This can be a stand-alone unit or can be a Software Defined Radio installed at an existing teleport which is receiving traffic from that SATCOM service. On the specified time slot and interval, the PNTaaS Monitor Station captures a snapshot from the designated SoOP and publishes that data over the PNTaaS Cloud. Multiple PNTaaS Reference stations, with access to a Master Clock tied back to a common time base, such as the USNO Master Clock, capture a SoOP snapshot at the same time slot and calculate the TOA relative to the Master Clock[6]. The TOA Observation is then

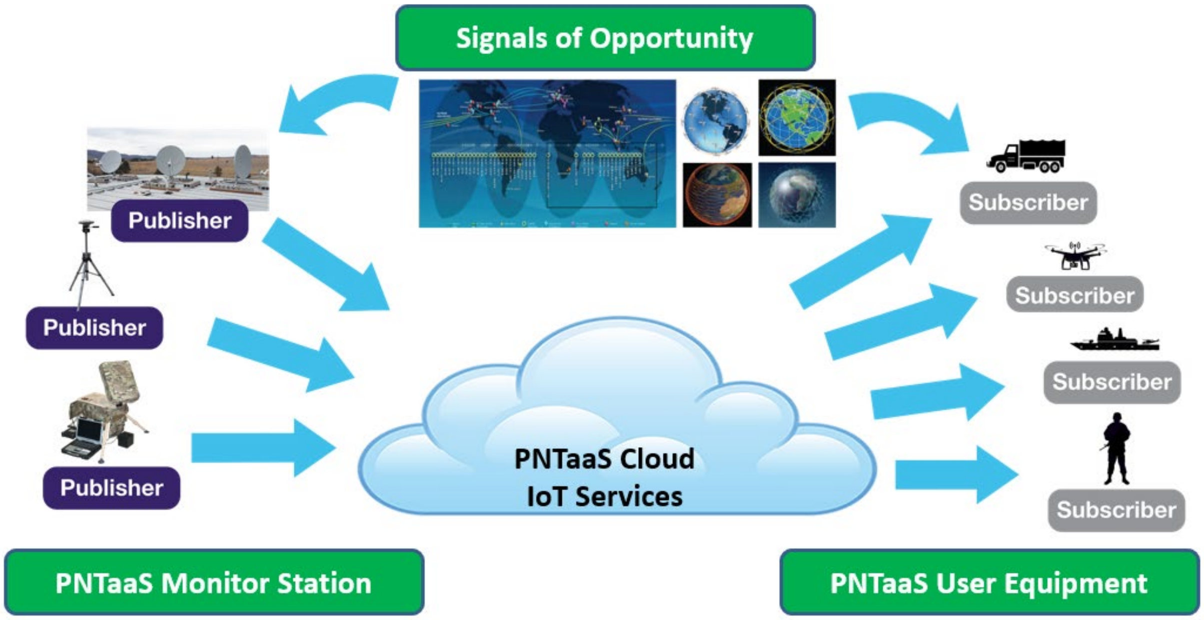

Fig. 5 PNTaaS Architecture

published over the PNTaaS Cloud with the location of the Reference Station.

Remote PNTaaS users can select the different SoOP that they wish to use from the published PNTaaS Server list and set up an automated subscription, using the IoT protocol, to subscribe to those SoOP. Through cross-correlation with the published SoOP snapshot they observe a TOA relative to their local clock. Using the published SoOP Location, calculated from a precise ephemeris, and the TOA Reference corrections to associate back to a Master Clock, a pseudo-range (PR) can be calculated and applied to an integrated inertial and clock A-PNT solution to calibrate the instrument errors and correct for drift in the position and time solution.

A key feature of the PNTaaS cloud IoT protocol is that Remote and Reference users are automatically made aware of available SoOP, which allows for new signals to be added as constellations are deployed. This allows them to select the desired SoOP to operate with and establish a SoOP sequence within their SDRs that is compatible with their radio and antenna configuration and also their sensed interference environment. This provides a high degree of resilience by leveraging autonomy within the PNTaaS subscriber units to adapt and take advantage of a wide array of different signals, operating on different frequency bands (see Table 1), as new SATCOM constellations are launched.

IV. PNTaaS Pseudorange Calculation

The SoOP Snapshot data and the associate TOA from a PNTaaS Reference Station are published over the PNTaaS Cloud. A subscribing Remote Receiver captures a snapshot at the published time for a particular PNTaaS SoOP and stores this internally (see Fig. 6). When the subscribed PNTaaS data for that SoOP is received, the Remote Receiver performs cross-correlation with its sampled snapshots to determine the Time of Arrival (TOA) relative to its internal clock.

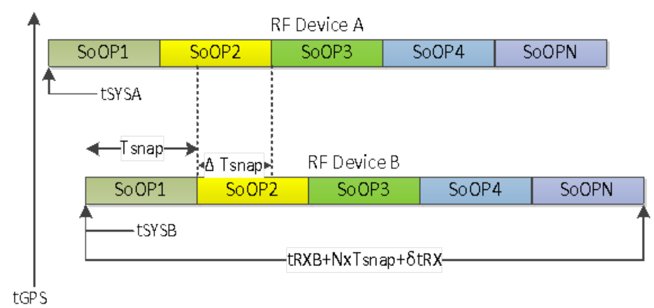

Fig. 6 SoOP Snapshot Time Sequence

By differencing the observed TOA at the Remote Receiver with the published TOA from one or more Reference Receiver, a pseudorange which observes the Remote Receiver clock offset and the location of the Remote Receiver is provided through the following equation.

$$PR^{i}_{REM} = TOA^{i}_{REM} - TOA^{i}_{REF} + R^{i}_{REF} = R^{i}_{REM} + Bu$$

Equation (1)

- R^{i}_{REF} is the range from the broadband satellite (i) to the location of the Reference Receiver (REF) calculated from the published satellite ephemeris over the PNT service.

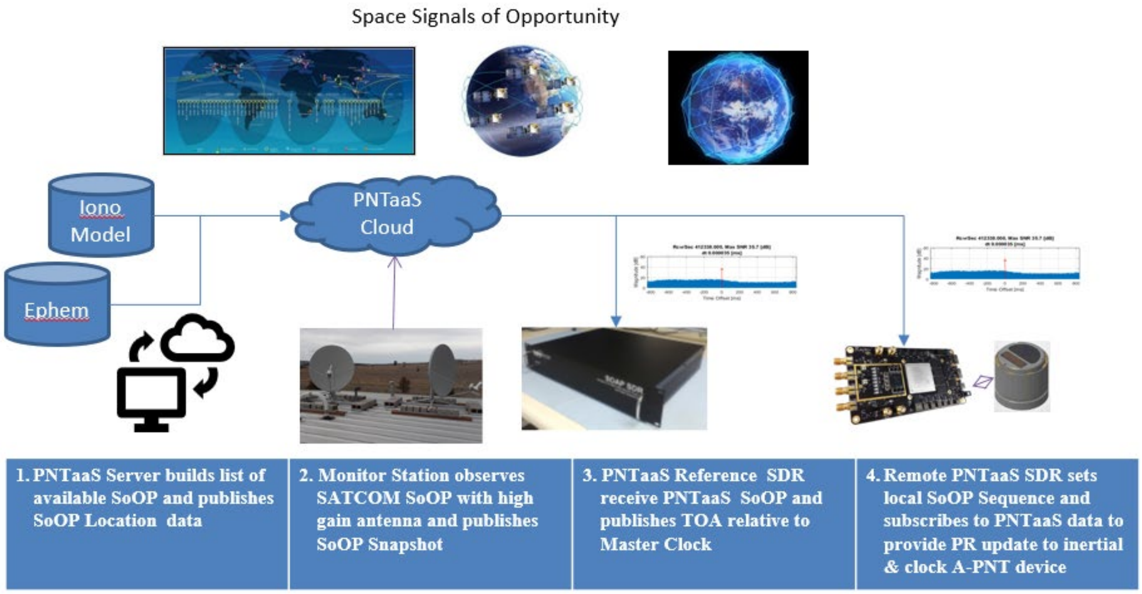

Fig. 7 PNTaaS Concept of Operation

- R^{i}_{REM} is the range from the broadband satellite (i) to the location of the Remote Receiver (REM) calculated from the published satellite ephemeris over the PNT service.
- Bu is the clock offset of the Remote Receiver local time reference.

Using the published SoOP location data, this pseudorange can be applied to update an inertial and clock A-PNT solution. A key feature of the InterNav[**Error! Bookmark not defined.**] data fusion algorithms, developed by NAVSYS for this purpose, is that the real-time inertial and clock outputs can be updated by observations that are delayed in time. This means that the PNTaaS performance is not noticeably affected by network latency in delivering the data services, unless that latency results in significant propagation errors in the inertial and clock PNT solution.

V. Example C-Band, Ku-Band and Ka-Band Link Margins

The accuracy of the Time of Arrival (TOA) generated by a Signal of Opportunity (SoOP) is a function of the received Signal/Noise Ratio (SNR) and the bandwidth of the sampled SoOP data. While for normal operation, the broadband SATCOM requires a high gain dish antenna or steered array to provide the link margin for data demodulation, with PNTaaS the data content of the SoOP snapshot is published by the monitor station. This means that the received SNR, when cross-correlating the remote SDR snapshot with the monitor SDR snapshot, is a function of the received signal/noise power in the bandwidth of the SoOP (dB-Hz) and the duration of the SoOP snapshot (secs). In Table 2 we show examples of the received SNR from different SoOP based on a link margin calculation that assumes an omni-antenna is used (0 dBi). This table shows that the predicted SNR calculated for GNSS satellites and C-band and Ku-band SATCOM signals based on their published Effective Isotropic Radiated Power (EIRP) is very similar. With the snapshot processing, the final SNR is a function of the received signal power in the SDR sampled bandwidth and the length of the SoOP snapshot and the SDR processing loss. For GNSS signals, the reference snapshot for correlation is generated using the published PRN codes. Depending on the alignment of the received and reference snapshots, there can be a 3 dB processing loss. This results in a predicted SNR of 24 dB as shown in Table 2.

Table 2 Link Margin Examples at L, C, Ku and Ka for PNTaaS

Downlink Performance	**L-Band**	**C-Band**	**Ku-Band**
	GNSS	**SES-3**	**SES-2**
Downlink EIRP per Carrier (dBW)	28.5	39.0	46.4
Power in Snapshot Bandwidth	27.5	32.5	40.8
Antenna pointing error	-0.5	-0.5	-0.5
Downlink Path Loss, Clear Sky (dB)	-184.1	-197.0	-206.1
Downlink Rain Attentuation	-0.5	-0.5	-0.5
Earth Station G/T (dB/K)	-24.8	-24.8	-24.8
Boltzman Constant (dBW/K-Hz)	228.6	228.6	228.6
Downlink C/N0 dB-Hz at SDR	**46.2**	**38.3**	**37.5**
Snapshot Length (msec)	11	85	85
Processing Loss (dB)	-3	-5	-5
SoOP SDR S/N (dB)	**23.7**	**22.6**	**21.8**
Antenna Gain (dBi)	0	0	0
Antenna Temperature (deg K)	303	303	303
Carrier Bandwidth (MHz)	20	36	36
PNTaaS SDR Bandwidth (MHz)	20	10	10
Broadcast Frequency (MHz)	1,575	4,200	12,020
Satellite Altitude (km)	20,200	35,800	35,800
Max Range to satellite (km)	24,200	40,000	40,000
Min Elevation (deg)	15	16	16

For the GEO SATCOM C-band and Ku-Band signals, typically the link margin for communications is calculated assuming high data rate demodulation and using a high gain dish antenna. When using these signals with the PNTaaS Monitor

Station data, the remote SDR operates with an omni (0 dBi) antenna. The received SNR in this case is a function of the received signal power in the SDR sampled bandwidth, the length of the SoOP snapshot and the SDR processing loss. The published EIRP is for a full transponder bandwidth which is typically 36 MHz for C-Band and Ku-band (higher for Ka-band). The SoOP snapshot published by the PNTaaS Monitor station defined the bandwidth and snapshot length. To compress the data, the SDR sampled signal from the Monitor Station dish is reduced to a 1-bit sample which introduces an additional 1.96 dB of processing loss in the SDR correlation. As shown in Table 2, this results in a received SNR similar to what is observed for the GNSS signals. In section VIII we show example processed data with the snapshot configurations shown in Table 2.

VI. SoOP Open Architecture PNT (SOAP) SDR

The SOAP SDR was developed by NAVSYS as a tightly coupled SDR/A-PNT solution with the capability to operate over multiple frequency bands to take full advantage of the PNTaaS SoOP data services with both GEO and NGSO constellations as shown in Table 1. This SDR adopts a modular design, based on commercial off-the-shelf components, and includes the following features as shown in Fig. 8. Tightly coupled inertial and clock integration with precise time synchronization

When generating pseudo-range or time-of-arrival updates from a GNSS, alternative navigation or SoOP source, it is essential that the different signals be tied to a common time reference in order to be used for PNT updates. This allows disparate observations from different sources and on different frequencies to still observe a common range and clock offset in an integrated inertial and clock A-PNT solution. Similarly, the inertial and other sensor aiding data must all be associated with the same common time reference for precise data fusion. This is accomplished in the SOAP SDR by deriving all HW timing via a Field Programmable Gate Array (FPGA) Phase Locked Loop (PLL) driven from an onboard or external high-quality reference oscillator. The modular approach allows for integration of multiple inertial and clock devices as shown in Fig. 8 and also optional integration of commercial or military GNSS user equipment to calculate a fused A-PNT solution using our InterNav software, as shown in Fig. 2.

A. Rapid sequencing and returning with precise time synchronization

A significant advantage of the tightly coupled SDR inertial/clock design, is that updates from different signal sources can be provided sequentially from a single SDR channel without loss of precision in the A-PNT solution. By sequencing rapidly over different frequencies, observations can be created on hundreds of different available signals from different sources, within tens of seconds, providing observations that can be used to update the inertial and clock solution. This requires extremely tight control of the RF transceiver device in the SDR with rapid retuning,

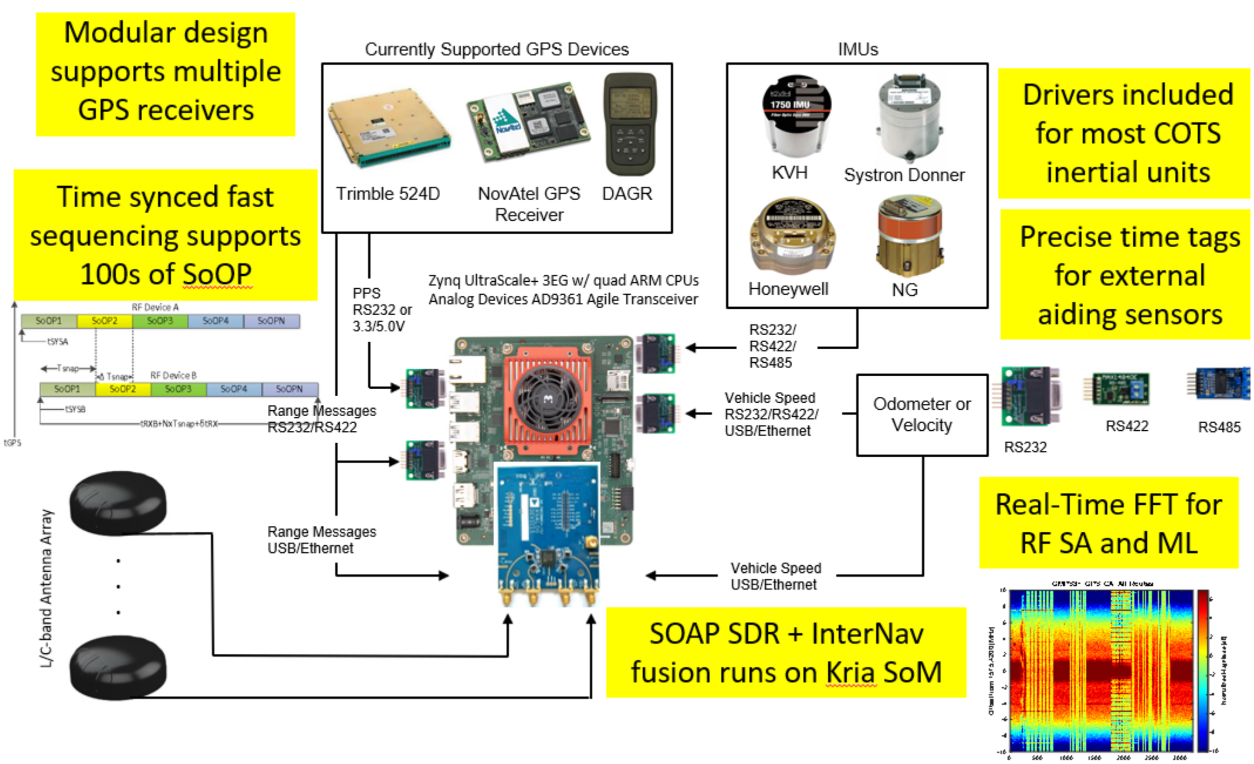

Fig. 8 SoOP Open Architecture PNT (SOAP) SDR

synchronized RF sample capture when using multiple RF channels, and high-speed data transfer and buffering of the sampled signals for signal processing. As shown in Fig. 6, the SDR capture must be precisely time controlled so that the PNTaaS Monitor SDR publishes data captured in the same time slots as the PNTaaS Reference or Remote SDRs. As long as the sampled data overlaps, a cross-correlation can be performed to generate a TOA observation of the SoOP.

B. *Operation over a wide frequency range with multiple antennae switching and control*

The SOAP SDR is capable of operating from L to C-Band directly, and when integrated with low-noise block downconverters (LNB), can operate with down converted signals from higher bands including X, Ku and Ka-band. For the SDR to operate over multiple frequency bands it is often necessary to use multiple antennas for signal reception. Also some platforms may require multiple antenna switching due to vehicle motion obscuring satellite visibility. With the tight A-PNT coupling, the SOAP SDR is able to switch between multiple antennas based both on the SoOP frequency selected for a snapshot and attitude information from the A-PNT solution. This is accomplished using fast onboard RF switching that can currently accommodate multipleantennas per RF channel.

C. *Enhanced signal processing for real-time operation*

In order to keep up with the real-time processing requirements, the SOAP SDR firmware has the capability of performing both simultaneous complex (IQ) data capture and also outputting real-time FFTs on the sampled data (FFT_{REM}). This feature allows for using efficient FFT-based correlation for Time of Arrival observation and rapid doppler searching for acquisition of LEO signals.

$$R(TOA,\Delta f) = IFFT(circshift(FFT_{REM},\Delta f). * conj(FFT_{MON})$$

Equation (2)

- FFT_{REM} is the FFT of the SDR sampled data that is output directly from the SOA SDR firmware
- FFT_{MON} is the FFT of the SoOP snapshot published by the Monitor Station
- Δf is the shift to search over [-Fsearch:Fsearch]*T integer doppler intervals where Fsearch is the peak doppler and T is the snapshot FFT length in seconds

Another feature of the SOAP SDR is the capability to use the real-time FFT spectrograms for real-time RF interference detection using embedded machine learning (ML) to select and deselect RF signals from the InterNav solution. The interference detection is used to select and deselect SoOP that should be used in the A-PNT solution[7]

VII. PNTaaS GEO +MEO/LEO Geometry

A. *GEO Geometry for PNT*

The PNTaaS Cloud can publish data from both GEO and NGSO satellites. Simulation and analysis have shown that a hybrid solution provides best A-PNT performance. GEO satellites have the advantage of providing wide area coverage. Example footprints for GALAXY-30 (C-Band) and SES 2 are shown in Fig. 11.

While there are large numbers of GEO satellites in view (except at high latitudes), GEO satellites alone cannot provide 4D geometry as they are all located in the same plane. GEO only observations can at best observe 3DOF. If altitude aiding and/or clock aiding is available, then GEO only signals will provide adequate geometry. Fig. 9 shows an example of DOP when tracking 4 GEO satellites and using altitude aiding. This illustrates how the geometry is weak between the north and clock states. When including a Chip Scale Atomic Clock (CSAC) in an A-PNT device, this exhibits random drifts, after calibration, of 1E-11 @1000 secs[8]. This means that time errors will be expected to drift at only 3 mm/sec. When periodic clock calibrations are available, then improved HDOP is also available when using GEO only satellites, as shown in Fig. 10. This shows that at higher latitudes, a PNT solution can be calculated from GEO-only observations with a calibrated clock and altitude aiding. At lower latitudes the geometry falls apart as altitude and clock observability line up with the plane of the equator that the GEO satellites are located in.

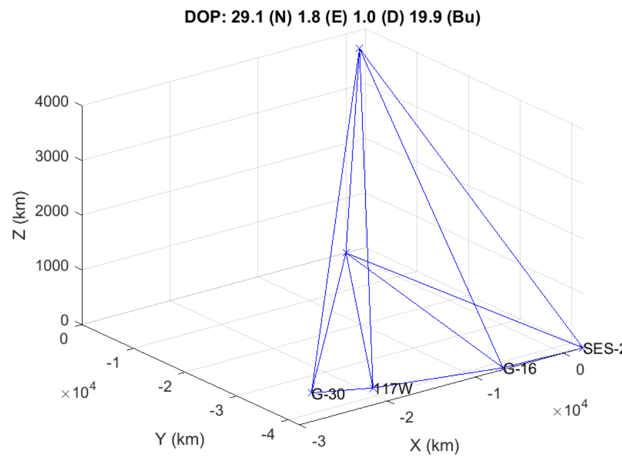

Fig. 9 Example of GEO + Altitude DOP at Monument, CO

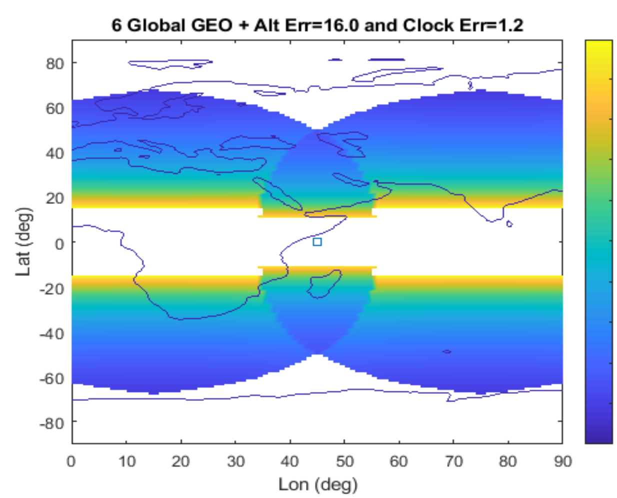

Fig. 10 GEO Only geometry with Altitude and Clock Aiding

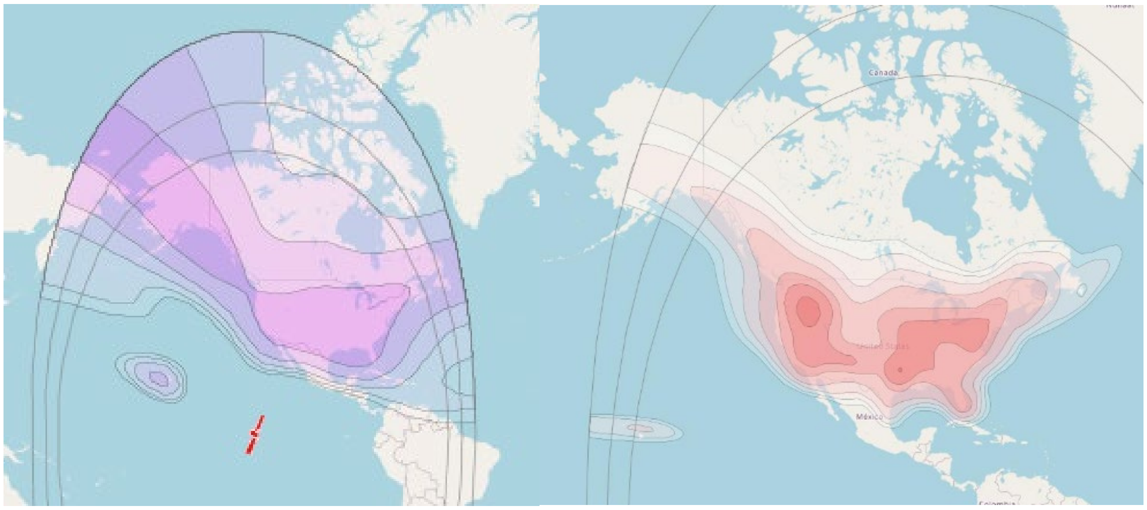

Fig. 11 GALAXY-30 and SES-2 Footprint (C- band and Ku-Band)[9]

B. *LEO Geometry for PNT*

When using LEO satellites as SoOP, the observation geometry changes. A LEO satellite has a smaller footprint than GEO, due to the lower altitude and spot beams size. Fig. 12 shows the typical footprint of a OneWeb satellite. With a LEO satellite, a single pass provides a 2DOF update from tracking the Doppler of the LEO Satellite as it "transits" across the sky. As shown in Fig. 13, the rate of change of the Doppler allows the time of closest point in LEO transit (θ) to be observed and also the declination from orbit (α). If a snapshot of the LEO broadcast is also provided during the period of transit this can be used to derive a TOA update, in addition to tracking the Doppler, which combined gives a 4DOF update. Examples of LEO satellites that broadcast known sequences and can provide TOA updates are the Iridium Satellite Time and Location (STL)[10] signals or the Xona Pulsar[11] signals. Other satellites such as the Starlink constellation broadcast pilot tones that can be used to provide Doppler only updates. By integrating PNTaaS Monitor Stations into a LEO SATCOM ground monitoring network, PNTaaS reference snapshots can be published allowing any LEO broadband SATCOM constellation to be used to provide A-PNT updates.

As an example, Fig. 14 shows the DOP from a simulated OneWeb pass when periodic PNTaaS snapshots are published. Although the OneWeb and other LEO SATCOM constellations are not designed to have four or more satellites simultaneously in view, like GNSS constellations, this simulation shows the effective geometry accumulated over time from PNTaaS observations providing updates to a tightly-coupled A-PNT device. Over a five minute period, the simulation shows that a single satellite pass occurs and also satellites from a second orbital plane appear. The combination of these two passes gives sufficient geometry to provide a 4DOF update an A-PNT device. The PNTaaS services allow for inclusion of LEO satellite updates in the A-PNT solution by publishing precise orbit and clock corrections, and also PNTaaS Monitor Station data published from ground stations.

Fig. 12 OneWeb Ground Track[12] (Ku)

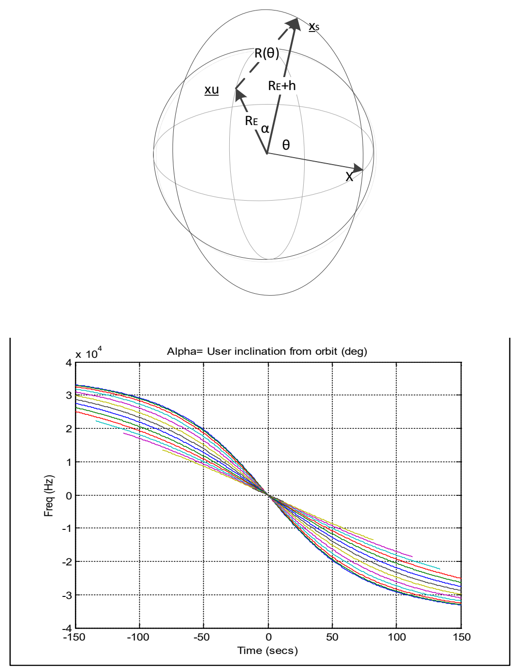

Fig. 13 LEO Only Geometry from Satellite Doppler Pass

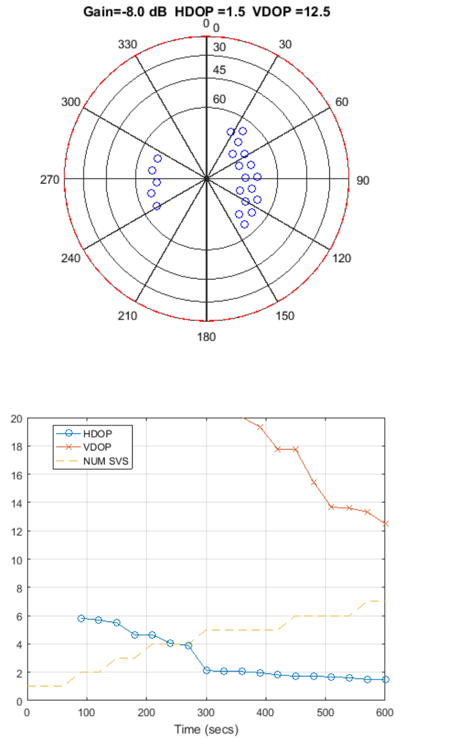

Fig. 14 Simulated geometry from OneWeb Pass over 5 Minutes

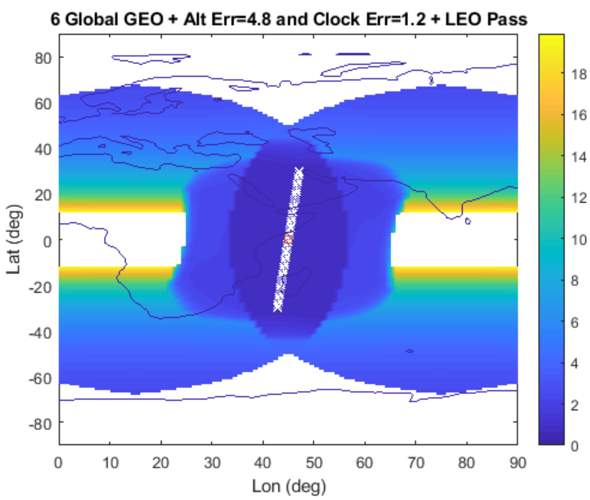

Fig. 15 GEO Geometry with Altitude aiding and a LEO pass

C. GEO and LEO Geometry for PNT

Using PNTaaS observations from GEO satellites provides the benefit of persistent coverage, but with the disadvantage of weak geometry at lower latitudes. Using PNTaaS observations from LEO or MEO satellites provides the benefits of improved geometry from multiple satellite passes. Combining observations from both GEO, MEO and LEO satellites has the advantage of coupling persistent coverage, with periodic updates to allow 4DOF geometry which can be used to apply to calibrate the embedded A-PNT clock within the SDR. While even high quality inertial solutions drift at around 1 nmi/hour a CSAC[**Error! Bookmark not defined.**] clock drifts at 1E-11 @1000 secs which is equivalent to only 11 m/hr of drift. An example of how single LEO pass augments GEO geometry and allows for clock calibration and provides 4DOF observability is shown in Fig. 15.

VIII. PNTaaS Test Results

In Fig. 16 we show a test run that was performed at NAVSYS using SoOP collected from GNSS satellites (L-Band) and also GEO satellites at C-Band and Ku-Band. GPS observations were collected to provide a truth reference but were not used as part of the PNTaaS solution.

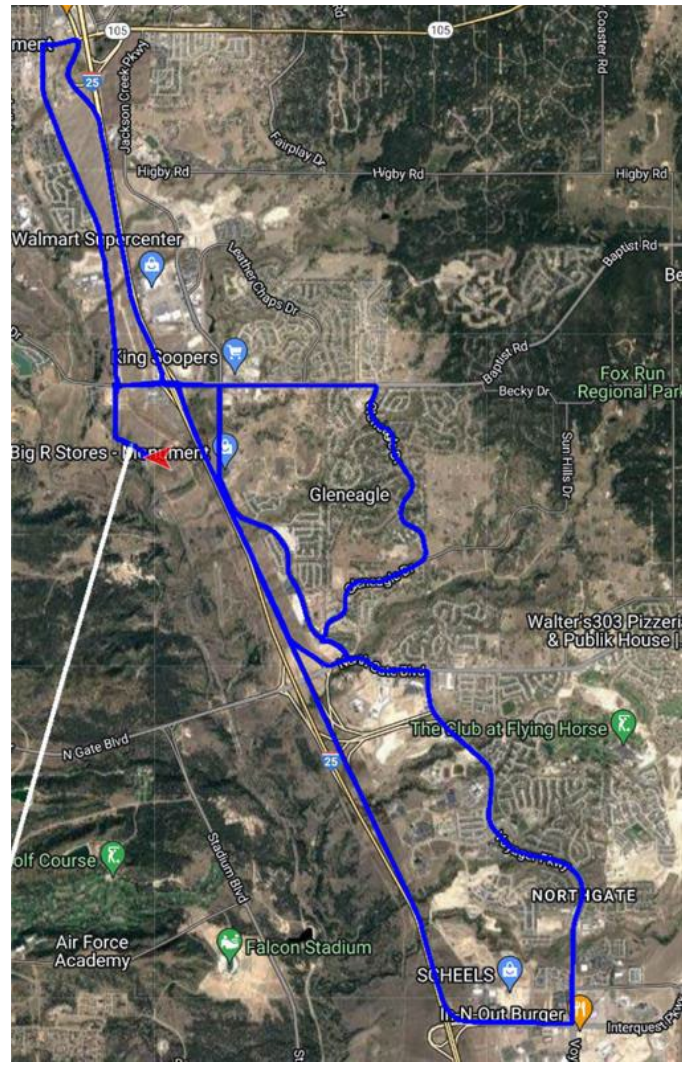

Fig. 16 Test Route in Monument, Colorado

GNSS snapshots were collected from GPS CA, L5, Glonass L1 and L2, and Beidou B1I. The spectrum of the GNSS signals from the snapshot FFT is used to provide situational awareness to the SOAP SDR of which of those signals provide valid SoOP (see Fig. 8). As shown in Fig. 17, from the observations calculated from the GNSS FFT correlations we observed SNR levels between 22 – 32 dB. From the C-Band snapshot correlations (GALAXY 16 and 30) we saw SNRs typically around 24 dB and on the Ku-band snapshot correlations (SES-2 and EUTELSAT 117W) we saw SNRs that varied between 22 – 30 dB. With C-band we were using a RHCP antenna while with Ku-band a dual polarization antenna was used. This resulted in more SNR swings when tracking Ku-band on the mobile unit. In future testing we will be using a custom designed Ku-Ka-band antenna to give better SNR performance.

In Fig. 18, we show the residual errors observed from processing the GNSS SoOP snapshots are 6.4 meters RMS. In Fig. 19, we show the residual errors from tracking the GEO SoOP are 4.5 meters RMS. The drift in the observations is caused by the crystal OCXO used in the SOAP SDR and would be reduced when using a CSAC clock.

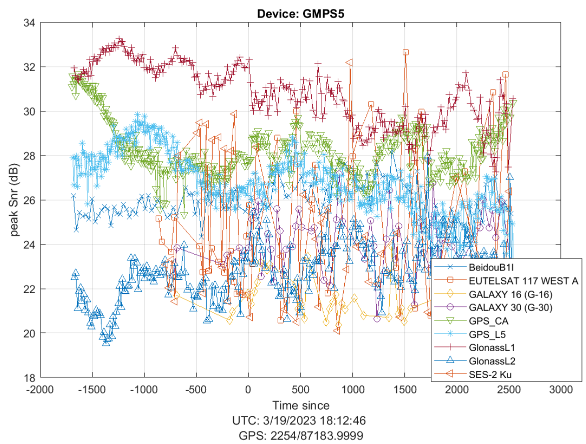

Fig. 17 Observation SNRs on Mobile SOAP SDR unit

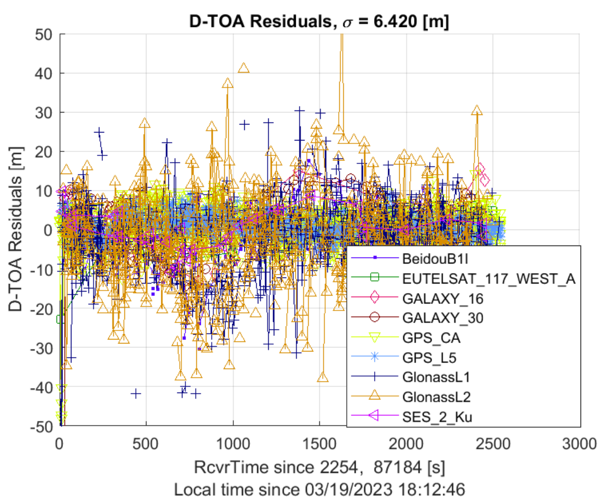

Fig. 18 Observation residuals from GNSS snapshot processing

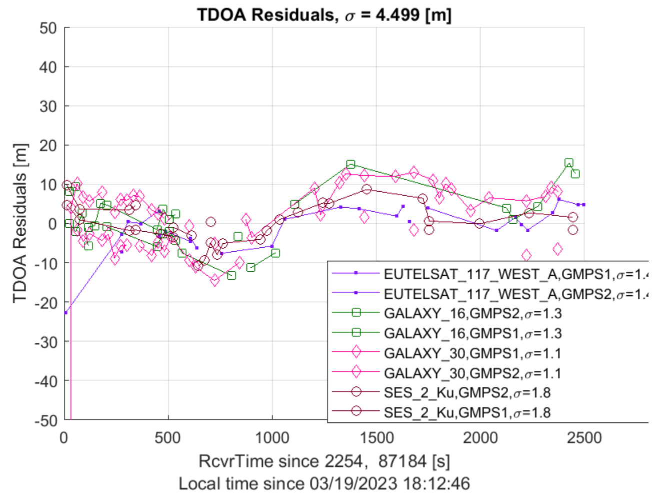

Fig. 19 Observation residuals from GEO satellites (SES-2 & Eutelsat 117W at Ku and GALAXY 16 and GALAXY 30 at C-band)

The PNT errors compared with GPS from the combined MEO/LEO results are shown in Fig. 20. This demonstrates that with good geometry, horizontal accuracies of 4.9 m RMS (4.7 m North and 3.2 m East) can be achieved.

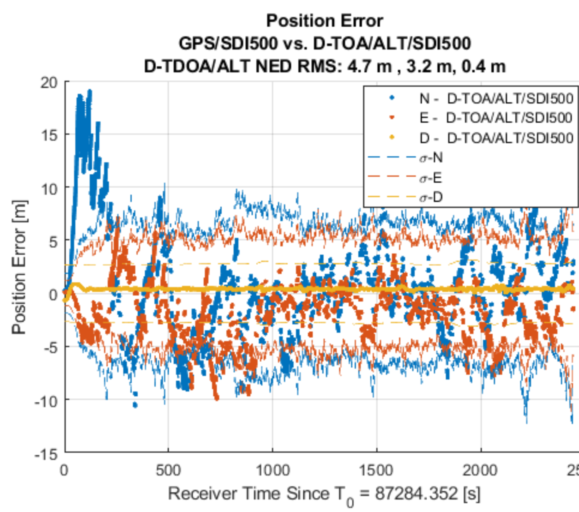

Fig. 20 PNT performance versus GPS (GEO+MEO)

In Fig. 21 the PNT errors using GEO only satellites is shown. As shown in Fig. 9, the geometry for this case causes coupling between the North and the Clock errors. With an OCXO used in the SDR clock, the North position error reaches a steady state covariance of 150 meters. The horizontal accuracies using GEO only satellites with altitude aiding were 56.5 m RMS (48.7 m North and 28.6 m East.

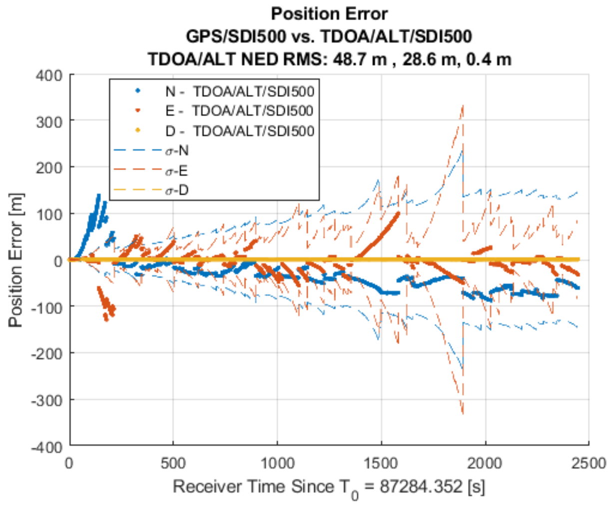

Fig. 21 PNT Scatter Performance versus GPS (GEO only)

IX. Conclusions

The PNTaaS solution has been shown to provide a cost-effective augmentation alternative to provide precision PNT in the absence of GPS. By leveraging a network connection, SATCOM signals can be used as Signals of Opportunity (SoOP) from existing constellations of satellites. The open architecture facilitates integration of new satellite constellations as they become available. Test results show that performance levels approaching GPS accuracies of horizontal accuracies of 4.9 m RMS (4.7 m North and 3.2 m East) can be achieved. The wide variety of frequencies that are available (L-band to Ku-band) and the hundreds of available GEO satellites and thousands of pLEO satellites that can be leveraged for PNT using the PNTaaS technology provides high levels of resilience in a congested RF environment.

NAVSYS is working with our commercial partners to integrate PNTaaS capability into their satellite infrastructure and to offer commercial SATCOM and A-PNT products to their customers. We are actively seeking additional partners interested in offering PNTaaS services and integrating A-PNT capability into their products by leveraging our SoOP Open Architecture PNT (SOAP) Software Defined Radio (SDR) technology.

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