TrakSat: Localization-Capable CubeSats **Symstemics / 101717**

Short description:
Unique location-determining service (using individualized per-CubeSat pseudorandomized number (PRN) code modulated L band carrier signals) provides SOF-controllable independent (from other infrastructure) hyper-local position determination for navigation and tracking.

Image:

iFigure

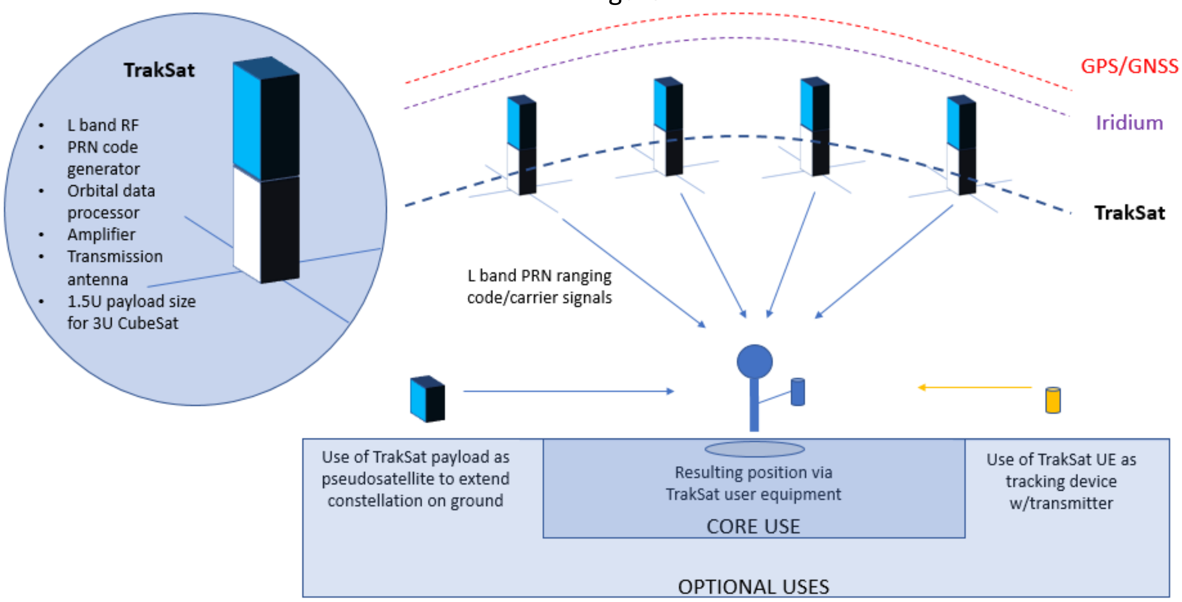

Figure 1 – The proposed TrakSat provides a SOF-controllable localizable position and navigation service in a 1.5U payload form independent of other national infrastructure assets.

Biography: Introduction, where from, based full time, ideal candidate for challenge
Temecula CA based / principal systems architect/engineer/technology director w/27+ years in military system architecture/development/design including navigation, communications, targeting, and weapon systems.

Problem overview / needs evaluation:
USSOCOM operations typically involve the insertion, support, and extraction of small (1-8+) teams in unique local environments and for lengthy periods without externalized support. Functions and capabilities required for most missions include (in no priority of order): power, communication, location (self and others), sensing/identification, targeting, strike, medical aid, transport, and logistics (supplies). In the support of SOF teams, existing global and tasked infrastructure elements such as the GPS constellation, military strategic and tactical radio networks, and select imaging and sensing assets are available for use; however, certain mission needs may often require additional visibility to certain assets (e.g. added navigational satellite vehicles/SVs to broaden coverage) or demand immediacy of access (e.g. commercial data links for video identification transmissions).

Regarding sensing and imaging, the ability to deploy immediately targetable (to a region or area) assets in sky (drone or SV) to detect movement or other in-area items of interest is a significant benefit. While national assets (local air/high sky/global) exist and are tasked for SOF operations, the use of compact sensing within CubeSat-deployable elements is of interest for rapid, localizable deployment. Currently, a global imaging program using 100+ CubeSats with high resolution cameras is in existence commercially, providing an option for future expansion. Beyond visual images, thermal and multispectral imaging is of the most utility to identify heat signatures (of in area participants or fires) and penetrate through foliage. At this moment, two potential sensors suitable for CubeSat use exist: one (from Goddard Space Flight Center) is a broadband array imager with 2 IR thermal detectors, optics, and diffuser sized to occupy 2/3 of a 3U CubeSat; the second (ESA) is a handheld-sized several hundred narrow bandwidth spectral sensor with supporting mirrors/optics suitable to fit in a 1U CubeSat. While interesting, both are low TRL in construction and require significant data compression and a supporting data transmission solution to communicate data in near real time while also incuring potential image stitching and additional image analysis (via undeveloped ground station facilities) prior to use.

Regarding communication, several approaches have been identified and utilized by SOF to extend access and availability of existing assets such as the use of Iridium for providing high bandwidth voice and data channels. The global visibility of Iridium's 66+ SVs and compact end user equipment enables a positive complement to existing tactical radio links by SOF teams.

Regarding positioning and navigation, the existing GPS constellation (and global GNSS systems by non-US entities) provides both commercial and military accessible precision positioning to most global locations. Similar to fielded tactical radios, GPS enabled end user equipment exists and is compact enough for individual team member use as well as tracking device elements that can contain both position determination and communication transmission elements.

Over time, the potential susceptibility of the GPS to localized jamming or spoofing (or to simply extend its availability in specific environments) has raised the interest in providing an augmentation system (either local or global) to help counter, aid, or in some cases supplant GPS. Iridium NEXT has implemented the STL service with precision timing (required for accurate distance estimation from SV to user) and range coding signal provision to act as a separate augmenting position, navigation, and timing (PNT) service. This is additionally beneficial due to the rapidly passing Iridium SVs at LEO (vs. GPS's MEO height) creating rapidly changing Doppler frequency effects that enable quick multiple carrier phase ambiguity selections (used in providing high precision range estimates via carrier signal phase vs. modulated codes) to provide highly precise position estimates in seconds. Additionally, the Iridium STL service operates in burst mode (compacting an initial set of carrier signals, SV codes, and operational data), enabling rapid derivation of position and time. The STL service is one-way (broadcast only), encrypted, and uses similar-to GPS QPSK modulation and operational elements. However, due to the unique signal and data structures, unique end equipment is required (essentially an Iridium handset with STL function chips).

All existing infrastructure elements (imaging, positioning, communications) are open to disruption and/or to limits in access or availability in some way, limiting their localized dependency to USSOCOM.

USSOCOM has already identified the utility and benefit of specific-to-SOF based assets including discrete tactical data and communications networks. The abilit to deploy locally-focused globally-deployable (from outside of theater) SV-based communications specifically for SOF operations has already been in exploration via USSOCOM's Prometheus program through the Office of Operationally Responsive Space (OSR) in which eight (8) 1.5U CubeSats with unique-to-SOF data/communication payloads have been launched and used since 2013.

A benefit of CubeSats to Iridium and other commercial services is the ability to select and optimize orbital insertions to maximize (for time and area) coverage of the desired function in a region of interest. An additional benefit is that CubeSats may operate in different LEO orbits, creating the opportunity for improved access (for communciations or navigation signals) using lower power when flying at lower LEO positions. One example is the existing Iridium STL provision that is able to transmit its ranging signal (for positioning) at a 300-2400x higher received power by terrestrial users while using less than ½ the transmission power of GPS.

Given the presence and prior (and current) experimentation by USSOCOM in CubeSats to provide specific-to-SOF imaging and communications possibilities, a valid new suggestion is to incorporate position determination that is GPS/GNSS/Iridium STL/existing infrastructure independent and can be extended to include SOF-specific ground pseudolites/PSVs or beacon elements used to either improve positioning further or to be used as tracking devices on assets of interest. Such a capability can be implemented simply via select frequency RF transmitter and antenna elements, PRN code generator, and pre-mission formulated orbital data and data block elements suitable for limited or (via updates) long term operation. The location-providing capability can have further benefits if translatable to existing user equipment (such as GPS/GNSS receivers), reducing the need for unique equipment to operate the system.

Solution:

The proposed TrakSat system utilizes a compact RF transmitter, PRN code generator, timing source, and orbital and signal data frame generator able to fit within a 1U CubeSat payload element (for a 1.5U component within a 3U CubeSat). For aiding GPS/GNSS or a ground network of PSVs, a single TrackSat providing time may be used; however, for minimal positioning (with no ground PSVs), at least 4 TrackSats would be required in orbit regionally for operation. Such a mission profile could be supported for small operational windows with 3-4 TrakSats and (depending on orbit selection) 6-8 TrakSats for extended windows.

Each TrakSat payload would transmit one signal (extendable to 2 or more) in available L band (between 1100-1900MHz avoiding existing GPS/GNSS/Iridium bands) with a unique PRN code per TrakSat payload or ground PSV. The code and supporting orbital data elements (ephemerides) are encrypted and modulated on the signal to create a low detectibility/high anti-spoof spread spectrum signal provided at sufficient power to enable a GPS/GNSS reception-level result from the TrackSat LEO positioning. The operational use can be controlled by SOF to either continuously or periodically (even event timed or burst) transmit, enabling its SOF-only availability and increase its covert utilization. The ephemeride/orbital data may be preloaded for short missions or updated via existing CubeSat uplink capabilities.

The on-space system includes a precision time source, L-band RF oscillator, PRN generator, navigation/ephemeride data FPGA/processor, related transmission power/amplifier electronics, and supporting helical transmission antenna. Power to the system is minimally impacting with an estimate of approximately 10W tapped from the existing CubeSat power bus. The user equipment (UE) system includes the reverse components of a L band antenna, LNA, signal oscillator and amplification, A/D, DSP, and associated processor for performing the PRN code correlation, carrier phase ambiguity determination and ranging, and resultant position determination including ephemeride decoding and use. The UE equipment can be cheaply constructed as a discretely operating device, battery powered, and compact enough to operate as a tracking module when coupled with a transmitting device of opportunity.

An optional consideration is the use of a translated receiver that converts the TrakSat L band signal to a GPS/GNSS frequency. Through correct selection of PRN codes and ephemeris conversion, the TrakSat signal could be translated and fed into a GPS/GNSS user equipment (UE) device that could perform correlation and resultant positioning, reducing the cost/impact of a specific TrakSat UE.

A second optional element could include the carrying of a TrakSat position generating payload via a ground vehicle, drone, or individual team member, enabling an additional location determination source (PSV) to either augment a limited visibility operational environment situation (cave/building/forest) or in the most extreme create a complete position constellation using at least one above-ground TrakSat. This concept is quite viable from proven GPS/GNSS efforts and the proposed compact generation capability of the TrakSat payload design.

<u>Size of proposed solution: U, mass/volume</u>
The TrakSat in-space payload components are intended to conform to a 1.5U payload volume and mass (10x10x15cm, ~1.9kg) constraint suitable for use on a 3U CubeSat. The in-space components include precision time source, L-band RF oscillator, PRN generator, navigation/ephemeride data FPGA/processor, related transmission power/amplifier electronics, and supporting helical transmission antenna.

<u>How does the proposed solution help SOF missions:</u>
As described, the provision of a SOF-controlled/accessible position determination service independent of any infrastructure elements (US or opportunistic) creates a highly available critical functionality for individual navigation and tracking use while minimizing spoofing or disability of existing services currently utilized. A viable-use constellation can be created with 3-4 rapidly deployed TrakSats, enabling fast response and use. LEO-based positioning enables higher power reception if designed correctly, increasing available signal strength and end use. Rapid LEO Doppler changes in frequency enable quick high precision carrier phase-derived range elements to be used for precision positioning. The simplicity of the design enables cheap UE development for individual use or use as tracking beacons when combined with transmission devices. The option for utilizing a translated approach enables the possibility for existing GPS/GNSS UE to be used to interact, saving fielded equipment funds. The option to deploy the compact TrakSat payload as a ground PSV/positioning source further extends the TrakSat service availability in difficult terrain, improving the overall utility of the service.

<u>Platform accomodation requirements for power:</u>
Power to the system is minimally impacting with an estimate of approximately 10W tapped from the existing CubeSat power bus.

Platform accomodation requirements for thermal control:
The proposed TrakSat in-space components can be included within a radiation-hardended payload shell common to the CubeSat payload system, minimizing thermal effects. Additionally, the proposed components are minimial in thermal generation due to effective electronics design and low power. The exposed component (antenna) is inert for thermal requirements.

Platform accomodation requirements for data transfer rate:
The proposed design suggests a similar-to GPS/GNSS data transfer rate of approximately 25-50 symbols per second for ephemerides/navigation data transmission. Uplinks for ephemeris updating is via the existing CubeSat medium bandwidth capabilities.

Platform accomodation requirements for data transfer volume per orbit:
See above. The proposed TrakSat payload is transmit-only (in this version), not requiring significant in-space bandwidth or data transfer considerations, only in the reception between each SV and UE.

Platform accomodation requirements for bus stability and attitude control:
The proposed TrakSat benefits from attitudinally-aligned (tangent of transmission antenna in orbital pattern to orbital tracking point on ground) SV positioning but is not critical. The emitted TrakSat footprint can radiate fairly broadly due to slight attitude variation given the individualized UE determination of real time ranging to each SV. The bus power is required to remain sufficient to enable a higher-than GPS/GNSS reception level at the ground UE position which is very broad.

Additional platform accomodation requirements:
The proposed TrakSat will require attachment and use of a transmit L band antenna in the ground/Earth facing surface of the CubeSat.

Solution implemented via state-of-art flight certified components or additional development:
The proposed in-space TrakSat components can be found today in suitable (when rad-hard payload shell surrounded) packaging via commercial entities. A most-compact discrete design can be rapidly developed to decrease volume. Sources can be provided by request.

Judging evaluation statements (25% each area):

Does the proposed solution advance the state of CubeSat technology?
Yes- There is no current localization/positioning capability propositions or functionality onboard CubeSats as described within.

Does the proposed solution advance SOF missions?
Yes – See above. An independently controllable positioning service with high precision and flexibility in constellation extendability (via in-space or on ground components) is a significant force multiplier for SOF in individual navigation and for localized tracking.

Is the proposed solution unique, stretches the bounds of science and engineering, and inspire a spirit of innovation?
Yes – The TrakSat combines the best of existing infrastructure elements from GPS/GNSS/Iridium into a SOF-specific service providing similar-to capabilities in a radically size/weight/volume/power reduced form suitable even for ground PSV operation at an individual level. The idea of translating the TrakSat receiver into a GPS/GNSS compatible UE for operational use is novel.

Is the proposed solution viable for a prototype demonstration within 12-24 months?
Yes – See above. The proposed design is simple and can be enabled with existing commercial components or a discrete design both for the in-space and UE device elements. Sources can be provided on request.

IP acknowledgement:
Yes

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