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TacSat-4: Military Utility in a Small Communication Satellite

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ABSTRACT

TacSat-4 is a Navy-led joint mission to augment existing Satellite Communication (SATCOM) capabilities and to advance the state of Operationally Responsive Space (ORS) capabilities. In September 2011 TacSat-4 launched from Kodiak Launch Complex in Alaska into a low Highly Elliptical Orbit (HEO). During the following 12 months, experimentation and formal utility assessment were performed. This operational testing allowed users from across the Department of Defense and other governmental agencies to use the capability. The spacecraft and operations were sponsor by Office of Naval Research and Office of Secretary of Defense with Naval Research Lab leading the execution. The ORS Office funded launch and was tasked by the Commander of United States Strategic Command to conduct a Joint Military Utility Assessment (JMUA) to support a transition to operations decision as well as future acquisition decisions. This paper provides a description of the TacSat-4 system and a summary of the testing performed including the results.

A primary objective of the TacSat-4 JMUA was to assess the use of small satellites to provide UHF SATCOM to support disadvantaged users in the tactical community. The TacSat-4 experimentation and JMUA activities performed to-date have shown TacSat-4's ability to provide SATCOM for a wide range of users and applications, using standard SATCOM equipment. Voice, chat, file transfers and other network applications were successfully performed. In addition to providing new SATCOM, the TacSat-4 program also advanced many elements of the ORS concept such as maturing the ORS bus standards, developing an enhanced Minotaur-IV+ launch vehicle capability, demonstrating the first long dwell orbit and mission for a small satellite, and developing highly automated command and control and mission planning systems.

SYSTEM DETAILS

Tactical Satellite 4 (TacSat-4) is a United States (US) Navy led joint mission to augment Ultra High Frequency (UHF) satellite communication (SATCOM) capabilities, and to advance Operationally Responsive Space (ORS) systems. The user mission, selected jointly at the Flag and General Officer level, is UHF SATCOM for underserved users and regions of the world. This includes users on the move as well as users in challenged environments such as mountainous or hi-rise urban areas. The science and technology mission objectives are to advance spacecraft bus standards, achieve a long-dwell low-earth orbit for a relatively low-cost mission, demonstrate effective command and control automation, increase mission planning automation and user access, and mature multiple spacecraft technologies.

The TacSat-4 space vehicle (SV) is comprised of the ORS Phase III Standardized Bus (Phase 3 Bus) and the "COMMx" payload, Figure 1. The Phase 3 Bus was jointly designed and built by the Naval Research Laboratory (NRL), and the Johns Hopkins University (JHU) Applied Physics Laboratory (APL). The NRL designed and built the COMMx payload. A separate group, the Integrated System Engineering Team (ISET) consisting of representative from industry, academia, and government organizations, produced a set of standards for an ORS system. The standards produced include "Mission Requirements and Concept of Operations (CONOPS) for the ORS Missions," "General Bus Standards," "Payload Developers Guide," and "ORS Standard Data Interfaces: Bus to Payload, Bus to Ground." The Phase 3 Bus was designed and

built to these standards, which state that a "standardized bus" provide services required by a typical spacecraft such as attitude control, power, propulsion, and telemetry, tracking and commanding (TT&C). The COMMx payload was designed and built to a preliminary version of the Payload Developers Guide. Tacsat-4's prototype bus and payload provided feedback to the standards which were updated accordingly based on the lessons learned from these first builds.

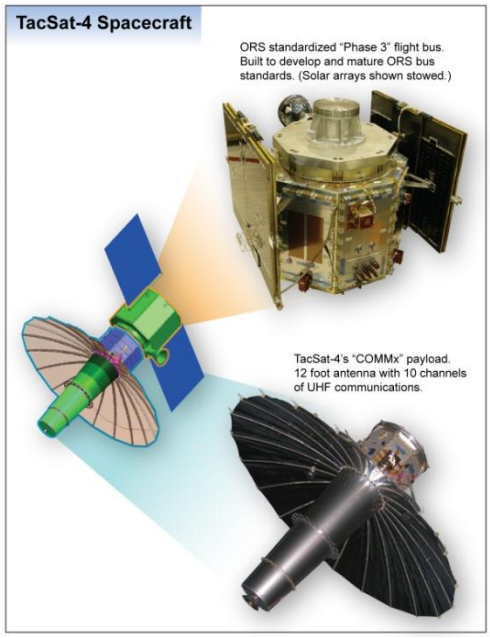

Figure 1: TacSat-4 Spacecraft

The TacSat-4 SV is a small class (450 kg, 1000W) spacecraft flying in a low, highly elliptical orbit (HEO) with a four-hour period. The payload provides channels of UHF capability for communications-on-the-move (COTM), friendly (blue) force tracking (BFT), and data exfiltration (Data-X). Ten channels are designed into the payload but on-orbit operations are limited to less than 5 channels due to thermal loop-heat pipe failure. The high gain payload enables COTM for legacy radios and low power Data-X sensors. The payload also allows for experimentation with advanced communications including voice and data over SIPRNET, bridging multiple communication channels, and flexible channel selection and theater support. Flexible up and down channel assignments improve the ability to operate in busy environments. The 24-hour tasking cycle allows for dynamic reallocation to different theaters worldwide if necessary. The HEO provides a long-dwell capability (2+ hours per pass) at higher latitudes, better support to mountainous and urban areas than geostationary orbits, and near global, but not continuous, coverage. Continuous coverage over multiple theaters of interest can be accomplished with a HEO constellation of three to six spacecraft depending on the location.

Command and control of the spacecraft is performed by NRL's Blossom Point (BP) Tracking Facility, and mission planning is handled via the Virtual Mission Operations Center (VMOC™), Figure 2. Once the initial spacecraft checkout phase was completed, BP transitioned to an automated process for most of the TacSat-4 command and control function. VMOC™ is a highly automated, Secret Internet Protocol Router Network (SIPRNet) based, mission planning system. VMOC handles all of the tasking, scheduling, and channel allocations for the TacSat-4 mission.

Figure 2: Blossom Point Tracking Facility

JOINT MILITARY UTILITY ASSESSMENT

The TacSat-4 experimentation and JMUA activities performed have shown TacSat-4's ability to provide SATCOM for a wide range of Users and applications, Figure 3. Successful SATCOM was achieved for soldier-to-soldier, USCG ship-to-ship, USCGC ship-to-comms station, USCG Cutter-to-SIPRNet, Marine-to-network, Marine-to-High Mobility Multipurpose Wheeled Vehicle (HMMWV), ship-to-Marine, and sub-to-shore. All testing used standard SATCOM equipment. Voice, chat, file transfers and other network applications were successfully performed.

Figure 3: Broad range of platforms tested during TACSAT-4 JMUA to validate capability

SPAWAR tested to verify TacSat-4 SATCOM support the MIL-STD-188-181. Military radios must comply with this standard. SPAWAR's carrier-to-noise and bit-error-rate testing confirmed that TacSat-4 does provide SATCOM supporting this military standard.

SMDBL tested multiple voice and data configurations and proved on-the-move performance even in the steep valleys of Colorado's Pikes Peak region. SMDC also provided the most extensive use of the VMOC which led to many user enhancements throughout the year and more going forward. Soldiers as far south as Kwajalein (~11 degrees latitude) successfully used TacSat-4 for planned training.

Figure 4: Successful SATCOM test in rough terrain and weather during JMUA

The USCG has demonstrated experimental and operational use of TacSat-4 on several of their cutters and their helicopters. USCG added a network ground terminal at the Kodiak Communication Station (COMMSTA) which enables SIPRNET voice and data communications to ships in the Bearing Straights all the way back to their Alameda California station. USCG has tested TacSat-4 with Cutters JUNIPER, HEALY, ALEX HALEY, HICKORY, MUNRO, BERTHOLF, SYCAMORE (voice), and SPAR (voice). Many of these have had SPAWAR's SATCOM "Fly Away Kits" installed on them as well. The USCGC Healy even used TacSat-4 while returning from its escort and ice breaking mission assisting a Russian tanker in delivering emergency fuel to Nome Alaska, Figure 5.

Figure 5: Successful SATCOM test in Arctic with the USCGC Healy after mission to Nome, Alaska

The CYBERFOR/NWDC successfully tested TacSat-4 in Trident Warrior 2012. In Trident Warrior, the amphibious assault ship, USS Essex (LHD 2) used TacSat-4 while underway to talk to Marines ashore at the Marine Corps Tactical Systems Support Activity in Camp Pendleton and the 3rd Marine Regiment located on Marine Corps Base Hawaii. Marines ashore were afoot and in a HMMWV equipped with 'eggbeater' omni-antenna using standard PRC-117F/G radios,

Figure 6. The ship's SATCOM system, the WSC-3 and OE-82 antenna, as well as the Marines' on-ship PRC-117F radio in the Landing Forces Operations Center attached to the ship's Enhanced Manpack UHF Tactical Conical Logarithmic Spiral Mobile Antenna were used. Marines ashore also used TacSat-4 SATCOM to communicate with a simulated Forward Operating Base (FOB) network for Voice over Internet Protocol (VoIP), chat and file data transfers. A fielded TacSat-4 Portable Ground Terminal (PGT) enabled this SATCOM to network interface; the PGT uses the same components as in deployed systems. Finally sub-to-shore communications was demonstrated between the USS Olympia (SSN 717) and the shore-based network operations center.

Figure 6: COMMS on the Move testing begins

Both Army and Navy operational communications trainers also verified TacSat-4's SATCOM capabilities. They found stronger than normal SATCOM signal consistent with other measurements. Their primary interest was augmentation of training since use of current SATCOM systems is often difficult as they are over tasked.

The US Air Force (USAF) CEASE payload, a radiation experiment, is showing proton radiation levels in TacSat-4's orbit are an order-of-magnitude higher than the models had predicted and previously known to exist.. Conversely the TacSat-4 CEASE data is showing that electron radiation is lower by an order-of-magnitude. The USAF and US Navy are using this information to update the AP-9 and AE-9 radiation models which are used broadly worldwide. In addition to the allow radiation updates, the solar cell degradation in this high proton environment allows new understand of the degradation behavior and survivability of triple-junction solar cells.

The major recommendation from the Joint Military Utility Assessment was to consider a follow-on operational constellation to augment the current geosynchronous UHF SATCOM. The performance of the single TacSat-4 satellite was extrapolated via M&S to estimate the capabilities of an operational satellite (OPSAT) constellation of small, responsive satellites during the JMUA. For 24/7 coverage in the high northern latitudes Artic this would be 4 spacecraft if the argument of perigee is rotated to peak at 63.4 degree instead of 28 degrees as TacSat-4 does. For broader global access, to two or three selectable theaters, consider a 6 satellite constellation. A six-ball constellation placed correctly could provide 22.3 hours of coverage any theater globally. In addition, the ITU filing is complete for a follow-on constellation of up to 6 satellites continuously for the next 40 years.

TRANSITION TO OPERATIONS

The Commander, USSTRATCOM has the authority to transition TacSat-4 to operations if certain criteria are met including demonstrated military utility, Operations & Maintenance funding source, and an executable operational concept of operations. The United States Strategic Command J6 decided not to pursue transition to operations of the TacSat-4 satellite due to the lack of a funding source. While TacSat-4 did not transition to operations, the capability demonstrated and the unique benefits inherent in the mission design will provide benefits to the government for years to come. Transitioning experimental missions to operations is difficult and rare due to many factors necessary to ensure reliability for the warfighter. TacSat-4 met the standards for transition but due to economic factors will remain an experimental satellite available for use with additional funding.

CONCLUSION

The TacSat-4 mission delivered successful flight hardware for on-orbit test, evaluation, and military utility assessment. This small (450kg) satellite demonstrated SATCOM performance that matches or beats current geosynchronous satellite in terms of radio frequency link margin; for voice TacSat-4 is at least two times (3 dB) stronger and for all uplink signals it is at least 4 times (6 dB) stronger. The program also demonstrated many elements of the ORS concept such as maturing the ORS bus standards, developing an enhanced Minotaur-IV+ launch vehicle capability, demonstrating the first long-dwell orbit and mission for a small satellite, and highly automated command and control as well as mission planning. The spacecraft is currently on orbit and available for experimentation

through the end of September 2013. While the experimental portion of TacSat-4 was very successful, the fiscal challenges prevalent today prevented a transition of the capability to operational status. Follow-on efforts have been studied and should the need arise a TacSat-4 like constellation could be procured and provide utility to any number of users. In addition, the ITU filing is complete for a follow-on constellation of up to 6 satellites continuously for the next 40 years.

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