U.S. Army Space and Missile Defense Command (SMDC) Nanosatellite Program (SNaP)-3

Joint Capability Technology Demonstration (JCTD)

Concept of Operations (CONOPS)

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Executive Summary

The U.S. Army Space and Missile Defense Command (SMDC) Nanosatellite Program (SNaP)-3 will help pave the way toward assured global access to communications for the disadvantaged tactical user, particularly while on the move. SNaP-3 will provide the United States Southern Command (USSOUTHCOM) and Partner Nations (PNs) with Beyond Line-of-Sight (BLOS) communications and Unattended Ground Sensor (UGS) data exfiltration capabilities using three nanosatellites in a Low-Earth-Orbit (LEO) constellation. These nanosatellites will provide communications capabilities supporting voice, text, and data device connectivity for remote users in the USSOUTHCOM Area of Responsibility (AOR).

The SNaP satellites will have the capacity for storing up to three communications waveforms, and providing compatibility with AN/PRC-117 and AN/PRC-152 radios, as well as all other radios conforming to MIL-STD-188-181B. A ground station will provide Command & Control (C2) of the satellites and relay of collected data from UGS gateways, providing Situational Awareness (SA) at the tactical level.

SNaP supports the USSOUTHCOM goal of multi-layered surveillance by enabling ground-level detection and monitoring capability through double- or triple-canopy foliage with BLOS data collected from UGS. When fully implemented, SNaP will provide both U.S. and PN Warfighters with reliable and actionable SA in an environment that previously provided very limited BLOS communications for the dismounted warfighter.

The true innovation of SNaP is the ability of tactical commanders to directly control and access LEO assets for immediate support to remote users in complex and dynamic environments. A full constellation of affordable and responsive SNaP-like platforms in LEO providing a spectrum of communications and remote sensing capabilities would significantly enhance the connectivity and awareness of remote ground forces and have a profound effect on the nature of distributed ground operations.

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1.0 Overview

> **concept of operations** — A verbal or graphic statement that clearly and concisely expresses what the joint force commander intends to accomplish and how it will be done using available resources. Also called **CONOPS**.
>
> Joint Pub 1-02, *Department of Defense Dictionary of Military and Associated Terms*, 8 November 2010 (As Amended Through 15 June 2015)

1.1 Purpose

This Concept of Operations (CONOPS) provides broad guidance to people and organizations on the use of the capabilities provided by the U.S. Army Space and Missile Defense Command (SMDC) Nanosatellite Program (SNaP)-3 Joint Capability Technology Demonstration (JCTD), sponsored by the U.S. Southern Command (USSOUTHCOM). This CONOPS does not provide detailed training on the mission management of SNaP-3, nor on the systems that connect to SNaP-3. That information is available separately.

1.2 Scope

This CONOPS provides foundational considerations and information for leveraging the communications capabilities provided by SNaP-3. This CONOPS is presented in a general form so as to be applicable to a broad range of users and missions, but also provides a limited set of example scenarios for amplification. This CONOPS is not authoritative, but is meant to guide the user by providing suggested best practices. This CONOPS does not address the doctrinal aspects of the missions that SNaP-3 can support, but defers to authoritative publications for that guidance.

1.3 How to Use This CONOPS

If you need to get started quickly, go directly to Sections 4 (Planning) and 5 (Operations). Otherwise, you should read through the document sequentially to fully understand the suite of SNaP-3 capabilities. The document is organized as follows:

- Section 2 (Operational Problem and Requirements) provides some background into the operational problem that validated the SNaP-3 JCTD, as well as the operational requirements that SNaP-3 was designed to address;
- Section 3 (Capabilities) provides an overview of the capabilities of SNaP-3;
- Section 4 (Planning) provides considerations for planning and preparing to employ SNaP-3 in an operational context; and
- Section 5 (Operations) provides a description of how SNaP-3 integrates into ongoing operations. The most concise description is given in Table 3, towards the end of Section 5.

2.0 Operational Problem and Requirements

2.1 Operational Problem

U.S. and Partner Nation (PN) forces are frequently deployed to remote areas with little infrastructure. Underserved regions lack vital beyond line-of-sight (BLOS) data and communications capabilities to serve terrestrial tactical users. When operating over great distance or in rugged terrain, tactical users cannot maintain radio line-of-sight (LOS). This creates gaps in situational awareness, increasing the possibility that threat or criminal activity goes undetected, unmonitored, unreported, and un-actioned. Tactical users operating in these regions have limited—or in some cases no—organic BLOS communications connectivity. In addition, the exfiltration of unattended ground sensor (UGS) data frequently requires friendly forces to expose themselves in order to get sufficiently close to the sensors to receive a signal, and may provide a tip-off to unfriendly forces. Furthermore, Combatant Commands (CCMDs) have no agile means to directly improve BLOS communications capabilities in response to operating environment dynamics.

A space-based network of low-cost communications satellites interfacing with current generation U.S. tactical radios (i.e., AN/PRC-117, AN/PRC-152) and PN tactical radios can provide critical BLOS communications. BLOS-enabled satellite communications ground terminals, however small, do not provide a means to operate effectively in rugged, mountainous, and jungle environments. These critical BLOS communications are normally enabled with heavier, higher-power radio ground communications systems or with commercially leased capabilities that are too cumbersome for tactical terrestrial formations operating in these environments. A constellation of low-cost communications satellites would enable networked UGS systems data exfiltration with no mission tip-off and no friendly forces exposure.

2.2 Operational Requirements

USSOUTHCOM and its security partners require persistent, secure, reliable, BLOS communications and data exfiltration in remote regions and through triple-canopy foliage. Critical technical objectives to be addressed include:

- Compatibility with the AN/PRC-117 and AN/PRC-152 tactical radios, as well as radios conforming to MIL-STD-188-181B[1];
- Store and forward of data from UGS via gateways using the Space and Missile Defense Command-Operational Nanosatellite Effect (SMDC-ONE) radio frequency (RF) module;
- Bridge between various compatible radio systems; and
- Scalability to a constellation providing continuous coverage in specified regions.

[1] Copies of the various MIL-STD-188 documents can be found by searching at https://assist.daps.dla.mil/quicksearch/

3.0 Capabilities

The SNaP JCTD will deliver the following systems:

- Three SNaP-3 satellites with directional antennae and Software-Defined Radios (SDRs);
- Three Satellite Command & Control (C2) Ground Stations (GSs) without Type-1 encryption; and
- One Satellite C2 GS with Type-1 encryption.

SMDC will provide additional support through its Satellite Operations Center (SOC).

3.1 Satellites

Each SNaP-3 satellite is a 3U[2] nanosatellite with dimensions of 10cm x 10cm x 34cm and a weight of approximately 5.3 kg. The initial SNaP-3 system will consist of three identical SNaP-3 satellites. Following a successful operational demonstration, USSOUTHCOM will advocate for a full constellation of satellites to provide near-continuous coverage throughout much of the USSOUTHCOM Area of Responsibility (AOR). A design drawing of a SNaP-3 satellite with communications antennae and solar array panels deployed is shown in Figure 1.

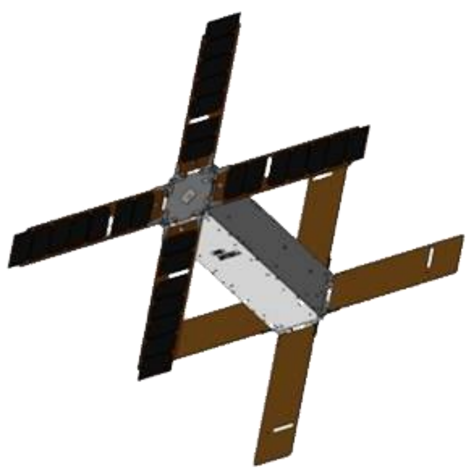

Figure 1. Design Drawing of SNaP-3 Satellite

Each SNaP-3 satellite consists of:

- Solar cell arrays for energy collection;
- Batteries for energy storage;
- Directional antennae with 100° beam width for ground communications with 6dB link margin at 10° elevation for a minimum of 56 kbps service for 250 simultaneous text message users and data exfiltration;

[2] A 1U Cubesat is a standardized type of nanosatellite that is a 10cm cube. A 3U Cubesat consists of three 1U sections integrated into a single Cubesat. More information is available at “CubeSat Design Specification Rev. 13”, California State Polytechnic University (http://cubesat.calpoly.edu/images/developers/cds_rev13_final.pdf).

- Orientation capability to point the antenna for increased reliability, as well as to point the solar cell array for more effective energy collection and charging of the batteries;
- Propulsion for orbital injection and station-keeping;
- Attitude Control System (ACS) for satellite orientation to support ground communications and solar cell array recharging;
- Satellite control system; and
- SDR for:
  - Communications relay between tactical radios;
  - Data collection from UGS; and
  - C2 from both the Ground Stations and the SOC.

Two critical aspect of the satellites are that:

- Each satellite can service a single communications link at a time; and
- The satellites do not relay communications along the constellation, so both the sending and receiving station must be in the communications footprint of the same satellite.

Additional technical information on the satellites include:

- Enough battery power for three orbits with one 9-minute radio transmission (reception uses less power) per orbit, followed by one orbit to re-orient the solar cell array and re-charge the batteries;
- Compatible with Blue Force Tracking (BFT), to include Personnel Recovery Emergency Beacons;
- Data Encryption using 256-bit AES with optional Type 1;
- Operational life of no less than two years;
- Radiation mitigation with key components and subsystems tested to >10 krad total dose; and
- Global Positioning System (GPS) onboard with ±15m position knowledge.

3.2 Orbits

The SNaP-3 satellites were launched as a secondary payload on a National Reconnaissance Office (NRO) mission, and are in a slightly elliptical Low Earth Orbit (LEO) with the following parameters:

- Apogee of approximately 808 km altitude;
- Perigee of approximately 503 km altitude; and
- Inclination of approximately 65°.

Following successful technical check-out, the satellites will be maneuvered to have phasing of 40° between satellites in the orbital plane.

These parameters produce an orbit with the following characteristics:

- Semi-major axis of approximately 655 km altitude;
- Eccentricity of approximately 0.0217;

– Orbital period of approximately 97.7 minutes; and
– Satellite ground footprint (i.e., the area on the surface of the Earth that can "see" the satellite at any given moment) of approximately[3] 18.6–28.7 million km^2.

The times of satellite visibility will change on every pass, will change every day, and are a function of the user's latitude and longitude. The long-term average visibility of the satellites will vary by latitude. The user will usually experience two successive passes, separated by about 97.7 minutes from the beginning of each pass. Usually each set of two passes are separated by about 12 hours from the beginning of each set of passes. Each pass during which the satellites are visible will be of varying duration, with gaps between each of the three satellites.

Essentially, the orbits will provide coverage that: varies from pass-to-pass; varies day-to-day; and varies according to the location of the user. The most difficult—and most critical— aspect of leveraging the operational capability of SNaP is constant coordination between the remote users and the GS to ensure that the remote users know the time windows during which the system supports communications. Figure 2 shows an example of the satellite footprint for the three-orbit constellation with a 10° elevation above the unobstructed horizon[4].

It is critical to understand that the circles shown in Figure 2 represent the locations on the Earth that can view the satellites with an elevation of at least 10° above an unobstructed horizon. Local terrain could preclude satellite visibility within the circle. It is also critical to understand that the antenna on the satellites only generate sufficient power within a 100° beam width, which further reduces the effective footprint for assured communications. Figure 3 illustrates this relationship by showing three different footprints for a satellite altitude of 720 km. These footprints represent, from largest to smallest:

– The locations on the surface of the Earth that can see the satellite with an unobstructed horizon, or "Satellite footprint";
– The locations on the surface of the Earth that can see the satellite with a minimum elevation of 10° above an unobstructed horizon, or "Footprint for minimum elevation"; and
– The locations on the surface of the Earth that are within the 100° beam width of the satellite antenna for a nadir-pointing beam, and thus able to get sufficient power for assured communications, or "Antenna footprint".

[3] The ground footprint varies with the satellite's altitude; it is largest at apogee and smallest at perigee.
[4] The satellites require a minimum of 10° elevation above an unobstructed horizon in order to ensure reliable communications.

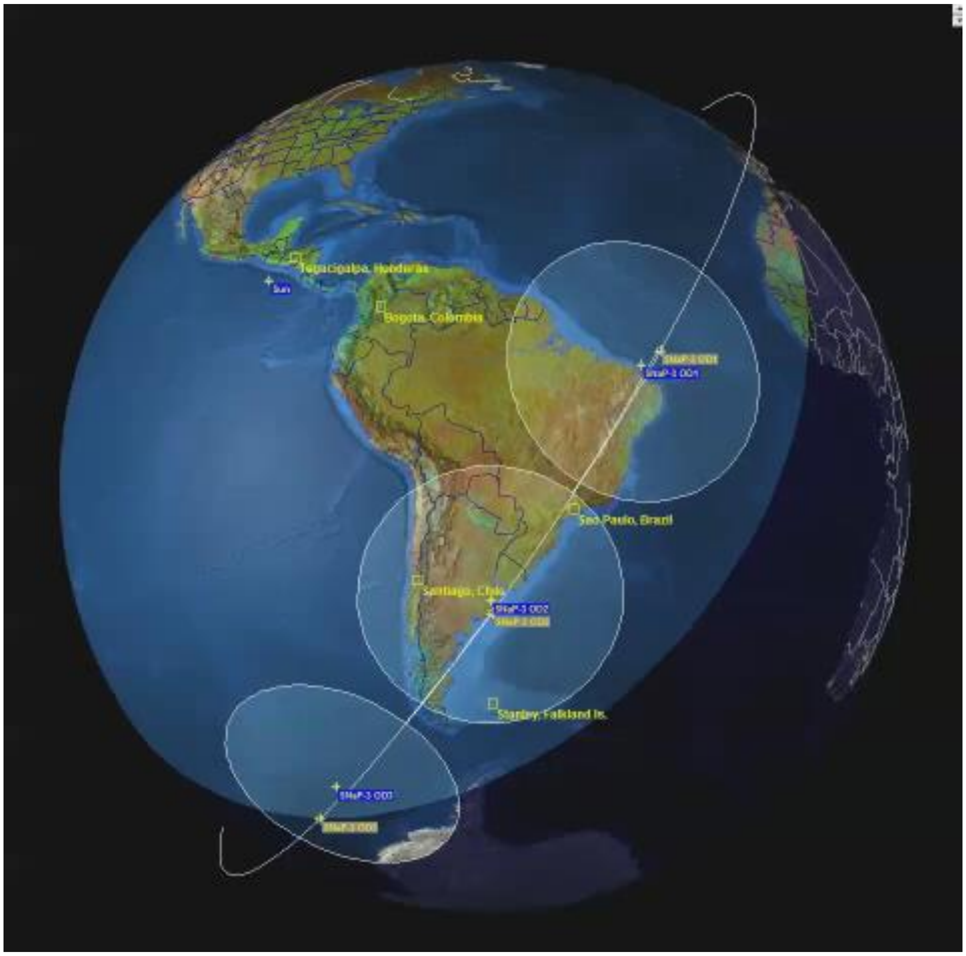

Figure 2. Example Satellite Footprints for the Three-Orbit Constellation with a 10° Elevation

All three footprints are centered over Brasília, Brazil, for reference. As apparent in Figure 3, the area within which users can expect reliable communications is significantly smaller than the area from which users can view the satellite. The satellite can maneuver the antenna footprint anywhere within the satellite footprint, but communications are only assured when the antenna footprint is within the footprint for minimum elevation.

Over the long-term, the average percentage of total time each day that the satellites will provide coverage is shown in Figure 4 for four cities in the USSOUTHCOM AOR. From Figure 4 it is clear that the expected orbits will provide the greatest coverage to latitudes close to 54.5° North or South, with fairly consistent coverage for latitudes between 30° North and 30° South. The curves in Figure 4 will vary according to the inclination of the final orbits as well as the eccentricity. Within the USSOUTHCOM AOR, the average total time for satellite support will vary from about one hour and five minutes up to about two hours and thirty minutes per day.

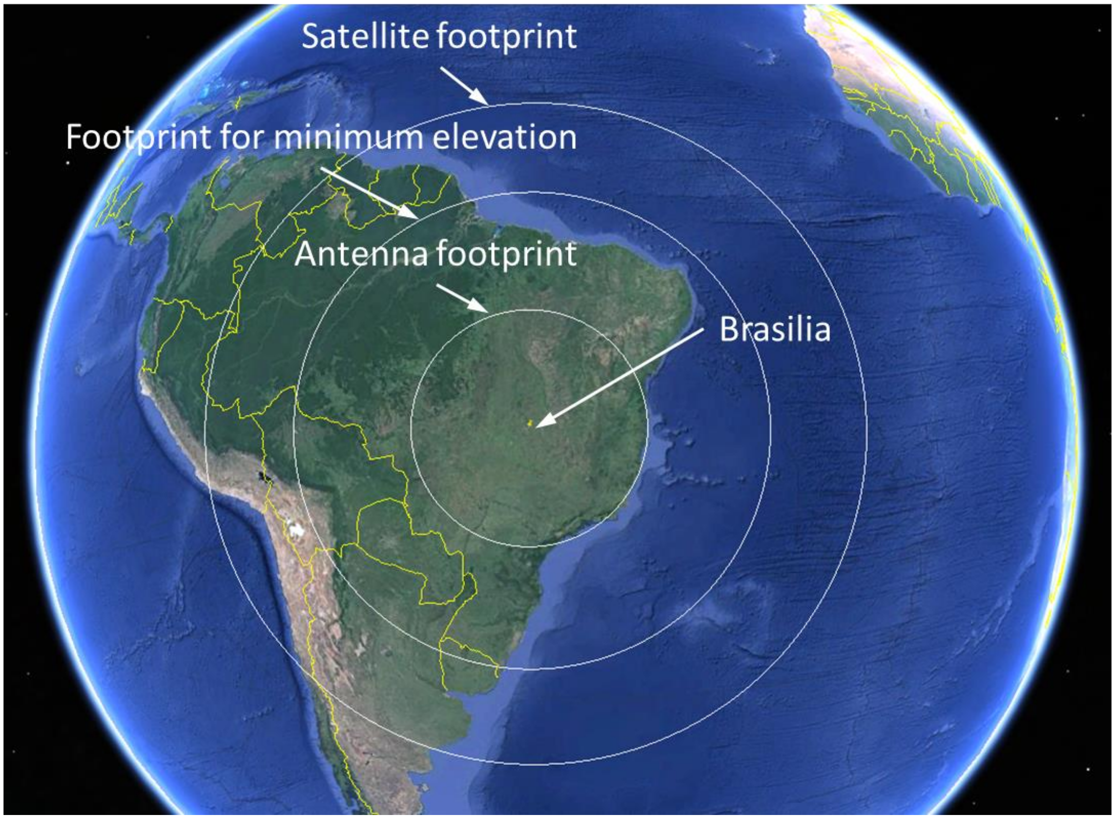

Figure 3. SNaP-3 Satellite Footprints

Average times in hh:mm, for inclinations of 63° and 66°

Bogotá, Columbia 4.6°N
1:05 – 1:03 per day

Tegucigulpa, Honduras 14.1°N
1:07 – 1:05 per day

São Paulo, Brazil 23.6°S
1:13 – 1:10 per day

Santiago, Chile 33.5°S
1:24 – 1:20 per day

Stanley, Falkland Is. 51.7°S
2:33 – 2:27 per day

Maximum visibility 54.5°N/S
2:35 – 2:37 per day

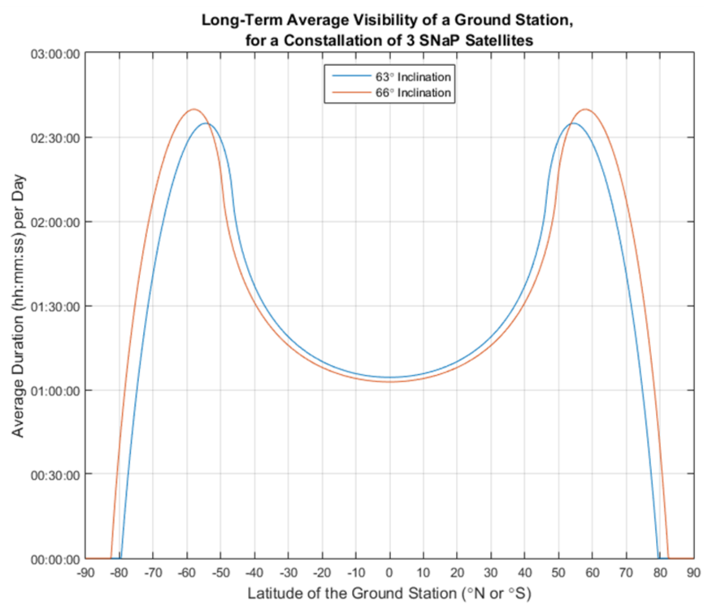

Figure 4. Long-Term Average Visibility per Day for a Three-Satellite Constellation

3.3 Software-Defined Radios (SDRs)

The SDR in the SNaP-3 satellites provides four critical functions:

– Relay of voice communications between users, all of whom are within the antenna footprint of the same SNaP-3 satellite;
– Relay of text communications between users, all of whom are within the antenna footprint of the same SNaP-3 satellite;
– Store-and-forward of data from UGS and UGS gateways to any GS within the antenna footprint; and
– Communications with any GS in the satellite footprint for C2 and health of the satellite.

U.S. tactical users will use the AN/PRC-117 or the AN/PRC-152 radio to communicate via voice to other users. These radios may be handheld, man-packed, or mounted (i.e., vehicles, aircraft, watercraft), and will use a satellite communications (SATCOM) Omni-Directional Antenna known as the "Nightstick" Antenna. The SNaP-3 satellite SDR will support the waveforms shown in Table 1. Tactical units will select the preferred waveform from this table. U.S. forces will use encryption to secure all communications. The encrypted communications will be relayed by the SNaP-3 Satellite to the intended user. U.S. users may also use the Harris 5800 Series and Harris 7800 Series exportable radios when operating with Partner Nation (PN) forces. PN units may use their own radios as long as they conform to MIL-STD 188-181B and are using one of the waveforms in Table 1.

Narrowband Modulations (5kHz BW) from MIL-STD-188-181 Table III							
Recommended For	**Priority**	**Option**	**I/O data rate (bps)**	**Modulation Type**	**Coding**	**Inter-leaving**	**Modulation Rate**
Voice, Data, Text (SBPSK)	2	10	2400	BPSK or SBPSK	None	None	2400
Voice, Data, Text	1	13	4800	CPM {12/16, 13/16}	None	None	2400
Voice, Data, Text	1	14	4800	CPM {7/16, 10/16}	RS:e=6[60.48]	Yes	3000
Data, Text	3	21	9600	CPM {5/16, 6/16}	None	None	4800

Wideband Modulations (25kHz BW) from MIL-STD-188-181 Table VIII							
Recommended For	**Priority**	**Option**	**I/O data rate (bps)**	**Modulation Type**	**Coding**	**Inter-leaving**	**Modulation Rate**
Voice, Data	1	132	16,000	FSK	None	None	16,000
Data	2	140	32,000	CPM {5/16, 6/16}	RS:e=10[126,105]	Yes	19,200
Data	2	141	32,000	CPM {6/16, 7/16}	None	None	16,000
Data	1	145	56,000	CPM {4/16, 5/16}	None	None	28,000

Table 1. Narrowband and Wideband Modulations

3.4 Ground Stations

The SNaP-3 GS is a transportable system consisting of the following three major components to allow for quick set-up in the field:

- Ultra-High Frequency (UHF) Antenna Assembly;
- Main Enclosure Assembly (MEA); and
- Ground Station Laptop (GSL).

Figure 5 provides a graphical illustration of the GS components.

The UHF antenna assembly consists of 2 UHF SATCOM antennas, a Low Noise Amplifier (LNA), a Pan/Tilt unit, a Tripod/Mast, and a Crossbeam. The antenna assembly requires a 15' x 15' level surface with clear line-of-site to at least 10° above an unobstructed horizon. This ensures more than sufficient stand-off distance to prevent potential RF radiation of local personnel; at full power, the safe stand-off range for these antennas is less than six inches. The antenna mast is designed for deployment in two positions: short and elevated height. If the line-of-sight permits, the short position is recommended for ease of antenna set-up and increased stability. The most optimum and stable configuration for the antenna assembly is at the discretion of the operator based on the anticipated length of installation, line-of-sight to horizon, and wind. The antennas must be aligned with True North, and the latitude, longitude, and elevation will need to be surveyed at time of installation. The use of a hand-held compass and GPS receiver is sufficient. The antenna pan/tilt unit requires a power supply of 120V/15A, 60Hz.

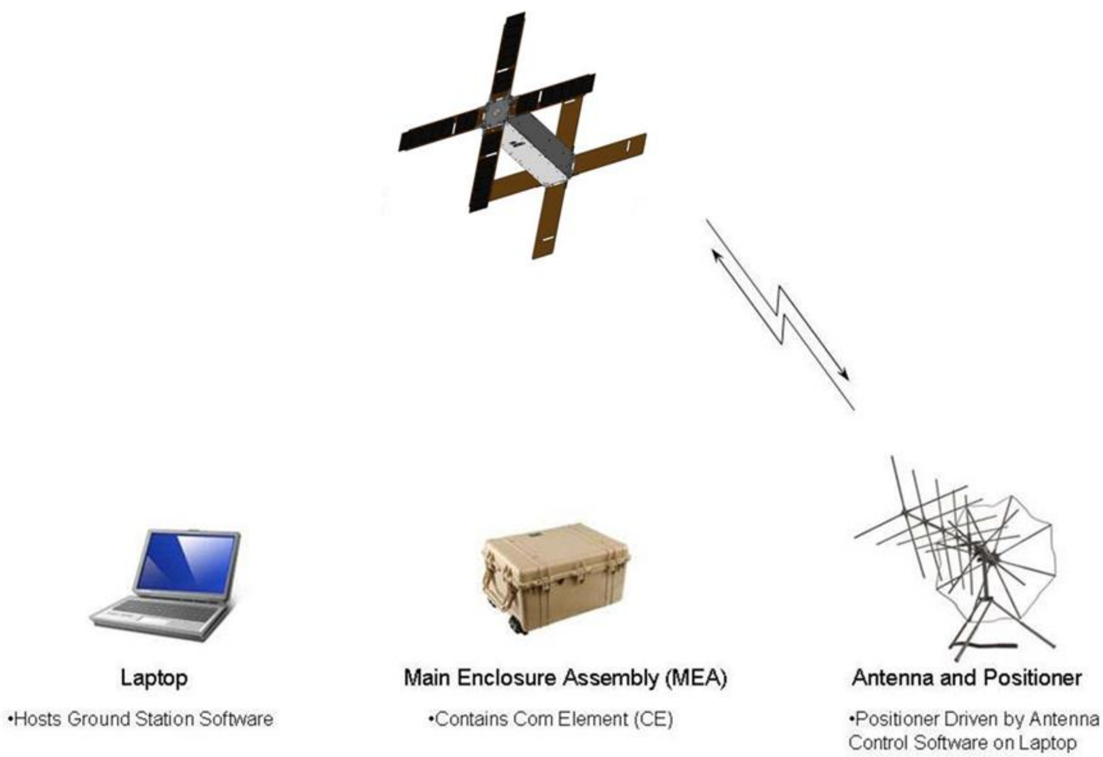

Figure 5. SNaP Space and Ground Segments

The MEA consists of a single Pelican case that contains an internal SNaP communication element (CE), power supply, network switch, and all required RF front-end equipment. The MEA is a self-contained SATCOM radio/modem for the Command and Control (C2) of the SNaP spacecraft. The

MEA provides the interface between the user interface hosted on the GSL and the RF input to the antenna assembly. The MEA requires 120V/15A, 60Hz power, but two 12V vehicle batteries can be used for remote operations. The MEA is ruggedized for extended out-door operations and should be sheltered, when possible.

The GSL is the man-machine interface for the GS to the satellite. It provides the host SMDC GS software used for C2, as well as the tracking software to control the UHF Antenna Assemblies Pan/Tilt unit. WXtrack[5] is an open source software package currently used for Pan/Tilt Control. There are two versions of the GSL available, but only one is ruggedized for extended outdoor operations. There are protections in place to discourage damaging commands from being issued by the GS to the satellite, but all users are capable of altering or otherwise compromising the capability of SNaP to perform its mission. As such, only trained operators should be allowed access to the GSL.

3.5 Satellite Operations Center

SMDC will provide monitoring and health and service support to the SNaP-3 satellites from the SMDC SOC. The scope and purpose of those operations are to ensure the continued availability of SNaP-3 operations, and should be completely transparent to the CONOPS.

4.0 Planning

This section addresses planning considerations for the development of plans that utilize SNaP-3 as part of the execution.

Effectively employing the capabilities of the SNaP-3 JCTD requires that planners consider the following primary factors when planning to utilize the SNaP-3 capabilities:

- The SNaP-3 satellites are single-channel relays that can only handle a single user transmission at any one time;
- The SNaP-3 satellites do not provide intra-orbit relay, so the sender and receiver of a SNaP-3 transmission must be in the antenna footprint of the same SNaP-3 satellite;
- The SNaP-3 satellites will provide short windows of coverage;
- The duration of these windows of coverage will vary from less than one minute to no more than about 12 minutes;
- The times and durations of these windows of coverage will vary throughout the day, but will generally occur in groups of two windows separated by about 90 minutes;
- These groups of windows will have a coverage gap of about 12 hours between each group;
- The times and durations of these windows of coverage will vary from one day to the next;
- The times and durations of these windows of coverage will vary according to the latitude and longitude of the remote stations, and will change as the users move;

[5] WXtrack is available at http://www.satsignal.eu/software/wxtrack.htm.

- The remote stations must be close enough to both be in the same antenna footprint of a single SNaP-3 satellite at the same time;
- The GS must be within the antenna footprint with each remote station in order to communicate with that remote station (i.e., transmit new tables for satellite visibility, or relay UGS data); and
- The GS must direct each SNaP-3 satellite to point its antenna to a ground location between the two remote stations to ensure reliable communications.

It is critically important to understand that the size of the antenna footprint for reliable communications is smaller than the footprint of the satellite itself. Table 2 provides values for the ground footprints of: the satellite at 0° elevation; the satellite at 10° elevation; and the antenna. These values are shown for the satellite at both the expected apogee of 808 km altitude and the expected perigee of 503 km altitude.

Table 2 clearly demonstrates that the distance and area over which the antenna can provide reliable communications is far less that the footprint of the satellite itself. As such, the remote users—to include the GS—can be no further apart than about 1,200–2,100 km, depending on the altitude of the satellite.

Footprint Type	Diameter (km)	Surface Area (km^2)
Satellite at Apogee (808 km) with 0° elevation	6,104	28,704,000
Satellite at Apogee (808 km) with 10° elevation	4,242	14,006,000
Antenna at Apogee (808 km)	2,152	3,629,000
Satellite at Perigee (503 km) with 0° elevation	4,905	18,662,000
Satellite at Perigee (503 km) with 10° elevation	3,139	7,697,000
Antenna at Perigee (503 km)	1,277	1,280,000

Table 2. Satellite and Antenna Footprint Comparison

Figure 3 is repeated here as Figure 6 to further highlight the difference between the satellite footprint and the antenna footprint. (The satellite altitude used for Figures 3 and 6 is 720 km, which is a compromise between the apogee of 808 km and the perigee of 503 km.) Although the antenna footprint is smaller than the satellite footprint, the SNaP-3 satellites can orient to place the antenna footprint anywhere within the satellite footprint. Figure 6 shows the antenna footprint centered on the satellite footprint for ease of comparison.

The two most critical, and potentially most difficult, aspects of planning to employ SNaP in an operational environment are:

- Providing a means for sending updated location information from the remote users to the GS; and
- Providing a means for sending updated communications windows from the GS to the remote users.

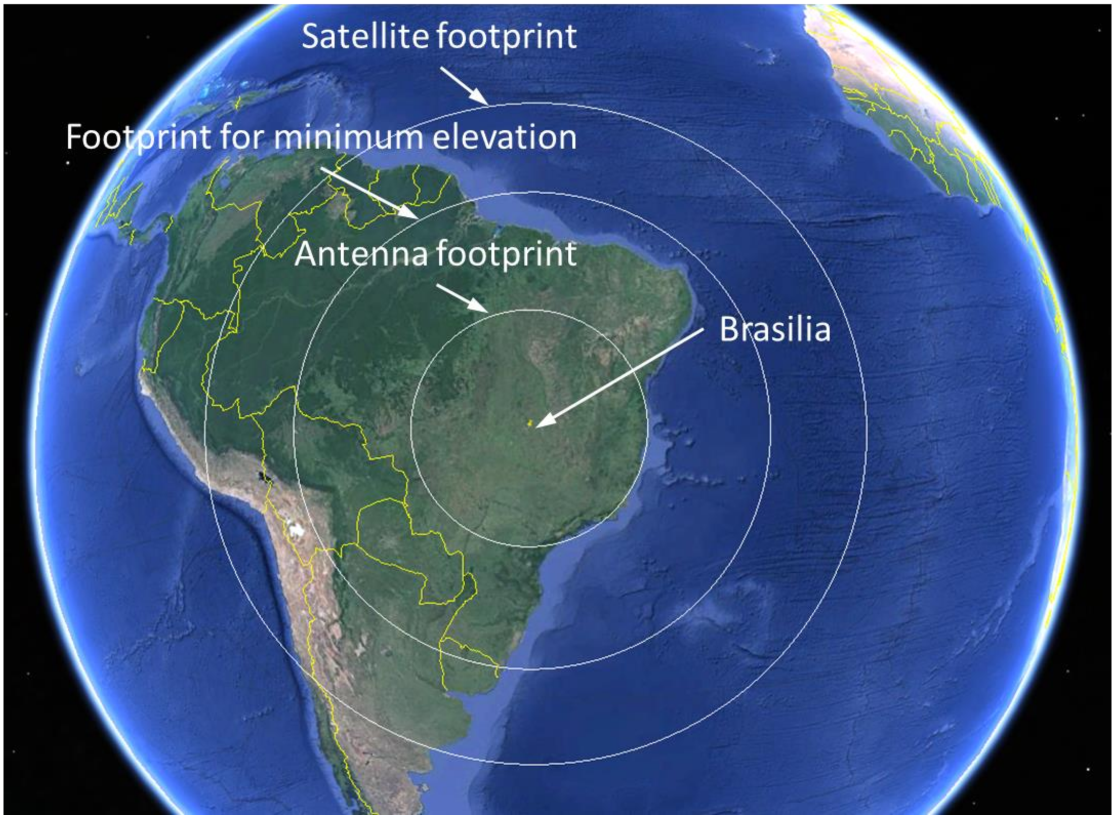

Figure 6. SNaP-3 Satellite Footprints

5.0 Operations

In its simplest form, SNaP-3 is a satellite system that provides a UHF bridge between two users, both of whom are using AN/PRC-117, AN/PRC-152, Harris 5800 Series, or Harris 7800 Series radios. The specific waveforms supported by SNaP-3 are in Table 1. The completeness (in area) and persistence (over time) of the coverage of SNaP-3 is a function of the number of satellites and their orbits. Initially, SNaP-3 will consist of three satellites in similar orbits that will provide coverage of:

- Two or three short windows of no more than 12 minutes each, with a few minutes between the windows, followed by a gap of about 97 minutes before the next group of windows.
- Each pair of groups of windows will have a gap of about 12 hours before the next set of windows.

These windows will vary: from one group to the next; from day-to-day; and by location of the users. As such, the users need to have a table of the windows for communication before beginning the operation. During the operation, the SNaP GS will compute updated windows based on the user locations and transmit these windows to the remote users.

In its initial configuration, the average total daily coverage provided by the SNaP constellation is shown in Figure 4. The average daily coverage varies by latitude, but not by longitude. Figure 4 also shows average daily coverage in hours and minutes for four locations in the USSOUTHCOM AOR, for comparison. These times are “best case” and may be less due to signal interference from: dense foliage, weather, space weather, or other signal degrading effects.

5.1 Concept of Employment (CONEMP)

A sufficient number of SNaP-3 satellites placed in the right orbits would provide nearly persistent coverage across much of the USSOUTHCOM AOR. With only three satellites, however, users will need regular updates on their available windows of coverage. With this information, the remote users can coordinate their communications to make best use of the SNaP-3 capability. The remote users do not need to interact with the SNaP-3 system directly, but rather communicate together during the windows of coverage. The GS will perform all interactions with the SNaP-3 system, to include updating windows of coverage and relaying UGS data collected by SNaP-3.

5.2 Operational View

Figure 7 provides an Operational View of the SNaP-3 system. As shown, with the exception of knowing the times of SNaP-3 coverage, the SNaP-3 system is transparent to the user. During the windows of connectivity, users who are BLOS can communicate as if they had direct line-of-sight.

Figure 7. SNaP-3 Operational View-1 (OV-1)

5.3 Concept of Operations (CONOPS)

The SNaP-3 JCTD capability provides three capabilities:

- BLOS voice communications for one transmission at a time, over the waveforms specified in Table 1;
- BLOS data communications for multiple users, over the waveforms specified in Table 1; and
- UGS data exfiltration with store-and-forward to the GS for further analysis and forwarding to remote users, possibly over SNaP data channels.

As SNaP-3 is mission agnostic, a typical mission will consist of the actions shown in Table 3. While the steps in Table 3 seem simple, it is critical that remote users keep the GS updated on their locations so that the GS can compute and relay new tables of communications windows. To enable this, the GS will need to be within the antenna footprint of the SNaP-3 satellite, which is shown in Table 2.

			Performed By	
	Step	Action	GS	Remote User
Mission Planning	1	Determine the dates and times during which the remote users will be at specific locations. Ensure that at least one of the remote users will always have a communications path to the GS, either through SNaP or by other means.		X
	2	Based on times and locations of operation, identify antenna pointing locations to best satisfy mission requirements.	X	
	3	Compute the table of communications windows and provide to the remote users.	X	
	4	Deploy for mission.	X	X
Mission Execution	5	Command the satellites to perform mission functions. Note that the remote users will not have access to a satellite's communications relay services while the GS is sending commands to the satellite or receiving data from the satellite.	X	
	6	Conduct voice and data communications during published communications windows.		X
	7	As necessary, relay UGS data collected by SNaP-3 to the remote users.	X	
	8	As necessary, report new locations to the GS before and after movement. Ensure that at least one of the remote users will always have a communications path to the GS, either through SNaP or by other means.		X
	9	Based on projected and reported new locations, update the antenna pointing locations to best satisfy mission requirements.	X	
	10	Based on projected and reported new locations, update the communications windows and provide to the remote users.	X	
	11	Go to Step 5 and repeat.	X	

Table 3. Steps for Employing SNaP-3

5.4 Considerations

SNaP-3 can provide a capability to remote users that otherwise does not exist. While SNaP-3 attempts to do this in a manner that is transparent to the remote users (other than knowing the times of the windows for coverage), users must be aware of a few considerations specific to the SNaP-3 system.

- As a single-channel radio relay, each SNaP-3 satellite can only service one transmission at a time. In normal radio operations, users get feedback from their radio when users are transmitting simultaneously. This may not be the case for SNaP-3. There may be no indication that multiple users are attempting to transmit simultaneously. As such, users should establish a transmission protocol before deploying to deconflict transmissions.
- The actual times of reliable radio relay from the SNaP-3 satellites will vary from the published times due to several factors, to include weather, terrain, and space weather phenomenon. The actual times may be longer or shorter than published, so users should begin trying to communicate shortly before the beginning of each window to maximize the time for voice and data exchange.

6.0 Summary

The SNaP-3 system will provide a limited capability for communications relay and data forwarding between remote tactical users. Effective use of SNaP-3 requires that the users understand the systems capabilities and shortfalls (Section 3), and plan accordingly (Sections 4 and 5). With proper planning and adherence to pre-planned communications protocols, remote users can leverage SNaP-3 for levels of connectivity and awareness that were previously unattainable.

The true innovation of SNaP is the ability of tactical commanders to directly control and access LEO assets for immediate support to remote users in complex and dynamic environments. A full constellation of affordable and responsive SNaP-like platforms in LEO providing a spectrum of communications and remote sensing capabilities would significantly enhance the connectivity and awareness of remote ground forces and have a profound effect on the nature of distributed ground operations.

Acronyms

ACS	Attitude Control System
AM	Amplitude Modulation
ANW2	Adaptive Networking Wideband Waveform
AOR	Area of Responsibility
BFT	Blue-Force Tracking
BLOS	beyond line-of-sight
BPSK	Binary Phase-Shift Keying
C2	Command & Control
CCMD	Combatant Command
CE	Communication Element
CONOPS	concept of operations
CPM	Continuous Phase Modulation
FM	Frequency Modulation
FSK	Frequency-Shift Keying
GPS	Global Positioning System
GS	Ground Station
GSL	Ground Station Laptop
HPW	High-Performance Waveform
IW	Integrated Waveform
JCTD	Joint Capability Technology Demonstration
JTRS	Joint Tactical Radio System
LEO	Low Earth Orbit
LNA	Low-Noise Amplifier
LOS	line-of-sight
MEA	Main Enclosure Assembly
MIL-STD	U.S. Military Standard
MUOS	Mobile User Objective System
NRO	National Reconnaissance Office
PN	Partner Nation
RF	Radio Frequency
SATCOM	satellite communications
SBPSK	Shaped Binary Phase-Shift Keying
SDR	Software-Defined Radio
SMDC	U.S. Army Space and Missile Defense Command (SMDC)
SMDC-ONE	Space and Missile Defense Command-Operational Nanosatellite Effect
SNaP	U.S. Army Space and Missile Defense Command (SMDC) Nanosatellite Program
SOC	Satellite Operations Center
SRW	Soldier Radio Waveform
UGS	unattended ground sensor
UHF	Ultra High Frequency

USSOUTHCOM	United Stated Southern Command
VHF	Very High Frequency

SNaP-3 Compatible Tactical Radios

The SNaP-3 system will support the following tactical radios: AN/PRC-117, AN/PRC-152, Harris 5800 Series, Harris 7800 Series, and any other radio that conforms to MIL-STD 188-181B and uses one of the waveforms in Table 4. This appendix provides a brief description of these radios.

Narrowband Modulations (5kHz BW) from MIL-STD-188-181 Table III							
Recommended For	**Priority**	**Option**	**I/O data rate (bps)**	**Modulation Type**	**Coding**	**Inter-leaving**	**Modulation Rate**
Voice, Data, Text (SBPSK)	2	10	2400	BPSK or SBPSK	None	None	2400
Voice, Data, Text	1	13	4800	CPM {12/16, 13/16}	None	None	2400
Voice, Data, Text	1	14	4800	CPM {7/16, 10/16}	RS:e=6[60.48]	Yes	3000
Data, Text	3	21	9600	CPM {5/16, 6/16}	None	None	4800

Wideband Modulations (25kHz BW) from MIL-STD-188-181 Table VIII							
Recommended For	**Priority**	**Option**	**I/O data rate (bps)**	**Modulation Type**	**Coding**	**Inter-leaving**	**Modulation Rate**
Voice, Data	1	132	16,000	FSK	None	None	16,000
Data	2	140	32,000	CPM {5/16, 6/16}	RS:e=10[126,105]	Yes	19,200
Data	2	141	32,000	CPM {6/16, 7/16}	None	None	16,000
Data	1	145	56,000	CPM {4/16, 5/16}	None	None	28,000

Table 4. Narrowband and Wideband Modulations

AN/PRC-117G

The FALCON® III AN/PRC-117G manpack, shown in figure 8, is a software defined tactical radio that provides wideband data performance and interoperability with fielded waveforms. This single channel radio covers 30 MHz to 2 GHz and operates off a single standard battery with peak transmit power of 10 watts VHF and 20 watts UHF. The AN/PRC-117G provides: SINCGARS, Havequick II, VHF/UHF AM and FM, DAMA, 181B Dedicated Channel TACSAT, High Performance Waveform (HPW), Integrated Waveform (IW), Soldier Radio Waveform (SRW), and the Harris Adaptive Networking Wideband Waveform (ANW2). The ROVER L-Band receive and APCO P25 are also available as optional waveforms. Future planned software upgrades include MUOS and SATURN waveforms (subject to NSA approval).

Figure 8. Falcon® III AN/PRC-117G Radio

Secured by the Harris Sierra™ II software programmable encryption module, the AN/PRC-117G is certified to carry up to U.S. Top Secret voice and data traffic. The Sierra II supports all JTRS COMSEC and TRANSEC requirements. The radio supports HAIPE® in-line encryption for secure network connectivity. Numerous legacy encryption modes are also supported, including: KY-57/VINSON, ANDVT/KYV-5, KG-84C, and keyfill modes of DS-101 and DS-102. The radio also supports Type-3 AES keys in VHF/UHF AM and FM mode.

The AN/PRC-117G stores multiple mission fill files, extending the time between reconfigurations. It also includes an embedded SAASM GPS receiver to display local position and provide automatic position reporting for situational awareness on the battlefield. A commercial GPS option is also available. Three separate antenna connections allow flexible use of antennas. The AN/PRC-117G includes the R/T, manuals, H-250 handset, radio programming application, and programming cables.

AN/PRC-152A

The FALCON® III AN/PRC-152A Wideband Networking Handheld, shown in Figure 9, provides simultaneous voice and high-speed networked data using the Harris Adaptive Networking Wideband Waveform (ANW2) and the Soldier Radio Waveform (SRW). ANW2 uses protocols that do not require the presence of a designated network control station; each radio automatically discovers and joins an authorized network. Ad-hoc networking allows automatic and transparent relay through an available station. It also heals the network if a station leaves, ensuring network reliability. Combined with the NSA certification for TOP SECRET and below communication, the AN/PRC-152A is capable of interoperating on either SECRET or Sensitive but Unclassified (Type-2) SRW networks.

The AN/PRC-152A is built with the same form factor as the widely fielded AN/PRC-152 Multiband Handheld, without compromise to size, shape, or weight. The handheld covers the multiband (30 to 512 MHz) frequency range and outputs 5W transmit power for line-of-sight (LOS) waveforms, 10W for SATCOM. On top of supporting next generation wideband (1.2MHz bandwidth) networking waveforms, the AN/PRC-152A continues legacy interoperability with the traditional narrowband waveforms such as

SINCGARS, HAVEQUICK I/II, and VHF/UHF AM and FM. The handheld incorporates a high band enhancement that increases the radios frequency coverage to 520 MHz and adds the 762–870 MHz band for select waveforms.

Figure 9. Falcon® III AN/PRC-152A Radio

The AN/PRC-152A features the Software Communications Architecture (SCA) operating environment, providing the optimal transition to software defined radio technology. JTEL certified without waivers (v2.2.2), the SCA architecture enables the upgrade to future waveforms supporting the evolution of communications from legacy narrowband to network-centric wideband operations. Secured with the Harris Sierra™ II encryption module, the AN/PRC-152A provides voice and data security supporting legacy and modern encryption, up to the TOP SECRET level. The AN/PRC-152A can deliver secure, IP-based mobile ad-hoc networking to operators at the tactical edge.

Harris 5800 Series

The Harris FALCON® II RF-5800H-MP Radio, shown in Figure 10, provides secure voice and data communications in the 1.6 to 60 MHz frequency band and enables connectivity where line of sight communication is not an option.

The RF-5800H includes Automatic Link Establishment (ALE), data rates up to 9600 bps with advanced error-free protocols, an embedded GPS receiver, MELP digital voice, Citadel® encryption, digital ECCM, and a built-in Internet Protocol (IP) interface. Where applicable, these capabilities conform to U.S. and NATO standards.

Covering the 1.6 to 60 MHz spectrum in 10 Hz steps, it goes beyond the standard HF band, making it an HF-SSB/VHF-FM transceiver, as well. The built-in multi-waveform modem and 600/2400 bps vocoder provide high data throughput and secure digital voice. The receiving radio automatically detects and processes the received waveform, whether it's voice or data. Multiple-tone excision filtering further enhances operation under high traffic and interference conditions. Embedded second and third generation of Automatic Repeat Request (ARQ) protocols are employed for error-free transmission of data.

Figure 10. Harris FALCON® II RF-5800H-MP Radio

The FALCON® II HF radio incorporates a digital ECCM waveform. Based on serial-tone modem technology, the ECCM operation delivers both secure voice and data in the presence of jamming and high channel congestion. A 600 bps vocoder is used with digital encryption to extend communications range. Data rates of 75 to 2400 bps are supported in ECCM mode.

The Citadel® encryption ASIC provides high-speed data encryption and customer-unique algorithms to enhance security. The secure voice and data modes of the RF-5800H manpack are interoperable with the VHF and VHF/UHF Multiband FALCON® II radios operating in the 30-60 MHz frequency band. In addition to encryption and ECCM capabilities, the RF-5800H-MP also includes link protection for second-generation (MIL-STD) ALE and third-generation (STANAG 4538) ALE.

The Harris FALCON® II RF-5800H-HH Radio, shown in Figure 11, provides continuous coverage in the 30 to 512 MHz frequency band. The RF-5800M-HH is interoperable with the other FALCON® II radios: the RF-5800V-MP VHF Manpack, the RF-5800H-MP HF/VHF Manpack, the RF-5800M-MP Multiband Manpack, and the RF-5800V-HH VHF Handheld. Voice communications are available through the built-in speaker/microphone, or through the standard headset connector. Automatic whisper sensitivity ensures that even quiet communication is clearly heard. Multimedia Data Communications are available through the side connector, enabling the radio to be seamlessly integrated into tactical data systems.

With CITADEL® encryption, Quicklook 1A, and the optional Talon or Havequick I / II ECCM, the RF-5800M-HH extends the security of the FALCON II family to the individual soldier for ground-to-ground and air-to-ground communications. The RF-5800M-HH also provides access to RF-6010 telephone systems through the radio keypad, automatic position reporting using an internal or external GPS receiver, integration with computer-based situational awareness systems, tactical messaging and image transmission applications.

Figure 11. Harris FALCON® II RF-5800M-HH Radio

Harris 7800 Series

The Harris FALCON® III RF-7800M-MP Radio, shown in Figure 12, provides secure voice and high-speed networked data services on-the-move. Leveraging wideband and narrowband interoperability, this single-channel voice and data radio covers the 30 MHz to 2 GHz frequency range with 20 watts of transmit power, and is capable of fixed-site, vehicular and man-portable battery-powered operation.

Designed with a Software Communications Architecture (SCA) operating environment, the RF-7800M-MP offers the optimal transition to future-proof, software-defined radio technology. Built-in AES and Citadel® encryption provides it with high-grade security using a 128- or 256-bit key, while Quicklook ECCM protects narrowband communications from hostile interference. With optional TALON CUID and HaveQuick waveforms, the RF-7800M-MP can deliver secure ground-to-air communications and interoperability with fielded airborne platforms.

It's also able to transmit high-speed, networked data at unprecedented rates using the Harris Adaptive Networking Wideband Waveform, (ANW2®). Using ANW2's routing protocols, the RF-7800M-MP can automatically discover and join authorized networks—no designated network control station necessary. This ad-hoc networking system enables automatic and transparent relay through any available station, and heals the network whenever a station leaves.

The RF-7800M-MP stores and operates on multiple mission fill files to reduce configuration time. With an embedded 12-channel GPS receiver, it can display local position and supply automatic position reporting for battlefield situational awareness and hopping waveform Time-of-Day (TOD) synchronization.

Figure 12. Harris FALCON® III RF-7800M-MP Radio

The Harris FALCON® III RF-7800M-HH Radio, shown in Figure 13, provides secure simultaneous voice and high speed networked data in a highly portable form factor. Using next-generation wideband waveforms—Harris Adaptive Networking Wideband Waveform (ANW2®C) and/or Mid-Tier TDMA Networking Waveform (M-TNW)—it delivers ad-hoc, self-healing and adaptive networking capabilities for reliable connectivity anywhere. The narrowband line-of sight, Quicklook 1A and 2, Frequency Hopping and the optional SATCOM Time-Division Multiple Access (TDMA) Capability (STC) Waveform capabilities ensures highly reliable communications for the severe conditions of tactical operations.

Providing situational awareness and data on demand, the RF-7800M-HH seamlessly links dismounted and upper-echelon networks. Even in challenging urban and tactical environments, it can easily transmit mission-critical voice, data, imagery and video – and provide dismounted operators with access to real-time intelligence for increased situational awareness and faster decision-making.

Covering the multiband frequency range—with 5W transmit power—supports next-generation ANW2C and M-TNW networking waveforms as well as UHF TACSAT with STC and the Quicklook 1A and 2 ECCM waveform which protects narrowband voice and data from hostile interference. Its standard high-band enhancement increases frequency coverage to 520 MHz and adds the 762-870 MHz band for interoperability.

The RF-7800M-HH features the Software Communications architecture (SCA) operating environment, providing the optimal transition to software defined radio technology. The SCA architecture enables loading of future waveforms. Built-in AES and Citadel® encryption provide high-grade security for all transmissions using a 256-bit key.

With the same form factor as the widely fielded Falcon® III ANN/PRC-152A, the RF-7800M-HH continues to support currently fielded accessories, and also supports interoperability with Harris' RF-7800M-MP wideband manpack — enabling enhanced connectivity in the hands of modern warfighters.

Figure 13. Harris FALCON® III RF-7800M-HH Radio