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GENERAL DESCRIPTION OF MODEL 9602-LP

Version 1.4.5

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GLOSSARY

AES	Advanced Encryption Standard
BIS	Bureau of Industry and Security
CEP	Circular Error Probable
DGPS	Differential Global Positioning System
DoD EMSS	DoD Enhanced Mobile Satellite Services
DTE	Data Terminal Equipment
DSN	Defense Switch Network
EAR	Export Administration Regulations
FDMA	Frequency Division Multiple Access
GND	Ground
GPS	Global Positioning System
GUI	Graphical User Interface
ID	Static Identifier
ISU	Iridium Subscriber Units
LED	Light Emitting Diode
LiIon	Lithium Ion
LNA	Low Noise Amplifier
LP	Low Power
NOC	Network Operation Center
OFAC	Office of Foreign Asset Controls
PMS	PECOS Message Structure
PSTN	Public Switch Telephone Network
PWR	Power
RHCP	Right Hand Circular Polarization
RUDICS	Router-Based Unrestricted Digital Internetworking Connectivity Solution
SBAS	Satellite Based Augmentation System
SBD	Short Burst Data
SMA	Sub-Miniature Version A
SMS	Short Message Service
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
VSWR	Voltage Standing Wave Ratio

1.0 PURPOSE

This document describes the electrical and mechanical interfaces of the 9602-LP. The 9602-LP is a pocket-size, low-cost, satellite tracker designed to operate with the Iridium low-Earth orbit satellite network. It is self-contained relying on an extremely low power consumption micro-controller for operation. The 9602-LP measures 2.73” x 2.17” x 0.94”, weighs less than 5 ounces and can be attached to high value, un-tethered or non-powered assets such as shipping containers, barges, railcars, trailers, buoys or even to a person. It can also be used to track environmentally demanding platforms including helicopters, fixed wing aircraft, unmanned aerial vehicles, rockets, high altitude balloons, ships, speed-boats, ground vehicles and remote unattended sensors. With the exception of smaller form-factor and wide input voltage range, model 9602-LP is functionally compatible with the 9601-DGS-LP.

The 9602-LP comprises of an Iridium 9602 transceiver module, a built-in 50-channel GPS receiver and low power micro-controllers. The 9602-LP allows only short-burst data (SBD) connectivity to the Iridium satellite network. It does not support voice, circuit switched data, or short message service (SMS). It can transmit messages in NAL Research’s defined formats compatible with models 9601-DGS and 9601-DGS-LP. The 9602-LP can also transmit in PECOS Message Structure (PMS). The PMS complies with the Blue Force Tracking Data Format Specification. The 9602-LP supports 256-bit AES encryption algorithm. NAL Research can enable the 9602-LP to utilize the DoD EMSS (Enhanced Mobile Satellite Services) Gateway when requested by an authorized user.

> **IMPORTANT:** EMSS-enabled 9602-LP must first be provisioned (signed up for airtime) with EMSS SBD Service before testing or field use. Accessing the DoD EMSS Gateway is not authorized until the 9602-LP is provisioned. Unauthorized attempts to access the DoD EMSS Gateway will result in immediate disabling of the offending device, which must then be returned to NAL Research for repair. See https://sbd.pac.disa.mil for more information regarding EMSS service provisioning.

When a data terminal equipment (DTE) is connected to the 9602-LP with SatTerm software installed (or any terminal emulator software), the DTE can be used to setup the operating parameters of the 9602-LP via a serial connection. A DTE can be a desktop computer, a laptop computer or a PDA.

2.0 GENERAL SPECIFICATIONS

2.1 Mechanical Specifications

Dimensions:	2.73” L x 2.17” W x 0.94” D (69 mm x 55 mm x 24 mm)
Weight:	4.8 oz. (136 g)
Enclosure:	Hard anodized aluminum/EMI shielding
	Waterproof version of the enclosure is available (Model 9602-BTI)
Multi-Interface Connector:	15-Pin D-Sub
Iridium Antenna:	SMA female
GPS Antenna:	SMA female
OFF/ON Switch:	Push Button
Emergency Switch:	Guarded Button and/or External via Multi-Interface Connector
Status LED Displays:	Power, GPS, Iridium, SBD status and Emergency

2.2 Iridium RF Specifications

Operating Frequency:	1616 to 1626.5 MHz
Duplexing Method:	TDD
Input/Output Impedance:	50 Ω
Multiplexing Method:	TDMA/FDMA

2.3 Iridium Radio Characteristics

Average Power during a Transmit Slot (Max):	1.6W
Receiver Sensitivity at 50Ω (Typical):	–117 dBm
Maximum Cable Loss Permitted:	2dB
Link Margin – Downlink:	13dB
Link Margin – Uplink:	7dB

2.4 Electrical Specifications

Input Voltage Range:	+3.6VDC to +5.3VDC or +6.0VDC to +32VDC
Main Input Voltage Ripple:	< 40mV peak-to-peak
Transmit Current (Average):	200mA @ 5VDC
Transmit Current (Peak):	1.5A @ 5VDC
Receive Current (Average):	45mA @ 5VDC
Receive Current (Peak):	195mA @ 5VDC
Message Transfer Power (Average):	<= 1.0W @ 5VDC
Current in Between Reports:	Less than 65μA @ 5VDC
Power Input Type:	DC power or LiIon battery

NOTE: The DC power requirement was measured at the 9602-LP multi-interface connector and not at the DC power supply. Users must take into account voltage drop across the power supply cable to ensure adequate current provided to the 9602-LP during SBD sessions. If input voltage does not stay above 3.0VDC during surge or high current demand, the 9602-LP will reset itself.

NOTE: The average current drawn during transmission may vary depending on the field-of-view between the 9602-LP antenna and the Iridium satellite, the type of Iridium antenna used and the cable loss.

2.5 Environmental Specifications

Operating Temperature Range:	–40ºF to +185ºF (–40ºC to +85ºC)
Operating Humidity Range:	≤ 75% RH
Storage Temperature Range:	–40ºF to +185ºF (–40ºC to +85ºC)
Storage Humidity Range:	≤ 93% RH

NOTE: Operating temperature range based on a duty-cycled usage model with the stand-alone 9602 transceiver sending one SBD message per hour and is otherwise turned off during the hour.

2.6 Data I/O Specifications

Short-Burst Data Mobile-Originated:	340 bytes per message
Short-Burst Data Mobile-Terminated:	270 bytes per message
Hardware Interface:	3-Wire RS232
Software Interface:	AT commands

2.7 Related Hardware

Antennas:	SYN7391 Series, SAF2040 Series, SAF5340 Series, SAF5350 Series, SAF4070-IG, SAF7352-IG and SAF5270-G
AC Power Adapter:	LA-3098 (100–240VAC, 47–60Hz input)
Car Adapter:	LA-7021 (12VDC car battery input)
Power Cable:	HRC-24-12, HRC-24-12A

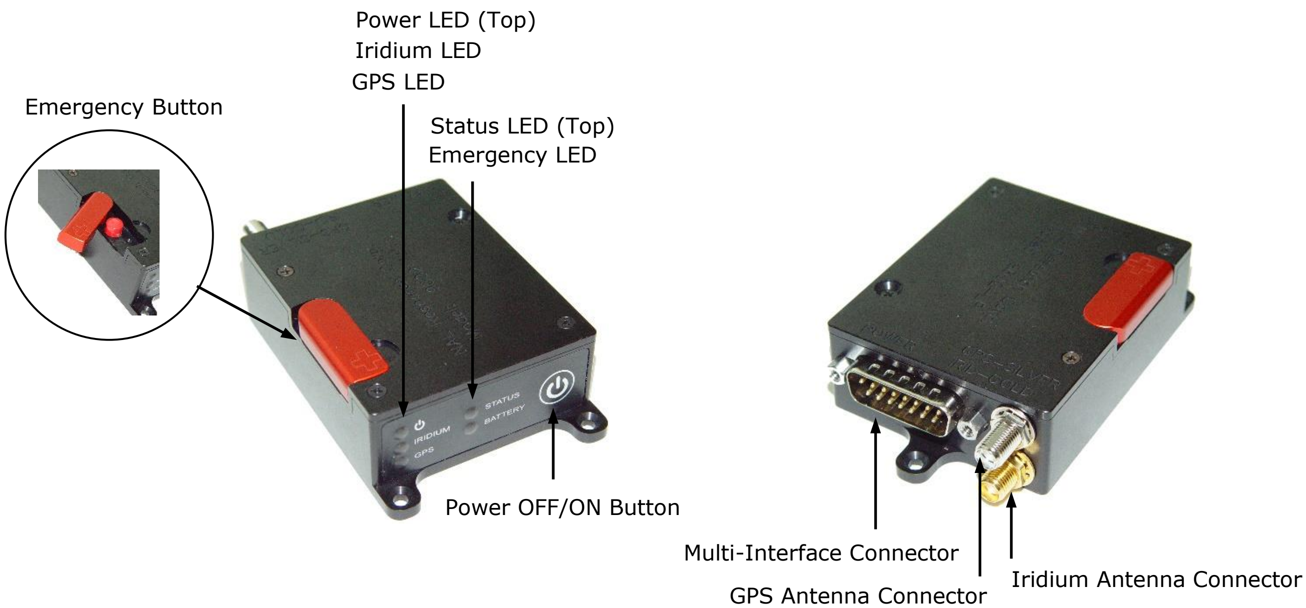


Figure 1. Iridium Satellite Tracker Model 9602-LP.

3.0 GPS RECEIVER PERFORMANCE DATA

Type of GPS Receiver:	NEO-6Q from u-blox AG	
Receiver Type:	L1 frequency	
	C/A code	
	50-Channel	
	SBAS: WAAS, EGNOS, MSAS, GAGAN	
Update Rate:	5Hz	
Accuracy:	Position	8.2 feet (2.5 meters) CEP
	Position DGPS/SBAS	6.6 feet (2.0 meters) CEP
Acquisition (typical):	Hot starts 1 second	

	Aided starts	1 second
	Warm starts	28 seconds
	Cold starts	28 seconds
Sensitivity:	Tracking	–160 dBm
	Reacquisition	–160 dBm
	Cold starts	–147 dBm
Operational Limits:	COCOM restrictions apply	
	Altitude	164,000 feet (50,000 meters)
	Velocity	1,640 feet/sec (500 m/sec)
	One of the limits may be exceeded but not both	

As long as power is provided to the 9602-LP, the GPS receiver will store ephemeris data in its memory before powering down (sleep between reports). The ephemeris data are valid up to two hours and can be used in future startup to improve time-to-first-fix. Unlike the 9601-DGS-LP, the 9602-LP does not need an extra back-up battery to retain ephemeris data.

4.0 MULTI-INTERFACE CONNECTOR

The multi-interface connector on model 9602-LP is a standard male 15-pin miniature D-Sub type (DB-15). The connector comprises of four interfaces with the pin assignments shown in Table 1. These interfaces include:

- External DC power input
- 3-wire RS232 serial data interface
- TTL/CMOS I/Os
- Reserved RS232 serial data interface

PIN #	SIGNAL	DESCRIPTION	INTERFACE
1	EXT_PWR	External power input (+3.6VDC to +5.3VDC)	DC Power (+)
2	EXT_GND	External power input (GND)	DC Power (GND)
3	Tx1	RS232 Input	RS232 Data
4	Rx1	RS232 Output	RS232 Data
5	Signal_GND	Signal Ground, 0V signal reference and return	RS232 GND
6	EMERGENCY	External TTL/CMOS Input S0	0 – 5V TTL
7	TTL	TTL/CMOS Output 0	0 – 5V TTL
8	TTL	TTL/CMOS Output 1	0 – 5V TTL
9	EXT_PWR	External power input (+6.0VDC to +32.0VDC)	DC Power (+)
10	Rx2	Reserved	RS232 Data
11	Tx2	Reserved	RS232 Data
12	TEST	External TTL/CMOS Input S1	0 – 5V TTL
13	TTL	External TTL/CMOS Input S3	0 – 5V TTL
14	TTL	External TTL/CMOS Input S2	0 – 5V TTL
15	TTL	TTL/CMOS Output 2	0 – 5V TTL

Table 1. Pin Assignments for the 9602-LP Multi-Interface Connector.

4.1 External DC Power Input

DC power interface comprises of two DC power inputs and a ground input as summarized in Table 1. The 9602-LP accepts either +3.6VDC to +5.3VDC input through pin#1 or +6.0VDC to +32VDC input through pin#9. The 9602-LP is shipped with hardware set for +3.6VDC to +5.3VDC input. It can be changed to +6.0VDC to +32VDC input through an internal jumper—POWER MUST BE DISCONNECTED BEFORE RESETING THE JUMPER. The jumper can be found by removing the modem's top plate. With the 9602-LP held in the position shown in Figure 2 (DB15 connector to the left), the 9602-LP is set for 3.6VDC to +5.3VDC when the red jumper is on the middle and top pins and is set for +6.0VDC to +32VDC when the jumper is on the middle and bottom pins. Each pin is also labeled with 5V and 32V to the left of the top and bottom pins, respectively. Both the power pins on the multi-interface connector and their corresponding voltage settings on the jumper must be used for the unit to power up properly. **NOTE:** User MUST remember not to apply voltage higher than 5.3VDC on pin 1 (or accidently swap voltage between pins 1 and 9). The 9602-LP will be damaged beyond repair with warranty voided if this were to occur.

Figure 2. Power Input Setting for the 9602-LP.

IMPORTANT: User can remove the 9602-LP's top plate to set the jumper but not for repair or services. The warranty is voided if the 9602-LP is disassembled for any reason other than to set the jumper.

Cables used to supply power to the 9602-LP should be kept as short as possible to prevent significant voltage drop, which can cause the 9602-LP to malfunction during an SBD session. Power reset by the 9602-LP during an SBD transmission is an indicative of the DC power source unable to sustain voltage above 3.0VDC at peak current demand. Plots of DC power requirement for the 9602-LP are found in Appendix A.

4.2 RS232 Serial Data Interface

The 9602-LP supports 3-wire serial interface to a host DTE through the multi-interface connector. The serial connection comprises of a transmit (Tx) line on pin 3, a receive (Rx) line on pin 4 and a signal GND on pin 5 as described in Table 1. The 9602-LP does not support auto-baud and the default baud rate is factory set at 19.2 kbits/sec. The baud rate can be reconfigured with the +IPR command ranging from 4.8kbits/sec to 115.2kbits/sec.

The serial port allows a connected DTE to configure the 9602-LP using NAL Research's defined AT commands and any terminal emulator software. These AT commands can be found in the manual "AT Commands for Model 9602-LP" TN2014-002-V1.4.5. Instead of trying to memorize various functions of AT commands, NAL Research recommends the use of SatTerm graphical user interface (GUI) software to configure the 9602-LP.

4.3 TTL/CMOS Inputs/Outputs

The 9602-LP has four TTL/CMOS inputs and three TTL/CMOS outputs. All I/Os are brought out to the multi-interface connector. SatTerm should be used to configure these I/Os as shown in Figure 3 under the I/O tab. The four CMOS/TTL inputs, denoted as S0 through S3, have internal pull ups which allow the inputs to float as high. The inputs can be configured as emergency, test, or general input with a trigger on a rising and/or falling edge. The trigger will activate the special functionality of the input type. Emergency configured inputs will enable the Emergency Tracking mode when triggered. Test configured inputs will enable the Test Tracking mode. General configured inputs will queue the transmission of an Input Report (see Appendix C in "AT Commands for Model 9602-LP" TN2014-002-V1.4.5). Regardless of the type or trigger configuration, the value of the input will be included in any version 5 GPS report sent. By default, S0 is configured as an emergency input triggered by a falling edge and S1 is configured as a test input triggered by a falling edge. S0 is shared with the on board emergency button. This means both the guarded emergency button on the 9602-LP and S0 can be used to activate Emergency Tracking.

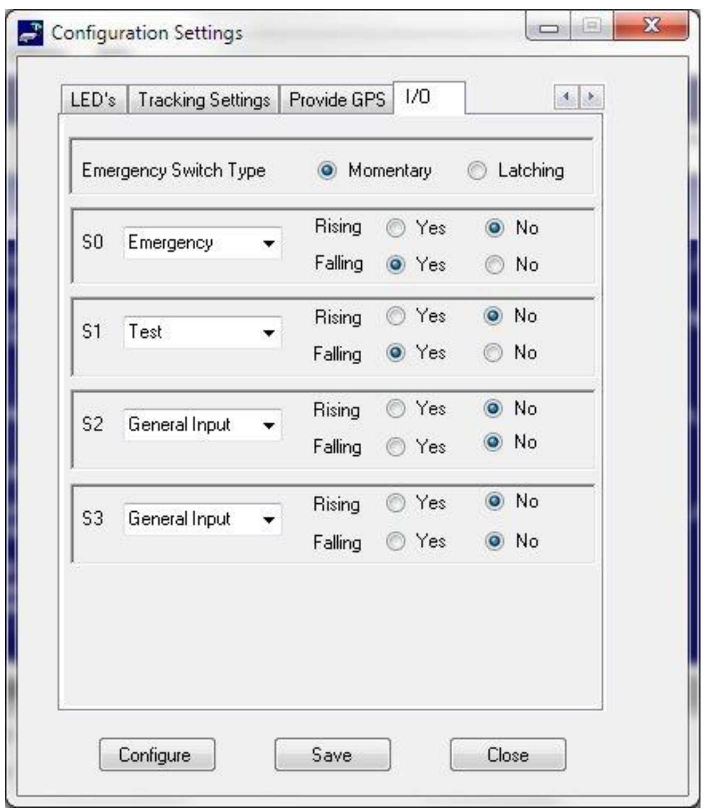


Figure 3. SatTerm Setup Window for I/Os.

Under the default configuration, Emergency Tracking can be triggered at any time by a quick press and release of the Emergency button (momentary switch). Once enabled, holding the Emergency button longer than three seconds takes the 9602-LP out of Emergency Tracking. When Emergency Tracking is active the Emergency LED will illuminate. The Emergency trigger can further be customized using the AT command ^EST. This command specifies the type of emergency switch as either momentary (default) or latching (similar to the toggle switch on the 9601-DGS-LP). The momentary switch type functions as described above, but when set to latching, Emergency tracking is enabled only when the trigger is active. For example, setting the emergency trigger to the falling edge and the switch type to latching will cause emergency tracking to enable when the input level is pulled from high to low and then it will disable when the input level returns to high.

The AT command ^PR controls input value reporting. When ^PR is enabled and a pin changes, an unsolicited response, ^PV, will be sent on the serial port indicating the values of the input pins. Setting the outputs is controlled by the AT command ^Pn. Outputs can also be set by remote update. For detailed information regarding I/Os, users are referred to the manual "AT Commands for Model 9602-LP".

5.0 CONFIGURATION SETTINGS

5.1 Modes of Operation

The 9602-LP can be in one of two operating modes at power up: (1) Command mode, or (2) Tracking mode. When in Command mode, AT commands can be entered to configure the 9602-LP's operating profiles or the 9602-LP can be operated as a 9602-G (standard SBD-modem with GPS). As a reminder, developers are encouraged to use SatTerm GUI software to set up the 9602-LP instead of using AT commands. When in Tracking mode, the 9602-LP automatically transmits GPS reports defined by parameters in the active operating profile (see description below). There are three different types of Tracking modes—Normal Tracking, Emergency Tracking and Test Tracking. The 9602-LP is factory-set for AT^START0 to power up in Command mode and can be reset to power up in Tracking mode by the AT^START1 command. After the 9602-LP is powered up, the AT^TRK command can be used to switch from Command mode to Tracking mode and switching from Tracking mode back to Command mode is done with the +++ escape sequence. The flow chart in Figure 4 describes operating modes of the 9602-LP.

There are three types of operating profiles—active operating profile, factory-default operating profile and user-defined operating profile. The active operating profile is the set of parameters currently in use by the 9602-LP. There are two user-defined operating profiles, profiles 0 and 1, available for the 9602-LP. Each user-defined operating profile can be edited and saved at anytime through the AT command &Wn. The factory-default operating profile is stored permanently on the 9602-LP's memory and cannot be changed by the user. Profiles 0 and 1 are initially set as the factory default profile.

At power up and as a default, the 9602-LP loads user-defined operating profile 0 into the active operating profile. However, either one of the two user-defined operating profiles can be designated as the active operating profile at power up through the use of the AT&Yn command. During power up, the factory-default operating profile can be loaded (soft reset) into the active operating profile using the AT&Fn command. The active operating profile will revert back to the user-defined operating profile designated under the AT&Yn command at power reset. Similarly, the active operating profile can be soft reset with either one of the two user-defined operating profiles during power up with the ATZn command. Again, the active operating profile will revert back to the user-defined operating profile designated under the AT&Yn command at power reset.

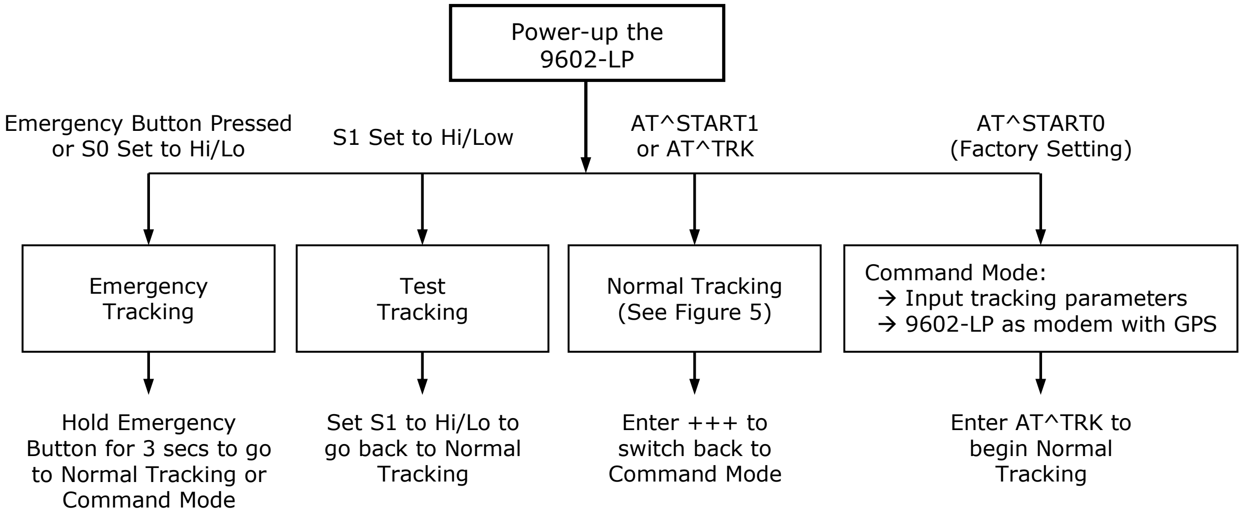


Figure 4. Different Operating Modes of the 9602-LP.

Normal Tracking Mode

Normal Tracking is the mode when the 9602-LP is configured to power up with AT^START1 command or after transitioning from Command mode to Tracking mode with the AT^TRK command. Normal Tracking offers a wide range of unique settings as shown in Figure 5. Each setting can be tailored to meet specific applications. For example, the 9602-LP can be pre-programmed to transmit reports at a fixed interval, to transmit reports triggered by the internal motion sensor, to transmit reports triggered by the Emergency switch or to transmit reports triggered by external devices. The "Callable (No)" option is implemented when lowest power consumption is required because of limited battery capacity. Or "Same Place Skip Reports" is chosen so that the 9602-LP does not repeatedly send the same location information back to a command center. The remaining of this section describes Normal Tracking settings.

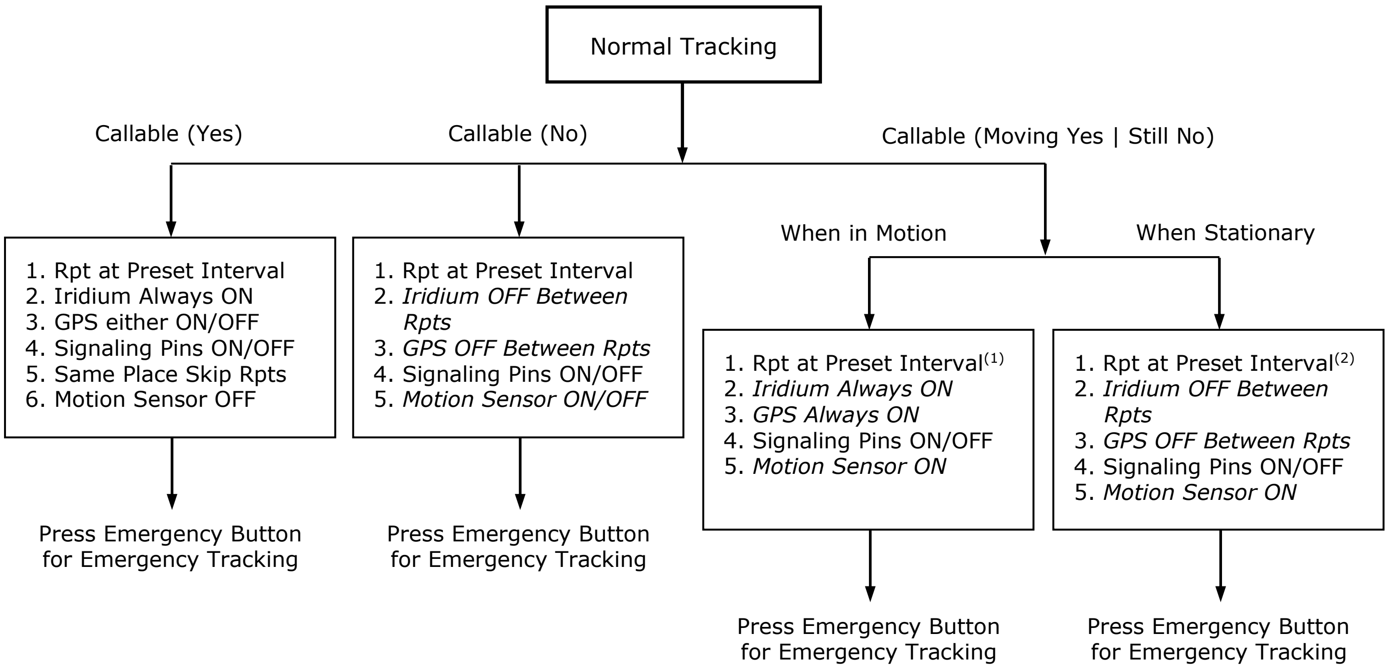


Figure 5. Block Diagram of Normal Tracking Mode of the 9602-LP.

During Normal Tracking and "Callable" is set to "Yes", the 9602-LP will automatically transmit GPS reports at a preset interval ranging from continuous to one report every seven days. The Iridium RF board will be ON in between reports allowing the 9602-LP's operating profile to be re-configured remotely in real-time. Since the Iridium RF board is ON at all times, the 9602-LP will consume the most power in between reports (~110mA at 5VDC). The GPS receiver can be left either ON or OFF in between reports to reduce power by ~40mA at 5VDC. Any of the four input pins (S0 through S3) on the multi-interface connector can be selected to trigger immediate transmission of GPS report(s) when a rising edge or a falling edge of a TTL/CMOS input signal is detected. Once the last GPS report is sent, the 9602-LP goes back to Normal Tracking. The "Same Place Skip Reports" option prevents GPS reports from being transmitted if the 9602-LP does not move outside a defined radius. Under "Callable (Yes)" option, the motion sensor signal is ignored by the tracker.

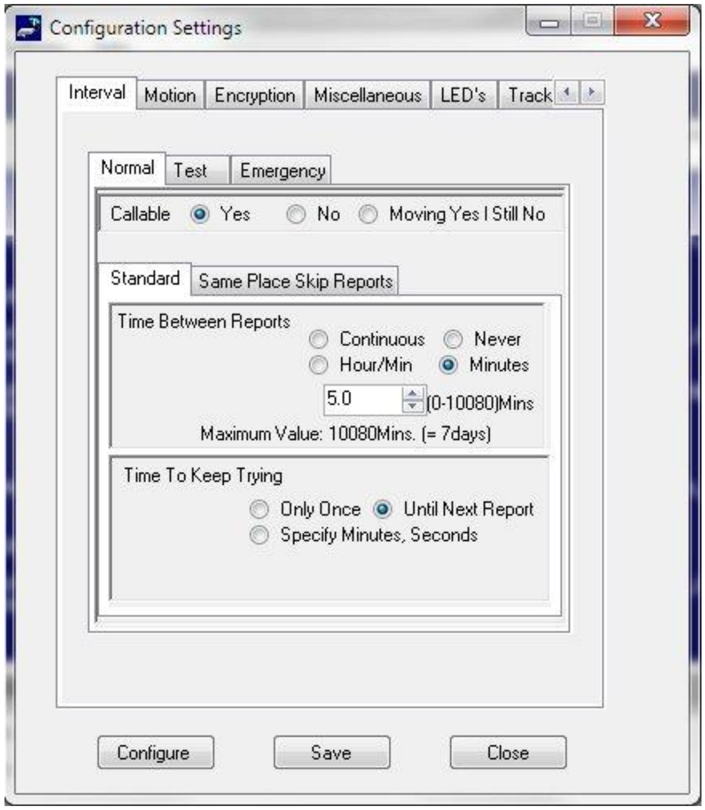


Figure 6. SatTerm Setup Window for Normal Tracking and "Callable (Yes)".

During Normal Tracking and "Callable" is set to "No", the 9602-LP will automatically transmit GPS reports at a preset interval ranging from continuous to one report every seven days. All internal circuits of the 9602-LP are turned OFF in between reports including the GPS receiver, GPS antenna's LNA, Iridium RF board, DC-DC converters and serial interfaces. The only active components are the microcontroller and the motion sensor. The 9602-LP will draw the lowest current in between reports of around 60μA at 5VDC. The 9602-LP will not respond to any entered commands including the +++. The +++ command will work only while the tracker is waiting for GPS acquisition or is transmitting a report. Updated operating profile sent to the 9602-LP from a command center will remain at the Iridium gateway until the 9602-LP wakes up and retrieves it. Any of the four input pins (S0 through S3) on the multi-interface connector can be selected to trigger immediate transmission of GPS report(s) when a rising edge or a falling edge of a TTL/CMOS input signal is detected. Once the last GPS report is sent, the 9602-LP goes back to Normal Tracking.

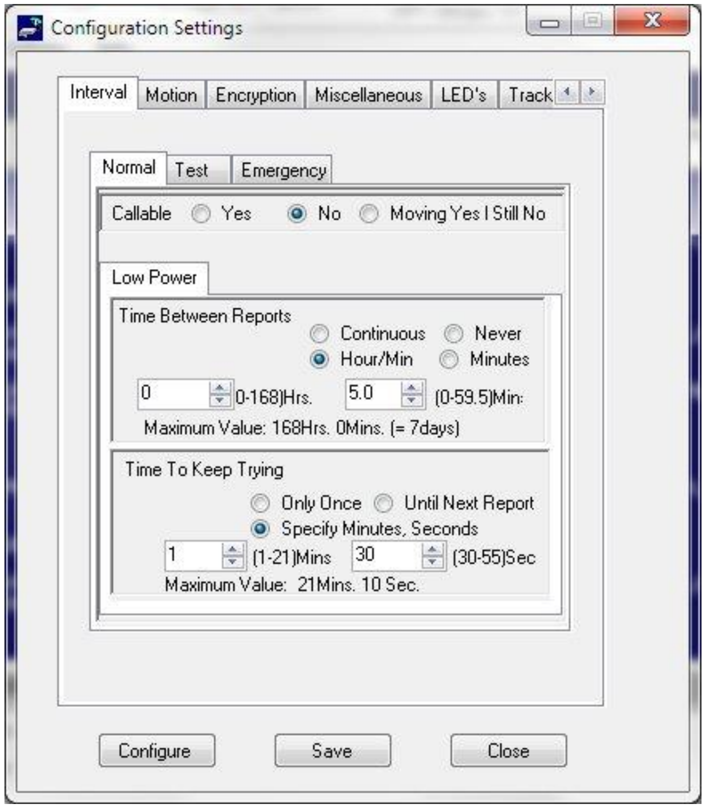


Figure 7. SatTerm Setup Window for Normal Tracking and "Callable (No)".

With "Callable" set to "No" and "Awake on Motion" option selected, the 9602-LP can be triggered by an internal motion sensor to send GPS report. The 9602-LP has a built-in motion sensor that works regardless of how the 9602-LP is mounted or aligned. It is sensitive both to tilt (static acceleration) and vibration (dynamic acceleration). When in motion, the sensor produces continuous on-off contact closures (a series of TTL level logic or pulse train) as it chatters open and closed. The signal level is fed directly into the 9602-LP's micro-controller. When at rest, it normally settles in a closed state.

Three parameters must be provided when choosing the "Awake on Motion" option— "Minutes of Motion Before Waking", "Sensitivity" and "Motion Sensor Wait". "Minutes of Motion Before Waking" is a user-defined duration within which *valid motion* must exist before the 9602-LP sends a GPS report. For example, a car must experience continuous motion for three minutes before a GPS report is sent. Otherwise, a slight bump by a person or by a gust of wind does not initiate a report. The duration of "Minutes of Motion Before Waking" is divided into one-minute blocks. "Sensitivity" is defined as the number of motion sensor on-off contact closures the 9602-LP must detect in each of the one-minute block for motion within that block to be considered *valid motion*. All contiguous one-minute blocks must have *valid motion* before a GPS report is sent. At any time a block has an *invalid motion*, the "Minutes of Motion Before Waking" timer is reset and the motion detection process starts over again. After *valid motion* is detected and a successful GPS report is sent, the 9602-LP goes back to sleep with all circuits OFF. It will ignore the motion sensor input signal for "Motion Sensor Wait" minutes. All other parameters and I/O pins are still observed by the 9602-LP.

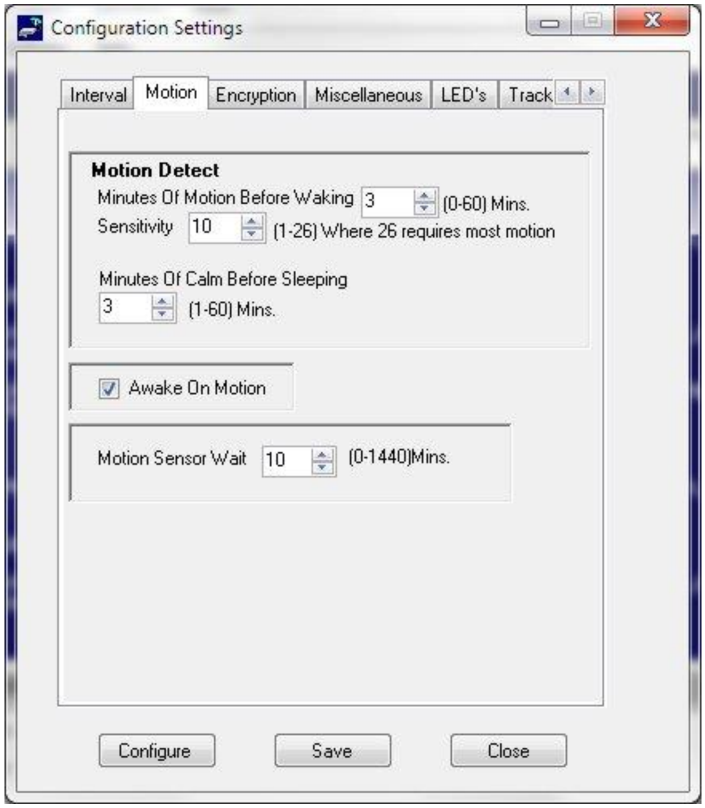


Figure 8. SatTerm Setup Window for Normal Tracking and "Awake on Motion".

The third Normal Tracking option is "Callable (Moving Yes | Still No)". This is a hybrid between the "Callable (Yes)" and "Callable (No)" configurations. When in motion the 9602-LP uses a set of "Callable (Yes)" parameters to send GPS reports and when not in motion the 9602-LP uses a set of "Callable (No)" parameters to send GPS reports. The goal is to allow users the flexibility to define different set of parameters for different operating conditions. For example, a stationary vehicle only needs to send position report perhaps once a day. However, when in motion a higher reporting frequency is required.

The setup parameters for "Callable (Moving Yes | Still No)" and "not in motion or Low Power" are shown in Figure 9. These parameters are very similar to the standard "Callable (No)" option except there is no "Awake on Motion". The 9602-LP uses "Minutes of Motion Before Waking" and "Sensitivity" to determine if *valid motion* is observed by applying the same approach described previously. Once *valid motion* is determined, the 9602-LP switches to "Callable (Moving Yes | Still No)" and "in motion" mode.

The setup parameters for "Callable (Moving Yes | Still No)" and "in motion or Motion" are similar to the "Callable (Yes)" option except the motion sensor is active. The 9602-LP uses "Minutes of Motion Before Waking" and "Sensitivity" to determine if *valid motion* is observed by applying the same approach described above. If *valid motion* is not detected before the "Minutes of Calm Before Sleeping" expires, the 9602-LP switches back to "not in motion or Low Power" mode.

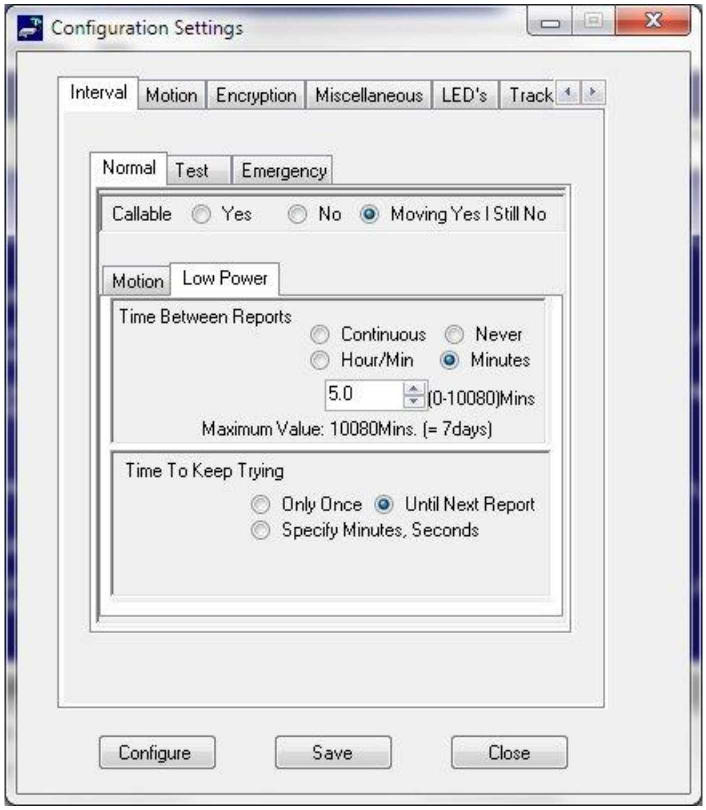


Figure 9. SatTerm Setup Window for Normal Tracking and "Callable (Moving Yes | Still No)".

Emergency and Test Tracking Modes

Emergency Tracking can be triggered by the Emergency button or by Input S0. Test Tracking can be triggered by Input S1. Emergency Tracking and Test Tracking operate similar to Normal Tracking in that they have individually configurable reporting parameters. While in Emergency Tracking, the 9602-LP does not respond to +++ escape sequence and at least one "report send attempt" must be completed before transitioning back to Normal Tracking. The Emergency GPS reports have a special data bit activated to alert the recipient of the message type. The 9602-LP allows GPS reports to be saved on its non-volatile memory when an Iridium satellite is not available.

5.2 Encryption Setting

The 9602-LP can send GPS reports in AES 256-bit encrypted format. Figure 10 displays SatTerm encryption setting window. The GUI allows the Crypto Officer Password to be changed, the encryption to be enabled or disabled, and the encryption key or decryption key to be set or changed.

A factory-default Crypto Officer Password is initially set and saved into the 9602-LP. This default Password must be changed before any encryption properties can be set or changed. To change the default Password, click on the "Change" button to open the "Change Crypto Officer Password" window. Then complete the form. The default Password should be displayed as the "Old Password". When done, click on the "Send" button.

Once the default Password has been changed, the encryption and decryption keys will need to be set in order to use encryption for the first time. In the "Change Encryption Settings" window, check "Use Encryption" and choose the option "Use". Then check "Encryption Key" and enter the key two times. Next check the "Decryption Key" and enter the key two times. When done, click the "Send" button. The message "Update Made" will be displayed.

After the default Crypto Officer Password has been changed and the Encryption and Decryption Keys have been set, encryption properties can be modified via the "Change Encryption Settings" window using the current Crypto Officer Password.

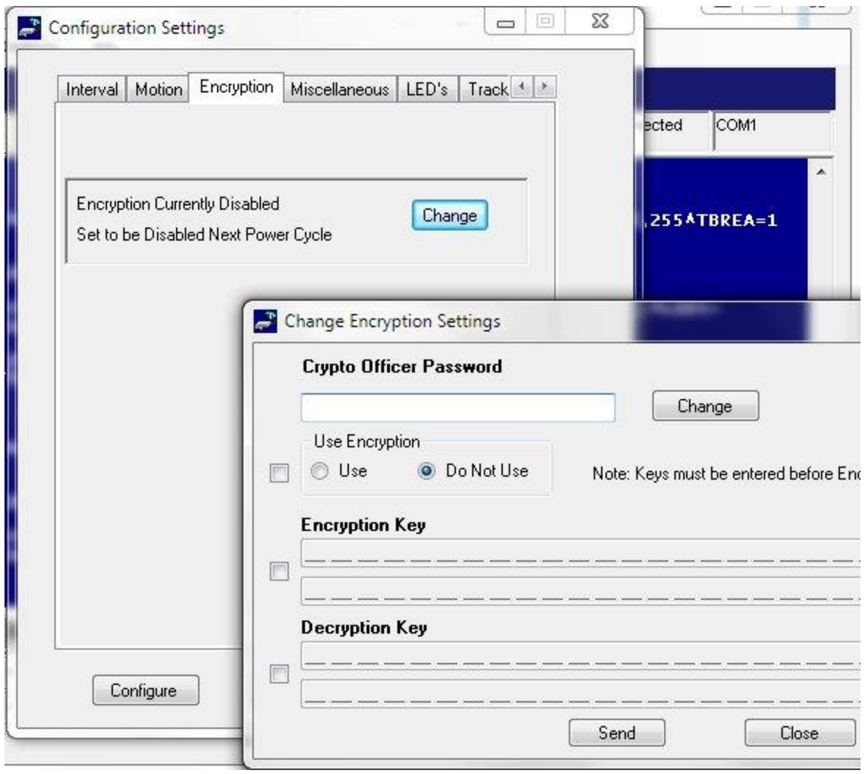


Figure 10. SatTerm Setup Window for AES-256 Bit Encryption.

5.3 Miscellaneous Settings

The Miscellaneous tab offers four settings. "Remote Update Password" sets the required password when a remote update to the current active operating profile is made from a command center while the 9602-LP is in the field. The <password> entered must be 8 characters in length and all printable characters are allowed. The factory-set password is 12345678 and there is no requirement to change this password. "Identifier in Reports" option allows a unique static identifier of up to 50 characters (platform identifier of the 9602-LP) to be entered and added to the GPS report. The power up text can either be displayed or hidden with the "Startup Information" option.

The 9602-LP has a single power on/off button. With the correct internal voltage jumper setting, the 9602-LP is default to power up automatically when DC power is first applied to either pin 1 or pin 9 on the multi-interface connector. It can be turned off/on again by momentarily holding down the power button and release.

Using AT command ^IPS, the 9602-LP can also be set to power up by pressing the power button when DC power is first applied to pin 1 or pine 9. If the device is sleeping in between reporting cycles, pressing the power button will turn the 9602-LP on for 10 seconds. During this time tracking mode can be exited by sending +++.

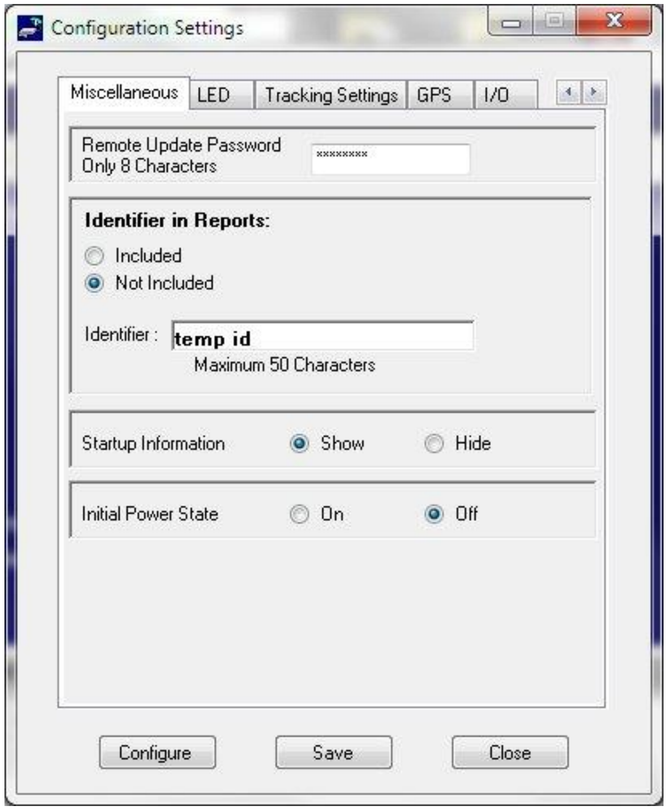


Figure 11. SatTerm Setup Window for Miscellaneous Options.

5.4 LED Settings

The 9602-LP has five status LEDs. These include power indicator, Iridium signal strength, GPS availability, SBD transmission status and Emergency mode alert. They offer users a quick visual check to ensure proper operations. These LEDs provide the following information during Normal tracking mode:

- Power LED: lights up when power is applied to the 9602-LP and power-on button is pressed.
- GPS LED: stays solid when there is a valid GPS position fix, blinks when there is 2D fix or using dead reckoning, and stays off when unable to obtain a position fix. Users have to watch closely for the LED since it can briefly stay on.
- Iridium LED: stays solid when the Iridium signal strength is between 3–5 bars, blinks when the Iridium signal strength is between 1–2 bars, and stays off when the Iridium signal strength is at 0 bars. Since the Iridium modem is on over a short period during a location report, this LED will light up very briefly and users might not be able to see if not watched closely.

- Status LED: when first entering Tracking Mode, the LED will not light up. This LED stays solid if the last SBD transmission had a valid GPS fix and successfully received by the gateway, blinks if the last SBD transmission was unsuccessfully sent or did not have a valid GPS fix but one was sent since the unit was turned on, and stays off if no SBD transmission with a valid GPS fix was sent to the gateway.
- Emergency LED: lights up when the Emergency button is pressed or the Input S0 is activated.

During Command Mode or while operating the 9602-LP as a 9602-G modem, the LEDs display information in the same manner as during Normal tracking mode. In addition, the Status LED provides:

- Status LED: when first entering the Command mode, this LED will not light up. If the last SBD session does not have an error the LED stays solid. An error occurs when a transmitted SBD message is not being acknowledged by the Gateway or if a message received from the Gateway contains an error(s). The LED blinks only after the 9602-LP is powered up with the last SBD session having an error but the next SBD session is error-free.

For those applications where prolonging battery life is essential, the LEDs can be turned OFF using the ^LEDS AT command or using the SatTerm LED's tab as shown in Figure 12. The 9602-LPs are shipped with all LEDs set to on.

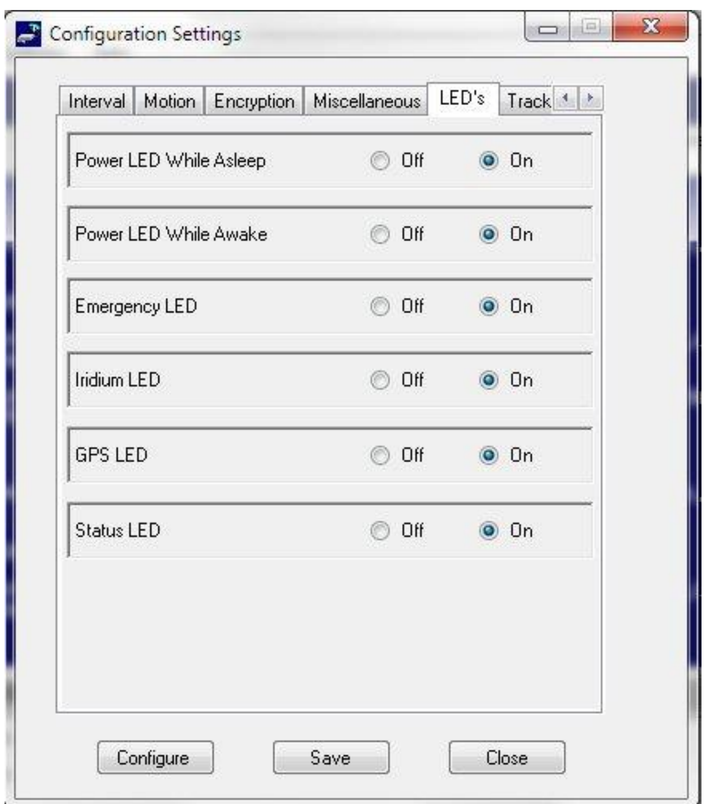


Figure 12. SatTerm Setup Window for LEDs.

5.5 Tracking Settings

The Tracking Settings tab offers multiple settings. “Emergency Report Flood” sets how many GPS reports will be sent out continuously when first entering Emergency Tracking. After <n> GPS reports have been sent, the pre-programmed reporting interval will take effect. “Remote Message Format” sets format of the messages that will be sent to the command center. “GPS Always ON” forces the GPS receiver to stay on in between reports allowing hot-start each time the 9602-LP wakes up. “Start-Up Mode” sets the power-up mode of the 9602-LP.

The 9602-LP allows GPS reports to be saved on its non-volatile memory with “Data Log Tracking” option turned on. When its memory is full, the oldest reports are over-written. SatTerm can be used to retrieve all position reports at a later time through the multi-interface serial port.

When the “Block Invalid Reports” is enabled and a tracking mode is selected, reports with invalid GPS fix will not be sent. “Test Report Flood” sets how many GPS reports will be sent out continuously when first entering Test Tracking. After <n> GPS reports have been sent, the pre-programmed reporting interval will take effect.

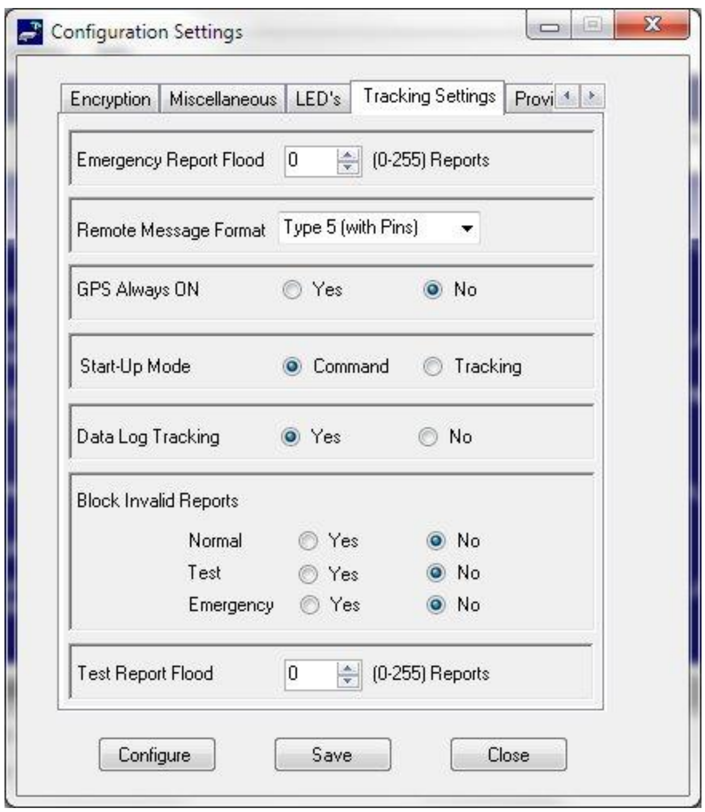


Figure 13. SatTerm Setup Window for Tracking Options.

5.6 GPS Settings

The GPS tab offers users the option to obtain GPS information from the 9602-LP serial port while the unit is in command mode or tracking mode (similar to the command ^PG). Both GPS NMEA formats and updating (streaming) rate can be defined.

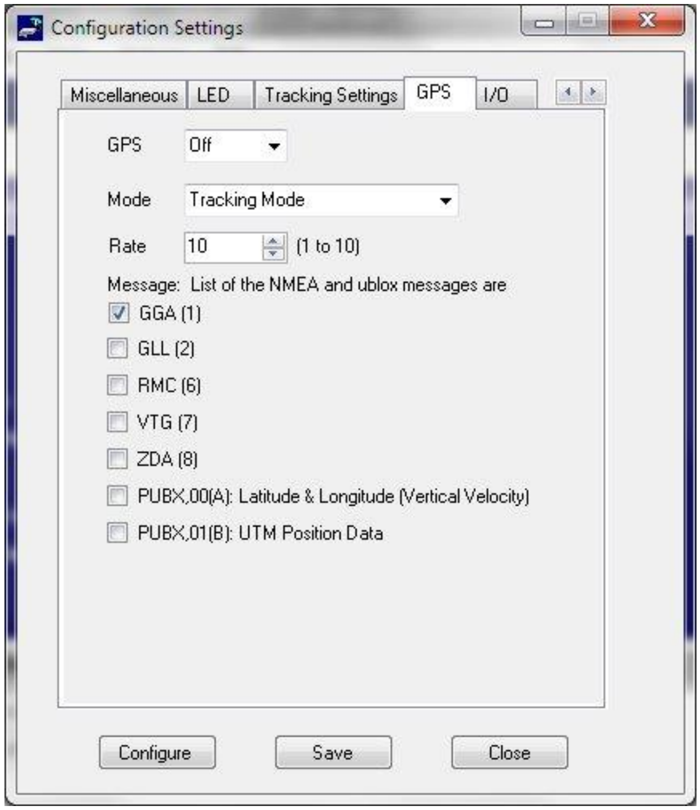


Figure 14. SatTerm Setup Window for GPS Options.

6.0 MOTION SENSOR

The 9602-LP has a built-in sensor that can reliably detect motion. It is truly an omni-directional movement sensor and will function regardless of how the 9602-LP is mounted or aligned. It is sensitive to both tilt (static acceleration) and vibration (dynamic acceleration). The sensor produces a series of TTL level logic or pulse train. The signal level is fed directly into the 9602-LP's micro-controller to "wake up" the 9602-LP out of sleep mode when activity is sensed and to transmit location report.

The 9602-LP's motion sensor can be enabled or disabled through an AT command (^MSA). When enabled, the motion sensor has a user-defined time out to prevent false alarm. The user-defined time out is the duration in which the 9602-LP must remain in motion before the signal level is asserted to the micro-controller. Additional motion sensor settings can be found in the AT manual. The motion sensor draws approximately 4μA at 4VDC power input regardless of whether it is software enabled or not.

7.0 IRIDIUM ANTENNA CONNECTOR

The 9602-LP uses a single SMA female 50-ohm antenna connector for both transmission and reception of the Iridium signals. The mating SMA male connectors are readily available from many RF hardware vendors/suppliers. Cable and connector losses between the 9602-LP and the antenna are critical and must be kept to less than 2dB at the operating frequency of 1616 to 1626.5 MHz.

NAL Research offers several types of antennas for use with the 9602-LP. These antennas include the fixed mast, mobile magnetic/permanent mount and portable auxiliary. For low-cost and applications where small form-factor and light-weight are required, NAL Research highly recommends model SYN7391-C as shown in Figure 15.

Figure 15. NAL Research's Antenna SYN7391-C.

If custom-designed antenna is required, it must meet the specifications shown in Table 2 below.

PARAMETER	VALUE
Measurement Frequency Range	1616 to 1626.5 MHz
Return Loss (Minimum)	9.5 dB
Gain	0.0 dBic (weighted average minimum)
VSWR	1.5 : 1
Minimum 'Horizon' Gain	–2.0 dBic (82° conic average)
Nominal Impedance	50 Ohms
Polarization	Right Hand Circular (RHCP)
Basic Pattern	Omni directional and hemispherical

Table 2. Recommended Iridium Antenna's Design Specifications.

8.0 GPS ANTENNA CONNECTOR

The 9602-LP tracker uses an SMA female connector for the GPS antenna. Any active antenna accepting a bias voltage of 3VDC is appropriate. However, the low-noise amplifier (LNA) gain should not exceed 30dB. NAL Research offers a magnetic mount GPS antenna as well as dual Iridium/GPS antennas for use with the 9602-LP. For low-cost and applications where small form-factor and light-weight are required, NAL Research highly recommends model SAF7352-IG as shown in Figure 16.

Figure 16. NAL Research's Antenna SAF7352-IG.

IMPORTANT: GPS antenna should only be connected to or disconnected from the 9602-LP when it is not powered. DO NOT CONNECT OR DISCONNECT THE GPS ANTENNA WHEN THE 9602-LP IS POWERED. The internal GPS receiver calibrates the noise-floor on power-up, and by connecting the GPS antenna after power-up can result in prolonged acquisition time and possibly damage the GPS receiver. To test GPS signal reacquisition, physically blocking the signal to the antenna rather than disconnecting and reconnecting the antenna is recommended.

IMPORTANT: Never feed external supply voltage into the active GPS antenna. Always use the bias voltage supplied by the 9602-LP via the SMA antenna connector to power an active GPS antenna. Feeding voltage to the GPS antenna other than the provided bias voltage will damage the 9602-LP.

9.0 POWER CONSUMPTION

This section gives users some insight to the electrical power profile of the 9602-LP. It does not describe every situation and permutation possible. It should be used as a starting point for the users to continue their own development design. The actual usage profile can vary for a number of reasons:

1. Poor visibility of the sky where clear line of sight is not available between the 9602-LP and satellite.
2. The higher the antenna VSWR the higher the current consumed.
3. And manufacturing variation from device to device.

Power consumption of the 9602-LP can be divided into distinct operating segments: (1) power up, (2) standby, (3) sleep between reports, (4) GPS acquisition, and (5) SBD report transmission. At power up in command mode, typical in-rush current of ~3A-4A over a few milliseconds is mainly due to the current drawn by the 9602 (see Figure 17).

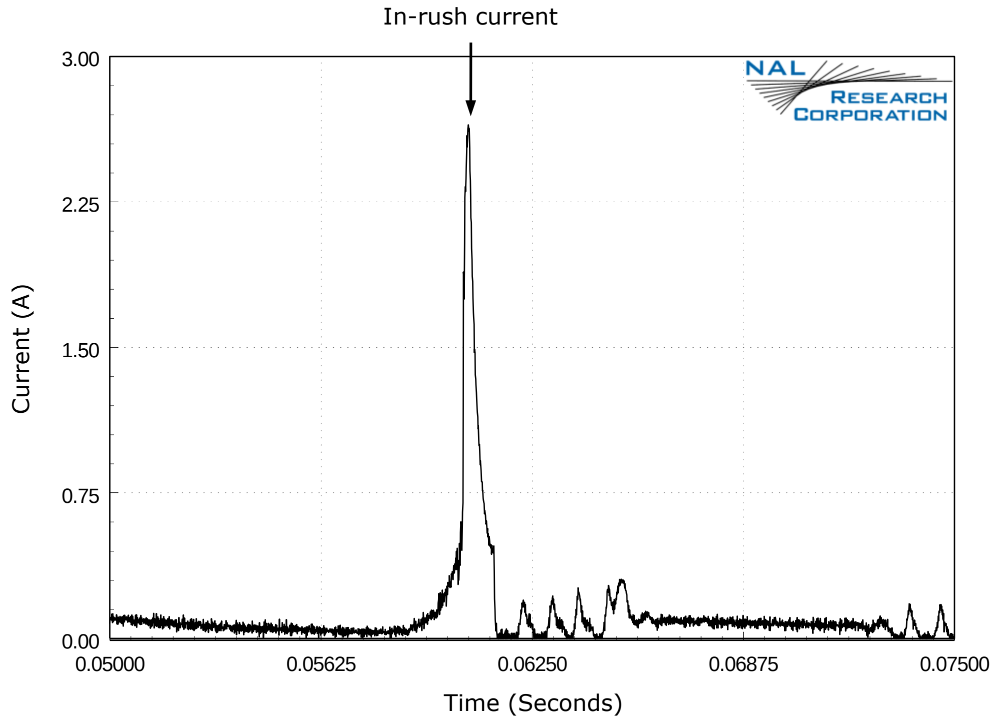


Figure 17. In-Rush Current Spike during Power-Up in Command Mode at 5VDC Input.

At standby in command mode, current is measured when all circuits are on. The average current drawn during standby with 3.6VDC – 5VDC input and 6VDC – 32VDC are shown in Figures 18 and 19, respectively.

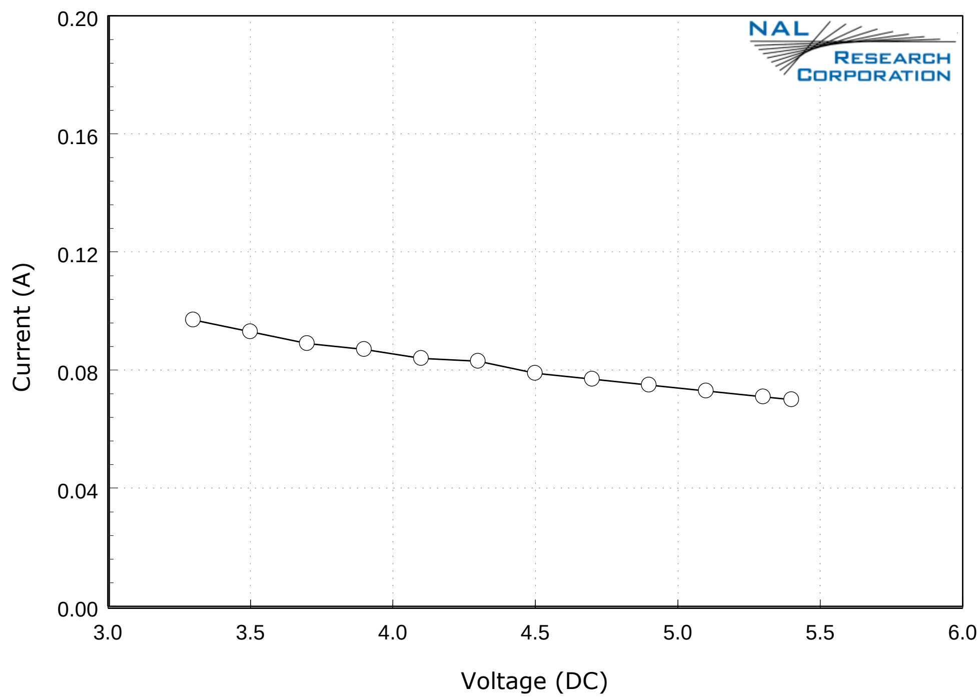


Figure 18. Average Current during Standby with 3.5VDC to 5VDC Input.

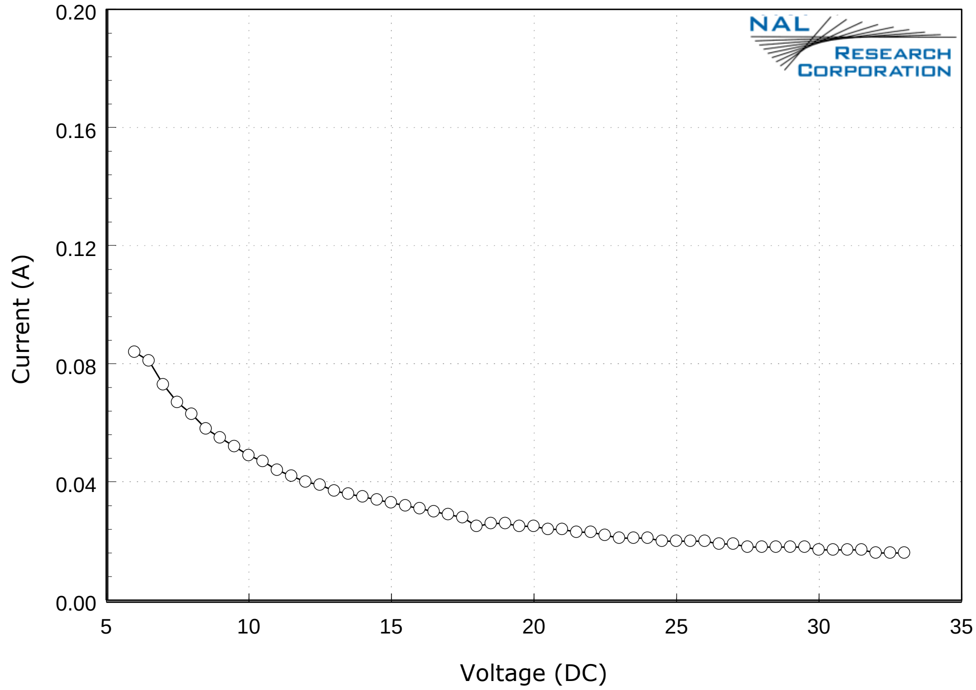


Figure 19. Average Current during Standby with 6VDC to 32VDC Input.

Figure 20 shows the average power consumption by the 9602-LP at standby in command mode for the entire voltage range.

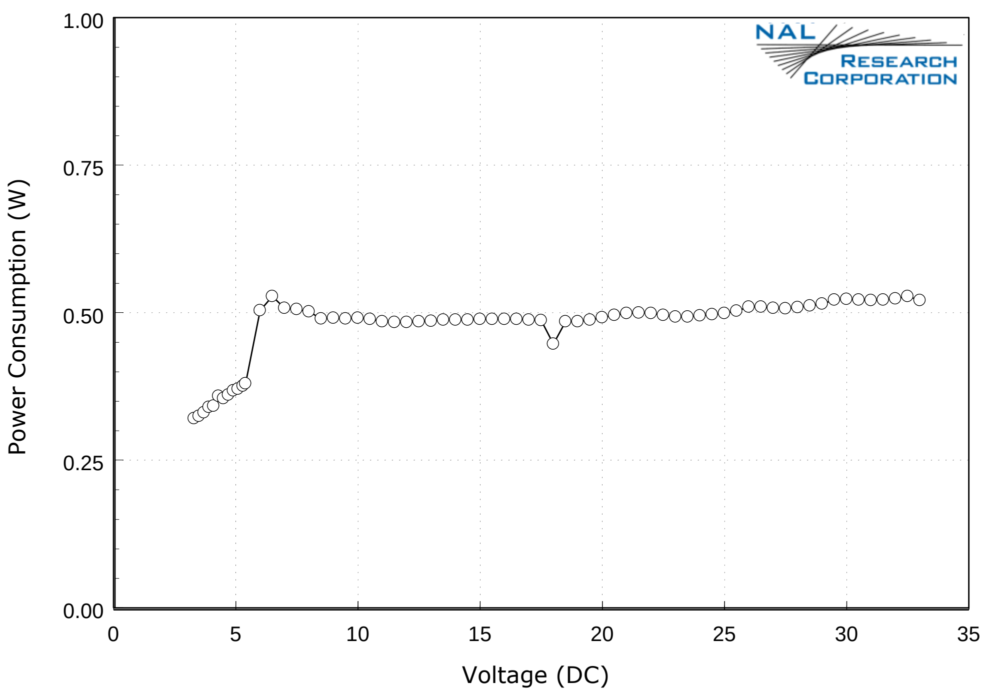
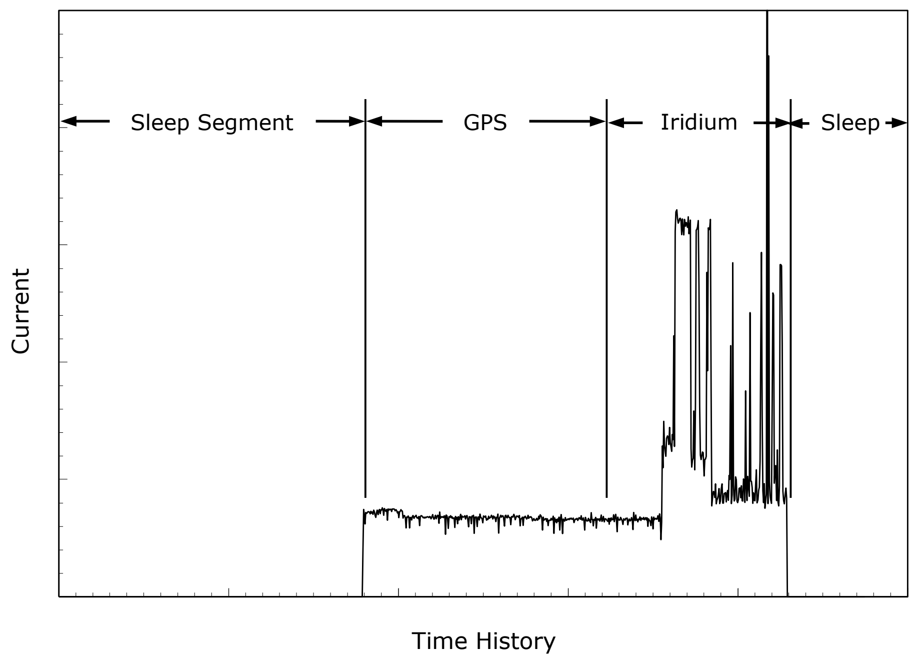


Figure 20. Average Power Consumption during Standby with 3.5VDC to 32VDC Input.

In tracking mode, the 9602-LP goes through three different power consumption segments: (1) the sleep (in between reports) segment, (2) GPS acquisition segment, and (3) SBD transmission segment. Figure below shows different stages of current drawn by the 9602 when in tracking mode. During the sleep segment, the 9602-LP goes into power-saving mode by shutting down all its internal circuits.



The average current drawn by the 9602-LP during sleep with 3.6VDC–5VDC input is shown in Figure 21.

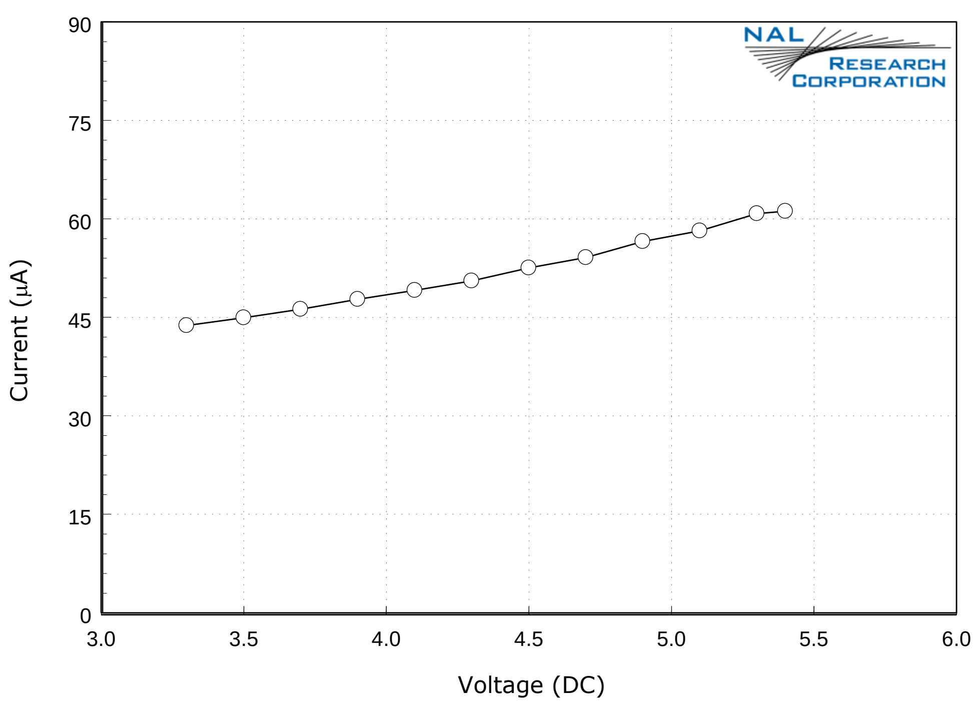


Figure 21. Average Current during Sleep with 3.5VDC to 5VDC Input.

The average current drawn by the 9602-LP during sleep with 6VDC – 32VDC is shown in Figure 22. Due to limitation of our signal analyzer, current drawn for voltages above 15VDC in the μA range could not be measured. The dashed line is resulted from curve fitting (cubic spline) of the data.

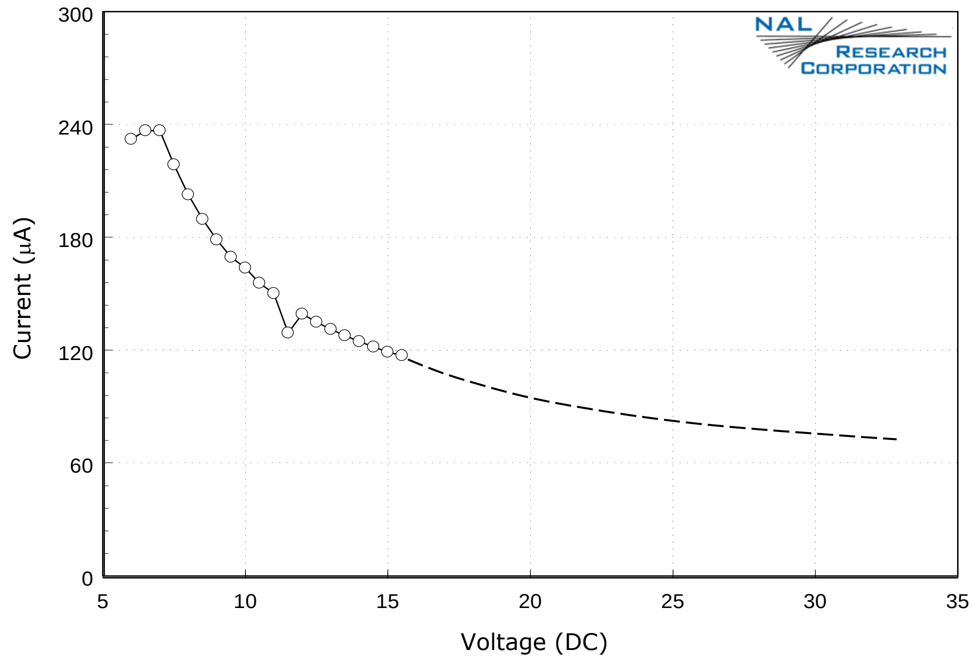


Figure 22. Average Current during Sleep with 6VDC to 32VDC Input.

Figure 23 shows the average power consumption by the 9602-LP during sleep for the entire voltage range.

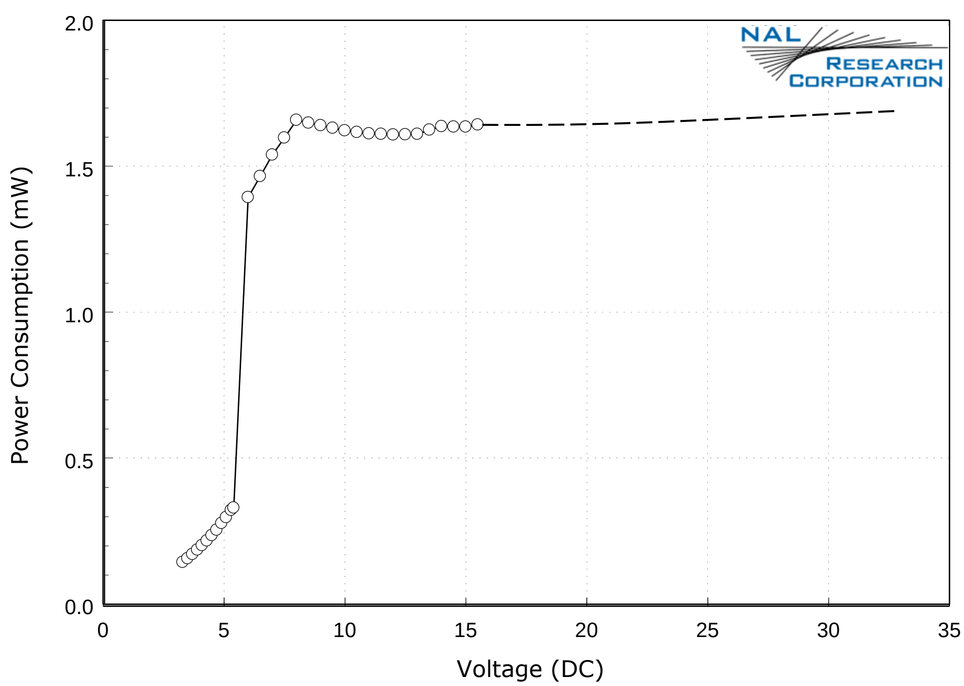


Figure 23. Average Power Consumption during Sleep with 3.5VDC to 32VDC Input.

During the GPS acquisition segment, the average current drawn by the 9602-LP with 3.6VDC – 5VDC input and 6VDC – 32VDC are shown in Figures 24 and 25, respectively. The GPS acquisition time can range from 1 second (hot starts) to 28 seconds (cold starts).

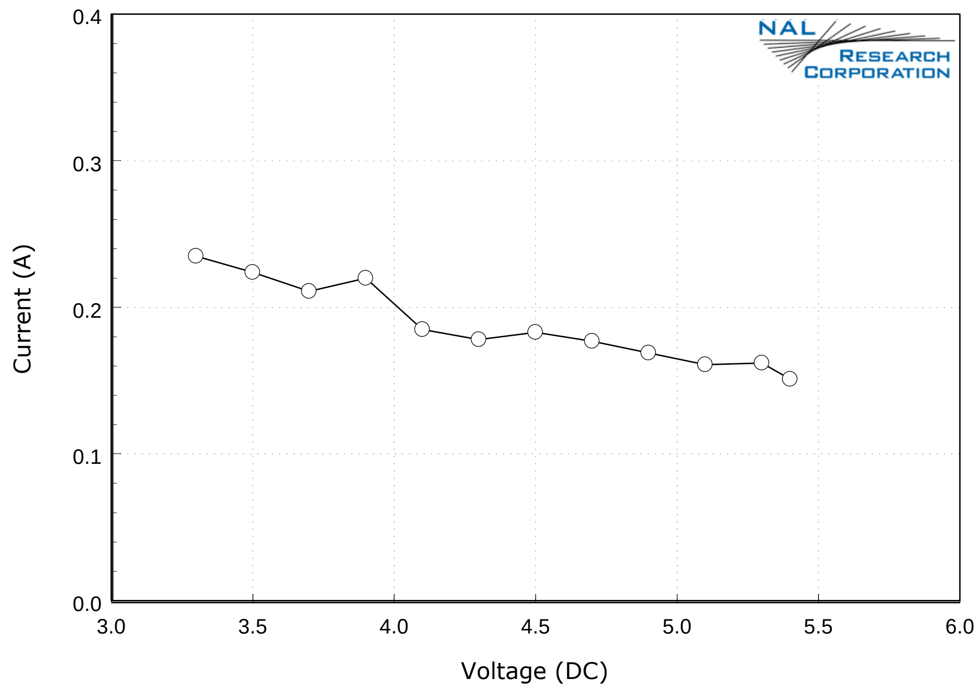


Figure 24. Average Current during GPS Acquisition with 3VDC to 5VDC Input.

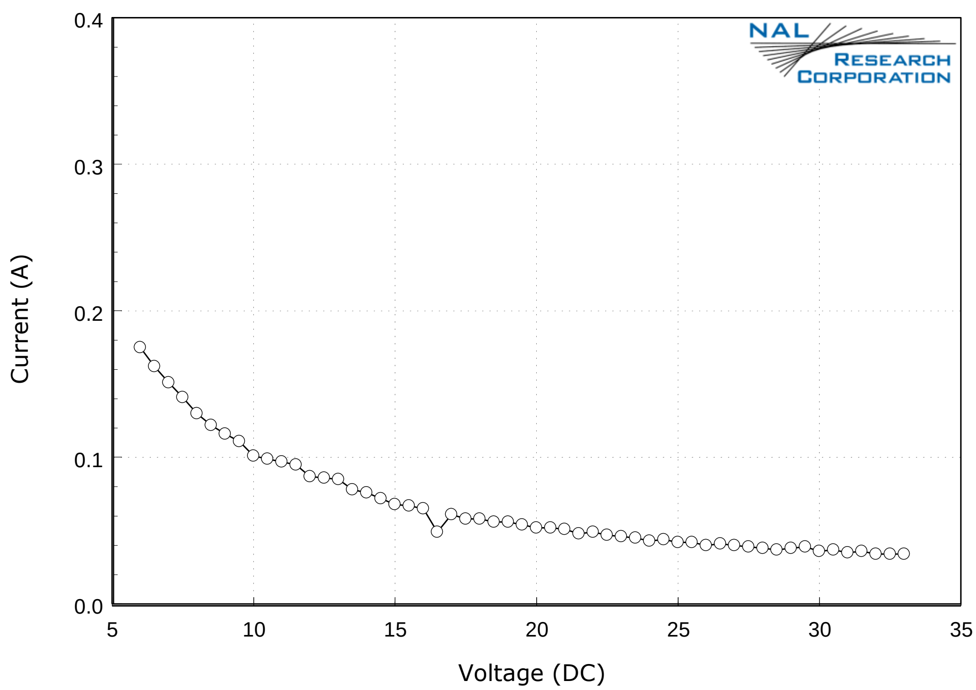


Figure 25. Average Current during GPS Acquisition with 6VDC to 32VDC Input.

Figure 26 shows the average power consumption by the 9602-LP during GPS acquisition for the entire voltage range.

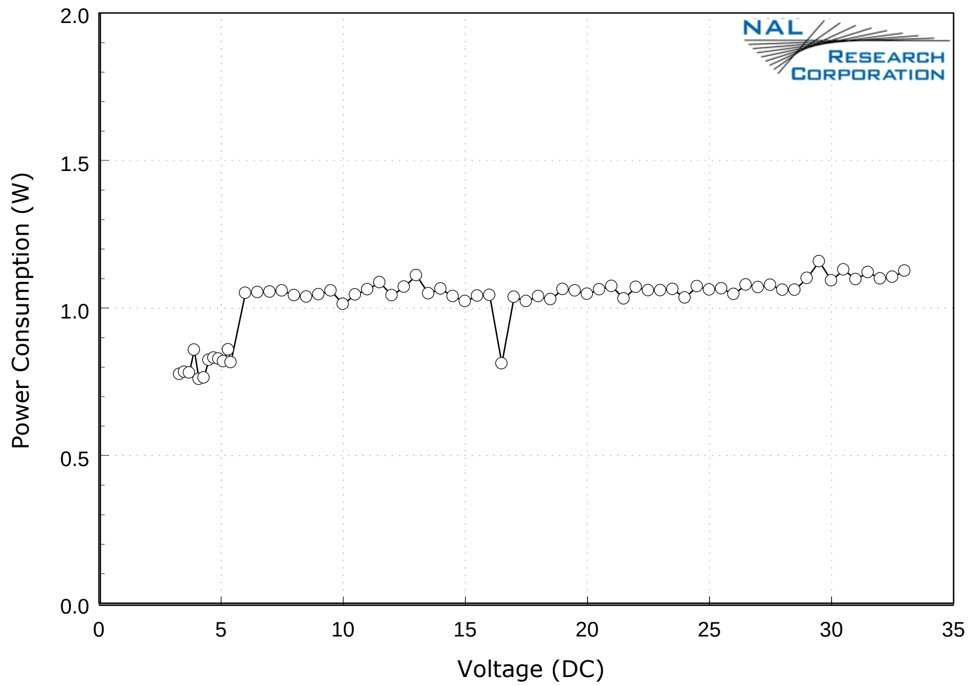


Figure 26. Average Power Consumption during GPS Acquisition with 3.5VDC to 32VDC Input.

During the SBD transmission segment, the average current drawn by the 9602-LP with 3.6VDC – 5VDC input and 6VDC – 32VDC are shown in Figures 27 and 28, respectively.

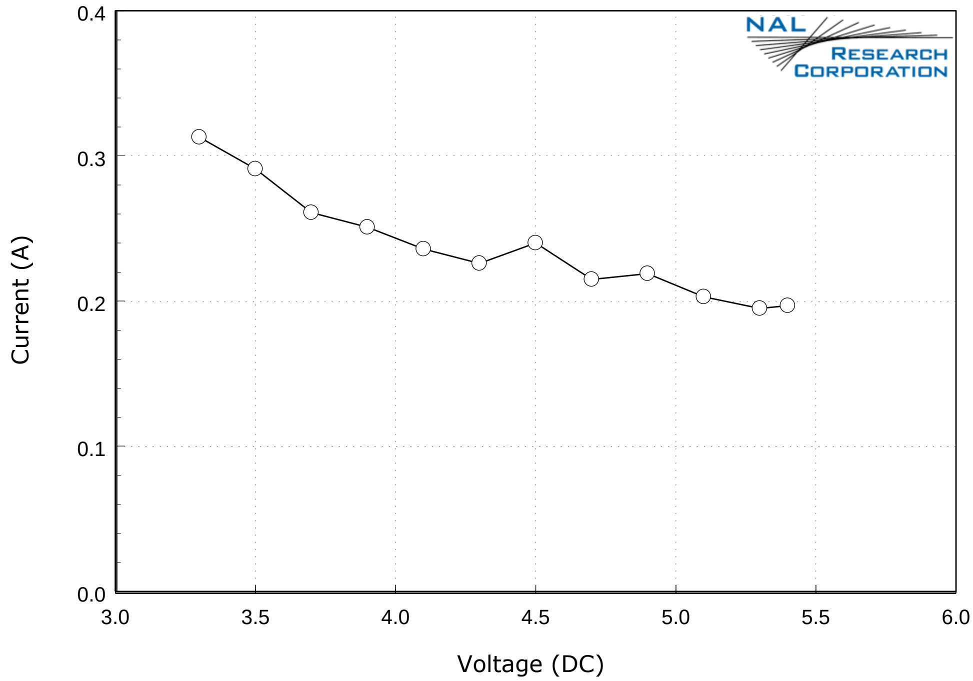


Figure 27. Average Current during SBD with 3VDC to 6VDC Input.

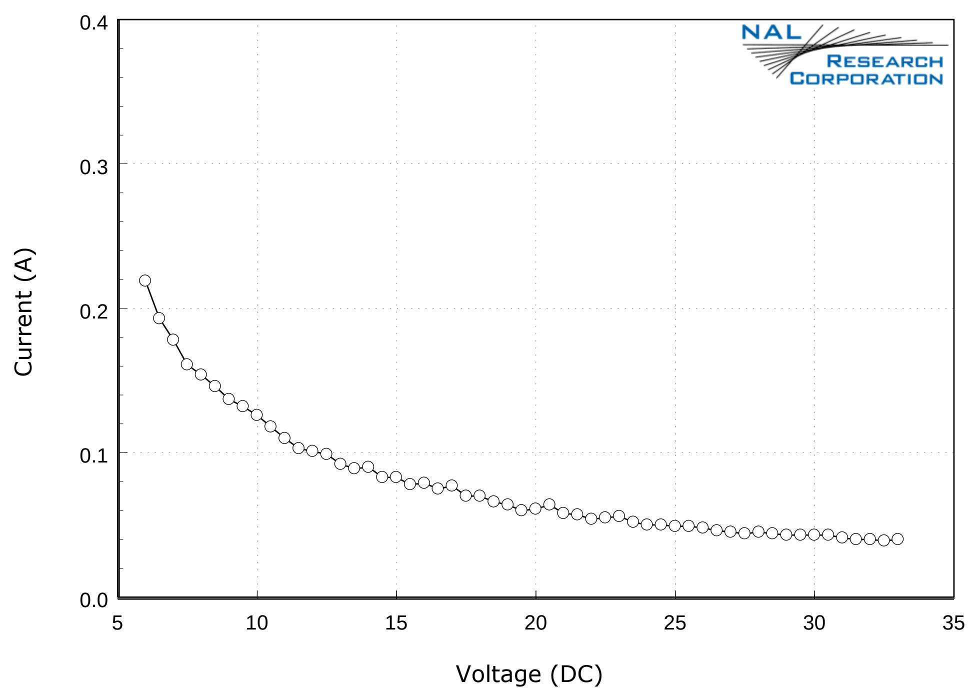


Figure 28. Average Current during SBD with 6VDC to 32VDC Input.

Figure 29 shows the average power consumption by the 9602-LP during SBD transmission on for the entire voltage range.

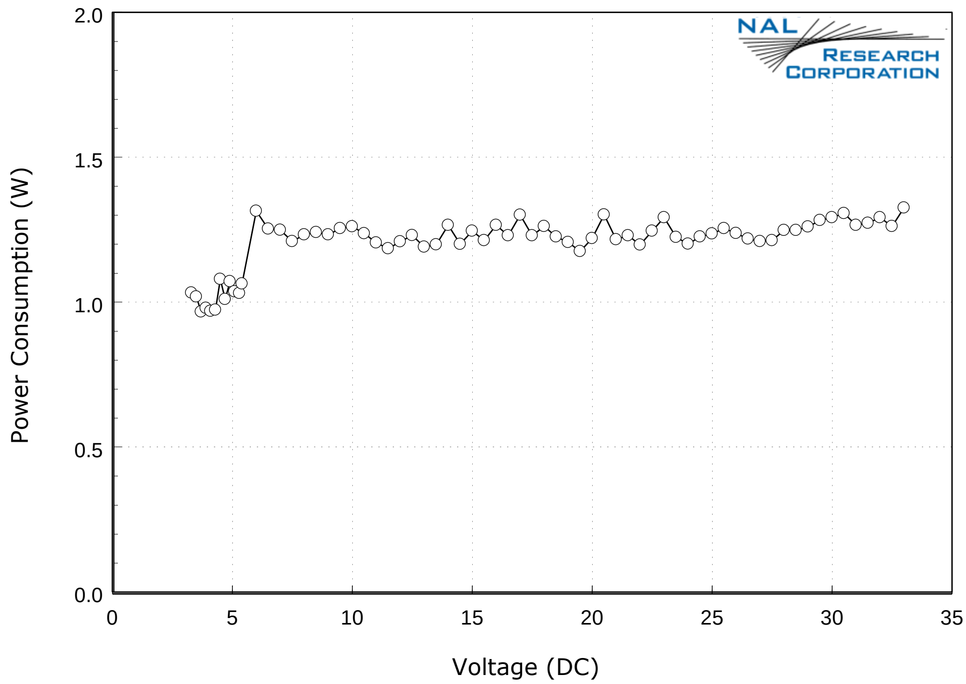


Figure 29. Average Power Consumption during SBD Transmission with 3.5VDC to 32VDC Input.

All the plots above show that the 9602-LP is more efficient (consumes less power) when operates in the 3.6VDC to 5.3VDC input range especially in between reports. It should be noted that the actual current profiles may vary for a number of reasons and users are again reminded to optimize their setup to attain the lowest possible power consumption. Some of the setup parameters to be carefully observed include:

1. Have a clear view of the sky for both the GPS and Iridium antennas—poor visibility of the sky is when a clear line-of-sight is not available between the 9602-LP and the satellites.
2. Keep the Iridium antenna's VSWR low—the higher the antenna VSWR the higher the current consumed by the 9602-LP.
3. Keep the antenna cables' loss to less than 3dB—the higher the antenna cable loss the higher the current consumed by the 9602-LP.
4. Select active GPS antennas with low-power consumption LNAs—a GPS antenna LNA with 30dB gain is sufficient.
5. Keep the power cable between the 9602-LP and the power source as short as possible.

10.0 LIST OF KNOWN ISSUES

a. Waking from motion with ^CAL0 may not cause a report to be sent

11.0 TECHNICAL SUPPORT

For technical support, please contact us at:
Phone: 703-392-1136 Ext. 200 or
E-mail: contact@nalresearch.com

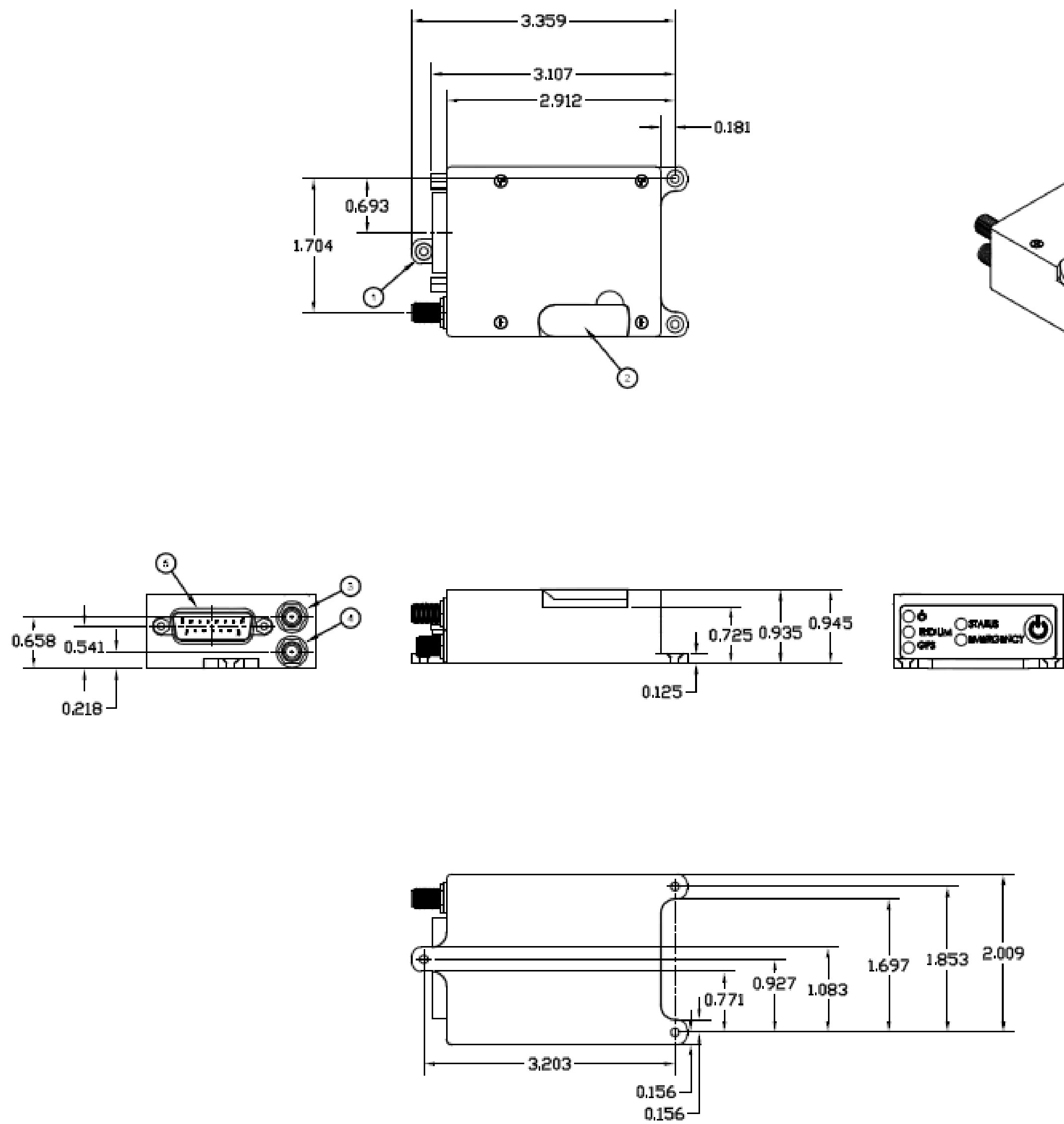
Technical documents are also available to download on NAL Research's website
www.nalresearch.com

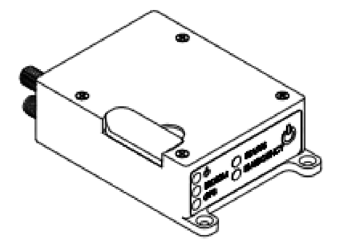
DWG NO. 92358	SH. 1	REV. 1.1

DWG REV	A
BD REV	
A/W REV	

REVISIONS

ZONE	REV	DESCRIPTION	DATE	APPROVED
	1.0	INITIAL RELEASE	02/07/2011	D. GAIBROIS
	1.1	TORQUE INFORMATION ADDED	2/15/2013	D. GAIBROIS





NOTES:
1. 100° COUNTERSINK FOR # 4 SCREW, UNTHREADED (X4)
2. EMERGENCY SWITCH ACCESS
3. GPS SMA CONNECTION, COLOR: SILVER
4. IRIDIUM SMA CONNECTION, COLOR: GOLD
5. DB15 DATA CONNECTION

*RECOMMENDED SMA MATING TORQUE: 8 IN-LBS

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS ± DECIMALS .XX ± .01" .XXX ± .005" ANGLES ±	CONTRACT NO.	NAL RESEARCH CORP.
MATERIAL	APPROVALS / DATE	DRAWING NAME 9602-LP
	DESIGNER E. RODERICK 2/15/2013	
	CHECKER	
FINISH	PROJ. ENG.	SIZE C — CAGE CODE — DWG NO. 92358 — REV 1.1
	APPROVED D. GAIBROIS 2/15/2013	SCALE 1:1 — SHEET 1 OF 1

CAD DRAWING FILE NAME: 9602-LP
CAD GENERATED DRAWING, MANUAL CHANGES NOT ALLOWED

92358 SH. 1 REV. 1.1

APPENDIX A: STANDARDS COMPLIANCE

The 9602 transceiver is designed to meet the regulatory requirements for approval for FCC, Canada, and CE assuming an antenna with a gain of ~3 dBi and adequate shielding. The 9602 transceiver is tested to the regulatory and technical certifications shown in table below.

Regulatory Approvals	Radio Tests	EMC Tests	Mechanical/ Electrical Tests
CE	ETSI EN 301 441 V1.1.1 (2000-05)	ETSI EN 301 489-1 V1.8.1 (2008-04) ETSI EN 301 489-20 V1.2.1 (2002-11)	EN60950-1:2006 Part 1
FCC	FCC CFR47 Parts 2, 15, and 25	EN61000-4-2: 1995/A2: 2001 Part 4.2 EN61000-4-3: 2002 Part 4.3 EN61000-4-4: 2004 EN61000-4-6: 1996/A1: 2001 Part 4.6 EN55022: 2006	
Industry Canada	Industry Canada RSS170 Issue 1, Rev 1, November 6, 1999		

APPENDIX B: EXPORT COMPLIANCE INFORMATION

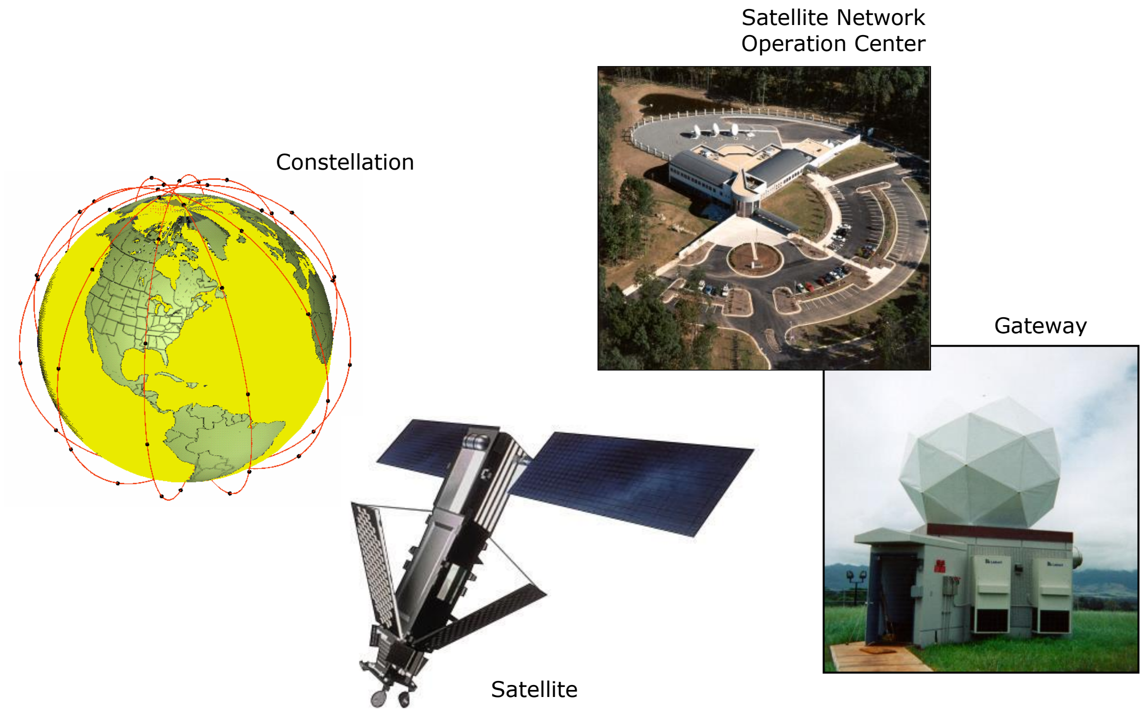
The 9602-LP is controlled by the export laws and regulations of the United States of America (U.S.). It is the policy of NAL Research to fully comply with all U.S. export and economic sanction laws and regulations. The export of NAL Research products, services, hardware, software and technology must be made only in accordance with the laws, regulations and licensing requirements of the U.S. Government. NAL Research customers must also comply with these laws and regulations. Failure to comply can result in the imposition of fines and penalties, the loss of export privileges, and termination of your contractual agreements with NAL Research.

The export and re-export of NAL Research products and services are subject to regulation by the Export Administration Regulations (15 CFR 730-744), as administered by the U.S. Department of Commerce, Bureau of Industry and Security ("BIS"). See: http://www.bxa.doc.gov for further information on BIS and the Export Administration Regulations (EAR). Additional export restrictions are administered by the U.S. Department of the Treasury's Office of Foreign Asset Controls ("OFAC"). See: http://www.ustreas.gov/ofac for further information on OFAC and its requirements.

APPENDIX C: DESCRIPTION OF THE IRIDIUM NETWORK

C.1 Description of the Iridium Network

The Iridium satellite network is owned and operated by Iridium Satellite LLC (ISLLC). It was constructed as a constellation of 66 satellites in low-earth orbit, terrestrial gateways and Iridium subscriber units (ISU). An ISU can either be an Iridium satellite phone or any of the modems. The satellites are placed in an approximate polar orbit at an altitude of 780 km. There are 6 polar planes populated with 11 satellites per orbit constituting the 66 satellite constellation. The near polar orbits of the Iridium constellation provide truly real-time and global coverage from pole-to-pole.



The Iridium is designed to operate in the band of 1616 to 1626.5 MHz although the exact frequencies used depend on the local regulating authorities and issued licenses in any particular region. Each satellite projects 48 beams on the surface of earth, which may be viewed as providing coverage cells on the ground similar to terrestrial systems. Each beam is approximately 600 km in diameter. The 66-satellite constellation has the potential to support a total of 3,168 spot beams; however, as the satellite orbits converge at the poles, overlapping beams are shut down. The satellite footprint is ~4,700 km in diameter. Under each footprint, a satellite is power limited to ~1,100 simultaneous circuits.

The Iridium network uses a time domain duplex (TDD) method and transmits and receives in an allotted time window within the frame structure. Since the system is TDD, the ISU transmit and receive in the same frequency band. The access technology is a FDMA/TDMA (frequency division multiple access/time division multiple access) method whereby an ISU is assigned a channel composed of a frequency and time slot in any particular beam. Channel assignments may be changed across cell/beam boundaries and is controlled by the satellite. The system will provide an average link margin of 13.1 dB.

Although there are multiple gateways, a user is registered to a single gateway. The gateways perform call connection setup and administrative duties such as billing and resource management. The satellite constellation provides connectivity between users, from a user to the Iridium system gateway, and between gateways. Within the Iridium network architecture, the satellites are cross-linked which allows ISU to ISU communication independent of gateway intervention once the call connection is established.

There are currently two commercial Iridium gateways located in Arizona, United States and Fucino, Italy. The U.S. government owns and operates an Iridium gateway located in Hawaii, United States. Each gateway generates and controls all user information pertaining to its registered users, such as user identity, geo-location and billing items. The gateway also provides connectivity from the Iridium system to the terrestrial based networks such as the PSTN.

C.2 Description of the Iridium Network Data Capabilities

For data communications, the Iridium network supports five different modes of operation as shown in Figure D1—dial-up data service, direct Internet connection, short-burst data (SBD), short-messaging service (SMS) and router-based unrestricted digital internetworking connectivity solution (RUDICS).

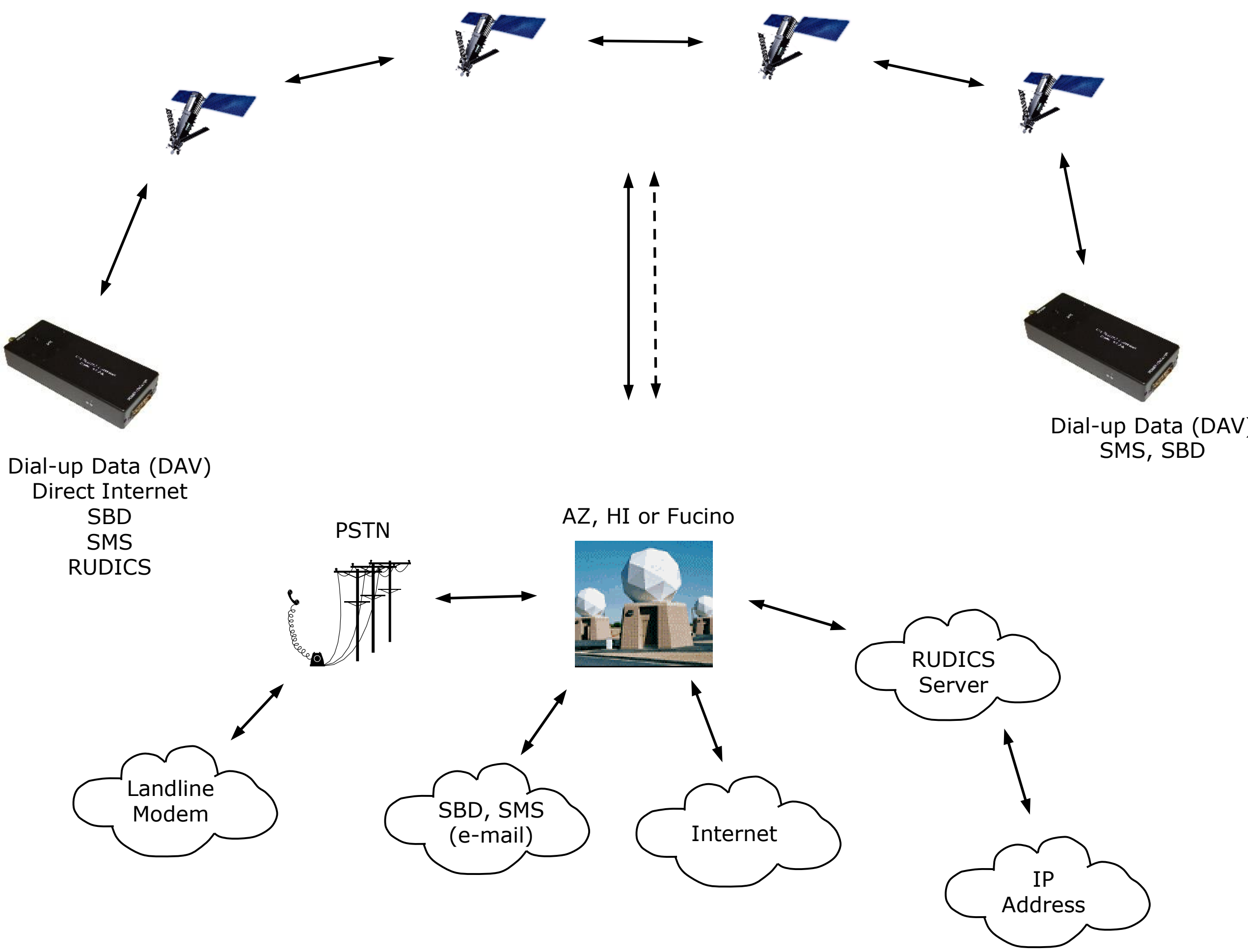


Figure D1. Iridium Network Data Capabilities.

C.3 Dial-Up Data Service

Dial-up data service provides connectivity through the Iridium satellite network to another Iridium modem, to the public switch telephone network (PSTN), to the Defense Switch Network (DSN), to a remote LAN (e.g., a corporate network) or to an Internet Service Provider (ISP) at a nominal data rate of 2.4 kilobits per second (Kbps). The connection time involving user authentication and handshaking (or modem training) can range from 15 to 30 seconds. For an Iridium-to-Iridium call, dial-up data service offers an additional option known as data after voice or DAV. Similar to a voice call, a DAV call is routed directly from one Iridium modem to another Iridium modem without going through the gateway.

Many desktop and laptop computers are equipped with either an internal or external modem to perform dial-up data applications across the landline telephone network (PSTN). On these computers, terminal emulator software or a dial-up networking connection can be configured to a specific modem with a phone number to dial, user identification and password. The modem can then be used to call another computer, a remote LAN or an Internet service provider as shown in Figure D2. The handshaking and protocols are established between the modems independent of the landline.

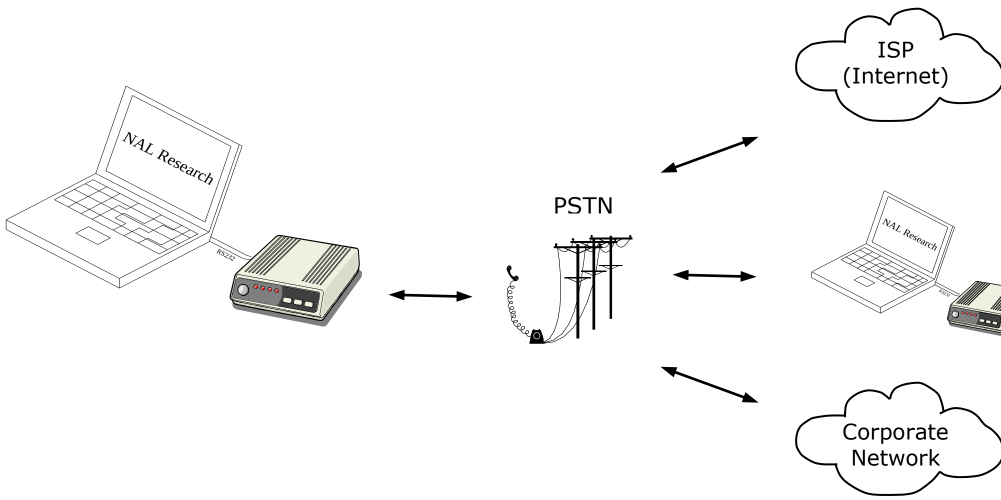


Figure D2. PSTN Dial-Up Connectivity.

The Iridium dial-up data service functions in much the same way as the PSTN dial-up connectivity. From the perspective of a computer, the Iridium modem is just another external modem. The only difference is that the dialed telephone number must conform to the international dialing pattern used by Iridium. When a data call is placed, the Iridium modem actually dials and initiates a connection with the Iridium gateway through the Iridium satellite constellation. Since the Iridium modem is requesting to establish a data connection, the switch at the gateway routes the call through another modem. The modem at the Iridium gateway then dials into and connects to another modem at the other end. Figure D3 illustrates how an Iridium dial-up data service call is routed. The handshaking and protocols established between the modems independent of the Iridium network.

For those ISU-to-ISU dial-up calls where data transmission delay is critical such as the application of TCP/IP protocol, DAV should be considered in the design. This option eliminates the Iridium gateway once authentication and registration is completed allowing ISU-to-ISU communication without the gateway in the loop.

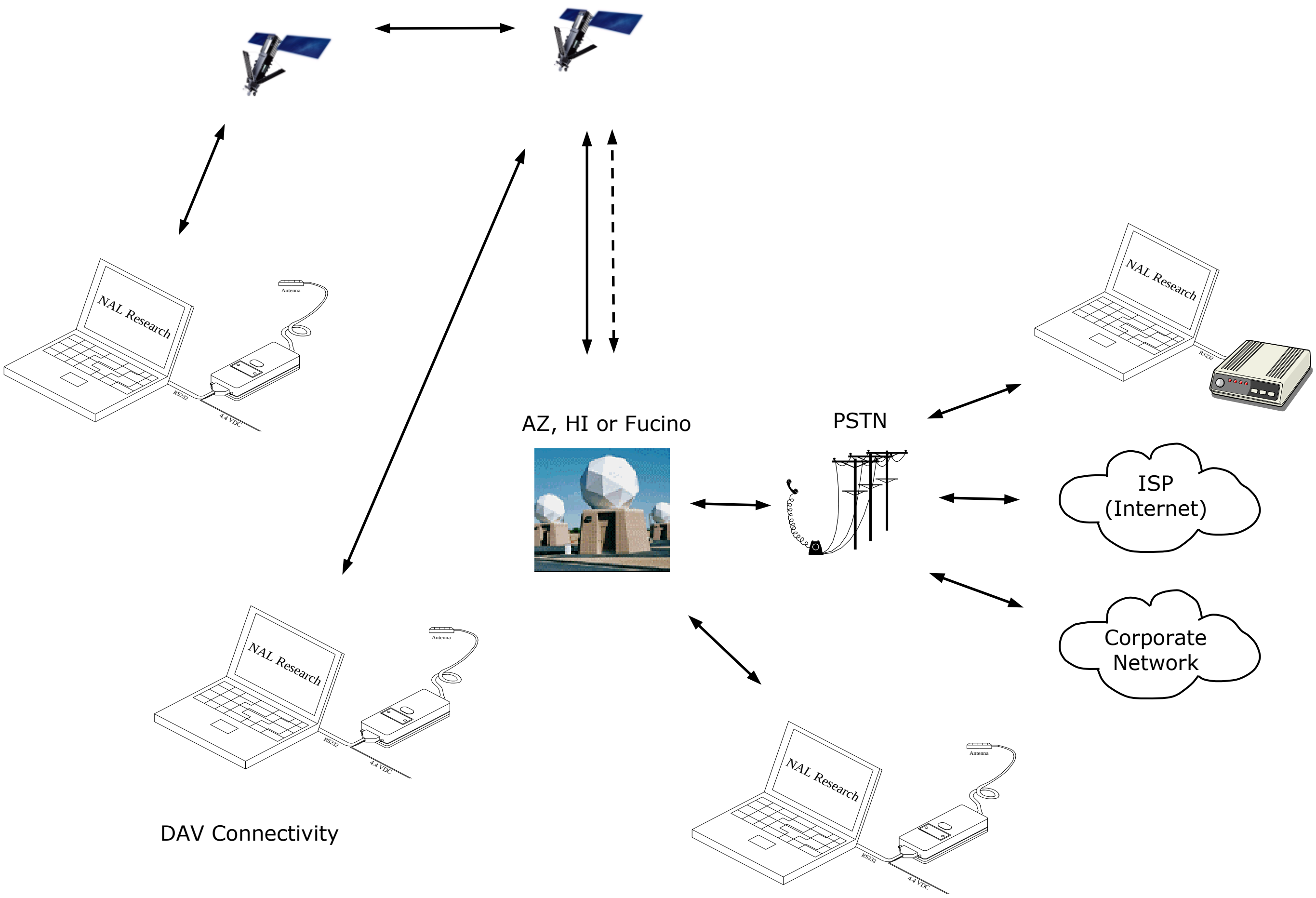


Figure D3. Iridium Dial-Up Data Service.

C.4 Direct Internet Connection

The Iridium Direct Internet service allows users to connect to the Internet via the Iridium gateway without having to sign up with an Internet service provider. This service utilizes a dedicated Apollo Server at the Iridium gateway, which provides high-speed connectivity to the Internet and optimizes server-to-Iridium modem communications. The dial-up networking setup is similar to the dial-up networking setup for landline telephone. The only difference is that the dialed telephone number is an international number provided by Iridium. Figure B3 illustrates how Iridium Internet (NIPRNet) call is routed.

Direct Internet service can be enhanced using Windows-based emulated point-to-point protocol (PPP) called the Apollo Emulator. With the use of the Apollo Emulator software instead of Microsoft Windows® dial-up networking, Direct Internet service can reduce connection time and improve data throughput. In addition, the Apollo Emulator offers a feature called Smart Connect™, which manages airtime by seamlessly connecting and disconnecting a user through the Iridium system. Airtime charges accumulate only while the call is connected. Improved effective data throughput is achieved through the use of user-transparent data compression. The channel rate is still 2.4 Kbps. However, 10 Kbps effective throughput can be achieved depending on content (graphics and images will result in lower effective throughput).

C.5 Short-Burst Data (SBD)

SBD is a simple and efficient bi-directional transport capability used to transfer messages with sizes ranging from zero (a mailbox check) to 1960 bytes. SBD takes advantage of signals within the existing air interface, without using the dedicated traffic channels. As a result, small amounts of data can be transferred more efficiently than those associated with circuit-switched data calls. Messages that originate from an Iridium modem can be delivered to a variety of destinations. Commonly, data are delivered across terrestrial communications networks (NIPRnet and Internet) to servers and applications that process data from one or multiple fielded Iridium modems. SBD service also supports the transfer of messages to Iridium modems, where messages may originate from terrestrial sources. Delivery methods and options are initially configured when the Iridium modem is first purchased and may be easily modified via web pages at a later time.

C.6 Short Messaging Service (SMS)

SMS is a mechanism to deliver short data messages over the Iridium satellite network to the NIPRNet/Internet. Iridium SMS service incorporates a subset of the GSM SMS features. Each SMS message can be up to 160 text characters (7-bit coded) in length. The text characters are based on a 7-bit alphabet, which is encoded and transmitted as 8-bit data, hence the 140 octet (byte) maximum message size.

SMS service is a store and forward method of transmitting messages to and from an Iridium modem. The short message from the modem is stored in a central Short Message Center (SMSC) which then forwards it to the destination. In the case that the recipient is not available, the SMSC will attempt to deliver the SMS until it is delivered or the validity period expires. SMS supports a limited confirmation of message delivery**.** The sender of the short message can request to receive a return message notifying them whether the short message has been delivered or not. With this option, the originator gets a confirmation that the message was delivered to the SMSC. Unlike standard GSM, the Iridium SMS can only acknowledge that the message was delivered to the SMSC and not the end-destination.

SMS messages can be sent and received simultaneously while a voice call is in progress. This is possible because SMS messages travel over and above the radio channel using the signaling path, whereas the voice call uses a dedicated “traffic” radio channel for the duration of the call.

C.7 RUDICS

RUDICS is an enhanced gateway termination and origination capability for circuit switched data calls across the Iridium satellite network. When an Iridium modem places a call to the RUDICS Server located at the Iridium Gateway, the RUDICS Server connects the call to a pre-defined IP address allowing an end-to-end IP connection between the Host Application and the Iridium modem. There are three key benefits of using RUDICS over the conventional PSTN circuit switched data connectivity or mobile-to-mobile data solutions: (1) elimination of analog modem training time, (2) increased call connection quality, reliability, and maximized throughput and (3) protocol independence.

C.8 Iridium Geo-Location

The Iridium network makes calculations of the geographical location (geo-location) of an ISU each time a call is placed. The technique employed to determine the geo-location of an ISU is based on measurements of the ISU and satellite propagation delay and Doppler frequency shift. These measurements are used to estimate cosines of spherical angles that identify the ISU's location relative to the satellite by the gateway.

The Iridium network can locate an ISU to within 10 km only about 78% of the time. The so-called error ellipse can have a large eccentricity with the major axis oriented in the azimuth dimension and the minor axis oriented in the radial dimension. The position of the ISU in the radial dimension relative to the satellite can almost always be determined to within 10 km with just one measurement. Errors in the azimuth dimension relative to the satellite are largest along the satellite's ground path and tend to increase with distance from the satellite. Geo-location errors in the east-west dimension, therefore, are sometimes more than 100 times greater than in the north-south dimension.