9602-NAL User Guide

Version A

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REVISION HISTORY

Revision	Date	Description	Author
1.0.1	02/25/2013	Initial version	A. Schiltz
A	03/28/2022	- Updated to new template; editorial update. - Formal release	A. Schiltz, A. Nguyen

REFERENCE DOCUMENTS

The latest revisions of the NAL documents are available from the NAL Research website at

https://www.nalresearch.com/support/documentation-downloads/.

Reference	Title	Revision/Date
[1]	Product Information Model 9602-N	2019
[2]	AT Commands for Models 9602 (TN2010-111-V1.0)	Version 1.0, 2010
[3]	SatTerm Software Manual (TN2009-19-V7.0)	Version 8.9.7, 2022
[4]	Additional Information on DirectIP SBD (TN2007-637-V1.0)	Version 1.0 2009
[5]	Additional Information on SBD (AN2007-07-V3.3.0)	Version 3.3 2009

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GLOSSARY

AT ....Attention. Two-letter sequence starting a string of terminal commands. The AT is intended to get the terminal's attention prior to executing a command.

BIS ....Bureau of Industry and Security

CE ....Conformité Européenne

CTS.............................Clear To Send

DAV ....Data After Voice

DC..............................Direct Current

DCD ....Data Carrier Detect

DoD ....Department of Defense

DSN............................Defense Switch Network

DSR ....Data Set Ready

DTE ....Data Terminal Equipment

EAR ....Export Administration Regulations

EMI ....Electromagnetic Interference

EMSS ....Enhanced Mobile Satellite Services

ETSI............................European Telecommunications Standards Institute

FCC ....Federal Communications Commission

FDMA ....Frequency-Division Multiple Access

GND ....Ground

GPS ....Global Positioning System

GSM............................Global System for Mobile Communications

I/O ....Input/Output

IP ....Internet Protocol

ISU ....Iridium Subscriber Unit

kbps............................Kilobits Per Second

LAN ....Local Area Network

LED ....Light-Emitting Diode

LNA.............................Low-Noise Amplifier

MT-SBD ....Mobile-Terminated Short-Burst Data

NIPRNet......................Non-classified Internet Protocol Router Network

OFAC..........................Office of Foreign Asset Controls

PDA............................Personal Digital Assistant

PPP ....Point-To-Point Protocol

PSTN ....Public Switched Telephone Network

PWR...........................Power

RI ....Ring Indicator

RF...............................Radio Frequency

RHCP..........................Right-Handed Circular Polarization

RTS.............................Request To Send

RUDICS ....Router-Based Unrestricted Digital Internetworking Connectivity Solution

RX ....Receiving

SatTerm......................Satellite Terminal Emulator Software

SBD ....Short-Burst Data

SIM ....Subscriber Identification Module

SMA ....SubMiniature version A (RF connector)

SMS ....Short Message Service

TCP ....Transmission Control Protocol

TDD............................Time-Division Duplex

TDMA ....Time-Division Multiple Access

TX ....Transmitting

VDC............................Volts (direct current)

VSWR.........................Voltage Standing Wave Ratio

1   INTRODUCTION

This document describes the operational features, configuration settings, and electrical and mechanical interfaces of the 9602-NAL. The 9602-NAL modem is a satellite transceiver comprising an Iridium 9602 transceiver with an extended input voltage range, and only allows Short Burst Data (SBD connectivity to the Iridium satellite network. It does not support voice, circuit-switched data, or Short Message Service (SMS). Similar to a standard landline modem, the 9602-NAL can be controlled by any Data Terminal Equipment (DTE) capable of sending standard AT commands via an RS232 serial port. A DTE can be a desktop computer, a laptop computer, a PDA, or even a microcontroller. NAL Research can enable the 9602-NAL to utilize either the Iridium commercial gateway or the DoD EMSS Gateway when requested by an authorized user. Key features of the 9602-NAL include:

- Does not incorporate nor need a SIM card to operate

- Has an automatic notification indicating a message is queued at the gateway

- Provides a maximum Mobile-Originated (MO) message size of 340 bytes

- Provides a maximum Mobile-Terminated (MT) message size of 270 bytes

- Supports RS232 serial connection

- Capable of voltage range from 5 VDC to 32 VDC

IMPORTANT: An EMSS-enabled 9602-NAL must first be provisioned (signed up for airtime) with EMSS SBD service before testing or field use. Accessing the Department of Defense (DoD) Enhanced Mobile Satellite Services (EMSS) Gateway is not authorized until the 9602-NAL 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. **Note**: This is a U.S. Government Information System website, and can only be accessed by authorized users with a valid certificate.

2   MECHANICAL INTERFACES

The 9602-NAL is intended to be used as a modem connected to a DTE via an RS232 serial interface. The 9602-NAL incorporates two different connectors—a multi-interface connector and a SubMiniature version A (SMA) Iridium antenna connector—as shown in **Figure 1**. When requested, an SMA Global Positioning System (GPS) pass-through connector can be installed as an option (see section **5**). The 9602-NAL is provided with four mounting holes, one at each corner. It is recommended to use 6-32 screws to fasten the modem down.

Multi-Interface Connector   Iridium Antenna Connector

Figure 1: Iridium 9602-NAL Connectors

3   MULTI-INTERFACE CONNECTOR

The multi-interface connector is a male 15-pin miniature D-Sub type (DB-15 connector) that includes five interfaces—DC power input, power on/off control, RS232 data interface, network availability output, and supply power indicator output. Individual pin assignments are summarized in **Table 1**.

Table 1: Pin Assignments for the Multi-interface Connector

Pin #	Signal	Description	Interface
1	EXT_PWR	External DC Power Input	+5.0 VDC ±0.5 V
2	EXT_PWR	External DC Power Input	+6.5 VDC to +32 VDC
3	EXT_GND	External GND Input	0 V
4	ON/OFF	ON/OFF Control Input; ON ≥2.0 V; OFF ≤0.5 V	Analog
5	SUPPLY_OUT	Supply Power Indicator Output	+3.3 V, 5 mA Max.
6	S_TX	RS232 Transmit Data Input	RS232 Data
7	S_RX	RS232 Receive Data Output	RS232 Data
8	SIG_GND	Signal Ground, 0 V Signal Reference and Return	0 V
9	DCD	RS232 Data Carrier Detect Output	RS232 Data
10	DSR	RS232 Data Set Ready Output	RS232 Data
11	CTS	RS232 Clear To Send Output	RS232 Data
12	RI	RS232 Ring Indicator Output	RS232 Data
13	RTS	RS232 Request To Send Input	RS232 Data
14	DTR	RS232 Request To Send Input	RS232 Data
15	NET AVAIL	Network Availability; Avail=High, Not Avail=Low	3.3 V Digital

3.1   RS232 DATA INTERFACE (9-WIRE CONFIGURATION)

The 9602-NAL supports a standard RS232 serial interface to a host system DTE incorporating hardware handshaking and flow control. The RS232 interface comprises eight signals and a ground, as shown in **Table 1**. The RS232 interface allows a connected DTE to utilize the 9602-NAL's functionality through AT commands. Note that the ring indicator is used by the 9602-NAL to indicate that a Mobile-Terminated SBD (MT-SBD) message is queued at the gateway. The

DTE can monitor this pin and use appropriate AT commands to retrieve the MT-SBD message. The 9602-NAL does not support autobaud. Set the baud using the AT+IPR command. The factory-set baud is 19.2 kbps.

3.2 RS232 DATA INTERFACE (3-WIRE CONFIGURATION)

The 9602-NAL's RS232 interface operates as a 9-wire connection and it is a recommended configuration. However, the 9602-NAL may also be operated with a 3-wire connection, where only transmit, receive, and ground signals are used with no flow control. Several steps must be taken to allow 3-wire configuration. These steps ensure the 9602-NAL and DTE work together without hardware handshaking.

1. Set AT&Dn to AT&D0 to ignore the DTR input.

2. Set AT&Kn to AT&K0 to disable RTS/CTS flow control.

3. The other output signals may be connected and operate as follows:

    a. CTS driven ON (low).

    b. DSR operates as normal.

    c. RI operates as normal.

    d. DCD driven ON (low).

NOTE: The Request To Send / Clear To Send (RTS/CTS) flow control when enabled, is only used when the data port is in SBD data mode. In AT command mode, RTS is ignored and CTS is driven ON (low).

3.3 DC POWER INTERFACE

The DC power interface comprises two DC power inputs, a ground input, and a control signal, as summarized in **Table 1**. The 9602-NAL accepts either +5 VDC input through pin #1 or +6.5 VDC to +32 VDC input through pin #2. The 9602-NAL is shipped with hardware set for +5 VDC input. It can be changed to +6.5 VDC to +32 VDC input through an internal jumper. Remove the modem's top plate to find the jumper. With the 9602-NAL held in the position shown in **Figure 2** (DB-15 connector on the left side and SMA antenna connector on the right side), the 9602-NAL is set for +5 VDC when the jumper is on the left pin, and it is set for +6.5 VDC to +32 VDC

when the jumper is on the right pin. Both 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.
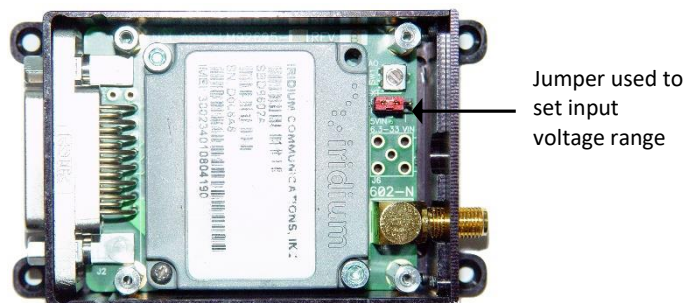

Jumper used to set input voltage range

Figure 2: Power Input Settings

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

Plots of DC power requirements for the 9602-NAL are in **Appendix A: Power Consumption of the** . In addition, the power supply must also guarantee the following:

- The supply voltage drops for an 8.3 ms burst is not more than 0.2 V.
- The power supply provides overcurrent protection in case of device malfunction.
- The supply noise is less than the limits in the following profile:
  - 100 mV peak-to-peak from 0 to 50 kHz
  - 5 mV peak-to-peak at 1 MHz measured in 50 kHz bandwidth
  - 10 mV peak-to-peak at 1 MHz measured in 1 MHz bandwidth
  - 5 mV peak-to-peak above 5 MHz measured in 1 MHz bandwidth

Keep cables used to supply power to the 9602-NAL as short as possible to prevent significant voltage drop, which can cause the 9602-NAL to malfunction during an SBD session.

Model HRC-24-11 is a data/power cable assembly designed to work with the 9602-NAL modem. The HRC-24-11 has a three-foot RS-232 cable for connection onto a computer and two wires for DC power input to a 9602-NAL. Model HRC-24-12 is available on the NAL website (www.nalresearch.com)

Figure 3: Model HRC-24-11 Data/Power Cable Assembly

Power reset by the 9602-NAL during an SBD session indicates the power source is unable to sustain required peak current demand.

3.4   POWER ON/OFF CONTROL

The 9602-NAL is shipped with hardware set for automatic startup when power is applied, whether the voltage setting is for +5 VDC or for +6.5 VDC to +32 VDC. As long as the input voltage is applied, an internal logic high on pin #4 turns on the 9602-NAL, ignoring the external voltage input to this pin.

If external ON/OFF control is required, pin #4 on the multi-interface connector can be set to accept an external analog signal (ON>=2.0V; OFF<=0.5V) to turn a powered 9602-NAL on and off, bypassing the internal controller.

- When pin #4 is pulled to GND level (i.e., below 0.5 V), the powered 9602-NAL will be in the off state.

- When it is pulled to HIGH level (i.e., above 2.0 V but not to exceed 5 V), the powered 9602-NAL will be in the on state. The current drawn on the external load used to pull the 9602-NAL to HIGH is no more than 0.5 mA.

The internal ON/OFF controller can be disconnected by turning the internal rotary switch counterclockwise. The switch can be found by removing the modem's top plate. With the 9602-NAL held in the position shown in **Figure 4** (DB15 connector on the left and SMA antenna connector on the right), the 9602-NAL is set for internal ON/OFF when the groove on the rotary switch is in the '\' position and is set for external ON/OFF when the grove on the rotary switch

is in the '/' position. A flathead screw driver can be used to turn the rotary switch to toggle between the two settings.
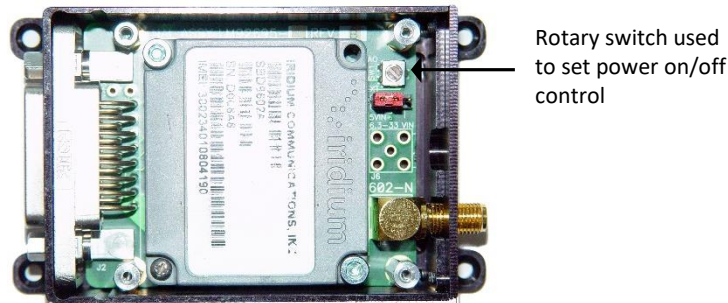

Figure 4: External ON/OFF Setting for the 9602-NAL

Prior to turning off the 9602-NAL, issue a "flush memory" (AT*F) command to ensure all memory-write activity is completed. When a 9602-NAL has been turned off, wait until power has reached 0 V, and then wait more than 2 seconds before reapplying power to a unit. Additionally, if a unit does not respond to AT commands, power off the module, wait 2 seconds, and then power it back on. When a 9602-NAL is powered off, the power-on reset circuit requires 2 seconds for voltages to decay. If the 2-second wait time is not adhered to, the reset circuit may not operate and the 9602-NAL could be placed in a non-operational state. The state is not permanent and can be rectified by the above procedure.

3.5 DC SUPPLY INDICATOR OUTPUT

A DC supply indicator signal is provided by the 9602-NAL on pin #5, which could be used directly for driving an LED to provide a visible indication that the 9602-NAL supply is on. Alternatively, the output signal could be used in application logic to determine whether the internal 9602-NAL power supply is on.

3.6 NETWORK AVAILABILITY OUTPUT

The digital output of pin #15 can be used to determine when the 9602-NAL has visibility to the Iridium satellite network or the Iridium network is "available." Network Available means that the 9602-NAL can successfully receive the Ring Channel, or, put more simply, it can see an Iridium satellite. Network Available is not a guarantee that a message is successfully sent. The Network Available state is evaluated every time the Ring Channel is received or missed. If the Ring Channel is visible, then it is updated every four seconds. If the Ring Channel is not

currently visible, then the update period can be as long as two minutes, depending on how long the lack of satellite visibility existed. This is because the 9602-NAL attempts to conserve power by increasing the ring-search interval while the satellites are not visible. Every time a ring search fails, the time to wait is increased until it reaches a limit at 120 seconds. The wait time between search windows is reset to 4 seconds every time a search succeeds.

If Network Available is currently off, you may still attempt an SBDI[X] session. This will force the 9602-NAL to look for the Ring Channel immediately, and on finding it, to attempt to send the message. In this case, Network Available will not come on immediately. Network Available does not turn on while in a +SBDI session. It will, however, turn on 4 seconds later, assuming that the Ring Channel is present. After the SBD session completes, the 9602-NAL performs a new Ring Channel search sequence, at the end of which Network Available gets turned on. That can take between 4 and 12 seconds. If the +SBDI attempt fails to find the ring channel, the search window does not reset to 4 seconds. Note that the behavior of +CIEV:1 is identical to that of the Network Available output.

3.7   S-METER PERFORMANCE

The S-meter readings reported over the AT command interface indicate the signal strength of a 9602-NAL. Be careful when using the S-meter readings for comparisons between devices. Of particular note are the following:

1. There is a 0.5 dB tolerance on calibrating the S-meter.

2. Each signal strength bar represents a 2 dB increment.

3. Multiple ring channels can be present at the same time, so units can lock to different signals.

4. If the reading is near the decision threshold, it would be easy to see a 1-bar difference.

4   IRIDIUM ANTENNA CONNECTOR

The 9602-NAL uses a single SMA female 50-ohm antenna connector to both transmit and receive. The mating SMA male connectors are readily available from many RF hardware providers. Cable loss between the 9602-NAL and the antenna is critical and must be kept to less than 3 dB at the operating frequency of 1616 to 1626.5 MHz. Implementation loss higher than this will affect the Iridium link performance and quality of service. Connect the 9602-NAL to an antenna with the characteristics shown in **Table 2**.

Table 2: Antenna Characteristics Required

Parameter	Value
Input/Output Impedance	50 ohms nominal
Gain	3 dBi
Polarization	Right-handed circular polarization (RHCP)
VSWR (Maximum Operational)	1.5 to 1

NAL Research offers several types of antennas for use with the 9602-NAL. 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 (see **Figure 5**). Model SYN7391-C is a small, inexpensive L-band antenna designed to operate with NAL Research satellite modems and trackers. It is optimized to operate under various data modes, specifically SBD.

Figure 5: SYN7391-C Antenna

If the specific application requires a custom antenna, it must meet the following characteristics in **Table 3**.

Table 3: Custom Antenna Characteristics Required

Parameter	Value
Operating Temperature Range	–40°C/+85°C without loss of function
Measurement Frequency Range	1616 to 1626.5 MHz
Return Loss (Minimum)	9.5 dB (<1.5:1 VSWR)
Gain	0.0 dBic (weighted average minimum)
Minimum 'Horizon' Gain	–2.0 dBic (82° conic average)
Nominal Impedance	50 ohms
Polarization	Right-handed circular polarization (RHCP)
Basic Pattern	Omnidirectional and hemispherical

5 GPS PASS-THROUGH

As an option, a second SMA connector can be installed by NAL Research on the 9602-NAL to be used as a pass-through connection from the Iridium antenna path. It is provided for GPS receivers with the ability to share the Iridium antenna. An overview of this circuit is provided in **Figure 6**. Select a wideband Iridium antenna with appropriate sensitivity in both the Iridium frequency and the GPS frequency. The 9602-NAL allows for GPS signals to pass at all times except during Iridium transmitter burst. This protects the GPS receiver from an electric overstress condition with a minimum impact on the GPS reception and functionality. However, the Iridium signal CANNOT be totally isolated. During the SBD transmit burst, there will be leakage of the 1616 to 1626 MHz to the GPS port, which can significantly degrade the quality of the GPS signals. Appropriate Surface Acoustic Wave (SAW) filters must be implemented in the front end of the GPS receiver. The GPS pass-through SMA connector must be terminated with a 50 Ω load when not in use. A suitable load is the Huber+Suhner 65_SMA-50-0-1/111_NE or equivalent.

The GPS pass-through can be turned on by applying a 1.2 VDC threshold to the GPS SMA connector. The DC bias on the GPS antenna connector is similar to having an active GPS antenna. In normal operation, this bias would be used to power the LNA inside the active antenna. For the Iridium 9602-NAL, the bias voltage is used to activate an RF switch and enable connection of the GPS port to the antenna port. With external power applied and the 9602-NAL off, the GPS path is still available for use. A DC voltage on the GPS connector activates the LNA in the 9602-NAL, and the 9602-NAL draws approximately 10 mA from the 9602-NAL supply. With external power applied and the 9602-NAL inactive, and the GPS path not enabled, the quiescent current consumption will be less than 0.5 mA.
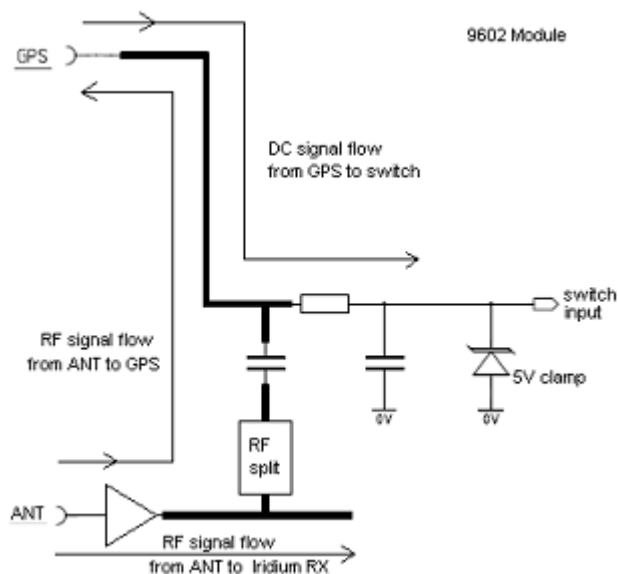
Figure 6: GPS Path When 9602-NAL is Not Transmitting and GPS is Active

Note the following operational points when using the GPS receivers connected to the pass-through GPS SMA connector:

- The GPS pass-through path is activated by detecting the presence of a DC voltage on the center pin of the GPS connector. The 9602-NAL uses the voltage from the GPS center pin to switch on the RX path and requires minimal current of less than 100 µA. The GPS path is activated when this center-pin voltage is higher than 1.2 V.

- There is a path loss of approximately 3 dB in the receive direction from Iridium SMA connector to the GPS SMA connector.

- The GPS receive path is temporarily switched off during transmissions from the 9602-NAL.

- As long as power supply to the 9602-NAL is connected and the DC voltage on the GPS connector is present, the GPS pass-through path is made available. The GPS path is available even when the 9602-NAL has been turned off using its on/off control signal.

- The GPS receiver must present 50 Ω impedance across the Iridium band or SBD performance could be degraded.

- The output return loss is typically −8 dB.

6 CONFIGURATION SETTINGS

The 9602-NAL allows the DTE to configure the data port communication parameters. The three configuration types are active, factory default, and stored.

- The *active* configuration is the set of parameters currently in use. They can be changed by the DTE individually via specific AT commands.

- The *factory-default* configuration is stored in permanent memory. This configuration can be recalled at any time through use of the AT&Fn command.

- Two groups of settings, or "profiles," can be *stored* as user-defined configurations.

The DTE first creates desired active configurations and then writes them to memory using the AT&Wn command. These profiles can be designated to be loaded as the active configuration upon 9602-NAL power-up through use of the AT&Yn command. The 9602-NAL can be reset without loss of power to these profiles through use of the ATZn.

7 MODES OF OPERATIONS

The RS232 serial interface to a host system DTE is always in one of three modes:

- Command mode,

- SBD Data mode,

- or SBD Session mode.

When the data port is in Command mode, AT commands can be entered to control the 9602-NAL. In Command mode flow control has no effect, because the RTS input is ignored and the CTS output is driven ON (low). When in SBD data mode, the 9602-NAL transfers binary or text SBD message data to or from the DTE.

In SBD Data mode:

- All characters from the DTE not forming part of the message data are ignored (i.e., no AT commands may be entered).
- No unsolicited result codes are issued.
- RTS/CTS flow control, if enabled, is active. When RTS is OFF (high), the 9602-NAL suspends transfer of data to the DTE; when CTS is OFF (high), the 9602-NAL expects the DTE to suspend transfer of data to the 9602-NAL.

When in SBD Session mode, the 9602-NAL attempts to conduct an SBD session with the Iridium network. In SBD session mode:

- The DTE must wait for the +SBDI [X][A] session result code.
- All characters from the DTE are ignored.
- Unsolicited result codes are issued where those codes have been enabled.

Transitions between the modes of operation are performed automatically by the 9602-NAL in response to the SBD AT commands; the DTE has no other control over the mode.

8 HARDWARE FAILURE REPORTING

If the 9602-NAL detects a hardware problem during initialization, it may not be able to function. Under such case, the 9602-NAL notifies the DTE by issuing an unsolicited result code at the end of initialization:

HARDWARE FAILURE: <subsys>,<error>

where <subsys> identifies the software subsystem that detected the error, and <error> is the subsystem-specific error code. Any AT commands that cannot be handled in the failure condition will terminate with result code 4 ("ERROR").

9 TECHNICAL SUPPORT

For technical support, please contact us at:

Phone: 703-392-1136, x203

Fax: 703-392-6795

Email: contact@nalresearch.com

Technical documents are also available to download on NAL Research's website

www.nalresearch.com in the Support > Documentation & Downloads section.

APPENDIX A: POWER CONSUMPTION OF THE 9602-NAL

This section provides some insight to the electrical power profile of the 9602-NAL. It does not describe every situation and permutation possible. It is a starting point to continue your own development design. The actual usage profile can vary for a number of reasons:

- View of the sky— poor visibility of the sky where a clear line of sight is not available between the transceiver and the satellite will increase power usage as the transceiver makes multiple attempts to access the satellite.
- The higher the antenna VSWR, the higher the current consumed.
- Frequent activation/deactivation of the 9602-NAL module by the host system computer will increase power usage.
- Manufacturing variations from transceiver to transceiver.

The host system designer should ensure their design covers worst-case power consumption scenarios. The figures below provide a graphical representation of the typical supply current profile of a 9602-NAL sending and receiving SBD messages.

- **Figure 7** displays a typical initial in-rush current of the 9602-NAL during power-up with 6 VDC input.
- **Figure 8** displays the in-rush current of the 9602-NAL for the entire input voltage range.
- **Figure 9** displays a time history plot of the current drawn by the 9602-NAL during standby mode.
- **Figure 10** displays a time history plot of the current drawn by the 9602-NAL during an SBD transmission.
- **Figure 11** displays a time history plot of the current drawn by the 9602-NAL during sleep.
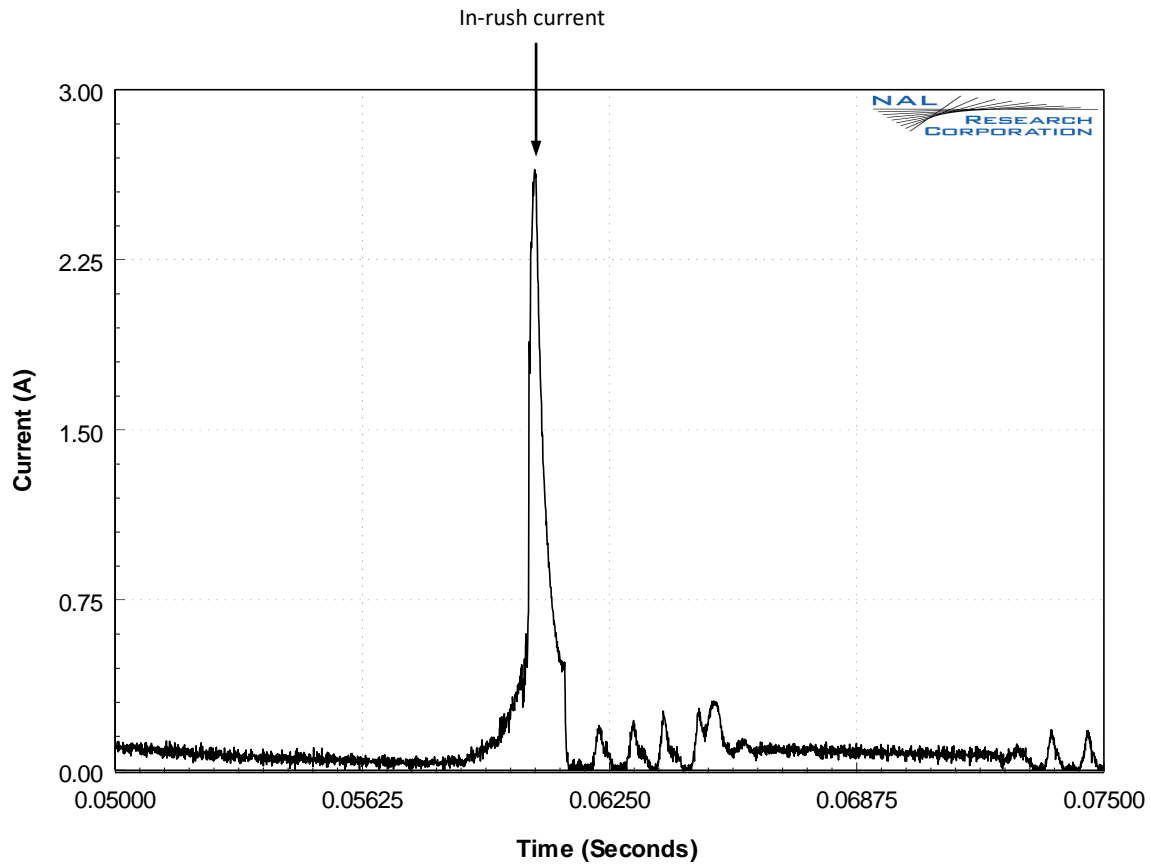
In-rush current

Figure 7: In-rush Current Spike During Power-up (6 VDC Input)
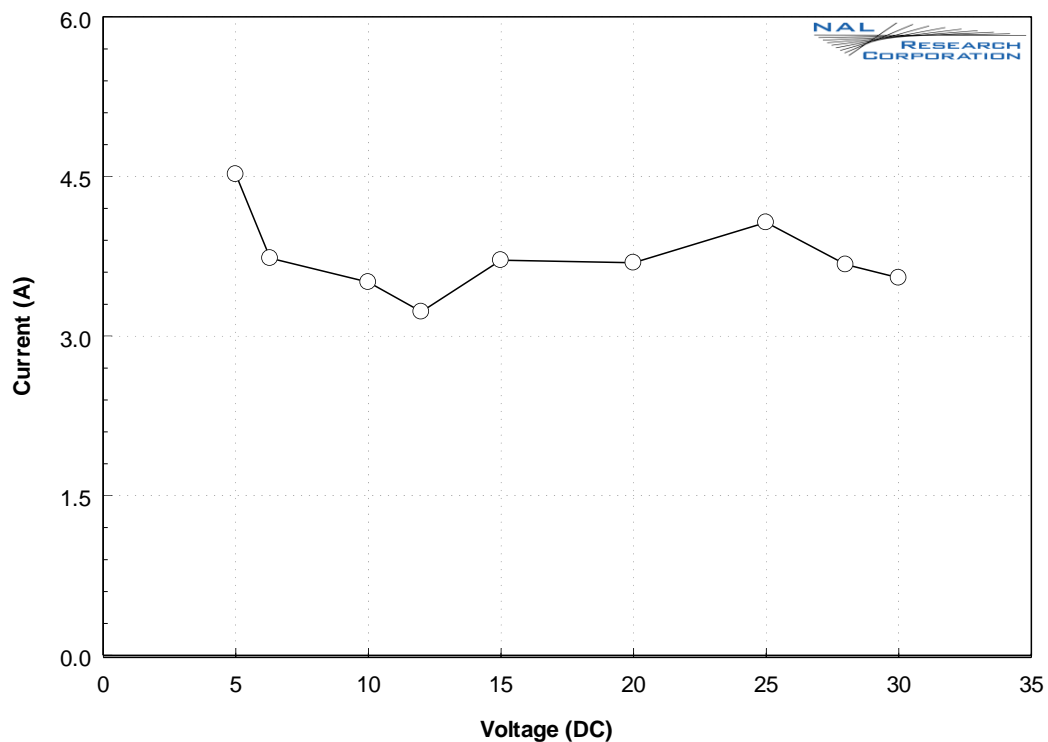

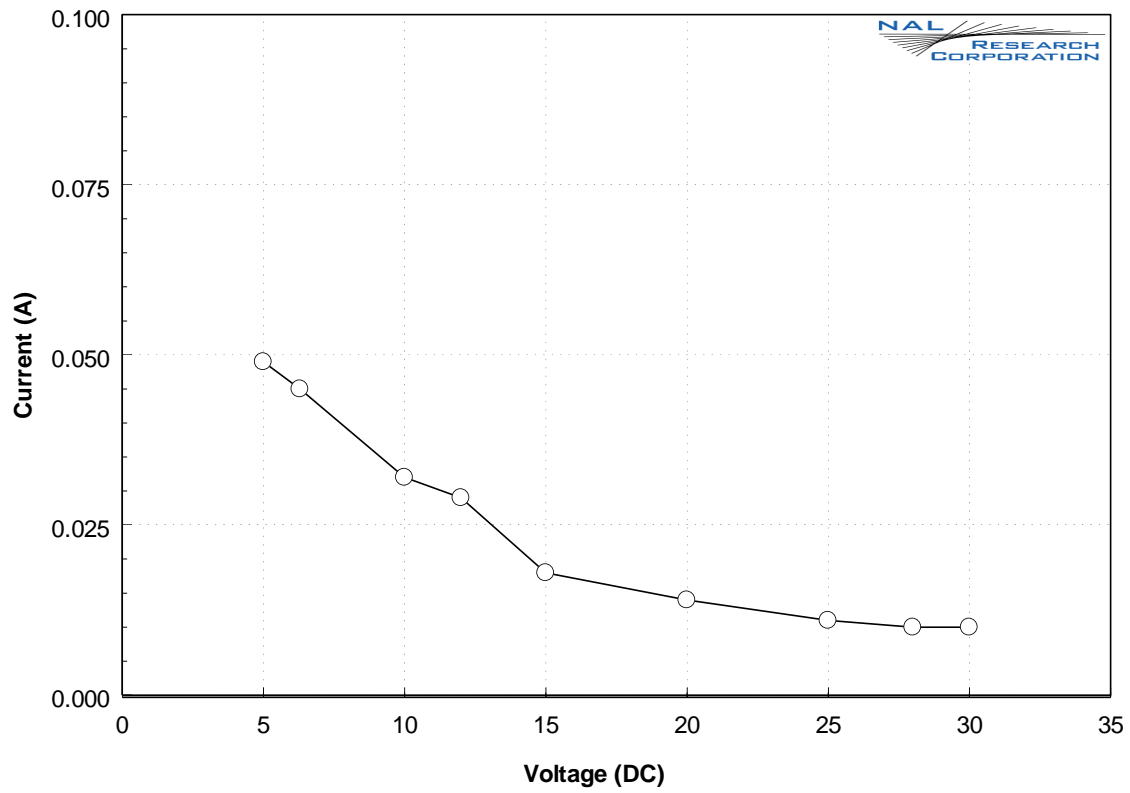*Figure 8: In-rush Current Spike During Power-up*
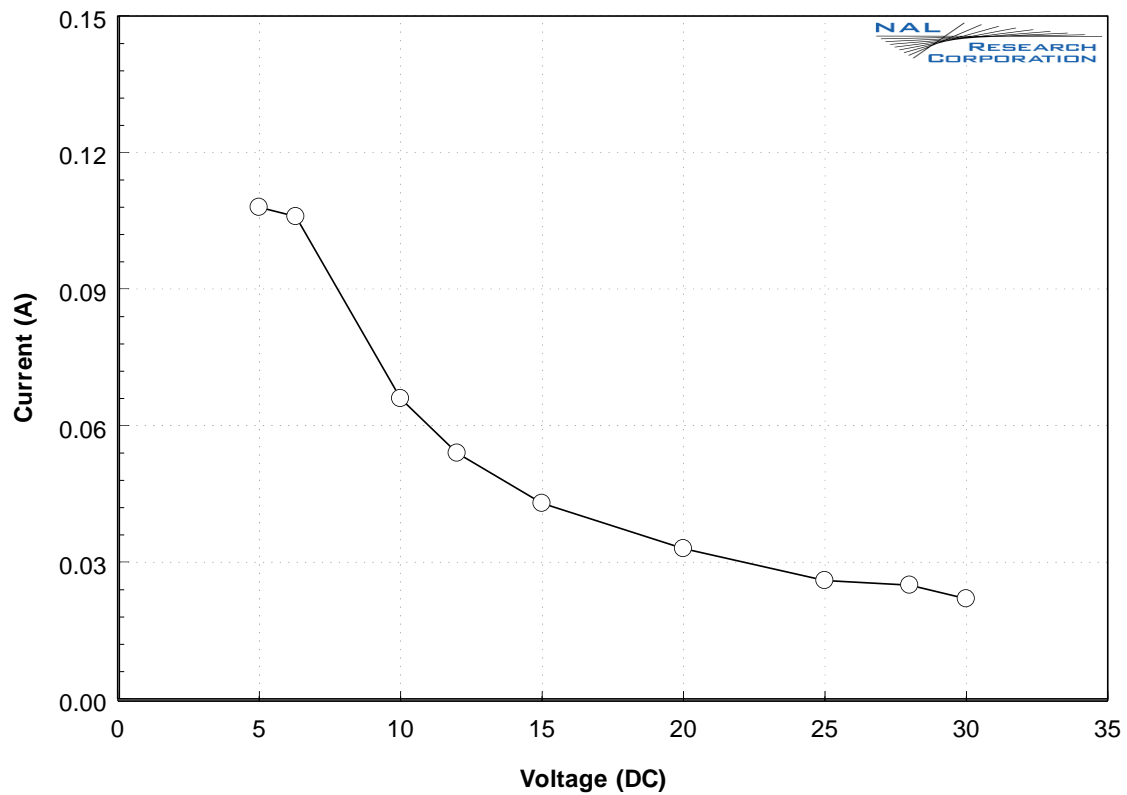
Figure 9: Current Drawn During Standby

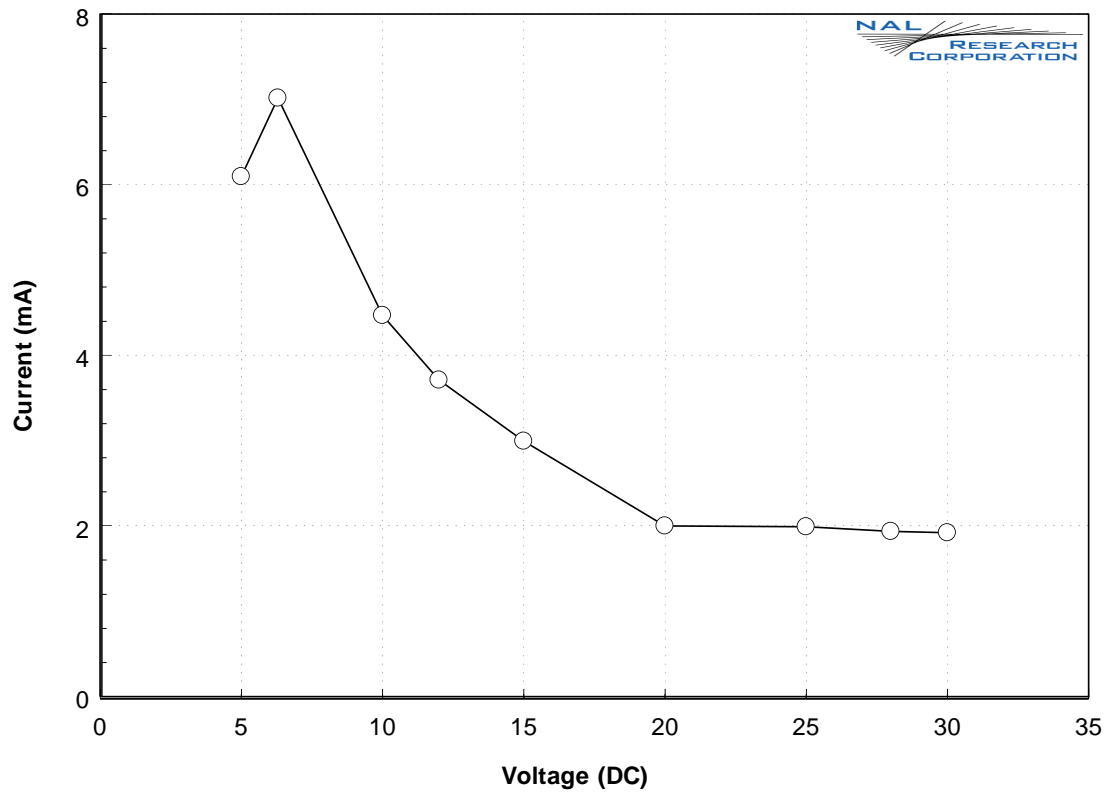*Figure 10: Current Drawn During SBD*

Figure 11: Current Drawn During Sleep

APPENDIX B: 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 approximately 3 dBi and adequate shielding. The 9602 transceiver is tested to the regulatory and technical certifications shown in the table below.

Table 4: Regulatory and Technical Certifications

Regulatory Approvals	Radio Tests	EMC Tests	Mechanical/ Electrical Tests
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		
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

APPENDIX C: EXPORT COMPLIANCE

The 9602-NAL is controlled by the export laws and regulations of the United States of America (USA). 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: https://www.bis.doc.gov/index.php/regulations/export-administration-regulations-ear 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 D: THE IRIDIUM NETWORK

The Iridium satellite network is owned and operated by Iridium Communications Inc. It is constructed as a constellation of 66 satellites in low-earth orbit, terrestrial gateways, and Iridium Subscriber Units (ISUs). An ISU can either be an Iridium satellite phone or various types of 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.
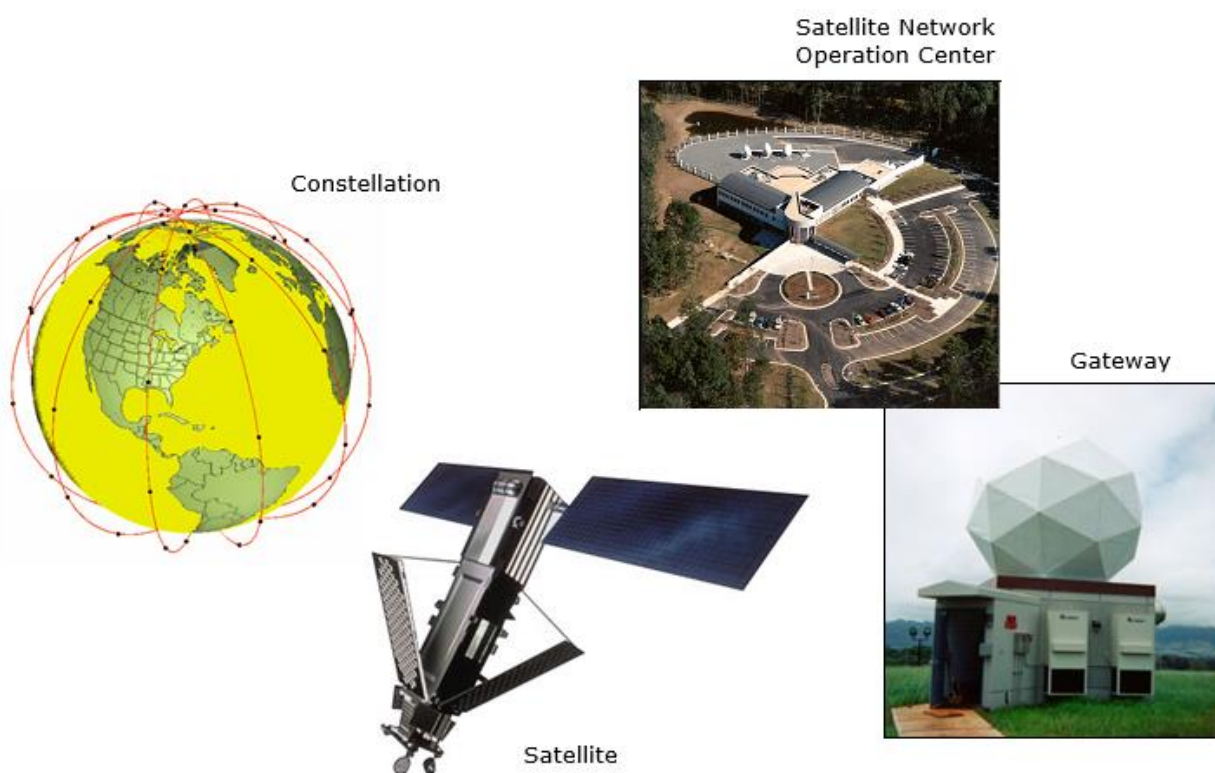
Figure 12: Iridium Network Major Components

The Iridium network is designed to operate in the band of 1616.0 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 approximately 4,700 km in diameter. Under each footprint, a satellite is power-limited to approximately 1,100 simultaneous circuits.

The Iridium network uses a Time-Division Duplex (TDD) method and transmits and receives in an allotted time window within the frame structure. Since the system is TDD, the ISUs transmit and receive in the same frequency band. The access technology is a Frequency Division Multiple Access/Time Division Multiple Access (FDMA/TDMA) 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 are controlled by the satellite. The system provides 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, geolocation, and billing items. The gateway also provides connectivity from the Iridium system to the terrestrial-based networks such as the Public Switched Telephone Network (PSTN) or the internet.

IRIDIUM NETWORK DATA CAPABILITIES

For data communications, the Iridium network supports five different modes of operation, as shown in **Figure 13**: dial-up data service, direct internet connection, SBD, SMS, and Router-Based Unrestricted Digital Internetworking Connectivity Solution (RUDICS).
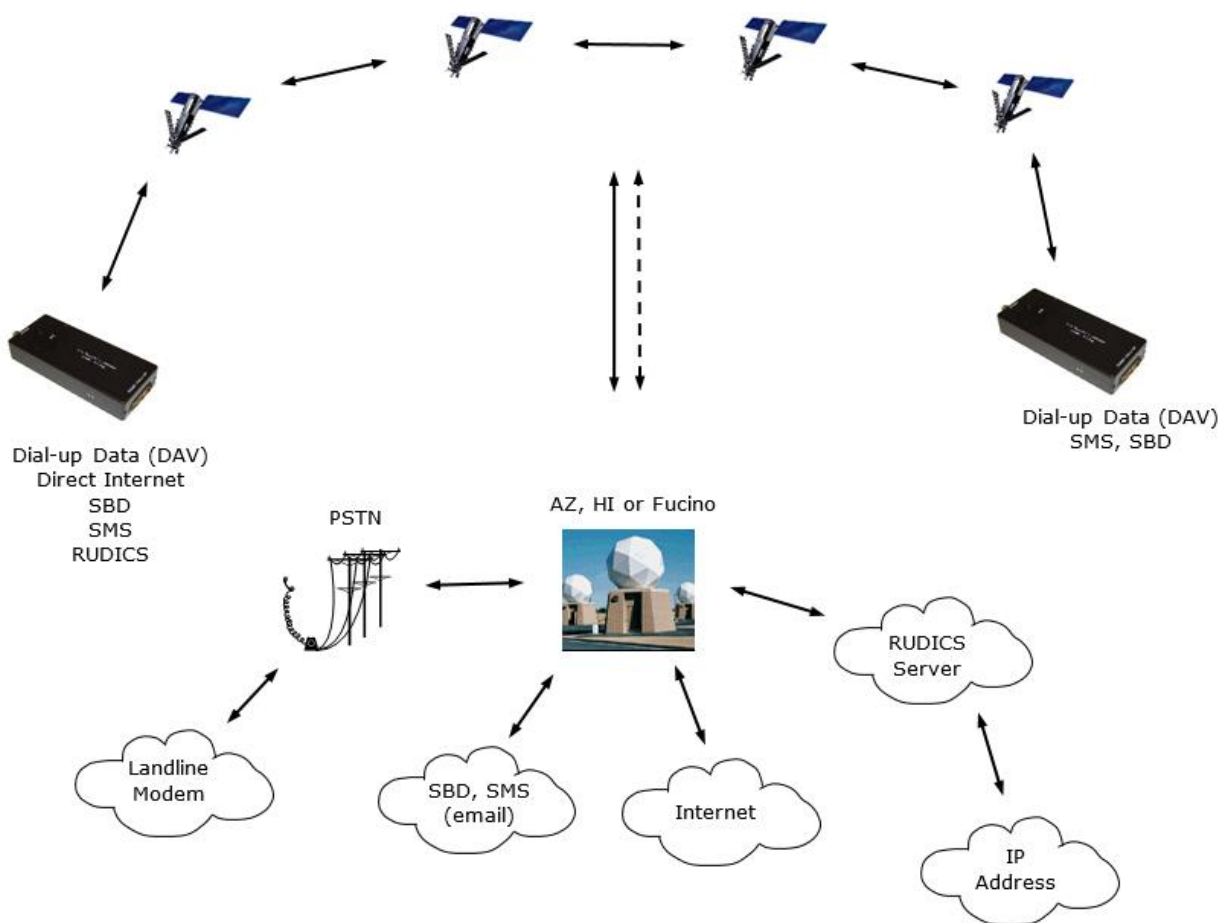
Figure 13: Iridium Network Data Capabilities

DIAL-UP DATA SERVICE

Dial-up data service provides connectivity through the Iridium satellite network to another Iridium modem, to the Public Switched Telephone Network (PSTN), to the Defense Switch Network (DSN), to a remote Local Area Network (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 (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 (ex: 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 ISP, as shown in **Figure 14**. The handshaking and protocols are established between the modems independent of the landline.
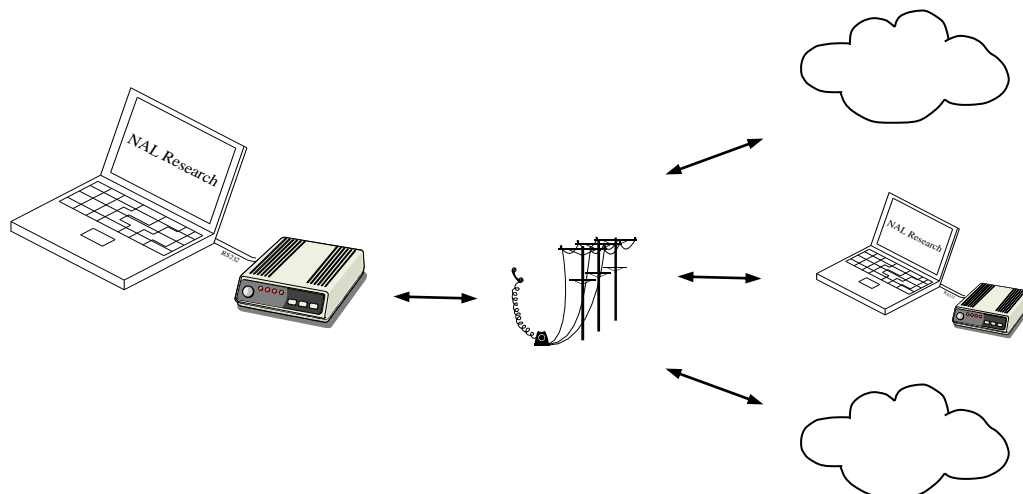

Figure 14: PSTN Dial-up Connectivity

The Iridium dial-up data service, as shown in **Figure 15**, 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. Because 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 15** illustrates how an Iridium dial-up data service call is routed. The handshaking and protocols established between the modems are 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.
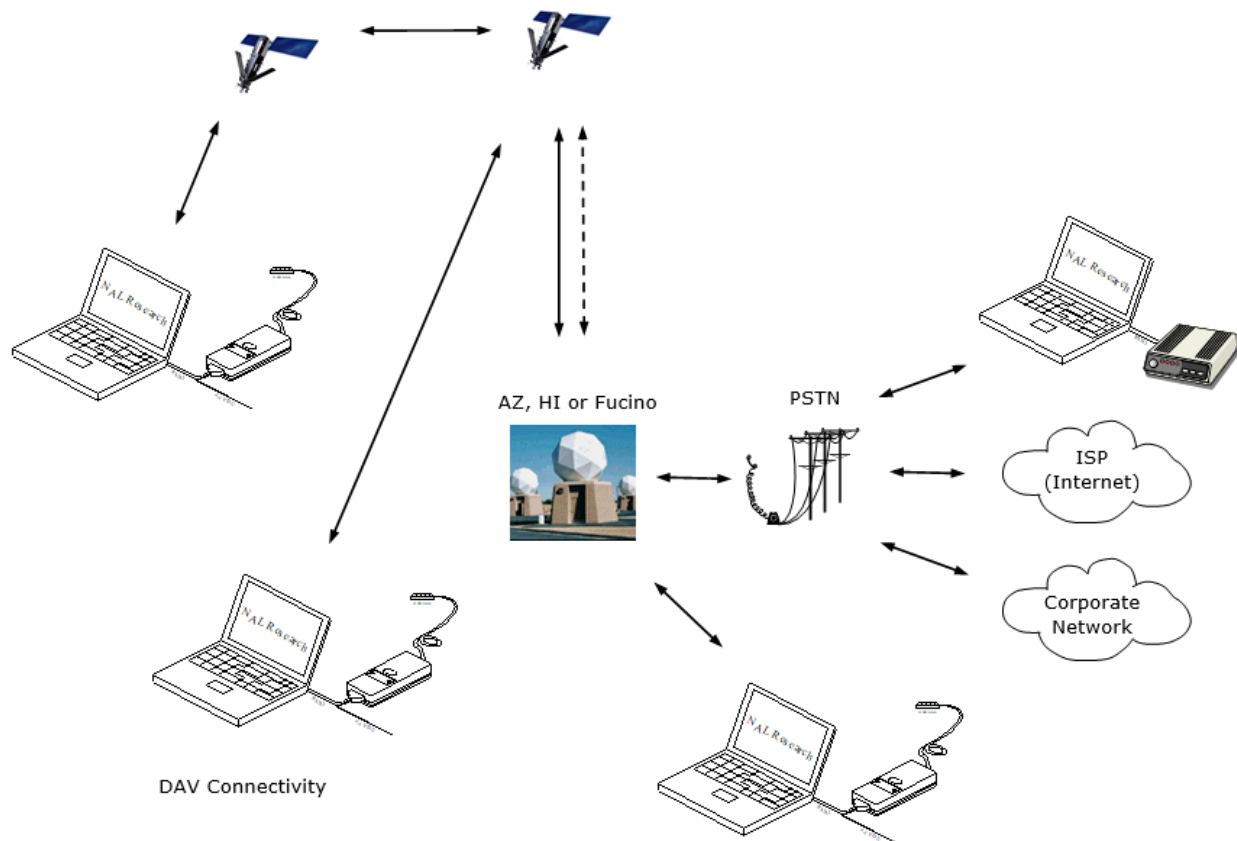
Figure 15: Iridium Dial-up Data Service

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 a landline telephone. The only difference is that the dialed telephone number is an international number provided by Iridium. **Figure 15** illustrates how an Iridium internet 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 result in lower effective throughput).

SHORT BURST DATA

SBD is a simple and efficient bidirectional 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 but 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 webpages at a later time.

SHORT MESSAGING SERVICE

SMS is a mechanism to deliver short data messages over the Iridium satellite network to the NIPRNet/internet. Iridium SMS 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 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 Service Center (SMSC), which then forwards it to the destination. If the recipient is not available, the SMSC attempts to deliver the SMS message 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 or not the short message has been delivered. 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.

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 predefined 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.

IRIDIUM GEOLOCATION

The Iridium network makes calculations of the geographical location (geolocation) of an ISU each time a call is placed. The technique employed to determine the geolocation 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. Geolocation errors in the east-west dimension, therefore, are sometimes more than 100 times greater than in the north-south dimension.

APPENDIX E: DESIGN SPECIFICATIONS

MECHANICAL SPECIFICATIONS

Dimensions:..2.81" x 1.90" x 0.91" (71 mm x 48 mm x

23 mm)

Weight (approximate):.............................4.8 oz (136 g)

Multi-Interface Connector: ....15-Pin D-Sub

Iridium Antenna: ....SMA

Enclosure:..Aluminum alloy/EMI shielding

RF SPECIFICATIONS

Operating Frequency: ....1616 to 1626.5 MHz

Duplexing Method: ....TDD

Input/Output Impedance:.........................50 Ω

Multiplexing Method: ....TDMA/FDMA

RADIO CHARACTERISTICS

Average Power during a Transmit Slot (Max):...........1.6 W

Receiver Sensitivity at 50 Ω (Typical):........................–117 dBm

Maximum Cable Loss Permitted:..............................2 dB

Link Margin – Downlink: ....13 dB

Link Margin – Uplink: ....7 dB

ELECTRICAL SPECIFICATIONS

Input Voltage Range: ....+4.5 VDC to +5.5 VDC or +6.5 VDC to

+32 VDC

Main Input Voltage Ripple: ....< 40 mV peak-to-peak

Idle Current (Average): ....45 mA @ 5 VDC

Idle Current (Peak):...................................195 mA @ 5 VDC

Transmit Current (Average): ....190 mA @ 5 VDC

Transmit Current (Peak):...........................1.5 A @ 5 VDC

Receive Current (Average): ....45 mA @ 5 VDC

Receive Current (Peak): ....195 mA @ 5 VDC

SBD Message Transfer Current (Average): ....190 mA

SBD Message Transfer Power (Average): ....≤ 1.0 W

Note: The power requirements apply to DC power measured at the 9602-NAL multi-interface connector input. The average power consumption may vary depending on the field of view between the 9602-NAL antenna and the Iridium satellite.

ENVIRONMENTAL SPECIFICATIONS

Operating Temperature Range: ....–40°F to +185°F (–40°C to +85°C)

Operating Humidity Range: ....< 75% RH

Storage Temperature Range: ....–40°F to +185°F (–40°C to +85°C)

Storage Humidity Range: ....< 93% RH

Note: The operating temperature range is 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.

DATA I/O SPECIFICATIONS

Short Burst Data: ....340 bytes for mobile-originated

Short Burst Data: ....270 bytes for mobile-terminated

Hardware Interface: RS232

Software Interface: ....Standard AT commands
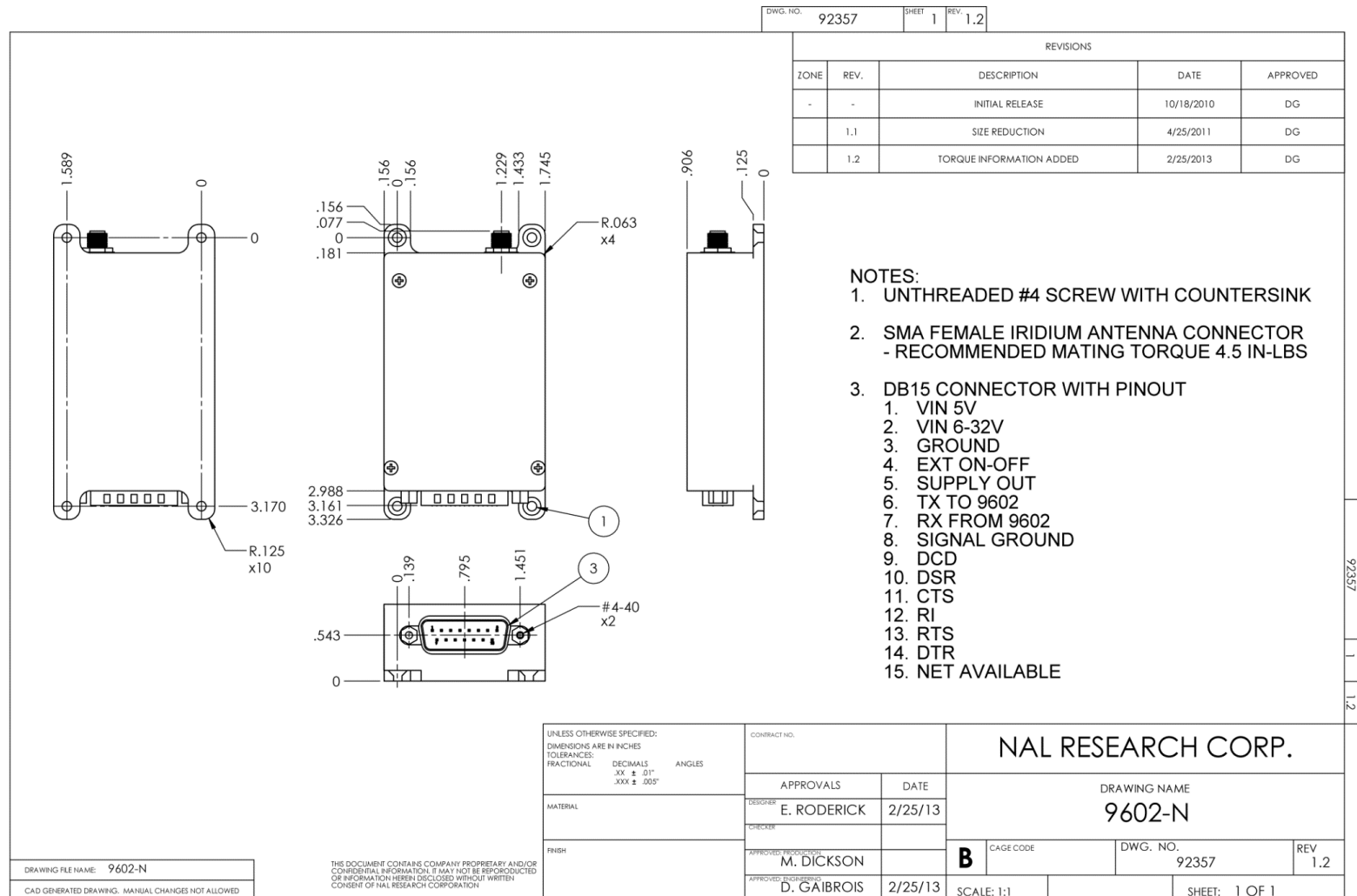
APPENDIX F: MECHANICAL DRAWING

Figure 16: 9602-NAL Mechanical Drawing