Iceland Liechtenstein Norway grants

The final conference of the POLNOR-LEADER project

Tests of Satellite Link for Flight Monitoring and Measurement Transmission

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Silesian University of Technology

NORCE

UNIVERSITY OF WARSAW

SkyTech eLab

Gliwice, 26.06.2024

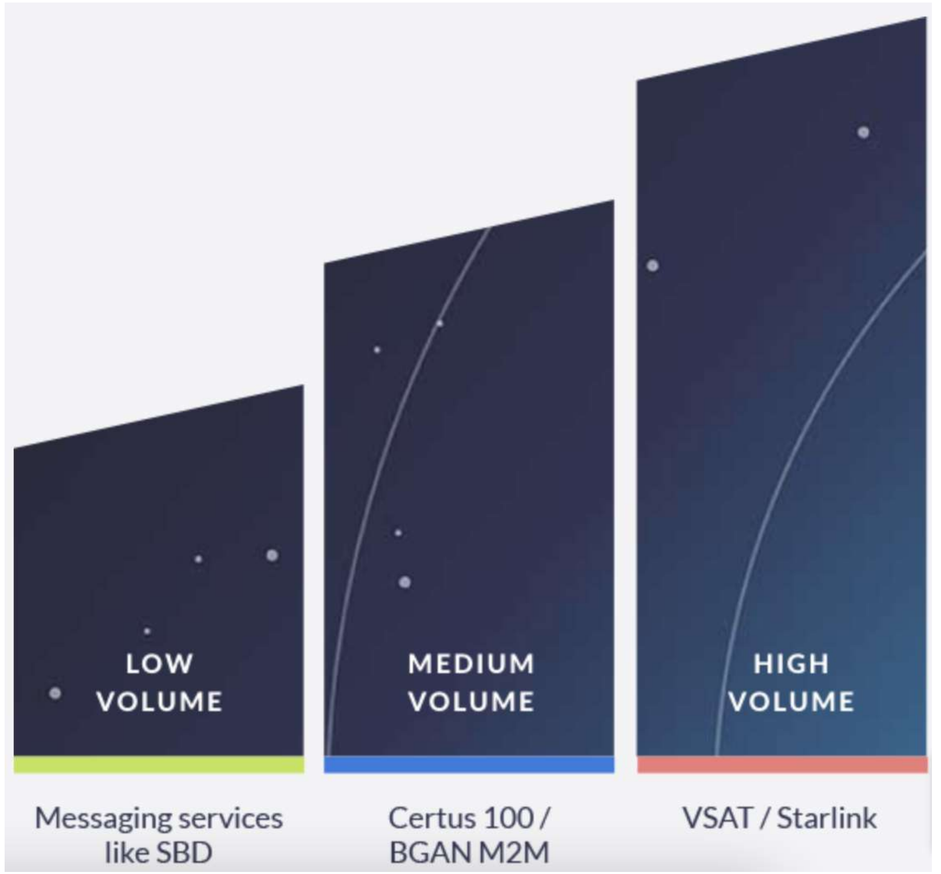
Satellite Links

Overview of available solutions

Low volume:
(Iridium SBD and Inmarsat IDP)
- Telemetry, sensor data.
  A few bytes to a few kilobytes.

Medium Volume:
(Iridium Certus 100 and Inmarsat BGAN M2M)
- Audio, images, log files.
  Kilobytes to a few megabytes.

High Volume:
(Starlink and VSAT)
- Video, high-resolution images.
  Megabytes to gigabytes.



RockBLOCK Rock7 service

Iridium operator – Rock7 Ground Control Technologies UK Ltd

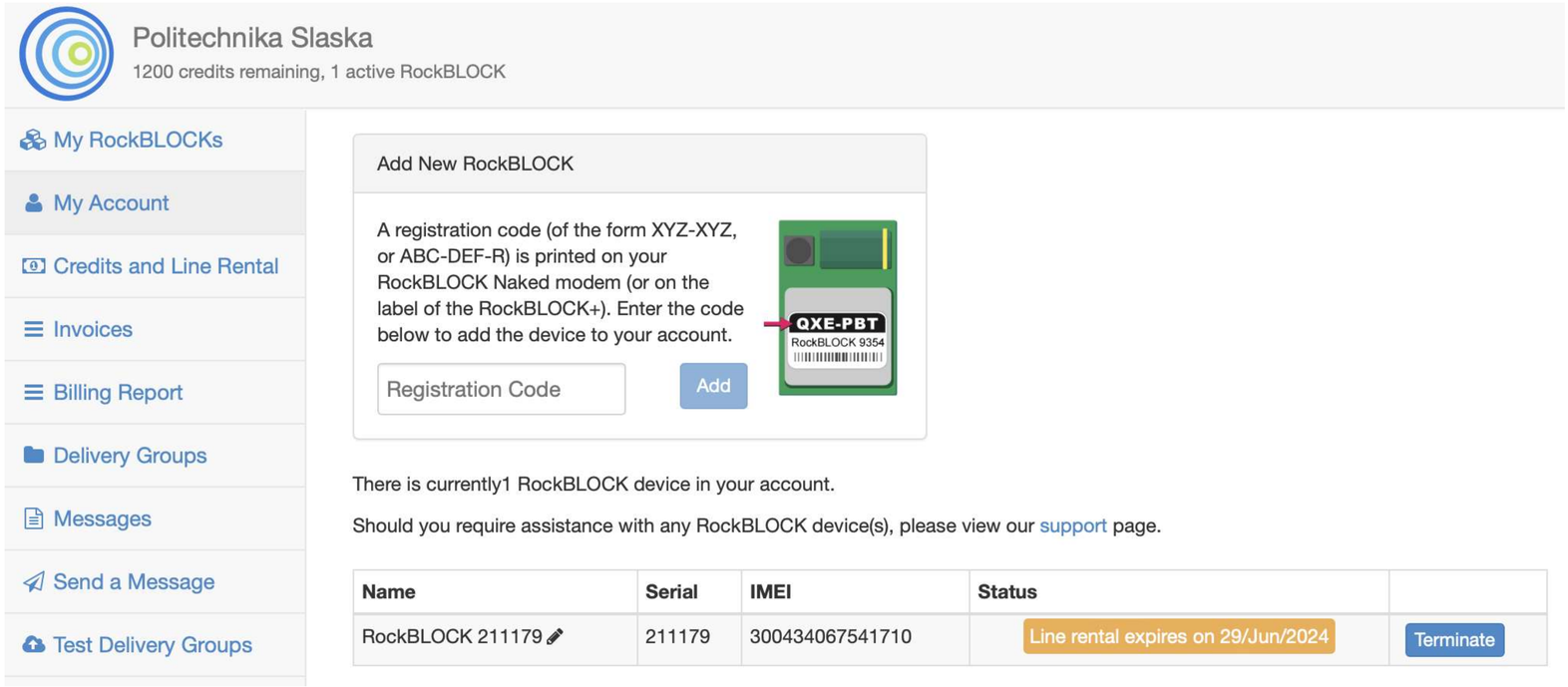
We have chosen RockBLOCK **Rock7** as our Iridium operator.

The company offers **RockBLOCK 9603** modems, which are based on the Iridium 9603N transceivers. It is currently one of the smallest and lightest modems on the market.

These ready-to-use devices allow for fast integration with computing modules and flight controllers such as PixHawk.

The admin web service provided by Rock7 offers various management options.

Users can send and receive messages directly from the web interface and monitor active devices.



RockBLOCK Rock7

Transmission cost and billing options

Line rental cost: £13.00 ($17.00)

Pay-as-you-go tariffs offer great flexibility for development purposes.

The validity of the credits is 1 year.

1 credit is used per 50 bytes (or part thereof) of message sent or received.

1 credit is used if you check your mailbox and there are no messages waiting.

1 MB cost from £1048.00 to £3041.00.

Rock7 Iridium pay-as-you-go tariff

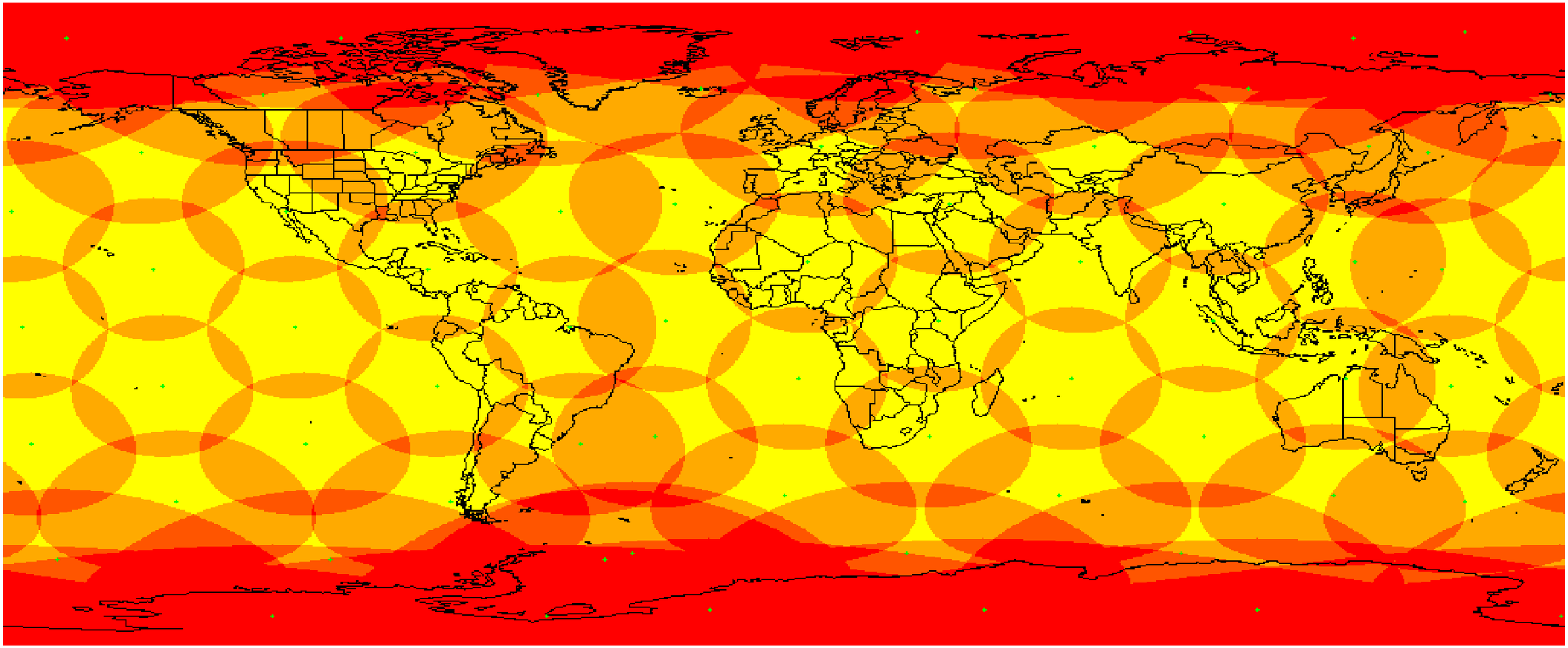
Number of Credits	Price per credit	Total price
100	£0.145	£14.50
200	£0.125	£25.00
500	£0.110	£55.00
1000	£0.099	£99.00
2000	£0.088	£176.00
5000	£0.077	£385.00
10000	£0.066	£660.00
20000	£0.050	£990.00

Apollo Satellite Iridium Certus Maritime Service

Plan Name	Contract Period	Monthly Allowance	Additional Usage	Monthly Price
Certus Maritime Base 0 MB	6 Months	0 MB | 0 Voice Min	$13.25 / MB	$100
Certus Maritime Starter 50 MB	6 Months	50 MB | 25 Voice Min	$7.17 / MB	$325
Certus Maritime Standard 100 MB	6 Months	100 MB | 50 Voice Min	$5.50 / MB	$575
Certus Maritime Adventurer 250 MB	6 Months	250 MB | 50 Voice Min	$3.93 / MB	$875
Certus Maritime Research 1 GB	12 Months	1 GB | 100 Voice Min	$1.50 / MB	$1275
Certus Maritime Explorer 5 GB	12 Months	5 GB | 100 Voice Min	$0.93 / MB	$1550
Certus Maritime Enterprise 10 GB	12 Months	10 GB | 100 Voice Min	$0.75 / MB	$2300
Certus Maritime VSAT 300 MB	6 Months	300 MB | 0 Voice Min	$1.00 / MB	$675

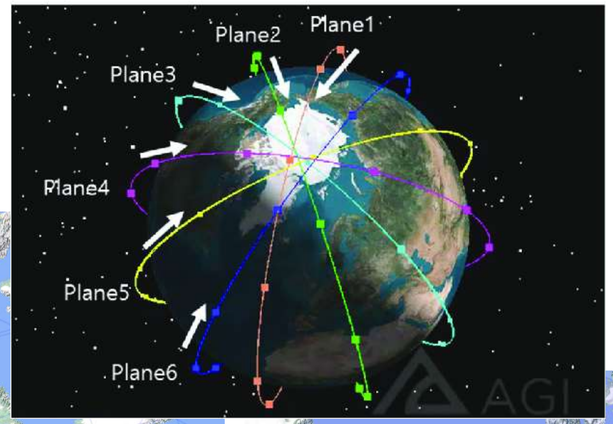
Iridium Satellite Constellation

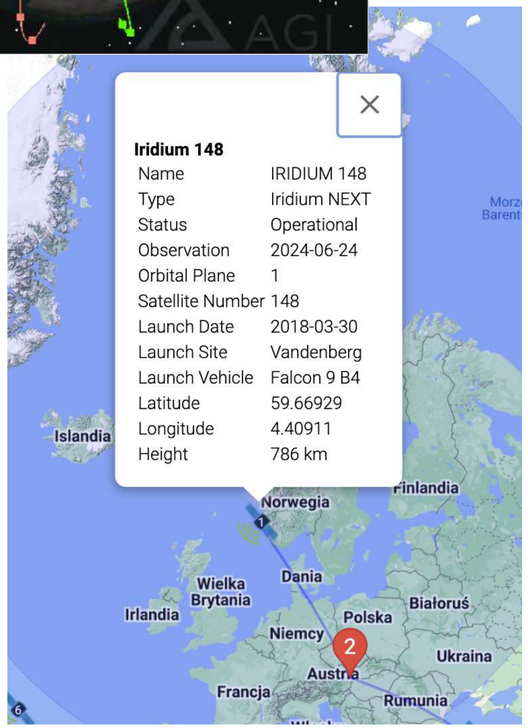
Coverage map – spot beam footprint of Iridium satellite system



Iridium Satellite Constellation

The Iridium satellites live map





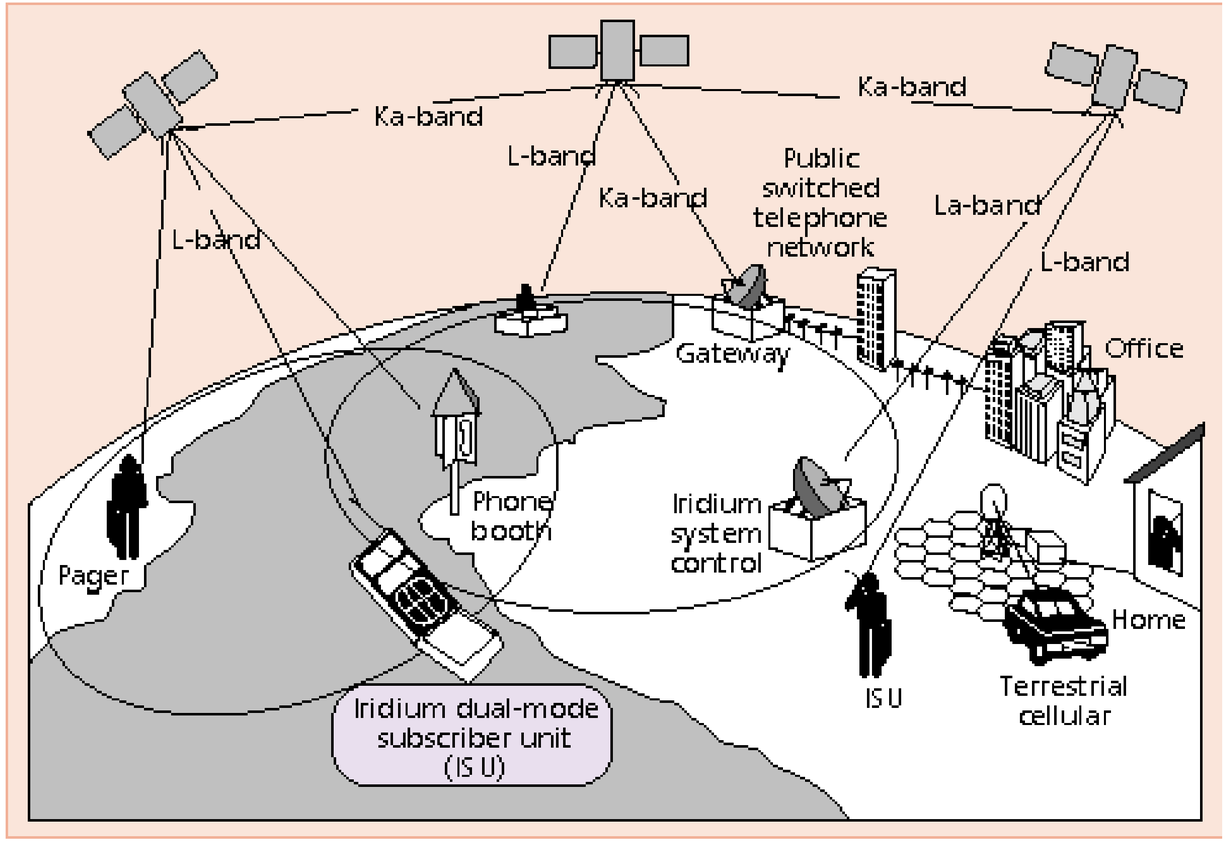
https://iridiumwhere.com

Technical Description of Iridium

General information about Iridium Satellite System

The original Iridium satellites were launched in the late 1990s. A new generation, **Iridium NEXT**, was launched between 2017 and 2019 to replace the original constellation and enhance service capabilities.

The name “Iridium” was chosen because the original design called for **77 satellites**, matching the atomic number of the element iridium.



The Iridium satellite system has three segments:

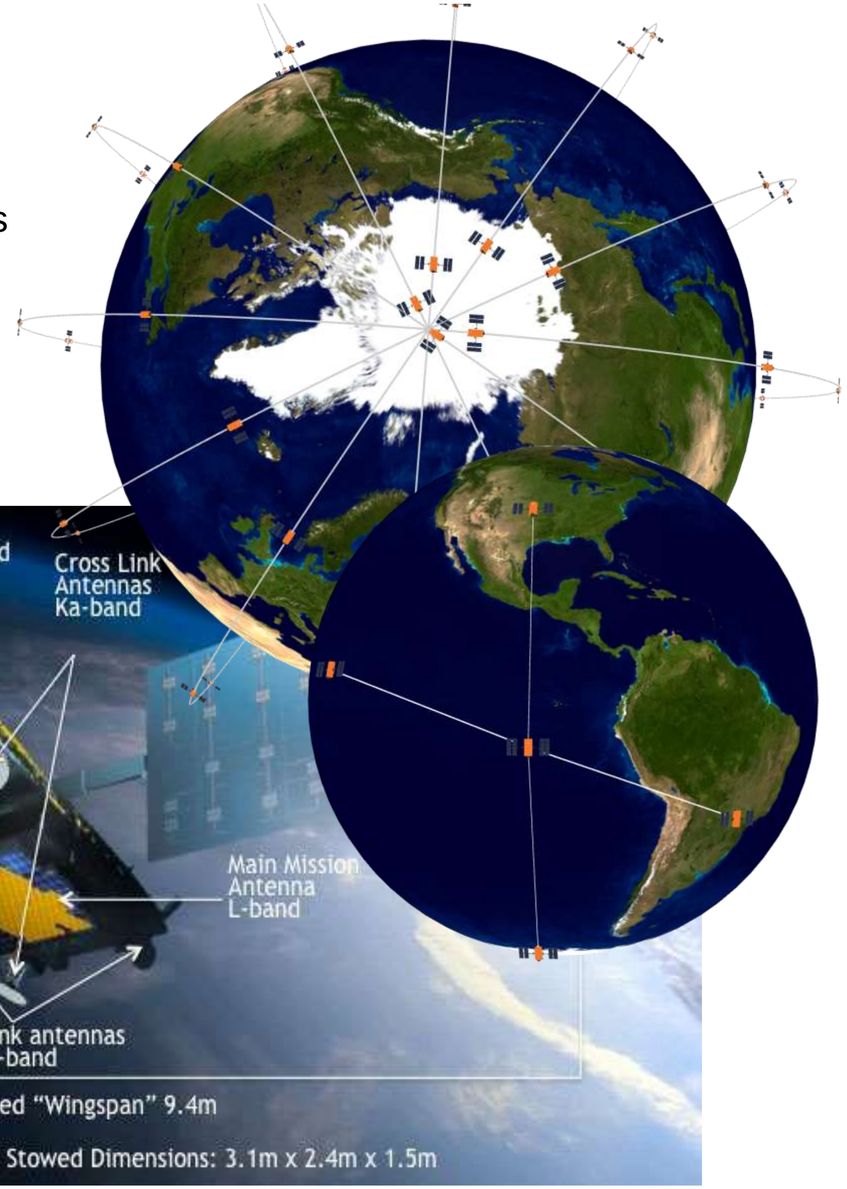
- satellites constellation,
- terrestrial base-stations,
- subscriber terminals/modems.

Technical Description of Iridium

Satellites constellation of Iridium

- Constellation of 66 satellites Iridium NEXT (6 orbits)
- Low-Earth Orbit (LEO)
  ~780 kilometres (485 miles) above the Earth
- Speed: ~27000 km/h (7500 m/s)
- L-band (1.6 GHz) frequencies for the end users,
  K/Ka-band (19/29 GHz) for gateway communication,
  K-band (23 GHz) for the inter-satellite links
- Good coverage in the remote high-latitude regions
- Each satellites is cross-linked to four others
- Together, the satellites create a global mesh of coverage over the Earth
- Cross-links provide network optimization and redundancy (data could be rerouted)
- Redundant monitoring centers:
  - Network Operations Center (NOC)
  Tempe, Arizona, USA
  - Emergency Network Operations Center (ENOC)
  Leesburg, Virginia, USA

- Orbit period: 100.13 minutes
- Transmitter power: 1400W
- Bandwidth: 10.5 MHz
  41.67 kHz per channel
- Number of Channels: 240
  (20 per cell)



Band Center Frequency: $1616 + 0.021875(2n - 1)$ MHz where $(n = 1, ..., 240)$

Technical Description of Iridium

Terrestrial base-stations of Iridium

- Iridium has multiple Gateway Earth Stations (GES), located around the world where terrestrial base-stations are situated
- These gateways act as the interface between the satellite network and the public switched telephone network (PSTN) and the global Internet network.
- The primary location of the Iridium gateways are:
  - **Tempe, Arizona, USA** - This is the primary gateway for the Iridium network, managed by Iridium Communications Inc.
  - **Fairbanks, Alaska, USA** - This gateway supports communications in the polar regions and is operated in collaboration with the University of Alaska Fairbanks.
  - **Svalbard, Norway** - Located in the Arctic region, this gateway ensures connectivity in the high northern latitudes.
  - **Beijing, China** - Operated by China Telecommunications Corporation, it serves the Asia-Pacific region.
  - **Punta Arenas, Chile**

Technical Description of Iridium

Terminal and modems based on 9602N/9603N

Iridium 9603N parameters

- Iridium Short Burst Data (SBD)
- AT commands-based control
- 3-wire UART communication (TX/RX/GND)
- Low weight: 36 grams including antenna
- Small form factor
  45.0 x 45.0 x 15.0m
- Low-power consumption
  100mA – 450mA, integrated supercapacitor
- Voltage required:
  3.4-5.4V
- Frequency range: 1616 MHz to 1626.5 MHz
- Hight temperature range and humidity:
  -45 to 85 degrees C, ≤ 75% relative humidity
- No SIM card
- Price: ~300 USD

Iridium 9603N

RockBLOCK 9603

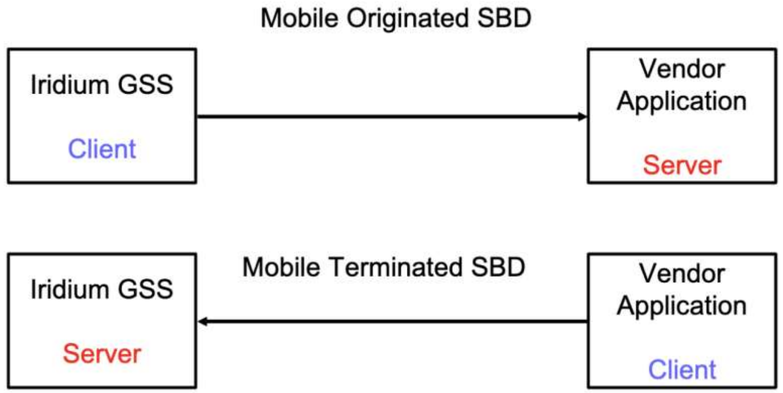
Iridium 9602N

RockBLOCK 9602

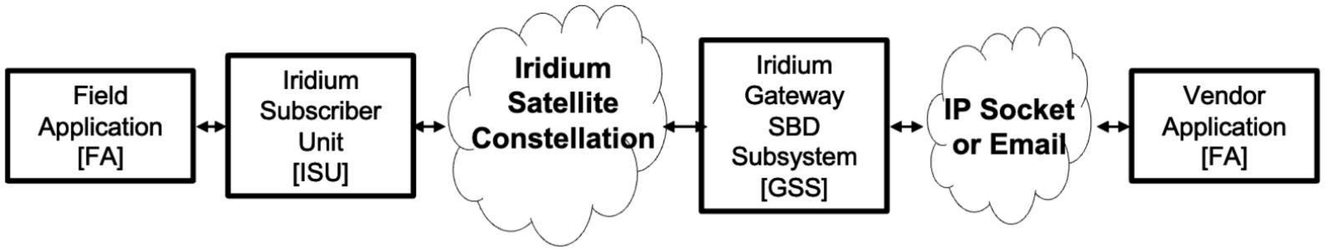
Iridium Short Burst Data (SBD)

Enabling Efficient and Reliable Packet-Based Data Communications

- SBD (Short Burst Data) is a messaging system with limited bandwidth, allowing for the transmission of packets up to **340 bytes** in size, while receiving packets of **270 bytes.**
- The modem uses a technique called “burst” transmission, which allows it to send data in short, quick bursts. This helps to conserve power and improve battery life.
- Typically, a successful SBD transmission has an average current consumption of between 45 and 50 milliamps (averaged over a 60 second period).



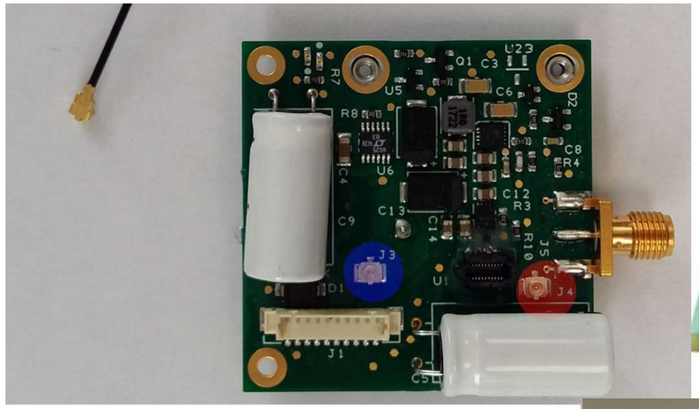
- In optimal conditions, with an unobstructed view of the sky, SBD allows for approximately one send/receive operation every 10 seconds.
- The latency from the gateway is less than 1 second.
- **SBD** may not be suitable for scenarios where very low latency is crucial or when the data to be transmitted exceeds a few thousand bytes.
- Binary protocols like **MAVLink can reduce data transfer** requirements. Message sizes should be minimized to **50 bytes or less** to minimize additional costs.

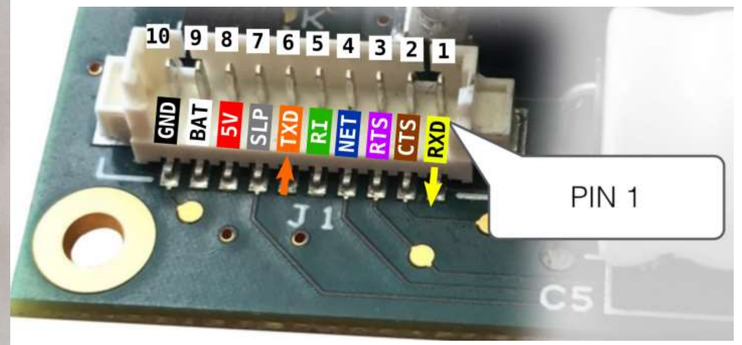


Test scenario and results

Test scenarios:

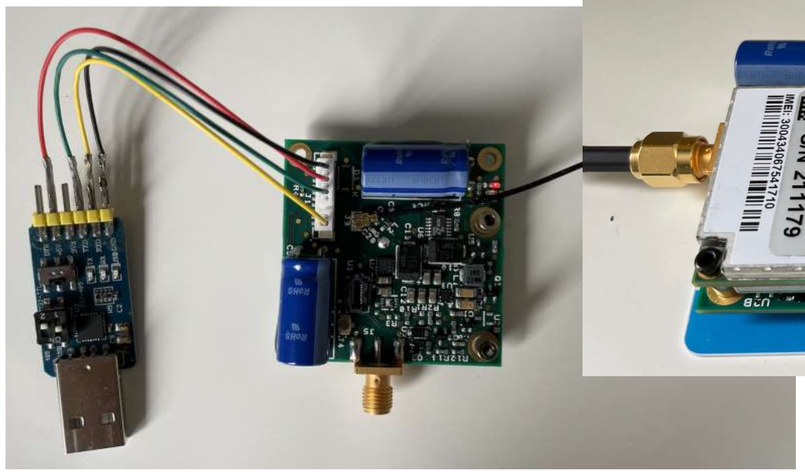
- **Direct connection with PC (Linux, macOS)**
  - AT commands test,
  - power consumption tests, latency tests,
  - Python scripts development.
- **Integration with the compute module Jetson Orin Nano (Linux):**
  - Python scripts tests,
  - Example sensor data generation.
- **Integration with PixHawk autopilot:**
  - Autopilot configuration,
  - LUA scripts development and test,
  - Real data test





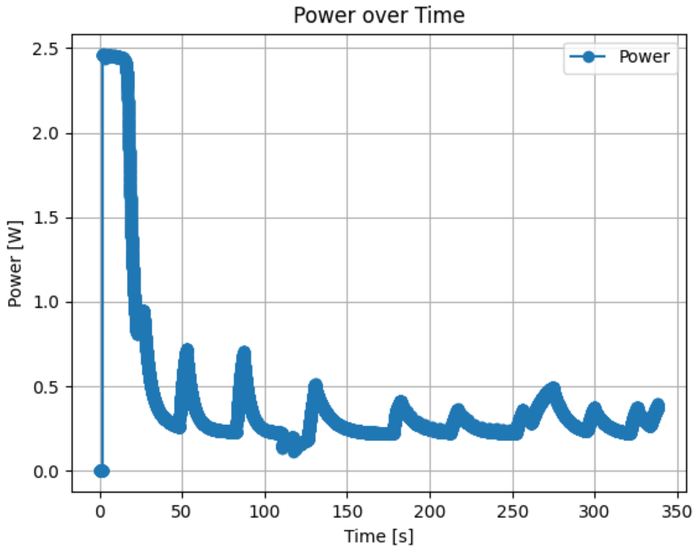
J3 : UFL CONNECTOR FOR PATCH ANTENNA

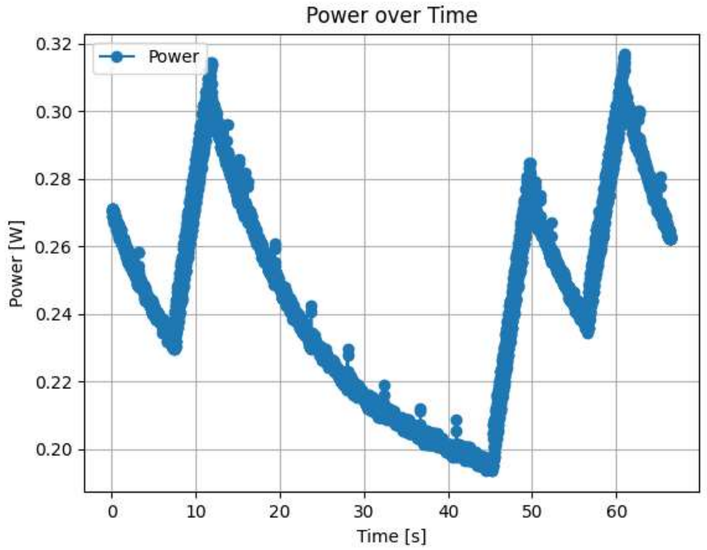
J4 : UFL CONNECTOR FOR SMA

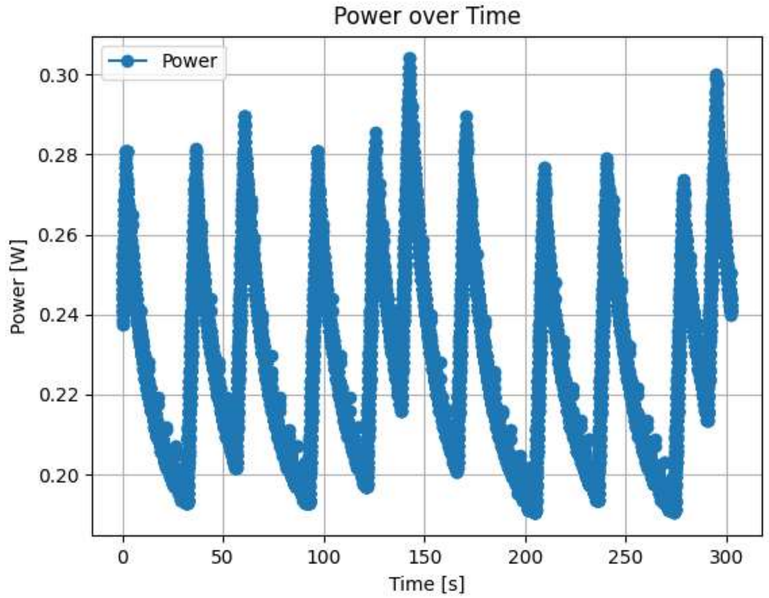


Power consumption

RockBLOCK 9603N power consumptions measurements results







The power consumption measurements were conducted at a frequency of 100Hz, utilizing an **INA219** sensor in conjunction with an ESP32 module. The **INA219** sensor is renowned for its high accuracy in measuring both current and voltage, making it ideal for monitoring power consumption.

The average measured power consumption was 0.25 W. The peak power consumption of 2.5 W was observed only for a few seconds due to the super capacitor charging.

Basics of communication

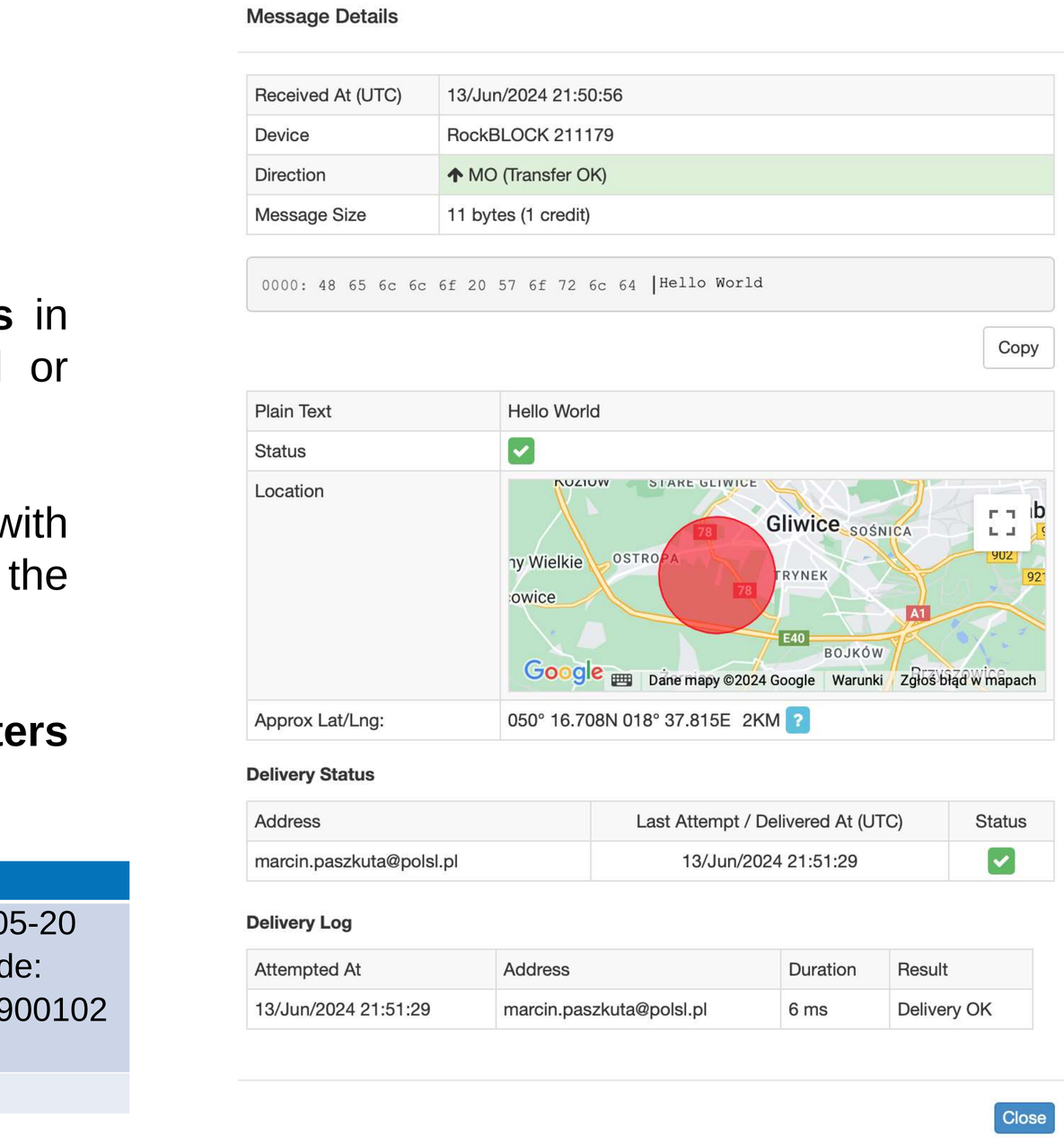
Sending and receiving messages

The device can prepare messages up to **340 bytes** in size. The message can be received as an **email** or consumed by a **REST service**.

Each received message from the device is marked with the **transmission time** to the Iridium network and the **estimated position** of the transmitter.

Position accuracy ranges from **several hundred meters** to **several kilometers**.

Subject	**'Message 1 from RockBLOCK 300434067541710**
Body	IMEI: 300434067541710 MOMSN: 1 Transmit Time: 24-05-20 14:59:15 UTC Iridium Latitude: 50.19761 Iridium Longitude: 18.67658 Iridium CEP: 3 km Data: 010203040506070809001020 --
Attachment	300434067541710-1.bin (11 bytes)



Basics of communication

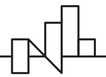
Sending MT messages using Rock7 API

To send a message to the device, we could use the Rock7 API. An example request is as follows:

https://rockblock.rock7.com/rockblock/MT?imei=300434067541710&username=user&password=pass&data=TEST&flush=yes

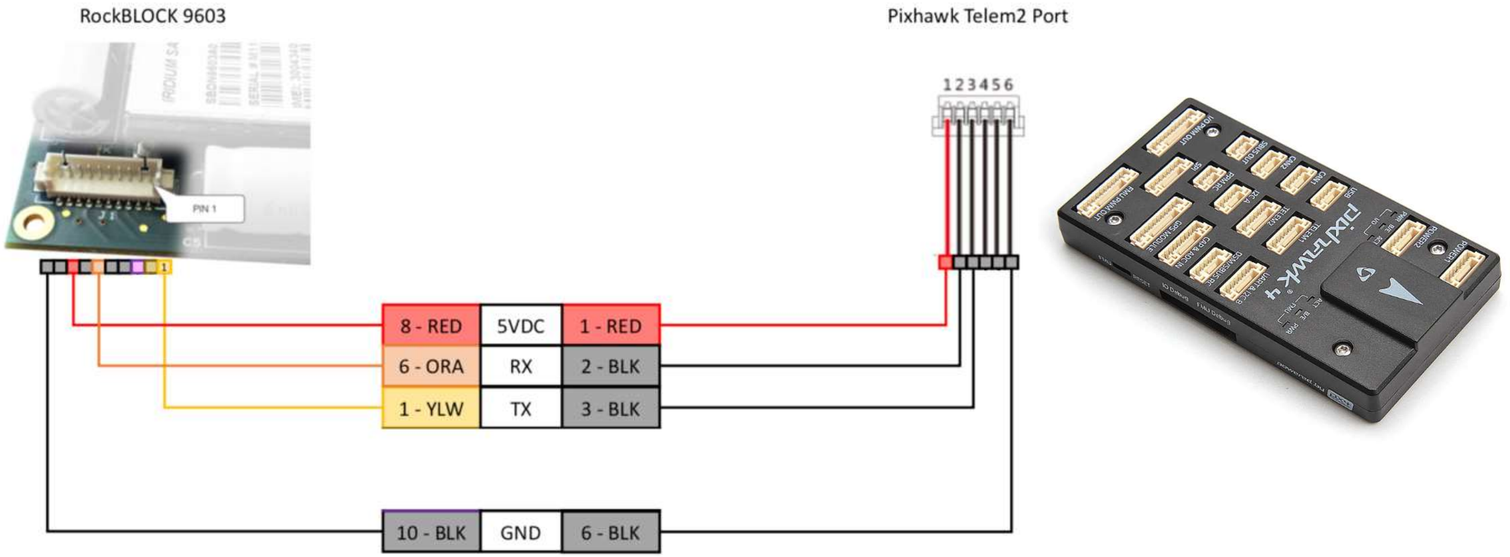
In this request:
•**imei**: Specifies the IMEI of the device.
•**username** and **password**: Credentials for authentication.
•**data**: Contains the message content ("TEST" in this example).

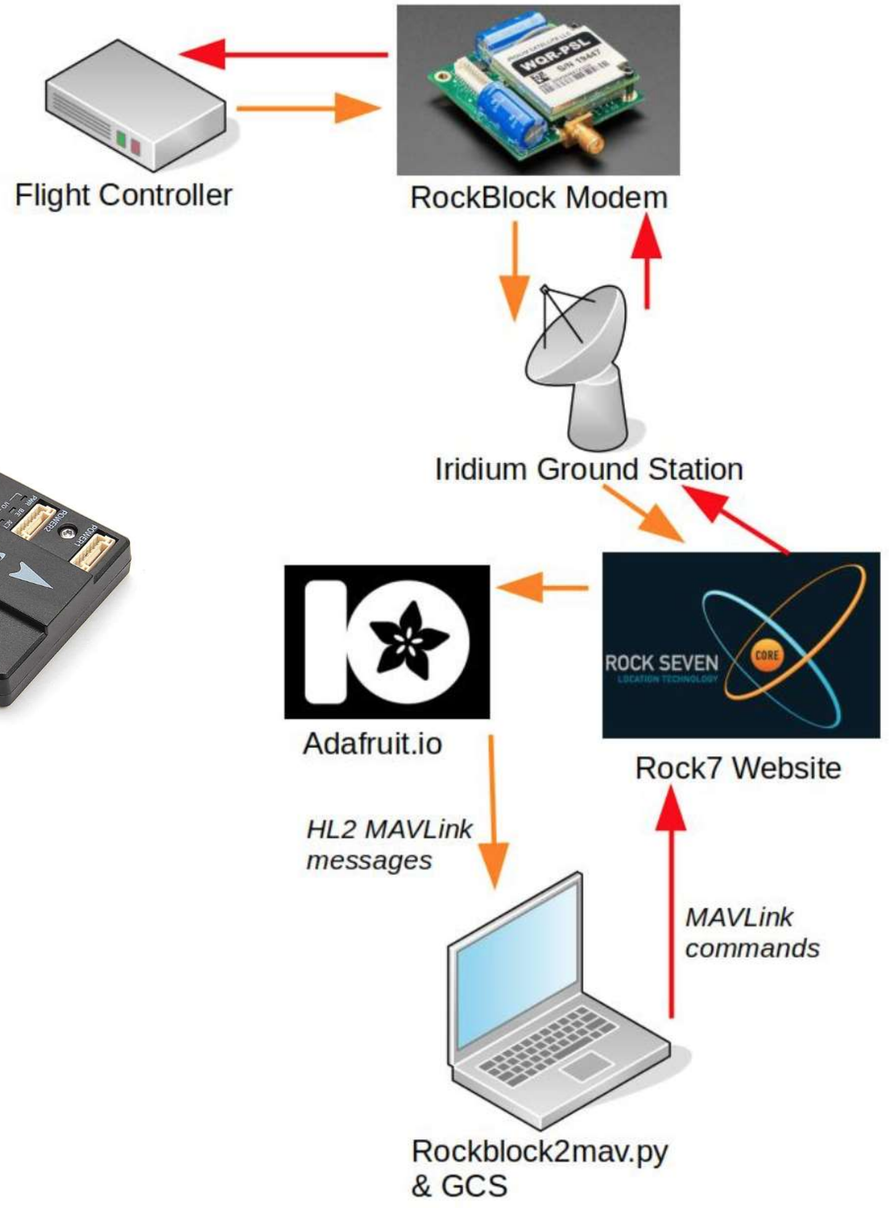
The messages could be sent directly form the webpage:
https://docs.rockblock.rock7.com/reference/testinput



Autopilot integration

PixHawk integration





The **RockBLOCK** modem can be easily integrated with the PixHawk autopilot using only a 4-wire connection. It can be used with both **PX4** and **ArduPilot >4.4** software, but different configurations are needed.

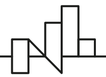
Autopilot integration

HIGH_LATENCY2 message structure

Field Name	Type	Units	Description
timestamp	uint32_t	ms	Timestamp (milliseconds since boot or Unix epoch)
type	uint8_t		Type of the MAV (quadrotor, helicopter, etc.)
autopilot	uint8_t		Autopilot type / class.
custom_mode	uint16_t		A bitfield for use for autopilot-specific flags (2 byte version).
latitude	int32_t	degE7	Latitude
longitude	int32_t	degE7	Longitude
altitude	int16_t	m	Altitude above mean sea level
target_altitude	int16_t	m	Altitude setpoint
heading	uint8_t	deg/2	Heading
target_heading	uint8_t	deg/2	Heading setpoint
target_distance	uint16_t	dam	Distance to target waypoint or position
throttle	uint8_t	%	Throttle
airspeed	uint8_t	m/s*5	Airspeed
airspeed_sp	uint8_t	m/s*5	Airspeed setpoint
groundspeed	uint8_t	m/s*5	Groundspeed
windspeed	uint8_t	m/s*5	Windspeed
wind_heading	uint8_t	deg/2	Wind heading
eph	uint8_t	dm	Maximum error horizontal position since last message
epv	uint8_t	dm	Maximum error vertical position since last message
temperature_air	int8_t	degC	Air temperature from airspeed sensor
climb_rate	int8_t	dm/s	Maximum climb rate magnitude since last message
battery	int8_t	%	Battery level (-1 if field not provided).
wp_num	uint16_t		Current waypoint number
failure_flags	uint16_t		Bitmap of failure flags.
custom0	int8_t		Field for custom payload.
custom1	int8_t		Field for custom payload.
custom2	int8_t		Field for custom payload.

Other supported MAVLink frames

Message ID	Description
CMD_NAV_RETURN_TO_LAUNCH	Return to launch location
CMD_NAV_LAND	Land at location
CMD_NAV_TAKEOFF	Takeoff command
CMD_NAV_VTOL_TAKEOFF	Takeoff from ground VTOL mode
CMD_NAV_VTOL_LAND	Land using VTOL mode
CMD_DO_SET_MODE	Set system mode
CMD_MISSION_START	Start running a mission
CMD_COMPONENT_ARM_DISARM	Arms/Disarms a component
CMD_CONTROL_HIGH_LATENCY	Request to start/stop transmitting over the high latency telemetry



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