

# User Guide

## HAB BALLASTER

Metered Ballast Release System



Balloon  
Ascent  
Technologies

The sky's not the limit; it's where we start.



### Overview

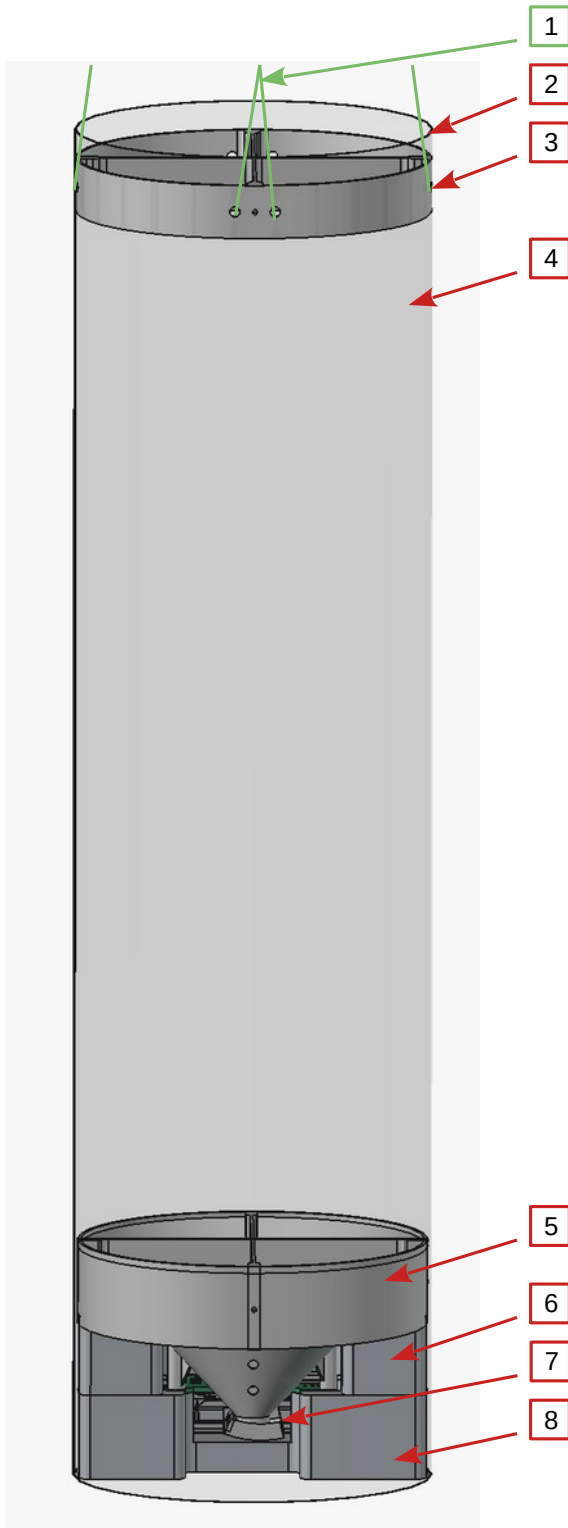
The HAB Ballaster is a light-weight, self-contained ballast release system:

- Metered Ballast Release
- Wireless BLE & LoRa Interface
- Wired UART Interface
- Uses Sand Ballast Media

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# Hardware Diagram



#	Component	Function
1	Rigging Harness	Attach flight train
2	Snap-on cover	Keep moisture out of ballast
3	Spider assembly	Cool-sounding line holder
4	Ballast tube	Empty container for ballast
5	Hopper assembly	Ballasting mechanism
6	Upper foam	Insulate batteries
7	Ballast Gate	Stop ballast from flowing
8	Lower foam	Insulate batteries

## Specifications

Parameter	Min	Typical	Max	Unit
Operating: Temperature	-60	-	60	°C
Operating: Battery Voltage	1	-	5.5	VDC
Ballast Release Rate	-	7.9	-	g/s
Ballast Amount (to fill hopper)	-	250	-	g
Ballast Amount (tube above hopper)	-	115	-	g/cm
Ballast Amount (standard 16" model)	-	4	-	kg
Setting: Internal Heater Set-point	-60	-10	60	°C
Sensor: Internal Temperature	-55	-	125	°C
Mechanical: Mass (standard 16" model, no Batteries)	-	180	-	g
Mechanical: Mass (2x L92 batteries)	-	15	-	g
Mechanical: Size (standard 16" model)	10.5 cm diameter, 41 cm height			
Mechanical: Size (max 48" model)	10 cm diameter, 122 cm height			

## Getting Started

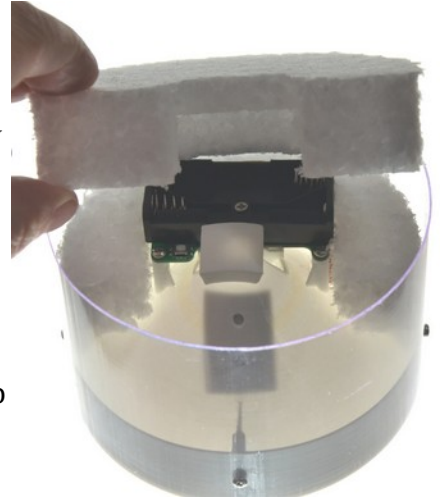
The HAB Ballaster is a light-weight, self-contained ballast releasing device.

### Unboxing

The HAB Ballaster is shipped with insulating foam around the battery holder. Keep this foam, it will be used again during the flight.

To remove the lower foam cover from around the battery holder use your fingers to grab it and gently lift it away.

A snap-on cover at the top of the hopper tube is included. We recommend using this cap for flights ascending through clouds to help keep moisture out of the ballast media. If liquid precipitation is expected then additional sealing will be needed around the spider assembly.

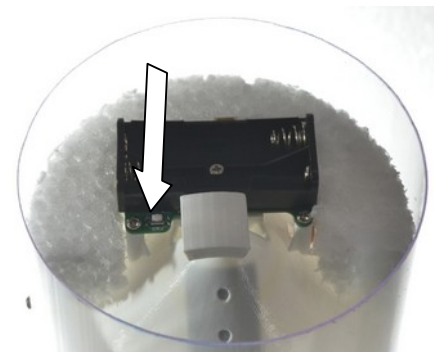


### Power-On Button

Press and hold the power-on button down until the blue BLE LED flashes, usually about three (3) seconds.

Pressing this button will turn the *HAB Ballaster* on. Repeated pressing or constant pressing will have no impact on the *HAB Ballaster* operation. It cannot turn off the HAB Ballaster.

To shutdown the *HAB Ballaster* remove its batteries or issue the shutdown command (`!iSD=Y`). Note: the *HAB Ballaster* will take a considerable time to fully shut-down when the batteries removed—usually 1-3 minutes.



## Connecting to the HAB Ballaster

To get started, we'll focus on using the BLE communication link with the HAB Ballaster. You will likely use this method during launch for setup and verification.

- 1) Connect via the Bluefruit Connect smartphone app. Use the QR Code links to download this app for Android and iOS smart phones.
- 2) Open the app. A list of one or more HAB Module devices will appear. Connect to the HAB Ballaster 'B'.

Note: the 'B' in the device name will change to the ID you specify with the **!bSI=\_\_\_** command.

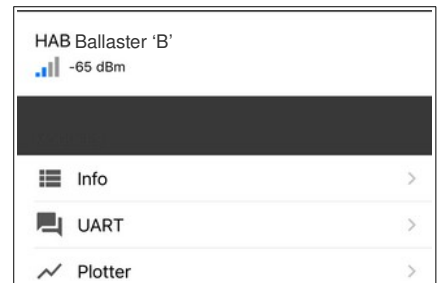
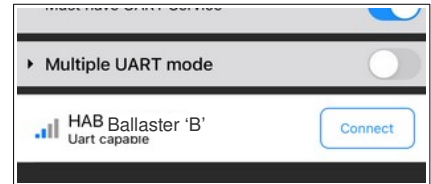
- 3) Select the UART interface. A blank response window with an input field at the bottom will appear. You can type in the commands in the field at the bottom and the *HAB Ballaster's* responses will appear above.
- 4) Below is a command cheat-sheet for the HAB Ballaster. It contains some of the more commonly used commands.



Android



iOS



<u>Command Overview</u>	<u>Common Commands</u>
<p>Format: <b>!iSC=VAL</b></p> <p><b>!</b> Commands start with <b>!</b></p> <p><b>i</b> Device ID (default 'B')</p> <p><b>S</b> Subsystem (B, S, or R)</p> <p><b>C</b> Command to carry out</p> <p><b>=VAL</b> Value if applicable</p> <p>ID can be changed with <b>!bSI</b></p> <p>Ex: <b>!bSI=a</b> sets ID to 'A'.</p> <p>Then <b>!bSC</b> becomes <b>!aSC</b></p> <p>Subsystems:</p> <p><b>B</b> – ballast subsystem</p> <p><b>S</b> – state subsystem</p> <p><b>R</b> – radio subsystem</p> <p><u>Help Commands</u></p> <p><b>!i</b> Recommended cmds</p> <p><b>!ib</b> All ballast commands</p> <p><b>!is</b> All state commands</p> <p><b>!ir</b> All radio commands</p>	<p><b>!bSC</b> View sys. charge</p> <p><b>!bSV</b> Battery voltage</p> <p><b>!bST</b> Internal temp.</p> <p><b>!bSH</b> Heater threshold</p> <p><b>!bSL</b> Display cmd log</p> <p><b>!bSX</b> System Status</p> <p><b>!bSW=90</b> Term. Timer, 90 s</p> <p><b>!bBA=4000</b> Set 4 kg of ballast</p> <p><b>!bBB</b> Indef. ballast drop</p> <p><b>!bBC</b> Stop ballast drop</p> <p><b>!bBD=8</b> Drop 8 g ballast</p> <p><b>!bBD=10s</b> Drop ballast for 10s</p> <p><u>Irrevocable Commands</u></p> <p><b>!bSZ=Y</b> Terminate seq.</p> <p><b>!bSD=Y</b> Shut down</p> <p><i>Note: the Terminate sequence commands the Ballaster to open indefinitely.</i></p>

## Indicator Lights

### Primary Status Indicator – Green

The *HAB Ballaster* has one green Primary Status Indicator. Possible blink patterns at 1 Hz are:

- **Pulsing** – Primary system is charging
- **Single** – Termination timer is enabled
- **Double** – Ballaster currently active
- **Quintuple** – Ballaster error

The green Primary LED will flash briefly once every ~3 seconds to indicate it is powered on and operating correctly.

### Communication Indicator – Blue

The *HAB Ballaster* has one blue communication Indicator. Possible blink patterns are:

- **Brief flashes** at 1-3 Hz – indicates BLE advertising and awaiting first command since power-on
- **Single** brief flash – indicates command received
- **Off** – a command has been received since power-on

## Control Interfaces

The *HAB Ballaster* can be controlled by one or more of the following: Bluetooth Low Energy (BLE) radio, wired Universal Asynchronous Receive Transmit (UART) serial protocol, or LoRa radio. Commands are sent to the desired HAB module by specifying its identifier (ID) character—default is ‘B’ for the HAB Ballaster. This permits multiple devices to share the same communication method.

### Bluetooth Low Energy Interface

*HAB Ballaster* uses the Nordic UART Service (NUS) for most Bluetooth communication, which enables the use of Adafruit’s Bluefruit LE Connect App.

Android: <https://play.google.com/store/apps/details?id=com.adafruit.bluefruit.le.connect>

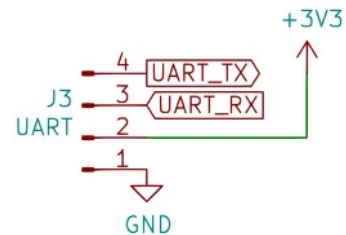
iOS: <https://apps.apple.com/app/adafruit-bluefruit-le-connect/id830125974>

Note: this protocol is not always reliable for the link between a flight computer and the HAB Ballaster on flights that are using active aviation transponders.

### Wired UART Interface

The HAB Ballaster includes a wired UART connection. It uses a 4-pin JST SH (1.0 mm pitch) connector with the following pin-out:

- Pin 1 – GRN/WHT – Ground
- Pin 2 – YELLOW – Power
- Pin 3 – BLACK – Ballaster Receives on this pin
- Pin 4 – RED – Ballaster Transmits on this pin



By default, messages are sent at 115,200 baud (user selectable), 8n1, at 3.3 VDC logic levels.

Power note: the available 3.3 VDC output is regulated, but should not be expected to source more than 20 mA. Use of it will impact expected battery life.

### LoRa Radio Interface

The *HAB Ballaster* has an integrated LoRa radio that can be used to send and receive communications to and from other modules on the balloon flight set to the same frequency, such as the flight computer.

The LoRa radio is based on a Semtech SX1262 chip which can be configured to operate in the 862-928 MHz frequency range over a distance of many meters. We recommend using the RadioLib library<sup>1</sup> on any flight computer that needs to connect with the HAB Ballaster’s LoRa radio.

<sup>1</sup> The RadioLib library was developed by jgromes. GitHub: <https://github.com/jgromes/RadioLib>

The radio can be configured in ‘gateway’ or ‘device’ mode. As a ‘gateway’, the radio will echo commands to/from the other communication interfaces, permitting one HAB module to forward commands to other HAB modules acting as as ‘devices’. With this, the LoRa radio network is self-contained, negating the need to add a custom LoRa radio module to the flight computer.

Refer to the **LoRa Radio** section for more details and a diagram of how to use LoRa ‘gateway’ functionality on flights with multiple HAB modules.

## Operation

### Filling with Ballast

- 1) Record the mass of the empty *HAB Ballaster*
- 2) Verify that the **ballast gate valve is closed**
- 3) Ensure it is vertical and secure
- 4) Remove snap-on cover from the top
- 5) Slowly pour in the ballast media, filling the hopper with desired amount
- 6) Replace snap-on cover
- 7) Record the mass of the filled HAB Ballaster
- 8) Set the total usable ballast with the **!bBA** command. The value is calculated by: Total Usable Ballast = Full mass – Empty mass.



### Termination Timer

The termination timer will count down from the initial time specified and indefinitely drop the remainder of the ballast when it reaches zero. Resetting, or feeding the timer, will restart the countdown to the initial time specified. This timer can be used to help ensure that the flight is terminated properly if something happens to the flight computer or the LoRa radio link (ex RF jamming).

We recommend programming the flight computer to send the **!bSX** command frequently to both check on the *HAB Ballaster*'s status and to feed the termination timer. We recommend sending this command at an interval of approximately one-third the termination timer's initial time specified so that a failure to receive the command and feed the timer must happen 3 times in a row before the flight is automatically terminated.

Example: start termination timer, feed once (restarts the timer from the previous value), re-enable once (restarts the timer from a new value), then stop feeding:

**!bSW=120** Start the timer counting down from 120 seconds

... can wait up to 119 seconds ...

**!bSW=F** Feed the timer, restarting the countdown from the prior setting of 120s  
... can wait up to 119 seconds ...

**!bSW=30** Reset the timer, starting the countdown from new time of 30 seconds  
... wait 30 seconds for time to expire ...

Resulting activation sequence:

1. *HAB Ballaster* issues the **!bSZ=Y** command to itself
2. Termination message sent out via BLE/LoRa/UART
3. Termination sequence is activated

## Terminate Sequence

Termination causes the *HAB Ballaster* to begin indefinitely dropping ballast. This ensures that the *HAB Ballaster* is completely empty during descent and landing. This is important during descent to decrease the descent rate. This is important during landing to help minimize the risk to people and property and to minimize damage to the *HAB Ballaster* itself.

The Terminate command can either be called directly by the user via the **!bSZ=Y** command, or by an expiring Termination Timer.

## Non-Volatile Parameters

Most of the *HAB Ballaster*'s parameters are saved in non-volatile memory. The value is not effected by powering the *HAB Ballaster* off, so values can be configured in advance of launch. See the **Commands** section for which parameters are saved to non-volatile memory.

During the power-on sequence, the non-volatile memory is verified and then loaded. If the memory is found to be corrupted then it is reformatted and default values are loaded. This is indicated by the green STATUS indicator flashing the rapid, continuous error pattern. This error state will be cleared the next time the unit is powered on.

## System Measurements

Every thirty (30) seconds while powered on, the *HAB Ballaster* will measure the battery voltage, system charge, and internal temperature.

If the temperature measurement is below the set heater threshold the battery heater will be enabled, or disabled if the temperature is above it. The heater threshold is the temperature where the heater will be turned on or off. It is -10 °C by default, and can be changed using **!bSH=\_\_\_**

## Command Logging

HAB Ballaster has a circular log that saves the last approximately 800 entries in non-volatile memory. Events that are recorded include:

- Incoming commands
- Command responses
- Bluetooth connection events

## Consumables

### Batteries

The *HAB Ballaster* has been designed to use primary lithium batteries in the ‘AAA’ size. The Lithium/Iron Disulfide (Li/FeS<sub>2</sub>) chemistry has proven to work well, even at the low temperatures experienced on balloon flights. Possible suppliers of these batteries include:

- Energizer [Ultimate Lithium L92](#) AAA Battery

While the *HAB Ballaster* will operate on standard alkaline batteries, it is strongly recommended against using them during flight due to their poor performance at cold. However, they work fine for bench testing.

### Ballast

The *HAB Ballaster* has been designed to use sand as the ballast media. Other ballast media is possible but not recommended due to either RF attenuation or ecological reasons.

Important selection criteria are:

- Medium grain size
- Minimal amount of dust
- Completely dry

Example sources of sand known to work with the *HAB Ballaster*

- [PetCo Aquarium Sand](#)
- Washed construction sand

# Checklist

## Night Before Launch

### Loading ballast

- 1) Remove lower foam, insert two batteries, then replace lower foam
- 2) Record the mass of the empty *HAB Ballaster*
- 3) Ensure *HAB Ballaster* is vertical, that the **ballast gate valve is close**, and remove snap-on cover
- 4) Slowly pour in the ballast, filling the hopper with desired amount
- 5) Replace snap-on cover
- 6) Record the mass of the filled HAB Ballaster

### Power-On

- 7) Remove foam cover, then press the power-on button for 3 seconds
- 8) Listen for the close routine attempt and ensure gate valve is closed
- 9) Replace foam cover
- 10) Connect with BLE, UART, or LoRa

### Calibration

- 11) Place over a container under to catch ballast
- 12) Command a timed ballast release: **! bBD=30s**
- 13) Wait for ballasting to complete
- 14) Record the new mass and calculate the drop rate (g/s)  
ex:  $(1,200\text{g} - 1,044\text{g}) / 30\text{sec} = 5.2 \text{ g/s}$
- 15) Set the correct drop rate: **! bBR=5.2**
- 16) Set the total usable ballast: **! bBA=1700**  
Full – Empty = Total Usable Ballast
- 17) Reload the ballast released during calibration
- 18) Replace snap-on cover

## Launch

### Pre-Inflation

1. Attach flight train to rigging harness
2. Power on the HAB Ballaster, then power on the flight computer
3. Verify ballasting operation **! bBD=5**
4. Verify flight computer is communicating with Ballaster **!?** → Comms Check

### Pre-Inflation

5. Use checklist command to make sure ballaster is ready **!?** → All good
6. Launch!

### Flight Termination

7. Send terminate flight command **! bSZ=Y**
8. Wait for termination to complete and provide confirmation
9. Locate and recover flight train once it lands
10. Shutdown Ballaster **! bSD=Y**

## Commands

The *HAB Ballaster* uses the same commands for the BLE, UART, and LoRa interfaces. All commands and responses are in easy-to-read ASCII text and follow predefined formats with searchable characters to aid with parsing.

### Command Format

Commands follow the following format: **!iMC=VAL**

Where “**!**” (0x21) denotes a new command start

Where “**i**” is the device’s UART address (A-Z)

Where “**M**” is the subsystem name (ex V or S)

Where “**C**” is the subsystem command (ex T or C)

Where “**=**” (0x3D) is only required when there is a VAL associated with the command

Where “**VAL**” is the optional command value

Note: no termination character is required.

### Response Format

Responses use the following format: **[iMC,VAL] Description (unit)**

Where “[ & ” (0x5B & 0x5D) enclose the command and it’s formal response

Where “**i**” is the device’s UART address (default is ‘B’)

Where “**M**” is the subsystem name (ex B or S)

Where “**C**” is the subsystem command (ex B or D)

Where “**,**” (0x2C) separates the command from its value

Where “**VAL**” is the command response value

Where “**Description**” and optional “**(unit)**” are only provided to help a human operator decipher the response

## Help Commands

These help commands do not follow the typical format, and will respond with information for the user rather than performing a task.

<b><u>CMD</u></b>	<b><u>Description</u></b>	<b><u>Reply</u></b>
<b>!i</b>	Command Cheat Sheet	Displays recommended commands for basic HAB Ballaster functions
<b>!ib</b>	Ballasting Commands List	Displays all available Ballasting commands
<b>!is</b>	State Commands List	Displays all available State commands
<b>!ir</b>	Radio Commands List	Displays all available LoRa radio commands
<b>!?</b>	Launch Final Checklist	Displays a launch checklist to complete before releasing balloon

## Ballaster Commands

This is a list of commands to control the *HAB Ballaster*'s ballasting functions.

<b>CMD</b>	<b>VAL</b>	<b>Description</b>	<b>Reply</b>	<b>Non-Volatile</b>
<b>!BBA</b>		Query Ballast Remaining[iBA, 950] Ballast Remaining (g)	[BBA,n] Ballast Remaining (g)	X
	<b>1000</b>	Set Current Amount of Ballast (grams)		
<b>!BBB</b>		Commence Dropping Ballast — indefinitely	[BBB,INDEF] Dropping Ballast	
<b>!BBC</b>		Stop Dropping Ballast	[BBC,NULL] Close	
<b>!BBD</b>		Query Ballaster Gate State	[BBD,GOOD ? FAIL] Status	X
	<b>10</b>	Drop X-grams of Ballast (grams)	[BBD,n] Dropping Ballast (g) [BBD,ERROR] Already Active [BBD,ERROR] Insufficient Ballast	
	<b>10s</b>	Drop Ballast for X-seconds (seconds)	[BBD,n] Dropping Ballast (s)	

<b>!BBP</b>		Motor Polarity → Query	[BBP,NORM ? REV] Motor Polarity	X
	<b>0</b>	Motor Polarity → Set to Reversed		
	<b>1</b>	Motor Polarity → Set to Normal		
<b>!BBR</b>		Ballast Drop Rate → Query	[BBR,n] Drop Rate (g/s)	X
	<b>7.9</b>	Ballast Drop Rate → Set		
<b>!BBS</b>		Gate Sensor Usage → Query	[BBS,ENBL ? DSBL] Gate Sensor	X
	<b>0</b>	Gate Sensor Usage → Set to disabled		
	<b>1</b>	Gate Sensor Usage → Set to enabled		

## LoRa Radio Commands

This is a list of commands to control the HAB Ballaster's LoRa Radio functions.

<b>CMD</b>	<b>VAL</b>	<b>Description</b>	<b>Reply</b>	<b>Non-Volatile</b>
<b>!BRA</b>		Preamble Setting → Query	[BRA,n] Preamble length	X
	<b>6 to 65535</b>	Preamble Setting → Set		
<b>!BRB</b>		Bandwidth Setting → Query	[BRB,n] Bandwidth	X
	<b>7.8 to 500</b>	Bandwidth Setting → Set		
<b>!BRC</b>		Coding Rate Setting → Query	[BRC,n] Coding rate	X
	<b>5 to 8</b>	Coding Rate Setting → Set		
<b>!BRE</b>		Echo Setting → Query	[BRE,n] Radio Echo Setting	X
	<b>D</b>	Echo Setting → Set as 'Device'		
	<b>G</b>	Echo Setting → Set as 'Gateway'		
	<b>0-255</b>	Echo Setting → Set bit mask manually		
<b>!BRF</b>		Carrier Frequency Setting → Query	[BRF,n] Carrier Frequency	X

	<b>862.0 to 928.0</b>	Carrier Frequency Setting → Set		
<b>!BRG</b>		Gain Setting → Query	[BRG,n] Gain	X
	<b>0 = AGC</b>	Gain Setting → Set		
<b>!BRH</b>		Latest Frequency Error (Hz) * <i>DEPRECIATED</i>	[BRH,n] Frequency error (Hz)	
<b>!BRN</b>		Latest Signal to Noise Ratio	[BRN,n] SNR (dB)	
<b>!BRO</b>	<b>0</b>	Turn Radio Module OFF	[BRR,ON] Radio State	*if other setting later set
	<b>1</b>	Turn Radio Module ON	[BRR,OFF] Radio State	
<b>!BRP</b>		Output Power Level Setting → Query	[BRP,n] Output Power	X
	<b>-17 to 22</b>	Output Power Level Setting → Set		
<b>!BRR</b>		Latest RSSI Value	[BRR,n] RSSI (dBm)	
<b>!BRS</b>		Spreading Factor Setting → Query	[BRS,n] Spreading Factor	X
	<b>6 to 12</b>	Spreading Factor Setting → Set		
<b>!BRW<sup>2</sup></b>		Sync Word Setting → Query (default = 0x12)	[BRW,n] Sync Word (dec)	X
	<b>≤ 8 bytes</b>	Sync Word Setting → Set		

<sup>2</sup> The Sync Word is displayed in HEX during the boot sequence but set in DEC by the RW command. It can be up to 8 bytes in length but ≥2 bytes has not been tested yet.

## System Commands

Below is a list of commands to control the HAB Ballaster's system functions.

CMD	VAL	Description	Reply	Non-Volatile
!BSA <sup>3</sup>		AUX State → Query	[BSA,n] AUX State	
	0	AUX State → Set, low output		
	1	AUX State → Set, high output		
!BSC		System Charge → Query Percentage	[BSC,52] System Charge (%)	
	T	System Charge → Query Time to Charged	[BSC,303] Time to charge (s)	
	V	System Charge → Query Voltage	[BSC,2.23] System Charge (V)	
!BSD	Y	Shutdown	[BSD,SHTDWN] Shutdown [BSD,ERROR] Use "iSD=Y" to shutdown	
!BSE		UART<->BLE Comm Echo → Query	[BSE,ENBL ? DSBL] Comm Echo	X
	D	UART<->BLE Comm Echo → Set to OFF		
	1	UART<->BLE Comm Echo → Set to ON		
!BSF		Display Settings	Returns multiple lines of text indicating Serial #, Sensors, and Parameters	
!BSG		Seconds Powered-On	[BSG, 123.4] Seconds Powered-On	
!BSH		Heater Set Point → Query	[BSH, -10] Heater Threshold (C) → Default is -10 C	
	10	Heater Set Point → Set (°C)	[BSH,10] Heater Set Point (C)	
!CSL		Displays Log (Cannot transmit over LoRa)	Returns multiple lines of text with past commands [BSL,ERROR] E=enable, D=disable, C=clear	X
	C	Clear Log	Log Cleared! [BSL,ERROR] Use "BSL=C" to clear log	
	D	Disable Logging	[BSL,DSBL] System Event Logging	
	E	Enable Logging	[BSL,ENBL] System Event Logging	

3 The AUX state command is present on the HAB Ballaster but it does not have the necessary AUX connector to be used on v2 hardware.

<b>!BSI</b>	<b>B</b>	Device Identification Letter → Set (A-Z)	[BSI,B] Device ID	X
<b>!BST</b>		Internal Temperature → Query	[BST,22.7] Temperature (C)	
<b>!BSU</b>		UART Baud Rate → Query	[BSU,115200] UART Baud Rate	X
	<b>1200</b>	UART Baud Rate → Set	[BSU,1200] UART Baud Rate [BSU,ERROR] UART Badu range: 1,200 to 115,200	
<b>!BSV</b>		Battery Voltage → Query	[BSV,2.78] Battery (V)	
<b>!CSW</b>		Termination Timer → Query	[BSW,-1] Term. Timer Inactive [BSW,n] Term. Timer Remaining (s)	
	<b>D</b>	Termination Timer → Disable	[BSW,-1] Term. Timer Disabled [BSW,ERROR] Failed to stop Timer	
	<b>F</b>	Termination Timer → Feed	[BSW,n] Term. Time Remaining (s) [BSW,ERROR] Term. Timer not Fed	
	<b>60</b>	Termination Timer → Set	[BSW,n] Term. Timer Enabled/Feed (s) [BSW,ERROR] Term. Timer invalid interval (1-4000000 s)	
<b>!BSX</b>		System Status → Query	[BSW,n,n,n] STV	
<b>!CSZ</b>	<b>Y</b>	Start Termination Sequence	[CSZ,TERM] Termination initiated [CSZ,ERROR] Use "iSZ=Y" to terminate	

## System Status Message Details:

**Description:** This message is intended to be called regularly to check on the *HAB Ballaster*'s status AND keep the termination timer fed, if it is enabled. It combines together the following commands: **!bST**, **!bSV**, **!bSW=F**, and provides the same information that the green status indicator is currently displaying.

It is recommended to send the **!bSX** command at an interval below one third of the termination timer's interval to ensure the timer is fed even if occasional connection issues occur. The command itself returns the decimal-value of a bit-mapped Status Field as well as the module's internal temperature and battery voltage.

**Status Field:** A decimal number converted from binary. Convert it back to interpret

7	6	5	4	3	2	1	0
System Charging	ERROR	Ballaster Active	N/A	Termination Timer Active	Open LS	Closed LS	Heater ON
1	0	0	0	0	0	0	1

**Temperature Field:** Board temperature in degrees C, zero decimal places

**Voltage Field:** Battery voltage in volts, two decimal places

**Example:** [BSX,129,16,5.03] STV

The returned decimal value of 130 converts to binary `0b10000001`. These digits correspond to the characteristics in the bitmap.

System power is charging, cutter heating system is on, other characteristics are off

Board temperature is 16 °C

Battery voltage is 5.03 VDC

## Unprompted Messages

The *HAB Ballaster* normally only sends information after a command is issued. Below are the common exceptions to that:

### **Stop Dropping Ballast**

The following command is issued when the *HAB Ballaster* stops dropping ballast, either because of the **!BBC** command or when it completes a **!BBD=xxx** command. It indicates the total amount of ballast it thinks it dropped, based on the Drop Rate. It also uses this amount to update the Ballast Remaining value.

```
[iBD,7] Ballast Dropped (g)
```

### **Termination Timer**

The following command is issued if the *HAB Ballaster*'s termination timer expires

```
[BSZ,TERM] Termination initiated
```

### **LoRa Message Information**

The *HAB Ballaster* currently displays a line of information each time it echos a LoRa interface message to/from the BLE and UART interfaces:

```
<LORA> RSSI: val, SNR: val
```

Note: These LoRa messages should be considered deprecated and expected to be removed in future firmware versions.

### **Power-On UART Message**

At power-on, the *HAB Ballaster* will transmit an introductory message over the hardware UART interface that includes basic parameters. This information can also be accessed by sending the **!bsf** command.

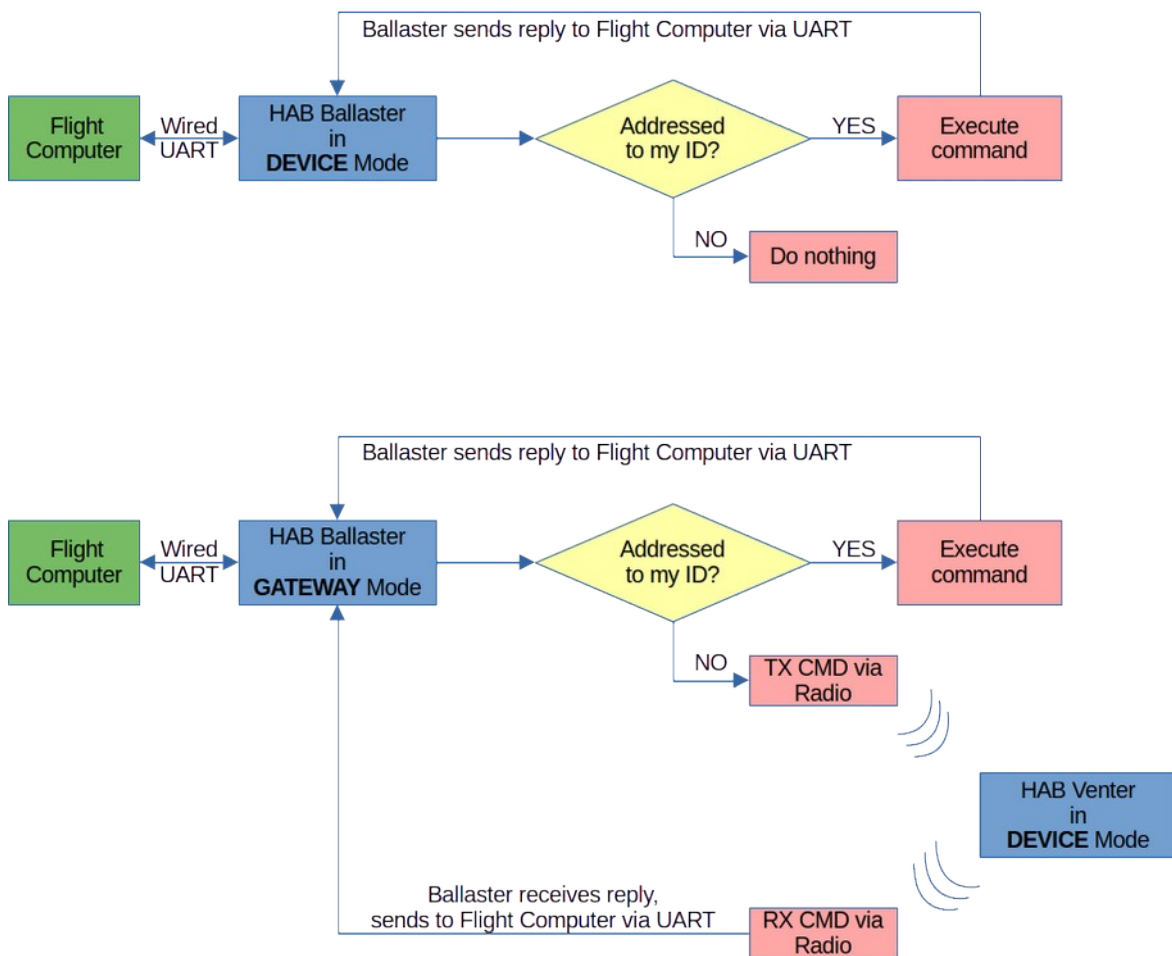
```
----- HAB Ballaster, rev 2.1 -----  
SERIAL NO   : XXXXXXXXXXXXXXXXX  
FIRMWARE    : Jun  4 2026  
----- Settings -----  
ID CHARACTER: B  
HTR SET PNT : -10 (C)  
COMM ECHO   : ENBL  
...  
...  
----- Loonatec.com -----
```

## LoRa Radio

The HAB Ballaster, and other HAB modules, can be controlled through messages sent over LoRa radio on the same frequency. All HAB modules receive the messages sent at that frequency so it is essential that each device has a different ID.

If the flight computer does not have LoRa radio capabilities, then it can be connected via wired-UART to a HAB module configured to LoRa ‘gateway’ mode. This gateway unit will then bi-directionally echo commands to/from the flight computers UART interface and its LoRa radio. Only one HAB module at a time should be set to ‘gateway’ mode in order to prevent endless command echoing.

**Example:** A HAB Ballaster is set to ‘gateway’. It will execute commands addressed to **!b** and echo commands addressed to other IDs. Sending a command such as **!vST** will be transmitted by the HAB Ballaster’s LoRa radio to the HAB Venter. The HAB Venter’s reply will be received by the HAB Ballaster and sent on to the Flight Computer via the UART connection.



## LoRa Settings & Effects

Below is a simplified overview of the basic LoRa and its chirp spread spectrum modulation settings.

### **Bandwidth**

The bandwidth is the frequency range each chirp covers. Decreasing this value increases the data rate, lowers transmit power consumption, but requires better oscillator tolerances between units. Frequency tolerances are typically  $\pm 25\%$  of this bandwidth to maintain a packet error rate below 10 %.

### **Spreading Factor**

The spreading factor is the number of RF chirps per symbol (encoded 4-bit data packet). Increasing this value makes the data more resistant to noise but lowers the data rate.

### **Coding Rate**

The coding rate is the total number of bits in encoded symbol—4-bit data packet plus bits added as a forward error correction. Increasing this value increases reliability while decreasing the data rate.

### **Sync Word**

The sync word can be used to isolate groups of LoRa devices. For instance if more HAB modules are installed on a flight train than device IDs (A-Z) permit then two groups, each with their own ‘gateway’ HAB module, could be created by using different sync words. Note that there are some restrictions on valid sync words, for instance 0x34 is reserved for LoRaWAN.

### **Power**

This is the transmit power level, in decibel-milliwatts. Its range spans transmit powers of approx 20 uW (-17 dBm) to 150 mW (22 dBm).

### **Preamble**

The preamble is used to detect the start of a data packet. It is the number of symbols that a long constant chirp is transmitted prior to data being sent to alert and allow the receive to achieve lock. Increasing this value increases the time on air.

### **Gain**

A value of 0 will permit the LoRa radio to use automatic gain control. In most circumstances this is best.

### **State**

This is an internal bit-mask value that controls the following:

- 0. Transmit Enabled → Enable LoRa TX echoing from BLE/UART

1. Receive Enabled → Enable LoRa RX echoing to BLE/UART
2. Send Reply Messages → TX device reply messages over LoRa
3. Forward Other Messages → TX received messages over LoRa
4. Forward My Messages → Also TX messages that match device ID over LoRa
5. Forward Reply Messages → Also TX reply messages that match device ID over LoRa

There are two preset options for State:

- Device → State = 7 → Tx & Rx enabled, send reply messages
- Gateway → State = 15 → Tx & Rx enabled, send reply messages, and forward other messages

Note: some care and experimentation with these settings may be required to avoid creating an echo chamber between multiple modules.

## Additional LoRa Resources

See: <https://www.semtech.com/products/wireless-rf/lora-tranceivers/sx1262#download-resources>

## LoRa Country Restrictions

Frequencies, transmit power, and duration restrictions vary from country-to-country. Below are the basic restrictions of two common regions.

Region	North America	Europe
<b>ISM Band</b>	902-928 MHz	863-870 MHz
<b>Regulated by</b>	FCC	ETSI
<b>TX Restriction</b>	400ms tx time	Generally 1% tx duty-cycle
<b>Payload sizes</b>	11 – 242 bytes	51 – 242 bytes
<b>Spreading factors</b>	7 – 10	7 – 12
<b>Data rates</b>	1 – 12.5 kbps	0.3 – 5.5 kbps
<b>Max transmit power</b>	21 dBm	Generally 14 dBm

Spreading Factor & Bandwidth	Transmit Data rate	Maximum Payload Size	
		North America	Europe
<b>SF_8 500kHz</b> (AT+SENDH)	12.5 kbps	242 bytes	-
<b>SF_7 125kHz</b>	5.47 kbps	242 bytes	242 bytes
<b>SF_8 125kHz</b>	3.125 kbps	129 bytes	242 bytes
<b>SF_9 125kHz</b>	1.76 kbps	53 bytes	115 bytes
<b>SF_10 125kHz</b>	0.98 kbps	11 bytes	51 bytes
<b>SF_11 125kHz</b>	0.44 kbps	-	51 bytes
<b>SF_12 125kHz</b>	0.25 kbps	-	51 bytes

From [Differences Between North America & Europe](#)

Note: All HAB Module messages are ≤ 50 bytes with the exception of displaying the system log (!iSL) which can only be transmitted over the BLE or UART interfaces.

## Safety Precautions and Recommendations

### ***Regulatory***

Always adhere to the regulations governing high-altitude ballooning applicable in the country of operation. In the United States, high-altitude balloon flights are governed by “FAA Part 101”.

### ***Falling Payload Hazard***

Always clear the launch area prior to launch. While unlikely, balloon or line failure after release may result in a falling payload impacting the ground before the parachute fully deploys.

The owner shall be liable for any damages resulting from any use of the *HAB Ballaster* and other related materials, and shall defend, hold harmless and indemnify Balloon Ascent Technologies LLC, officers, employees and agents, against any and all claims, suits, actions, costs, counsel fees, expenses, damages, judgments and decrees, by reason of any person or property being injured or damaged directly or indirectly by use of the *HAB Ballaster* or activities arising therefrom.