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

Table of Contents

1 Operating Specifications

Parameter	Min	Typical	Max	Unit
Operating: Temperature	-60	-	60	°C
Operating: Battery Voltage	1	-	5.5	VDC
Ballast Amount (small version)	-	-	0.7	kg
Ballast Release Rate (small version)	-	5.2	-	g/s
Ballast Amount (short version)	-	-	1.8	kg
Ballast Amount (tall version)	-	-	TBD	kg
Ballast Release Rate (short & tall versions)	-	7.9	-	g/s
Setting: Internal Heater Set-point	-60	-	60	°C
Sensor: Internal Temperature	-55	-	125	°C
Mechanical: Mass (small, no Batteries)	-	70	-	g
Mechanical: Mass (short, no Batteries)	-	135	-	g
Mechanical: Mass (tall, no Batteries)	-	TBD	-	g
Mechanical: Mass (2x L92 batteries)	-	15	-	g
Mechanical: Size (small)	8 cm diameter, 20 cm heigh			
Mechanical: Size (short)	10 cm diameter, 20 cm heigh			
Mechanical: Size (tall)	10 cm diameter, 120 cm heigh			

2 Interface

The *HAB Ballaster* can be controlled either via Bluetooth Low Energy (BLE, v 4 or 5), LoRa radio, or via a hardware Universal Asynchronous Receive Transmit (UART) serial protocol interface. Each module uses an identifier character to permit multiple devices to be placed into the same group or onto the same bus.

Bluetooth Low Energy Interface

HAB Ballaster uses the Nordic UART Service (NUS) for most Bluetooth communication. This permits using widely-available apps such as Adafruit's Bluefruit BLE Connect App for ground-testing prior to launch.

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

LoRa Radio Interface

The *HAB Ballaster* has an integrated LoRa radio based on a Semtech SX1262 chip. It can be configured to operate in the 862-928 MHz frequency range over a distance of many meters.

The radio interface can be configured to 'echo' commands to/from the other communication interfaces, permitting one HAB module to act as a 'gateway' 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. Example:

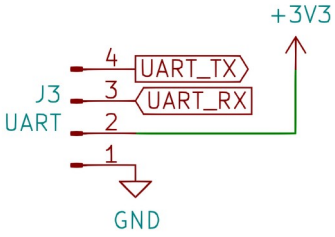
- A HAB Ballaster can be wired to the flight computer via the UART interface and configured as the 'gateway' with device identifier (ID) 'B'
- A HAB Clipper can be configured as a 'device' with ID 'C' and added above the parachute
- A HAB Venter can be configured as a 'device' with ID 'V' and added to the balloon
- Commands sent via UART to device 'B' are not echoed by the LoRa radio
- Commands sent via UART to ID 'C' are echoed by the LoRa radio. Any responses received from ID 'C' via LoRa radio are then echoed onto the UART interface so the flight computer can confirm that the command was received and acted on.
- The HAB Venter will also receive the ID 'C' commands via its LoRa radio but will ignore them because it is addressed to a different ID.

Hardware UART Interface

A low-level, unprotected interface is available via a 4-pin JST SH (1.0 mm pitch) connector.

Specs: 115,200 baud, 8n1, @ 3.3 V logic

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



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 (**`!iSD=Y`**), the shutdown command. Note: the *HAB Ballaster* will take a considerable time to fully shut-down when the batteries removed—usually 1-5 minutes.

BLE LED

The *HAB Ballaster* has one blue BLE LED. Possible blink patterns are:

- Briefly flashing at 1-3 Hz to indicate BLE advertising (1285 ms advertising rate) and awaiting the first UART command since power-on
- Single, 100 ms second pulse to indicate command received
- Off once a BLE or UART command has been received

Status LED

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

- **Pulsing** – super-cap is charging
- **Single** – Watchdog Timer is enabled
- **Double** – Venter currently active
- **Triple** – Venter is currently active and moving
- **Quintuple** – Venter error

The green Status LED will flash briefly once ever 30 seconds to indicate it is powered on and operating correctly.

3 Checklist

Setup

Loading ballast

1) Remove foam cover and insert two batteries
2) Attach rigging harness
3) Record the mass of the empty *HAB Ballaster*
4) Ensure the *HAB Ballaster* is oriented correctly & that the ballast gate valve is close
5) Slowly pour in the ballast media, filling the hopper

Power-On

7) Press the power-on button for 3 seconds
8) Listen for the close routine attempt and ensure gate valve is closed
   If not, Motor Polarity may be set incorrectly **`!iBP=0/1`**
9) Connect with BLE or UART
10) Configure UART ID if desired

Calibration

11) Record the mass of the full *HAB Ballaster*
12) Place over a container to catch ballast media
13) Command a timed ballast release: **`!ABD=30s`**
14) Wait for ballasting to complete
15) Record the new mass and calculate the drop rate (g/s)
    ex: (1,200g – 1,044g) / 30sec = 5.2 g/s
16) Set the correct drop rate: **`!ABR=5.2`**
17) Set the total ballast: **`!ABA=1700`**
    Full – Empty = Total Usable Ballast
18) Reload the ballast released during calibration
19) Close cover

4 Operation

Manual Ballaster Operation

The HAB Ballaster can be controlled via the **!iBD** command.

Ballaster Checks

Every two (2) minutes while powered on, the *HAB Ballaster* will check the gate valve position. If found to be in the incorrect position it will attempt an automated open/close operation. If that isn't successful, then the Status LED will flash the double-flash error pattern.

Note: this check only occurs if the Gate Sensor is enabled (**`!iBS`** is Enabled).

Ballaster Gate Move Faults

HAB Ballaster will automatically try four (4) times to clear a jammed gate valve. If it is successful in one of these attempts then operation will not be impacted but noted by one or error messages:

```
[iBD,ERROR] Gate Move
Fault #1 Closing
```

If it is not successful in clearing the jam automatically after the fourth attempt, the user can try issuing a Ballaster Gate Valve Close command (**`!iBC`**). This will clear the fault counter and attempt the sequence again. It is recommended to wait at least 30 seconds before issuing this command to give the gate valve motor's super capacitor time to recharge.

Watchdog Cutter Operation

The *HAB Ballaster* can be automatically opened indefinitely by an expiring watchdog timer. This can be used to ensure that the *HAB Ballaster* is empty before landing to reduce landing mass and impact speed.

Example: start watchdog timer, re-enable once (alternative method to the feed command), feed once, then stop feeding:

!iSW=30 Start the watchdog timer counting down from 30 seconds

… can wait up to 29 seconds …

iSW=30 Reset the watchdog timer, reseting the countdown from 30 seconds

… can wait up to 29 seconds …

!iSW=F Feed the watchdog timer, reseting the countdown from 30 seconds

… wait 30 seconds for watchdog time to expire …

Resulting activation sequence:

1. *HAB Ballaster* issues the **!iBB** command to itself
2. Command message receipt sent out via BLE/LoRa/UART
3. Gate valve is activated, emptying ballast media

System Measurements

Every thirty (30) seconds while powered on, the *HAB Ballaster* will measure the battery voltage and internal temperature. Using this temperature measurement it will then enable/disable the battery heater.

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 Controls section for which parameters are saved to non-volatile memory.

During the boot 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:

- STATUS LED flashing the rapid, continuous error flash.
- The following message sent via the UART interface:
  `[SM,WARN] Non-volatile parameters have been reset to defaults`

5 Controls

Command Section

The *HAB Ballaster* uses the same commands for both the BLE and UART 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 'A')

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

Where "**C**" is the subsystem command (ex T or V)

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

Ballasting Commands

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

CMD	VAL	Description	Reply	Non-Volatile
BA		Query Ballast Remaining[iBA, 950] Ballast Remaining (g)	`[iBA,n] Ballast Remaining (g)`	X
	1000	Set Current Amount of Ballast (grams)		
BB		Commence Dropping Ballast — indefinitely	`[iBB,INDEF] Dropping Ballast`	
BC		Stop Dropping Ballast	`[iBC,NULL] Close`	
BD		Query Ballaster Gate State	`[iBD,GOOD ? FAIL] Status`	X

	10	Drop X-grams of Ballast (grams)	`[iBD,n] Dropping Ballast (g)`
			`[iBD,ERROR] Already Active`
			`[iBD,ERROR] Insufficient Ballast`	

	10s	Drop Ballast for X-seconds (seconds)	`[iBD,n] Dropping Ballast (s)`	
BP		Motor Polarity → Query	`[iBP,NORM ? REV] Motor Polarity`	X
	0	Motor Polarity → Set to Reversed		
	1	Motor Polarity → Set to Normal		
BR		Ballast Drop Rate → Query	`[iBR,n] Drop Rate (g/s)`	X
	7.9	Ballast Drop Rate → Set		
BS		Gate Sensor Usage → Query	`[iBS,ENBL ? DSBL] Gate Sensor`	X
	0	Gate Sensor Usage → Set to disabled		
	1	Gate Sensor Usage → Set to enabled		

LoRa Radio Commands

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

CMD	VAL	Description	Reply	Non-Volatile
RA		Preamble Setting → Query	`[iRA,n] Preamble length`	X
	6 to 65535	Preamble Setting → Set		
RB		Bandwidth Setting → Query	`[iRB,n] Bandwidth`	X
	7.8 to 500	Bandwidth Setting → Set		
RC		Coding Rate Setting → Query	`[iRC,n] Coding rate`	X
	5 to 8	Coding Rate Setting → Set		
RE		Echo Setting → Query	`[iRE,n] Radio Echo Setting`	X
	D	Echo Setting → Set as 'Device'		
	G	Echo Setting → Set as 'Gateway'		
	0-255	Echo Setting → Set bit mask manually		
RF		Carrier Frequency Setting → Query	`[iRF,n] Carrier Frequency`	X
	862.0 to 928.0	Carrier Frequency Setting → Set		
RG		Gain Setting → Query	`[iRG,n] Gain`	X
	0 = AGC	Gain Setting → Set		
RH		Latest Frequency Error (Hz) **DEPRECIATED*	`[iRH,n] Frequency error (Hz)`	
RN		Latest Signal to Noise Ratio	`[iRN,n] SNR (dB)`	
RO	**0**	Turn Radio Module OFF	`[iRR,ON] Radio State`	*if other setting later set
	1	Turn Radio Module ON	`[iRR,OFF] Radio State`	
RP		Output Power Level Setting → Query	`[iRP,n] Output Power`	X
	-17 to 22	Output Power Level Setting → Set		

RR		Latest RSSI Value	`[iRR,n] RSSI (dBm)`	
RS		Spreading Factor Setting → Query	`[iRS,n] Spreading Factor`	X
	6 to 12	Spreading Factor Setting → Set		
RW[1]		Sync Word Setting → Query (default = 0x12)	`[iRW,n] Sync Word (dec)`	X
	≤ 8 bytes	Sync Word Setting → Set		

1 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
SA[2]		AUX State → Query	`[iSA,n] AUX State`	
	0	AUX State → Set, low output		
	1	AUX State → Set, high output		
SC		Super-Cap Voltage → Query	`[iSC,2.78] Scap (V)`	
SD	**Y**	Shutdown	`[iSD,SHTDWN] Shutdown`	
SE		UART<->BLE Comm Echo → Query	`[iSE,ENBL ? DSBL] Comm Echo`	X
	0	UART<->BLE Comm Echo → Set to OFF		
	1	UART<->BLE Comm Echo → Set to ON		
SH		Heater Set Point → Query	`[iSH,-10] Heater Set Point (C)`	
	10	Heater Set Point → Set (°C)	`[iSH,10] Heater Set Point (C)`	

SL		System Event Logging → Query	`---System Log---`
			`[sys-cmd, payload] batt(V), scap(V), temp(C), BLE(dB), MET(ms)`
			`[SC,2] 3.1, 2.9, 26, 100, 74403`
			`[SV,3] 3.1, 2.9, 26, 100, 74250`
			`---DONE---`
				X

	0	System Event Logging → Set Disabled	`[iSL,DSBL] System Event Logging`	
	1	System Event Logging → Set Enabled	`[iSL,ENBL] System Event Logging`	
	C	System Event Logging → Clear Note: also resets non-volatile settings to default	`[iSL,Cleared] Shutting down`	
SI	**B**	Device Identification Letter → Set (A-Z)	`[BSI,B] Device ID`	X
ST		Internal Temperature → Query	`[iST,22.7] Temperature (C)`	
SU		UART Baud Rate → Query	`[iSU,115200] UART Baud Rate`	X

2 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.

	1200	UART Baud Rate → Set	`[iSU,1200] UART Baud Rate` `[iSU,ERROR] UART Badu range: 1,200 to 115,200`	
SV		Battery Voltage → Query	`[iSV,2.78] Battery (V)`	
SW		Watchdog → Query	`[iSW,-1] WDT Inactive` `[iSW,n] WDT Remaining (s)`	
	D	Watchdog → Disable	`[iSW,-1] WDT Disabled` `[iSW,ERROR] Failed to stop WDT`	
	F	Watchdog → Feed	`[iSW,n] WDT Remaining (s)` `[iSW,ERROR] WDT not Fed`	
	60	Watchdog → Set	`[iSW,n] WDT Enabled/Feed (s)` `[iSW,ERROR] WDT invalid interval (1-60,000 s)`	
SX		System Status → Query	`[iSW,n,n,n] STV`	

System Status Message Details:

Description: This message is intended to be called regularly to both check on the module's status as well as keep the watchdog timer feed (if enabled, same as **iSW=F**). It returns a bitmapped Status byte as well as the module's internal temperature and battery voltage.

Example: [ASX,130,16.00,5.03] STV

Status Field: A bitmapped byte is returned as a decimal number:

7	6	5	4	3	2	1	0
SCap Charging	ERROR	Valve Active - Moving	Valve Active - Waiting	WDT Active	Open LS	Closed LS	Heater ON

Temperature Field: Board temperature in degrees C, two decimal places

Voltage Field: Battery voltage in volts, two decimal places

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 **`!BC`** command or when it completes a **`!BD=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)
```

Gate Move Fault

Four (4) attempts will be automatically made to clear a jammed gate valve. If the attempt is successful no message will be issued. If the fault persists, the following error message will be issued:

```
[iBD,ERROR] Gate Move Fault #1 Closing
```

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. Some of this information is also available via the Bluetooth Device Information Service (0x180A):

```
--------- HAB Ballaster ---------
  Hardware ver: 2
  Serial No   : XXXXXXXXXXXXXXX
  Firmware    : Oct 13 2022
------------ Settings ------------
  ID CHARACTER: A
  HTR SET PNT : -30 (C)
  COMM ECHO   : ENBL
  BLST AMOUNT : 585 (g)
  BLST DROP R : 5.20 (g/s)
  BLSTR MTR P : NORM
  BLSTR SENSR : ENBL
------------- Sensors -------------
  INT TEMP    : ENBL
  BATTERY VOLT: ENBL
  SCAP VOLT   : ENBL
---------- LoRa Settings ----------
  FREQUENCY   : 915.0000
  BAND WIDTH  : 125.0000
  SPREAD FACT : 9
  CODE RATE   : 7
  SYNC WORD   : 0x12
  POWER       : 2
  PREAMBLE    : 8
  STATE       : 7
---------- Loonatec.com ----------
```

6 LoRa Radio

LoRa Settings & Effects

Below is a simplified overview of the basic LoRa and its chirp spread spectrum modulation settings. Default values are shown on the previous page in the *Power-On UART Message*.

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

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

7 Consumables

Batteries

The *HAB Ballaster* has been designed to use primary lithium batteries in the 'AAA' size. The Lithium/Iron Disulfide (Li/FeS2) 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 due to their poor performance at cold.

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

8 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.