HAB Cutter

Mechanical Release System

Balloon
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Technologies

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

Overview

The HAB Cutter™ is a light-weight self-contained mechanical release system for separating balloons, deploying instruments, dropping ballast, and other tasks that can be achieved by simply cutting a synthetic line.

- Cut synthetic line with a mechanical knife
- Wireless BLE and LoRa Interfaces
- Wired UART Interface
- Stand-alone watchdog timer activation option for termination redundancy

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1   Operating Specifications

Parameter	Min	Typical	Max	Unit
Operating: Temperature	-60	-	60	°C
Operating: Battery Voltage	1	-	5.5	VDC
Line: Paracord Type (MIL-C-5040)	I	III	IV	Type
Line: Tensile Strength	45	250	455	kg
Line: Tension on line to ensure proper cut	1		4400	N
Setting: Internal Heater Set-point	-60	-30	60	°C
Sensor: Internal Temperature	-55	-	125	°C
Mechanical: Mass (no Batteries)	-	55	-	g
Mechanical: Mass (2x L92 batteries)	-	15	-	g
Mechanical: Size (no foam enclosure)	48 x 68 x 35 mm			

2   Interface

The *HAB Cutter* 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 Cutter uses the Nordic UART Service (NUS) and basic ASCII commands for easy Bluetooth communication. This permits using Adafruit's Bluefruit LE Connect App for configuration and 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 Cutter* 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 Cutter 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.
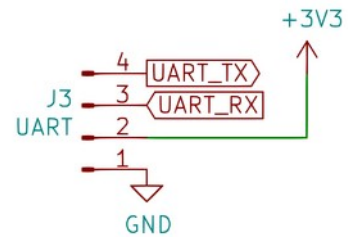
Power-On Button

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 Cutter* on. Repeated pressing or constant pressing will have no impact on the *HAB Cutter* operation. It cannot turn off the HAB Cutter.

To shutdown the *HAB Cutter* remove its batteries or issue (**!iSD=Y**), the shutdown command. Note: the *HAB Cutter* will take a considerable time to fully shut-down, even with the batteries removed—usually 15+ minutes.

BLE LED

The *HAB Cutter* has one <u>blue</u> 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 Cutter* has one <u>green</u> Status LED. Possible blink patterns at 1 Hz are:

- **Single** – super-cap is charging

- **Double** – Cutter currently active

- **Quintuple** – Cutter error

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

3 Operations

Preflight Checklist

Rigging

1) Open *HAB Cutter* by grasping and lightly pinching the lid and lifting up (red arrow)

2) Insert two new batteries

3) If blade is down (shown raised in photos):

   1. Turn on by pressing power-on button for 3 seconds

   2. Connect via BLE with smart phone

   3. Send `!iCO` command to open (raise) the cutting blade

   4. Turn off with `!iSD=Y` command

4) Thread line to be cut through the circular tube (white 550 paracord in photo)

5) Attach retaining line (yellow line in photo) to attach *HAB Cutter* to flight train for retention after cut
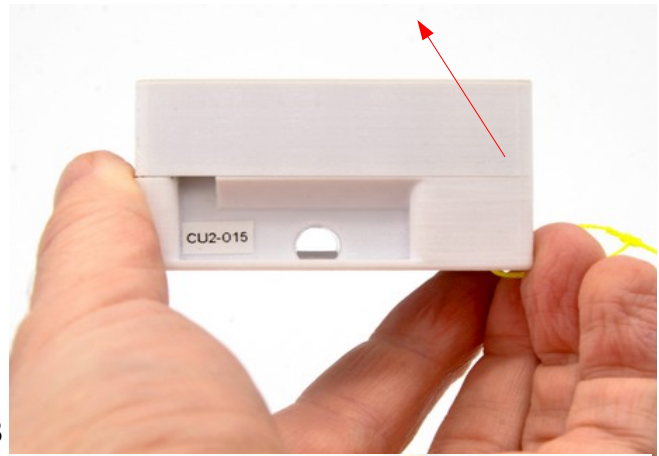
Power-On

6) Press the power-on button for 3 seconds

7) Connect with BLE, LoRa, or UART

8) Verify that blue BLE LED turns off

Cutter Activation

9) Cut line with `!iCC` command

10) Or start watchdog timer with `!iSW=x`

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Operation

Manual Cutter Operation

The *HAB Cutter's* line cutter can be controlled via the **iCC** (cut) and **iCO** (open) commands.

Example:

> **!iCO**   Open the line cutter mechanism to permit the rigging of a new line to be cut
>
> **!iCC**   Activate the line cutter mechanism to cut the rigged line

Watchdog Cutter Operation

The *HAB Cutter's* line cutter can be activated by an expiring watchdog timer. 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 Cutter* issues the **!iCT=Y** command to itself
> 2. Command message receipt sent out via BLE/LoRa/UART
> 3. Mechanical line cutter repeatedly activated → line cut

Non-Volatile Cutter Parameters

Most of the *HAB Cutter's* parameters are saved in non-volatile memory. The value is not effected by powering the *HAB Cutter* 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
  ```

System Measurements

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

4   Controls

Command Section

The *HAB Cutter* 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 "**!**" (ox21) denotes a new command start

Where "**i**" is the device's UART address

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

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

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

Cutting Commands

This is a list of commands to control the HAB Cutter's Cutting functions.

CMD	VAL	Description	Reply	Non-Volatile
CC		Cutter Cut Command	`[iCC, CUT] Cutting` `* Note: On early versions CLOSING was used instead of CUT`	
CE[1]		External Trigger → Query	`[iCE, n] EXT State`	
	0	External Trigger → Set to OFF		
	1	External Trigger → Set to RISING		
	2	External Trigger → Set to FALLING		
CO		Cutter Open Command	`[iCS, OPEN] Opening`	
CP		Cutter Motor Polarity → Query	`[iCP, NORM ? REV] Motor Polarity`	X
	0	Cutter Motor Polarity → Set to reversed		
	1	Cutter Motor Polarity → Set to normal		
CT	Y	Start Terminate Sequence[2]	`[iCT, START] Terminate Sequence` `[iCT, ERROR]  Terminate Sequence`	

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1   The External Trigger command is present on the HAB Cutter but it does not have the necessary connector to be used on v2 hardware.

2   The Terminate Sequence repeatedly opens and closes the cutter to ensure the line is fully cut. Send the Cutter Open Command to stop the Terminate Sequence.

LoRa Radio Commands

This is a list of commands to control the HAB Cutter'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[3]		Sync Word Setting → Query (default = 0x12)	`[iRW, n] Sync Word (dec)`	X
	≤ 8 bytes	Sync Word Setting → Set		

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3   The Sync Word is displayed in HEX during the boot sequence but set in DEC by the RW command. It can also 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 Cutter's system functions.

CMD	VAL	Description	Reply	Non-Volatile
SA[4]		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
	D	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

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4   The AUX state command is present on the HAB Cutter 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 (1-4000000 s)`	

Unprompted Messages

The *HAB Cutter* normally only sends information after a command is issued. Below are the exceptions.

External Trigger

The *HAB Cutter* will transmit a message when the external trigger is activated.

```
[iCE, START] EXT Trigger Activation
```

LoRa Message Information

The *HAB Cutter* 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
```
for SX1262

```
<LORA> RSSI: val, SNR: val, Freq: val
```
for prototype SX1272 variants

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 Cutter* 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 Cutter, rev 2 -------
  SERIAL NO   : XXX86XXX2DXXX728
  FIRMWARE    : Mar  9 2023
------------ Settings ------------
  ID CHARACTER: A
  HTR SET PNT : -20 (C)
  COMM ECHO   : ENBL
  CTR MTR POL : REV
  CTR SENSR   : DSBL
------------ Sensors ------------
  INT TEMP     : ENBL
  BATTERY VOLT: ENBL
  SCAP VOLT   : ENBL
----------- LoRa Radio -----------
  FREQUENCY   : 915.00 MHz
  BAND WIDTH  : 125.00 kHz
  SPREAD FACT : 9
  CODE RATE   : 7
  SYNC WORD   : 0x12
  POWER       : 2
  PREAMBLE    : 8
  STATE       : 7
---------- Loonatec.com ----------
```

5   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.

6   Consumables

Batteries

The *HAB Cutter* 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 Cutter* will operate on standard alkaline batteries, it is strongly recommended against using them during flight due to their poor performance at cold.

Line

The *HAB Cutter's* mechanical cutter has been designed to cut the following types of MIL-C-5040 Paracord:

- Type I (100 lbs, 45 kg tensile strength)
- Type II (400 lbs, 180 kg tensile strength)
- Type III (550 lbs, 250 kg tensile strength) aka 550 paracord, with 7 inner strands
- Type IV (750 lbs, 340 kg tensile strength) aka 750 paracord, with 11 inner strands
- Type V(1000 lbs, 455 kg tensile strength) aka 1000 paracord, with 14 inner strands

The mechanical cutter is capable of cutting other synthetic line, but ground-testing should be conducted to confirm that the line is reliably cut.

Note: the line is usually completely cut through, but occasionally a thread may be remain uncut. Ensure at least 1 N of force is present on the cut line to ensure any remaining threads are pulled free and the line separates. For force-free separation of light loads use a HAB Cutter instead.

Knife Blade

The *HAB Cutter's* mechanical cutter relies on a very sharp knife blade to cut the synthetic line. It is possible to replace this blade should it become dull. Please contact support for more information.

7   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".

Always adhere to the regulations governing radio transmissions applicable in the country of operation. In the United States, radio transmissions are governed by "FCC Part 15" ISM regulations.

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.

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