allocortech inc.

Comet FTS Operators Manual

600-0049-000

Revision A

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Table of Contents

Version History

Revision	Changes
A	Initial Draft

Introduction

The allocortech inc. Comet is a Flight Termination System which is composed of an airborne unit, and a number of ground units. The system is designed to prevent single faults from causing an uncommanded termination, but is not designed to guarantee a commanded termination in the face of a single fault.

The Comet Air unit can be factory configured with any combination of voted or non voted voltage or current termination outputs. Optional communication with either ground or air equipment for telemetry and redundant termination commands can happen either through CAN or 10/100 ethernet.

Scope of this Document

This document covers the software configuration and operation of the Comet AIR and GND units in a nominal configuration. allocortech allows end users to customize the software that runs on each unit and therefore some aspects of the operation of the unit may differ between serial numbers. Further, although allocortech has a standard communications protocol for the Ethernet and CAN interfaces for internal test purposes, this is very likely different per aircraft integration.

For information about the electrical and mechanical aspects of the devices, including any installation guidelines, see document 601-0049-000 Comet FTS Mechanical ICD.

List of Abbreviations

BIT	Built in Test
CAN	Controller Area Network
FTS	Flight Termination System
FTS-AIR	Flight Termination System - Airborne Unit
FTS-GND	Flight Termination System - Ground Unit
ICD	Interface Control Document
RSSI	Received Signal Strength Indicator

References

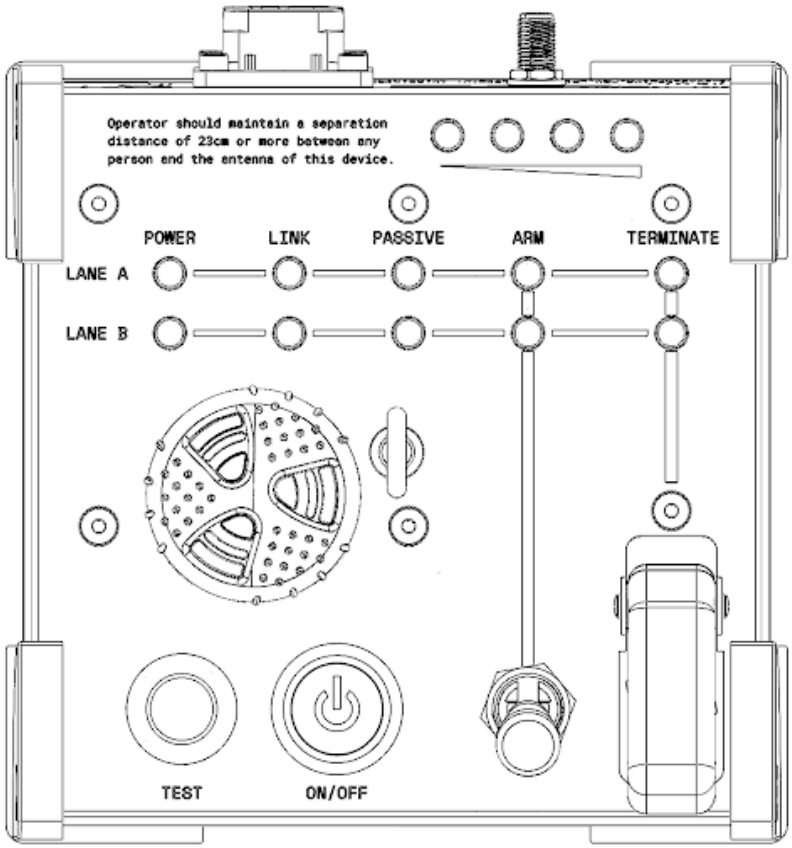
601-0049-000 Comet FTS Mechanical ICD

DO-160G: Environmental Conditions and Test Procedures for Airborne Equipment

STMicroelectronics AN3155 USART protocol used in the STM32 bootloader

FTS-GND

Operational Summary



As a quick summary of the operation of the Comet FTS-GND through termination:

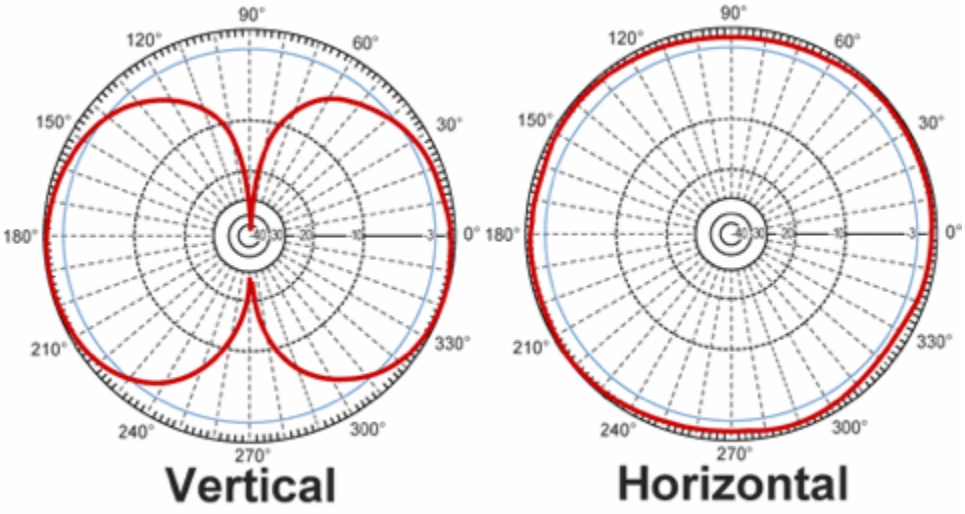
1. Press the power button, the LED ring will illuminate Green or Red (indicating low battery)
2. The Power and Passive LEDs for each lane will illuminate solid
3. The Link LED will illuminate either Solid (good link) or Blinking (link not yet established)
4. With a solidly illuminated Link LED, actuating the ARM switch will:
    a. Solidly illuminate the Arm LED and extinguish the Passive LED
    b. Cause the buzzer to emit a warbling tone
5. Actuating the terminate switch will blink the Terminate LED until FTS AIR confirmation of termination, at which point it will solidly illuminate.
6. Actuating the Terminate and Arm switches back to the off position will result in the Terminate LED and either the Arm or Passive LED blinking. If the FTS AIR is allowed to disengage Terminate, then once the command is acknowledged, the GND unit will solidly illuminate the Arm or Passive LED.

Note: The buzzer only sounds with the GND Arm or Terminate switches is actuated and does not reflect the acknowledged state of the AIR unit.

Radio Operation

The FTS-GND contains an active radio transmitter that has not been certified for near range operation next to a human. During operation, ensure the separation between the antenna and any personnel, including the operator, is at least 23 centimeters.

The FTS radio link, in its recommended configuration, uses linearly polarized omnidirectional rubber duck antennas. These antennas have a strong overhead null and function best when antennas are parallel to each other.



Example quarter wave antenna radiation pattern.
90 degrees vertical is through the tip of the antenna.

For best operation, ensure a clear line of sight to the FTS-AIR antenna. Note that obstructions near to the line of sight path may still significantly interfere with signal quality due to Fresnel zone effects.

Indications

In general, the Comet FTS-GND will only illuminate LEDs for positive acknowledgement. A lack of illumination should be taken as an indication of failure.

There are two independent lanes inside of the Comet FTS-GND, and each lane controls its own set of Power, Link, Passive, Arm, and Terminate LEDs. These lanes and their association are marked with black horizontal lines across the face of the unit.

Black vertical lines visually connect the Arm and Terminate LEDs with their respective switches.

Link

Solidly Illuminated	FTS-AIR unit has acknowledged at least one command in the last 750 milliseconds.
Blinking	No message from the FTS-AIR has been received in the last 750 milliseconds.

Passive, Arm, and Terminate

Solidly Illuminated	FTS-GND and FTS-AIR are in the same state. This implies an active Link and acknowledgement of commands from the FTS-AIR.
Single Blinking LED	FTS-GND is in this state, but does not have link or acknowledgement from the FTS-AIR unit.
Multiple Blinking LEDs	FTS-GND and FTS-AIR are in different states.
Extinguished	If other Passive, Arm, and Terminate LEDs are illuminated, neither FTS-GND or FTS-AIR are in this state. Otherwise the state of the system is unknown.

Note: If the Terminate switch is actuated before the Arm switch, the unit will remain in the Passive state and the LED indications will reflect that (solid if the FTS-AIR is also Passive, and blinking if otherwise.)

Note: If the unit is powered with the Arm switch already actuated, it will not progress out of its power on-built in test. In this case, the Power indicators will be illuminated and the buzzer will sound, but no other indicators will be illuminated.

Note: In the case where the FTS-GND unit has terminally failed it's built in test, all the state LEDs for the failing lane will be extinguished.

Power

Solidly Illuminated	The processor for the respective lane is working normally.
Blinking	The processor for the respective lane has not booted, is not configured, or has otherwise had a terminal failure.

RSSI - Radio Received Signal Strength Indication

There are four RSSI LEDs controlled by the Lane A processor reflective of information received from the radio about the quality of link between the FTS-GND and FTS-AIR unit. LEDs will illuminate from left to right as the signal strength improves.

# of LEDs Illuminated	RSSI (dBm)	Approximate SNR (dB)	Estimated Distance to FTS-AIR (km)
1	-90 to -80	20	22 to 8
2	-80 to -75	30	8 to 5
3	-75 to -70	35	5 to 2.5
4	Better than -70	40	Less than 2.5

Buzzer

The buzzer will sound when either lane detects it's Arm or Terminate switch actuated into the active state. This is true regardless of which switch was actuated first.

On/Off

Solid Green	Unit has more than 30 minutes of estimated battery life remaining.
Solid Red	Unit has less than 30 minutes of estimated battery life remaining.

Battery Charging

There is a 6 cell 2.6Ah Lithium-ion battery inside the FTS-GND unit that needs to be recharged routinely to no more than 25.2 volts. A commercially available constant current / constant voltage (CC/CV) charger that allocortech has identified is the BatterySpace CH-L2215-V1. Regardless of charger, it should be connected to pins 4, positive, and 9, negative of the EN-4165 J1 connector.

The battery will accept charge current regardless of the state of the power button.

The battery installed by allocortech, a BatterySpace CU-N105, has over-voltage, under-voltage, and over-current protection. However, to extend battery service lifetime, care should be taken to ensure that the battery remains within the 20% to 80% state of charge window when storing the unit for long periods of time.

The state of charge of the battery can be monitored via three means:

- The On/Off button will turn red when the battery has less than 30 minutes of runtime remaining.
- Pressing the test button three times in rapid succession will cause the unit to enter brightness adjustment mode, which will also indicate the battery state of charge in the RSSI LEDs where each illuminated LED indicates at least 20% state of charge.
- Monitoring the telemetry of the Lane A processor, only this processor has the ability to see the battery input voltage.

With normal use, the battery should last more than 8 hours at 20°C. The Comet GND unit should always be operated between -20°C and 60°C and to maximize battery life should be stored and charged at room temperature and out of direct sunlight.

Alternative Modes

Several alternative operating modes for test and maintenance of the FTS-GND are available via the Test button.

Functional Test Mode

Any time the FTS-GND is in Passive mode, where neither the Arm or Terminate switch is actuated, the unit may be functionally tested by the operator by pressing the Test button. This unit will remain in this mode while any switch is in the actuated state.

In this mode all indicators will present with the following pattern:

Power, Link, and Passive LEDs	Solidly illuminated
RSSI LEDs	Solidly illuminated
Arm and Terminated LEDs	Blinking if the associated switch is not actuated, solid otherwise
On/Off Switch	Alternating between Red and Green
Buzzer	Audible

Brightness Adjust Mode

If the test button is pressed three times in three seconds, the unit's will enter brightness adjustment mode where the panel illumination can be modified until the unit is power cycled. In this mode, further presses of the test button will cycle through the available brightness settings.

The unit will return to Passive mode if no further presses of the test button are detected in a three second time window and if the Arm and Terminate switches are not actuated.

In this mode all indicators will present with the following pattern:

Power LEDs	Solidly illuminated
RSSI LEDs	Each blinking LED indicates an additional 20% battery state of charge
On/Off Switch	Alternating between Red and Green
All other LEDs	Blinking
Buzzer	Silent

Adjusting Panel Brightness

The brightness of the Comet FTS-GND panel is controlled by Lane B and can be adjusted in one of two ways:

Temporarily Adjusting Brightness
In the field, the operator can set the panel brightness until the next unit reset by pressing the test button three times in rapid succession to enter Brightness Adjust Mode as discussed in the Alternative Modes section.

Persistently Adjusting Brightness
A persistent change to the unit's panel brightness can be made with the `backlight` command using the command console on Lane B. Backlight intensity is adjustable from 1 to 10 as the single argument to this command, and the setting will need to be saved using the `write_cfg` command to take persistent effect.

More information on the command console is available in the System Setup section.

Adjusting Volume

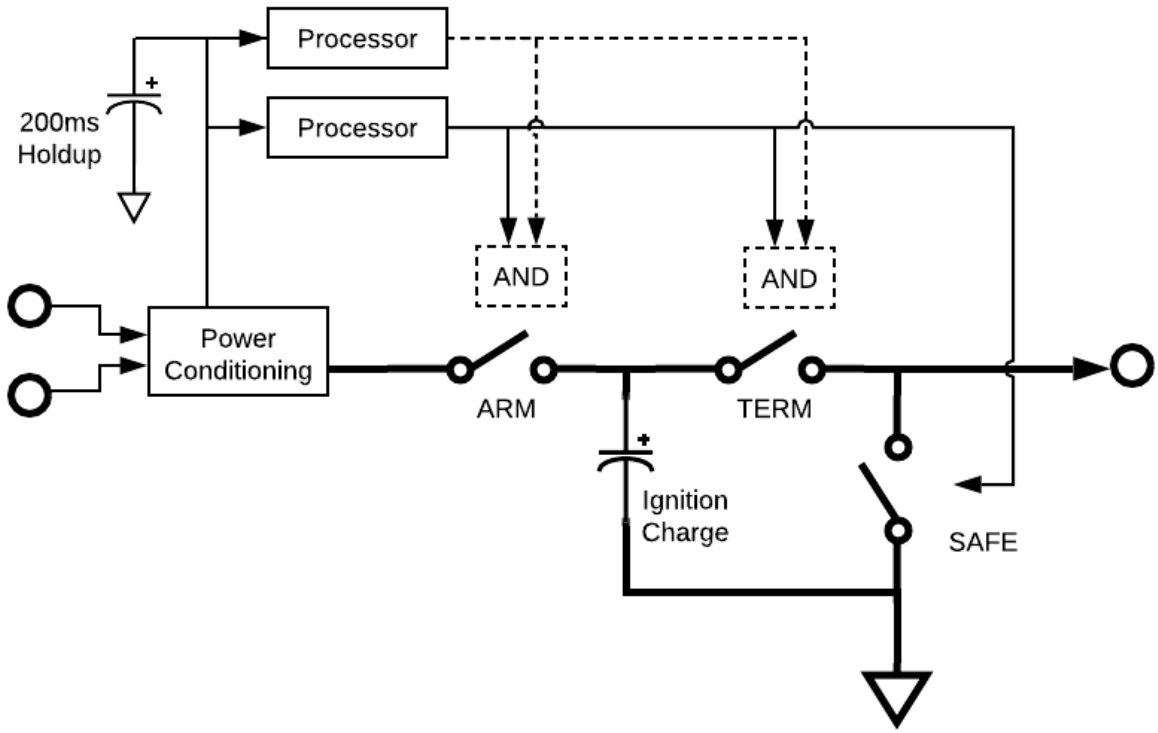
The speaker on the front panel of the FTS-GND unit has a rotating shutter capable of 10dB of attenuation between the fully open and fully closed positions. The operator can adjust this shutter at any time and test the resulting volume change using the Test button.

More control over the range of volume is available via an adjustable trim pot located between the 4 pin battery connector and 2 pin speaker connector on the indicator printed circuit board. This trim pot is user accessible by removing only the back panel of the FTS-GND unit.

FTS-AIR

Theory of Operation

The FTS-AIR has two independent termination lanes (consisting of a microprocessor, Arm, Terminate, and Safety switches) with power regulation and holdup being shared between the two lanes.



Normally a single processor controls a single termination output, however, as a factory option a logical AND gate can be added such that each termination output is voted upon by both processors.

Once the Air unit has received a valid termination command from the Ground unit, it will open the SAFE switch, close the ARM switch, allow the ignition charge capacitor to charge, and then close the TERM switch. The unit will relay the termination command via Ethernet or CAN to the rest of the aircraft upon receipt of the command without waiting for the ARM, TERM, and SAFE switches to be in the terminate state.

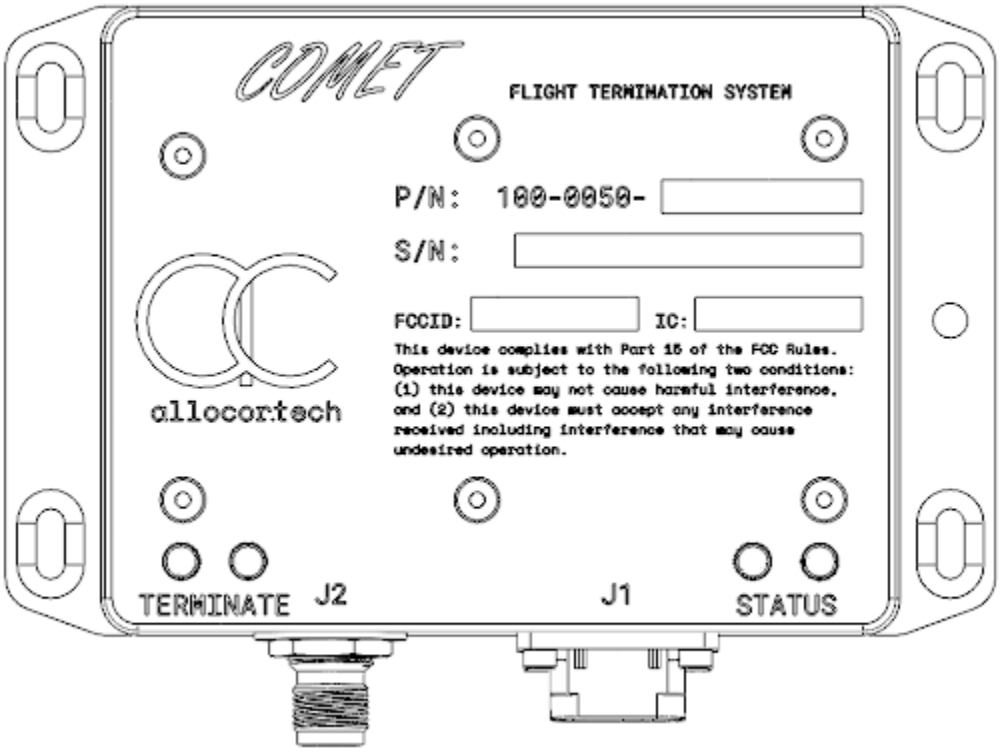
In the event of power failure on a single power input, the unit will seamlessly switch to sourcing all power from the redundant power input. Failure of an internal power supply may result in the entire unit becoming non functional although it will not result in an inadvertent termination.

Termination After Loss of Power

Units configured for digital termination output with the signal coming from the voltage bus after the voltage clamp and hold up capacitor are capable of providing a 50mA termination signal with decaying voltage (from the input down to about 12V) for approximately 200ms. In this case, the termination signal and unit power are sourced from the same hold up capacitor and so the signal will no longer be applied to the output once the unit shuts down due to low voltage. If the voltage later recovers, although the unit will reboot, it is unlikely that it will have had the energy to retain hardware latched termination command.

Units configured for pyrotechnic operation are unable to terminate after loss of power as there is no method to transfer charge from the hold up capacitor to the ignition charge capacitors. Customers needing pyrotechnic termination after power failure are advised to monitor the input voltage rails or flight conditions and Arm the FTS-AIR prematurely so that sufficient charge is available if needed.

Indications



Each lane of the Comet FTS-AIR independently controls a Terminate and a Status LED.

Status

Solidly Illuminated	FTS-AIR unit is in contact with at least one FTS-GND unit.
Blinking	FTS-AIR is either not in contact with an FTS-GND unit, or the unit has failed it's built in test (in which case Terminate will also be blinking.)

Terminate

Solidly Illuminated	FTS-AIR terminate output is live.
Blinking	FTS-AIR is performing or has failed its self test, or is preparing to terminate.
Off	FTS-AIR is in the Passive state and has passed the self test.

System Setup

Connecting to the Units via RS-232 Serial Port

A Lane multiplexed RS232 port is present on the J1 connector. Selecting the Lane to talk to is accomplished by toggling pin 8 (MCU Select) on J1 where a short to GND indicates Lane 0 and a 5V signal indicates Lane 1. It is most convenient to the operator if MCU Select pin is connected to the RS232 cables DCD pin for programmatic operation.

The default application listens on this port at 500kbps with 8 data bits, no parity bit, and 1 stop bit. (This is also the configuration of the JTAG UART.)

Once connected, pressing enter should bring up a command shell. The following basic commands are available:

`help`	Print the list of known commands and a brief description of what each command does.
`reset`	Performs a soft reset of the Lane processor. Will not reset the other Lane.
`adc`	Print the status of all analog inputs to the Lane.
`gpio`	Print the status, or modify the value of, all the GPIO pins connected to the Lane.
`mem`	Read or modify arbitrary memory locations on the processor.

Working with Non-Volatile Storage

The last sector of each Lane processor flash is dedicated to storing the application configuration. End users are welcome to add additional configuration keys, but this manual only details those commands present in the standard configuration.

In general, each console command, if given without arguments, will print the current configuration. If given with arguments, changes are saved to RAM and not written to the flash until the `write_cfg` command is issued. Changes are generally not applied to the running application until the unit is power cycled or `reset`.

`write_cfg`	Commit the configuration stored in RAM into the internal non-volatile Flash.
`read_cfg`	Read the configuration stored in Flash into RAM.
`erase_cfg`	Erase the configuration stored in non-volatile Flash.

Commissioning Units

Each complete Comet Flight Termination System, consisting of 1 AIR unit and up to 2 GND units, is uniquely specified using a common aircraft ID and Lane specific cryptographic signing keys. Each unit in the system is identified with a unit ID, where the AIR unit is always 0.

Note that the limitation of 2 GND units per FTS is a soft limitation, but altering this limit will require changes to either the radio protocol, or the message transmission frequency. Therefore, the GND unit IDs, in a nominal configuration, will be either 1 or 2.

Additionally note that the aircraft ID and the Lane A signing key feed into the radio network ID which additionally specifies the radio channel hopping pattern. Unique aircraft IDs are required to differentiate telemetry sources in shared telemetry networks, and unique lane keys are required to prevent message forgery from third party adversaries and to prevent message confusion between lanes.

Unique Lane keys can be generated on device using the built in hardware random number generator using the **`gen_key`** command.

Once a key has been generated, the units may be paired using the **`commission`** command which takes 3 arguments, in order: the aircraft id (from 0 to 7), the unit ID (0 if AIR, 1 or 2 if GND), and the cryptographic signing key. Running the **`commission`** command without arguments will print the current pairing settings.

The commission command must be run on both Lanes as configuration is not shared between Lanes. Note that the Lane key should be different between the two Lanes, but all Lanes in the pairing should share the same key.

Once the `commission` command has been run, save the configuration to non volatile storage using the `write_cfg` command.

Ethernet Network Settings

The Ethernet stack on the Comet is capable of 10/100 Mbps full duplex communication with a MAC address generated from the CPUs unique ID. As this is effectively a random, albeit static, MAC address that is not allocated by the IEEE, the locally administered address bit is set. At this time it is not possible to set the MAC address of the interface using the console.

It is however possible to set the IP address to either a static IPv4 address, or to instruct the unit to request an address via DHCPv4. Do this with the `set_ip_config` command.

`set_ip_config`	**`off`**	Disable networking on this Lane
	`dhcp`	Obtain a dynamic IPv4 address via request to the DHCP server
	`static`	Using three arguments set the IP address, network mask, and gateway. For example: **`set_ip_config static 192.168.0.2 255.255.255.0 0.0.0.0`**

Controller Area Network (CAN) Settings

The Comet FTS has a CAN-FD link per Lane. Configure the baud rates and FD mode using the `set_can_config` command.

`set_can_config`

`off`	Disable CAN on this Lane
Single argument	Set the nominal CAN bitrate and disable CAN-FD
Two arguments	Set the nominal and the FD bitrates

Diagnosing the Radio Link

There are several built in console commands available for diagnosing and debugging problems with the radio link. These are

`radio_shell` Lane A is capable of stopping the Comet application and allowing an operator, through the FTS shell, to interact directly with the radio's data port. The radio shell is specific to the serial port the operator is interacting with:
RS232, the command is `radio_shell RS232`
JTAG, the command is `radio_shell JTAG`

In either case, once the shell has been established, whatever the operator types into the console will be forwarded to the radio. To exit this mode, the operator should type `exit` or power cycle the unit.

To interact with the radio's build in text configuration menu, wait 1 second without any traffic and then type +++. For more information on the capabilities of the Microhard radio's options, see the Microhard P Series Operating Manual.

`radio_diag` This command will print Comet radio protocol information such as number of received and corrupted frames; and on Lane A will print information gathered from the radio over its Diagnostic Link.

`set_debug rf_sync true`
The radio link between units is usually protected by a software version specific synchronization header. If units have software versions build from different git repository commits, then they will normally not synchronize. This behaviour can be changed by setting the rf_sync debug flag to `true` which will set the radio synchronization value to `0x1234`.

Software Updates

The software on the Comet FTS can be updated via the RS232 port using the STM32 UART Bootloader protocol detailed in ST application note AN3155. For users convenience, allocortech bundles a tool, installable via the `allocortech/mk/scripts/stm32flash_install.sh` script from the repository root, that speaks this protocol and is capable of manipulating the RTS pin to toggle between lanes.

To flash either Lane's processor it is first necessary to place the unit into bootloader mode. This is accomplished by shorting to ground pin 3 (bootloader recovery) on J1 and power cycling the unit.

The operator should then select which Lane they want to flash using pin 8 (MCU Select) on J1 where a short to GND indicates Lane 0 and a 5V signal indicates Lane 1. It is most convenient to the operator if MCU Select pin is connected to the RS232 cables DCD pin for programmatic operation.