Linear Transponder Module (LTM) Acceptance Test and Familiarization Procedure

Document Change Log

Revision	Date	Author(s)	Change Log
v1.0	January 5, 2020	Eric Skoog (K1TVV)	Initial LTM-1 acceptance & training draft.
v1.1	February 29, 2020	Eric Skoog (K1TVV) Burns Fisher (WB1FJ) Chris Thompson (AC2CZ)	Corrections/updates to initial draft version from on-the-bench checkout of unit LTM-1A and FoxTelem and flight demonstration software.
v1.2	March 22, 2021	Eric Skoog (K1TVV) Burns Fisher (WB1FJ)	Updates to reflect preliminary changes in LTM design.
v1.3	Nov 20, 2021	Eric Skoog (K1TVV) Burns Fisher (WB1FJ)	Corrections/updates to reflect the more ‘generic’ LTM design
v1.4	Feb 8, 2023	Eric Skoog (K1TVV) Burns Fisher (WB1FJ)	Updates to support Fox+ development and LTM familiarization

PURPOSE: This document has been written to provide AMSAT's University Partners with a step-by-step Acceptance Test Procedure (ATP) to verify the operational performance of AMSAT's Linear Transponder Module (LTM), a 3 Printed Circuit Board (PCB) integrated module consisting of a Legacy Internal Housekeeping Unit (LIHU) board, an Improved Command Receiver (ICR) board, and an RX/TX Transponder board. This ATP is intended to be executed by AMSAT engineers before shipping LTM Engineering Model (EM) or Flight Model (FM) units to University Partner engineering development teams. Additionally, the execution of this ATP serves as a familiarization exercise for University engineering teams to become acquainted with the basic operational features of not only the LTM, but the supporting FoxTelem ground station receive software, a USB umbilical connected serial terminal control, and status monitoring software.

GO – NO GO ACTIONS: Upon successful execution of this procedure against a received LTM, the University Partner will notify AMSAT and integrate the operational module into their test bench set-up or engineering/flight model spacecraft structure for further testing and development. Should the received module fail this acceptance test procedure, AMSAT and the receiving University Partner will jointly investigate the test data and determine the appropriate next step actions.

DOCUMENT REVISIONS: Changes, corrections, and suggested enhancements to this procedure may be made by either a University Partner or AMSAT by sharing the proposed changes in a draft version that will be formalized in an updated document version by AMSAT.

Table 1: Linear Transponder Module (LTM-1A) Hardware/Software Under Test

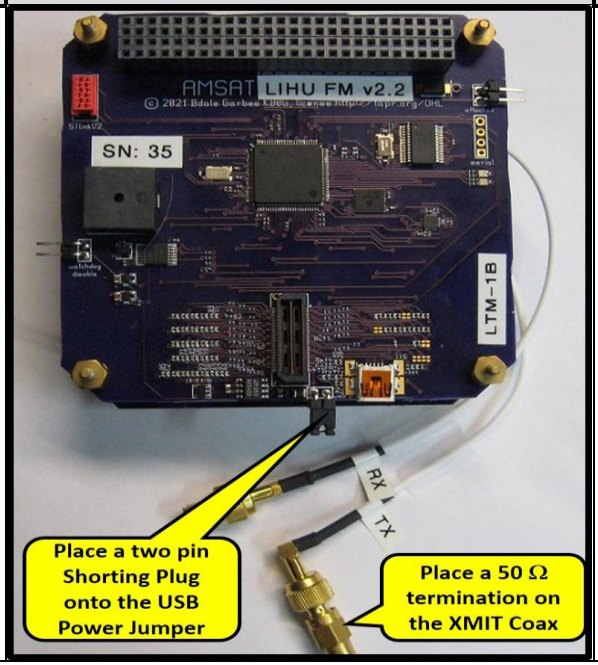
LINEAR TRANSPONDER MODULE (LTM-1) PCBs	☑ ENGINEERING UNIT (EM) ☐ FLIGHT UNIT (FM)
Legacy Internal Housekeeping Unit (LIHU) PCB	FM v2.2 SN: 36
Receiver/Transmitter (RX/TX) PCB	FM v2.1 SN: 35
Improved Command Receiver (ICR) PCB	FM v2.0 SN: 34
Flight Software Version	V9.5c or later

EQUIPMENT REQUIRED:

The following (minimum) equipment is required to execute the steps in this procedure:

- Device Under Test (DUT): LTM-1A
- FoxTelem Software (1.12z3 or later)
- Flight Software (V9.5c or later)
- Personal Computer with USB cable
- 50 Ω SMA termination
- Software Defined Radio (SDR) USB Dongle (Fun Cube Dongle Pro+ or RTL-SDR)

PROCEDURE (for STAND-ALONE functional verification and familiarization – NOT IN a satellite integrated stack)

STEP #	DESCRIPTION	EXPECTED RESULT(s)	NOTES	PASS ✓ FAIL ✖
1.	**SET UP** (see picture): Ensure an **UNPOWERED** LTM is in the following condition: -- A Universal Serial Bus (USB Power) two-pin jumper inserted onto the Legacy Internal Housekeeping Unit (LIHU) PCB. -- A 50 Ω SMA termination on the LTM's transmit (TX) coax. Alternatively, a 10 dB "through-attenuator" (not provided with the LTM) could be attached on the TX cable if it is desired to measure RF output via external RF power monitoring equipment.		This ATP version assumes that LTM checkout and familiarization will be accomplished in a stand-alone configuration. When a USB cable is plugged into the mini-B USB connector on the LTM's LIHU board, and the USB power pins are jumpered, +5V power is supplied via a Personal Computer (PC) terminal USB connection. This connection will not only power the LTM, but also asserts the LIHU's MicroController Unit's (MCU) umbilical 'attached' signal to alert the LTM's MCU that umbilical control is intended. The USB umbilical also provides active USB data lines for PC console terminal control commands and status information.	

STEP #	DESCRIPTION	EXPECTED RESULT(s)	NOTES	PASS ✓ FAIL ✖
2.	**SET UP:** Personal Computer with a USB umbilical cable and FoxTelem software: -- Provide a PC loaded with FoxTelem software, and a serial terminal program. -- Prepare terminal software for a serial connection (9600 baud, no parity, 8 bits, 1 stop bit, and no flow control). -- Plug in an SDR Dongle, ideally a FUN CUBE DONGLE PRO PLUS (FCDPP), or an RTL-SDR, connected to a piece of short, unterminated coax. -- Open the FoxTelem telemetry (TLM) downlink monitoring software program.(see FoxTelem doc. manual for installation instructions). On FoxTelem's main INPUT tab display, set the Center Frequency to 435825.0 kHz to avoid SDR "DC (feed-through) spike" problems. For the FCDPP, the FoxTelem software display "LNA" and "Mixer Gain" boxes can be checked if needed to ensure a 'stronger' signal display in step 11 if desired. For the RTL-SDR, adjust the Gain Master for a strong enough signal. The following entries should be filled in automatically by FoxTelem for the FCDPP: "IF Filter" and "RF Filter." Lastly, the "Bias T" box should not be checked.		**NOTE: This LTM-1A uses a TCXO originally purchased to support AMSAT's HS-1 and LTM CubeSat development. Consequently, its UHF downlink frequencies are the same as used in that satellite.** Under the "Spacecraft/LTM" tab of the FoxTelem software, the "Downlink Freq (kHz)" should be set for 435800 kHz and the "upper and lower frequencies" should be ± 10 kHz from that value, respectively. Also, the "Track this Spacecraft" box should be checked; then Save to exit. In the upper middle part of the "INPUT" tab screen display, Above and to the right of the "Start/Stop" button, are 3 pull-down menus. With an FCDPP or RTL-SDR dongle plugged in, confirm that FoxTelem has chosen the correct device and that the IQ radio button is chosen. FoxTelem will also fill in the entries listed in step 2 automatically as well as the sample frequency. Under the top left "File / Settings" tab, the "PSK: Use Costas, Use Left Stereo Channel, and Find Signal" boxes should be checked. Also, for later on-orbit use, one should get used to entering the latitude and longitude of the tester's location (or easier, the equivalent amateur radio Maidenhead six-character grid square identifier) as well as the altitude in meters; then enter 'Save' to exit. On the "INPUT" tab display, click on the "Start" button and ensure FoxTelem is running.	
3.	TEST: Plug in a standard USB-A to USB Mini-B umbilical cable from a PC to the LTM's mini-B connector. The LTM should now be powered.	Using a LINUX terminal emulator, the serial port will 'normally' be enumerated as /dev/ttyACMn 9600-8-N-1 in the terminal program, but it may not, depending on the particular Linux program. Also, WINDOWS® terminal programs will identify active USB ports as COMn, where in both cases "n" is a number that depends on what other devices are connected.	When the USB umbilical plug is connected to the LTM, a short "blip" may be heard from the LTM's piezoelectric sounder.	

STEP #	DESCRIPTION	EXPECTED RESULT(s)	NOTES	PASS ✓ FAIL ✖
4.	When the terminal program has established a serial connection to port dev/ttyACM0, type 'v' on the PC's terminal command line.	The terminal display should then present the following boot loader information: USB AMSAT/altos-loader manufacturer amsat.org product LTM/AltosFlash flash-range 08002000 08080000 Software-version 1.0.1		
5.	Type 'a' on the PC's terminal command line.	After approximately 20 seconds, the LTM's green Light Emitting Diode (LED) illuminates on the LIHU PCB (along with a short audible 'buzz' from the piezoelectric sounder). After approximately 20 more seconds the LIHU's green LED extinguishes.	The serial terminal connection disappears immediately after you type 'a' (for some programs like puTTy the window closes). There will be a few seconds of audible beep from the sounder, some silence, and then a brief distinctive sound from the sounder indicating that the LTM flight software is ready. After about 20 seconds the green LED extinguishes.	
6.	After the green LED on the LIHU board extinguishes, re-establish a serial connection and type "return" several times.	The message, "I don't understand. Enter Help for a command list" may appear. After each return a prompt such as LTM> will appear.	The "I don't understand" message may NOT appear, depending on what OS/terminal program is being used. In addition, the terminal may appear on a different COMn (Windows) or ttyACMn (Linux) port.	
7.	After the cursor symbol reappears, type 'get version'and press Enter.	The message, "AMSAT-NA LTM IHU Console AMSAT LIHU Serial Number 36 Software_Version Vxx.x Built Mth Day Year Hrs:Mins:Secs with gcc version 6.3" plus some other information, including "No Encryption Key. Using default"	The version, date, and time of the flight software loaded is displayed and confirms the flight software is executing.	
8.	Type "get mode" and press Enter.	The response "Satellite is in xxxxx mode" appears.	Most likely, the satellite will be in SAFE MODE or HEALTH MODE depending on what mode it was in when last shut down. Regardless of the previously set mode, with the LTM's 'attached' line held high from USB power, the flight software knows a controlling umbilical is connected and thus prevents any LTM RF transmissions from occurring.	
9.	Type "disable transponder" and press Enter. Then type "set autosafe usb" and press Enter.		This step is for the possibility that when last shut down, the module was in an 'Enabled Transponder' state which would have been saved in non-volatile memory. It also ensures that the autosafe voltage is set for the USB (+5) voltage rather than for the normal spacecraft voltage.	

STEP #	DESCRIPTION	EXPECTED RESULT(s)	NOTES	PASS ✓ FAIL ✖
10.	Type "ignore umbilical" and press Enter.		This command will allow initiation of RF downlink transmissions if directed by subsequent mode commands. Without this command, no RF will be transmitted while the USB connector is plugged in.	
11.	If step 8 showed the LTM was in Safe Mode, then type "health mode" and press Enter. Once transmission spectrum is observed on the "INPUT" tab spectrum display, select the LTM tab display. Check the Real Time ("RT") bullet in the lower left hand corner screen area, and verify updating Real Time (RT) data (a line for each realtime payload, about twice per minute) is being displayed.	Transmissions should begin immediately and should be seen on FoxTelem's "Input" tab spectrum display. In the lower right hand corner of both FoxTelem's main display tabs, the "Frames" and Payloads" numbers should be incrementing confirming proper TLM decoding.	The enhanced BPSK decoding software (including Costas) should automatically tune the FoxTelem cursor to better position it over the suppressed carrier portion of the received BPSK's signal spectrum on the display to ensure good decoding. Note the open "Eye Diagram" and the calculated SNR as well as the (approximately) linear line "Phasor" pattern for the TLM downlink's antipodal modulation. If the decoding cursor does not move to the signal or if the eye diagram does not open, click on the signal peak with your mouse.	
12.	On FoxTelem's "INPUT" tab display observe the continuous Health Mode transmission spectrum. Type "safe mode" and press Enter.	Transmissions immediately cease and for this ATP software version, every 2 minutes thereafter SAFE MODE transmissions are evident for a period of approximately 14 seconds.	As the name implies, SAFE MODE is a power saving mode that (in the final flight software) sends TLM every 120 seconds with 2 frames being transmitted during the 14 second interval that SAFE MODE transmissions are active.	
13.	Type "Health Mode" and press Enter. In the lower left hand corner on the FoxTelem "LTM" tab telemetry readout display, select the "Current" button. This should be the ONLY button selected. Then, in the "AMSAT Transmitter" box, note the "Fwd Power (mW)" and "Ref Power (mW)" values.	"Satellite LTM (EM) Mode: HEALTH" should be displayed near the top of the screen after a minute or two. The "Fwd Power (mW)" reading should be approximately 100 to 200 mW and the "Ref Power (mW)" should read less than 1.0 mW if the TX cable has been properly terminated with a 50 ohm load.		
14.	Go back to the "INPUT" frequency spectrum display; type "heed umbilical".	Health Mode transmissions should cease.	The "heed umbilical" command cancels the "ignore umbilical" command (step 10) that was in effect. The "heed umbilical" command tells the LIHU that LTM transmissions are NOT allowed from this point forward if the USB connector is plugged in.	
15.	***OPTIONAL***: Steps 16 to 19 are optional if it is desired to verify the LTM's Radio Frequency (RF) output power via Spectrum Analyzer (SA) measurements.	One could also measure the RF output power with an RF Power Meter. However, SA measurements afford the opportunity to also observe the signal spectrum, any spurious emissions, and frequencies of operation.	From the previous "heed umbilical" command, all transmissions have been terminated and it is safe to remove the XMIT coax's termination.	

STEP #	DESCRIPTION	EXPECTED RESULT(s)	NOTES	PASS ✓ FAIL ✖
16.	Remove the 50 Ω termination from the LTM's XMIT coax, but leave the "through-attenuator" (step 1) connected.		The through attenuator will protect the input of the spectrum analyzer, as the LTM's RF output power could approach 30 dBm. Hence a 10 dB attenuator is recommended.	
17.	Using an SMA coax cable, connect the LTM's XMIT coax to the signal measuring input of a Spectrum Analyzer.		The Spectrum Analyzer's maximum RF input power level rating should be > 30 dBm, even with the step 1 10 dB through-attenuator.	
18.	Set up the SA to display a narrow band signal on a center frequency of 435.800 MHz; with suggested SA settings of: frequency span = 100 kHz; RBW = 10 kHz; and VBW = 1 kHz. Type "ignore umbilical" and press Enter. Type "health mode" and press Enter. Note the SA's measurement of the Peak Power reading at the center carrier frequency.	Health Mode telemetry transmissions should be continuous. Peak measured power on the Spectrum Analyzer should be approximately +18 to +22 dBm.	The SA peak power measurements should be "fairly consistent" but will vary with the LTM's TLM BPSK modulated signal.	
19.	Type "heed umbilical" and press Enter. Remove the SA coax's connection and reconnect a 50 Ω SMA termination to the LTM's XMIT coax along with the 10 dB "through-attenuator."	Health Mode transmissions should cease.	This step prevents any transmission on an open XMIT coax line while the SA RF connection is removed.	
20.	Type "ignore umbilical," press Enter, and then type "Health Mode" and press Enter.	Continuous TLM transmissions should be observed on the FoxTelem "INPUT" tab spectrum display.		
21.	Practice sending the three LTM mode commands (SAFE MODE; HEALTH MODE; and SCIENCE MODE) using the PC's terminal program. Other "Used in Testing" commands can be sent depending on what actions are desired to be verified for familiarization (see Appendix I). End this step by entering HEALTH MODE and press Enter.	On the first line of FoxTelem's "LTM" tab display, "Satellite LTM (EM) Mode: xxxx" should show the current Mode that is active, but ONLY AFTER a period of time when change of mode TLM information has been received and IF the "Current" button (see step 13 expected result) has been selected. For other (non-Mode) commands, the data displayed must be analyzed iaw the commands sent and the conditions simulated.	The LTM's reaction to other commands and the TLM details displayed will vary depending on what sensor input stimulus and sensor information is being simulated.	

STEP #	DESCRIPTION	EXPECTED RESULT(s)	NOTES	PASS ✓ FAIL ✖
22.	The next steps (23 to 38) are used by AMSAT engineers to verify the performance of the LTM's Amateur Radio Linear Transponder. **<<These steps should NOT be executed by University Partners UNLESS the testing individual holds a valid Amateur Radio license. These steps are neither necessary nor LEGAL to be executed by University Partners if the satellite is licensed by the University under the FCC's CFR 47 Part 5 EXPERIMENTAL RADIO SERVICE. When transmitting from a "Handi-Talky" (HT), be sure to regularly transmit your amateur radio call sign ID in accordance with Part 97 regulations.>>**		AMSAT engineers use these steps to gain confidence that the Amateur Radio purposed Linear Transponder is functioning as designed and can therefore be utilized once the University Partner's spacecraft has completed its primary mission and has been turned over to AMSAT as the responsible control operator to support Amateur Radio operations.	
23.	Using an amateur radio portable HT transceiver (Xcvr), set its transmit frequency to 145.925 MHz and its output power to the LOWEST level NOT greater than 100 mW. Key the HT's transmitter for 3 seconds and observe the Health Mode received signal on the FoxTelem spectrum display.	No change in the FoxTelem spectrum should be observed.	This is because the step 9 command "disable transponder" was saved in NVM and therefore any transmissions should NOT include transponding. **CAUTION: To avoid RF overload and possible damage to the LTM's power amplifier signal path, all HT transmissions (even at levels ≤ 100mW) should be at distances of at least 10 feet away.**	
24.	Type "enable transponder" and press Enter. Key the HT's transmitter for 3 seconds and observe the Health Mode received signal on the FoxTelem spectrum display. **<< Despite the fact that the LTM is transmitting low power into a 50 Ω termination, proper station identification of test transmissions with the control operator's amateur radio call sign iaw CFR § 97.119 should be followed.>>**	Health mode TLM signal transmissions should continue to be present on the FoxTelem spectrum display WITH the addition of the HT transponded signal at 435.825 MHz.	The LTM's transponder is inverting therefore a passband input signal low in the satellite's VHF uplink passband will be transponded to the HIGH end of the satellite's UHF downlink passband. Additionally, the observed level of the single transponded signal will generally be greater than that of the TLM signal at 435.800 MHz depending on the level of the received transponder passband signal.	
25.	Type "disable transponder" and press Enter.			
26.	Key the HT's transmitter for 3 seconds and observe the Health Mode received signal on the FoxTelem spectrum display.	No transponded signals should be observed on the FoxTelem spectrum display; only Health Mode TLM transmissions.		

STEP #	DESCRIPTION	EXPECTED RESULT(s)	NOTES	PASS ✓ FAIL ✖
27.	Set up a Very High Frequency (VHF) 2 meter command radio (or signal generator) on a frequency of xxx.xxx MHz modulated by an AFSK-FM (~5 kHz deviated) audio signal connection to a PC running AMSAT Over-The-Air (OTA) command software (AMCOM). An antenna should be connected to this command radio/signal generator and the RF output power should be NO greater than 100 mW for OTA command transmissions.		**The PC can be connected to the 2mtr transceiver and the transceiver setup as though one were sending "packet" or "APRS" data. The specific VHF Command Uplink transmit frequency (xxx.xxx MHz) is sensitive information and therefore not identified in this document. AMSAT will provide this frequency information along with uplink OTA command (AMCOM) software and a transmit authorization file.**	
28.	Using AMSAT OTA command software, send the **HARDWARE** command "SAFE MODE". Wait 3 minutes and observe the LTM tab TLM data display on FoxTelem.	Health Mode transmissions cease and Safe Mode transmissions begin on a 2 minute duty cycle after the LTM's Green LED has extinguished. FoxTelem's LTM tab TLM data display shows Safe Mode.	AMSAT OTA commands include both **HARDWARE** (ICR decoded) and SOFTWARE (MCU decoded) commands. To verify proper reception of commands, one can "enable comprint' to get immediate feedback on command reception. Additionally, one can enter "get mode" to see if the intended mode "took!"	
29.	Using AMSAT OTA command software, send the software command "(sw) Transponder State" and in the "Software Parameters," double click on "Val1 0" and type in "1" indicating YES.		In the AMSAT command OTA software, "Val1 1" is YES (ENABLE) and "Val1 0" is NO (DISABLE). So for this step, Transponder operation will be enabled upon the next Health mode activation, but NOT with Safe Mode.	
30.	Using AMSAT OTA command software, send the software command "(sw) Health Mode". Wait 30 seconds and observe the LTM tab TLM data display on FoxTelem.	Health mode transmissions begin and FoxTelem's LTM tab TLM data display shows Health Mode.	FoxTelem's "Radio" data box display should also indicate the "Transponder Status" as "Enabled"	
31.	Using an HT Xcvr, set its transmit frequency to 145.915 MHz and its output power to the LOWEST level NOT greater than 100 mW. Key the HT's transmitter for 3 seconds and observe the Health Mode received signal on the FoxTelem INPUT tab spectrum display.	Health mode TLM signal transmissions should continue to be present on the FoxTelem INPUT tab spectrum display WITH the addition of the HT transponded signal at 435.805 MHz.	CAUTION: To avoid RF overload and possible damage to the LTM's PA signal path, ALL HT transmissions (even at levels ≤ 100mW) should be at distances of at least 10 feet away.	
32.	Using AMSAT OTA command software, under the Val 1 section of the transponder enable command, click on 1 and replace it with "0" indicating DISABLE. Then send the command.	Health Mode TLM signal transmissions continue.		
33.	Key the HT's transmitter for 3 seconds and observe the Health Mode received signal on the FoxTelem INPUT tab spectrum display.	While the Health Mode TLM signal transmissions should continue, NO transponded HT signal transmissions should be present in the FoxTelem INPUT tab spectrum display.	Looking at the LTM tab display, the "Radio" data box should also indicate the "Transponder Status" as "Disabled" after enough time has passed for the tab to be updated.	

STEP #	DESCRIPTION	EXPECTED RESULT(s)	NOTES	PASS ✓ FAIL ✖
34.	Using AMSAT OTA command software, send the software command "(sw) Safe Mode". Wait 3 minutes and observe the LTM tab TLM data display on FoxTelem.	Health mode transmissions cease and Safe mode transmissions start on a 20 sec duty cycle. FoxTelem's LTM tab TLM data display shows Safe Mode after telemetry frames are received.		
35.	Key the HT's transmitter for 3 seconds and observe the Safe Mode received signal on the FoxTelem spectrum display.	NO transponded HT signal should be present on the FoxTelem display, only the Safe Mode TLM signal transmissions should be present every 20 seconds.		
36.	Using AMSAT OTA command software, send the **HARDWARE** command "HEALTH MODE". Wait 30 seconds and observe the LTM tab TLM data display on FoxTelem.	Health mode transmissions begin and FoxTelem's LTM tab TLM data display shows Health Mode.	AMSAT OTA command software's list of commands includes both **HARDWARE** (ICR decoded) and **SOFTWARE** (MCU decoded) commands. For commands that can be sent via either method, the only difference is that HW Science Mode has a default argument, while that argument can be varied in the software command version.	
37.	Key the HT's transmitter for 3 seconds and observe the Health Mode received signal on the FoxTelem INPUT tab spectrum display.	NO transponded HT signal transmissions should be present in the FoxTelem INPUT tab spectrum display, only Health Mode TLM signal transmissions should be present.		
38.	Using AMSAT OTA command software, send the software command "(sw) Safe Mode". Wait 3 minutes and observe the LTM tab TLM data display on FoxTelem.	Health Mode transmissions cease and Safe Mode transmissions start on a 20 sec duty cycle. FoxTelem's LTM tab TLM data display shows Safe Mode.		
39.	Using the PC terminal umbilical commands, type "heed umbilical" and press Enter.	Safe Mode transmissions should cease.	See step 14 Notes for an explanation of this step.	
40.	Unplug the USB cable from the LTM.	The LTM module is powered down.		
41.	**END of ACCEPTANCE TEST……**			

Verification:

I verify that the AMSAT Linear Transponder Module LTM:

LTM-1A	<Date>	<Name(s)>	

has been tested as shown above and the result is:

PASS/ACCEPTED _____

FAIL/RETURNED _____

Notes to any exceptions that exist if result is PASS or FAILED.

STEP NUMBER	NOTES

Signed

_____

<Name>

<Title>

<Date>

APPENDIX I

Linear Transponder Module (LTM) Software Acceptance Testing and Familiarization Umbilical Commands Listing

TEST and FAMILIARIZATION COMMANDS		
COMMAND	**PURPOSE**	**NOTES**
test alert	Test the audio tone(s) from the Piezoelectric Sounder by serially sounding 8 different tone sequences with a display of "Alert x,y"	x = ON time; y = OFF time (in hundreds of seconds)
reset i2c	Resets both I2C busses	
poll i2c	Use to see if I2C devices are present and responding	A return message: "I2C Status after poll=1" means at least one I2C device has responded. Use “get i2c” command to display the exact results.
get i2c	Displays which I2C devices are responding.	"I2C device state: xxxx" displayed for responding devices.
get deploy	Displays the status of the spacecraft's deployables	
enable canprint	Initiates CAN messages display	Adding numeral '0' for a list of CAN message types results in the following list: Specify 1=Health, 2=Telemetry, 3=Commands, 4=WOD in, 5=WOD out, 6=Error Count, 7=All/most packets
disable canprint	Add 'n' to stop CAN message ID type 'n' from printing.	
test leds	Blinks/Flashes LIHU card's four LEDs	Sequence = **RED** - **GREEN**……..**RED** - **GREEN;** testing all four LEDs on the LIHU board.
deploy ant1	Sends deploy signal to spacecraft antenna #1	"Type any key within 5 seconds to abort deployment."
deploy ant2	Sends deploy signal to spacecraft antenna #2	"Type any key within 5 seconds to abort deployment."
deploy all	Sends deploy signals to all deployable antennas	1 = Deployed; 0 = Not Deployed
get gpios	Displays all GPIO current values.	0 = LOW output and 1 = HIGH output for all 36 GPIOs, but most GPIOs are not used in the stand alone Linear Transponder Module (LTM).
enable comprint	Prints uplink command information	
disable comprint	Disables printing uplink command information	
start loader	Resets processor and starts code loader	
get rf power	Displays RX/TX card's PA RF High or Low RF output power setting	LOW power (27 dBm) or HIGH power (30 dBm) maximum
set rf power 'n'	Commands RX/TX card's PA RF output power level	'n' = 0 for low power; 1 for high power level
get status	Displays current status information for LTM's key functional areas.	This is used mostly for development and will likely change somewhat from release to release.
get min telem	Displays NVM stored minimum values for telemetry data	
get max telem	Displays NVM stored maximum values for telemetry data	
get realtime telem	Displays latest health telemetry data.	The output format may change somewhat from release to release for additional data or ease of reading
get science telem	Displays latest telemetry from SCIENCE mode	
get diag telem	Displays the latest diagnostic telemetry	-
get wod health	Displays the next whole orbit data (WOD) health record	
get wod sci	Displays the next whole orbit data (WOD) science record	Code required to display science WOD record

get wod range	Displays the index number that will be overwritten next and the s/c time of the next, oldest, and newest WOD record.	WOD is stored in a circular buffer with indices from 1 to <max number>.
get wod contents	Displays the spacecraft time for each WOD record	
get mode	Displays the LTM's current operational mode	SAFE, HEALTH, or SCIENCE
get time	Displays several system time measurements	
get commands	Displays the number of hardware and software commands received since the last reset along with the indices of the last 3 software commands received	
get version	Displays the currently loaded LTM software version, MCU SN, Free heap size and Watchdog (WD) enabled/disabled, and previous reboot reason	
clear minmax	Clears all data in the NVM minimum/maximum registers	Also done by preflight init
clear epoch	Zeros the epoch (reset count) for spacecraft time	Also done by preflight init
clear errors	Clears the MRAM error count	Also done by preflight init
clear inorbit flag	Causes the LIHU to NOT wait the post LV-release time after boot and NOT attempt to release the antennas regardless of the state(s) of the deployment sensor(s).	Only needed for testing after preflight init or set inorbit flag.
clear wod store	Clears ALL Whole Orbit Data (WOD) telemetery data stored in NVM	Also done by preflight init
preflight init	Sets software to execute "first orbit" actions	It sets the satellite to start in Safe Mode; enables auto-safe for low Vsys; WOD frequency and size set to default values and WOD indices initialized; TLM Min/Max in MRAM initialized; Reset Counter set to 0; DSP overlfow count zeroed; Nonfatal error count zeroed; In-Orbit flag set to 'no'; CRC calculated for initialization code and full code; WOD storage and all variables initialized and ready for flight.
enable transponder	Enables the LTM's 30 kHz v/U transponder transmissions	Transponder only operates in health mode and with no umbilical or umbilical ignored
disable transponder	Disables the LTM's 30 kHz v/U transponder transmissions	
health mode	Commands the LTM into HEALTH MODE	
science mode 'n'	Commands the LTM into SCIENCE MODE for 'n' minutes.	If ‘n’ is not specified, the science mode timeout defaults to 5 minutes for ground testing. (The time can also be specified in an uplink command)
safe mode	Commands the LTM into SAFE MODE	
reset ihu	Resets the in-control Internal Housekeeping Unit (IHU) On Board Computer (OBC) and does not stop at the flash loader	
set cor mode	Commands the transponder into degraded/autonomous mode operation	Emulates non-functional OBC(s)
clear cor mode	Commands the transponder out of degraded/autonomous mode operation	
ignore umbilical	Allows an 'on bench' LTM to transmit	
heed umbilical	Prevents an "on bench" LTM from transmitting	
set inorbit flag	Forces OBCs to function as if in-orbit	Skips first orbit actions, including the 30 minute delay to starting flight software actions
test eclipse 'n'	To acts as though satellite has entered or left eclipse	0 = Sun and 1 = Eclipse. No action by default. Executes eclipse enter or leave action if one is selected
set eclipse action	Sets the actions to be taken upon entering an eclipse	Requires eclipse info from host
help	Lists only the commands for LTM "Test and Familiarization" in support of bench testing and integration efforts.	If a text argument suffix ('devo', 'setup', or 'all') is appended, the displayed list shows only those commands affiliated with that specific grouping argument. With NO suffix appended, the "help" command lists ONLY the commands relevant to the "Test and Familiarization" grouping. **Even though in that list the other "help<suffix>" commands are also included, it is *NOT ADVISED* that any of those other group commands be attempted as such actions could result in anomalous operatinal conditions!**