User Guide

Lyra P/S & Lyra24 P/S
AT Interface Application

Version 3.2

REVISION HISTORY

Version	Date	Notes	Contributor(s)	Approver
1.0	22 July 2022	Initial Release	Mahendra Tailor Adam Ruehl Colin Pigott Julian Alden-Salter Greg Leach	Jonathan Kaye
1.1	07 February 2023	Corrected bitfield for ATS 100 parameter. Reworded description for ATS 219 parameter. In Pin Features section, changed wording from 'processor' to 'module' for clarity. Added SIO limitation for ATS 109 parameter. In section 5.1.3.28, added note the 'source' element is unused in the Lyra AT Interface implementation. In section 4.11.5, added note describing disconnection behaviour upon failure to complete an AT+PRSP request. Removed ATS parameters 118, 202 and 203 due to not being applicable to the Lyra AT Interface firmware implementation.	Rikki Horrigan Florian Baumgartl Julian Alden-Salter Greg Leach	Jonathan Kaye
1.2	13 March 2023	Added details of Encrypted Connection and Connection Indication SIOs. Added details of User Functions feature. Revised sleep current figure for Low Power UART mode of operation. Corrected default and upper limit of Max Connections as Central writable parameter. Removed unused writable parameters VSP Transmit Buffer Size (204) and VSP Receive Buffer Size (205).	Florian Baumgartl Julian Alden-Salter Leo Genuardi Greg Leach	Jonathan Kaye
2.0	16 March 2023	Updated major release number to coincide with GA2 firmware release.	Florian Baumgartl Julian Alden-Salter Leo Genuardi Greg Leach	Jonathan Kaye
3.0	20 July 2023	Added details of Lyra 24 P10, P20, P20RF and S10 modules. Removed message size constraint from section 4. Removed unused parameter BLE Transmission Buffers from section 4.2.5. Moved SIO, SIO function and User function details to separate Peripheral Interface document.	Florian Baumgartl Julian Alden-Salter Leo Genuardi Greg Leach	Jonathan Kaye

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3.1	23 August 2023	Corrected the functionality of bit 4 of the start-up flags in 4.2.5 ATS. Parameter enables/disables extended advertisements rather than data length extension.	Leo Genuardi	Jonathan Kaye
3.2	12 September 2023	Updated link to peripheral interface guide	Leo Genuardi	Johnathan Kaye

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1 Overview

This document is a user guide for the AT Interface application written for the Lyra P [A], Lyra S [B], Lyra 24P [G] and Lyra 24S [H] Bluetooth Low Energy modules. It exposes an industry standard AT command/response protocol. This protocol instructs the module to advertise, scan, connect, and pair. In addition, the application exposes AT commands that enable the creation of a GATT server table on-the-fly and, conversely, enables it to be a GATT client to interact with remote GATT servers. It also provides commands to read and write to GPIO pins.

The module may also operate as a single connection virtual serial port device for the transparent relay of data between a remote device and the module's UART. This occurs in a similar manner as AT modems used for data communications on telephone lines.

The latest version of the AT Interface application is always available for the Lyra family from the Lyra firmware Github repository [C] and for the Lyra 24 family from the Lyra 24 firmware Github repository [I].

Note: New feature requests are encouraged via Github pull requests or Sales channels.

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2 Application Loading Instructions

Refer to [D] for details of programming the AT application firmware.

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3 OPERATION

3.1 Configuration

The Lyra AT Interface application is configured via a plurality of non-volatile parameters, these are divided into numeric and string-based datatypes. Writable numeric parameters are configured using the **ATS** AT command, and writable string parameters are configured using the **AT%S** AT command.

Note: Non-volatile parameters must be saved following alteration using the **AT&W** AT command. The new values are not applied until the next power-cycle. This can be performed using the **ATZ** AT command which triggers a warm reset of the module.

Read-only parameter data providing runtime information, and fixed module parameters, can be interrogated via the **ATI** command. Factory default non-volatile data can be restored at any time using the **AT&F** AT command.

3.2 Modes

This application provides two mutually exclusive modes of operation on start-up depending on the value of writable numeric parameter 100 (referred to as VSP and non-VSP modes).

3.2.1 VSP

In VSP mode (the default), where bit 0 of writable numeric parameter 100 is set, the application initializes the GATT server table by populating it with the VSP service (and the mandatory GAP and GATT services). It then starts advertising to welcome incoming connections. Once connected, data to/from the VSP service is bridged to the UART. Because of this, once a connection is established, AT commands cannot be parsed. While there is no connection, AT commands are parsed and actioned (such as the ATD command to initiate an outgoing connection). The UART is bridged to the VSP service only on connection, either incoming or outgoing.

Note: By default, in VSP mode, the peripheral device (‘server’) is advertising and waiting for the central device (‘client’) to perform and apply some initial setup operations via GATT once the BLE connection has been opened; otherwise, the VSP connection is not deemed completed and ready. If two Lyra devices for example are in VSP mode and connected with each other, then this will happen automatically in background – no further actions are required in that case.

A good example is when establishing a connection from a non-VSP device such as a mobile phone: In this case, the user must follow and apply the below instructions manually. This usually takes a couple of seconds and is the reason why you only see the RING event. In that case, the CONNECT event gets delayed and will only appear after 15 seconds when the timeout is exceeded.

With no prior VSP setup and configuration, the connection will be still possible and allowed, however, VSP operation cannot be guaranteed until the setup has been performed within a timeout period / window of 15 seconds. This timer will start after the RING event. It should be assumed that VSP – without any prior set up and configuration – does not function as intended, thus data exchange may not work and/or might be limited at this point.

The Laird VSP protocol and implementation consists of a single GATT service with 4 characteristics. Refer to [J] for reviewing the full specification. Both **TX_FIFO** and **MODEM_OUT** characteristics need their notifications enabled for VSP operation. Additionally, the **MODEM_IN** characteristic must have the value *0x01* written to it to signal ‘CTS’.

If the timeout occurs the above can still be done, but in this state VSP operation will be undefined. It’s important to follow the sequence, and the final step must be writing *0x01* to the **MODEM_IN** characteristic. If this is performed without the notifications having been enabled behaviour is undefined.

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3.2.2 Non-VSP

In the Non-VSP mode, where bit 0 of writable numeric parameter 100 is not set, the GATT table contains only the mandatory GAP and GATT services. GATT server-related AT commands are provided that are used to add services and their characteristics. In addition, depending on the states of bits 1 & 2 of writable numeric parameter 100, the module will automatically start advertising and/or scanning. In this mode it is possible to start/stop advertising and scanning as required and to accept or make connections. Once connected, the AT parser is still active, so it is possible to restart adverts or make further connections. In connected states, it is possible to send GATT client-related commands to interact with a peripheral device.

Note that in this mode virtually all commands are modal, meaning an OK or ERROR response is sent immediately after the command is processed, followed by one or more asynchronous messages. All the asynchronous responses start with a unique 2 letter sequence and so can be demultiplexed and actioned appropriately by the host.

Note: If scanning is enabled, the UART host should expect asynchronous (unsolicited and arriving anytime) responses which contain advert reports. These could be interleaved with normal responses. For this reason, every response type in the **Responses** section has a unique two letter (case-sensitive) start which allows the host to demultiplex them appropriately.

3.3 Data Flow Control

The host that is driving the UART interface must strictly adhere to RTS/CTS handshaking to ensure that data buffering and management are not compromised. If the module de-asserts its RTS line, the host stops sending data as soon as possible and conversely, if the host de-asserts its RTS line, the module stops sending data to it.

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4 AT COMMANDS

These are text commands starting with the character sequence AT and terminated by a \r character (ASCII code 0x0D). Commands are not case sensitive and have zero or more parameters. Multiple parameters are separated by the comma (,) character. Some commands tolerate empty fields (two consecutive commas) and provide a default value. If more parameters are supplied than those specified, then the extra parameters are either silently ignored or result in a syntax error response.

The AT commands are described in this section in alphabetical order and are grouped by functional area. Also listed are responses to these commands which are described in the next chapter.

Many commands take parameters which are either integer values, strings or hex strings:

- Integer values – Can be entered as binary or in hexadecimal using the syntax 0xhh..hh
- Strings – Textual data that must be enclosed within inverted commas
- Hex strings – Only contain the letters 0-9, A-F and a-f and shall be exactly an even number long. Otherwise they are treated as syntax errors

Note: Spaces are shown between the AT commands and the parameters accepted. The spaces are not mandatory and included for visual clarity.

4.1.1 [Empty Line]

Command	Empty line with any amount of whitespace characters
Possible Responses	`OK`

4.1.2 AT

Command	**`AT`**
Description	No action performed other than to send the OK response
Possible Responses	`OK`

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4.2 Parameter access commands

4.2.1 AT%S

Command	**`AT%S n="string"`** **`AT%S n?`** **`AT%S n=?`**
Description	These commands are respectively used to set, get, and retrieve the range of valid lengths of any writable string parameter. The parameter ID is identified by the integer value n. **n="string"** - When setting values, "string" is the new value; the double quotes are mandatory. Non-printable characters can be embedded in the new value. These should be escaped using the three-character \hh sequence where hh is the ASCII value of the character in hexadecimal. For example, to null terminate the string "Hello", it is entered as "Hello\00" **n?** and **n=?** – For these variants, the returned value is enclosed in \n and \r and are sent before the OK. The two integer values returned by **n=?** are separated by a comma. **Note:** Modified values are not retained over a power-cycle or a warm reset triggered using the ATZ command. Refer to the AT&W command to make modified values permanent. The following writable string parameters are defined. **ID** — **Description** 0 — *Device Name* The length is between 1 and 20 alpha-numeric characters. 1 — *VSP Service Base 128-bit UUID* The length is 32 hexadecimal characters. 2 — *Scan Pattern* The length is between 0 and 20 alpha-numeric characters. This string specifies a pattern for filtering incoming advert report via scans. If the advert report contains at least one match, then it is reported to the host via the UART. For example, it can be set to the device name of a device and in that case, only that device's adverts are sent to the host. The three-character sequence \hh can be used to enter a non-printable character in the string.
Possible Responses	`OK` `ERROR`

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4.2.2 AT&F

Command	**AT&F**
Description	Sets all writable parameters to default values *and* clears the trusted device bond database then performs a warm reset.
Possible Responses	`OK (after the warm reset)` `ERROR`

4.2.3 AT&W

Command	**AT&W**
Description	Saves all writable parameters to non-volatile memory.
Possible Responses	`OK` `ERROR`

4.2.4 ATI

Command	**ATI n**
Description	Queries read-only parameter data identified by the integer argument n. Values returned are either integer or string data. Returned values are preceded by a \n character and terminated with a \r character. The following information is returned with identifier ‘n’ as stated.

ID	Description
0	The unique device name. Returned as follows. ▪ ”LYRA-S” for Lyra S ▪ “LYRA-P” for Lyra P ▪ “LYRA24-S10” for Lyra 24 S10 ▪ “LYRA24-P10” for Lyra 24 P10 ▪ “LYRA24-P20” for Lyra 24 P20 ▪ “LYRA24-P20RF” for Lyra 24 P20RF
3	The firmware version of the module. This is returned in the format WWW.XXX.YYY.ZZZ, with the fields being defined as follows. ▪ WWW is the unique product number, returned as follows. ▪ 125 for Lyra-S ▪ 126 for Lyra-P ▪ 129 for Lyra 24 P10 ▪ 130 for Lyra 24 S10 ▪ 131 for Lyra 24 P20 ▪ 133 for Lyra 24 P20RF ▪ XXX is the top-level revision of the Silabs SDK in use ▪ YYY is the major release number ▪ ZZZ is the minor release number
4	The Bluetooth address of the module This is returned as a 14-digit hexadecimal string

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11	Low-power UART operation Will return 1 if Low-Power UART operation has been enabled. Writable numeric parameter 109 needs to be configured for an available SIO and writable numeric parameter 213 to a value equal or greater than 250ms to enable Low-Power UART operation.
14	Static random Bluetooth address This is returned as a 14-digit hexadecimal string
24	Public IEEE Bluetooth address
42	Application state This provides a high-level indication of the current application state. Possible values are as follows. ▪ 0: Initialising ▪ 10: Idle, non-VSP ▪ 20: Idle, VSP ▪ 30: Scanning, VSP ▪ 40: Fast Connected, VSP ▪ 41: Fast Connecting, VSP ▪ 50: Connecting, VSP ▪ 51: Wait for Encryption, VSP ▪ 52: Get Handles, VSP ▪ 53: Write CCCDs, VSP ▪ 54: Pairing, VSP ▪ 55: Disconnecting, VSP ▪ 60: Connecting, non-VSP ▪ 70: In Wait Encryption, VSP ▪ 80: Connected, non-VSP ▪ 90: Caret Connected, VSP ▪ 91: Caret Connecting, VSP
1002	Minimum baud rate This is the minimum configurable baud rate of the AT Interface UART.
1003	Maximum baud rate This is the maximum configurable baud rate of the AT Interface UART.
2000	Reset Reason This provides more details on the reason for the reset. Possible values are as follows: ▪ 0: None ▪ 1: AT&F issued ▪ 2: ATZ issued ▪ 17: Hard fault ▪ 18: Bus fault ▪ 19: Usage fault ▪ 33: Brown out ▪ 34: Brown out while in low energy mode

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2001	Cause of last reset This indicates the root cause of the reset. Possible values are as follows: ▪ 0: Unknown reset cause ▪ 1: Power on reset ▪ 2: Software reset ▪ 3: Brown out ▪ 4: Reset pin ▪ 5: Lockup ▪ 6: Watchdog
2008	Current TX Power This is the TX Power in dBm currently in use.
2009	Number of devices in the trusted device bond database
2012	Maximum number of devices that can be saved in the trusted device bond database
2013	Maximum length of GATT table attribute
2016	BLE Radio activity. This is an eight-bit bit-field, used to indicate the current activity being performed by the BLE radio. Possible bit settings are as follows. ▪ Bit 0 : Advertising (0x1) ▪ Bit 1 : Connected as peripheral (0x2) ▪ Bit 2 : Initiating a connection (0x4) ▪ Bit 3 : Scanning for adverts (0x8) ▪ Bit 4 : Connected as central (0x10)
2018	TX Pairing Power Returns the TX Power in dBm whilst pairing is in progress
2040	Maximum number of devices that can be stored in the trusted device database
2041	Number of devices in the trusted device database
2090	BLE maximum packet length in bytes
2091	BLE Connection Event length
2092	BLE maximum number of Central connections
2093	BLE maximum number of Peripheral connections
2094	BLE maximum number of combined connections
2100	Connection Scan Interval
2101	Connection Scan Window
2102	Peripheral Connection Latency default
2105	Connect Multi-Link Connection Interval periodicity in milliseconds
2108	Incoming Connection Update Request Action
2109	Incoming PHY Request Action
2110	PHY with which connection attempts are made
2111	Extended Connection Mode
2150	Scan Interval Scanning
2151	Scan Window Scanning

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	2152	Scan Type ▪ 0 : Passive ▪ 1 : Active
	2153	Minimum Number of Scan Reports The minimum number of Scan Reports to be held in cache
	2154	Scanning PHY
	2155	Extended Scanning
	2203	Advertising Channel Mask
	2204	Primary Advertising PHY
	2205	Secondary Advertising PHY
Possible Responses	`OK` `ERROR`	

4.2.5 ATS

Command

`ATS n=m`

`ATS n?`

`ATS n=?`

Description

These commands are respectively used to set, get and retrieve the range of valid values, for any writable numeric parameter. The parameter is identified by the integer value n. When setting, m is the new value.

For the ‘n?’ and ‘n=?’ variants the returned value will be enclosed in \n and \r and will be sent before the OK. The max and min integer values returned by ‘n=?’ are separated by a comma.

Note when setting the value that it will not be retained over a power-cycle or a warm reset triggered using the ATZ command. Refer to the AT&W command to make all changed values permanent.

The following writable numeric parameters are defined.

Parameter	Description
100	*Start-up Flags* ▪ Bit 0: Enable VSP mode on boot and start BLE advertising as per [J]. It will automatically set up and populate the VSP GATT table in background. ▪ Bit 1: Ignored if bit 0 is 1; otherwise start advertising with no timeout. ▪ Bit 2: Ignored if bit 0 is 1; otherwise start scanning with no timeout. ▪ Bit 3: Set for max bidirectional throughput of about 127kbps; otherwise half of that. ▪ Bit 4: Enable Extended advertisements. (must be set when using LE coded PHY or 2MPHY). ▪ Bits 5:6: PHY Rate 00 – 1MPHY. 01 – Long Range – 125kbps. 10 – RFU. Defaults to 1MPHY. 11 – 2MPHY. ▪ Bit 7: Reserved for Future Use (RFU).
101	*TxPower* This is the TX Power in dBm.

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102	*Encryption Requirement for incoming VSP connections* ▪ Bit 0: Enable(1)/Disable(0) ▪ Bit 1: (MITM(1) /NoMITM(0)
103	*Device Name Format in adverts and Gap Service (valid values 0 to 7)* If this value is 0 then the name will be “DEVNAME” which is specified using the writable string parameter command AT%Sn=s where n is 0 and the command AT%S is described elsewhere in this section. If this value is non-zero, then the name will be “DEVNAME-HH..HH” where the number of HH is exactly double the value in this parameter and those hex digits correspond to the rightmost hex characters of the Bluetooth address. For example, if the Bluetooth address is 0123456789ABCD and this parameter contains 3, then the device name is “LAIRD”, and the advertised device name will be “LAIRD-89ABCD”.
104	This is the peripheral latency that will be negotiated when connected as a peripheral. This negotiation will start about 5 seconds after the connection is made.
105	*Flags AD* This is the flags bit in the Flags AD element when adverts are started. It specifies general or limited discoverability. Valid values are as follows. • 0 = Do not include Flags AD in advertisement • 1 = Limited Discoverable Mode • 2 = General Discoverable Mode This defaults to a value of 2 (General Discoverable Mode).
106	*Default Scan Timeout in seconds* When starting scans for adverts using the AT+LSCN command, if the timeout value is omitted this parameter’s value will be used.
107	*I/O Capability to use during initial negotiation when pairing.* This specifies the user interface that is available to expedite a pairing. ‘Just Works’ pairing implies there is no user interface and so the resulting encryption key will not be authenticated and so not immune to MITM (man-in-the-middle) attacks. Valid values are as follows. ▪ < 0 = Prefer OOB ▪ 0 = Just Works ▪ 1 = Display with Y/N ▪ 2 = Keyboard only ▪ 3 = Display Only ▪ 4 = Keyboard + Display
108	*Idle Advert Type* This specifies the advert type to use advertising in non-VSP mode. ▪ 0 = ADV_IND (Connectable and will respond to scan requests) ▪ 1 = ADV_DIRECT_IND (connectable but only from specific device) ▪ 2 = ADV_SCAN_IND (Not Connectable, but responds to scan requests) ▪ 3 = ADV_NONCONN_IND (Not Connectable, ignores scan requests) If this is changed, then a save using AT&W is required and will only take effect after the next power cycle or warm reset.

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109	*SIO used to control VSP command mode or low power UART operation.* If set to -1, to drop a VSP connection, the ^^^^ escape sequence needs to be sent, otherwise the state of this SIO is used to disconnect from a VSP connection. The SIO must be high to allow connection to continue. If there is an outgoing connection attempt and this pin is low, the connection will not be allowed. Similarly, for an incoming connection, if this pin is low, on connection an immediate disconnection will be requested. For low power UART operation, this SIO is continuously monitored. When transitioning to low, the module is allowed to automatically close the UART after the idle period that is set in milliseconds via writable numeric parameter 213. Writable numeric parameter 213 being set equal to or greater than 250 milliseconds is used to govern the behaviour of this SIO. If less than 250 milliseconds, VSP Command mode is enabled. Only SIOs 0 through 7 may be used to implement this functionality.
110	*Connection Timeout in seconds* When making an outgoing connection using the command ATD or AT+LCON, this parameter specifies the maximum time for connectable adverts from the device to be connected to.
111	*Number of '^' characters to send over the UART to trigger a disconnect* If writable numeric parameter 109 is -1 then multiple '^' characters can be used, interspaced by delays to disconnect when there is a VSP connection. The delay is specified by writable numeric parameter 210.
112	*Active or Passive Scan Type* Set to 0 for passive scanning and 1 for active. Active scanning means that if an advert is received with type ADV_IND or ADV_SCAN_IND a scan request will be sent such that the advertiser sends a scan response which contains a further 31 bytes made of AD elements. By default, this is set for active scanning.
113	*Scan RSSI minimum in dBm* When scanning for adverts, each incoming advert is reported with its reported RSSI. If the RSSI of that advert is less than specified by this writable numeric parameter, then it will not be reported to the host connected at the UART. This allows the host to filter adverts based on how weak the signal is (usually corresponding to how far away the origin is). The default setting is -120; given that the receive sensitivity is around -100 this implies that all adverts no matter how weak, if received, will be reported to the host.
114	*Link Supervision Timeout (Seconds) as Peripheral* This is the link supervision timeout that will be requested for an incoming connection after 5 seconds if the connection interval is not in the required range. This value is written to the GAP service on power up.

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115	*Minimum Encryption Key Length* This can be between 7 and 16. Essentially at pairing this information will be determined and saved in the trusted device bond database. In the future, if a service requires a minimum key length for data exchange and the connection is encrypted, if the length of the key for that encryption is less that this value then data exchange cannot happen.
116	*MITM (man-in-the-middle) for Encryption Required* This is used by a central role device when it wishes to start encryption. If this set to 1, then it implies that the encryption request shall only succeed if the stored key was authenticated when the most recent pairing happened. Valid values are 0 for no MITM requirement and 1 for required.
117	*DCD Output for VSP Connection* This parameter allows an SIO to be configured to indicate when a VSP connection is active. When configured for an appropriate SIO, the SIO is driven low when there is a VSP connection, and high otherwise.
126	*Max Connections as Central* For Lyra, can be up to 4. Default is 4. For Lyra 24, can be up to 20. Default is 20.
137	*Polarity of Connection Indication Pin and Encrypted Connection Indication Pin* Selects the polarity for pins specified in writable numeric parameters 138 and 139. Bits 0-1 are used as follows: ▪ Bit 0: connection indication pin (writable numeric parameter 138) ▪ 0 = low active ▪ 1 = high active (default) ▪ Bit 1: encrypted connection indication pin (writable numeric parameter 139) ▪ 0 = low active ▪ 1 = high active (default) Valid values are 0 to 3.
138	*Connection Indication Pin* Selects the pin used to indicate that a non-VSP connection is active. The pin will remain active as long as there is at least one non-VSP connection active. Polarity of the pin can be selected with writable numeric parameter 137.
139	*Encrypted Connection Indication Pin* Selects the pin used to indicate that a non-VSP connection has been encrypted. The pin will remain active as long as there is at least one encrypted non-VSP connection active. Polarity of the pin can be selected with writable numeric parameter 137.

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200	*VSP Encryption Disconnect Timeout (milliseconds)* If a VSP service is specified with encryption requirement, then on a VSP connection a timer is started. If that timer times out before the connection goes encrypted, then the peripheral will initiate a disconnection. This is a form of resilience to a denial-of-service attack, in which a device just connects and then does nothing to prevent legitimate users from connecting. The timer is cancelled as soon as the connection is encrypted.
201	*VSP Advert Interval (milliseconds)* When starting adverts for incoming VSP connections, this specifies the advert interval to use.
206	*Link Supervision Timeout in milliseconds* When making an outgoing connection using ATD or AT+LCON this specifies the link supervision timeout to use in the connection request.
207	*Appearance (Optionally used in Adverts)* This specifies the value to use in the Appearance AD element in an advert. A value of 0 implies that the Appearance AD element will not be added to the advert report.
208	*Idle Advert Interval in milliseconds* When advertising in non-VSP mode, this specifies the default advert interval. Also used when not supplied in the AT+LADV command.
210	*VSP Escape Character Minimum Inter-Character Spacing (milliseconds)* When ^ is used to drop a VSP connection, this specifies the minimum delay that has to exist between consecutive ^ characters for a disconnection to be triggered. This is so that normal data traffic containing a train of ^ characters does not induce a disconnection. See writable numeric parameter 111 which is used to specify the number of consecutive ^ characters needed to trigger the disconnection.
211	*Scan Interval in milliseconds*
212	*Scan Window in milliseconds* When a scan for adverts is initiated, writable numeric parameters 211 and 212 specify the interval and window respectively, for scanning. The ratio of window over interval specifies the duty cycle. When both are set to the same value the duty cycle is 100% and so here is minimal probability that an advert report will be missed. However, setting 100% duty cycle implies the radio receiver is ON all the time and so will result in maximum power consumption. Setting the ratio as low as possible reduces power consumption but at the expense of missing adverts.
213	*UART Idle Time in milliseconds for low power UART operation* If no UART activity is detected for this length of time and the SIO defined by writable numeric parameter 109 is low, the UART will be automatically closed. If there is incoming data over the air that needs to be conveyed to the host, the UART is automatically opened regardless of the status of the SIO defined by writable numeric parameter 109.

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	217	*Core Voltage in Millivolts* This is the operating voltage the module is intended to operate at. This is used to define the reference used by AD routines to properly scale input voltages against the reference value defined here. This defaults to 3300mV.
	219	*DLE Attribute Size* Sets the desired GATT Server MTU. Valid values 20…244, Default value is 96. See writable numeric parameter 307 to adjust throughput performance.
	300	*Minimum Connection Interval in microseconds*
	301	*Maximum Connection Interval in microseconds* When making an outgoing connection using ATD or AT+LCON, these specify the minimum and maximum intervals that is acceptable for the connection interval. A range needs to be specified to give the stack flexibility in arranging the optimal connection intervals when there are multiple connections. If you are going to only have a VSP connection and so know that the radio is not going 'object' it is possible to set both these values to the same value and in that case, you should get the value you require. When the connection is established, it is reported using the CONNECT response which will supply the actual interval negotiated by the stack with the peer.
	302	*UART Baud rate* This specifies the baud rate to use for commands and data transfer. After setting, a power cycle or a warm reset will be required.
	303	*VSPTxUUID*
	304	*VSPRxUUID*
	305	*VSPMdmInUUID*
	306	*VSPMdmOutUUID* These are values in the range 0x0 to 0xFFFF and are the 16-bit UUID offsets to use for the VSP service. Changing this will mean that mobile apps supplied by Laird Connectivity to interact with VSP will stop working as they will not find the expected UUIDs. Only change this if you really need to. A good reason would be to make the VSP private to you and so other devices expecting the standard Laird Connectivity UUID will not work and so yet another way to restrict access to your device.
	307	*BLE Connection Event Length* Maximum number of packets that can be transmitted per connection per connection interval. The factory default value is 12.
Possible Responses	`OK` `ERROR`	

4.3 Bond database commands

4.3.1 AT+BNDD

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Command	**AT+BNDD address**
Description	This command is used to delete a device from the trusted device bond database. **address** – This is the 14-hexadecimal digit BLE address of the device to remove from the trusted device bond database
Possible Responses	OK ERROR

4.3.2 AT+BNDT

Command	**AT+BNDT address**

Description	Checks if a device identified by *address* (a 14-digit hexadecimal string) is present in the trusted device bond database (a result of a successful pairing).
	The following response is sent before the OK if it is not trusted:
	`\n0\r`
	If trusted, the response is:
	`\n1, 0, 14digithexaddr\r`
	14digithexaddr is the actual Bluetooth address of the device if the *address* passed to this command is a resolvable address.
	At any time, the command ATI 2009 returns the number of devices in the trusted device bond database.
	Note: Due to underlying SDK limitations this command currently does not work with random resolvable addresses as the address stored in the bond database does not correspond to the 'random' address given at connection. If you require a bond check in your application, please make sure to only use public (00) and/or static (01) address types with your end device(s) instead. A random resolvable address is a security feature of BLE that prevents tracking by randomizing the MAC address. Common portable devices such as a smartphone, tablet or notebook are most likely to enforce a random resolvable address and thus trigger the issue outlined.

Possible Responses	OK ERROR

4.3.3 AT+BNDX

Command	**AT+BNDX**
Description	This command is used to delete all devices from the trusted device bond database.
Possible Responses	OK ERROR

4.4 GATT Client commands

4.4.1 AT+GCTM

Command	**AT+GCTM hIdx**

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Description

This command is used to obtain the GATT table schema (such as the structure) of the peer connected on the handle identified by **hIdx**.

This results in many responses starting with either `TM:S` or `TM: C` and `TM: D`.

For example, the following from a device contains three services:

- First service – Contains four characteristics
- Second service – Contains one characteristic
- Third service – Contains four characteristics

In addition, the characteristic in the second service has a descriptor. In total, there are three descriptors in the entire GATT table.

```
AT+GCTM1
TM:S:1, (9), FE011800
TM: C:3, 00000002, FE012A00, 0
TM: C:5, 00000002, FE012A01, 0
TM: C:7, 00000002, FE012A04, 0
TM: C:9, 00000002, FE012AA6, 0
TM:S:10, (13), FE011801
TM: C:12, 00000020, FE012A05, 0
TM:  D:13, FE012902
TM:S:14, (65535), FD021101
TM: C:16, 00000010, FD022000, 0
TM:  D:17, FE012902
TM: C:19, 0000000C, FD022001, 0
TM: C:21, 00000010, FD022002, 0
TM:  D:22, FE012902
TM: C:24, 0000000C, FD022003, 0
OK
```

Where:

TM:S	Indicates the start of a BLE Service whose starting attribute handle is the integer value after the second ':' in that line.
The next integer parameter (in brackets)	The last attribute handle in that service.
Last eight-digit hex number	The UUID handle supplied by the firmware ***Note:*** *This is not the index mentioned in the AT+UUID command description.*

TM: C	Indicates the start of a BLE Characteristic
The integer after the second ':'	The handle for the value attribute
The next integer	Eight-digit hex value that denotes the characteristic properties (see command AT+GSCB for details)
The next eight-digit hex number	The UUID handle supplied by the firmware
The final decimal number	Is always 0. Intended as a place holder for the *Included Service UUID Handle*. ***Note:*** *We have not yet encountered an Included Service. We will add this functionality as needed.*

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	TM: D	Indicates the start of a BLE Descriptor that belongs to a Characteristic (such as CCCD)
	The integer after the second colon (:)	Its attribute handle
	Next hex number	The UUID handle supplied by the firmware. The last four digits of the UUID are the 16-bit adopted UUID if the first four digits are FE01. For example, if the last four digits are 2902, it is a CCCD. This means that you can use the attribute handle with the AT+GCWC command to write an enable/disable notify/indicates for the characteristic to which it belongs.
	The end of the table information is indicated by an OK or ERROR message.	

Possible Responses

```
OK
ERROR
TM:S
TM: C
TM:  D
```


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4.4.2 AT+GCFA

Command	**`AT+GCFA hIdx, uS, x, uC, y <,uD, z>`**
Description	This command is used to search for the handle of the value attribute of a Characteristic or the attribute handle of a descriptor attached to a characteristic in the peer connected on the handle identified by hIdx. **<uD, z>** (Optional) When this is absent, it implies that the search is for the value handle of a characteristic. When present, it implies that the search is for the descriptor. `OK` or `ERROR` terminates this command. If a characteristic or descriptor is found, the FC or FD responses have been received respectively. **uS, uC, uD** These are the UUID index that were used to pre-create a UUID handle using the command AT+UUID. **x, y, z** The 0-based instance index of the appropriate entity in the remote GATT table. For example, if x=1, y=2, and z=0, it means search for the second instance of a service with the UUID *uS*. In that service, search for the third instance of the characteristic with UUID *uC*; and in that characteristic, look for the first instance of the descriptor with UUID *uD*. **Note:** Typically, GATT tables do not have multiple instance services. The main use of such a command is to locate a characteristic or descriptor in a server device to obtain the attribute handle so that it can be subsequently used in read/write requests using commands AT+GCRD, AT+GCWA, AT+GCWC. This command immediately responds with OK or ERROR and, at some time subsequent, the asynchronous response FC or FD is received When the attribute handle specified in the FC or FD is 0, it implies that the object was not found in the remote GATT table.

Possible Responses	`OK`
	`ERROR`
	`FC`
	`FD`

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4.4.3 AT+GCRD

Command	**AT+GCRD hIdx, hAttr, nOffset**
Description	This command is used to read the content of a remote attribute starting at offset specified within that attribute. For example, if the attribute contains *Hello World,* setting nOffset to 6 results in *World* being read. hldx — The connection handle of the server from which it reads hAttr — The attribute of the handle that was extracted using either AT+GCTM or AT+GCFA commands This command immediately responds with OK or ERROR and at some time subsequent, the asynchronous response AR is received. If the read was successful, then an AR response is received which contains the data. If the read failed (for example, if the attribute does not exist or it requires the connection to be authenticated), then the AS response is received. In rare occasions, an AB could also be received if, for example, the module is low in memory.
Possible Responses	OK ERROR AR AS AB

4.4.4 AT+GCWA

Command	**AT+GCWA hIdx, hAttr, hexDataString**
Description	This command is used to write data to an attribute in a remote GATT table and expects an acknowledgement which will be received as an asynchronous response “AW” after the terminating “OK” response. **hldx** — The connection handle of the server from which it reads **hAttr** — The attribute of the handle that was extracted using either AT+GCTM or AT+GCFA commands **hexDataString** — A string consisting of only hexadecimal characters which must be an even number in length. It is converted to binary before writing to the peer. It always writes to offset 0 in the destination attribute. If the attribute rejects the write because say the connection is not encrypted, then the AW will have the appropriate status value.
Possible Responses	OK ERROR AW

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4.4.5 AT+GCWC

Command	**AT+GCWC hIdx, hAttr, hexDataString**
Description	This command is used to write data to an attribute in a remote GATT table; it does not expect an acknowledgement after the terminating OK response. If the command fails to write the value, then there will eventually be a disconnection because the link supervision timer will timeout.

Hldx	The connection handle of the server from which it reads
hAttr	The attribute of the handle that was extracted using either AT+GCTM or AT+GCFA commands
hexDataString	A string consisting of only hexadecimal characters which must be an even number in length. It is converted to binary before writing to the peer.

It always writes to offset 0 in the destination attribute.

If the attribute rejects the write because say the connection is not encrypted, then the AW will have the appropriate status value.

Possible Responses	OK ERROR

4.4.6 AT+LMTU

Command	**AT+LMTU hIdx**
Description	This command is used to request the desired attribute MTU size from the remote GATT server. By default, the ATT_MTU size is 96. This can be adjusted using writable numeric parameter 219.
Possible Responses	OK ERROR MT

4.5 GATT Server commands

These are GATT server-related commands used to populate the local GATT server table with services, characteristics, and descriptors. A characteristic can have properties like read/write and CCCD descriptors which may or may not require authentication.

When adding a characteristic, those attributes must be specified. You can achieve this by using a metadata object which must be pre-created using the AT+GSMD command. Just like UUID handles management, this app provides for an array of metadata objects that are referenced using the index *m* in the range 0 to 3.

The GATT server commands need to be executed in a defined sequence such that foundational elements are defined first. Refer to [F] for further details.

4.5.1 AT+GSMD

Command	**AT+GSMD m, rdRights, wrRights, len**
Description	The AT+GSMD command is used to create a metadata object in array index *m* and creates an opaque integer value that contains the read and write which can be any one of these values:

0	No access
1	Open
2	Encrypted with no man-in-the-middle (MITM) protection

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	3 Encrypted with man-in-the-middle (MITM) protection Once the metadata object is created its index can be used to refer to in any command (like AT+GSCB) that needs it.
Possible Responses	OK ERROR

4.5.2 AT+GSCB

Command	**AT+GSCB uC, prop, mVal <,mCccd<,mSccd>>**
Description	The GSCB command is used to define a characteristic which can have a CCCD and/or SCCD descriptors attached to it. If the arguments mCccd and mSccd are not supplied, then the characteristic will have neither. To add a SCCD but not a CCCD, use the syntax: **,,mScc** …where the empty field between the two commands conveys that desire. The parameter *uC* is the index of a UUID handle was pre-created using AT+UUID; and *prop* is a bit mask whose value is in the range 1 to 63 (0x3F) which are the properties as per the definition in the Bluetooth Specification. The following are the properties: 0 Broadcast-capable (Sccd descriptor must be present) 1 Can be read by the client 2 Can be written by the client without an ACK 3 Can be written (ACK is sent back) 4 Can be notifiable (Cccd descriptor must be present) 5 Can be indicatable (Cccd descriptor must be present)
Possible Responses	OK ERROR

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4.5.3 AT+GSCE

Command	**AT+GSCE hexDataString**
Description	The GSCE command is used to commit the new characteristic and ***hexDataString*** supplies the initial value (after conversion to binary). If CCCD or SCCD descriptors are specified, then the initial values are 0. This command responds with an integer value in the \nNN\r format (an integer value in the range 0 to N). This command will respond with an integer value in format "\nNN\r" which is an integer value in the range 0 to N. This integer value is an index value into an array of handles which MUST be noted by the host as associated with the newly created characteristic which is referenced in the commands AT+GSWC, AT+GSNO, and AT+GSIC. Think of this index value as an identifier.
Possible Responses	OK ERROR

4.5.4 AT+GSSB

Command	**AT+GSSB uS**
Description	The GSSB command is used to define the start of a service which has a UUID that was pre-created using the AT+UUID command.
Possible Responses	OK ERROR

4.5.5 AT+GSSE

Command	**AT+GSSE**
Description	The GSSE command is used to define the end of a service so that a new Service can be added using AT+GSSB.
Possible Responses	OK ERROR

4.5.6 AT+GSIC

Command	**AT+GSIC i, hexDataString**
Description	This command is used to send a value indication if the client has enabled indications via the referenced characteristic's CCCD. **i** — The characteristic identifier that was returned by the AT+GSCE command **hexDataString** — The data that is first converted to binary and is then sent as an indication to all clients that enabled them. When the indication is acknowledged by the client, it results in an asynchronous AK message.
Possible Responses	OK ERROR AK

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4.5.7 AT+GSNO

Command	**AT+GSNO i, hexDataString**
Description	The GSNO command and is used to send a value indication if the client has enabled indications via the referenced characteristic's CCCD.
	i — The characteristic identifier that was returned by the AT+GSCE command
	hexDataString — The data that is first converted to binary and is then sent as an indication to all clients that enabled them.
Possible Responses	OK ERROR

4.5.8 AT+GSWC

Command	**AT+GSWC i, hexDataString**
Description	This command is used to set a new value for the characteristic identified by 'i'. If the characteristic is created with a property bit set for readable, then a remote GATT client is able to read this new value when it next polls it. 'i' refers to the characteristic identifier that was returned by the AT+GSCE command and hexDataString is the data that is first converted to binary and then sent as an identification to ALL the clients that have enabled them.
Possible Responses	OK ERROR

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4.5.9 AT+UUID

Command	**`AT+UUID u, 16bitUuid`** **`AT+UUID u, 32HexDigitNumber`** **`AT+UUID u, 16bitUuid, v`**
Description	*BLE makes wide use of UUIDs (universally unique identifiers) which are 128-bit (16-byte) random values. These values can be cumbersome to manage as string objects and so the module firmware exposes a concept of a 32-bit integer value which is a handle to an internal 16-byte buffer that contains the actual value.* *The Lyra AT Interface firmware extends that concept by using an array of integer variables to store those handles provided by the firmware. Those firmware handles are never exposed, but instead an index value* 'u' *is.* The 'u' in these three variants of the command is the index into that integer array. To understand this, imagine a collection of mailboxes numbered 0 to N (see MAX_UUID_HANDLES in the source code) which are your scratchpads to load UUID handles into (using these commands) as and when you need to supply a UUID into any of the AT commands that require a UUID. For example, the command AT+GSSB takes a parameter which is one of these 0 to N indices. For Lyra, the value for 'u' shall always be in the range 0 to 15. For Lyra 24, the value for 'u' shall always be in the range 0 to 31. The command variant "AT+UUID u, 16bitUuid" is used to create a handle from a Bluetooth SIG adopted 16-bit UUID and store it in the array index 'u'. The value 16bitUuid shall be in the range 0 to 0xFFFF. The command variant "AT+UUID u, 32HexDigitNumber" takes the 32-character hexadecimal string and converts that into a handle and stores it in the array index 'u'. The command variant "AT+UUID u, 16bitUuid, v" takes the '16bitUuid' which is a value in the range 0 to 0xFFFF and creates a sibling of the handle stored in array index v and stores in array index 'u'. By sibling, it is meant that the base UUID of the handle stored in array index 'v' is used to create the new UUID.
Possible Responses	`OK` `ERROR`

4.6 I2C commands

I2C is a two-wire serial protocol. It facilitates communication between host microcontrollers and external peripheral devices. The I2C connections are defined as follows.

- SDA: This is a bidirectional line used by the host device to send data to external peripheral devices, and for the peripheral device to send data to the host.
- SCL: This is permanently configured as an output by the host microcontroller. It is used to clock individual data bits into the controller and peripheral devices.

Note: Prior to usage of the I2C commands, the appropriate SIO configuration is required using the **AT+SIOC** commands.

Note: Refer to [K] for examples of I2C commands being used.

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4.6.1 AT+I2R

Command	**AT+I2R hexDataString, outLength**
Description	This command is used to perform an I2C device read. Data is returned in hexadecimal format. **hexDataString** — This is the hexadecimal data string sent to the device. This should include the device address byte and associated read command data. Data should be sent in hexadecimal format. For example, an address value of 1 and a data byte of 254 would be sent as 01FE. **outLength** — This is the number of bytes to read back from the device
Possible Responses	OK ERROR

4.6.2 AT+I2W

Command	**AT+I2W hexDataString**
Description	This command is used to perform an I2C device write. **hexDataString** — This is the hexadecimal data string sent to the device. This follows the same format as read command data.
Possible Responses	OK ERROR

4.7 Advertising commands

4.7.1 AT+AARA

Command	**AT+AARA tag, "payload"**
Description	This command is used to add an AD element with tag and payload specified to the advert report cache variables for adverts that are used when operating in non-VSP mode. **<tag>** can take the range of 0..255 To add to the scan report, the AT+ASRA command should be used. This does not affect the adverts that are already committed to the radio and can be called multiple times to add more AD elements. To commit to the radio, the AT+ACMT command should be used.
Possible Responses	OK ERROR

4.7.2 AT+ACMT

Command	**AT+ACMT**
Description	Non-VSP advert and scan report caches created using AT+ARST, AT+AARA, and AT+ASRA are committed for transmission by the radio using this command.
Possible Responses	OK ERROR

4.7.3 AT+ADAD

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Command	**AT+ADAD** **AT+ADAD <advset>**
Description	This command is used to retrieve the advertising address of the specified advert set (or default if not provided). Device must be advertising to use this command. **<advset>** can take the range 0..n, where n is the maximum number of advert sets.
Possible Responses	OK ERROR ADAD

4.7.4 AT+ARST

Command	**AT+ARST <connectable>**
Description	This command is used to clear the advert and scan report cache variables for adverts that are used when operating in non-VSP mode. **<connectable>** range of 0 to1. If 0 will completely clear the advert and scan buffers allowing completely custom adverts to be built. If 1, adds the flags and the default device name as defined by writable numeric parameter 103. This does not affect the adverts that are already committed to the radio.
Possible Responses	OK ERROR

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4.7.5 AT+ASRA

Command	**AT+ASRA tag, "payload"**
Description	This command is used to add an AD element with tag and payload specified to the scan report cache variables for adverts that are used when operating in non-VSP mode. To add to the advert report, the AT+AARA command should be used. **<tag>** can take the range 0..255 This does not affect the adverts that are already committed to the radio and can be called multiple times to add more AD elements. To commit to the radio, the AT+ACMT command should be used.
Possible Responses	OK ERROR

4.7.6 AT+LADV

Command	**AT+LADV <advType <,advIntvlMs>>**
Description	Start adverts which are non-VSP related. If the optional parameters are missing, then default values are used. Writable numeric parameter 108 is used for the advType and writable numeric parameter 208 for advIntvlMs. **Note:** These default values are cached on powerup/reset. If the parameter values are changed, an AT&W command must be issued, followed by a reset. If this command is received when in VSP mode, the module exits to non-VSP mode and remains in that new mode. Also see the AT+EADV command which is used to send extended adverts, for example LECODED.
Possible Responses	OK ERROR

4.7.7 AT+LADVX

Command	**AT+LADVX**
Description	The LADVX command is used to stop all adverts. **Note:** If an incoming connection is established, adverts are automatically stopped and a new AT+LADV command is required to restart adverts. At any time, the command ATI2016 can be used to determine the current advertising status. Bit-0 is set if the module is advertising.
Possible Responses	OK ERROR

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4.7.8 AT+EADV

Command	**`AT+EADV <advProp>, <advIntvlMs>, <maxCount>, <priSecPhy>, <peerAddr>, <chanMask>`**
Description	This command starts normal or extended adverts which are non-VSP related. If the optional parameters are missing, then default values are used as follows (**Note that the advProp parameter is mandatory**): ▪ advIntvlMs: value from writable numeric parameter 208 ▪ maxCount: 0 ▪ priSecPhy: 0 ▪ peerAddr: empty hex string ▪ chanMask: empty hex string An example command is as follows: `AT+EADV3, 100, , , "123457890", ""` In this example, advProp is 3, advIntvlMs is 100, maxCount and priSecPhy are left default, peerAddr is 1234567890, and chanMask is default. ▪ 'advProp' is a bitmask where bit 0 is set for connectable adverts, bit 1 is set for scannable adverts, bit 2 for directed adverts and in that case 'peerAddr' must be a valid 14 hex digit string and bit 3 is set for extended adverts. ▪ 'advIntvlMs' is the interval in milliseconds for the repeated adverts and must be a minimum of 20ms and a maximum of 32 seconds ▪ 'maxCount' is a value in the range 0 to 255. If non-zero is specified, then the advertising will automatically stop after that many adverts have been sent and the "AE:" async response will be sent to the host. ▪ 'priSecPhy' specifies the PHY on which the primary and secondary packets are sent. Bit 0 is clear for primary adverts on 1MPHY and is set for primary adverts on LECODED. Bits 1, 2, and 3 specify the PHY on which the secondary packets are sent, where 000 means same PHY as primary, 001 means 1MPHY, 010 means 2MPHY and 011 means LECODED. ▪ 'peerAddr' is either empty (when bit 2 of 'advProp' is clear) or a 14-hex digit string which specifies the central device the advert is targeted at. ▪ 'chanMask' is either empty (which means use all channels) or a 10-hex digit string which specifies the value for a 5-byte binary string that denotes the 40 channels. **Note:** These default values are cached on powerup/reset. If the parameters are changed, an AT&W command must be issued followed by a reset. If this command is received when in VSP mode, the module exits to non-VSP mode and remains in that new mode. When these adverts are received by a scanner running this application then they will appear as 'ADE' and 'ADS' response for advert and scan responses respectively. Also see the AT+LADV command which is used to send normal BLE 4.x adverts.
Possible Responses	`OK` `ERROR`

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4.8 Connection commands

4.8.1 AT+CSEC

Command	**AT+CSEC hIdx**
Description	This command queries the security of an active connection where **hIdx** is the connection handle, data is returned via the CSEC response if a valid connection handle was supplied.
Possible Responses	OK ERROR CSEC

4.8.2 AT+LCON

Command	**AT+LCON <L> address**
Description	Makes a non-VSP connection, with a peripheral latency of 0, to the device identified by *address* which is a 14-digit hex string (such as *000016A40B1623*). To make a VSP connection, the ATD command should be used. If 'L' is present, then the connection attempt will be on LECODED PHY On connection, the *connect* response contains parameters (which are detailed in the **Responses** section) but, because there can be multiple non-VSP connections, the parameters must be identified. A number between 1 and N is provided in that response so that it can be subsequently used to interact with the device on that connection. **Note:** The handle is 1 and above. 0 is used internally for special use to identify the one VSP connection that is possible. The following writable numeric parameter values are used to expedite the connection: ▪ 300 – Minimum connection interval ▪ 301 – Maximum connection interval ▪ 206 – Link supervision timeout ▪ 110 – Connection timeout (wait this long for the peer to accept) To change these values prior to initiating a connection, the ATS command should be used. The AT parser is then suspended until either a *connect*, *discon*, or *ERROR* response is sent. For example, if the address specified is not exactly a 14-digit hexadecimal string then the ERROR response is sent.
Possible Responses	connect… discon ERROR

4.8.3 AT+LDSC

Command	**AT+LDSC hIdx**
Description	This command is used when in non-VSP mode to drop a connection (identified by the integer ***hIdx***, that was supplied in the *connect* response). It is a value in the range 1 to N and initiates a disconnection. Later, after an OK response is sent, the actual disconnection occurs. At that time the discon message is sent.
Possible Responses	OK ERROR

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4.8.4 AT+LENC

Command	**AT+LENC hIdx**
Description	This command is used when in non-VSP mode to encrypt a connection (identified by the integer ***hIdx*** that was supplied in the *connect* response). It is a value in the range 1 to N and initiates the negotiation with the peer for the connection to go encrypted. Later, after an OK response is sent, the *encrypt* ***hIdx*** message is sent.
Possible Responses	OK encrypt hIdx ERROR

4.9 Scanning commands

4.9.1 AT+SFMT

Command	**AT+SFMT <frmt>**
Description	When AT+LSCN is used to scan for adverts it will display each advert in a default format where only the device name from the advert data is displayed. This command is used to determine the format used to display the results of scans. **<frmt>** can take the range 0..1 That default format is specified by frmt=0 and will be the default value if <frmt> value is not provided. If frmt=1 then the full advert/scan report data is displayed in hex format.
Possible Responses	OK ERROR

4.9.2 AT+LSCN

Command	**AT+LSCN <timeout_sec <,"escaped_pattern"<,rssi<,scanType>>>>**
Description	The LSCN command is used to start scanning for adverts. All parameters are optional and, if missing, the default value for ***timeout*** is obtained from writable numeric parameter 106, ***escaped_pattern*** is set to an empty string and ***rssi*** is set to -128. If in VSP mode of operation and the ***timeout_sec*** is set to 0, then the module exits from VSP operation mode into non-VSP mode. It stays in that mode, otherwise the AT parser is suspended for the timeout value specified while scanning is in progress. ***'scanType'*** is a bitmask where bit 0 is set to scan for primary adverts on 1MPHY, bit 1 for primary adverts on LECODED (if both are set then scanning will happen on both PHYs). Bit 2 is set for extended scanning into the secondary channels (if bit 1 is set, then this is forced) and bit 3 is set for passive scanning otherwise clear for active scanning where scan request packets will be sent if an advert is scannable.
Possible Responses	OK ERROR AD0:... AD1:...

Bit	Meaning
0	Primary adverts on 1MPHY
1	Primary adverts on LECODED PHY
2	Secondary channel extended scanning
3	Passive scanning

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4.9.3 AT+LSCNX

Command	**AT+LSCNX**
Description	This command is used to stop scanning for adverts.
Possible Responses	OK ERROR

4.10 GAP commands

4.10.1 AT+LPHY

Command	**AT+LPHY hIdx**
Description	This command is used to request the desired PHY from the remote device as per the start-up flags. It can be adjusted using writable numeric parameter 100.
Possible Responses	OK ERROR PU PF

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4.11 Pairing commands

4.11.1 AT+PAIR

Command	**AT+PAIR hIdx**
Description	This command is used when in non-VSP mode to initiate a pairing with the device on the connection identified by the index handle **hIdx**. Later, if OK is sent and if pairing is successful, then the asynchronous response *encrypt* is sent. Also, if the Pairing I/O Capability (writable numeric parameter 107) is not JustWorks, then there are other intervening responses related to authentication which require a response, such as: ▪ showcode hIdx code ▪ comparecode hIdx code ▪ passkey? hIdx ▪ oobkey? hIdx ▪ lescoob? hIdx ▪ xxkey? hIdx The response commands to these asynchronous responses are detailed in the **Responses** section. Because this is all event-driven using responses, it is sufficient to act accordingly when the events happen as detailed. At any time, the command ATI2009 returns the number of devices in the trusted device bond database. In VSP mode, if via writable numeric parameter 102 an encrypted VSP connection was enforced, and writable numeric parameter 107 is set to 0 (i.e. JustWorks) and the device is not trusted, then it allows a pairing during the connection initiated by ATD.
Possible Responses	OK ERROR

4.11.2 AT+PCFG

Command	**AT+PCFG mode**
Description	This command changes the setting of the pair confirmation requests which is a bitmask value. *Mode* bitmask values are as follows: **Bit** / **Value** / **Description** 0 / If database is full, new bonding attempts will fail **11** / 0x0800 / *New bonding will overwrite the existing bonding* **12** / 0x1000 / *New bonding will overwrite the bonding used the longest time ago* **15** / 0x8000 / *If set pairing is automatically confirmed. AT+PCNF is not required.* Where mode is an integer value in the range 0 to 32768 (0x8000)
Possible Responses	OK ERROR

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4.11.3 AT+PCNF

Command	**AT+PCNF hIdx, accept**
Description	Replies to an incoming pair confirmation event (CP) to either accept or decline it, where '**hIdx**' is the connection and **'accept'** is 0 to decline or 1 to accept.
Possible Responses	OK ERROR

4.11.4 AT+PKEY

Command	**AT+PKEY nnnnnn**
Description	If pairing I/O capability is appropriately set via writable numeric parameter 107 so that this module has keyboard capability for use in authenticated pairing, then this command can be used to issue a static passkey to the underlying stack for use during a pairing procedure in a future connection. It allows for a use case similar to what PIN codes provided in classic Bluetooth before simple secure pairing was introduced in v2.1. The value of **nnnnnn** is an integer in the range 0 to 999999 **Note:** The pairing still uses LESC Diffie-Hellman based exchanges, but the only difference is that instead of a random number this static value is used. **Note:** Repeated pairing attempts using the same pre-programmed passkey makes pairing vulnerable to MITM attacks.
Possible Responses	OK ERROR

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4.11.5 AT+PRSP

Command	**AT+PRSP hIdx, [Y|y|N|n]** **AT+PRSP hIdx, 32HexDigitNumber** **AT+PRSP hIdx, nnn**
Description	If pairing I/O capability is appropriately set via writable numeric parameter 107 so that this module has a user-interface to expedite an authenticated pairing (as opposed to Just Works), then during the pairing process (which is initiated by the AT+PAIR command), if the peer device also has pairing capability, then the variant of this command to use is as per the response as follows: ▪ *showcode hIdx code* :: AT+PRSP hIdx, [Y|y|N|n] ▪ *comparecode hIdx code* :: AT+PRSP hIdx, [Y|y|N|n] ▪ *passkey? hIdx* :: AT+PRSP hIdx, nnn ▪ *oobkey? hIdx* :: AT+PRSP hIdx, 32HexDigitNumber ▪ *lescoob*? hIdx :: AT+OOBR hIdx, oob_hash, oob_rand ▪ *xxkey? hIdx* :: AT+LDSC hIdx Where hIdx is the same value as per supplied in the response from the module: ▪ [Y|y|N|n] – One of those four single characters to imply a Yes or No. ▪ Nnn – An integer value in the range 0 to 999999 ▪ 32HexDigitNumber – A hexadecimal string consisting of exactly 32 characters. If *xxkey?* was received which will be unexpected, then the best action is to disconnect and exists to future proof the device just in case a future Bluetooth specification adds a new type of pairing authentication mechanism. If a connection is denied upon processing of an AT+PRSP request, the connection will immediately be dropped.
Possible Responses	OK ERROR

4.12 Out of Band Pairing Commands

4.12.1 AT+OOBL

Command	**AT+OOBL**
Description	Used to retrieve the local LESC OOB data from the underlying stack to pass to the remote radio via OOB means.
Possible Responses	OL:local_address, oob_hash, oob_rand ERROR

4.12.2 AT+OOBR

Command	**AT+OOBR remote_address, oob_hash, oob_rand**
Description	Used to submit remote address, OOB_hash, and OOB_rand to the underlying stack for use in future LESC OOB pairing. These values should be received from the remote device via OOB means.
Possible Responses	OK ERROR

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4.13 SIO commands

Note: Refer to [K] for examples of SIO commands being used.

4.13.1 AT+SIOC

Command	**`AT+SIOC sionumber, function, subfunction`**
Description	The module Signal Input/Output (SIO) pins may have their functionality configured at run-time using this command. ***sionumber*** is a value in the range 1 to N which identifies the signal pin number ***function*** is the SIO function required ***subfunction*** is the SIO function context specific feature that is required. **Note:** Refer to **[K]** for details of the features supported by each Lyra variant SIO. Refer to **[K]** for details of the function and sub-function codes. Refer to **AT+UFU** for more details on how to configure and use SIOs in User Functions.
Possible Responses	`OK` `ERROR`

4.13.2 AT+SIOR

Command	**`AT+SIOR sionumber`**
Description	SIOs configured for Digital Input or AD operation can have their state queried with this command. ***sionumber*** is a value in the range 1 to N which identifies the signal pin number If configured as a Digital Input, 0 or 1 are returned to indicate a low or high logic level. For an SIO configured for AD operation, the returned value represents the number of counts read by the Lyra 12-bit AD converter. This is referenced to the supply voltage, as configured via writable numeric parameter 217. To convert this value to voltage data, the following formula should be used: *Vout = (4096 / Vsupply) x (returned AD counts)* The integer value returned has a starting \n character and ending \r character.
Possible Responses	`OK` `ERROR`

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4.13.3 AT+SIOW

Command	**`AT+SIOW sionumber, val`**
Description	SIOs configured for Digital Output, Frequency or PWM operation can have their state set using this command. ***sionumber*** is a value in the range 1 to N which identifies the signal pin number ***val*** is the value to apply to the SIO If configured as a Digital Output, a value of 0 sets a logic low level and a value of 1 a logic high level. If configured as a Frequency pin, values of up to 1000000 are permitted here to set the corresponding frequency in Hz on the SIO. If configured as a PWM pin, values of 0 to 100 are permitted here to set the corresponding duty cycle percentage on the SIO. Note that the PWM frequency is fixed to 10kHz.
Possible Responses	`OK` `ERROR`

4.14 SPI commands

SPI is a minimum three-wire serial protocol. It facilitates communication between host microcontrollers and external peripheral devices. The SPI connections are defined as follows.

- CIPO: This is the Controller In Peripheral Out pin, used to clock data into the Controller
- COPI: This is the Controller Out Peripheral In pin, used to clock data into the Peripheral
- CS: Each peripheral device has a Chip Select pin that is driven by the Controller to select the Peripheral device for communication on the SPI bus
- SCK: This is permanently configured as an output by the host microcontroller. It is used to clock individual data bits into the controller and peripheral devices.

Note: Prior to usage of the SPI commands, the appropriate SIO configuration is required using the **AT+SIOC** commands.

Note: CS SIOs should be configured prior to SPI CIPO, COPI and SCK SIOs.

Note: Refer to [K] for examples of SPI commands being used.

The following commands are used to perform SPI Controller operations on SPI Peripheral devices.

4.14.1 AT+SPR

Command	**`AT+SPR id, hexDataString, outLength`**	
Description	This command is used to perform an SPI read operation.	
	Id	The SPI device instance configured via the AT+SIOC command with SPI CS1 or CS2 argument, with a value of 1 indicating the device at CS1 and a value of 2 indicating the device at CS2
	hexDataString	This is the hexadecimal data sent to the device
	outLength	This is the number of bytes to read back from the device.
Possible Responses	`OK` `ERROR`	

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4.14.2 AT+SPW

Command	**AT+SPW id, hexDataString**
Description	This command is used to perform an SPI write operation. **Id** — The SPI device instance configured via the AT+SIOC command with SPI CS1 or CS2 argument, with a value of 1 indicating the device at CS1 and a value of 2 indicating the device at CS2 **hexDataString** — This is the hexadecimal data sent to the device.
Possible Responses	OK ERROR

4.15 Transmit Power commands

4.15.1 AT+REG

Command	**AT+REG reg**
Description	This command is used to set the required regulatory region for Lyra 24 modules. Until set, the module will operate at a power level suitable for use in all regulatory regions. Notes: • This may be lower than the maximum allowable level for the region where the module is intended for use. • Setting this value to an incorrect regional setting may violate regulatory limits within the region where the module is in use. • Attempting to set this while the radio is active will produce an error. Ensure the radio is not advertising or connected before issuing this command. **reg** — The required regulatory region, allowable values as follows. • GL – Global, valid for all regulatory regions • EU – Europe (CE) • UK – UK (UKCA) • US – North America / Canada (FCC/ISED) • CA – Canada (ISED) • AU – Australia (RCM) • NZ – New Zealand (RCM) • JP – Japan (MIC ARIB STD-T66) • SK – South Korea (KC)
Possible Responses	OK ERROR

4.15.2 AT+TXPO

Command	**AT+TXPO** **AT+TXPO hIdx**
Description	This command is used to query the default transmission power for connections.

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	The transmit power for an active connection is returned when the optional parameter ***hIdx*** is provided. This specifies the connection handle to query the active transmission power for.

Possible Responses	`OK`
	`ERROR`
	`TXPO`

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4.16 User Function commands

User Functions allow an AT Command string to be associated with a system event.

Event types can be divided into the following three categories.

- SIO events: SIO events are associated with various logic states being applied to SIOs that support event generation. Before an SIO can be used in a User Function, it must be configured for User Function behaviour via the **AT+SIOC** command.
- BLE events: BLE events are associated with BLE connections being opened and closed.
- Boot events: This event is trigged each time the application starts.

Note: Refer to **[K]** for examples of User Function commands being used.

Note: Refer to **[K]** for details of the SIOs that allow User Function behaviour association.

Note: Refer to **[K]** for details of the available events.

The following command is used to configure a User Function.

4.16.1 AT+UFU

Command	**AT+UFU id, commandDataString**	
Description	**Id**	This is the id of the user event with which to associate the passed AT Command string. Refer to **[K]** for details of the available event IDs.
	commandDataString	This is the AT Command to execute upon occurrence of the associated event.
Possible Responses	OK ERROR	

Note: User Functions can be disabled by sending an AT Command parameter set to “0” with the id of the event to be disabled.

Note: Only one AT Command can be associated with each user function.

Note: The number of user functions that can be configured is limited by the number of characters consumed by the AT Command parameters configured. A total of 320 bytes of storage are available for storing AT Command parameters.

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4.17 VSP commands

4.17.1 ATD

Command	**ATD <L> address**
Description	Make a VSP connection, with a peripheral latency of 0, to the device identified by 'address' which is a 14-digit hex string like for example 000016A40B1623. To make a non-VSP connection the command AT+LCON should be used. If the optional parameter 'L' is present, the connection attempt will be made using LECODED PHY. The following writable numeric parameter values are used to expedite the connection: 110 Connection timeout (wait this long for peer to accept) 206 Link supervision timeout 300 Minimum connection interval 301 Maximum connection interval These values should be adjusted prior to initiating a connection using the ATS command. The AT parser is suspended upon the VSP connection being established, until either a "CONNECT" or a "NOCARRIER" response is sent. Please note this is one of the few commands that is NOT terminated by an OK or ERROR response. If for example, the address specified is not exactly a 14-digit hex string then the NOCARRIER response will be sent.
Possible Responses	CONNECT… NOCARRIER

4.17.2 AT+LVSP

Command	**AT+LVSP**
Description	When in non-VSP mode, this command sets the module into VSP mode. This means if the VSP service is not already installed in the GATT table, it will be installed.
Possible Responses	OK ERROR

4.17.3 ^

Command	**^**
Description	When in a VSP connection and writable numeric parameter 109 is set to -1, the VSP connection can be dropped by sending instances of this character. The number of ^ characters required to trigger a disconnection is set via writable numeric parameter 111. At least three instances of the character must be sent by the host, with intervening delays of at least the time specified in writable numeric parameter 210 between each instance of the character. Writable numeric parameter 210 is defaulted to 250 milliseconds. This may need to be increased to ensure that the probability of unintended connection drop is lower than what it is when set to the default value of 4 for writable numeric parameter 111.

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	The purpose of the intervening delay is to ensure that normal data transfer containing consecutive ^ characters does not induce a disconnection.
Possible Responses	`NOCARRIER`

4.18 Module Management commands

4.18.1 ATZ

Command	`ATZ`
Description	Restart the module by performing a warm reset.
Possible Responses	`OK`

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5 RESPONSES

To simplify reception of messages in the receiving device, each message starts with a \n character and ends with a \r character, and may contain additional embedded \n characters, where \n is the linefeed character with ASCII code 0x0A and \r is the carriage return characters with ASCII code 0x0D.

After stripping the \n start character, each response will start with a unique 2-character sequence to help the host decode the response quicker in a stateless manner.

Some responses are synchronous which mean they are used to terminate a command so that the command parser can process more commands.

5.1.1 Response: Synchronous and Terminating

When a host receives these responses, it can issue new commands and expect them to be processed immediately.

5.1.1.1 CONNECT

```
CONNECT 0, address, interval, sprvsnTout, latency
```

The command ATD has successfully created a VSP connection to the device with Bluetooth ***'address'*** where the connection interval is ***'interval'*** which is in microseconds, ***'sprvsnTout'*** is the link supervision timeout in microseconds and ***'latency'*** is the peripheral latency.

The first parameter will always be 0 as that handle index is dedicated for VSP connections.

5.1.1.2 ERROR

```
ERROR nn
```

A command was not successfully actioned and 'nn' is an error code. Error Codes are as follows.

01	Invalid Parameter number
02	Value supplied is out of range
05	Syntax Error
09	Invalid Address has been supplied
14	Command cannot be processed in current state
15	Unknown Command
33	Value supplied is not valid
46	GPIO specified is not available
47	Too few parameters supplied
48	Too many parameters supplied
49	Hex String is not valid
50	Save Fail
51	Restore Fail
52	VSP open fail
53	Invalid Advert Type
54	Invalid UUID
55	Service Not Ended
56	Characteristic Not Ended
57	Service Not Started
58	Too Many Characteristics
59	Characteristic Not Started
62	Directed advert but peer address is missing
63	Invalid Channel Mask
64	Invalid Advert Reports
65	Invalid Advert Report Data
66	Invalid Advert Report Data Size
67	Invalid out of band (OOB) data

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68	Newline character was expected but was not found
71	I2C Pin Already Defined
74	PWM Channel Overflow
75	Wrong GPIO Type
77	Frequency Channel Overflow
79	AD Channel Overflow
82	Command Pin State incorrect
99	Functionality not coded

5.1.1.3 NOCARRIER

```
NOCARRIER 0
```

The command ATD has failed to establish a VSP connection.

'i' is an integer number which is the error code describing the failure as follows:

Value	Description
6	PIN or link key missing
7	memory capacity exceeded
8	connection timed out
19	remote user terminated connection
20	remote user terminated connection due to low resources
21	remote user terminated connection due to power off
22	local user terminated connection
30	Invalid LMP parameters
31	Unspecified error
34	LMP response timed out
36	LMP PDU not allowed
58	Controller busy
59	Connection interval unacceptable
61	MIC failure
62	Connection failed to be established
80	BleConnect function returned an error
81	Invalid address
82	Command pin state
83	Too many connections
84	Timeout
85	Out of memory
86	Unencrypted
87	No VSP service
88	Expected pairing process input was not received
90	User disconnected
91	Authenticated link required

5.1.1.4 OK

```
OK
```

A command was successfully processed.

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5.1.2 Response: Synchronous & Not Terminating

When a host receives these responses, it cannot issue new commands and expects them to be processed immediately as a terminating response is still to come.

5.1.2.1 TM:S

```
TM:S:i, (j), HHHHHHHH
```

AT+GCTM command in progress and this specifies details of an attribute in a remote table that contains a Service attribute.

'i' is an integer number which is the attribute handle.

'j' is an integer number which is the last attribute handle in this service

'HHHHHHHH' is an 8-digit hex value corresponding to a UUID handle. If the first 4 HHHH is 'FE01' then it is a Bluetooth SIG adopted UUID and the 16-bit value is the next 4 digits.

5.1.2.2 TM: C

```
TM: C:i, 000000PP, HHHHHHHH, 0
```

AT+GCTM command in progress and this specifies details of an attribute in a remote table that contains a Characteristic attribute.

'i' is an integer number which is the handle for the value attribute.

'HHHHHHHH' is an 8-digit hex value corresponding to a UUID handle. If the first 4 HHHH is 'FE01' then it is a Bluetooth SIG adopted UUID and the 16-bit value is the next 4 digits.

The final '0' is for future use and is related to included services.

Note the one space between the first ':' and the 'C'

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5.1.2.3 TM: D

```
TM:  D:i, HHHHHHHH
```

AT+GCTM command in progress and this specifies details of an attribute in a remote table that contains a Descriptor attribute.

'i' is an integer number which is the attribute handle.

'HHHHHHHH' is an 8-digit hex value corresponding to a UUID handle. If the first 4 HHHH is 'FE01' then it is a Bluetooth SIG adopted UUID and the 16-bit value is the next 4 digits.

Note the two spaces between the first ':' and the 'D'

5.1.2.4 ADAD

```
ADAD:advSet, address
```

This response is emitted after the AT+ADAD command has been used to query the advertising address and contains the requested advertising address, if no advertising set was provided then the value of 'advSet' will be '*'

5.1.2.5 TXPO

```
TXPO:hIdx, power
```

This response is emitted after the AT+TXPO command has been used to query the transmission power and contains the requested value, if no connection handle was provided then the value of 'hIdx' will be '*', the resultant power level is in dBm.

5.1.2.6 CSEC

```
CSEC:hIdx, flags, secMode, secLevel
```

This response is emitted after the AT+CSEC command has been used to query the connection security and contains the requested details, 'flags' is in hexadecimal format and consist of the following bitmask values:

Bit	Value	Description
0	0x1	Device is in central mode for connection
1	0x2	A bond exists in the bond database for this address
2	0x4	The connected device is encrypted using the data in the bond database
3	0x8	Encryption for this connection is enabled
4	0x01	MITM for this connection is enabled
5	0x20	LESC for this connection is enabled

'secMode' refers to the security mode of the connection and security level refers to the security level of the connection, which can be one of the following:

Mode	Level	Description
1	1	Open (no security/encryption)
1	2	Encrypted link, no MITM protection
1	3	Encrypted link with MITM protection
1	4	LESC 128-bit key encrypted link with MITM protection
2	1	Signed or encrypted link, no MITM protection
2	2	Signed or encrypted link with MITM protection

5.1.2.7 ENCRYPT

```
ENCRYPT
```

The command ATD is in progress and has reached the encrypted state before final confirmation which will be the "CONNECT" response.

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5.1.3 Response: Asynchronous

A host must be designed to expect any of these responses at any time. To help with enabling a host to be as stateless as possible, all these responses have a unique 2 letter starting sequence to quickly determine what it means and how it gets processed.

5.1.3.1 AB

```
AB:hIdx, respcode
```

This is triggered when the AT+GCRD command attempts to read the content of an attribute in a remote GATT table and it is successful, but it fails to store that content locally. RespCode is a value that can referenced in the Laird Connectivity utility UwTerminalX.

5.1.3.2 AD

```
AD0:t addr14hex rssi "name"
AD1:t addr14hex rssi "name"
ADE:t addr14hex rssi "name"
ADS:t addr14hex rssi "name"
```

These messages happen asynchronously when scanning for advertisements.

- The 'AD1' variant is when scanning using the AT+LSCN command while waiting for an incoming VSP connection.
- 'ADE' response is when an extended advert report has arrived.
- 'ADS' response is when an extended scan report has arrived.
- 't' is the advert type which will be 0 to 3 as per the Bluetooth specification where 0 implies that advert is connectable and is always 0 (and has no meaning) when the response is 'ADE' or 'ADS'
- 'addr14hex' is a hex string exactly 14 characters long that is the address present in the advert and the first 2 characters are used to determine the type (such as resolvable, static, etc.).
- 'rssi' is the RSSI of the received packet and will usually be a value between abut -30 and -100. Lower values indicate weaker signal.
- ' "name" ' is the device name if it has been supplied in the advert.

None of the other AD elements are displayed. If that information needs to be displayed, the AT+SFMT 1 command should be used to force all the data in an advert to be sent in the response as a hex string. Be aware that extended adverts can have a payload as large as 255 bytes and so in that case the response will be at least double that.

See function HndlrAdvReport00(). This function is called each time an advert report is received (look for the 'print' statement).

5.1.3.3 AE

```
AE:
```

When adverts are started with AT+EADV and the 'maxCount' parameter is non-zero, then this async response is sent when those many adverts have been sent and advertising is automatically stopped.

5.1.3.4 AK

```
AK:i
```

An indication that was initiated using the command AT+GSIC has been acknowledged and 'i' is the index of the characteristic that was indicated, and to recap 'i' was provided when the characteristic had been entered into the local GATT table using the command AT+GSCE.

5.1.3.5 AR

```
AR:hIdx, offset, hexDataString
```

This is triggered when the AT+GCRD command is used to read the content of an attribute in a remote GATT table and it successfully reads it. Here, 'hIdx' is the connection handle index, 'offset' is the offset that was requested when the read was requested and 'hexDataString' is the data in hex string format.

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5.1.3.6 AS

```
AS:hIdx, erStatus
```

This is triggered when the AT+GCRD command is used to read the content of an attribute in a remote GATT table and it fails. Here, 'hIdx' is the connection handle index, 'erStatus' is the reason for the failure and will be an integer value as follows:

Hex	Dec	Description
0x0001	1	Unknown or not applicable status
0x0100	256	Invalid error code
0x0101	257	Invalid attribute handle
0x0102	258	Read not permitted
0x0103	259	Write not permitted
0x0104	260	Used in ATT as invalid PDU
0x0105	261	Authenticated link required
0x0106	262	Used in ATT as request not supported
0x0107	263	Offset specified was pas the end of the attribute
0x0108	264	Used in ATT as insufficient authorisation
0x0109	265	Used in ATT as prepare queue full
0x010A	266	Used in ATT as attribute not found
0x010B	267	Attribute cannot be read or written using read/write blob requests
0x010C	268	Encryption key size used is insufficient
0x010D	269	Invalid value size
0x010E	270	Very unlikely error
0x010F	271	Encrypted link required
0x0110	272	Attribute type is not a supported grouping attribute
0x0111	273	Encrypted link required
0x0112	274	Reserved for Future Use – Range 1 begin
0x017F	383	Reserved for Future Use – Range 1 end
0x0180	384	Application range begin
0x019F	415	Application range end
0x01A0	416	Reserved for Future Use – Range 2 begin
0x01DF	479	Reserved for Future Use – Range 2 end
0x01E0	480	Reserved for Future Use – Range 3 begin
0x01FC	508	Reserved for Future Use – Range 3 end
0x01FD	509	Profile and Service Error: (CCCD) improperly configured
0x01EE	510	Profile and Service Error: Procedure already in progress
0x01FF	511	Profile and Service Error: Out of range

5.1.3.7 AW

```
AW:hIdx, status
```

This is triggered when the AT+GCWA command is used to write the content of an attribute in a remote GATT table and demonstrates the outcome of that attempt. Here, 'hIdx' is the connection handle index, 'status' is an integer value which will be 0 for success otherwise a value as listed in the section for the "AS" response.

5.1.3.8 CC

```
CC:i, newValue
```

This message happens asynchronously when a remote GATT client writes into a CCCD descriptor of one of the local characteristics identified by 'i', which was provided as a result of AT+GSCE when the characteristic was created and committed. The parameter 'newValue is an integer.

See responses 'WR' and 'SC' when the Characteristic Value and Sccd are written.

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5.1.3.9 CONNECT

```
CONNECT 0, address, interval, sprvsnTout, latency
```

For a device waiting for an incoming VSP connection, this is an asynchronous message to confirm that a connection is fully setup from a device with Bluetooth 'address' where the connection interval is 'interval' in microseconds, 'sprvsnTout' is the link supervision timeout in microseconds and 'latency' is the peripheral latency.

The first parameter will always be 0 as that handle index is dedicated for VSP connections.

Note: Lower case 'connect' implies a non-VSP connection.

5.1.3.10 connect

```
connect hIdx, address, interval, sprvsnTout, latency
```

For a device waiting for an incoming non-VSP connection this is an asynchronous message to confirm that a connection is setup from a device with Bluetooth 'address' where the connection interval is 'interval' in microseconds, 'sprvsnTout' is the link supervision timeout in microseconds and 'latency' is the peripheral latency.

The first parameter 'hIdx' is the handle index which are non-zero and dedicated for non-VSP connections.

Note: An upper case 'CONNECT' implies a VSP connection.

5.1.3.11 discon

```
discon hIdx, reason
```

This indicated that the connection identified by the handle hIdx has been dropped and the reason for disconnection is specified by the integer value 'reason'.

5.1.3.12 encrypt

```
encrypt hIdx
```

This indicates that the connection identified by the handle hIdx has entered the encrypted state.

5.1.3.13 FC

```
FC:hIdx, hAttr, props
```

This is triggered by the AT+GCFA command to search for a characteristic's attribute handle. 'hIdx' is the connection handle index, 'hAttr' is handle of the attribute if found, otherwise it will be 0. 'Props' is the property bitmask of that characteristic.

Note: hAttr==0 if characteristic not found.

5.1.3.14 FD

```
FD:hIdx, hAttr
```

This is triggered by the AT+GCFA command to search for a descriptor's attribute handle. ***'hIdx'*** is the connection handle index, ***'hAttr'*** is handle of the attribute if found, otherwise it will be 0.

Note: ***hAttr*** is set to 0 if descriptor not found.

5.1.3.15 IN

```
IN:hIdx, hAttr, hexDataString
```

This message happens asynchronously when a remote GATT server sends this device a notification or an indication where ***'hIdx'*** identifies the server connection, ***'hAttr'*** is the handle of the attribute that got updated with the new data in ***'hexDataString'*** which is hexadecimal format.

Note: If it is an indication then a GATT acknowledgement has been automatically sent.

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5.1.3.16 NOCARRIER

```
NOCARRIER 0
```

While pairing if the I/O capability (writable numeric parameter 107) is appropriate and the other end also has a user interface, then this could be sent to the host to request a 32 hex characters string which it then submits using the AT+PRSP command.

5.1.3.17 passkey

```
passkey? hIdx
```

While pairing if the I/O capability (writable numeric parameter 107) is appropriate and the other end also has a user interface, then this could be sent to the host to request an integer value in the range 0 to 999999 which it then submits using the AT+PRSP command.

'hIdx' identifies the server connection.

5.1.3.18 oobkey

```
oobkey? hIdx
```

While pairing if the I/O capability (writable numeric parameter 107) is appropriate, then this could be sent to the host to request an out-of-band (OOB) key which it then submits using the AT+PRSP command.

'hIdx' identifies the server connection.

5.1.3.19 lescoob

```
lescoob? hIdx
```

While pairing if the I/O capability (writable numeric parameter 107) is appropriate, then this could be sent to the host to request an out-of-band (OOB) LESC key which it then submits using the AT+OOBR command.

'hIdx' identifies the server connection.

5.1.3.20 xxkey

```
xxkey? hIdx
```

This response indicates an unsupported authentication type during paring.

'hIdx' identifies the server connection.

5.1.3.21 RING

```
RING address, [U|T]
```

When waiting for a VSP connection, this message is the first indication to the host that a connection is in progress from a device with Bluetooth 'address'.

The ***[U|T]*** implies either a 'U' which implies that the 'address' is not in the trusted device bond database or a 'T' which implies the incoming VSP connection is from a trusted device.

5.1.3.22 SC

```
SC:i, newValue
```

This message happens asynchronously when a remote GATT client writes into a SCCD descriptor of one of the local characteristics identified by 'i', which is provided as a result of AT+GSCE when the characteristic was created and committed.

The parameter ***'newValue'*** is an integer.

See responses 'WR' and 'CC' when the Characteristic Value and CCCD are written.

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5.1.3.23 showcode

```
showcode hIdx, passcode
```

While pairing, if the I/O capability (writable numeric parameter 107) is appropriate and the other end also has a user interface, then this could be sent to the host to display the integer value ***'passCode'*** as a 6-digit decimal number with trailing 0's so that a 6-digit number is shown, where ***'hIdx'*** identifies the server connection. This end needs to confirm with a Yes or No to complete the pairing using the command AT+PRSP. **Note that this is a passkey entry only and is not for LESC numerical comparison**, the two events are different, numerical comparison events will come through as comparecode (described below)

5.1.3.24 comparecode

```
comparecode hIdx, comparisonCode
```

While pairing, if the I/O capability (writable numeric parameter 107) is appropriate and the other end also has a user interface, then this could be sent to the host to display the integer value ***'comparisonCode'*** as a 6-digit decimal number with trailing 0's so that a 6-digit number is shown, where ***'hIdx'*** identifies the server connection. This end needs to confirm with a Yes or No to complete the pairing and that is done using the command AT+PRSP. **Note that this is an LESC numerical comparison entry only and is not for passkey entry**, the two events are different, passkey events will come through as showcode (described above)

5.1.3.25 scanned

```
scanned
```

When waiting for an incoming VSP connection it is possible to also scan for adverts for a specified interval using the command AT+LSCN which will then trigger advert report "AD". When the scan times out, this response will be sent to the host.

5.1.3.26 WR

```
WR:i, hexDataString
```

This message happens asynchronously when a remote GATT client writes into one of the local characteristics identified by ***'i'*** which was provided as a result of AT+GSCE when the characteristic was created and committed.

The parameter ***'hexDataString'*** is the new data that was written into the characteristic.

See responses 'SC' and 'CC' when the SCCD and CCCD are written.

5.1.3.27 LL

```
LL:hIdx, txrxTimeReducedBy, txSizeReducedBy, rxSizeReducedBy
```

This message happens asynchronously when the packet length or transmission/reception time has been limited due to constraints of the local or remote device.

The time value '***txrxTimeReducedBy'*** is in us and the size values ***'txSizeReducedBy'*** and ***'rxSizeReducedBy'*** are in bytes, ***'hIdx'*** identifies the connection.

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5.1.3.28 PI

```
PI:hIdx, code, source, hexFlags, hexSecurityModeLevels
```

This message happens asynchronously when a pairing has been successful or failed and includes details of it.

'hIdx' identifies the connection, ***'code'*** indicates success if 0, otherwise failure (if a failure has occurred, all other fields should be ignored), ***'source'*** is unused by Lyra and fixed to 0, ***'hexFlags'*** is a bitmask field in hex format with the following bit values:

Bit	Value	Description
0	0x1	Bonded
1	0x2	*Reserved for future use*
2	0x4	LESC pair/bond

'hexSecurityModeLevels' is a bitmask field in hex format with the following bit values:

Bit	Value	Description
0	0x1	Security mode 1, level 1: No security, open link
1	0x2	Security mode 1, level 2: Encrypted link, without MITM protection
2	0x4	Security mode 1, level 3: Encrypted link, with MITM protection
3	0x8	Security mode 1, level 4: Encrypted LESC link with 128-bit encryption key, with MITM protection
4	0x10	Security mode 2, level 1: Signed or encrypted link, without MITM protection
5	0x20	Security mode 2, level 2: Signed or encrypted link, with MITM protection

5.1.3.29 SR

```
SR:hIdx, hexFlags
```

This message happens asynchronously when a remote peripheral device has issued a security request, this should be responded to by pairing/authenticating/disconnecting using AT+PAIR, AT+LENC or AT+LDSC.

'hIdx' identifies the connection, ***'hexFlags'*** is a bitmask field in hex format with the following bit values:

Bit	Value	Description
0	0x1	Bonding is supported
1	0x2	MITM is supported
2	0x4	LESC is supported
3	0x8	*Reserved for future use*
4	0x10	Key press generation events are supported

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5.1.3.30 CP

```
CP:hIdx, initiator, hexFlags, ioCap, minKeySize, maxKeySize
```

This message happens asynchronously during a pairing/bond process when the process needs to be confirmed due to the confirm pairing status, which was set using AT+PCFG, this needs to be responded to by using the AT+PCNF command to accept or decline the pairing. 'hIdx' identifies the connection, 'initiator' indicates the device that started the process which will be 0 for the local device and 1 for the remote device, 'hexFlags' is a bitmask field in hex format with the following bit values:

Bit	Value	Description
0	0x1	Bonding is supported
1	0x2	MITM is supported
2	0x4	LESC is supported
3	0x8	OOB is supported
4	0x10	Key press generation events are supported

'ioCap' describes the input/output capability of the device:

Value	Description
0	No input/output capability (just works)
1	Display with yes/no input
2	Keyboard only
3	Display only
4	Keyboard with display

'minKeySize' is the minimum size of the encryption key that the remote device supports in bytes (or 0 if encryption is not supported), ***'maxKeySize'*** is the maximum size of the encryption key that the remote device supports in bytes.

5.1.3.31 MT

```
MT:hIdx, vspChunkLen
```

This message happens asynchronously after an MTU exchange has occurred.

'hIdx' identifies the connection, ***'vspChunkLen'*** is the maximum size of on-air VSP messages in bytes.

5.1.3.32 PU

```
PU:hIdx, txPhy, rxPhy
```

This message happens asynchronously when a PHY update has succeeded.

'hIdx' identifies the connection, ***'txPhy'*** and ***'rxPhy'*** specify what the new PHY is for the connection as per:

Value	Description
1	1M PHY
2	2M PHY
3	*500Kbps* LE Coded PHY – this is not supported
4	125Kbps LE Coded PHY

5.1.3.33 PF

```
PF:hIdx, status
```

This message happens asynchronously when a PHY update has failed.

'hIdx' identifies the connection, ***'status'*** is the error for the PHY request/update not being successful.

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6 Low Power UART Operation

The Lyra AT Interface application requires a host to control it by sending AT commands over the UART interface. It operates like a modem where the data is relayed over a virtual serial connection in a BLE connection.

The UART interface that is embedded inside the microcontroller at the heart of the Laird Connectivity module consumes about 1 milliamps when it is open.

Laird Connectivity has shown that it is possible to operate the module in **doze** mode so that the total current consumption can be as low as sub 3 microamps.

BLE is a low power radio technology and the radio chip has been optimised so that in-between radio events it can go to sleep and so a typical power profile can be shown to be doze current of sub 10uA and then about 8000 microamps when there is a radio event which can be of duration from a few 10s of microseconds to over 1000 microseconds and the radio event can occur as quickly as 7500 microseconds and as slow as over 4000000 microseconds. This shows that the duty cycle of low to high power provides for overall low average current consumption.

When the AT Interface application is loaded in the module, it by necessity requires that the UART is in operation and so the average quiescent current is going to be in the region of 1 milliamps instead of the expected sub 3 microamps.

It is possible to enable a mode so that it will operate such that the UART is disabled when data is not being exchanged with the host.

This requires a **cooperative** existence with the host which means an extra GPIO line connected between the host and the module is used to manage the open/close operation of the module's UART.

This GPIO, which is a digital output from the UART host, which for convenience in this guide, will be called the 'Keep UART Open' line and can be changed via writable numeric parameter 109 using the command ATS109=X where X is the new GPIO line. Note that writable numeric parameter 109 is also used to specify the 'drop connection' line when in fast VSP connection mode. For the 'Keep UART Open' SIO to behave in Low Power UART mode, writable numeric parameter 213 must be configured for a value of 250 or greater. If less than this, the 'Keep UART Open' line will be used to drop VSP connections.

The AT Interface firmware monitors the 'Keep UART Open' SIO. If high then it will NOT try to close the UART automatically. If low, and the time configured in writable numeric parameter 213 is exceeded, the UART is closed to reduce the current consumption.

When the UART is automatically shut down, it will de-assert the RTS line which is a signal to the serial port in the host that it should stop sending data. If the host sees that the module's RTS is de-asserted (which it will detect via its own CTS input line) and that it has set the 'Keep UART Open' line low, then it can set that line high which will result in the RTS line being reasserted after the module reopens the UART and so that data can be received by the module.

In summary, low power operation is only available in normal throughput operation and requires an additional GPIO line output from the host that conveys a 'Keep UART Open' command to the module and RTS line from the module should be monitored for serial port status.

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7 APPENDIX A – REFERENCES

Ref	Details
[A]	Laird Connectivity Lyra P – Datasheet https://www.lairdconnect.com/documentation/datasheet-lyra-p
[B]	Laird Connectivity Lyra S – Datasheet https://www.lairdconnect.com/documentation/datasheet-lyra-s
[C]	Lyra Firmware GitHub – Software & Firmware Repository https://github.com/LairdCP/Lyra_Firmware
[D]	Lyra Series – Firmware Options and Upgrading (User Guide) https://www.lairdconnect.com/documentation/user-guide-firmware-options-and-upgrading-lyra-series
[E]	Lyra Series – How to Set Up a VSP Connection (Application Note) https://www.lairdconnect.com/documentation/application-note-how-set-vsp-commands-lyra-series
[F]	Lyra Series – Custom GATT Database (Application Note) https://www.lairdconnect.com/documentation/application-note-custom-gatt-database-command-set-lyra-series
[G]	Laird Connectivity Lyra 24 P – Datasheet https://www.lairdconnect.com/documentation/datasheet-lyra-24p
[H]	Laird Connectivity Lyra 24 S – Datasheet https://www.lairdconnect.com/documentation/datasheet-lyra-24s
[I]	Lyra 24 Firmware GitHub – Software & Firmware Repository https://github.com/LairdCP/Lyra_24_Firmware
[J]	Laird Connectivity – VSP & Custom BLE Serial Port Implementation and Specification https://www.lairdconnect.com/documentation/application-note-laird-custom-ble-serial-port-service
[K]	Laird Connectivity – Lyra, Lyra 24 & RM126x Peripheral Interface Guide https://www.lairdconnect.com/documentation/application-note-peripheral-interface-guide-lyra-lyra-24-and-rm126x-series

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8 Appendix B – Definitions, Abbreviations and Acronyms

Term	Definition
AD Element	**Starting indicator for a BLE advertisement block.** Advertisements are divided into blocks of information, with each block being indicated by an AD element.
ASCII	**American Standard Code for Information Interchange** Defined list of numeric codes used to represent textual characters.
CCCD	**Client Characteristic Configuration Descriptor** Means of allowing a BLE client to request Notification/Indications from the server.
CTS	**Clear To Send** UART flow control line used by a device to indicate it is ready to receive data.
GAP	**Generic Access Profile** BLE stack layer responsible for establishing and maintaining connections.
GATT	**Generic Attribute Profile** BLE stack layer responsible for exchange of data between devices.
GPIO	**General Purpose Input Output** Microcontroller pins available for function assignment.
LESC	**LE Secure Connections** Enhanced BLE security feature introduced in BLE v4.2.
OOB	**Out Of Band** Pairing mechanism where pairing credentials are provided in a different means other than the BLE connection.
RTS	**Request To Send** UART flow control line used to indicate when a device is ready to send data.
SIO	**Signal Input/Output** The Lyra module GPIOs available for usage.
UART	**Universal Asynchronous Receiver Transmitter** Established technology used to send and receive data in a serial manner
UUID	**Universally Unique Identifier** 16-bit (for pre-defined service) or 128-bit (for vendor defined service) number used to uniquely identify BLE services.
VSP	**Virtual Serial Port** BLE service where data is sent in a serial manner between two capable BLE devices.
Whitespace	Any non-printable character with an ASCII code of 0x20 and lower is treated as a whitespace character.

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