

INNOVATION
SOLUTIONS
TECHNOLOGY
EXPERIENCE

VOXTELOPTO



INNOVATION
SOLUTIONS
TECHNOLOGY
EXPERIENCE

SOFTWARE INTERFACE CONTROL DOCUMENT (ICD)

LASER RANGEFINDER MODULES, KITS, AND COMPONENTS



INNOVATION
SOLUTIONS
TECHNOLOGY
EXPERIENCE

INNOVATIVE PHOTONIC
SYSTEMS & DEVICES

EXPERIENCE

INNOVATION

FIRMWARE VERSION NOTICE

LRF firmware revisions are designed to be backwards compatible; however, some command sets vary between LRF firmware versions. This document supports the LRF firmware versions 2.3.16 and greater. The current LRF firmware is available for download at <http://voxtel-inc.com/voxtel-news/user-resources/>.

CONTENTS

Firmware Version Notice	2
Serial Settings	3
Serial Command Format	4
Command Strings	4
Response Strings	4
Parameter Values	4
Command Sets	1
LRF Command Set	1
Quick Reference List—LRF Command Set	1
Overview	2
Features for Configuration	2
General LRF Parameters	2
Multi-pulse Parameters	2
LRF System Configuration Commands	8
General LRF Parameters	8
Multi-Pulse Parameters	13
Parameter Save and Restore Commands	14
LRF Version Query Commands	14
Ranging	15
False-Alarm Rate Monitoring and Calibration	17
Auxiliary Functions	18
Error Codes	20
LRF Attitude and Heading Reference System (AHRS) Command Set	21
Quick Reference List—AHRS Command Set	21
AHRS Configuration	21
AHRS Measurement	23
Additional Guidance	24
Range-Walk Correction Parameters	24

SERIAL SETTINGS

To configure a device or PC to communicate with the LRF, input the serial communication protocol settings in Table 1.

The characters that appear on the serial terminal application can be echoed when using the LRF with a terminal application such as PuTTY.

To echo the characters on the serial terminal application window, set **Local Echo** to **Force On**.

Table 1. Serial Comm Protocol Settings

Settings	Value
Baud	57,600
Data bits	8
Stop bits	1
Parity	None
Flow control	None

SERIAL COMMAND FORMAT

COMMAND STRINGS

All command strings:

- Begin with a colon character followed by two ASCII command characters input as comma-separated arguments (command dependent).
- End with a carriage return character (<CR>).

Within a command string:

- <SP> indicates there is a space in the command or a space in the returned string of data.
- [] represents command parameters and returned values, where the brackets are replaced with the ASCII parameter or value string as shown in the command and response syntax for the particular command.

The general command string syntax is shown in Table 2.

RESPONSE STRINGS

For commands that are accepted:

- Response strings have the general form and syntax shown in Table 3.
- For commands that accept parameters with a range of possible values, the notation (X, Y) may be used to indicate a valid range of parameter values from X to Y, inclusive.

For commands that are not accepted:

- Response strings have the general form and syntax shown in Table 4.
- Errors for configuration commands are caused by command parameters that are outside the valid range.
- Errors for range commands are explained in the “Error Codes” section of this ICD.

Table 2. General Command String Syntax

Initial Character	ASCII Command		Comma Separated Arguments	Command Termination
:	XX	<SP>	Variable—see command syntax	<CR>

Table 3. General Response String Syntax

	Initial Character	ASCII Command		Comma Separated Response Data		Command Acceptance	
<CR><LF>	~	XX	<SP>	Variable—see response syntax	<SP>	OK	<CR><LF>

Table 4. Error Response String Syntax

	Initial Character	ASCII Command		Comma Separated Response Data		Error	
<CR><LF>	~	XX	<SP>	Variable—see response syntax	<SP>	ERROR	<CR><LF>

PARAMETER VALUES

All configuration commands can be issued with or without a parameter value:

- When a parameter value is not provided, the current value stored for that setting will be displayed.
- When a parameter value is provided:
 - If the value is valid, the current setting will be changed based on the parameter value and the OK response will be displayed.
 - If the value is not valid the current setting will not be changed, and the ERROR response will be returned.

COMMAND SETS

LRF COMMAND SET

QUICK REFERENCE LIST—LRF COMMAND SET

LRF SYSTEM CONFIGURATION COMMANDS

General LRF Parameters	
Enable/Disable Asynchronous Range Pin	8
Enable/Disable Range-Walk Correction.....	8
Enable/Disable Time-Variable Threshold	8
Select T0 Source	9
Set Capacitor Charge Time	9
Set Default False Alarm Rate	9
Set High-Voltage Threshold	10
Set Low-Voltage Threshold.....	10
Set Maximum Reported Range.....	10
Set Minimum Reported Range	10
Set Number of Reported Range Returns	11
Set Range Mode.....	11
Set Range-Offset Calibration	11
Set Range Reporting Mode.....	12
Set Range Result Units.....	12
Set Receiver Mode.....	12
Multi-Pulse Parameters	
Set Multi-Pulse Bin Adjacency	13
Set Multi-Pulse Threshold.....	13
Set Number of Multi-Pulse Laser Shots	13
Parameter Save and Restore Commands	
Restore Factory Defaults	14
Save User Settings	14
LRF Version Query Commands	
Get FPGA Firmware Version	14
Get LRF Software Version	14

RANGING

Continuous Range.....	15
Multi-Pulse Range.....	15
Multi-Pulse Range with Automatic Calibration ...	15
Single-Pulse Range.....	16
Single-Pulse Range with Automatic Calibration ..	16

FALSE-ALARM RATE MONITORING AND CALIBRATION

Calibrate False-Alarm Rate	17
Measure False-Alarm Rate.....	17

AUXILIARY FUNCTIONS

Enable/Disable High-Repetition-Rate Mode....	18
Enable/Disable Pulse Repetition Frequency	
Transmit Mode	18
Enable/Disable Sleep Mode.....	18
Read Laser Delay.....	19
Read Pulse Widths	19

ERROR CODES 20

OVERVIEW

FEATURES FOR CONFIGURATION

Voxtel LRF devices are preconfigured with generic known-good settings. Integration with other systems may require modification of one or more configuration parameters. The following LRF features are available for configuration:

GENERAL LRF PARAMETERS

Asynchronous Range Pin: Arm or disarm the asynchronous range pin (LRF_RANGE, pin 1).

Capacitor Charge Time: Sets the minimum time that capacitors are allowed to charge before a ranging cycle. This directly affects the duration of a multi-pulse ranging cycle.

Default False Alarm Rate (FAR): Sets a default FAR. This value is used with the **Single-Pulse Range with Automatic Calibration** command; or with a **Calibrate False-Alarm Rate** command that is issued without a parameter argument.

High Voltage Threshold: Only used with time-variable threshold (TVT) enabled. This is the starting threshold for a range cycle.

Low Voltage Threshold: If TVT is enabled, the voltage threshold transitions from the high threshold to the low threshold over a set period. If TVT is disabled, the low voltage threshold is always used.

Maximum Reported Range: Sets a maximum range for the device. Range measurements greater than this value will not be reported to the user.

Minimum Reported Range: Sets a minimum reported range for the device. Range measurements less than this value will not be reported to the user.

Number of Reported Range Returns: Sets the maximum number of range returns that will be reported during a single ranging cycle.

MULTI-PULSE PARAMETERS

Multi-Pulse Bin Adjacency: Sets the width of the bin averaging window. Bins that are spaced equally to or closer than the adjacency will be merged and averaged.

Range Mode: Sets the type of measurement performed by continuous or asynchronous ranging—single or multi pulse, with or without automatic FAR calibration.

Range Offset Calibration: Sets a static offset that is applied to all range results.

Range Reporting Mode: Sets the way in which range returns are processed and sorted—by range or signal strength.

Range Result Units: Sets the units of measure for the reported range results.

Range-Walk Correction: Enables range-walk correction for all ranging modes.

Receiver Mode: Sets the operating mode of the photoreceiver. For descriptions of available operating modes, see the [“ROX InGaAs Avalanche Photodiode \(APD\) Photoreceivers” datasheet](#).

T0 Source: Selects either the receiver or external input as the outgoing laser pulse (T0) source.

Time-Variable Threshold (TVT): Enables the TVT functionality, using an RC filter circuit in the photoreceiver. For all standard Voxtel LRF devices (i.e., not custom-configured), the time constant for transitioning from high to low threshold voltage is set to 2.6 μ s (custom-configured devices may vary).

Multi-Pulse Threshold: Sets the number of coincident range returns that will count as a range result.

Number of Multi-Pulse Laser Shots: Sets the number of times that the laser will fire during a multi-pulse ranging cycle.

LRF SYSTEM CONFIGURATION COMMANDS

GENERAL LRF PARAMETERS

Example code is provided in this section. Unless otherwise specified, all examples use the factory default settings.

ENABLE/DISABLE ASYNCHRONOUS RANGE PIN

Description Enables or disables the asynchronous range pin functionality. When the pin is armed, a rising edge on the asynchronous range pin (LRF_RANGE, pin 1) will trigger a range cycle, with output on the UART interface.

Command Syntax	:AR<SP> [On/Off] <CR>	
Command Parameter Values	Enable/disable asynchronous range pin	0 – Disable the range pin. 1 – Enable the range pin.
Command Example	:AR<SP>1<CR>	Arm the asynchronous range pin.
	:AR<CR>	Read the current range pin setting.
Response Syntax	<CR><LF>~AR<SP> [Arm/Disarm] <SP>OK<CR><LF>	
Response Values	Current range pin setting	
Response Example	~AR 1 OK	

ENABLE/DISABLE RANGE-WALK CORRECTION

Description Enables or disables range-walk correction for all LRF ranging modes.

Command Syntax	:RW<SP> [On/Off] <CR>	
Command Parameter Values	Range-walk correction	0 – Disable range-walk correction 1 – Enable range-walk correction
Command Example	:RW<SP>1<CR>	Enable range-walk correction.
	:RW<CR>	Read the current range-walk setting.
Response Syntax	<CR><LF>~RW<SP> [On/Off] <SP>OK<CR><LF>	
Response Values	Range-walk correction setting	
Response Example	~RW 1 OK	

ENABLE/DISABLE TIME-VARIABLE THRESHOLD

Description Enables or disables time-variable threshold. TVT lowers the voltage threshold over the course of the ranging cycle to compensate for the decreasing intensity of returns at longer ranges.

Command Syntax	:TV<SP> [On/Off] <CR>	
Command Parameter Values	Enable/Disable time variable threshold	0 – Disable time-variable threshold 1 – Enable time-variable threshold
Command Example	:TV<SP>1<CR>	Enable time-variable threshold.
	:TV<CR>	Read time-variable threshold setting.
Response Syntax	<CR><LF>~TV<SP> [On/Off] <SP>OK<CR><LF>	
Response Values	Current time-variable threshold setting	
Response Example	~TV 1 OK	

SELECT TO SOURCE

Description *Selects the source from which outgoing laser pulse (T0) is recorded. A setting of 0 uses the receiver for T0, and a setting of 1 uses an electrical T0 source. For systems sold with lasers that have an integrated T0 detector, the default setting is for an external electrical T0.*

Command Syntax	:XT<SP>[Source]<CR>	
Command Parameter Values	T0 source	0 – Receiver T0 1 – External, electrical T0
Command Example	:XT<SP>0<CR>	Use the receiver as a T0 source.
	:XT<CR>	Read the T0 source.
Response Syntax	<CR><LF>~XT<SP>[Source]<SP>OK<CR><LF>	
Response Values	Current T0 source setting	
Response Example	~XT 0 OK	

SET CAPACITOR CHARGE TIME

Description *Sets the time that the capacitors on the laser driver board are allowed to charge before a ranging cycle. This directly affects the maximum repetition rate for single-pulse ranging cycles and the duration of multi-pulse ranging cycles.*

Command Syntax	:CT<SP>[Charge Time]<CR>	
Command Parameter Values	Capacitor charge time	(1, 1000) ms
Command Example	:CT<SP>100<CR>	Set the capacitor charge time to 100 ms.
	:CT<CR>	Read the capacitor charge time.
Response Syntax	<CR><LF>~CT<SP>[Charge Time]<SP>OK<CR><LF>	
Response Values	Charge time in ms	
Response Example	~CT 100 OK	

SET DEFAULT FALSE ALARM RATE

Description *Sets the default false alarm rate. Any command that calibrates the false alarm rate will use this value, unless otherwise specified.*

Command Syntax	:UF<SP>[Default FAR]<CR>	
Command Parameter Values	Default false-alarm rate	(0, 100000) Hz
Command Example	:UF<SP>300<CR>	Set the default false-alarm rate to 300 Hz.
	:UF<CR>	Read the default false-alarm rate.
Response Syntax	<CR><LF>~UF<SP>[Default FAR]<SP>OK<CR><LF>	
Response Values	Default false-alarm rate	
Response Example	~UF 300 OK	

SET HIGH-VOLTAGE THRESHOLD

Description *Sets the starting voltage threshold for ranging with time-variable threshold. The high-voltage threshold is not used if TVT is disabled.*

Command Syntax	:TH<SP>[VthHi]<CR>	
Command Parameter Values	High Voltage Threshold	(0, 4095) DN One DN corresponds to 0.488mV.
Command Example	:TH<SP>1331<CR>	Set the high voltage threshold to 1331 DN.
	:TH<CR>	Read the high voltage threshold.
Response Syntax	<CR><LF>~TH<SP>[VthHi]<SP>OK<CR><LF>	
Response Values	High voltage threshold	
Response Example	~TH 1331 OK	

SET LOW-VOLTAGE THRESHOLD

Description Sets the ending voltage threshold for ranging with time-variable threshold. If TVT is disabled, the low-threshold value will be used for all ranging. The default low-voltage threshold values vary between systems.

Command Syntax	:TL<SP> [VthLo] <CR>	
Command Parameter Values	Low voltage threshold	(0, 4095) DN One DN corresponds to 0.488mV.
Command Example	:TL<SP>1024<CR>	Set the low voltage threshold to 1024 DN.
	:TL<CR>	Read the low voltage threshold.
Response Syntax	<CR><LF>~TL<SP> [VthLo] <SP>OK<CR><LF>	
Response Values	Low voltage threshold	
Response Example	~TL 1024 OK	

SET MAXIMUM REPORTED RANGE

Description Sets the maximum range at which range results will be reported in decimeters.

Command Syntax	:MR<SP> [Max Range] <CR>	
Command Parameter Values	Maximum range	(0, 640000) decimeters
Command Example	:MR<SP>150000<CR>	Set a maximum range of 150,000 decimeters.
	:MR<CR>	Read the max range.
Response Syntax	<CR><LF>~MR<SP> [Max Range] <SP>OK<CR><LF>	
Response Values	Max range	
Response Example	~MR 150000 OK	

SET MINIMUM REPORTED RANGE

Description Sets the minimum range, beyond which range results will be reported.

Command Syntax	:LR<SP> [Min Range] <CR>	
Command Parameter Values	Minimum range	(0, 640000) decimeters
Command Example	:LR<SP>200<CR>	Set a minimum range of 200 decimeters.
	:LR<CR>	Read the minimum range.
Response Syntax	<CR><LF>~LR<SP> [Min Range] <SP>OK<CR><LF>	
Response Values	Minimum range	
Response Example	~LR 200 OK	

SET NUMBER OF REPORTED RANGE RETURNS

Description Sets the maximum number of range returns, including T0, which will be reported by the **Single-pulse Range** command. This does not affect the number of returns reported by the **Multi-pulse Range** command. For example, a parameter value of 7 would mean that the LRF will process a T0 return and six additional returns.

Command Syntax	:MH<SP> [# Returns] <CR>	
Command Parameter Values	Number of reported range returns	(1, 20) range returns
Command Example	:MH<SP>7<CR>	Report 6 range returns.
	:MH<CR>	Read the number of reported range returns.
Response Syntax	<CR><LF>~MH<SP> [# Returns] <SP>OK<CR><LF>	
Response Values	Maximum number of reported range returns (including T0)	
Response Example	~MH 7 OK	

SET RANGE MODE

Description *Selects a range measurement type to be used for range measurements initiated by the **Continuous Range** command or the **Set Asynchronous Ranging Pin** command.*

Command Syntax	:RM<SP> [Measurement Mode] <CR>	
Command Parameter Values	Range measurement mode	0 – Single Pulse 1 – Multi Pulse 2 – Single Pulse with Automatic FAR Calibration 3 – Multi Pulse with Automatic FAR Calibration
Command Example	:RM<SP>1<CR>	Set the range mode for continuous and asynchronous ranging to Multi Pulse.
	:RM<CR>	Read the range mode.
Response Syntax	<CR><LF>~RM<SP> [Measurement Mode] <SP>OK<CR><LF>	
Response Values	Range measurement mode	
Response Example	~RM 1 OK	

SET RANGE-OFFSET CALIBRATION

Description *Sets a static offset, in decimeters, which is added to all range results.*

Command Syntax	:RC<SP> [Offset] <CR>	
Command Parameter Values	Range offset	(-32768, 32767) decimeters
Command Example	:RC<SP>-23<CR>	Apply a -2.3-meter offset to all range results.
	:RC<CR>	Read the range offset.
Response Syntax	<CR><LF>~RC<SP> [Offset] <SP>OK<CR><LF>	
Response Values	Range offset	
Response Example	~RC -23 OK	

SET RANGE REPORTING MODE

Description *Selects the way that range results are reported to the user. The default setting reports pulse returns in ascending order by range, from shortest to longest. The other two modes report by: signal strength; and signal strength normalized by range.*

Command Syntax	:RP<SP> [Reporting Mode] <CR>	
Command Parameter Values	Range reporting mode	Reports pulse returns in the following order: 0 – Ascending by range 1 – Descending by pulse width 2 – Descending by pulse width, normalized by range
Command Example	:RP<SP>0<CR>	Ranges reported in order of ascending range.
	:RP<CR>	Read the reporting mode.
Response Syntax	<CR><LF>~RP<SP> [Reporting Mode] <SP>OK<CR><LF>	
Response Values	Range offset	
Response Example	~RP 0 OK	

SET RANGE RESULT UNITS

Description *Selects the units in which range results are displayed. This does not affect the units in which maximum reported range or range offset are entered and read.*

Command Syntax	:RU<SP> [Units] <CR>	
Command Parameter Values	Range units	0 – Decimeters 1 – Centimeters 2 – Millimeters
Command Example	:RU<SP>0<CR>	Get range results in decimeter units.
	:RU<CR>	Read the range units.
Response Syntax	<CR><LF>~RU<SP> [Units] <SP>OK<CR><LF>	
Response Values	Range offset	
Response Example	~RU 0 OK	

SET RECEIVER MODE

Description *Selects one of the pre-programmed receiver gain modes. For more information about the receiver gain modes, see the [“ROX InGaAs Avalanche Photodiode \(APD\) Photoreceivers” datasheet](#).*

Command Syntax	:GN<SP> [Mode] <CR>	
Command Parameter Values	Receiver Gain Mode	0 – Maximum damage threshold (Mode 1) 1 – Optimum sensitivity at 60 Hz FAR (Mode 2) 2 – Custom programming (Mode 4) 3 – Optimum sensitivity at 15 kHz FAR (Mode 3)
Command Example	:GN<SP>1<CR>	Set the receiver for optimum sensitivity at 60 Hz FAR.
	:GN<CR>	Read the receiver mode.
Response Syntax	<CR><LF>~GN<SP> [Mode] <SP>OK<CR><LF>	
Response Values	Receiver Gain Mode	
Response Example	~GN 1 OK	

MULTI-PULSE PARAMETERS

SET MULTI-PULSE BIN ADJACENCY

Description Sets the maximum distance at which adjacent range-return bins are merged and averaged during multi-pulse ranging. Only bins adjacent to an over-threshold bin are merged. For example, with an adjacency of 2 meters, an over-threshold bin at 50 meters would be merged with bins at 48 meters and 52 meters, even if those bins were sub-threshold. Additionally, any bins closer than 2 meters to the 48-meter and 52-meter bins would be merged, continuing until no more adjacent bins are found.

Command Syntax	:MB<SP> [Adjacency] <CR>	
Command Parameter Values	Multi-pulse bin adjacency	(1, 5) meters
Command Example	:MB<SP>3<CR>	Set bin adjacency to 3 meters.
	:MB<CR>	Read the multi-pulse bin adjacency.
Response Syntax	<CR><LF>~MB<SP> [Adjacency] <SP>OK<CR><LF>	
Response Values	Width, in meters, of multi-pulse range return bins	
Response Example	~MB 3 OK	

SET MULTI-PULSE THRESHOLD

Description Sets the number of coincident range returns required to be considered for a range result. Ranges are considered coincident if they fall into the same 1-meter-wide bin after truncation and rounding. For example, any result between 10.6 meters and 11.5 meters would be coincident.

Command Syntax	:MT<SP> [Threshold] <CR>	
Command Parameter Values	Multi-pulse threshold	(1, < multi-pulse shots) coincident returns
Command Example	:MT<SP>3<CR>	Set the threshold to 3 coincident returns.
	:MT<CR>	Read the multi-pulse threshold.
Response Syntax	<CR><LF>~MT<SP> [Threshold] <SP>OK<CR><LF>	
Response Values	Reporting threshold for coincident multi-pulse returns	
Response Example	~MT 3 OK	

SET NUMBER OF MULTI-PULSE LASER SHOTS

Description Sets the number of times that the laser will fire during a multi-pulse ranging cycle.

Command Syntax	:MS<SP> [# Shots] <CR>	
Command Parameter Values	Number of laser shots	(2, 10) shots
Command Example	:MS<SP>7<CR>	Fire the laser 7 times per multi-pulse ranging cycle.
	:MS<CR>	Read the number of multi-pulse shots.
Response Syntax	<CR><LF>~MS<SP> [# Shots] <SP>OK<CR><LF>	
Response Values	Number of multi-pulse shots	
Response Example	~MS 7 OK	

PARAMETER SAVE AND RESTORE COMMANDS

RESTORE FACTORY DEFAULTS

Description Restores the factory configuration setting. Factory settings include LRF configuration settings, AHRS configuration settings, and range-walk correction settings. Current user settings will be overwritten.

Command Syntax	:RF<CR>	
Command Parameter Values	None	
Command Example	:RF<CR>	Restore factory settings.
Response Syntax	<CR><LF>~RF<SP>OK<CR><LF>	
Response Values	None	
Response Example	~RF OK	

SAVE USER SETTINGS

Description Saves the current configuration setting. User settings include LRF configuration settings, AHRS configuration settings, and range-walk correction settings.

Command Syntax	:SV<CR>	
Command Parameter Values	none	
Command Example	:SV	Save user settings.
Response Syntax	<CR><LF>~SV<SP>OK<CR><LF>	
Response Values	None	
Response Example	~SV OK	

LRF VERSION QUERY COMMANDS

GET FPGA FIRMWARE VERSION

Description Displays the current FPGA firmware version.

Command Syntax	:VF<CR>	
Command Parameter Values	None	
Command Example	:VF<CR>	Return current FPGA firmware version.
Response Syntax	<CR><LF>~VF<SP>X.X.X<SP>OK<CR><LF>	
Response Values	Version	0-9.0-9.0-9
Response Example	~VF 1.0.4 OK	

GET LRF SOFTWARE VERSION

Description Displays the current software version.

Command Syntax	:VE<CR>	
Command Parameter Values	none	
Command Example	:VE <CR>	Return current LRF software version.
Response Syntax	<CR><LF>~VE<SP>X.X.X<SP>OK<CR><LF>	
Response Values	Version	0-9.0-9.0-99
Response Example	~VE 2.3.22 OK	

RANGING

CONTINUOUS RANGE

Description Repeatedly performs a range measurement at a specified period of repetition. The Type of range measurement performed is selected with the **Set Range Mode** command. The period parameter is in digital units, with a conversion factor of approximately 1 DN = 34.133 μ S. Command results correspond to the selected range mode. When a **Continuous Range** command is sent without a parameter, ranging ceases after the current measurement is finished.

Command Syntax	:CR<SP>[Range Period]<CR>	
	:CR<SP>	
Command Parameter Values	Range Period	Time between range cycles. 1 DN = 34.133 μ S. Parameter range is (0,65535) DN.
Command Example	:CR<SP>14648<CR>	Single-pulse range at ~2 Hz
Response Syntax	<CR><LF>~ [rangemode] <SP> [range1] , <SP> [range2] , <SP>...OK<CR><LF>	
Response Values	Range1 ... RangeN	Values are displayed with the programmed unit of measurement (Set Range Result Units command).
Response Example	~AM 15846, 15944 OK In auto-calibrated multi-pulse continuous range mode 'AM' is returned; Range1 is 15,846 units; Range2 is 15,944 units; there are no errors. (For error-condition response strings, see the "Error Codes" section of this document.)	

MULTI-PULSE RANGE

Description Performs and time-correlates several range measurements. Extends range, increases range accuracy, and increases detection probability. Reports 6 range returns, no parameter fields. For information about multi-pulse ranging parameters, see the Features for Configuration listed in the Overview of the LRF Command Set.

Command Syntax	:ER<CR>	
Command Example	:ER<CR>	Multi-pulse range
Response Syntax	<CR><LF>~ER<SP> [range1] , <SP> [range2] , <SP>...OK<CR><LF>	
Response Values	Range1 ... Range6	Values are displayed with the programmed unit of measurement (Set Range Result Units command).
Response Example	~ER 32643 OK Range is 32,643 units; there are no errors. (For error-condition response strings, see the "Error Codes" section of this document.)	

MULTI-PULSE RANGE WITH AUTOMATIC CALIBRATION

Description Combines the **Multi-Pulse Range**, **Set Receiver Mode** and **Calibrate False Alarm Rate** commands. The LRF will be calibrated to ~40-kHz false-alarm rate. The receiver will be set to **Mode 3** and a multi-pulse range measurement will be taken. Command results are the same format as the **Multi-Pulse Range** command.

Command Syntax	:AM<CR>	
Command Example	:AM<CR>	Multi-pulse range with calibration
Response Syntax	<CR><LF>~ER<SP> [range1] , <SP> [range2] , <SP>...OK<CR><LF>	
Response Values	Range1 ... Range6	Values are displayed with the programmed unit of measurement (Set Range Result Units command).
Response Example	~AM 32643 OK Range is 32643 units; there are no errors. (For error-condition response strings, see the "Error Codes" section of this document.)	

SINGLE-PULSE RANGE

Description Performs a single range measurement using the setting from the **Set Receiver Mode** command. The number of returns reported is programmable (**Set Number of Reported Range Returns** command). Shows only non-zero values. When the **Single-pulse Range** command completes, the LRF returns to the standby power mode. There are no parameter fields.

Command Syntax	:RR<CR>	
Command Example	:RR<CR>	Single-pulse range
Response Syntax	<CR><LF>~RR<SP> [range1] , <SP> [range2] , <SP>...OK<CR><LF>	
Response Values	Range1 ... RangeN	Values are displayed with the programmed unit of measurement (Set Range Result Units command).
Response Example	~RR 15846, 15944 OK Range1 is 15846 units; Range2 is 15944 units; there are no errors. (For error-condition response strings, see the “Error Codes” section of this document.)	

SINGLE-PULSE RANGE WITH AUTOMATIC CALIBRATION

Description Combines the **Single-Pulse Range** and **Calibrate False Alarm Rate** commands. The LRF will be calibrated to the default false alarm rate, and a single pulse range measurement will be taken. The default false alarm rate can be set with the **Set Default False Alarm Rate** command. Command results are the same format as the **Single-Pulse Range** command.

Command Syntax	:AS<CR>	
Command Example	:AS<CR>	Single-pulse range with calibration
Response Syntax	<CR><LF>~AS<SP> [range1] , <SP> [range2] , <SP>...OK<CR><LF>	
Response Values	Range1 ... RangeN	Values are displayed with the programmed unit of measurement (Set Range Result Units command).
Response Example	~AS 15846, 15944 OK Range1 is 15846 units; Range2 is 15944 units; there are no errors. (For error-condition response strings, see the “Error Codes” section of this document.)	

FALSE-ALARM RATE MONITORING AND CALIBRATION

CALIBRATE FALSE-ALARM RATE

Description Calibrates the low-threshold voltage (VThLo) for a specified false-alarm rate. Updates the low-threshold voltage value but does not save the value to memory. If no parameter value is sent, the false-alarm rate is calibrated to the default false-alarm rate, which is set with the **Set Default False Alarm Rate** command. The calibration algorithm results in a best-effort solution within a 200 – 400-ms time constraint.

Command Syntax	:CL<SP>[False Alarm Rate]<CR>	
Command Example	:CL<SP>300<CR>	Calibrate false-alarm rate to 300 Hz.
	:CL<CR>	Calibrate false-alarm rate to default FAR.
Response Syntax	<CR><LF>~CL<SP>VThLo<SP>set<SP>XXXX<SP>OK<CR><LF>	
	<CR><LF>~CL<SP>VThLo<SP>stuck<SP><high/low><SP>ERROR<CR><LF>	
	Return shows a calibration failure; system could not find a calibration solution.	
Response Values	Voltage thresholds	Previous and current low-threshold voltage settings
Response Example	~CL VThLo set 1200 OK Solution was found, and the low-threshold voltage was changed to 1200 DN.	
	~CL VThLo stuck high ERROR or ~CL VThLo stuck low ERROR Solution was not found, and threshold voltage was not modified.	

MEASURE FALSE-ALARM RATE

Description Measures the false-alarm rate for the current low-threshold voltage setting and returns the rate in Hz.

Command Syntax	:FL<CR>	
Command Example	:FL<CR>	FAR count request
Response Syntax	<CR><LF>~FL<SP> [RATE] <SP>Hz<SP>OK<CR><LF>	
	Return the measured false-alarm rate.	
Response Values	False alarm rate	Calculated rate as counts per second.
Response Example	~FL 320 Hz OK Measured FAR is 320 Hz	

AUXILIARY FUNCTIONS

ENABLE/DISABLE HIGH-REPETITION-RATE MODE

Description Enables or disables high-repetition-rate mode. This prevents the LRF from returning to the standby power mode. This will reduce the time necessary to perform ranging, calibration, and other commands, at the cost of increased power consumption.

Command Syntax	:HR<SP> [On/Off] <CR>	
Command Parameter Values	High-repetition-rate mode	0 – Disable high-repetition-rate mode 1 – Enable high-repetition-rate mode
Command Example	:HR<SP>0<CR>	Disable high-repetition-rate mode.
	:HR<CR>	Read the mode setting.
Response Syntax	<CR><LF>~HR<SP> [On/Off] <SP>OK<CR><LF>	
Response Values	High-repetition-rate mode setting	
Response Example	~HR 0 OK High-repetition-rate mode is disabled.	

ENABLE/DISABLE PULSE REPETITION FREQUENCY TRANSMIT MODE

Description Enables or disables pulse repetition frequency transmit mode. When pulse repetition frequency transmit mode is enabled via this command, the LRF automatically sends repeated pulses at the specified pulse period.

Command Syntax	:PT<SP> [Pulse Period] <CR> :PT<SP>	
Command Parameter Values	Pulse period	Time between laser pulses. 1 DN = 10 ns. The parameter range is 10,000,000 to 200,000,000 DN.
Command Example	:PT<SP>10000000<CR>	Pulse laser at 10 Hz.
	:PT<CR>	Disable pulse transmit mode.
Response Syntax	<CR><LF>~PT<SP>10000000<SP>OK<CR><LF>	
Response Values	Pulse period	
Response Example	~PT 10000000 OK	

ENABLE/DISABLE SLEEP MODE

Description Puts the LRF in a low-power sleep mode. All peripherals are turned off, and the microcontroller is placed in a sleep mode. The microcontroller can be returned to the standby power state by sending any UART command.

Command Syntax	:SM<CR>	
Command Parameter Values	None	
Command Example	:SM<CR>	Commands the LRF to enter sleep mode.
Response Syntax	<CR><LF>~SM<SP>OK<CR><LF>	
Response Values	None	
Response Example	~SM OK The LRF is in sleep mode.	

READ LASER DELAY

Description *Displays the laser delay time from the previous ranging cycle. The laser delay is the time between the rising edge of the laser gate and the optical laser pulse.*

Command Syntax	:RD<CR>	
Command Parameter Values	None	
Command Example	:RD<CR>	Read laser delay time.
Response Syntax	<CR><LF>~RD<SP>[Delay Time]<CR><LF>	
Response Values	Laser delay	Laser delay time in microseconds.
Response Example	~RD 2502 OK A laser delay of 2,502 microseconds was measured during the previous ranging cycle.	

READ PULSE WIDTHS

Description *Displays the pulse widths of the T0 signal and all range returns from the previous ranging cycle.*

Command Syntax	:PW<CR>	
Command Parameter Values	None	
Command Example	:PW<CR>	Read pulse widths.
Response Syntax	<CR><LF>~ER<SP>[width_T0],<SP>[width1],<SP>...OK<CR><LF>	
Response Values	Pulse widths	Pulse widths in picoseconds.
Response Example	~PW 34567, 25648, 19762 OK The pulse width of the T0 signal was 34,567 ps, and the pulse widths of the range returns were 25,648 ps and 19,762 ps.	

ERROR CODES

<i>Error code</i>	<i>Description</i>
1000	No T0 pulse was detected.
1001	A T0 pulse was detected, but no return pulses were detected.
1002	A T0 pulse was detected before the minimum laser delay time.
2100	The FPGA did not acknowledge the ranging command. Time-to-digital calibration may be in progress, or the FPGA may not be programmed.
2200	The FPGA failed to initialize within the set period of time. The range measurement can be repeated immediately.

LRF ATTITUDE AND HEADING REFERENCE SYSTEM (AHRS) COMMAND SET

This command set is only used for devices that have been sold and configured with the AHRS option and its associated hardware.

QUICK REFERENCE LIST—AHRS COMMAND SET

AHRS CONFIGURATION

Enable/Disable AHRS	21
Load AHRS Calibration	21
Save AHRS Calibration	21
Set AHRS Local Magnetic Declination	22
Set AHRS Offsets	22
Set AHRS Orientation	22

AHRS MEASUREMENT

Get AHRS Sample	23
Enable/Disable AHRS Data Stream	23

AHRS CONFIGURATION

ENABLE/DISABLE AHRS

Description Powers up and configures the AHRS and sensors or returns the AHRS and sensors to a low-power state.

Command Syntax	:F8<SP> [On/Off] <SP><CR>	
Command Parameter Values	AHRS enable/disable	0 – Disable AHRS 1 – Enable AHRS
Command Example	:F8<SP>1<SP><CR>	Enable AHRS.
Response Syntax	<CR><LF>~F8<SP>1<SP>OK<CR><LF>	
Response Values	None	
Response Example	~F8 1 OK	

LOAD AHRS CALIBRATION

Description Loads the calibration data previously stored in memory.

Command Syntax	:F2<CR>	
Command Parameter Values	None	
Command Example	:F2<CR>	Load AHRS calibration parameters.
Response Syntax	<CR><LF>~F2<SP>OK<CR><LF>	
Response Values	None	
Response Example	~F2 OK	

SAVE AHRS CALIBRATION

Description Saves the current cumulative sensor calibration to non-volatile memory. Calibration includes hard- and soft-iron magnetometer calibration for ferrous metal and EMI.

Command Syntax	:F1<CR>	
Command Parameter Values	None	
Command Example	:F1<CR>	Save AHRS calibration parameters.
Response Syntax	<CR><LF>~F1<SP>OK<CR><LF>	
Response Values	None	
Response Example	~F1 OK	

SET AHRS LOCAL MAGNETIC DECLINATION

<i>Description</i>	<i>Stores the programmed declination value to non-volatile memory.</i>	
Command Syntax	:F3<SP> [-]XXX.XX<CR>	
Command Parameter Values	ASCII floating point	Magnetic declination
Command Example	:F3<SP>-15.34<CR>	Set the declination to -15.34 degrees.
	:F3<CR>	Read the declination.
Response Syntax	<CR><LF>~F3<SP> [-]XXX.XX<SP>OK<CR><LF>	
Response Values	Local magnetic declination	
Response Example	~F3 -15.34 OK	

SET AHRS OFFSETS

Description Sets the offset for the Heading (:F4), Pitch (:F5), or Roll (:F6) and stores the offset in volatile memory. The offset value will be added to the raw AHRS output data.

Command Syntax	:F[X]<SP> [-]XXX.XX<CR>	
Heading offset	:F4<SP> [-]XXX.XX<CR>	
Pitch offset	:F5<SP> [-]XX.XX<CR>	
Roll offset	:F6<SP> [-]XXX.XX<CR>	
Command Parameter Values	ASCII floating point	Offset value
Command Example	:F4<SP>-1.23<CR>	Set the heading offset to -1.23 degrees.
	:F4<CR>	Read the heading offset.
Response Syntax	<CR><LF>~F[X]<SP> [-]XXX.XX<SP>OK<CR><LF>	
Response Values	Axis offset	
Response Example	~F4 1.23 OK	

SET AHRS ORIENTATION

Description Sets the device orientation. Orientation is specified by 90-degree rotations in the roll axis, to correspond to common rail-mounting options. AHRS output data are automatically normalized for the selected device orientation.

Command Syntax	:F7<SP> [X] <CR>	
Command Parameter Values	Mounting orientation, rotations in the roll axis.	
	0	IMU mounted 0° [DEFAULT]
	1	IMU mounted 90°
	2	IMU mounted 180° (i.e., upside down)
	3	IMU mounted 270°
Command Example	:F7<SP>3<SP><CR>	Set the orientation of the AHRS to 270°.
	:F7<CR>	Read the orientation.
Response Syntax	<CR><LF>~F7<SP>X<SP>OK<CR><LF>	
Response Example	~F7 3 OK	

AHRS MEASUREMENT

GET AHRS SAMPLE

Description Returns the current pitch, roll, and heading of the AHRS. All units are in degrees. Pitch scale is $\pm 90^\circ$. Roll and Heading scale is ± 180 degrees.

Command Syntax	:FS<CR>			
Command Parameter Values	None			
Command Example	:FS<CR>		Returns the most current pose data.	
Response Syntax	<CR><LF>Pitch:<SP>[-]XX.XX,<SP>Roll:<SP>[-]XXX.XX,<SP>Heading:<SP>[-]XXX.XX,<SP>Status:<SP>X<SP>OK<CR><LF>			
Response Values	Pitch, roll, and heading in signed decimal notation.			
Output Range and Behavior	The pitch output is specified for four 90° quadrants of rotation, starting level and pitching up. Roll and heading output values below are specified for rotations in clockwise (CW) and counterclockwise (CC) directions.			
Pitch	Q1 : 0° -> 90°	Q2: 90° -> 0°	Q3: 0° -> -90°	Q4: -90° -> 0°
Roll	CC: 0° -> -180°		CW: 0° -> 180°	
Heading	CC: 0° -> -180°		CW: 0° -> 180°	
Status Code	Codes are represented as an ASCII integer.			
Bit 0	Reserved			
Bit 1	Reserved			
Bit 2	Reserved			
Bit 3	Calibration status. Set to 1 when sensor calibration is complete.			
Bit 4	Magnetic transient detection. May toggle between 1 and 0 as online calibration is performed.			
Bit 5	Unreliable sensor data. Bit is set if abnormal sensor data is detected.			
Response Example	~FS P: 12.34, R: -1.23, H: -123.45, S: 8 OK			

ENABLE/DISABLE AHRS DATA STREAMING

Description Enables/disables the streaming of AHRS data at 30 Hz over a UART connection.

Command Syntax	:RN<SP>[Start/Stop]<SP><CR>		
Command Parameter Values	Data streaming enable	0 – Data streaming is disabled	1 – Data streaming is enabled
Command Example	:RN<SP>1<SP><CR>	Stream AHRS data.	
Response Syntax	<CR><LF>~RN<SP>1<SP>OK<CR><LF>		
	The LRF then begins sending AHRS data samples automatically, until commanded to stop. For AHRS data sample format, see Get AHRS Sample command.		
Response Values	See “Get AHRS Sample” command.		
Response Example	~RN 1 OK ~FS P: 12.34, R: -1.23, H: -123.45, S: 8 OK ~FS P: 12.34, R: -1.23, H: -123.45, S: 8 OK ~FS P: 12.34, R: -1.23, H: -123.45, S: 8 OK Note: In the example above, the device is level and stationary, which results in the same response being repeated multiple times without user intervention.		

ADDITIONAL GUIDANCE

RANGE-WALK CORRECTION PARAMETERS

Range walk is a phenomenon where measured ranges increase with decreasing return signal intensity. This effect can be compensated for by collecting data on measured pulse width (**Read Pulse Widths** command) vs. range error against a target at a calibrated distance. Voxel LRFs come pre-configured with parameters for range-walk correction that are specific to our lasers. If using a third-party laser, these parameters may require modification to meet a range-accuracy specification. For more information about how to collect the necessary data with your laser, contact Voxel.

The range-walk correction parameter commands set the coefficients and offset for a polynomial approximation of the graph of measured pulse width vs. range correction. Range-walk correction is subtracted from the calculated range value in the single-pulse and multi-pulse ranging commands. The correction is calculated and applied in units of picoseconds to match the raw LRF timestamps. The equation for determining range walk correction is shown below. The value 'x' is the measured pulse width, as seen by the LRF (**Read Pulse Widths** command). P5 through P1 and the offset are the programmable parameters.

$$Correction = (P5 * x^5) + (P4 * x^4) + (P3 * x^3) + (P2 * x^2) + (P1 * x) + offset$$

The correction value is subtracted from measured range. It is also important to note that parameter values for each of the coefficients and the offset can be entered in either decimal or scientific notation.

SET RANGE-WALK CORRECTION PARAMETERS

<i>Description</i>	<i>Sets the coefficient and offset parameter values for the range-walk correction algorithm.</i>	
Command Syntax	:P[X]<SP>[Value]<CR>	
Command Examples	:P5<SP>1.234e-24<CR>	Set coefficient 5.
	:P4<SP>-1.234e-20<CR>	Set coefficient 4.
	:P3<SP>1.234e-16<CR>	Set coefficient 3.
	:P2<SP>-.00000001234<CR>	Set coefficient 2.
	:P1<SP>3.456<CR>	Set coefficient 1.
	:PO<SP>10567.1<CR>	Set offset.
Command Parameter Values	Coefficient and offset values	Decimal or scientific notation
Response Syntax	<CR><LF>~P[X]<SP>[Value]<SP>OK<CR><LF>	
	When a coefficient command is sent with no parameter, the parameter value in the response is formatted [-]X.XXXXXXe[-]X	
	When the offset command is sent with no parameter, the parameter value in the response is formatted as an integer.	
Response Values	Coefficient and offset values	Scientific notation (coefficients) Integer (offset)
Response Examples	~P4 -4e-16 OK	Command sent with parameter.
	~P4 -4.000000e-16 OK	Command sent with no parameter.
	~PO 10567.1 OK	