1421 Research Park Dr
Lawrence, KS 66049

Long Range Radar Altimeter

LR-D1

User Manual

D00.01.08

2/20/2023

1421 Research Park Dr
Lawrence, KS 66049

Revision History

Version Number	Date	Authors	Notes
D00.00.01	Sep 13, 2018	Hao Liu, Liqiang Ren, Zhenyu Hu	Initial Draft
D00.00.03	Oct 17, 2018	Zhenyu Hu	Add section 7 - Known Issues
D00.01.01	Nov 5, 2018	Andrew Megaris	Technical Revision
D00.01.02	Dec 6, 2018	Zhenyu Hu	Spec updates
D00.01.03	Jan 14, 2019	Zhenyu Hu	Data protocol update
D00.01.04	May 17, 2021	Zhenyu Hu	From original version of V2.2
P00.01.04	June 2, 2021	Ethan Perrins	Public Version
D00.01.05	June 18, 2021	Zhenyu Hu	From original version of V2.4
D00.01.06	September 17, 2021	Camron Myers	Added 8. Firmware Change Log, 9. Firmware Update Instructions, and 10. Test Tool GUI.
D00.01.07	Oct 7, 2021	Zhenyu Hu	From original version of V3.0 for firmware 3.223.7/3.0.7
D00.01.08	Feb 20, 2023	Camron Myers	V2.2 Hardware Changes

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Table of Contents

1. Product Description

1.1 LR-D1

The LR-D1 Radar Altimeter uses the principles of radio detection and ranging to determine the altitude of the aircraft. A microwave signal is transmitted out of the sensor, reflects off the target and is received by the sensor. Distance and horizontal velocity from the sensor to the terrain (altitude) is derived by the difference in time from when the signal is sent from the sensor to when the signal is received by the sensor.
The LR-D1 is enclosed in a black metallic case, the radome, which is conducive to radar telemetry.

1.2 Compliances

FCC and CE certifications pending.

2. Installation Guidelines

2.1. Mounting Angle

When mounting the device, the front face of the LR-D1 must be **perpendicular** to the ground below the aircraft. There should not be any angle of inclination in any direction while the device is fastened to the aircraft.

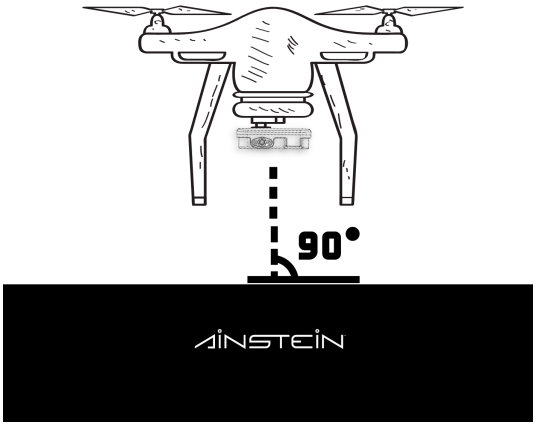

Figure 1

2.2 Mounting to an Aircraft

The device should be secured to the aircraft, where it is not free to move in any direction.

2.3. Line of Sight Clearance

Keep the face of the radar clean, and do not cover it with any additional materials. Any coatings, coverings, and modifications to the radome can degrade the performance of the radar device.
Additionally, keep any unexpected objects out of the radar's FoV (Field of View). Obstructions to the LR-D1's field of view will cause a decrease in the performance of the radar. It is highly recommended that the LR-D1 be mounted on the underside of the aircraft far away from the landing gear, other aircraft structures, or other equipment.

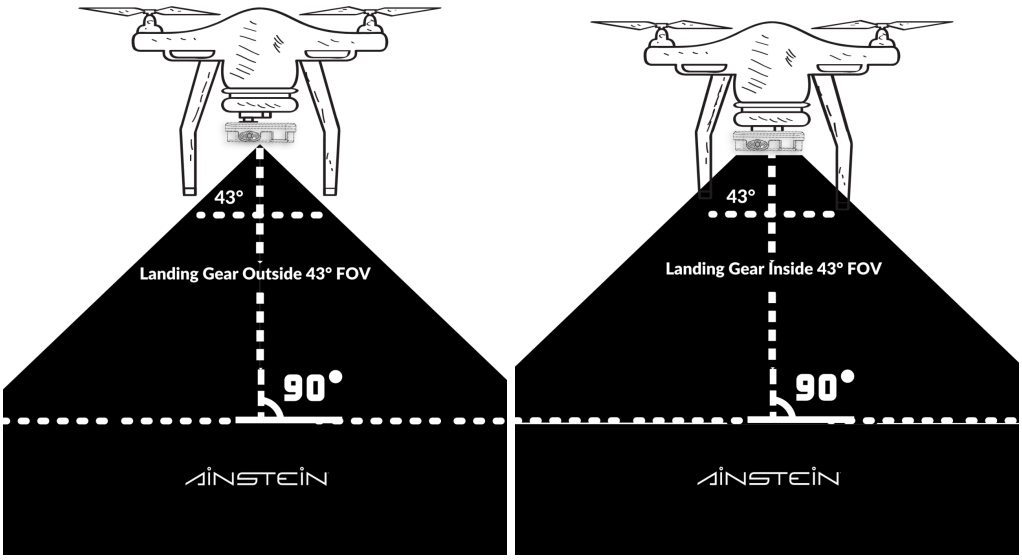

Figure 2

2.4. Integration Requirements

The LR-D1 outputs altitude measurements and signal-to-noise ratio (SNR) measurements when operational. When integrating the LR-D1 radar altimeter, it is necessary to use SNR measurements in conjunction with malfunction alerts (see

appendix 1) to properly filter out erroneous altitude values.

Caution! Altitude measurements associated with a SNR value of 13dB or lower are considered erroneous.

The altitude measurements should not in any circumstances be used as true measurements independently of the corresponding SNR values.

A filtering algorithm should be used to estimate vehicle position, velocity and angular orientation based on rate gyroscopes, accelerometer, compass, GPS, airspeed and barometric pressure measurements in addition to the recorded LR-D1 measurements. Sensor redundancy is heavily advised for the LR-D1.

3. Operational Requirements

The LR-D1 will perform optimally if the operational requirements below are fully satisfied. Failure to meet the operational requirements may cause a decrease in performance, accuracy, or reliability of the LR-D1 altimeter and is not advised.

3.1 Obstruction to the LR-D1 Field of View

Objects or aircraft structures that are located within the LR-D1's conical field of view which obstruct the radar's view of the ground may cause multipath reflections or other degrative phenomena to occur. The LR-D1 should be mounted a safe distance away from the landing gear and any other components of the aircraft below it.

3.2 Excessive Pitch/Roll

Pitch and roll angles that exceed 21.5° and 15° respectively may also cause the performance of the LR-D1 to worsen. This sensitivity increases with altitude.

3.3 Terrain

Terrain with poor reflectivity may cause the performance of the LR-D1 to worsen. Flying at the limit of the LR-D1's range over dry, loose soil, such as tilled farmland, or sand is not recommended.

Terrain with high reflectivity may cause the LR-D1 to output abnormally high values at low altitudes due to high saturation.

3.4 Power Source

Any power source used to operate the LR-D1 that does not provide the minimum power and voltage can worsen the performance of the device or cause it's operation to stop altogether.

3.5 Orientation of LR-D1

The LR-D1 must be mounted upon the aircraft in such a manner as to be fully horizontal, it's radome directly facing the ground. Any angle of inclination may degrade performance.

3.6 Minimum and Maximum Operating Altitude

Operating the LR-D1 at altitudes below 0.7 meters and above 500 meters will result in a degradation of performance and potentially erroneous measurements. Also, any reading at the altitude of greater than 655.35m would be considered as the error or overflowed reading (see appendix 1) .

4. Technical Data:

Table 1: Specification

Frequency Band	24 GHz
Bandwidth	250 MHz
Power Consumption	< 11.00 W
Operating Voltage	10 - 30 V
Altitude Range	1.0m~500m (1)
Altitude Precision	±0.3644m (2)
Update Rate	40Hz
Detection Angle Range	Azimuth 43°, Elevation 30° (3)
Maximum Velocity	± 30 m/s in elevation
Temp. Range	-40℃~60℃
Dimensions	<112mm*102.5mm*31mm (mounting bracket is NOT included)
Weight	316g (excluding external connector cable)
IP Rating	Built to the requirements of IP67 (Test pending) (4)
Vibration Rating	IEC 60068-2-6.1995 sine vibration 5g XYZ three axis
Shock Rating	IDT IEC 68-2-27:1987 half sine shock 20g XYZ three axis
ESD Rating	IEC 61000-4-2.2008 8K/15K contact/air B class

Note:

1. Radar data may vary over different terrains when radar is out of its detection range. Usually we recommend mounting the LR-D1 at the minimum height of at least 1.0m.

   We do not recommend using LR-D1 at either lower than 1.0m or greater than 500m.

When actual altitude is greater than 500m at some solid terrain, for example concrete, the radar can operate normally till 600m. LR-D1 will report **SNR = 0 and Altitude = 1.46m** to indicate there is no target detected; Therefore, SNR = 0 can be considered as this detection is invalid.

2. Range detection might be limited by terrains, pitch and roll of aircraft, etc.. The range precision here only indicates the lab experiment/calibration result in the ideal case.

   LR-D1 altitude data report step size could be smaller than this precision because of the post processing.

3. Based on mm-wave radar specs, a large angle of pitch and roll would bring error for detection.Under the same measurement circumstance, larger angle by aircraft bring more error.
4. IP rate here only focuses on radar itself. This rating does not cover any cabling interface.

5. UART Data Protocol For LR-D1:

- Protocol: UART
- I/O Standard: RS-232 (Default) and RS-422 (Per Request)
- Baud Rate: 115200 b/s
- Data length: 8 bits, plus one start bit and one stop bit, and no parity bit

Table 2: Data Packet Definition

From	LR-D1	To	Receiver
Byte	Data	Note	
data1	0xEB	Packet Header MSB (Most Significant Bits)	
data2	0x90	Packet Header LSB (Least Significant Bits)	
data3	deviceID	Device ID Byte (0x00)	
data4	0x1C	Data packet length; Fixed as 28 Bytes	
data5	0x00: Normal Others: Malfunction(1)	Malfunction Alert FW 6.0.7.X: Malfunction Alert MSB FW 18.X.X.X: Malfunction Alert LSB	
data6	0x01	FW 6.0.7.X: Object Number; Fixed as 1; FW 18.X.X.X: Malfunction Alert LSB	
data7	high1_h(2)	Object 1 Altitude MSB	
data8	high1_l(2)	Object 1 Altitude LSB	
data9	snr1	Object 1 SNR	
data10	speed1_h(3)	Object 1 Velocity MSB	
data11	speed1_l(3)	Object 1 Velocity LSB	
data12	high2_h	0xFF(4)	
data13	high2_l	0xFF	
data14	snr2	0xFF	
data15	speed2_h	0xFF	
data16	speed2_l	0xFF	
data17	high3_h	0xFF	
data18	high3_l	0xFF	
data19	snr3	0xFF	
data20	speed3_h	0xFF	
data21	speed3_l	0xFF	
data22	high4_h	0xFF	
data23	high4_l	0xFF	
data24	snr4	0xFF	
data25	speed4_h	0xFF	
data26	speed4_l	0xFF	
data27	high5_h	0xFF	
data28	high_l	0xFF	
data29	snr5	0xFF	

data30	speed5_h	0xFF
data31	speed5_l	0xFF
data32	checksum	Checksum: (data4+data5+…+data29+data31) bitwise-AND with 0xFF

Note:

1. Please see Appendix 1 for details about malfunction information.
2. Altitude Data Parse: Altitude = (high_h * 256) + high_l; unit: **0.01 m (cm)**; Type: **Unsigned**
3. Velocity Data Parse: Velocity = (speed _h * 256) + speed _l; unit: **0.01m/s**; Type: **Signed**
4. Only support single target detection in the released version. When altitude reading is overflowed, please see the Appendix 1 for details.

   We use a 16-bit integer to indicate the LR-D1's altitude reading in centimeters, therefore the maximum valid altitude would be 65535 cm (655.35 m). If actual altitude is greater than that, altitude reading overflow would occur.

6. Mechanical Drawing:

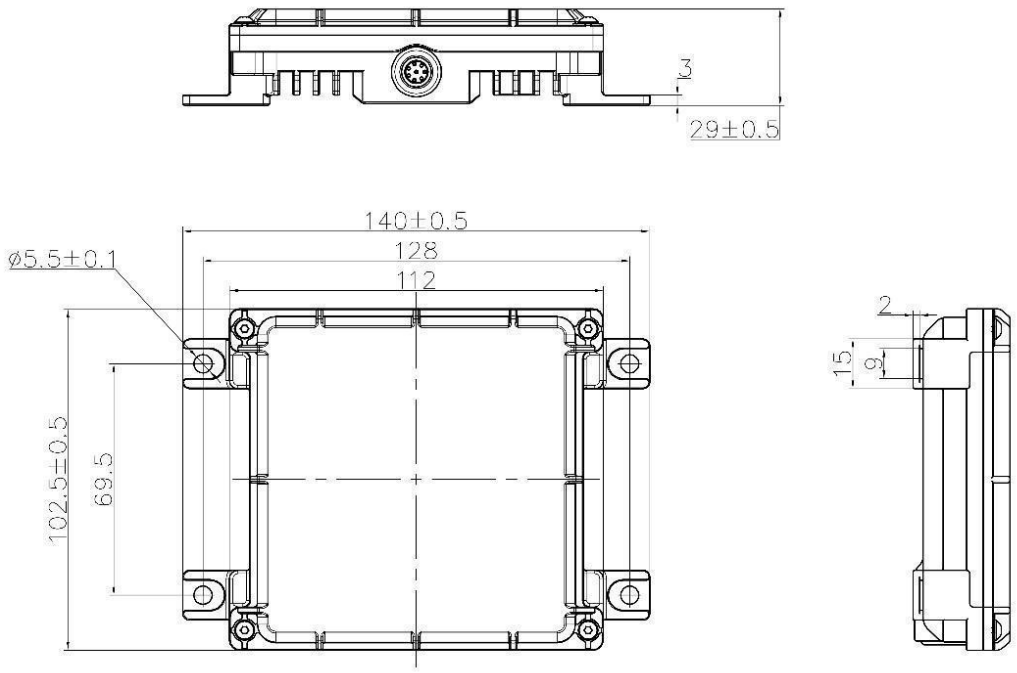

Figure 3: Dimensions of LR-D1 (Units: mm)

7. Radiated Emissions

Maximum Transmit Power (EIRP)	32 dBm

8. Hardware Interface:

Table 3: Pin Out Definition

Pin	Wire Color	Pin Name	Function	Note
1	Red	VCC	Input Voltage	10 - 30 V Power < 11W
2	Red	VCC	Input Voltage	10 - 30 V Power < 11W
3	Blue	RS-422 T+ / RS-232 T	RS422: TX+ RS232: TX	Default Setting: RS232
4	Brown	RS-422 T- / RS-232 R	RS422: TX- RS232: RX	Default Setting: RS232
5	White	RS-422 R+	RS422: RX +	Leave unwired for RS232
6	Green	RS-422 R-	RS422: RX-	Leave unwired for RS232
7	Black	GND	Ground	
8	Black	GND	Ground	

Note:

LR-D1's default hardware interface is RS-232. If the RS-422 interface is required, please contact Ainstein for assistance.

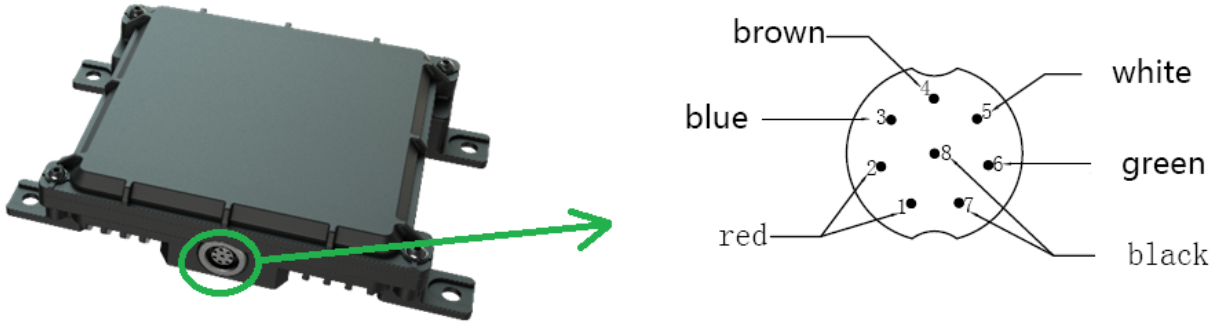

Figure 4: LR-D1 Pinout Diagram

9. Cabling Diagram:

The LR-D1 includes a 6 wire cable attached to a 90° connector. See Figure 4

BINDER 99-0425-75-08

Figure 4: 6 wire cable with 90° connector

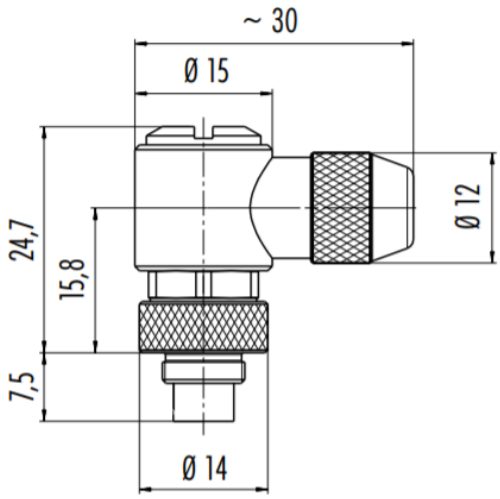

Figure 5: 90° Connector Diagram

BINDER 99-0425-10-08

Figure 6: 6 wire cable with straight connector

10. Known Issues

LR-D1 is a product still in development. Table 4 lists the known issues that will be addressed in later revisions.

Table 4: LR-D1 Known Issues

Issue ID	Description	Notes
1	If the radar is mounted within its minimum detection range (1.0 meters) to the ground, the radar's altitude data may incur unexpected noise and erroneous spikes.	• For full confidence, mount the radar with at least 1.0 meters of separation from the ground • If the radar is mounted within 1.0 meters of the ground, DO NOT consider altitude data while on the ground. • It usually would trigger error code of **0x0080** in appendix 1
2	Altitude data from radar may have unexpected or incorrect readings if the application scenario is indoor. Reason is the multipath reflection of radar is complicated indoors, it may give unexpected or incorrect reading under this circumstance.	• DO NOT apply radar in any indoor application scenario
3	Altitude data from radar may have unexpected or incorrect readings if aircraft pitch and/or roll are beyond the radar's detection angle (Azimuth 43°, Elevation 30°). The ideal case is keeping radar perpendicular to ground.	• Add a gimbal with radar mounting • DO NOT consider any altitude data as valid if aircraft's pitch and/or roll are beyond the radar's detection angle.

11. Firmware Change Log:

Table 5: LR-D1 Firmware Change Log

Firmware Version	Release Date	Notes
3.0.7	10/14/2021	• Increase accuracy to 0.36m from .74m • Increase stability of altitude measurements • Add malfunction alert for IF saturation and altitude overflow
6.0.7.2	07/16/2021	• Add firmware update feature, information readability, and parameter configuration via serial port. • Fix negative velocity reading bug. • Maintain performance from 6.0.7.
6.0.7	06/07/2018	• Original Firmware.

12. Firmware Update Instructions:

Remote Firmware Update

To update the firmware:

1. Open the GUI application entitled “main”.
2. Select the Serial Port connected to the LR-D1.
3. Set the Baud Rate to 115200.
4. Click Browse and select the desired .bin file. (the bin file will be entitled “fpga_232.bin” for RS-232 and “fpga_422.bin” for RS-422.
5. Click Load to update the firmware on the LR-D1.
6. Upon successful completion of the firmware update, the device will automatically restart.

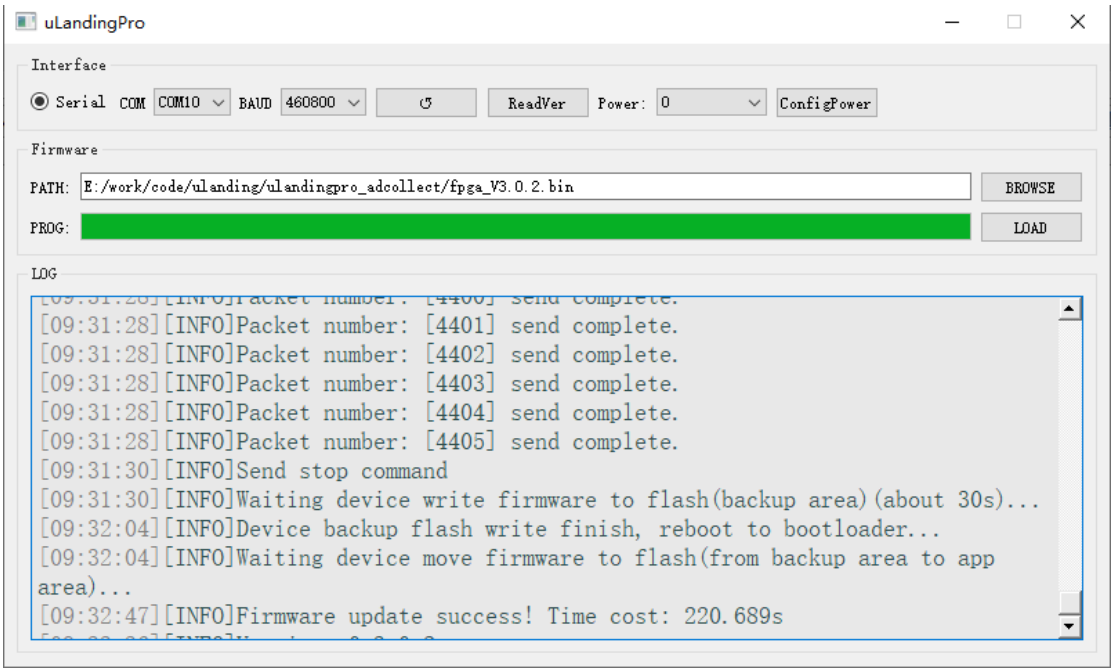

Figure 7: LR-D1 “main” Firmware Update GUI

13. LR-D1 Altimeter Test Tool GUI :

Operating the Test Tool GUI

To use the LR-D1 Altimeter Test Tool, follow the instructions below:

1. Download the Drone Radar Test Tool GUI (or request from Ainstein).
2. Install the Test Tool as directed.
3. Open the "Ainstein Drone Product GUI Tool Beta V0.4.1" Application. This will open both a terminal window for the .exe (which will display the data) and a GUI window for selecting the options of operating the device.
4. Under the "Radar Device" dropdown menu, select the LR-D1.
5. Under the "Connection Mode" menu, select "Serial Port".
6. Select the proper port and change the Baud Rate to 115200.
7. Click the green "Connect" button.
8. Click the green "Play" button, and navigate to the terminal window to watch the LR-D1 measurements in real-time.
9. Click the red "Stop" button to stop recording data.
10. To retrieve data files from the LR-D1, go the the "DATA" folder in the folder containing the "Ainstein Drone Product GUI Tool Beta V0.4.1" Application.

14. Contact Us:

ADDRESS:
2029 Becker Drive,
Lawrence, KS 66047 USA

EMAIL:
hi@ainstein.ai

PHONE:
785-856-0460

Appendix 1: Malfunction Alert Information List

There are four types of alert open to the end users, the type of alert can be distinguished by its special code below.

There is one Byte data reserved for the Malfunction Alert. All four types of alert are represented by a bit in this Byte. For example:

- 0x01 (0b00000001) of the temperature alert is represented by the bit-0 of the Malfunction Alert Byte;
- 0x02 (0b00000010) of the voltage alert is represented by the bit-1 of the Malfunction Alert Byte;
- 0x40 (0b01000000) of the IF signal saturation alert is represented by the bit-6 of the Malfunction Alert Byte;
- 0x80 (0b10000000) of the altitude reading overflow alert is represented by the bit-7 of the Malfunction Alert Byte;

Also, some of these Malfunction Alerts might be combined. For example:

- (TBD)

Malfunction Alert Code	Malfunction Alert Info	Possible Reasons	Suggestion
0x01	Temperature alert	Error in device or ambient temperature is out of LR-D1's operational temperature	Stop use and checking
0x02	Voltage alert	Error in device	Stop use and checking
0x40	IF signal saturation alert	Reflection signal received by LR-D1 is overloaded	It occurs when LR-D1 is within 1m to the ground. Check if there is any other target within LR-D1's FoV
0x80	Altitude reading overflow alert	Altitude reading is greater than the maximum	Occurs when LR-D1 detects the altitude is greater than 655.35 meters.

		integer of 16-bit (655.35 meter)	