LI-600 Porometer/Fluorometer

Stomatal conductance and chlorophyll *a* fluorescence at the speed of research.

The LI-600 Porometer/Fluorometer is a handheld porometer and Pulse Amplitude Modulation (PAM) fluorometer that measures leaf-level stomatal conductance and chlorophyll *a* fluorescence in seconds.

With the LI-600, you can quickly assess plants to identify individuals that express desired traits or to screen individuals from a large population for further assessment.

"The LI-600 could increase our data collection by an order of magnitude over the summer, just due to its ease of use, transportability, and speed."

– Dr. Nathan Lemoine, Marquette University

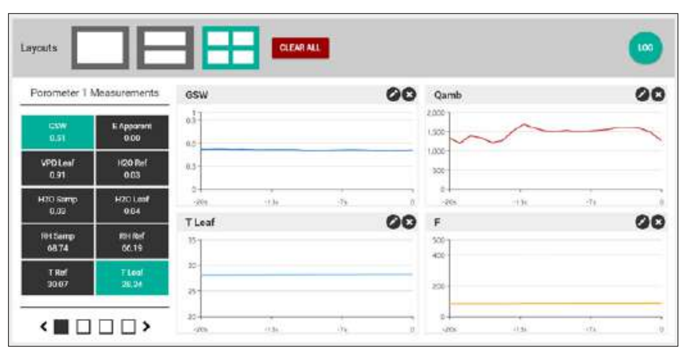
Each leaf has a story to tell—the LI-600 helps you tell it

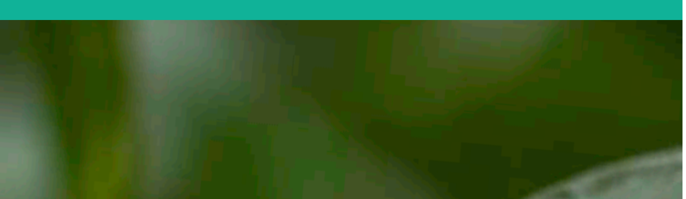
Measurements of stomatal conductance and chlorophyll *a* fluorescence are part of a plant's story—revealing details about genetics, life history, or stress. When combined with additional data, including incident angle of the sun to the leaf, location on earth, and exact time of day, the story becomes filled with details that can help you understand the physiology of a plant.

The LI-600 features a GPS receiver[1] to record the location and an accelerometer/magnetometer to measure pitch, roll, and heading of each leaf. Location, orientation, and time are all used to compute solar angle, and in turn, the angle of incidence in combination with stomatal conductance and chlorophyll *a* fluorescence for each leaf.

Data at the speed of urgency

After clamping onto a leaf, measurements from the porometer stabilize in seconds, and the LI-600 completes the measurement in just a few more seconds. It performs consistently when sampling different species and when sampling leaves with very low or very high g_{sw} rates. Fluorometer measurements are even faster—taking less than 1 second per sample.





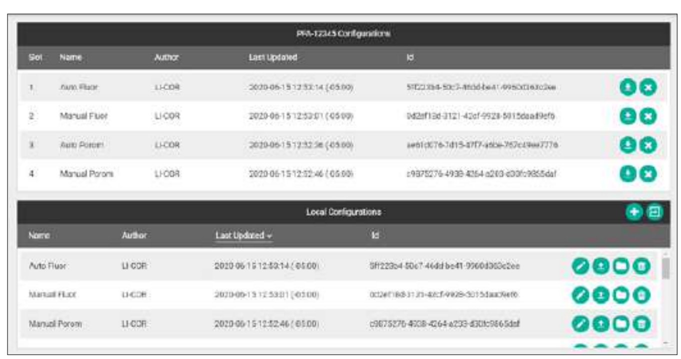
[1] The GPS receiver and accelerometer are available in new instruments only.

An instrument that inspires

- Automatic and manual data logging – each measurement is recorded automatically based on user-definable stability parameters or manually when you press the log button.
- User-settable prompts and remarks to annotate the dataset.
- Built-in light sensor measures ambient photosynthetic photon flux density (PPFD) with each measurement.
- Barcode scanner on the instrument to scan sample labels and organize data.
- Sunlight-readable display guides you through measurements, shows live data, and informs you of instrument status.
- Rechargeable battery provides up to 8 hours of data collection and features USB fast charging technology.

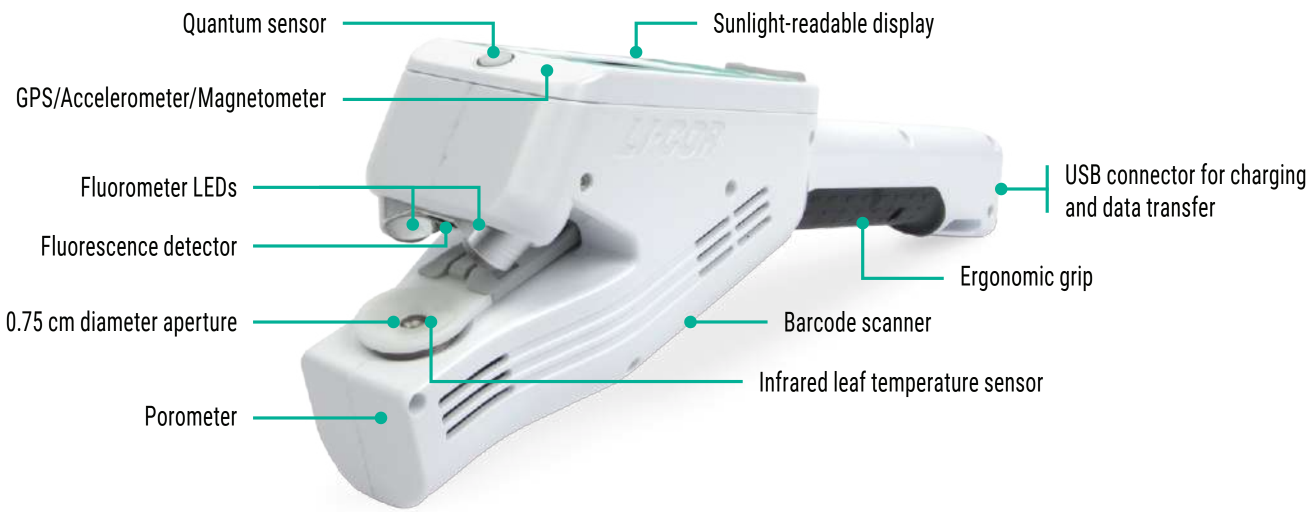
Software that solves problems

- Intuitive software for Windows® or macOS® computers makes it easy to configure measurements, manage data files, and stream live data.
- Barcode generator included with the computer software to create your own sample labels.
- USB data transfer to simplify data management.



What is stomatal conductance?

Stomatal conductance to water (g_{sw}) is a measure of the degree of stomatal openness and density on a leaf surface. This measurement indicates a plant's physiological response to environmental conditions. It can reveal insights into the genetics of a plant—providing data to identify the expression of characteristics or to select individuals for further analysis.

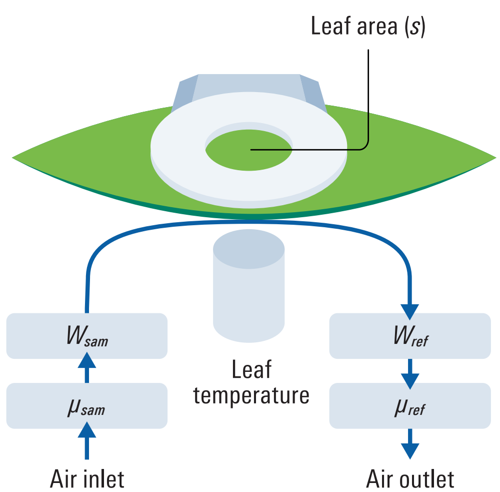


How the LI-600 measures stomatal conductance

The LI-600 quantifies transpiration (E) by measuring water vapor in an air stream before (W_{ref}) and after (W_{sam}) it interacts with the leaf surface. This difference, combined with flow rate (μ) and leaf area (s), are used to compute transpiration:

$$E = \frac{\mu(W_{sam} - W_{ref})}{s}$$

In the LI-600, leaf area (s) is 0.44 cm². Total conductance to water vapor (g_{tw}) is computed as a function of E and vapor pressures in the leaf and cuvette. Boundary layer conductance is computed as a function of flow rate and cuvette geometry. Finally, stomatal conductance to water (g_{sw}) is computed as a function of g_{tw} and the boundary layer conductance to water vapor (g_{bw}).



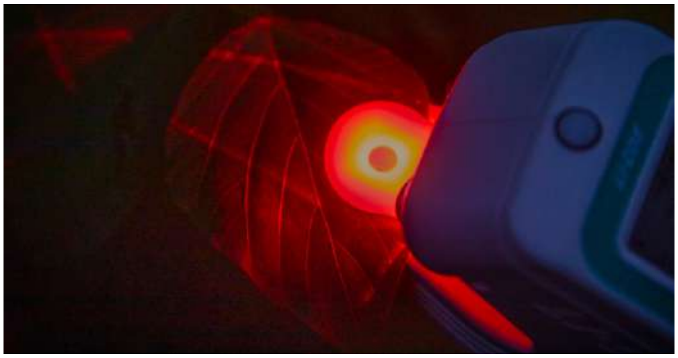
What is chlorophyll *a* fluorescence?

Leaf-level chlorophyll *a* fluorescence measurements reveal information about the photochemistry of a leaf, including the quantum efficiency, electron transport rate (ETR), and non-photochemical quenching (NPQ), along with other reactions that collectively protect a leaf when it absorbs excessive light energy. The LI-600 can take fluorescence measurements from both light- and dark-adapted leaves.

How the LI-600 measures chlorophyll *a* fluorescence

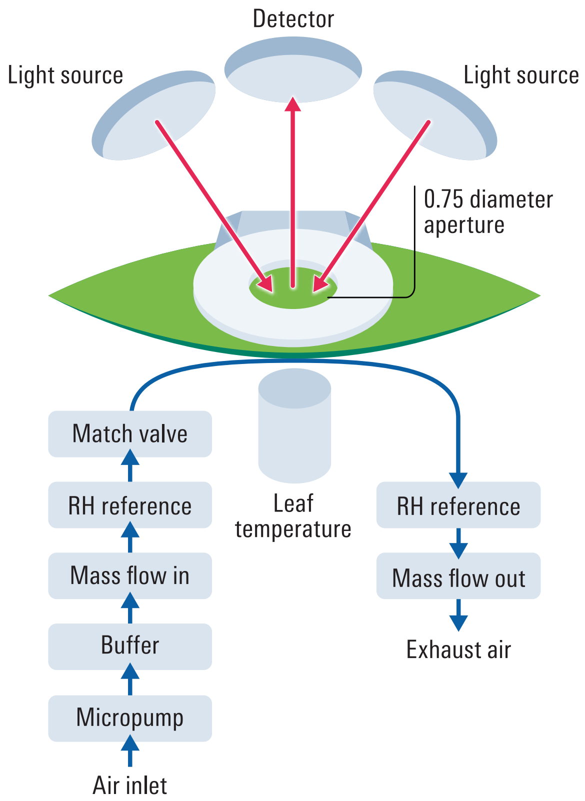
For light-adapted leaves, the LI-600 measures the quantum yield of fluorescence (ΦPS_{II}), which is the proportion of absorbed light by photosystem II that is used for electron transport. F_m' is maximum fluorescence yield in a light-adapted leaf; F_s is steady-state fluorescence yield in a light-adapted leaf.

$$\Phi PS_{II} = \frac{F_m' - F_s}{F_m'}$$



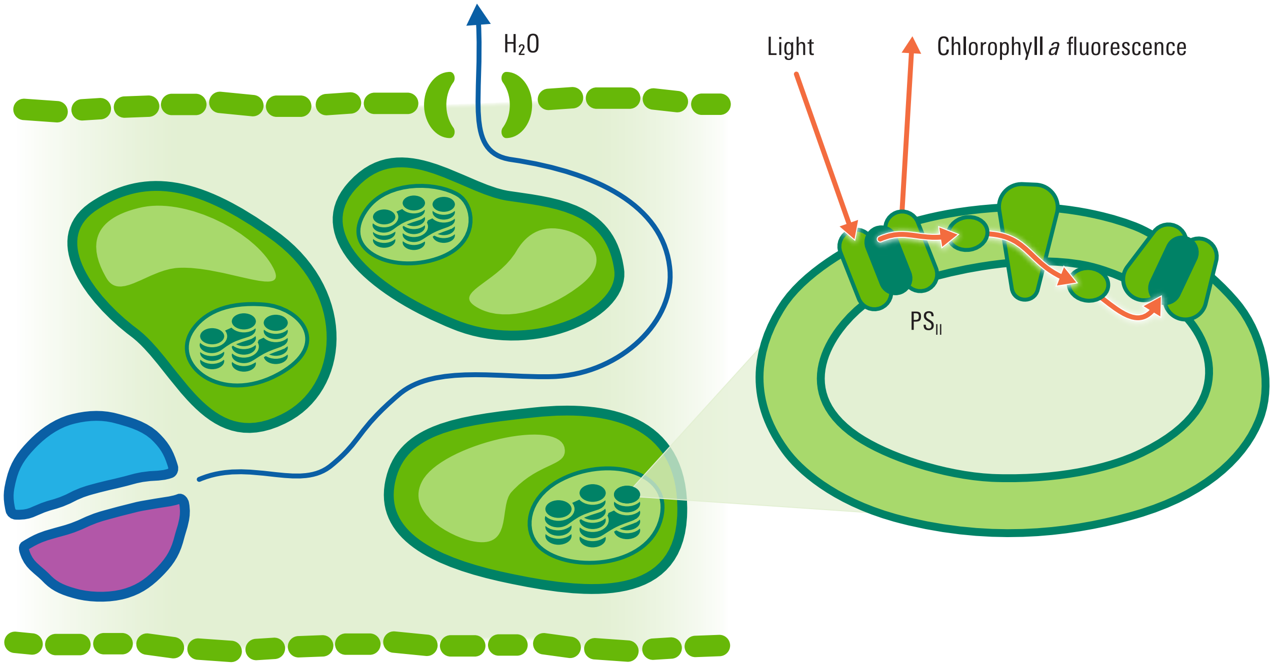
For dark-adapted leaves, the LI-600 measures maximum quantum yield (F_v/F_m), or the maximum proportion of absorbed light that can be used to drive electron transport. F_v is variable fluorescence yield in a dark-adapted leaf; F_m is maximum fluorescence yield in a dark-adapted leaf; F_o is minimum fluorescence yield in a dark-adapted leaf.

$$\frac{F_v}{F_m} = \frac{F_m - F_o}{F_m}$$



Why measure conductance and fluorescence simultaneously?

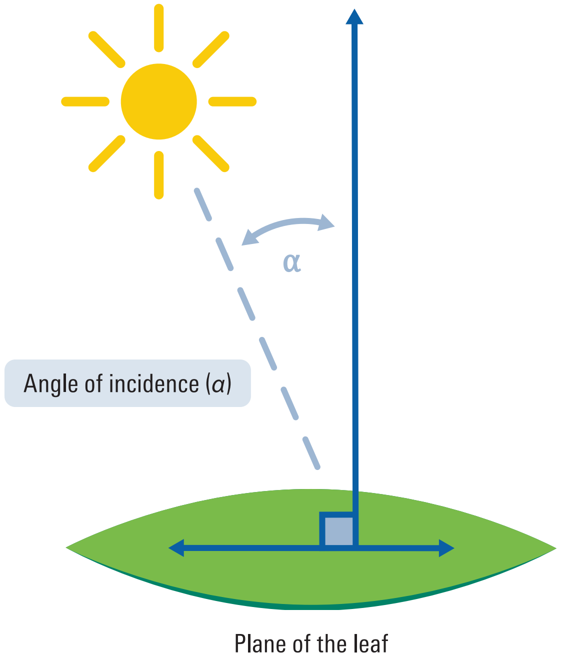
By taking both stomatal conductance and chlorophyll *a* fluorescence measurements together, you can learn more about a plant's physiology, stress conditions, and internal biochemical reactions. Understanding these processes is important to many research applications—including genetic screening, agronomy, plant physiology, ecology, climate change research, and stress tolerance. Combined measurements present a more complete picture of a plant's physiological state than either technique on its own.



Leaf angle measurements

The angle of incidence of a leaf—its orientation to the sun at a given time and place—is useful for understanding a plant's architecture and its physiological responses to the environment. A leaf's angle of incidence may change, for example, to maximize light intensity for photosynthesis, minimize light intensity to conserve water, or allow light through a canopy to lower leaves. Knowing the angle of incidence of a leaf can lead to insights into how light intensity drives photosynthesis and into the differences in measurements taken on the same plant.

The LI-600 accelerometer/magnetometer measures three variables—heading, pitch, and roll—while the GPS receiver records the sample location. The LI-600 computer software uses these data to calculate the angle of incidence for each leaf measurement, allowing you to evaluate the condition of a plant more thoroughly.



GPS coordinates

The LI-600 records its position using GPS data when a measurement is taken, giving you the ability to map data and return to specific areas at another time. It also records the date, time, latitude, longitude, and altitude of each measurement. These data, when combined with measurements from the accelerometer/magnetometer, are used by the LI-600 computer software to calculate the angle of incidence for each leaf.

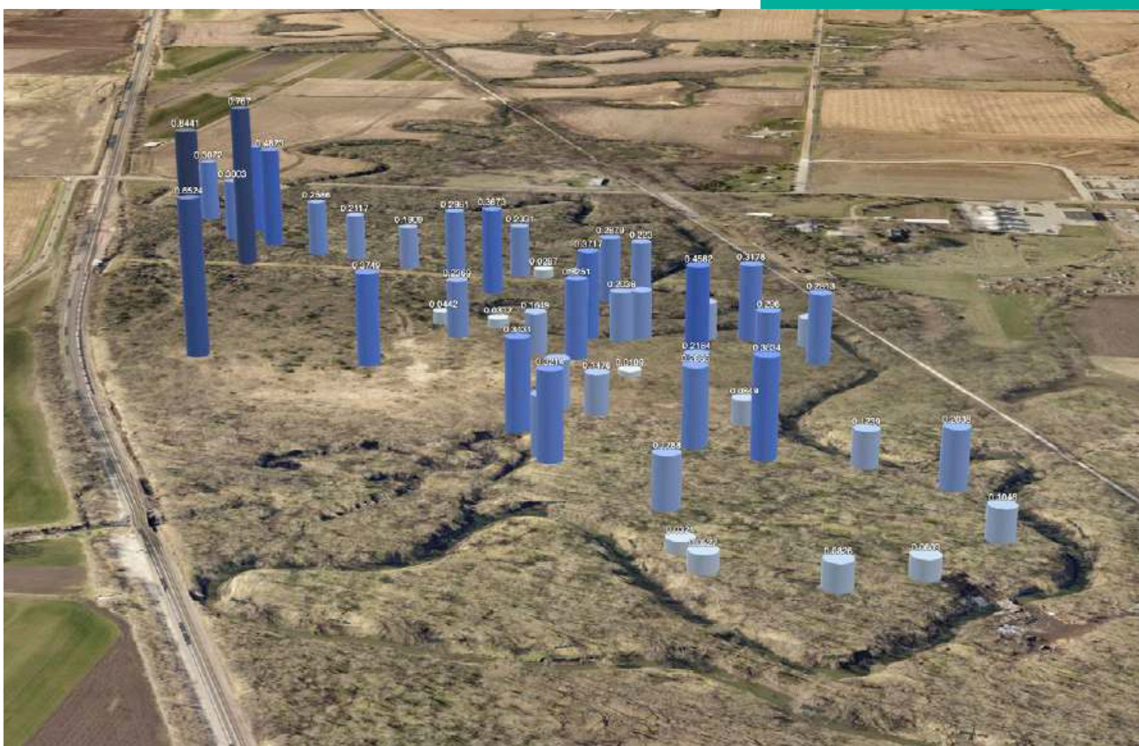


Figure 1. Stomatal conductance (g_{sw}) measured with a GPS-enabled LI-600. Georeferenced measurements from the LI-600 are easily viewed in mapping applications including Google Earth™ and Esri® ArcGIS®.

Complementary measurements with the LI-600 and LI-6800

The LI-600 Porometer/Fluorometer provides high-speed leaf-level measurements of stomatal conductance and chlorophyll *a* fluorescence in ambient conditions. In contrast, the LI-6800 Portable Photosynthesis System provides detailed measurements in controlled conditions, including measurements of CO_2 response, light response, and high-frequency chlorophyll *a* fluorescence.

By combining the fast survey measurements from the LI-600 with detailed data from the LI-6800, you can record larger, more informative data sets while saving time. For example, you can quickly screen a population with the LI-600 to identify individuals for detailed measurements with the LI-6800. Or you can characterize stomatal ratio with the LI-600 and use these measurements in the LI-6800 to improve calculation of important parameters related to stomatal ratio.

> Ready to learn more? See the webinar at:
> licor.com/600-6800-webinar

Ordering Information

LI-600PF Porometer/Fluorometer

The LI-600PF includes the porometer and fluorometer for stomatal conductance and chlorophyll *a* fluorescence measurements. Includes a carrying case, wrist strap, battery charger, USB cable, spares kit, manual, and quick start guide.

LI-600P Porometer

The LI-600P includes the porometer for stomatal conductance measurements. Includes a carrying case, wrist strap, battery charger, USB cable, spares kit, manual, and quick start guide.

600-01F Fluorometer Upgrade Kit

The 600-01F Fluorometer Upgrade Kit adds the fluorometer module to the LI-600P (porometer only) model for chlorophyll *a* fluorescence measurements.

Contact us at **envsales@licor.com** for purchase inquiries.

Specifications

Measurement time:
Porometer: 5 to 15 seconds typically, depending on species, leaf surface characteristics, and leaf conditions
Fluorometer: 1 second
Operating conditions:
Temperature: 0 to 50 °C
Pressure: 50 to 110 kPa
Humidity: 0 to 85%; non-condensing
Weight: 0.68 kg (porometer only); 0.73 kg with fluorometer
Dimensions: 32.4 cm × 16.9 cm × 6.2 cm (L × W × H)
GPS accuracy: 2.5 m CEP (circular error probable)
Display:
Dimensions: 6.8 cm diagonally
Resolution: 400 × 200 pixels; sunlight readable monochrome
Keypad: 5-button membrane pad
Battery:
Built-in Li-ion
Operating hours: 8 hours typically
Capacity: 5200 mAh
Recharging time: 3.5 hours typically; 2 hours with Qualcomm® Quick Charge™ 2.0 or 3.0
Data storage: 128 MB
USB specifications: Communication/charging interface: Micro-B Qualcomm® Quick Charge™ 2.0 or 3.0 for rapid charging
Universal charging adapter:
Input: 90 to 264 VAC; 50 to 60 Hz
Output: 5 VDC; 1 Amp
Configuration software: Windows® and macOS® applications
Data files: Plain text data compatible with any spreadsheet application or data analysis program
Output: .CSV format
Barcode scanner: 1-D and 2-D, including Code 39, Code 128, PDF417, 100% UPC, Data Matrix, QR Code
Photosynthetically Active Radiation (PAR) measurement:
Units: Photosynthetic Photon Flux Density (PPDF); µmol m^{-2} s^{-1}
Calibration Accuracy: ±10% of reading; traceable to NIST
Cosine correction: Cosine corrected up to 60° angle of incidence

Porometer

Aperture: 0.75 cm diameter
Flow rates:
Low: 75 µmol s^{-1}
Medium: 115 µmol s^{-1}
High: 150 µmol s^{-1} *
RH sensor accuracy: ±2% RH
Reference temperature: ±0.2 °C
Leaf temperature sensor accuracy: ±0.5 °C
Inlet flow measurement: ±1% of reading from 75 µmol s^{-1} to 150 µmol s^{-1}
Exhaust flow measurement: ±5% of full scale up to 150 µmol s^{-1}
Parameters:
- g_{sw} mol m^{-2} s^{-1}; g_{bw} mol m^{-2} s^{-1}; g_{tw} mol m^{-2} s^{-1}; E mmol m^{-2} s^{-1}
- VP_{cham} kPa; VP_{ref} kPa; VP_{leaf} kPa; VPD_{leaf} kPa
- H_2O_{ref} mmol mol^{-1}; H_2O_{samp} mmol mol^{-1}; H_2O_{leaf} mmol mol^{-1}

Fluorometer

Flash types: User configurable Rectangular and Multi-phase Flash™ (MPF)
Measuring light peak wavelength: 625 nm
Measuring light peak intensity: 0 to 10,000 µmol m^{-2} s^{-1}
Flash intensity: 0 to 7500 µmol m^{-2} s^{-1}
LED risk group: Exempt group in acc. with IEC 62471:2006. The LED does not pose any photobiological hazard
Parameters:
F_o, F_m, F_v, F_v/F_m, F_s, F_m', Φ_{PSII}, ETR

GPS Receiver

Accuracy: 2.5 m CEP (circular error probable)

**High flow may not be achievable at higher altitude. Specifications subject to change without notice.*

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ISO 9001:2015 certified 980-20118 05/22

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