Defining "rugged": Deciphering ruggedness testing standards

By Dale Kyle

Handheld computers are becoming increasingly popular for use outside the office. Their versatility makes them useful tools for public safety, law enforcement, field service and construction, as well as utility, forestry and military applications.

However, consumer-grade handhelds like Hewlett Packard iPAQs and Palm Pilots are not meant for everyday use outdoors. They're not designed or built for applications where users often work in rain, extreme heat or cold, or at job sites that are dusty, wet or muddy. Nor can consumer-grade handhelds withstand repeated drops or vibration. For these harsher environments and for rough everyday use, fully rugged and semi-rugged handhelds are a much better choice.

Trimble and its subsidiary Tripod Data Systems design and manufacture two fully rugged handhelds—the Ranger™ and the Recon®. Since its introduction, the Trimble Recon has been deployed in a number of Department of Defense applications. From the city streets of Baghdad to the jungles of Central and South America, the Recon has been validated in applications where a laptop computer—with its boot time, weight and battery limitations—is not a feasible option. The Recon also offers an optional AA PowerBoot Module™ that uses two alkaline or lithium AA batteries to power the Recon for up to 16 hours.

Introduced in 2000 and substantially updated in 2005, the Trimble Ranger has the features field professionals depend on, like field-ready ruggedness, a 30-hour battery and an easy-to-use keypad and touchscreen. Like the Recon, the Ranger gives users the option of integrated Bluetooth and 802.11 wireless, so they can communicate without bulky cables. In addition to CompactFlash (CF) slots, the Ranger features a Secure Digital (SD) slot that lets users works with SD memory, SD I/O and other SD accessory cards.

In this white paper, I'll explain the difference between semi-rugged and rugged handhelds, define IP and MIL-STD durability standards, and describe the testing protocols. I'll follow that with a more detailed description of how Trimble tests its rugged handhelds to these specifications. The IP and MIL-STD standards provide objective information to help you select a handheld computer that will stand up to your users' working environments.

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IP Ratings and MIL-STD-810F

Two basic standards—Ingress Protection (IP) ratings and MIL-STD-810F—are used to determine the ruggedness of handheld computers. The IP rating uses two numbers to describe how well the unit is protected against incursion by dust and water. The first number (1 to 6) measures dust protection; the second number (1 to 8) describes water protection.

The second major standard—MIL-STD-810F—is a series of U.S. military testing standards that have gained acceptance in industries beyond the military for their methods of objectively determining whether a device is able to withstand potentially destructive elements such as drops, dust, water immersion, vibration, and altitude or temperature extremes.

Semi-Rugged Handhelds

Semi-rugged handhelds can handle rougher treatment than a consumer-grade handheld, but they are not fully waterproof or dustproof, generally have a narrower temperature range, and do not meet all MIL-STD-810F specs. Most semi-rugged handhelds come with an IP rating of IP54. That means the unit is protected, though not sealed, against dust. It is resistant only to light splashing, but it's not able to withstand jet sprays or immersion.

Rugged Handhelds

Trimble's Recon and Ranger are two examples of rugged handheld computers. They come with an IP67 rating, which means they are sealed against dust and can survive temporary immersion. They have also passed a full battery of MIL-STD-810F tests, including drops, vibration, immersion and temperature extremes.

IP Codes

The Ingress Protection (IP) Code, prepared by the International Electrotechnical Commission (IEC), is a system for classifying the degrees of protection provided by the enclosures of electrical equipment. The system was intended to establish a uniform method for describing the protection provided by the enclosure. The numbers in the IP code describe the various levels of protection as outlined below:

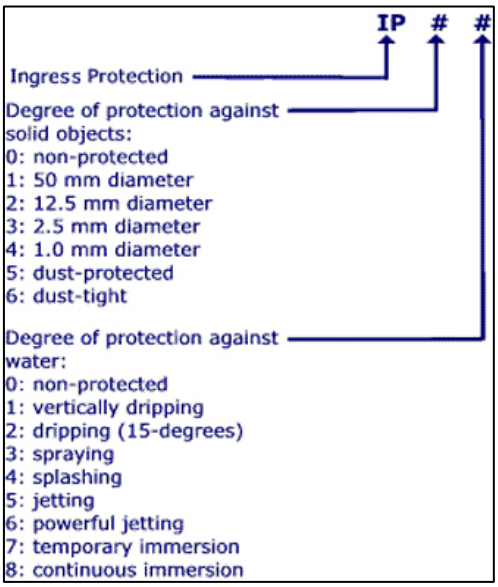

Figure 1—Ingress Protection (IP) Code definitions

As described earlier, most semi-rugged handhelds have a rating of IP54. That means the unit is protected, but not sealed, against dust and is splash-protected. Rugged handhelds like the Trimble Recon and Ranger have an IP67 rating. That means dust cannot get inside the enclosure, and the units can survive temporary immersion, such as being dropped in a puddle.

The MIL-STD

The MIL-STD testing procedures determine the effect of natural and artificial impact on equipment. Started in 1961, MIL-STD-810 has seen six revisions over the past 45 years. Product data sheets often make claims like "designed using MIL-STD-810 test procedures." Since MIL-STD-810 includes hundreds of testing procedures, each of which tests different types of protection, the mere reference to MIL-STD-810 testing is insufficient. It's important to know both which MIL-STD-810 tests were performed on the unit,

and how the unit performed, in order to determine how rugged it truly is. Just because a unit was tested to MIL-STD-801 specifications doesn't mean it passed those tests.

I've described the relevant MIL-STD-810 tests below. After outlining the specifications for each procedure, I've described how Trimble and its subsidiary company Tripod Data Systems test Recon and Ranger handheld computers to meet each specification.

MIL-STD-810F Method 500.4—Low Pressure

Low-pressure (altitude) chamber tests determine if materiel can withstand and operate in a low-pressure environment. The test also determines if materiel can withstand rapid pressure changes. Some problems that might occur after exposure to reduced pressure are:

1. Rupture or explosion of sealed containers
2. Change in the physical and chemical properties of low-density materials
3. Erratic operation or malfunction of equipment resulting from arcing or corona
4. Overheating of equipment due to reduced heat-transfer properties
5. Failure of hermetic seals

How Trimble Tests for this Spec:

Sample units are exposed to atmospheric pressure simulating an altitude of 8,000 ft and then stabilized for 15 minutes. They are then exposed to a simulated increase in altitude to 40,000 ft in 15 seconds or less. The units are held at 40,000 ft for 10 minutes. Finally, the units are returned to the site altitude and are subject to a test of all standard functions.

Figure 2—MIL-STD-810F Method 500.4 low-pressure test

MIL-STD-810F Method 501.4—High Temperature

High temperatures may temporarily or permanently impair the performance of a handheld computer by changing the physical properties or dimensions of its casing as well as internal components. Some problems that might occur after exposure to high temperature include:

1. Parts binding due to materials expanding at different rates
2. Materials changing in dimension, either totally or selectively
3. Permanent gasket deformation
4. Deterioration of closure and sealing strips
5. Changes in the value of fixed-resistance resistors
6. Variations in electronic circuit stability caused by materials expanding at different rates
7. Overheating transformers and electromechanical components
8. Shortened operating lifetime
9. High pressures created within sealed cases
10. Discoloration, cracking or crazing of organic materials

How Trimble Tests for this Spec:

Following a two-hour stabilization period at 65 C, sample units are exposed to three 24-hour cycles at 65 C. The first 24 hours are at 65 C with the units not running, followed by 48 hours at the same temperature with the units operating

MIL-STD-810F Method 502.4—Low Temperature

Extremely low temperatures have adverse effects on almost all basic materiel. As a result, exposing test items to low temperatures may either temporarily or permanently impair the operation of the test unit by changing the

physical properties of its casing and components. Therefore, a low-temperature test must be considered whenever the test item will be exposed to temperatures below standard ambient. Some problems that might occur after exposure to extreme cold include:

1. Materials becoming hard and brittle
2. Parts binding due to materials expanding at different rates in response to temperature changes
3. Changes in electronic components such as resistors and capacitors
4. Stiffening of shock mounts
5. Reduced material strength from cracking and crazing
6. Static fatigue of restrained glass
7. Water and moisture condensing and freezing

How Trimble Tests for this Spec:

After the sample units have passed a pre-exposure function test, they are turned off, and with adapters connected the units are exposed to -40 C for a 24-hour period. The units are then returned to ambient conditions and allowed to stabilize for two hours. Then the units run through the same function test.

MIL-STD-810F Method 503.4—Temperature Shock

Exposure to sudden, extreme temperature changes may temporarily or permanently affect the operation of the unit. Temperature-shock tests are conducted to determine if materiel can withstand sudden changes in temperature without experiencing physical damage or deterioration in performance. Some problems that might occur after exposure to sudden temperature changes include:

1. Glass shattering
2. Moving parts binding or slackening
3. Component separation, deformation or facture
4. Stiffening of shock mounts
5. Changes in electronic components
6. Electronic or mechanical failures due to rapid water condensation or freezing
7. Materials expanding or contracting at different rates in response to temperature changes
8. Surface coatings cracking
9. Sealed compartments leaking

How Trimble Tests for this Spec:

Operating sample units are exposed to temperature extremes from -35 C to 65 C. Units are held for four hours at each extreme for a total of three cycles.

MIL-STD-810F Method 506.4—Rain

The rain test is conducted to determine if the protective covers or cases effectively prevent rain from penetrating the unit. The rain test also determines if the unit can satisfy its performance requirements during and after exposure to rain. Some problems that might occur after exposure to rain include:

1. Loss of physical strength
2. Metal corrosion
3. Surface coatings deterioration
4. Electrical component malfunctions

How Trimble Tests for this Spec:

Sample units are sprayed for one minute per square meter of enclosure. The spray nozzle has a 12.5 mm internal diameter with a delivery rate of 100 L/min. from a distance of 2.5 to 3 meters.

MIL-STD-810F Method 507.4—Humidity

Moisture can cause multiple types of physical and chemical deterioration. These include: surface effects such as corrosion and organic growth such as mold and mildew; moisture penetration that changes material properties; and condensation that affects electrical or mechanical performance. Some problems that result from exposure to a warm, humid environment include:

1. Swelling of materials due to moisture absorption
2. Loss of physical strength
3. Changes in mechanical properties
4. Degradation of electrical and thermal properties in insulating materials
5. Electrical shorts due to condensation
6. Moving parts binding due to corrosion or fouling of lubricants
7. Metal oxidation and/or galvanic corrosion
8. Loss of plasticity
9. Accelerated chemical reactions

How Trimble Tests for this Spec:

Two sample units are pre-conditioned for 24 hours at 23 C and 50% relative humidity. The two samples are then exposed to five 48-hour temperature/humidity cycles at 60 C and 95% relative humidity.

MIL-STD-810F Method 510.4—Sand and Dust

The sand and dust test is divided into two procedures. The small-particle procedure (dust and fine sand) is performed to determine the ability of equipment to resist the effects of dust particles that may penetrate into cracks, crevices and joints. The blowing sand test is performed to determine the ability of equipment to be stored and used under blowing sand conditions. To pass the blowing sand test, there must be no loss of performance, effectiveness, reliability or maintainability due to the abrasion (erosion) or clogging effect caused by large, sharp-edged particles. Examples of some problems that could occur as a result of exposure to sand and dust are:

1. Surface abrasion
2. Seal penetration
3. Surface erosion
4. Degradation of electrical circuits
5. Clogging of openings and filters
6. Physical interference with mating parts
7. Moving parts binding or fouling

How Trimble Tests for this Spec:

Sample units are exposed to dust with a concentration of 2kg/M3 for eight hours. A vacuum pump is attached to the unit to maintain 2kPa vacuum during testing.

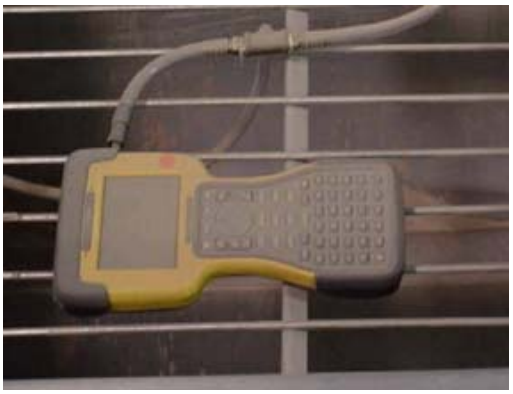

Figure 3—MIL-STD-810F Method 510.4 sand and dust test

MIL-STD-810F Method 512.4—Immersion

The immersion test is conducted on operating and non-operating units that may be exposed to partial or complete immersion. In some cases this test may be used in place of the rain test (Method 506.4) to verify that a unit is watertight. This is acceptable provided the materiel configuration would be the same for both situations, and the method of water ingress is well understood. However, there are documented situations where the impact of the

spray causes a pumping of water across the seals during the rain test. This does not occur in the immersion test, where the seals are held tight against a backing plate by the static pressure. For this reason, both the rain and immersion tests should be performed.

Penetration of water into materiel or packaging enclosures can result in multiple problems. Consider the following typical problems to help determine if this method is appropriate for the equipment being tested. This list is not intended to be all-inclusive.

1. Fouling of lubricants between moving parts
2. Formation of electrically conductive paths that may cause electrical or electronic equipment to malfunction or become unsafe to operate
3. Corrosion due to direct exposure to the water or due to the high relative humidity levels

How Trimble Tests for this Spec:

Sample units are immersed for 30 minutes. The lowest point of the sample units is 1,000 mm below the water surface.

Figure 4—MIL-STD-810F Method 512.4 immersion test

MIL-STD-810F Method 514.5—Vibration

Vibration testing is performed to determine the resistance of equipment to stress caused by vibration during shipment and in typical application environments. Problems caused by vibration include:

1. Wire chafing
2. Loosening of fasteners
3. Intermittent electrical contacts
4. Touching and shorting of electrical parts
5. Seal deformation
6. Component fatigue
7. Display/touchscreen misalignment
8. Cracking and rupturing
9. Excessive electrical noise

How Trimble Tests for this Spec:

Two vibration tests are performed. In the first test, operating sample units are subjected to one hour per axis of random vibration with a frequency range of 20 Hz - 2 kHz, as outlined in Method 514.5C-17. The second test is performed with an unrestrained sample unit, with fences around the sample. The sample unit is subject to 30 minutes of vibration at a frequency of 5 Hz with the display facing horizontally. It is then exposed for 30 minutes with the display facing vertically to 1-inch displacement, again at a frequency of 5 Hz.

Figure 5—MIL-STD-810F Method 514.5 vibration test

MIL-STD-810F Method 516.5—Shock

Shock tests are performed to assure that materiel can withstand the relatively infrequent, non-repetitive shocks or transient vibrations encountered in normal use and transport. Shock

tests are also used to measure an item's fragility, so that packaging may be designed to protect it if necessary. Mechanical shocks will excite an item to respond at both forced and natural frequencies. This response, among other things, can cause:

1. Failures due to increased or decreased friction, or interference between parts
2. Changes in dielectric strength, loss of insulation resistance and variations in magnetic and electrostatic field strength
3. Permanent deformation due to overstress
4. More rapid material fatigue

How Trimble Tests for this Spec:

At ambient temperature, a sample unit is dropped 26 times on all six faces, edges and corners. The sample unit is then cooled to -35 C, stabilized for three hours and immediately dropped on all six faces. Then the unit is heated to 65 C, stabilized for three hours and dropped on all six faces again. The drop height is four feet onto two-inch-thick wood over concrete.

Making an Informed Decision

The versatility of today's handheld computers is making them increasingly useful. Building ruggedness into normally fragile computers' parts extends their reach and increases their utility in applications where users and their equipment are subjected to outdoor conditions. The IP and MIL-STD standards provide objective information to help you select a handheld computer that will stand up to your users' working environments. For true outdoor computing longevity and reliability, units must achieve a rating of IP67 and have been successfully tested against the most relevant MIL-STD-810F procedures. When assessing the suitability of a handheld computer to your particular application, be sure to look past claims of "MIL-STD-810F" and ask for testing reports of the specific testing procedures

About Dale Kyle

Dale Kyle is Rugged Handhelds Product Manager for Tripod Data Systems, a wholly owned subsidiary of Trimble. He has more than 15 years of experience in product development, systems testing, quality assurance and customer support for GPS and other navigation hardware and software. At Magellan Corp., he managed the development and technical approval of an OEM board that combined GPS and wireless communications via the ORBCOMM satellite constellation. At Glenayre Electronics, he managed the development, marketing and early production activities of a consumer wireless/GPS personal location and asset tracking device. He also produced a number of user manuals and other technical documentation for GPS receivers and software at Thales Navigation. Dale has bachelor's degrees in geology and environmental studies from the University of Maryland. He can be reached at dale_kyle@trimble.com or 541-750-9200.