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Javad Triumph-LS

The tiny Triumph-2 is a fantastic base station receiver for the Triumph-LS and connects by Bluetooth to any of Javad's modems. In this picture, I have the Triumph-2 mounted to our office monument, POST, and I am making use of the Triumph-2's ability to connect via WiFi to my internet router, about 100 feet away. The Triumph-LS then connects to the internet via the internal GSM or by Bluetooth to my smart phone. This would make an excellent internet base station solution and requires no computer or software to pipe out corrections to the internet.

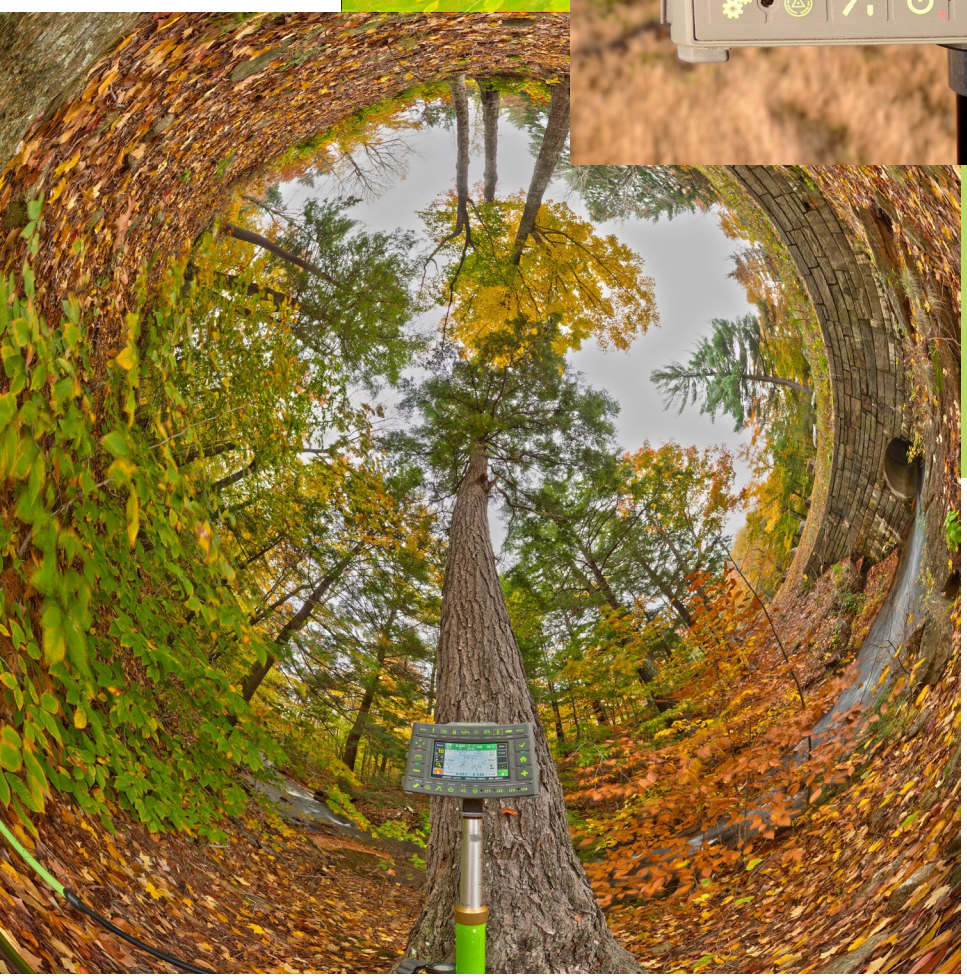
Triumph-LS

In June of 2013, Marc Cheves, my friend and editor asked me to cover a product announcement by Javad GNSS in San Jose, California. Javad and his team can be credited with countless advancements in GNSS precise positioning over the past 30 years, but I was unprepared for what I experienced upon my arrival. Rather than meeting an elite academic, I found Javad to be incredibly down-to-earth. In spite of his numerous innovations, he seldom looks back on those past achievements, seemingly fixated on creating new technologies to make precision GNSS even better. I also found that, together with Javad's storied success, he is also a gifted teacher, and has the ability to break complicated subjects down to understandable concepts. Lastly, and perhaps most significant to this story and review, Javad likes surveyors. I don't quite understand why he is so devoted to surveyors, but he is. He has made considerable investments of time, energy and money to understand the unique needs of conscientious surveyors and developing hardware and software that meets those needs. When we first spoke, he admitted that although his gear had always established the state-of-the-art, his software had not. To address this, he landed on the idea of bringing together a small group of licensed surveyors—all experienced in the use of GNSS—to teach him what was important to American surveyors and why.

Upon our arrival, guests were introduced to mockups and the magnesium skeletal frame of the Triumph-LS, Javad's latest flagship product. The highlights of the design specifications called for an 864 channel all-in-one GNSS receiver. While an impressive feat, to be sure, I wondered, "What could the possible benefit of 864 channels be for tracking less than 30 visible satellites?" Javad's 30 years of success suggested he deserved the benefit of the doubt. His answer: 864 channels allow the receiver to listen to each signal (GPS C/A, P1, P2, L2C , L5; GLONASS C/A, L1, L2, L3, L2C; Galileo E1, E5A, E5B, AltBoc; Beidou B1, B2; and QZSS L1C, L2C, L5 and SBAS L1, L5) with multiple independent channels (like several ears listening to the same whisper).

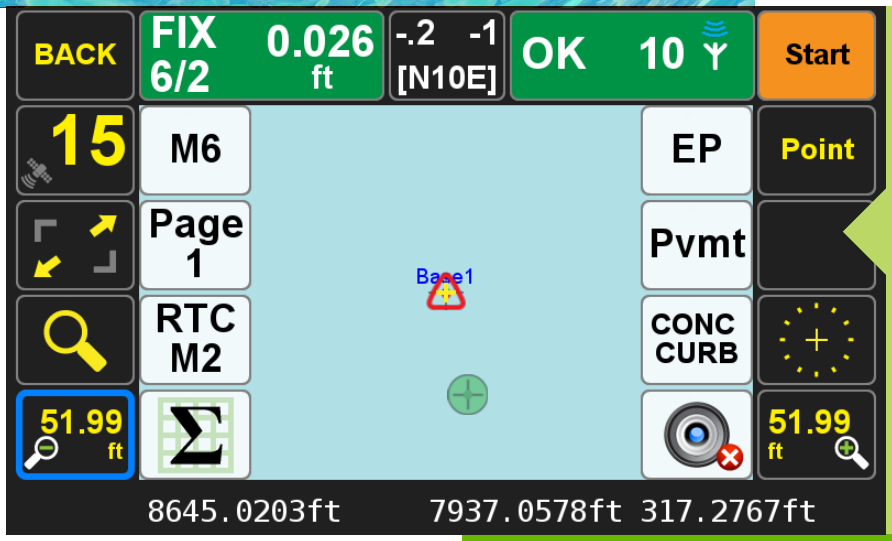
» SHAWN BILLINGS, PS

In initial testing of the LS, the original screen was poorly received by the test group. Javad sourced another screen for the LS that is far better for field use. This is an actual picture of the screen in direct sunlight. As can be seen, the screen is still incredibly visible, even with direct late-day sun.



One hundred of the 864 channels listen for in-band interference from sources such as cellular, FM, AM, TV, airport, military, civilian, etc. When I asked him about the radical departure from the conventional rover/data collector, he explained that the all-in-one is more portable, with forward pointing compass/camera sensors, a unique heads-up operation (both of which are the foundational to Visual Stakeout and pixelated angle measurement), tilt compensation and one battery pack for everything.

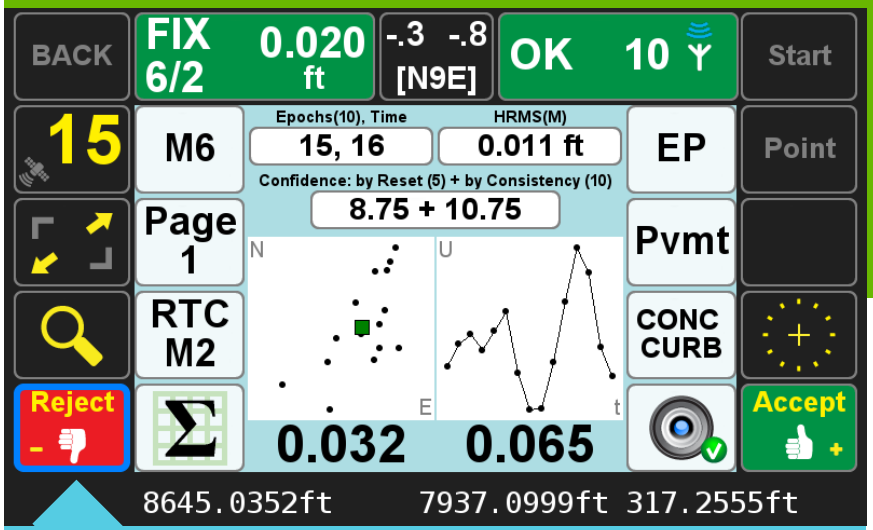
The Triumph-LS is not Javad's first attempt at an all-in-one receiver. The Triumph-VS was the bellwether for this type of configuration, but tepid acceptance in the US showed this format has yet to prove itself. I left that first meeting in San Jose still skeptical about the concept—until I used it. What I found was that the box-on-a-stick approach is very appealing. Using the supplied monopod, I could collapse the pole and place the entire rover system in the floorboard of a small car. Walking across a large site proved to be much more comfortable with the compact receiver and pole over my shoulder than the more conventional two meter pole, receiver head and data collector. Navigating through underbrush was much easier with the collapsed monopod and clean receiver than with a gangly two meter pole, bracket and external UHF antenna dangling from it. After a couple of weeks of use I found the configuration to be very compelling. In conversations with other test-group surveyors, I've heard similar conversion stories: skepticism, giving way to acceptance, leading to enthusiastic approval. Ergonomically, no more sore back after long days of RTK topographic surveying—and added to improved comfort, a new set of features: Lift and Tilt (hands free start/stop point collection), Tilt compensation, and Guide stake out.



This is a screen capture of the Collect/Action screen. Visible in the map is the base location (red triangle), rover location (green circle), the eight user configurable white boxes (which are set to point name, active page, point description, base/rover status, Tag, Code, Attributes, and image attach). The top row indicates that I have six RTK engines fixed with my minimum set to two (J-Field will not store a point unless this minimum is met). The bracketed bearing is the grid direction from the internal compass, and the upper right green "OK" button shows the radio signal is good and that the LS is currently set to use corrections up to 10 seconds old.

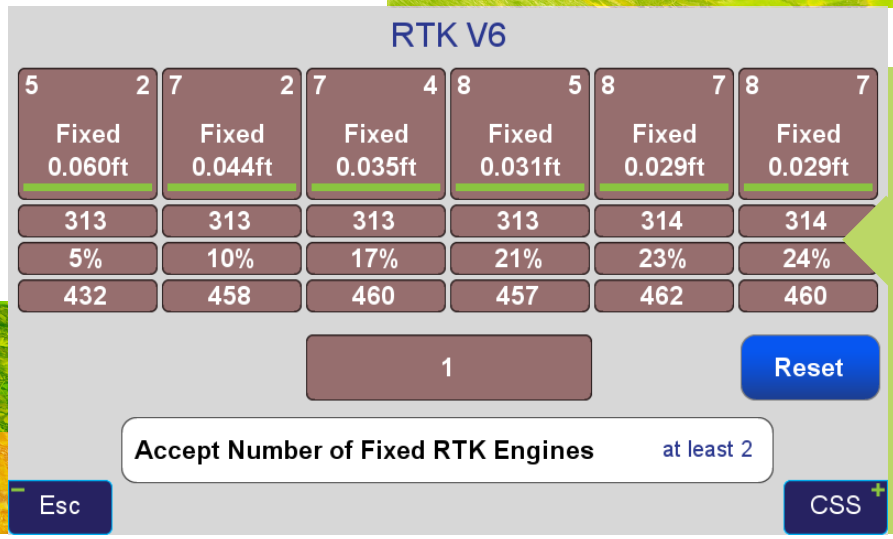
Included with the Triumph-LS: 864 GNSS channel, single chip receiver with six parallel RTK engines, internal radio modem (UHF or Spread Spectrum), two internal GSM SIM card slots (supporting the ability to easily switch between two carriers), internal Spectrum analyzer (identifies presence of interference to GNSS signals), internal UHF scanner, two cameras (one pointing to nadir, one pointing forward), internal tilt sensors, internal compass, WiFi, Bluetooth, two USB ports (host and client), optional RS-232 serial port, microSD card slot, LED flashlight, 20 hour run time on a single charge (with the optional second internal battery), 16 gigabyte internal memory, a brilliant, 4.3 inch, capacitive touchscreen, protected by Dragontrail glass, and Windows Compact 7 operating system.

The six parallel RTK engines are retained from the Triumph-VS, but are used in a more sophisticated way in the Triumph-LS with J-Field data collection software. Each of the six RTK engines constantly work independently to obtain and maintain a fixed, centimeter-level position, and each one uses slightly different parameters and assumptions in its algorithms, and when more than one is fixed, J-Field uses a weighted average of each fixed engine to compute a position. This allows for some fantastic features in the field. For years conscientious surveyors have understood that observations to obstructed or critical points required (at a minimum) observing the point with a fixed solution, resetting the engine and returning to the point with a new fix and comparing them, with the assumption being that it is unlikely for an RTK processor to provide the same wrong fix more than once. The LS does this automatically both faster and with more statistical robustness with *Auto-Verify with V6 resets*.



As an observation is in progress, the user is presented with a scatter plot of the epochs used in the position. On the bottom left, 0.032 ft, represents the horizontal size of the box necessary to contain all of the observations (a sort of peak-peak), on the bottom right, the vertical plot and the extreme spread, 0.065 ft. Once the minimum settings have been satisfied, the user can set J-Field to automatically accept the shot or (in this case) prompt for accept/reject. Here the receiver accumulated 8.75 engine resets, with a minimum requirement of 5; 15 epochs of data, with a minimum of 10 required; and a consistency of 10.75 with the minimum set to 10. Once all three were satisfied, J-Field concluded the observation.

Auto-Verify with v6 resets employs a two-step approach to observing a point and provides impressive confidence in a single observation of a point. In Phase 1 of an observation, J-Field waits for an engine to fix, notes the position, and forces the engine to reset. This process repeats continuously for all six engines until the user defined number of independent engine fixes has been met. This could be a low number (less than ten) or a large number (more than 100), depending on the confidence the user desires and the amount of time he is willing to wait. While the LS can fix in very difficult environments, more time is required to fix in these areas than in open areas. During Phase 1, if two or more engine fixes disagree with one another, J-Field temporarily holds both positions until additional engine fixes prove one or both to be incorrect and then the errant fix is discarded from the point average. Once Phase 1 is complete, the software moves to Phase 2 in which the



A screen capture of the RTK V6 status screen—this screen displays the current status of each of the 6 RTK engines which are constantly processing incoming data and corrections independent of one another. In the upper left corner of each block is the current GPS satellite count used by that particular engine in the solution, while the upper right displays the current GLONASS satellite count. Each engine uses slightly different parameters (which is the reason not all engines are using the same satellites) and each has slightly different error estimates. These estimates are used for determining how much weight the engine has in the reported position (see the percentages).

engines are no longer forced to reset and are allowed to contribute additional epochs to the average until the total epoch count is satisfied. Rather than the good practice of getting two or three positions with independent fixes, J-Field proves the point reliability by repeating the fix numerous times and automatically including each valid fix in the final position.

Slightly less rigorous (and faster) is the *Auto-Verify without v6 resets* which uses a single Phase and a different metric called the *consistency level*. The consistency level is a unitless value that advances with each epoch so long as the epoch is based on two or more fixed engines. Two engines advance the counter slowly, while six engines advance very quickly. This works well for sites with varying conditions. Generally in marginal areas the LS will fix with fewer engines, while in the open it will generally fix all six engines. A point collected with *Auto-Verify without v6 resets* in an obstructed area will require more time on site automatically than a point in an open area. For example, a point collected with two engines fixed and consistency level set to 10, requires 100 seconds on-point. With six engines fixed this can be done in less than 10 seconds. Intuitively, J-Field adjusts the time on site in this mode based on the engines' ability to fix.

One last point regarding multiple engines, the user can specify the minimum number of engines required to be fixed before allowing a point to be collected. I like a minimum setting of two fixed engines as this provides some assurance that the fix I am relying on has been minimally tested with a second fix.

Between the 864 channels and the six parallel RTK engines, the LS tracks in some miserable places for GNSS surveying. Accuracy is diminished as a result of multipath and non-line-of-sight signals in really difficult environments. This is an inescapable consequence of physics, and because the signals are distorted before reaching the receiver, it is impossible to correct them. At best, the receiver can carefully determine (in the presence of multipath) which signal is the right one and which are reflections. In the case of non-line-of-sight signals (reflections only without the direct line of sight signal) the best the receiver can do is recognize the presence of this signal and disregard it. With that said, I was impressed with the places the LS could good fixed positions. In suitable places for GNSS surveying the LS provided very precise results, so long as I was careful in my procedure. The scatter plots and statistics that are shown with every shot provide excellent detail and can even help an experienced surveyor recognize the presence of multipath.

> "Auto-Verify does what conscientious surveyors have done for years, but automates the process and provides more statistical robustness."

Collection of points and lines is fast and simple. The interface is highly customizable. In the main collection and stake screens (referred to as the Action screen), there is a series of four white buttons on each side of the map. These buttons can be assigned by the user to display all sorts of information and actions. In Collect, a button can be set for the point name (alpha-numeric names are supported), point description, code, attributes, Tag, RMS values, base/rover status, rod height, and for immediately attaching photos to a point (and others). Stake offers white boxes for DTT (distance to target), CTT (course to target), right, left, ahead and back, delta N and E, and Cut/Fill (and others). Many surveyors use only point numbers and descriptions, opting not to create line work in the field. J-Field supports this type of surveying. Simply set a white box to "point name" and another to "description." At any time, a user can add more advanced features such as tags and codes and attributes or continue to survey with point names and descriptions for the entirety of his career.

For those that like to build maps in the field, J-Field supports code free line work generation: Press the button labeled "Point" and change the collection to "Line." All subsequent points will be connected as a line. Press the same button again and change the collection to "Curve" to build simple arcs. Curve collection is ingenious: Set the curve

The compact Triumph-LS and monopod are a radical departure from the 2 meter pole, receiver head and data collector. The LS/monopod combination is highly portable. Some early users expressed concern that the low mounted LS would not receive signals as well as a 2 meter mount, including worries that the user's head might obstruct satellite signals. I have not found that to be the case in my testing. The LS, at eye level, tracks as well as any 2 meter mounted receiver I've used.

counter to build a curve using 3 or more (*n*). No more PC, PT coding, J-Field does it automatically and the "Curve" button updates to tell you which *n* point you are about to locate along the curve. Codes in J-Field operate as GIS feature codes with user assignable attributes. A point could have a user-defined code for "boundary" with user-defined attributes for monument type, size, found/set, ID cap, etc. Codes also act as AutoCAD layers at export, so a line collected with code "boundary" will be exported in layer "boundary".

Tags in J-Field control connectivity of points and can be thought of as line names. All of the points collected under the Tag name "EP" would be connected by a series of lines and curves until that polyline is ended. If you want to begin a new line at an existing point or continue the current line through an existing point, simply select that point from the map (no need to remember point numbers) and J-Field will draw the currently active line from the point (if the line is new) or through the point (if the line has already been started) and continue adding collected segments beyond it.

Stake out handles staking of points and lines. Lines can be staked by particular stations and offsets or can be staked at random intervals. Point staking is helped substantially by the "Guide" feature, which shows the point being staked superimposed on the live image from the front facing camera. No more guessing at the direction to a point, line it up in the live video screen and start moving.

Base/Rover setup in J-Field is the simplest I have ever used. Initially, the procedure for base setup was torturous. Javad's development team has been extremely fast at responding to user requests, particularly from his PLS team. The PLS team made recommendations to make this better and the development team went to work. Now the procedure is smooth and lightning fast. Javad insists that using a local base is better than remote network solutions, and I am inclined to agree. The LS will work with corrections from Real Time Networks with good results, but fix times and precision are markedly improved with a local base. Pairing the Triumph-LS with the miniature Triumph-2 and an external base radio modem makes for a great package. The Base/Rover setup routine configures the base modem and rover modem simultaneously (no chance of setting the base frequency, or message type differently from the rover). The position sent to the base is compared against the running autonomous position of the base and the difference reported to the user, something I've never seen another software do. The likelihood of selecting the wrong base coordinate is reduced immensely with this feature. The LS's UHF scanner can be employed in Base/Rover setup to scan all of the frequencies in the user's frequency library to find a clear channel.

COGO is incredibly sophisticated. Few survey software developers have a geodesist on staff, much less a team of geodesists. Javad's team of geodesists insist on creating geodetically pure software for his users. Nowhere is this more apparent than in COGO. Inverse between two points, and at the touch of a button, the user can view the Grid bearing, Geodetic bearing, or magnetic bearing between two points. Similarly, a distance can be related to Grid, Ground, Geodetic (along the ellipsoid) or Slant (mark to mark slope distance). When the user creates a point at some direction and distance from a point, he can select the type of direction and distance to use. This same adherence to geodetic purity is even applied to the internal compass. At all times in Collect and Stake, the compass direction is shown and is automatically corrected for magnetic declination and for grid convergence when applicable. Point averaging is extraordinarily robust. Average two or more surveyed points together and the software weights the average by the error estimates of each point and the result is not only a coordinate point but a vector with newly created error estimates as well.

Internally—and transparent to the user—all surveyed points are stored in WGS84(ITRF2008). These points are transformed and projected on the fly to whatever coordinate system the user wants: State Plane, UTM, Geodetic, several statewide county-level LDP systems, or hundreds of other predefined systems across the world, not to mention support for custom projections. However, at the core, all surveyed coordinates are stored in the database as

ITRF2008 latitude, longitude and ellipsoid height. This helps to future proof the user's data. As new coordinate systems and adjustments become available, the coordinates can be transformed by translations and velocities to these new systems.

Javad's J-Field software also offers a new concept to many surveyors: Pages. Each project in J-Field is given ten Pages which can be thought of as sub-projects. The user is free to employ pages however he or she may choose, perhaps placing imported data in one page, primary control in another, project design data in another, and topographic data in yet another. Of course, a surveyor could choose to keep all of her data in a single page and not get mired by the concept. But for a savvy surveyor, Pages can offer a lot of help in organization of his or her data for a complex project.

Data export is customizable and covers everything a surveyor might need, from simple text file export, to dwg, dxf, shape and LandXML, to vector file export (NGS G-File and user-defined). Export to a thumb drive plugged into the USB port and then easily import that data into a third party data collector or vice versa. Use vector file export to adjust RTK vectors in a desktop least squares program. While the software may still need improvement in some areas, I have seen that when Javad's team focuses their energy on a feature, they consistently surpass expectations. At the time of this writing, collecting points by offset still needs some work, mostly in overall simplification, and there are a number of exciting features in development—such as Verify Base, which performs an adjustment of surveyed points tied to an autonomous base position after the base station raw data is processed to NGS CORS in Javad's DPOS positioning service.

Javad and his team have created a device that turns conventional wisdom on its head, rethinking field surveying from the ground up. Increasingly, while working in the field, using some proprietary routine, I recall that "Javad and I talked at length about this feature." I smile, realizing that he insisted when I first met him that he should embark on this new software rather than adhering to the status quo by putting existing software in the LS, and now I believe it has been for the best. Javad has a long history of introducing alien technology that eventually becomes main stream. The Triumph-LS will be no different. I have found the form factor captivating. It is far more comfortable to use in the field with its collapsible monopod than anything else I've ever used. The hardware provides a platform for receiving corrections from most any source with the ability to verify that the positions it provides are reliable by use of its v6 RTK engines. The software has been heavily influenced and tested by real surveyors and offers features no other platform does. Coupled with the pocket-sized Triumph-2 as a base, an entire RTK base/rover system can be fitted into a small duffel bag, and can be had for about $20k. The Triumph-LS is supported by a detailed manual authored and edited by experienced American surveyors, and a new message board and support team provide quick, free access to knowledgeable users. ■

In places like this, the theoretical intersects experiential. Six parallel RTK engines, 864 channels, multi-constellation tracking, built-in *Auto Verify* procedures all make the work of collecting accurate positions in environments such as this, much more likely and give the user confidence that the reported position is within tolerance.

Shawn Billings is a licensed land surveyor in east Texas and works for Billings surveying and Mapping Company, which was established in 1983 by his father, J. d. Billings. Together they perform surveys for boundary retracement, sewer and water infrastructure routes, and land development.