The Role of F.I.G. in Leading the Development of International Real-Time Positioning Guidelines

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SUMMARY

The rapid growth of real-time reference station networks (RTN) and the application of positioning in real-time are driving a demand for the international community of geospatial professionals to formulate guidelines, specifications and procedures to achieve accurate, consistent and reliable coordinates from this technology. The National Geodetic Survey (NGS), a program office of the National Oceanic and Atmospheric Administration (NOAA) in the United States of America, recognizes that while much work has been done by public agencies, scientific and academic professionals and private sector Global Navigation Satellite Systems (GNSS) companies world-wide, there still exists a great need for comprehensive documentation to address the many variables involved with reliable real-time positioning.

The International Standards Organization (ISO) Technical Committee 172 Subcommittee 6 (ISO/TC172/SC6) has done extensive testing for "GNSS field measurement systems in real-time kinematic (RTK)**"** using statistical means to authenticate manufacturers' GNSS hardware and firmware in normal field conditions. Building upon this procedure to measure the real-time precision capabilities of the GNSS equipment, procedures to ensure that particular accuracies are achieved at the 95% confidence level in diverse conditions should be developed. The NGS feels that these areas should include: classical single-base positioning for the user, RTN positioning for the user, establishing and adjusting coordinates on RTN reference stations, planning and site considerations for a RTN and methods for providing consistency between overlapping RTNs and between a RTN and a national reference frame. Due to the multitude of variables present with this application of GNSS positioning, the NGS feels that FIG. can provide the international collaboration necessary to successfully develop comprehensive guidelines.

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I. BACKGROUND

The International Standards Organization (ISO) Technical Committee 172, Subcommittee 6, (ISO/TC172/SC6) which deals with geodetic and surveying instruments, has recently published international standards[1] for GNSS field measurement systems. The subcommittee is comprised of 8 participating countriesand 10 observing countries and also includes representatives from major GNSS manufacturers.
This document:
"…specifies field procedures to be adopted when determining and evaluating the precision (repeatability) of GNSS field measurement systems (this includes GPS and GLONASS as well as the future systems such as GALILEO) in real-time kinematic (GNSS RTK) and their ancillary equipment when used in building, surveying and industrial measurements. Primarily, these tests are intended to be field verifications of the suitability of a particular instrument for the required application at hand, and to satisfy the requirements of other standards**.** *They are not proposed as tests for acceptance or performance evaluations that are more comprehensive in nature*."

This then gives confidence that the GNSS equipment is functioning properly and will achieve precisions to meet the manufacturer's claim. The ISO 17123-8:2007 document describes two distinct types of tests to determine the GNSS equipment's capability to meet manufacturers' precision specifications: The *Simplified Test* and the *Full Test*

Both methods use the following configuration of one base and two rover points as shown in the ISO 17123-8:2007 document (replicated below):

[1] ISO 17123-8:2007 Optics and optical instruments -- Field procedures for testing geodetic and surveying instruments -- Part 8: GNSS field measurement systems in real-time kinematic (RTK), web page:
http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=42213&commid=53686

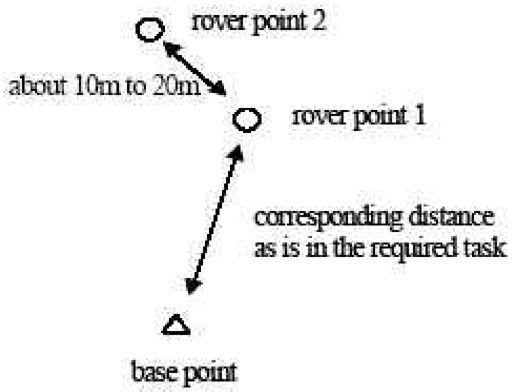

Figure 1 — Configuration of the field test network

In both tests, a 'series' is defined as a group of measurements obtained via real-time methods and taken at 5 "sets" or unique pairs of locations (rover 1 and rover 2), where each unique pair is visited for XXXX seconds, and these measurements are spaced 5 minutes apart. Such a series of measurements to the 5 pairs of rover locations are then compared to independent measurements of distance and height taken at a nominal precision of 3 mm or better.

The *Full Test* utilizes 3 such 'series' of these measurements to develop statistical values and statistical tests from least squares procedures, while the *Simplified Test* applies just one series. All measurements must fall within the manufacturer's deviation tolerances for horizontal and vertical precision (or if these are unavailable, 15 mm horizontal and 25 mm vertical). Temperature and general weather conditions are noted by the observer.

The extensive work put into these tests can therefore yield an assurance that the user's GNSS equipment conforms to manufacturers' specifications in typical field conditions.

While the ISO 17123-8:2007 document addresses one needed component of RTN standardization, it fails to answer other questions. It describes a precision test, but does not address coordinate accuracy or consistency. This is where FIG could play a leading role.

II. THE REAL-TIME USER COMMUNITY

Because real-time positioning involves a multitude of variables that must be considered by the rover in field conditions, crafting concrete, reliable guidelines to ensure accurate positioning is not a straightforward task. Unlike static GNSS work involving post processed network adjustments, most users want the assurance of centimeter level precision positions on-the–fly, in the field. It is important that the user is aware of the following for performing reliable field work:

- Multipath
- Position Dilution of Precision (PDOP)
- Baseline Root Mean Square (RMS)
- Number of satellites
- Elevation mask (or cut-off angle)
- Base accuracy- datum level, local level
- Base security
- Redundancy, redundancy, redundancy
- Part(s) Per Million Error (ppm) – iono, tropo models, orbit errors
- Space weather- sunspot numbers, solar maximum
- Geoid quality
- Site calibrations (a.k.a. Localizations)
- Bubble adjustment
- Latency, update rate
- Fixed and float solutions
- Accuracy versus Precision
- Signal to Noise Ratio (S/N or C/N0)
- Float and Fixed Solutions
- Carrier phase
- Code phase
- VHF/UHF radio communication
- CDMA/SIM/Cellular TCP/IP communication
- WGS 84 versus local and national datums
- GPS, GLONASS, Galileo, Compass Constellations

Many public entities and other academic, scientific and private agencies have developed informal best methods to achieve their desired precision. There also exists varied documentation that attempts to deal with the plethora of variables present in this technology.

Even with these considerations, users across the world are increasingly turning to real-time technology for their applications. RTN are the norm in Europe and many parts of Asia and are presently sweeping across the USA. By providing interpolated correction parameters for atmospheric and orbit errors, the first order part-per-million (ppm) error is drastically reduced or eliminated. While there are many facets of RTN that need to be addressed to provide the user with homogenous, accurate coordinates, the focal point of any real-time positioning survey is at the rover. It is this place that must be first addressed by the real-time positioning survey community.

Finally, without an international standard, "best practices" developed by small groups either for academic or marketing purposes will not achieve the greater goal of absolute accuracy of RTN within a national or international datum, nor will it address the issues which will plague overlapping RTNs which process data in different ways.

III. THE ROLE OF FIG COMMISSION 5

There exists a need to produce an accepted, cohesive best-methods set of guidelines for world-wide users of real-time positioning. Therefore, as the preeminent international organization for surveyors, and as a liaison organization to ISO, it is incumbent upon FIG Commission 5 delegates to develop comprehensive user guidelines by assembling existing documentation from experienced users, unifying concepts important to achieving successful real-time campaigns, simplifying procedures to obtaining accurate results, and documenting proper procedures for legacy and current real-time users. FIG Commission 5 can augment the excellent work done by ISO/TC172/SC6 by taking further steps in user methodology to achieve certain accuracies at the 95% confidence level, and address the ability of all RTN operators to achieve accuracy and consistency within national and international datums. To this end, NGS has recently made publicly available draft user guidelines for classical real-time positioning[2]. User guidelines from several other countries were referenced to produce this document. (see *Acknowledgements*, page *i* and R*eferences*, page 75). A summary example of the precision (labeled accuracy) classes from these guidelines is replicated below:

ACCURACY CLASS SUMMARY TABLE

	CLASS RT1	CLASS RT2	CLASS RT3	CLASS RT4
ACCURACY (TO BASE)	0.015 HORIZONTAL., 0.025 VERTICAL	0.025 HORIZONTAL., 0.04 VERTICAL	0.05 HORIZONTAL., 0.06 VERTICAL	0.15 HORIZONTAL., 0.25 VERTICAL
REDUNDANCY	≥ 2 LOCATIONS, 4-HOUR DIFFERENTIAL	≥ 2 LOCATIONS, 4-HOUR DIFFERENTIAL	NONE	NONE
BASE STATIONS	≥ 2 , IN CALIBRATION PROJECT CONTROL	RECOMMEND 2 IN CALIBRATION	≥ 1 , IN CALIBRATION	≥ 1 , IN CALIBRATION RECOMMENDED
PDOP	≤ 2.0	≤ 3.0	≤ 4.0	≤ 6.0
RMS	≤ 0.01 M	≤ 0.015 M	≤ 0.03 M	≤ 0.05 M
COLLECTION INTERVAL	1 SECOND FOR 3-MINUTES	5 SECONDS FOR 1-MINUTE	1 SECOND FOR 15 SECONDS	1 SECOND FOR 10 SECONDS
SATELLITES	≥ 7	≥ 6	≥5	≥ 5
BASELINE DISTANCE	≤ 10 KM	≤ 15 KM	≤ 20 KM	ANY WITH FIXED SOLUTION
TYPICAL APPLICATIONS	PROJECT CONTROL CONSTRUCTION CONTROL POINTS CHECK ON TRAVERSE, LEVELS SCIENTIFIC STUDIES PAVING STAKE OUT	DENSIFICATION CONTROL TOPOGRAPHIC CONTROL PHOTOPOINTS UTILITY STAKE OUT	TOPOGRAPHY CROSS SECTIONS AGRICULTURE ROAD GRADING SITE GRADING	SITE GRADING VETLANDS GIS POPULATION MAPPING ENVIRONMENTAL

The broad range of international surveyors who have used real-time applications for many years can draw on their experience to produce a document which would remain the international standard, and thus be referenced both academically as well as for contractual work performed using real-time methods. It should be noted that due to the dynamic nature of the technology (additional and changing constellations and frequencies, better hardware and firmware, increased communication technology and coverage, etc.), the guidelines must be regularly updated. Additionally, they must be ported over to be applicable to users of RTN by addressing the particular conditions involved.

Therefore, the next steps proposed toward this end are:

1. The Commission 5 delegates must become familiar with the ISO/TC172 standards as a building block.

[2] National Geodetic Survey User Guidelines for Real Time GNSS Positioning, v 2.0 April 2008, Henning, William. Web page http://www.ngs.noaa.gov/

2. National survey organizations, such as NGS, should draft their best practices for real-time positioning – both for classical single-base and RTN methodologies.
3. Commission 5, workgroup 5.1, in charge of standards, quality assurance and calibration, should be tasked with compiling these best practices and preparing a summary for review by the international surveying community.

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