N90-20528

The Rapid Geodetic Survey System (RGSS)

J.R. Huddle

Litton Guidance and Control Systems Division, Woodland Hills, California

ABSTRACT

The RGSS is a system employing a high-accuracy gimbaled inertial platform. It provides a cost-effective capability for accurate direct measurement of the change in position, elevation, gravity intensity and deflection of the vertical from an initial point. The RGSS is an adaptation of the production version of the U.S. Army Position and Azimuth Determining System (PADS). Several hardware and software enhancements to improve the performance of the system, primarily for gravity vector survey, have occurred over the last few years. The basic principles for the control of error in the survey measurements due to noise and systematic error are discussed below. Actual acceptance test results for the RGSS which indicate an inherent capability of the system to measure change in the deflection of the vertical to a few-tenths of an arcsecond over survey periods of one to two hours using careful survey techniques are also presented. Finally a simple method to extend the capability of the system for longer duration surveys is indicated.

1. Introduction

The RGSS depicted in Figure 1 is based upon the Litton high-accuracy gimbaled LN-15 platform which employs 2 two-degree-of-freedom low drift rate G300-G2 gas spin bearing gyros and 3 low-noise A-1000 accelerometers. The full system includes a digital computer, control and display unit, power supply and tape recording unit. In a typical single traverse survey the system is aligned at the initial point, a process which brings the instrument coordinate system into coincidence with the local east, north and vertical geodetic coordinates, and is also provided with initial values of position, elevation and if available, the gravity disturbance vector. The system is then moved by land vehicle or helicopter to a new point where it is stopped to allow the real-time survey measurements to be recorded and system corrections to be made. It is well-known[1] that these corrections using the observable error in system computed velocity at the stops (called "ZUPTS"), effectively counteract the error effects of system noise sources during the travel periods, including the dominant source which is the change in the gravity disturbance vector. Additionally when the survey vehicle encounters the final point of the traverse, misclosures in the real-time position and elevation are used in a post-survey adjustment to remove the effects of accelerometer scale factor error and misalignment which are not observable with the velocity error observations at vehicle stops.

The manner in which the change in deflection of the vertical is measured with the RGSS is depicted schematically in Figure 2. At the initial point, the level accelerometers are aligned parallel to the reference ellipsoid. The Schuler-tuned inertial platform then maintains the parallel orientation of the level accelerometers with respect to this ellipsoid as it is moved across the surface of the earth. Consequently when the survey vehicle is stopped and there is no acceleration, any change to the deflection of the geoid from the ellipsoid can be observed with the level accelerometers.

2. Theory for Control of Error in a Vertical Deflection Survey

Any source of erroneous change in tilt of the level accelerometers will cause an error in measuring the change in the deflection of the vertical. Acceleration measurement error during the travel periods cause identical error in survey position and platform tilt. However, it has been well-documented[2] that the zero velocity updates and post-survey adjustment can control position error and consequently tilt, to the 10-cm (0.003 arcsec) level for short surveys. Hence it turns out that the principal source of erroneous tilt occurs due to the gyro drift rate integrated over the duration of the survey. Accelerometer noise and vehicle vibration are an additional

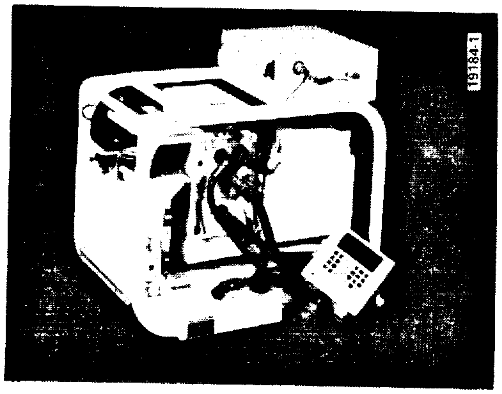

Figure 1. Rapid Geodetic Survey System

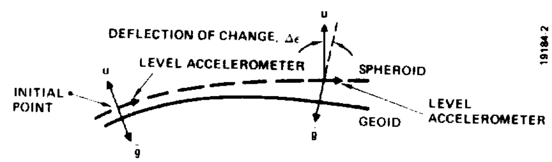

Figure 2. Measurement of Deflection Change

direct source of deflection measurement error at vehicle stops but can be substantially reduced by averaging over the stopping period. When the terminal point of the survey is encountered, the reference deflection change over the survey derived from astronomic points can be used to remove a substantial amount (depending on the ratio of total survey time to drift rate correlation time) of the integrated drift rate which causes real-time deflection measurement error at the intermediate survey points.[1] For example, a drift rate of 0.0005 arcsec/sec (1σ) with correlation time of 2 hours causes an accumulated tilt of 1.35 arcsec (1σ) for a 1 hour survey. After adjustment, the peak residual error occurs at the mid-point (0.5 hour) of the survey and is only 0.23 arcsec (1σ).

3. System Test Results

Acceptance tests for the RGSS[3] were conducted in August of 1986. Two types of test courses were employed. The first course was a straight north-south traverse performed in a land vehicle which took approximately 1.2 hours to traverse with travel periods of 1 to 1.25 minutes and stop periods of 2 minutes. The repeatability of the results for four traverses for the two deflection components are shown in Figures 3 and 4. The real-time measurements have been linearly-smoothed using astronomic reference points accurate to approximately 0.2 arcsec. Reference deflection values of similar accuracy are shown at three points along the traverse.

The second traverse is "L-shaped" lying north-south and east-west. Repeatability of the linearly-smoothed results and their relationship to astronomic reference values are shown in Figures 5 and 6. The total traverse times were 1.5 and 1.9 hours with vehicle travel times of 3 minutes and stop periods of 2 minutes.

In collection of these survey measurements extreme care was taken in the installation of the equipment in the land vehicle to minimize vibration disturbances to the inertial instruments which can induce bias shifts. Also for the "L-shaped" traverse, an outer gimbal was employed to maintain the outer case of the inertial system fixed with respect to the instrument cluster despite vehicle heading changes. This procedure minimizes any changes in environmental influences which can also induce instrument bias shifts.

4. Performance Improvement

There is interest in enhancing the capability of the RGSS so that it can accurately measure the deflection change over longer duration traverses. Figure 7 depicts the stability of the inertial platform tilt for a static 3-hour laboratory test run. Clearly if measurements of the slopes of the tilt histories were periodically available, it would be possible to obtain improved estimates of the tilt over the full duration of the test. This is easy to do in the course of an actual survey by extending the stop periods slightly so as to observe the tilt change.

Figure 8 illustrates the significant theoretical performance improvement obtainable by such a procedure relative to the single point smoothing procedure. An exponentially-correlated drift of

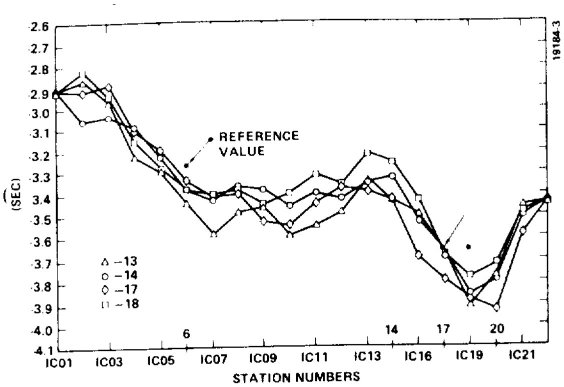

Figure 3. Meridional Deflection, Straight 10-Mile Traverse

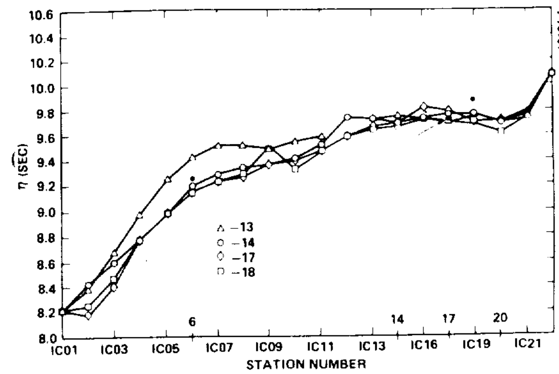

Figure 4. Prime Vertical Deflection, Straight 10-Mile Traverse

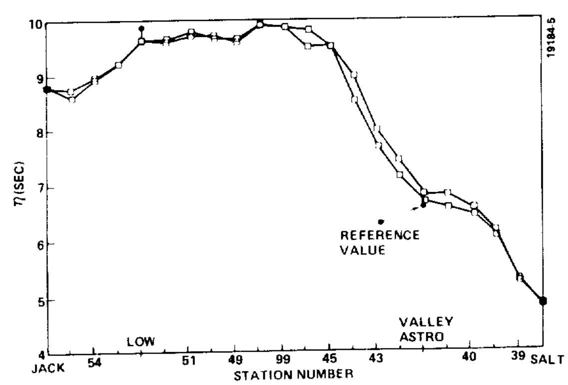

Figure 5. Prime Vertical Deflection, RGSS Test Line

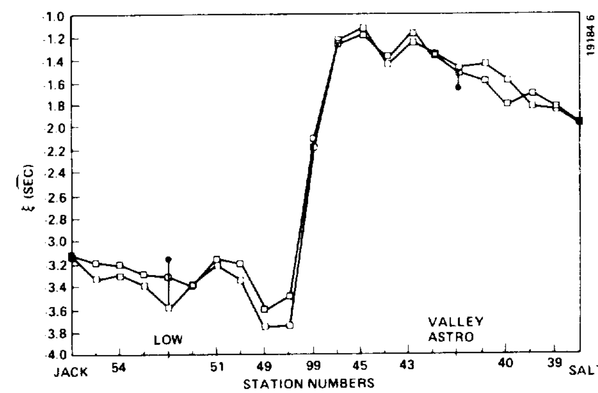

Figure 6. Meridional Deflection, RGSS Test Line

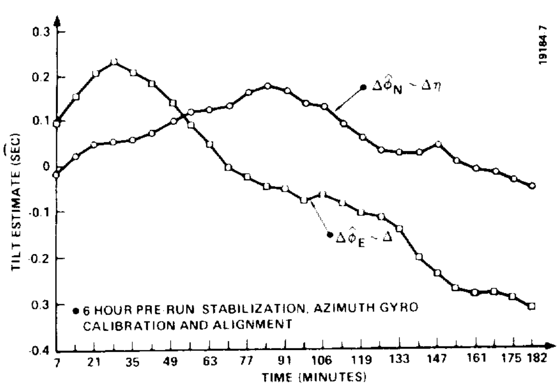

Figure 7. Platform Stability for Static Laboratory Test

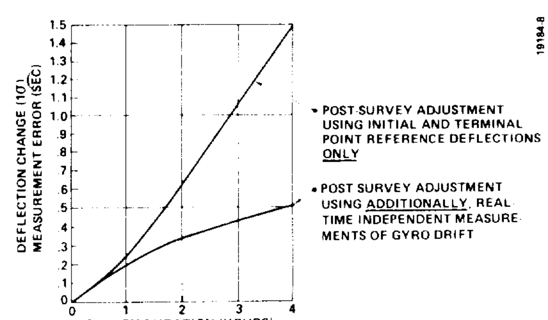

Figure 8. Peak (1σ) Error in Deflection Change Measurements versus Time Between Initial and Terminal Points of Survey Traverse

0.0005 arcsec/sec (1σ) with a 2-hour correlation time has been assumed for these results along with the assumption that an independent measurement of drift rate to an accuracy of 0.0005 arcsec/sec (1σ) is available every 6 minutes during the survey traverse.

Acknowledgments. The author would like to thank Mr. E.F. Roof of USAETL[3] for providing the RGSS acceptance test data discussed above and for answering many questions relative to the system testing.

References

1. Huddle, J.R. "Theory and Performance for Position and Gravity Survey with an Inertial System," AIAA Journal of Guidance and Control, Vol. 1, No. 3, May-June, 1978, Pp. 183-188.

2. Proceedings of International Symposia on Inertial Technology for Surveying and Geodesy, First at Ottawa, Canada in October, 1977; Second at Banff, Canada, June 1981; Third at Banff, Canada in September, 1985.

3. Roof, E.F., A number of private correspondences in 1987 and 1988.