I.S.S.
THE INERTIAL SURVEYING SYSTEM

Its Development and Use by Geodetic Survey

BY G. BABBAGE

INTRODUCTION

Geodetic acquired a Litton Auto-Surveyor TM system in early 1975. It was immediately dubbed the Inertial Surveying System (I.S.S — a name by which it continues to be known in Canada).

After being tested in the Los Angeles area in February, 1975, the system was transferred to Ottawa for cold weather evaluation and later, to the Okanagan Valley area of B.C. for further tests in a region of high relief, numerous gravity anomalies and large deflections of the vertical. All these tests were conducted with the system mounted in a motor vehicle. A trial followed with the system helicopter - mounted in which control was established in some Manitoba Indian reserves. Some production work was done with a motor vehicle in Ontario towards the end of 1975.

Full scale production work commenced in the spring of 1976 when most of Vancouver Island was covered with vertical control for 1/50,000 mapping using a motor vehicle. This was followed immediately by our first, and to date, our largest helicopter type operation, when horizontal and vertical control were established in a 50,000 square kilometre area south-east of Calgary, Alta.

One of the functions of the Geodetic Survey is to supply control for 1/50,000 N.T.S. mapping to our sister division Topographical Survey. The I.S.S. was bought in 1975 with this function chiefly in mind. During the past two field seasons, the I.S.S. has been used mainly for this purpose. However, in many cases it has been employed to establish good second-order multi-purpose control while satisfying the mapping need. For example, in the prairie provinces there has been a recent need for this type of control to anchor and reinforce the rapidly deteriorating Dominion Lands township system. This need has fortuitously coincided with the plans of Topographical Survey for 1/50,000 NTS map revision in the southerly parts of Canada. Consequently, we have been able to enter into cooperative arrangements with the Alberta, Saskatchewan and Manitoba governments whereby large blocks of prairie are being provided with second and third-order horizontal control and mapping elevations in the form of I.S.S. traverse grids. Station spacing is 10 km to 20 km. A project of this type conducted southeast of Calgary will be described later.

Other uses to which the I.S.S. has been put include such items as third-order control in Indian reserves for photo-mapping purposes and as reference control for future boundary retracements, the establishment of elevations on the surface of the Columbia Icefields to help determine fluctuations in the water content of these majestic features, the traversing of important highways, and the location of blunders in lower order spirit levels.

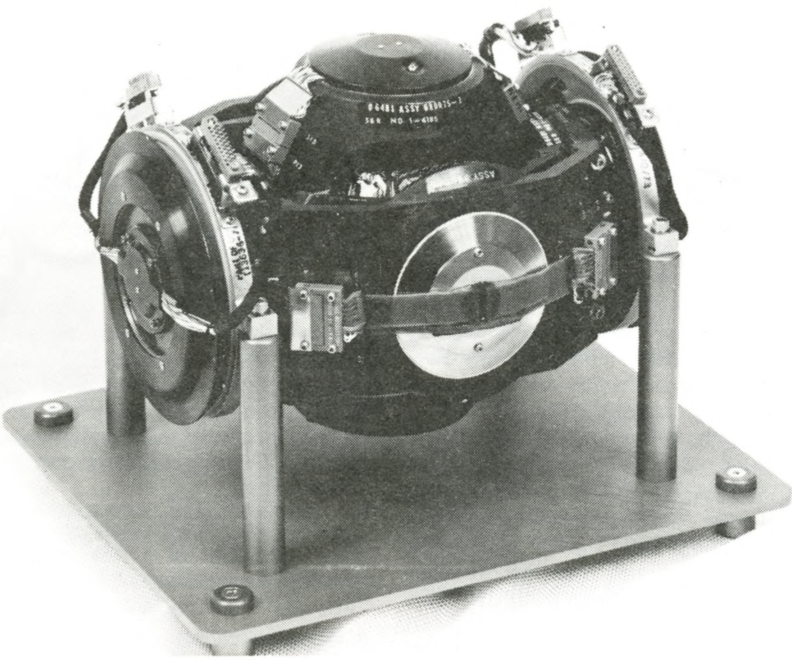
Fig. 1 Inertial Measuring Unit - Gyros and Gimbals

DESCRIPTION OF THE I.S.S.

The I.S.S. consists basically of a portable platform which is kept level and properly oriented by gyroscopes as it is moved from place to place either by motor vehicle or helicopter. The platform has three mutually perpendicular axes: North, East and Vertical. Each axis features an accelerometer which senses the acceleration of the platform along that axis. As the platform moves, the x, y and z accelerations are sensed and fed to an onboard computer which integrates them every 17 milliseconds to yield, initially, axis velocities. These velocities are immediately reintegrated to give, finally, axial distances travelled; that is, "northings", "eastings" and height differences. The northings and eastings are actually spheroidal distances, reduced to sea level and to any given spheroid, expressed by the on-board computer as differences in latitude, longitude and elevation.

Because the platform is levelled and oriented by gyroscopes, the accelerometer measurements would normally relate to inertial space. To refer these to the Earth's surface, they must be adjusted to allow for the earth's rotation and normal gravity and the platform must be continually tilted to follow the curvature of the chosen reference spheroid.

The I.S.S. equipment consists of the following five major items:

1. Inertial Measuring Unit (I.M.U.) — the platform previously referred to. It consists of 2 air-bearing gyroscopes (each with 2 degrees of freedom), 4 gimbals connected to torquing motors, and 3 accelerometers (the x and y accelerometers have a sensitivity of 6 ug to 10 ug, the z accelerometer a sensitivity of 1 ug to 2 ug). See Figure 1.

2. On-Board Computer (D.S.U.)
This is the brains of the system. It is an electronic tour de force (the flow charts of its operation fill a 186 page book) which has two main functions: to calculate the mssion and to control the system.

The software is very sophisticated and features a process called "Kalman filtering" which can be explained in very general terms as follows. The computer attempts to estimate continually the best real-time position of the platform. To do this it initially assumes errors for the more important measurement elements. There are hundreds of error sources in the system; the Kalman filter responds to 42 in most cases and to 17 in others. It produces an "error budget" which includes information on the accuracy of its estimate. As the computer senses systematic changes developing in any of the error parameters as the mission proceeds, it updates its error assumptions and produces a new error budget and redistributes the aggregate error. This is a continuous process.

The computer can also make a "misclosure" adjustment on known control in which the residuals are distributed according to the error budget and as a function of time.

Other functions of the computer are to:

a. calibrate the system when it is turned on and to level and orient the inertial platform automatically — a procedure known as an "alignment" — before a mission is started,
b. to produce torquing signals which compel the platform, through forces applied to the gimbals, to follow the reference spheroid and
c. to realign the platform to the local vertical at updating stops (ZUPTS.) More will be said about these stops later.

3. Cassette Recorder
This also performs a double function: it records measurement data and records the biases, outputs and changes occurring in the entire system. The latter facilitates the monitoring of the system to determine whether anything has gone wrong and, if so, where, how and when.

4. Power Supply (PSU)
This unit supplies a 24 volt current to the system either from the system of the vehicle or, in the case of engine stoppage, from batteries (for up to one hour).

5. Display and Command Unit (CDU)
This unit consists of a display panel and switches with the following features:

a. Switches to command the system.
b. Display of the measurement data upon command.
c. A continuous display of the state of the system.
d. Interrogation of the system by the operator.
e. Communication by the computer to the operator.

See Figure 2.

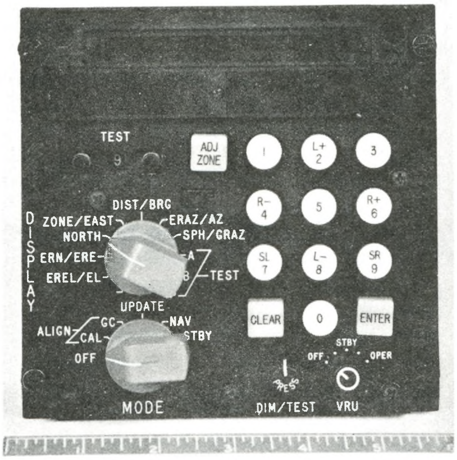

Fig. 2 Display and Command Unit

The various items of equipment can be arranged in any reasonable way. Obviously the CDU must be close to the operator. Installation or transfer of the equipment from one vehicle to another takes about 6 to 8 hours. (See Fig. 3)

Since the centre of the IMU cannot be conveniently centred over a survey station, a convenient point is chosen on the vehicle from which short offset measurements can be made to the station. The difference in position between this point and the centre is automatically provided for in the computer, but the measured offset from point to station must be recorded manually and computed off-line later.

METHOD OF OPERATION

At the start of a field season and, roughly, once every 2 or 3 months thereafter, the system must be calibrated. This is done by measuring repeatedly with the system each of 2 calibration lines arranged in the form of a right-angle and oriented preferably in N-S and E-W directions. These lines must be about 40 km long and be accurate to first-order or high second-order standards. Once calibration has been done the mission can commence. The first step is to align the system — to level and orient the inertial platform at or near an existing control station. It should be noted that the I.S.S. is essentially an interpolator of control — it must work between known control stations. Furthermore the interpolation must be done in an approximate straight line, or within a corridor, between control stations. This is particularly important for horizontal control establishment. The alignment is done automatically by the computer and takes about 1 hour. During this operation the system must not be disturbed. Once the alignment has been performed the vehicle, whether it be a motor vehicle or helicopter, can move off visiting, in turn, each of the new control stations to be fixed, finally ending its run at another known control station. During travel, the vehicle must avoid sharp turns and, in the case of the motor vehicle, any bumps likely to cause bottoming of the IMU shock mountings. On smooth roads speeds up to 50 or 60 mph are feasible, while for helicopter operations maximum speeds of 120 mph or so are quite common. During the running of a mission an important operation must be carried out about every 4 minutes — zero velocity updating (ZUPT). This entails stopping or landing the vehicle for a period of about 30 to 40 seconds. The main purpose of this exercise is to keep the errors of the system stemming from gyro drift within reasonable bounds. This has a very significant effect on the accuracy. If, while the vehicle is at rest during a ZUPT, the horizontal accelerometers have output, it is because the platform is not level and they are sensing the effect of gravity. This dislevelment has two causes: one is accumulated system error mainly from drift of the gyros, the other is deviation of the vertical from its direction at the previous stopping point. During the ZUPT period the Kalman filter analyses the accelerometer outputs, adjusts the measured data according to its error budget which in turn is updated to fit the new evidence. Then the vertical axis of the platform is automatically aligned with the local gravity direction. This, incidentally, produces a measurement of the local deviation of the vertical which, together with gravity difference measurements also obtainable from the system, can provide useful geodetic information supplementary to the main task of gathering positional data.

If the ZUPT location should coincide with that of a new control station, the I.S.S. operator occupies his time during ZUPT by measuring the x, y and z offsets between the measurement reference point on the vehicle and the station. It is usually impossible to position the

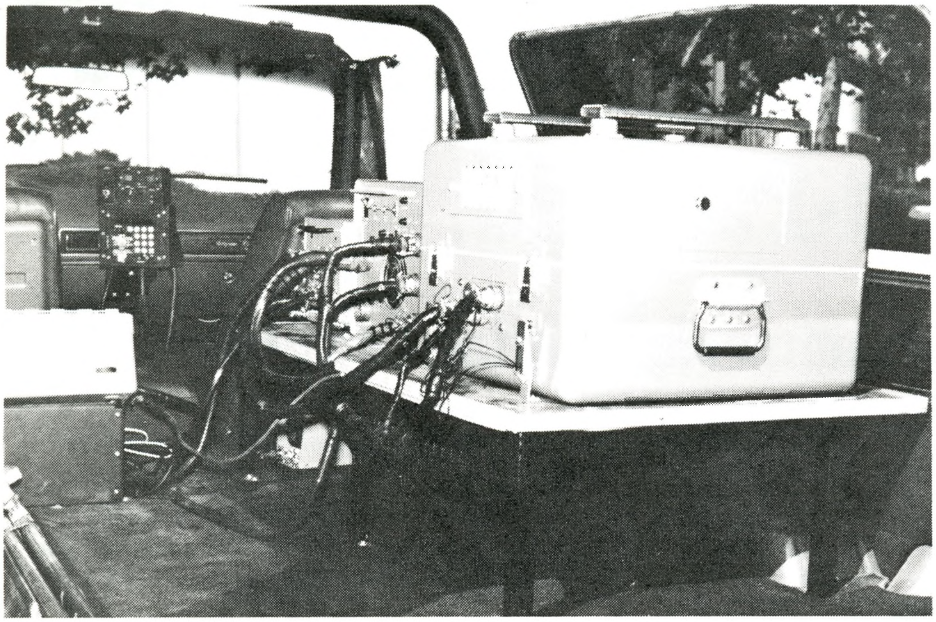

Fig. 3 System mounted in a motor vehicle

point exactly over the station but for most determinations the x and y offsets seldom exceed 20 cms. By proceeding along the line in 4 minute "hops" in this way, the vehicle finally reaches the terminal control point where a position update occurs. Position updates must be done at least every 2 hours.

The update values are entered into the computer which then performs a misclosure adjustment in accordance with its most recent error budget. The mission is then usually repeated in the opposite direction resulting in another misclosure adjustment. The forward and back values for each new station established are then compared to determine whether the mission has been successful or whether one or more additional runs are required.

Note that azimuth lines are not normally established at stations. Azimuths can be obtained from the system. A device known as a porro-prism is mounted on the IMU to facilitate the transfer of an azimuth from the system by theodolite to an azimuth line. However, the procedure necessary to do this is too time-consuming and, if followed, would prolong the I.S.S. stopover at a station to the point where mission accuracy would deteriorate unduly. In I.S.S. work, time is the enemy of accuracy.

To summarize, the limitations on I.S.S. measurements are as follows:

1. The system must operate between fixed control points.
2. For horizontal control measurement, it must stay within a narrow corridor between these points. (Maximum corridor width about 1/10 of the distance between control).
3. Calibration on two first or high second order lines each about 40 km. long, disposed at right angles and oriented N-S and E-W respectively, must be done at the commencement of the field season and every 2 to 3 months thereafter.
4. An alignment (levelling and orientation) must be done at the commencement of each day's work and at intervals of no more than 4 to 5 hours during the working day.
5. For good accuracy, independent runs must be made between existing control stations in both directions and the results meaned.
6. During a run, ZUPT's must be conducted about every 4 minutes.
7. Position updates on terminal control must be done at least every two hours.

MAJOR GEODETIC I.S.S. OPERATIONS

Two of our major production jobs occurred in 1976. The first consisted of covering Vancouver Island with elevations for 1/50,000 mapping control. The I.S.S. was mounted in a motor vehicle for this purpose — one of the few occasions in our operations when the vehicle mode of transportation has been used. The field work for this project was carried out from May 23 to July 17, 1976 and, despite some annoying equipment breakdowns, was highly successful. Preliminary work included establishing initial vertical control by spirit and trigonometric levelling to provide the overall control framework within which the I.S.S. could function, choosing two lines for the initial calibration, reconnoitring and marking the I.S.S. stations.

The measurements consisted of 45 double runs in the vehicle. Fifteen runs with spreads of over 1 metre between back and forward determinations were redone. Single runs occupied from 2 to 6 hours; ZUPT intervals averaged 2 minutes. Total miles traversed was 4310 (including all reruns) during the course of which 430 new I.S.S. stations were established in elevation. Vehicle average speed per run, including all intermediate stops, was 15 m.p.h. There were 17 days in which the equipment was "down" due to various minor and major breakdowns. The cost per station was $127.00 including office planning, field reconnaissance and measurement, and data processing. After the project was completed a Geodetic precise levelling party started levelling along the road between Campbell River and Gold River in connection with other work and was asked to check 16 I.S.S. elevation established earlier along the road. The comparisons are shown in Table 1. As indicated, the maximum difference was 0.35 metres, the mean difference 0.11 metres and the standard deviation of a single difference +— 0.14 metres. These results are remarkable and far better than we expected. We are still trying to discover what went right!

The second major project referred to above followed the Vancouver Island work in July of 1976, and was carried out over a 50,000 sq. km. area southeast of Calgary. This area extends easterly to the Alberta-Saskatchewan boundary and contains the cities of Lethbridge and Medicine Hat. See Figure 4.

The project was a cooperative one: participants were two departments of the Alberta government, Topographical and Geodetic Survey. During a 7 week period the area was blanketed with some 445 second and third order stations, established at 10 and 20 kilometre intervals. Positions and elevations were determined for all stations by the I.S.S. mounted in a helicopter — the first production use of this form of transportation by Geodetic Survey for I.S.S. work. The average cost per station was about $700. This included all costs of planning, reconnaissance, preliminary levelling, monumentation, measurement, identification photography and field computations. Equipment depreciation was not included and is estimated to have been about $100 per station. It is estimated that the cost of doing this work by the best traditional method would have been about $1700 per station and that the project would have taken about 18 weeks to complete. A fortunate coincidence occurred on this project. The distance the helicopter could fly during the four minute interval allowed between ZUPT's was about 10 kilometres (6 miles), the

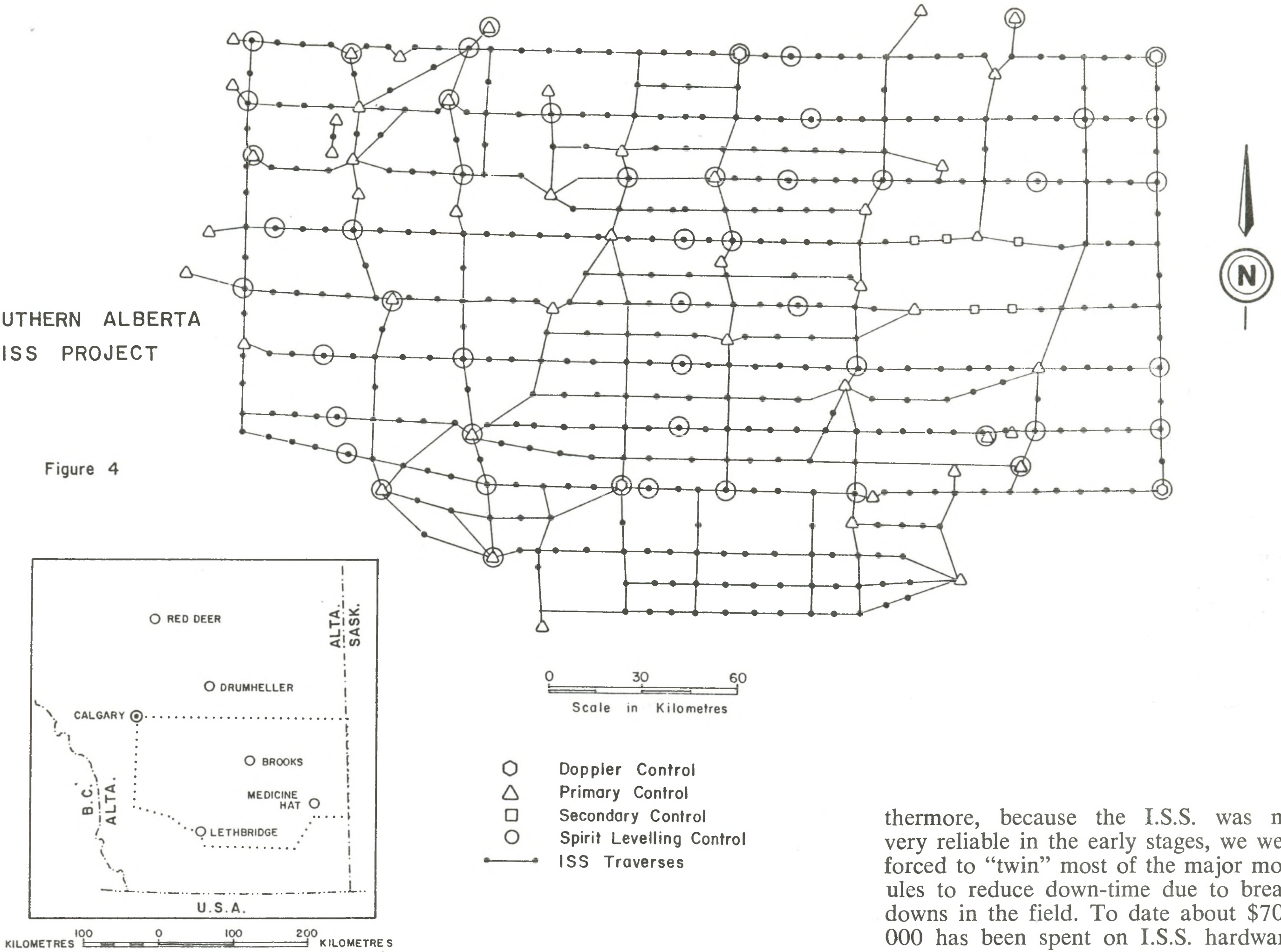

Figure 4

nominal width of a township. Consequently, most ZUPT points could be used as control stations in areas where this density of control was required. The exact accuracy of the control established on this project has not been determined yet. However, we estimate that the standard deviation (lo) of the difference of position between two neighbouring stations (derived from the means of backward and forward runs) is +— 0.5 metres or less.

LESSONS LEARNED FROM EXPERIENCE

MODE OF OPERATION

Since the I.S.S. is essentially a "straight-line interpolator" of control the unit must be helicopter - mounted for greatest efficiency when control is required in all three dimensions, or in x and y only. This is one of the first lessons we learned. In an area where only vertical control is needed and where a good road system exists, a case can be made for mounting the I.S.S. in a ground vehicle.

Usually, however, the helicopter mode is dominant.

TABLE 1
COMPARISON — ISS ELEVATIONS AND FIRST ORDER LEVELLING VANCOUVER ISLAND

Station No.	ISS Elev. (metres)	First Order Elev. (metres)	Discrep. (metres)
3001	188.54	188.186	—.35
3003	225.57	225.717	+.14
3004	232.52	232.467	—.05
3008	268.63	268.931	+.30
3010	256.68	256.927	+.25
3012	225.90	225.840	—.06
3015	251.04	250.901	—.14
3017	313.12	313.185	+.07
3018	264.88	264.719	—.16
3021	114.11	114.099	—.01
767023	10.031	10.029	—.002
1502	215.79	215.857	+.07
1503	218.54	218.488	—.05
1505	189.36	189.422	+.06
1506	146.08	146.055	—.03
1507	113.40	113.291	—.11

CAPITAL INVESTMENT

Although few surveying systems are cheap, the I.S.S. posed special problems for Geodetic Survey because of the massive capital expenditure required. Furthermore, because the I.S.S. was not very reliable in the early stages, we were forced to "twin" most of the major modules to reduce down-time due to breakdowns in the field. To date about $700, 000 has been spent on I.S.S. hardware. Clearly, the system must be kept very busy if the effects of capital depreciation are to be kept within reasonable bounds. Bearing in mind the vagaries of the Canadian climate and the limits of our divisional resources, we aimed initially for a production rate of at least 1000 stations per year. At this rate, and assuming a seven-year life for our system, the capital depreciation cost per station is about $100. For stations established in the prairies as part of a large grid of interlocking traverses, this comprises about 15% of the station cost.

I.S.S. systems can now be rented — an option not available until comparatively recently. This obviates the capital expenditure problems for short-term users.

PERSONNEL AND ORGANIZATION

Initially one of our greatest problems was to develop competent field teams and knowledgeable data processing staff. We discovered, that above-average surveying technologists make excellent operators and party chiefs. Electronic technologists have usually been an integral part of the field team and, on occasion, have also been successful operators.

For our present operations we have two field teams, each consisting of a party chief, operator, maintenance and repair man, a data processor and two labourers. The first four are usually technologists. The team is supplemented, usually, by a helicopter pilot and engineer under contract bringing the field personnel total to eight persons. The field teams operate from our Ottawa headquarters and alternate on large projects, each term of duty being about six weeks. The total duration of a field season is about 5 to 6 months.

TRAINING

Initial training of operators occurred at the Litton plant in California. On-the-job training followed, carried out under the general guidance of Litton field engineers whose services were part of the warranty contract for the first nine months. In the spring of 1976 a two month course was given to potential team members at Geodetic headquarters in Ottawa by Litton personnel. This course covered operation, data processing and maintenance. During the 1976 field season a student was trained as an operator and during the spring of 1977 a two-week course in practical operation and calibration took place with two new operators being initiated.

We now have seven persons capable of operating the I.S.S. in the field. Early in 1977, an electronic technologist from Geodetic was reassigned to the Litton plant for 3 months for further training and experience in system maintenance.

MAINTENANCE

Maintenance was a problem during the first year of operation when we did not have "back-up" modules for the system. We soon realized the need. The reliability of the system was at best, spotty, during the first two years (55 "down" days from June 75 to June 77), but has improved since then.

Our electronic technologists have repaired faults in connectors, relays, switches, lamps and wiring but are not yet equipped to trace and replace faulty components on circuit boards. Our conclusion after sending an electronic technologist to the Litton plant for training is that major repairs will still have to be done there. The test jigs and other equipment required to diagnose important malfunctions are simply too expensive to contemplate purchasing. We expect, however, for a reasonably modest investment, to be able to increase significantly our present "in-house" capability to detect problems and make repairs.

Our experience with the Litton plant regarding repairs has been fair. Service has usually been reasonably prompt: however, on occasion there have been delays in getting a malfunction diagnosis made and the resulting repair done, possibly because of the sheer complexity of the system apparatus.

PLANNING

One of our more pressing problems is the need to establish north-south and east-west calibration lines each about 40 km long in the vicinity of important projects. Often existing control has sufficed but in many cases has not been entirely suitable. The accuracy requirement is such that Doppler determinations are marginal. In future we intend to include the establishment of these lines as part of the pre-flight reconnaissance operation.

In general, I.S.S. planning needs to be done very thoroughly so that once measurement commences, it can be carried out with a minimum of interruption. For example, the failure of the operator to rapidly identify from the air the location of the next station to be approached can imperil the accuracy of a whole mission, and possibly mean the rejection of data that have taken several hours to accumulate. For this reason, virtually all stations have to be targetted. In addition, it is sound practice to scale the approximate coordinates of all stations, particularly new ones, from the best available maps, plug them into the system and fly the helicopter "to zero" between successive stations. Naturally, any clearing required around landing points, including ZUPT points, must be done thoroughly so that the eventual landing can be made as promptly and safely as possible and the pilot is not forced to indulge in sudden unforeseen manoeuvres likely to upset the system. Fuel stops must also be carefully planned and refueling done as quickly as possible. Similar careful forethought must be devoted to the making of measurements. One must realize that the operator, on alighting from the helicopter at a station, has less than one minute to single-handedly measure and record the x, y and z offsets between the landing point and station. (Our helicopter pilots have generally shown high skill in landing near stations — the majority of x and y offsets are less than 20 cms).

ACCURACY

We are conducting research and development to better assess and improve the accuracy of I.S.S. measurements. From our experience to date it can be safely said, however, that, if the system is used as directed by the manufacturer, if ZUPT intervals do not exceed 4 minutes, and if "interpolation" is in a reasonably straight-line between overall control spaced no more than 80 km apart, an accuracy σ of +— 0.5 metres, for the difference in positions between adjoining stations (mean of 2 runs in different directions) is readily achievable in production work. According to the Surveys and Mapping Branch specifications published in 1973 this means that I.S.S. work will usually satisfy second-order standards for horizontal control if stations are spaced at least 20 km apart and third-order if spaced at least 10 km apart. Should the I.S.S. double-run traverses be closely knitted together in grid form then the accuracy is likely to be better.

Vertical accuracy can safely be assumed to be at least the same as the horizontal, that is, 1σ of about +— 0.5 metre for elevation differences between adjoining stations. However, there are indications, for example, from the comparisons between I.S.S. and spirit levelling results on the Vancouver Island project mentioned previously, that the vertical accuracy can be much improved over this figure, particularly if the ZUPT intervals are reduced.

RATE OF PRODUCTION AND COST

When I.S.S. was first introduced, there was much glib talk about its potential for producing automatically, great quantities of inexpensive control. It is undoubtedly a revolutionary, powerful and versatile tool. However, in its present form it is not an automated panacea for all our control ills and its capability must be kept in proper perspective.

Our experience in assessing the rate of production and cost of I.S.S. control versus conventional methods is still limited. Our best estimate of comparison stems from the multi-purpose secondary control project we conducted in Alberta and which has already been referred to in this talk. As you will recall the project was large, covering some 50,000 sq. km of flat or gently rolling, mainly open prairie country, and some 445 new second and third-order stations were established in approximately 7 weeks at an average cost of about $800 each (including equipment depreciation). This compares with our estimate of the average station cost of $1700 by conventional methods. Since that project was done we have improved our I.S.S. work efficiency by 15% to 20%, consequently a better comparison would be $680 versus $1700 per station. This is not a cost saving as large as some of the claims made by others, but is nevertheless quite significant.

PROBLEMS RESOLVED AND UNRESOLVED

To date we have successfully resolved a myriad of small technical, or-

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The Township of Kingston had a troubled survey history, particularly the eastern boundary which today runs directly through the City of Kingston. Lot 25 in particular was the subject of several court actions, and a number of heated letters to the editor of the Kingston Herald. The correspondents, each evidently representing a certain faction in the debate, used the pen names Mentor, Philo and Subscriber. Mentor was so proud of the way he handled the other two that he published the correspondence along with the pertinent acts and statutes in a book titled, rather unimaginatively, MENTORIANA. But during this exchange of letters, Philo raises the following point which was never answered by his antagonist, Mentor:

"And first, if he will examine a map obtained by the Venerable Archdeacon of this Town from the Surveyor General's Office, at Quebec, he will find that the Township of Kingston was originally intended to be six miles square; that the Lots in each Concession are represented to be about 64 chains long, and that there is an allowance for Road between every nine lots; while on the Government map obtained at Toronto, bearing nearly the same date, he will find that the Township, instead of being six miles square, is six miles by ten; that between the lots there is no allowance for Roads laid out, and that the lots by the latter map, instead of being only 64 chains long, are 105 chains, 27 links. Will "Mentor" account for this, and show us which is correct?"

Kingston, May 22nd, 1841

So we see that the original plan of survey, or more probably a copy of it, has survived in Kingston at least until 1841 to cause confusion about the original survey of 1783 and its alteration in 1784.

The early settlement of what is now Ontario was a successful application of the resources available (surveyors and land) to the problem at hand (the settlement of refugees). Haldimand's original concept of farm lots surveyed out in concession rows within the administrative unit, the township, was extended to cover much of Ontario. Modifications in the survey pattern were made from time to time, but basically the original principles were maintained.

Without a doubt the first few years following 1783 were the hardest. There were three basic reasons why success crowned the settlers' efforts. First of all, the land available for settlement in Southern Ontario included some of the best farm land in North America. Secondly, the settlers that the Americans sent us were exactly the right type, namely frontier farmers that were just as familiar with the axe as with the plow; (the city Loyalists left via New York!). Thirdly, the surveyors preceded the settlers to set out farm lots that were well marked and roughly equal in size to be distributed without quarrel or favour. With good land in adequate quantity for each family, it required only dogged perserverance and hard work to establish the family farmstead and in turn the successful township.

If Ontario had not been properly settled in those difficult years following 1783, there would have been little or no resistance to an American take-over during the relentless American westward expansion that started two decades later. Anyone who doubts this statement has only to read the history of New Mexico and California to obtain the proper perspective.

It would of course be ridiculous to claim that those early surveyors, the predecessors of the present Ontario Land Surveyors, were alone responsible for maintaining the British presence in Central and Western Canada. It should, however, be well understood that they did their part.

Note: There appears to be no existing document from Haldimand, or any other person in authority, ordering a change in Haldimand's original survey instructions, some reference to the change may still exist in old letters, memoirs, etc.; and those Ontario Land Surveyors that are interested in history are encouraged to watch for such a reference.

*This plan is on file in the Public Archives of Canada, in Ottawa.

*This letter is also included in the Proceedings of the OLS Sixth Annual Meeting.

IS.S.

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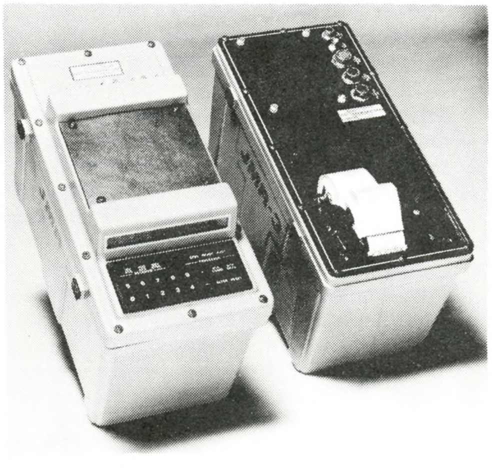
ganizational and administrative problems required to make our I.S.S. system reasonably efficient and reliable. We have also successfully established an interface between the Datametric recorder of the system and an HP 9830 calculator. Programs have been produced which allow acceptance of Datametrics data, the addition of offsets, the changing of coordinate values in the terminals of runs and the prompt production of final smoothed values suitable for data analysis to ascertain rapidly the quality of field measurements. The output consists of corrected "smoothed" values, closure and scaling discrepancies, misorientation and scaling factors of the raw data, means of the forward and backward runs and differences between them, the relative error between adjoining points and of any point in the run with respect to the initial station. As indicated earlier we have recently developed a method of adjusting large blocks of I.S.S. traverses.

One of the most important of the problems yet to be resolved is that of developing a system for the establishment of stations which depart significantly from the straight line joining the terminal control stations. We are also interested in improving the accuracy, extending the range and increasing the ZUPT interval. Less important problems are the development of a facility that will allow the insertion of offsets into the I.S.S. on board computer, a method of obtaining "smoothed" values on tape when using the input-output control or designing a "smoothing" program for use on the HP 9830, and the development of better guidelines to determine the acceptability of traverses (to replace our current rules of thumb). The search for improvement continues . . . .

NEW PRODUCTS



JMR3 SURVEY SYSTEM

JMR instruments of Chatsworth, Calif. announces this system which by observing the Doppler shift from two satellite broadcast frequencies, computes the receiver's latitude, longitude and elevation.

Three metre accuracy, or one metre with two instruments is possible, and the unit is fully portable.

TD Communications of Calgary, Alberta is the Canadian sales representative.