Geodetic Survey in North America.[1]

THE United States Coast and Geodetic Survey has long had in progress an arc of primary triangulation along the 98th meridian of longitude. This arc was completed to the north, up to the Canadian boundary, in 1907. To the south there is a similar arc along the same meridian through Mexico, originally surveyed by the "Commission Géodésique Mexicaine" between 1906 and 1910, terminating to the north at the international boundary on the Rio Grande and extending southward to the Pacific Ocean.

It was obviously desirable that these two arcs should be connected, and it was accordingly arranged to make the connection in 1913, when the last section of the work in the United States was done. The internal condition of Mexico, however, did not permit any joint operations at that time, and a postponement was necessary. Opportunity was taken of the improved condition of the country in 1915 to revive the question. The arrangements proceeded without hitch and the final observations were successfully made in May, 1916. The publication under review gives an account of the southern end of this arc in Texas, surveyed in 1913, the junction with the Mexican arc in 1916, and a general summary of the progress to date of the lines of first order triangulation in the United States.

Since 1901 the Coast and Geodetic Survey has reduced all its work to a common datum and computed all positions and azimuths upon Clarke's 1866 spheroid. These, both datum and spheroid, have been accepted, on one hand by the Canadian, and on the other by the Mexican, Geodetic Surveys, so that they are now common to the whole of North America. An inspection of the index map of the triangulation lines in the United States computed to these data shows, however, that there is still a considerable block of triangulation in the Eastern States not yet readjusted. When this readjustment is made and when certain lines in the Central and Western States, now in progress, have been completed, the network over the whole area will be so close that no point will be situated at a greater distance from a main triangulation line than about 170 miles. In fact, even this distance will be rarely attained, and over almost the whole area the maximum distance will be under 150 miles.

Such a network of absolutely first-class work is amply sufficient to satisfy the most exacting geodesist and is, of course, more than a sufficient basis for any possible map upon any practical scale. We may, therefore, congratulate the U.S. Coast and Geodetic Survey upon the now not distant completion of one of the main sections of its great task.

[1] Department of Commerce, U.S. Coast and Geodetic Survey. Geodesy. Serial No. 97. Report on the Connection of the Arcs of Primary Triangulation along the Ninety-eighth Meridian in the United States and in Mexico, and on Triangulation in Southern Texas. By William Bowie. (Special Publication No. 51.) Pp. 93. (Washington: Government Printing Office, 1919.) Price 10 cents.

The execution of the small section of triangulation under review was marked by no special technical advances; but as exhibiting a high level of technical efficiency and as being of possible use for future guidance in similar work that may be planned in British territories, we may briefly advert to one or two practical points. One question of considerable importance is to decide whether it is desirable to restrict observations to the night or whether day observations should be included. The U.S. Survey adopts the principle of allowing only night observations, for the stated reason that experience has shown that there is less deviation in the geodetic azimuths of the lines when this restriction is enforced than when the observing is done by day or is a combination of day and night work. In other words, the atmospheric conditions are more stable at night and observations of angles, therefore, more accurate. This is in accordance with general experience and practice. It has, however, been argued, not without a certain show of plausibility, that though undoubtedly the apparent errors are thus reduced, this may be at the risk of introducing systematic errors, due, let us say, to unsymmetrical atmospheric refraction operating only when observations are made upon a falling temperature, which might be eliminated if observations under different atmospheric conditions were combined. Though plausible, this argument is, we think, not tenable, or, perhaps more correctly, not applicable to the case of a triangulation.

The ultimate test as to whether, in deriving the most probable mean of any set of observations, systematic errors are likely to be diminished by the inclusion of observations of an inferior degree of accuracy but differing in their conditions can be decided only by experience. Now in this case the "experience" is immediately available, being, in fact, implicitly contained in the figure expressing the closing error of the triangle. Any method of observation and any system of combining the results of the observations into a mean value which reduce this closing error *ipso facto* increase the probable accuracy of the finally derived figures of position and azimuth. Night observations, preferably between, say, three hours after sunset and one hour before sunrise, fulfil this condition and are therefore rightly accepted as ideal.

The U.S. Survey, operating over a huge area with a necessarily limited budget, has perforce to pay attention to the question of cost. Survey is, in fact, on exactly the same basis as other engineering operations. The problem is to get the maximum output of work of a strictly defined and practicable degree of precision at the minimum cost, and not, as has sometimes been assumed, to reach the highest attainable precision regardless of cost.

The standard for first order work in the United States is an average triangular error of one second of arc and a maximum error of under three

seconds. This already high degree of precision was, however, surpassed in the particular section under notice. Thus over a total of sixty-eight triangles the average closing error was 0·63″ and the maximum error of any one triangle 1·86″. This pitch of excellence was moreover attained without any increase of time spent at the stations; indeed, it is claimed, we think with justice, that the arc establishes a "record," both technically and financially. The average cost per point occupied was, in fact, lower than has been attained with any previous work of the same class, and as, owing to the nature of the country, high and expensive signal scaffolds were necessary, it seems that the reduction made in the cost of the actual observing was even more notable than appears on first inspection.

This conveys a lesson which may be taken to heart by those responsible for future survey operations. It seems clear that the difference in method of execution between what we are accustomed to call first order or primary triangulation (*i.e.* triangular error under 1″) and secondary work (triangular error under 3″) lies mainly in the nature of the signals. If lamps only are used it is a matter of indifference as regards rate of progress, and hence as regards cost, whether a large instrument capable of first order precision or a smaller one capable only of second order is used. In either case one observer can complete the observations at a station in one night, and no reduction in size of instrument, in number of rounds taken, or in order of accuracy will enable him to do more. The difference in cost of transport between the two instruments is in most cases negligible. The only extra cost involved is that caused by the necessity of providing five lampmen or lamp parties and moving them from point to point. In rough country this might undoubtedly prove a formidable addition, but in the case of future boundary commissions or land surveys in Africa it is anyhow worth serious consideration whether a backbone or net of primary triangulation, planned so as to fit in with a comprehensive geodetic scheme, cannot be undertaken without a prohibitive increase in expenditure.

This is the sort of question for which the co-ordinated experience and authority of a geodetic institute would prove invaluable, and it is to be hoped that it will not be long before such an institution, long overdue, is established in England for the British Empire. E. H. H.

Science and Research in the Air Service.

THE Air Estimates for the year 1920–21, recently presented to Parliament, show a total estimated expenditure of 21 million pounds compared with 54 million pounds in the previous year. The apparent saving in cost is 33 millions, but it is really greater, for in the year 1919–20 the cost of the experimental and research services was borne jointly by the Admiralty and the Ministry of Munitions, and is now wholly included in the Air Ministry vote.

As regards the Royal Air Force, the number of officers, warrant officers, non-commissioned officers, airmen, and boys provided on the establishment (exclusive of those serving in India) has fallen from 150,000 in 1919–20 to rather less than 30,000 in 1920–21—a striking reduction. The 21 million pounds for the new financial year includes rather under a million for civil aviation and two and a half millions for experiment and research. This latter sum would have been more than three millions (3,177,000*l.*) had not an "appropriation in aid," due to the sale of certain airships for 600,000*l.*, come to the relief of the vote. The actual figures are as follows:—

	£
Liquidation of war liabilities	1,334,000
Works, buildings, and lands	140,000
Aeronautical inspection	80,300
Airship constructional establishment ...	315,000
R.A.E., Farnborough	401,200
Technical equipment and materials ...	844,390
Salaries and wages	48,800
Miscellaneous	13,850
	3,177,540

An expenditure of more than three millions for research alone in a single year would appear to be a generous provision, but an examination of the foregoing figures shows that much of the expenditure will not be employed for this purpose.

The air vote for meteorological services has risen from 12,000*l.* in 1919–20 to 77,629*l.* in 1920–21, and part of this will doubtless be used in research work of some kind, though these services are not part of the research directorate, but come under the civil aviation side of the Air Ministry. The sum of 77,629*l.* includes the provision of only 358*l.* for "experimental stations," which is such a very modest amount that we assume experimental research in meteorology is provided for by other aid. In any event, the amount cannot represent the degree to which attention is given to research, since in meteorology there is ample scope for original work based upon the observations from what may be termed routine stations.

The printed Estimates convey the intention of the Government to make liberal provision for research in aeronautics, but it is impossible to determine precisely what sum of money is thereby devoted solely to "experiment and research," since such work is sometimes carried on at the ordinary air stations. Moreover, 40,000*l.* for the National Physical Laboratory is not borne on the Air Estimates at all, but on those for the Civil Service. The Estimates do, however, include the sum of 20,340*l.* for research "grants to scientific bodies," and 600,000*l.* as an encouragement to invention.