A Tribute to Brigadier Guy Bomford OBE, MA, DSc, FRICS 1899-1996

Compiled from information supplied by former students and professional colleagues.

Circulated at the Bomford Symposium held at the School of Military Survey Newbury, Berkshire on 5 December 1996

Under the auspices of RICS Wessex Branch, Land & Hydrographic Survey Division School of Military Survey, Newbury, Berkshire

Made possible by a generous donation from Leica UK Ltd

Introduction and acknowledgements

When it was decided to hold a symposium in memory of Guy Bomford and the tremendous legacy he left in the field of geodesy, it was suggested that a small commemorative volume might be appropriate. This contains

- Tributes by Martin Coulson and Professor Peter Dale
- Papers by Alwyn Robbins and Jean-Jacques Levallois written for the symposium,
- Notes by Jack Weightman,
- Brief notes about Guy's life and works, particularly his Geodesy,
- A series of recollections by former students and professional colleagues
- A reprint of a paper Guy wrote in the Survey Review. This is one of the few documentary sources that give any information on his life and work in S E Asia.

Thanks are due to all those who responded to the request for information. In the short time available to compile this sketch of his life it is almost inevitable that some possible contributors have been overlooked or proved untraceable. To them, our sincere apologies. If they make themselves known they will certainly be kept informed of any relevant future events.

Iain Greenway, Chairman, RICS Wessex Branch, Land & Hydrographic Survey Division, Ordnance Survey, Romsey Road, Southampton SO 16 4GU, UK

Jim Smith, Editor, 24 Woodbury Avenue, Petersfield, Hants GU32 2EE, UK

A Tribute from Martin Coulson
President, Land & Hydrographic Surveying Division, RICS

Guy Bomford had enormous talents as a soldier, surveyor and academic and he combined many of the professional and diplomatic skills from all three as an active corporate member of the Land Surveyors Division of the Royal Institution of Chartered Surveyors. He was appointed as a Fellow of the Institution in 1950 and his name first appeared on the list of Members of General Council in 1953-54.

He was on the Land Surveyors Divisional Committee from 1952-53 until 1961-62 and was elected Chairman for the year 1956-57, and apparently led the Committee in an efficient manner, cajoling and reminding others of the Land Surveyors' requirements, as necessary. His stature as a surveyor of international significance, and his service to the Council was recognised in 1968 when he was elected an Honorary Member of the Institution, a most exceptional achievement.

I was delighted some ten years ago to become the proud possessor of an old edition of Bomford. This has been a special book for me partly because it had helped me squeak through the exams at Hermitage, but mainly because it was so clearly enthusiastic in its writing. So, I am pleased to be back at Hermitage on behalf of the Royal Institution of Chartered Surveyors to honour the memory of Guy Bomford in these very fitting surroundings.

A Tribute from Professor Peter Dale
President, International Federation of Surveyors (FIG)

It used to be said that 'Hydrographer' was one of the few titles other than God that did not require the definite pronoun. Bomford however was, in its own way, another - but not as a person but rather as a text. The Bible is, but Bomford was and still is a noun representing excellence, a milestone in the history of surveying that saw science and intellectual rigour brought to what, up until then, had been a pragmatic subject. Bomford meant Geodesy, just as Clark meant Plane and Geodetic Surveying (and later, Allan, Hollwey and Maynes meant Practical Field Surveying and Computations). Bomford appeared at a time when land surveying was moving from a method-oriented set of procedures to a scientific discipline. It was a work that as one reviewer put it was complete, succinct, and authoritative.

Guy Bomford played no direct part in the affairs of the International Federation of Surveyors (FIG) although he had been the President of what later became the Land and Hydrographic Surveying Division of the RICS which is the UK Member Association of FIG. Nevertheless, he inspired and informed many surveyors all around the world through his understanding and teaching of scientific principles and theory and of technical practices.

As a young surveyor I never had the privilege of knowing him personally, though like several generations of land surveyors both in the UK and overseas, I sensed his indelible mark upon our subject. The proceedings of the meeting held in his memory are an appropriate way to mark the passing of one of the all-time great teachers of the surveying world.

Bomford and the IAG

Jean-Jacques Levallois. France. Former Secretary General IAG.

As early as 1951 I was in touch with Guy Bomford during the Brussels General Assembly of IUGG [International Union of Geodesy and Geophysics]. We discussed some questions of common interest on atmospheric refraction. In 1954 at the Rome General Assembly I was struck by his mastery in guiding the discussion of his SSG [Special Study Group] No 10 'The Geoid in Europe and geodetically connected countries'. I was admitted as a member of that SSG.

The task was the continuation of an IAG [International Association of Geodesy] project. It had been preceded by the adjustment of all available first order triangulation nets in Europe (European Net 1950). It consisted of the comparison of the geographic coordinates of the vertices of the net with their astronomical values, so as to obtain the deflections of the vertical at each of them and to compute the geoid by integration. It required:

- a perfect and complete knowledge of the documents describing the nets involved
- an attempt to obtain from the interested countries an astronomical action survey of their territory (for instance in France, about 500 new astronomical stations were finally observed)
- precise instructions to the members of the SG
- a general publication of the results.

Only those who have partaken of such a job can realise how tedious and irksome it is to look for the records, to compare them and to check the results. At the time, there existed no Internet.

Almost twenty years were spent before the final list was issued as *Liste No 4: Liste des stations de déviation de la verticale rattachées au réseau Européen 1950*. The result of Bomford's work was published by IAG in 1971, a few weeks before the Moscow General Assembly. About 3 400 points were registered and through some new connections, the European geoid would be extended down to India and along the 30th meridian to South Africa.

It should be noted that this was the same year as Bomford published the 3rd edition of his Geodesy.

When he took the chair of an IAG meeting he carefully prepared an agenda. He was a courteous and straightforward chairman, who listened attentively to the speakers but did not let the debates go astray. Such meetings were always interesting and successful with, from time to time, a little bit of subtle humour.

The central Bureau is a marvellous observatory of the life of the Association and the right place to acquaint with its officers. There I spent 24 years, 9 as an assistant secretary and 15 as Secretary General. During that period, the chair was occupied by seven presidents C F Baeschlin of Switzerland 1951-54; J de Graaff-Hunter of UK 1954-57; G Cassinis of Italy 1957-60; C Whitten of USA 1960-63; G Bomford of UK 1963-67; A Marussi of Italy 1967-71 and Y Boulanger of USSR 1971-75.

All of them were well known geodesists who managed IAG according to their own temperament and sometimes to some instructions suggested by their national scientific authorities.

The President is really the head, the moderator of the Association and its official representative. He has to cope with internal problems such as general organisation and structure, tasks and scopes of the sections, Commissions, study groups etc. He has also to solve exterior problems with other associations where he represents IAG at JUGG meetings particularly in discussions concerning regulations, administration, and finance. Close cooperation between the President and Secretary General is essential. With Guy Bomford it was easy and efficient. With his experience of IAG he felt the necessity of internal evolution but was nevertheless aware of the consequence of premature decisions.

His Presidential address at the 1967 General Assembly, in Switzerland expresses some of his views.
.....During the last four years we have held no less than 15 or 20 symposia or discussions on various subjects, as well as some smaller meetings of commissions and study groups. That is an excellent sign of the activity of our members and of the general interest, which is taken in our subject, but there are some who think that this activity has gone too far.

It is of course sometimes necessary for a small number of people to meet to discuss the details of some common activity, such as for instance the details of the adjustment of the European triangulation or of the European satellite net. Personal contact is essential and economical.

Meetings which are perhaps less easy to justify are those at which papers on some subjects are presented without immediate intention of proceeding to some common action. The papers may be of great value, but it may be felt that they could have been more profitably, and less expensively, read at home.

Those who think of convening a symposium should ask themselves whether the result will be worth the cost to themselves and to others, and if it is not, they should not hold it. Especially I think that this is necessary if the proposed symposium is one of a series that has begun to be held every three years. If every symposium is to be self-perpetuating, there will clearly be no end to their number.

The other remedy is with those who are invited to attend. If you think that your presence will make little contribution to the meeting, and that you yourself will get little benefit from hearing the papers read, instead of reading them yourself, then do not go. If you would all think on those lines, I think we could be sure that such symposia as are held will be worth their cost.

The number of Sections [to IAG], five, is not sacrosanct, but I think it is true to say that all good organisation is based on each major unit containing not less than three or more than seven sub-units. The number five is a good one, but four or six are equally acceptable.

There are difficulties. However, you divide the work, there will always be some items which fall on the border line between two Sections, but we need not magnify these difficulties.

Practically the experience of the more recent General Assemblies has proved that the Associations could hold a certain number of common meetings and have time enough to discuss separately their own problems. This is exactly, what Guy Bomford wanted and suggested.

To mark the contributions to geodesy by Guy Bomford the IAG agreed to the inauguration of a Guy Bomford Prize for distinguished contributions to geodesy. The prize is awarded at intervals of four years on the occasion of the Assembly of the IAG during the General Assembly of IUGG.

It is awarded to a young scientist (defined as being under 40 years of age) for outstanding individual contributions to geodetic studies, particularly in the four-year period preceding the General Assembly. Exceptionally, the prize may be shared between two or more young scientists who have been jointly responsible for a particular geodetic study.

So far as I remember it, the funds came as a gift of the British National Sub-committee of Geodesy to IAG, provided that its income would be agreed upon as being dedicated to a Guy Bomford prize.

That reward is really a token of excellence. I have been told that its account has been recently increased up to $2000, which will be surely much appreciated by the winner. I personally believe that in spite of its humble initial value, the name of the prize was sufficient to honour its laureate.

Bomford in India and Bomford the Man
Dr Alwyn Robbins

Guy Bomford had a very varied and distinguished career. He lived during an age when science and technology were changing and advancing not just man's knowledge and abilities but his whole life style, from a man with a red flag walking in front of the new-fangled vehicle called an automobile, and a time when geodesists travelled in the field on foot or by mule, elephant or camel, to modern travel by jet plane and helicopter and geodesy by satellite. During these incredible changes he was always not only completely up to date with the new thinking but often in advance of it.

Guy was the son of Surgeon-General Sir Gerald Bomford of the Indian Medical Service. From an early age he and his father would compete during sermons in church to see who could calculate the square root of the sum of the hymn numbers to the greatest number of decimal places. It was no wonder then that he won a scholarship to Marlborough and, after joining the army, that he passed out top of his year at the RMA, Woolwich. He was commissioned in 1917 and was later sent to France with 94 Field Company, but he was still at base when the war ended. However, he saw action in India in 1919 with the 2nd Queen Victoria's Sappers and Miners, when he spent nine months with 14 Company RE in the Wana Column in Waziristan, an area with hills of over 2000 m and wide extremes of temperature. This campaign has been described as the most desperate and costly in the history of the NW Frontier, and the fate of anyone captured alive was more than unpleasant. The tribesmen, directed by a skilled Afghan general, were numerous, well-armed, and included considerable numbers of soldiers who had deserted from the British-Indian Army, led on by tribal loyalties and the promises of agitators. After one foray Guy was the only officer to return alive and he was mentioned in despatches.

Guy was posted to the Survey of India where he spent one year going to Cambridge to read Engineering, graduating with first class honours (marked distinguished). Thereafter he was with the Survey of India until the outbreak of World War II. During the latter he again distinguished himself. He was in charge of survey and mapping for PAI (Persia and Iraq) Force. When Persia and Iraq were occupied, he established a small survey group in Burma in 1941 for the triangulation and production of maps. When the Japanese invaded, the records were buried at Myitkina. Subsequently Bomford and his companions had to walk many hundreds of miles in conditions of great hardship to reach the safety of India. The Japanese discovered the buried records and took them to Singapore from where they were recovered after the Japanese surrender.

He was Deputy Director of Survey, 14th Army from 1942-1945, Director of Survey, South East Asia Command. in 1946, and he was made OBE.

During his time with the Survey of India Guy entered into a fruitful collaboration and partnership with the late Dr J de Graaff-Hunter CIE, FRS, which made the name of the Survey of India second to none in the geodetic field. His most important contributions were probably in developing geoidal surveys and methods of adjustment of triangulation on a continental scale - in pre-computer days of course, using log tables, hand operated calculating machines or, on occasion, a slide rule!

He was one of the first geodesists in the world to recognise the importance of the relatively large height variations of the geoid - in that era for correctly positioning the spheroid relative to the geoid at the origin of the control system of a country or continent, but later also in computing the orbits of near-earth satellites and in relating satellite data to terrestrial. He also realised that, in those pre-satellite days, it was not possible to utilise directly geoid height variations computed from gravity data because (a) the data was insufficient to give reasonable accuracy, and (b) there were then no means of determining the position of any particular spheroid relative to the gravimetric spheroid on which geoid contours would be computed, which was by definition geocentric. His experience in India thus enabled him, at Oxford after the War, to compute single-handedly the readjustment of the triangulation of SE Asia for the IAG (International Association of Geodesy). As President for many triennia of its Special Study Group 5.10, Determination of the Geoid, he was responsible for determining a map of the geoid on European Datum and, for the first time ever, for extending this to Asia and Africa and then preparing the way for a link to the geoid in America, North and Southern, and to Australia after the Pageos programme (a geodetic satellite programme) had produced some results.

One or two minor anecdotes. Before the War Guy was the author of many geodetic publications of the Survey of India. One of these, he once remarked to me, could with hindsight have been given a more appropriate title - it was *Three sources of error in precise levelling*, by Captain G Bomford. After the War when he came to Oxford, he would enliven his undergraduate lectures with references to travel by mule, camel, or elephant and with such throw-away phrases as 'Take a shot on to that mosque'.

His audience much appreciated his dry wit and humour but the reference to a mosque would no longer be so amusing. Then there was the unfortunate who telephoned the Department, expecting and wishing to speak to the secretary but hearing a male voice, who stuttered: 'Um ... er ... um ... is that Bombardier Brigford?'.

Guy's interests were by no means solely directed to geodesy. As a young man he played rugby and he then became a keen collector of stamps and an even keener collector of ammonites. Every summer he and his family used to holiday in Dorset where he would look for ammonites. His collection was indeed internationally renowned and one of the many new specimens found was given the name *Parkinsonia Bomford*. It is not given to many of us to be of high international repute in two very different branches of science.

Guy once or twice said, largely in jest but I think not entirely, that he planned to live until the year 2000 so that he could say that he had been around for three centuries. Sadly, he did not quite make it but, until about his last decade, he was extremely fit. He had a large garden and an adjoining paddock. He looked after it himself and would even mow the paddock occasionally but, contrary to being completely up to date in his science, he insisted on clipping his very long hedge with hand shears, rather than using electric ones.

Guy was a quiet and kindly man, devoted to his family. For instance, when he visited my house, even in earlier days, he would occasionally glance at his shirt cuff - he had written on it the names of my children so that he could be certain to be able to ask after them by name. He was also extremely modest, never mentioning his military service in India or during World War II. Those who did not know him might have thought that he was soft, but they would have been very wrong. After he had listened to any discussion, he would make up his mind on the facts, come to a decision and hold to it very firmly against any opposition. At one time, when he was President of the IAG, he was pressed very hard to recommend to other international bodies, formally on behalf of IAG, a new value for the figure of the earth which had resulted from the most recent data and developments. He refused to do so, on the grounds (a) that the IAG had recommended a different 'new' value only a year or so back and he was not prepared to give the impression that the IAG did not know its own mind, and (b) that yet another new and improved value would emerge in another year or so, which could then be recommended. This decision was opposed strongly and was very unpopular indeed at the time but, later and with hindsight, he was of course shown to be quite right.

Guy was then a modest, gentle, and kindly man, but one who was always very firm in sticking to his principles and beliefs come what may. In short, he was a gentleman of the old order.

Guy Bomford and Geodetic Office
Jack Weightman

In 1953 I nearly came from East Africa to Oxford to read geodesy, but it was not till 1959, invalided home, that I joined 561 Electronic Computing Unit of Military Survey and began to see Guy Bomford regularly.

As Survey Adviser to the Directorate he dispensed wise counsel freely, promptly and in his own inimitable fashion with immense kindness, courtesy, and forbearance towards one who was very much his junior. He had the simplicity, even humility, of the very great and was as ready to learn from others as to teach.

There were many memorable occasions:
a) Using the longitudes of the US computations of the 30th arc triangulation for his African geoid but the latitudes of the DOS computation.
b) Hearing of a group velocity which contravened the principle that nothing travels faster than the speed of light and pursuing Brigadier Denison until he had all the details.
c) We at Geodetic Office were similarly grilled on Schreiber's device (he called it 'Schreiber's trick') for adjusting triangulation observed using the method of directions and on Professor Wolf's technique of 'buffer matrices' (we originally misread the manuscript as 'puffer matrices') for the readjustment of the European triangulation.
d) Having prepared 1000 copies of the Bomford geoid for distribution at the IUGG Moscow Assembly and losing the lot in the mysteries of the Soviet postal system.
e) Computing the South Asia adjustment carrying European Datum through Singapore only to find that the Italian deflections of the vertical were supplied by Marussi with a non-standard sign convention.
Below are a few extracts of an extensive correspondence I had with Guy in 1971-72 on the effect of 'bumps' in the earth's gravity field on the local shape of satellite orbits. He will be sadly missed.
Bomford writes to Rawlence and Weightman:
The subject is difficult, and I know little about it... I disagree with JAW's note 'analogous errors of much the same magnitude ... relative to which the satellite orbits are defined.' JAW must forgive me if I misunderstand him or am otherwise foolish, but I get the impression that he thinks as follows: 'If PQR is the orbit on the assumption that the equipotential surface ABC has no unsuspected hump in it, then if there is actually a hump AB'C the orbit will rise above Q by an amount equal to BB'.' Which I think is wrong.

If ABC is the equipotential, there will be a forward component of g between P and Q and a backward component between Q and R. The former will accelerate the satellite and the latter will do the opposite. Between P and R there will also be an increase in the vertical component. Computing the perturbed orbit takes me out of my depth, although there must be innumerable people who know the answer well.

An old book by Loney provides some guidance, the net result is (I think) a fall.

I think his (JAW) approach to finding the resulting errors is all wrong, and probably pessimistic. I cannot provide a correct substitute, but the right answer is knowable.
Weightman responds:

You are of course perfectly right... what I wrote before was a gross oversimplification of the position. I am most grateful to you for pointing this out (though rather angry with myself for not having seen it before).

This said, I still wonder whether ... the truth does not lie somewhere in between us. I relied in my arguments upon the energy principle and, wrongly assuming that if the 'bump' was sufficiently smooth there would be insignificant change to forward velocity, deduced that the satellite would need to follow the equipotential surface upward as, the kinetic energy remaining constant, the potential energy would need to remain constant also.

Having written the above... I have read again your arguments for a fall and find them even more convincing ... In particular your decrease of the radius of curvature of the path (implying a fall) looks very much, in my terms, like an attraction towards an additional buried mass below the surface, which has created the disturbing potential bump (again a fall).

I must therefore fall back on my second line of defence and say that, however the effect of the bump is distributed between change of velocity and change of elevation, the change of planimetric position of the satellite resulting from the former will surely be just as detrimental to the determined position of the ground station as will be the doubt in elevation already discussed...

Bomford responds:
I think there are three points we have to decide:
(1) Do errors in the position of the satellite have to be multiplied by a cosec to get the errors in the fix? I think not.
(2) How smooth are equipotential surfaces at 1100 km?

I accept 35 m as a possible error at sea level in these geoid charts... But there is room for a misunderstanding. Is this 35m the difference between the chart height and the true height? If so, 35 m is certainly a possible figure.
(3) How does this anomaly affect the motion of the satellite? This is where we need an expert . ....
My inclination is to say that an average of 5 mgals downward acting for 200 seconds will pull it down by 100 cm. The orbit will be permanently changed unless an adjacent negative anomaly pulls it back. Presently the orbit will get within range of a fixed station and the change will be noted. But I think that is where we need help.

Weightman responds:
(1) My estimate of the errors of fix resulting from given errors in the orbit of the doppler satellite originally leaned heavily on the 177 Geodetic Survey System ... I have since obtained a paper by Sluiter ... which has very much the same diagram, so it seems a generally accepted result.

Whether this in fact implies 'multiplying by a cosec' I am not sure, but at all events errors in height are multiplied by 0.7 to get plan errors if the elevation at closest approach is 20°, by unity if it is about 33° and by no less than 3.5 if it is 70°, with the curve increasing very rapidly indeed thereafter. It certainly looks like a cosec or something similar.

(2) How smooth are the equipotential surfaces at 1100 km? If I may misquote the Scripture, I have the firm impression that when 2 or 3 such satellite men are gathered together then there is usually a rather heated disagreement in the midst of them as to what are the magnitudes (and very often even the signs) of the harmonics above about the 8th or 10th degree and much talk also of the unknown truncation errors arising from stopping at whatever degree they decide to stop at.

So, each satellite man would say that his own results are very reliable, but would this not imply an opinion that those of all the rest are not?

(3) On the question of how the anomaly affects the motion of the satellite, I find myself in some confusion. In your letter of ... you said the net result was a fall. Although I at first took issue with you, you converted me to your point of view. I now read that you withdraw the words 'the net result is a fall' - and I do not know what to think! Having I hope put the ball back in your court I await with some apprehension the neat drop shot that I know from experience will surely come (and will prove to be quite unplayable), I think I would agree with your suggestion that we should get help.
Bomford responds:

I have made a little progress on two of our items.
(1) How accurate are these satellite geoid charts? I asked Gebel what he thought and ... enclose his chart of the differences. The contours take the form of longish ridges and dips rising and falling to over 20 m in small areas, with a width (smaller dimension) of about 2500 km. These would be representable by harmonics of degree ten and higher, and their 20 m would be reduced to 4m or less at 1100 km....
My general impression is that the above has not got us much further forward but think that errors in the best determinations of the 1100 km surface perhaps may not exceed 10 m. ... A cautious statement.
(2) When one consults an expert, it is a good thing to have an idea about what the right answer is, so I have computed a case by integrating the accelerations in 500 km elements ....
If Allen agrees within 30%, I will congratulate myself. If he disagrees by 100% or more, I will look for my mistake and expect to find it. If I cannot find it, I will ask him to look for his.

Bomford concludes his next letter:
In my correspondence with you and Gebel and others in the US I sit upon a sharp-edged fence, between the prophet of gloom on one side and the apostles of the new satellite geodesy on the other.
Weightman's last response sums up the situation:
I think it to be commonly considered that the NWL results are in some measure more reliable than those of APL and, if this is the case, your 'prophet of gloom' when, as in your last letter, you sit upon your 'sharp-edged fence' wonders whether you will not find that your 'apostles of the new satellite geodesy' on the other side will in the end turn out to be priests of Baal calling in vain for a response from an imaginary deity.

Ed. note. The above are but brief extracts from long detailed letters liberally sprinkled with formulae and sketches. However, they do illustrate the intense exchanges that Bomford indulged in on topics that were pushing forward the frontiers of knowledge. Not only will he be sadly missed but sorely so also.

Recollections
Dr Arthur Allan
Some years ago, I stood in for Dr Robbins to run the surveying field course for Engineers at Oxford. I had to follow Bomford's instructions, written several years previously. They were very detailed and specific. Such as 'Set up the theodolite

on Cumnor Hill station, and observe four rounds of horizontal angles', to this that and other stations whose coordinates were given. This went on, including instructions to measure Tellurometer lines. We followed it all to the letter. Then to my surprise and also the students', came the statement 'It will now be one o'clock!' Immediately we spied our watches to find we (or Bomford) were only ten minutes adrift!

Professor Peter Angus-Leppan, Australia
I do not know when I first heard of Brigadier Bomford but no doubt it was from Col Desmond Crone, who was my first lecturer in Surveying, at the University of the Witwatersrand (Wits) in Johannesburg. Desmond and his wife Meg had been contemporaries of Brig Bomford in India. They had left after the partition, and spent a short time in South Africa, before returning to the United Kingdom, while Bomford had stayed on in India.

Since then, his name, and what it stands for, has run like a strong thread through the texture of my life, not always visible, but nevertheless important. It had to be so for anyone who had an interest in geodesy, as I did. There was, of course, his comprehensive textbook on geodesy, which he continued for so long and so courageously to revise. There have been several introductory textbooks published recently on geodesy, but none has had the huge scope of 'Bomford'. It is marvellous that one person could have such a complete grasp of the complex range of topics that was required of the author of such a textbook.

I completed my studies in surveying, and later took a lectureship at Natal University. As a young undergraduate at 'Wits', I had some contact with Dr James de Graaff-Hunter, who visited our Department under a visiting lecturer's program, and told of his experiences in researching that elusive phenomenon, atmospheric refraction. Not surprising then, that when I took up a PhD, the topic was, in fact, geodetic refraction. When I had finished the work, it was entrusted to three external examiners, one of whom was Brigadier Bomford. I felt highly honoured by this, although I was only informed, unofficially, after the marking was completed.

Apparently, it passed without any problems, with everything in order, although, like all PhD candidates, I had submitted with the feeling of being not at all sure whether I had 'done enough'. After the completion of the PhD, I took leave and toured Europe, visiting some of the high points of the surveying world. Of course, Oxford was one of these, and I arranged to meet Brig Bomford one day in the summer. I was totally naive then, and the experience was something totally awesome and exciting.

In was 1959, and the summer had already started, so Guy Bomford was coming from Abingdon village, where he lived, to see me. I was travelling with my wife, Pam. Afterwards we went to the Commonwealth Survey Officers Conference in Cambridge, and met Brig Hotine, also from the Survey of India. By now we knew two Brigadiers and one Colonel from the Survey, as well as a geodetic adviser, Dr de Graaff-Hunter; we were suitably impressed with the calibre of personnel, and in particular their special approach to problems in surveying. We were visiting Oxford for the first time, and Brig Bomford was most affable in showing us around.

We discussed everything except geodesy and ended up good friends. He showed us around the colleges, and while they were to us, magical, he dismissed their pretensions airily, telling us of the idealised views which the inhabitants held about themselves. We did not visit the Geodesy Department in Banbury Road, though later I did spend some very happy times there, under his successor, Dr Alwyn Robbins. I also remember an argument which we had, and which I lost, about whether the beautifully carved stone mouldings of a building which we examined, would be, as he maintained, just as good made out of plastic, if there was no way we could tell the difference between the plastic copy and the original. We argued on and on, and eventually agreed that it would be best if we ended the afternoon with some refreshments. The nearest place turned out to be a Wimpy Bar, very widespread in those days, and I can still see clearly, in my mind's eye, Brig Bomford's large frame perched on the inadequate stool. He partook, and I think we joined him in eating a 'wimpy', something like a hamburger; he cautioned us not to tell his wife, as she had him on a strictly controlled diet. We were sufficiently naive that we were highly embarrassed to risk disturbing family arrangements, but what could we do? He obviously enjoyed his stolen snack, and I am sure it did him no harm.

In later years I met his son, Tony, who had very definite opinions on matters, and who had fascinating hobbies, such as how to tile spaces, which included weaving carpets, and white-water canoeing in Alaska. From my point of view, Tony had only one drawback, and that was that life was too interesting and exciting to waste it all working, he took early retirement from his important position of Director of National Mapping in Australia. Since then there have been major changes, resulting in the absorption of National Mapping by another body. Personally, I believe that they were inevitable, and Tony avoided some unpleasant experiences by resigning when he did. But unfortunately, he lives in Canberra., and I in Sydney, so we drifted apart...

Derick Bell
I fear that there are many others better able than I to speak to the great achievements and merits of Guy Bomford as it must be almost 20 years since I had the pleasure of meeting him.

My recollection at this distance in time is of the great respect he engendered at any meeting which I was privileged to attend in his company. Whether within the Institution, technical committees in UK, or in the context of the International Association of Geodesy and the IUGG, Guy commanded all the respect due to his immense knowledge and experience. Perhaps his greatest gift was his ability to grasp the techniques and significance of new ideas and methods in his chosen field of Geodesy. This was particularly well displayed when he attended the Stockholm meeting of the Working Party on the Re-triangulation of Europe in 1964 when the participants were coming to terms with Prof Helmut Wolf's ideas on the use of matrices when joining first order national networks.

On a personal note, the two great figures which dominated my early days in survey were Brigadiers Hotine and Bomford. In was admiration for the intellectual stature and consummate skills which each, in his own way, displayed which shaped my own much lesser ambitions. One of my most treasured references is the brief acknowledgement which appears in the foreword to Edition 3 of his superb standard work on Geodesy.

Bernard Chiat
Bomford's lecturing style impressed me when he gave a special lecture to those attending a short course on matrix algebra conducted by Vidal Ashkenazi at the University of Nottingham in 1968. All of the mathematical analysis had been written on the blackboard beforehand and this enabled his lucid discourse to be understood very easily. I learnt subsequently from the secretary in the Oxford Department of Surveying and Geodesy that he devoted a considerable amount of time to preparing for all his lectures in this way.

Bernard Chovitz. USA
My personal association with Guy Bomford goes back to the mid-50s. At that time, I was working at the US Army Map Service, and in collaboration with Irene Fischer was doing research on the global geoid. During the period 1954-57 Brig Bomford was President of Section V (Geoid determination) of the IAG [International Association of Geodesy] and also President of its Special Study Group [SSG] on the European Geoid. In 1956 he invited me and Mrs Fischer to become members of the SSG. The following year at the IAG General Assembly in Toronto, I met him and participated in the activities of his Section and SSG. During the course of that year my field of work changed and my interaction with Bomford ceased although Mrs Fischer continued communicating for many years afterwards. (She is now about 90 years of age.)

My own memory of Brig Bomford is extremely hazy, so I am not in a position to make any remarks based on recollection. However, I would like to say that he made a much more substantial impression on me through his magnificent reference work Geodesy, the 4th edition (1980) of which I still possess. Although I appeared in the bibliography of an earlier edition, I was dropped in the 4th, but you can find references to Mrs Fischer. I believe that Bomford will be remembered for many years in the geodetic field because of the great monument he created in Geodesy.

Maj Gen P F Fagan CB, MBE
I am not a geodesist and cannot offer anything useful on his work that cannot be said better by far more worthy contributors.
But I do have a strong memory of him, coming to Hermitage when I was a student and giving us a lecture one day. The eminent professor arrived, clad in a succession of pullovers under a jacket and overcoat- it was very cold and snowy in the winter of 1962-63. All of us warmed to his informal and friendly approach and prepared to listen. He wrote a simple quadratic equation on the blackboard and asked if we were familiar with that. 'Yes', we replied, rather surprised to be asked such an obvious question. Within moments we were, however, out of our depths as he jumped to very much more advanced mathematics, apparently just as simple and familiar to him as the simple quadratic, but way beyond anything we had previously encountered. But we endeavoured to stay with him as he took us off on mathematical flights of fancy, getting more and more heated and carried away as he continued. The overcoat was off already, of course, and was followed in turn by the jacket, a long-sleeved pullover, a short-sleeved one, and then cuffs unbuttoned and sleeves rolled up, and even tie first loosened and then removed. Fascinated, we wondered where it was all going to stop! But the lesson ended without further stripping, though with fond admiration for a delightful man whose greatness we were aware of, though unable - as yet at least - to grasp.
That is my abiding - and very happy - memory of Guy Bomford.

Mrs Irene Fischer USA
The first time that I encountered Brigadier Bomford was as a textbook - solid, hardcover, stern, full of knowledge - one of the mainstays of geodesy.

Later I got interested - and later even much involved - in his work to construct geoid profiles across Europe.

And later he became a frequent pleasant correspondent. He was then President of Section V of the IAG and chairman of its Study Group 10 on geoid profiles in Europe from astrogeodetic deflections of the vertical, and he invited me to join his group, which led to my constructing a geoid map of North America.

And then there was the triennial International Assembly of the IAG in Toronto in 1957. It was the first time that I was a member of the American delegation and it was a great experience for me; here I was meeting all the great geodesists from all over the world. There were smiles and friendly greetings everywhere, and there were talks all over the place, formal and informal, all through the days and evenings. There was a curious spell of experiencing books and letters, even formulas, turn into people who mostly looked so different from what you might have thought.

And there was Bomford! He had a pleasant way of putting people at ease, which I had felt already in the previous correspondence. With his marvellous sense of humour, he explained to us the didactical usefulness of his bulging middle to quickly impress on his students in the classroom the notion of the equatorial bulge of the Earth.

He tried to impress on me the need for establishing a connection between the hemispheres so that world geodetic charts on one and the same datum could be drawn; and he appealed to me for American enthusiasm to get such work funded. I could easily assure him of my personal enthusiasm - if that would help. I believe it did help eventually.

In its time, Bomford extended the European geoid all over Europe and Asia. He constructed a new South Asian Datum on a new ellipsoid. Other pieces of the picture puzzle, including Australia with Anthony Bomford's participation, were filled in by others.

At the 1967 Assembly in Lucerne, Bomford, then IAG President, showed his leadership in the discussion of an unexpectedly explosive topic: 'Do we need a new IAG ellipsoid? - and if so, which one should it be?' There were good arguments on either side; the amazing feature was the emotional involvement. The President, Bomford, let them fight and shout for a while and then managed to calm the waters by appointing a committee to draft a compromise resolution and bring it back for a vote. The compromise would acknowledge the rapid change of so-called 'best values' (for technical journals) versus major trends (represented by the Association).

I wish that all international conflicts could be smoothed out so amiably.

Brigadier L J Harris. USA
Until D-Day and the August invasion of Southern France one month later, the Allies were not able to consider more than defensive action against the Japanese occupation of Burma. Under Mountbatten's command offensive action succeeded in overcoming that occupation. Under him, Brigadier Tim Heaney was the Director of Military Survey at HQ ALFSEA and I was his Assistant Director from October having been flown from Italy after the invasion of the South of France. I was attached to the HQ of the American Army Group to oversee the invasion 'S & M' requirements and expected to go in with the Invasion Force - (a desirable task after experiencing 'Dunkirk' in May 1940). However, the London Ministry of Defence ordered my transfer to Tim Heaney's Dte on the Mountbatten HQ. Guy Bomford was DD Survey in the 14th Army, and then was a Lt Col A D Controlling the 'S & M' at the HQ of the African Group in Western Burma.

Peace came with the 'Bomb' dropped. Tim Heaney retired to become Surveyor General of the Indian Government; Guy Bomford succeeded him and so I continued as AD Survey at ALFSEA HQ under Guy. I returned to Britain in 1947 to become chief instructor at the Survey Trg Centre, which we converted into the School of Military Survey at Longleat. So, I became involved in the Oxford University Proposal!*

* Ed. note. Brig. Harris is here referring to the paper he gave at the Conference of British Commonwealth Survey Officers in 1947 (pp 292-298). There he floated proposals which were to lead to the formation of the geodesy course at Oxford, where Bomford was to play such a major role from 1948 to 1966.

Maj Gen B St G Irwin CB, MA
My impressions of Guy, which are second hand, are of a man of wit, humour, culture, and considerable intellect. He was neither the stereotypical senior Army Officer of his era nor the stereotypical mathematician. As to the latter, I doubt if he were anywhere near Senior Wrangler standard, or that he would have been much practical use to us if he had been. But he was certainly a long way ahead of most people who claim to like mathematics, and moreover he had the will and the ability to communicate his gift to others.

Guy undoubtedly rendered a huge service to the Surveying profession by discovering and exploiting a gap in the market. The teaching of geodesy is not within everyone's capability nor likely to be understood by more than a few, but it was an undoubted need and it came at just the right time when satellites and global geodesy were looming over the horizon.
Maj Gen J Edge used to tell a story of how, during the War, Guy had been posted to a snake infested area and was discovered hopping from one foot to the other because, he said, with only one foot on the ground at any one time, he effectively halved the chance of a snake bite.

Norman Leppard
I first met Guy in 1975, when I became Secretary of the Ground and Hydrographic Surveys Committee of the Joint Advisory Survey Board. Guy had served on that committee for many years and continued after he retired from Oxford University, always ready to give sound advice and keen to keep abreast of developments in geodesy. He gave as the reason for retiring from the committee the fact that 'I cannot really contribute much to the discussions'. This was far from the case, as anyone who knew him will know. There was a delightful extra piece in his letter when he asked 'would you please pass on anything of interest in the development of satellite geodesy for my 5th edition', which I was pleased to do. Although the 5th edition of Geodesy never came into print* I am sure Guy must have amassed a fair volume of material for it.

Guy's correspondence in the years I knew him was always typewritten, economic in style and size of paper and characterised by corrections carried out by overprinting the offending letters with Xs and typing the correction above. One could feel for his sense of frustration at having hit the wrong key.

In 1992, Military Survey was looking for a name for the Directorate building at Feltham, the only un-named building on the site. A new building directly opposite had been named after Martin Hotine and my proposal that the Directorate building should be named after Guy Bomford was duly accepted. Military Survey was much pleased to have Guy and his wife come to Feltham to unveil the plate naming the building. Although rather frail, he met many of the staff to whom his name was so synonymous with geodesy. His inquisitive mind was still very much in evidence. This must have been his last public appearance. One of Guy's 1939-45 war activities involved the saving of a large number of triangulation station records from the Topografische Dienst offices in Batavia (Jakarta) a very short time before the Japanese invaded. These records ended up in the Geodetic Library, known collectively as the Bomford Registers. They proved invaluable during the early 1960s when mapping was prepared during the confrontation period with Indonesia in Borneo.

* Ed note from correspondence with A G Bomford re the mention of Geodesy 5th Edition. When he was 77, he (Guy) wrote to say that he was conscious of being a little slower than he used to be, but he was feeling pretty good, and thought that if he allowed himself an extra year, he might perhaps bring out a fourth edition of Geodesy. What did I think? Of course, I encouraged him, and he wrote back pleased; but added that if he wrote again ten years later suggesting that he brought out a fifth edition in his nineties, I was to dissuade him.

Alastair Macdonald
Reading Bomford in the bush. I am one of that rare breed of Chartered Surveyor who grew up in an era when there were no exemptions on offer, and one had to actually write a full Final Examination. Perhaps I am even rarer for I elected to take the geodesy option. I made that choice in the confident belief that, even though I was working in the wilds of Northern Malawi at the time, all I had to do was to read Bomford's classic text on Geodesy from cover to cover and I could take on anything the examiner threw at me.

In 1960, the traditional 'local' venue for Central Africa was Harare (then Salisbury). I was much too mean to contemplate the air fares and hotel expenses that this would involve so I wrote to RICS and demanded a more convenient location.

I nominated Rumphi, a village under the Nyika Plateau which was a District Headquarters, as my preferred venue and the District Officer as the invigilator. To my surprise this was accepted.

I was working on the high grasslands of the Nyika Plateau immediately before the examination, using the new Tellurometer to measure the scale of the primary triangulation by day and dutifully reading Bomford in bed at night. It was true geodetic saturation! The evening before the examination, I drove down to Rumphi (with cook to look after my creature comforts - in true imperialist style) and camped at the boma.

The District Officer, who had other more important things to do than watch me writing an examination, invited me to sit in the thatched and open-ended courthouse for the day, handed me the first paper and departed. I only saw him again when he delivered the second paper in the afternoon and when I handed him the completed manuscripts. I had a minor panic halfway through the afternoon and had to run around the boma trying to find some more paper while the minutes ticked by - but, as it turned out, it did not matter because I was my own timekeeper!

Sadly, I cannot remember now how much of Bomford I was able to use in my answers. I do still remember the delight I felt when I saw one of the questions was 'How would you use the Tellurometer to measure the scale of a primary triangulation?' and I could respond 'It was only yesterday that I was at NP85 with my Tellurometer and ...'

Whether, in the event, I used Bomford a great deal or not, I feel it was a tribute to the coverage, the clarity and the authority of this classic book that I could confidently use it, and it alone, in the wilds of Malawi to cram for the examination.

Peter McMaster
As Reader in Surveying and Geodesy, Guy Bomford taught RE officers attending the Army Geodesy Course at Oxford University. I was on the last course that he taught, the only other military student being Alex Laing. Since Laing became

Director of Military Survey in Australia and I became Director General of Ordnance Survey, Guy Bomford's last two students obviously owe him much.

I remember him as an intensely practical man and much of his teaching was based on his experience in India and the East. We were always delighted when we could side-track him on to tales of the Indian Survey, as this would save us from his intellectually arduous teaching. For practical work, he would sometimes set his students abstract calculations of Stokes Integral, or some such, and we would beaver away for perhaps two days with Peter's tables and mechanical calculators. At the end of this, to our great admiration (but considerable irritation), he would take a slide rule from his pocket and check our work in about two minutes or so.

On Monday mornings our lesson would often consist of an analysis of the geodetic content of a letter from his son in Australia. Guy Bomford would often start off by saying 'I have had a letter from my boy, Tony, and he has a most interesting idea...' We were always pleased when Tony wrote as this relieved us of more demanding work.

Guy Bomford was born in 1899. I remember him saying he hoped to be a man of three centuries - sadly, with his death just four years short of the 21st century, this was not to be.

Lt Col N J D Prescott

I first met Brigadier Guy Bomford in Autumn 1962 when I started a geodesy course under his tutelage. The class consisted of Mike Richards, an Australian (lecturer from Adelaide University) and myself. Although the course was conducted in a very relaxed and friendly manner, we found ourselves rapidly stretched to our intellectual breaking points! Sessions would generally start with Bomford lecturing at the blackboard (which rapidly became filled with a mass of complex formulae and data) while we struggled to keep up with our notes. One helpful aspect was that much of the subject matter was covered in our 'Bible' - Bomford's Geodesy and as the second edition had just come out it was fairly well up to date. Bomford was a formidable sight as the more he scribbled on the blackboard and the colder the weather got so he seemed to take off more clothes! The building had no central heating and I seem to remember we wore our winter woollies and had to jockey for position near a small electric fire!

Much of the instruction took place in the form of discussion with Bomford and the rest of us (often joined by Alwyn Robbins) sitting round a table. He was very good at drawing us out and listening to our experiences, especially on the practical side.

For example, Mike and I had recently been with DOS in East Africa using Tellurometers which at that time were revolutionising the traditional methods of establishing survey control. Considering his age and experience it was remarkable how ready Bomford was to accept these new techniques and we had many interesting and constructive debates on this and numerous other subjects. Often after such discussions Bomford would rapidly distil the information and put together a draft on the subject for the next edition of his Geodesy, on which we would be invited to comment.

Bomford's approach to life was much influenced by his upbringing and service in India and he even selected a north facing office because h regarded 'the sun as an enemy!' As a result, Alwyn Robbins had the more cheerful office with a south window.

As students we all had to work hard to understand the syllabus but Bomford also encouraged us to research any particular aspects that interested us. I was particularly grateful to Bomford for his help and advice when I later published a paper based on some work done at Oxford.

On retiring from my second career I have taken up the hobby of genealogy (not bad spelling for geodesy!) and have recently found that my mother was a third cousin of Bomford! Sadly, Bomford died before I could let him know.

I personally found the course at Oxford immensely interesting and enjoyable. Although I left the survey world in 1970, I have no doubt that Bomford made a most valuable contribution to surveying and geodesy especially through his writing and teaching and that he will be sorely missed in the profession.

Ken Pugh

In 1971, whilst at RMCS David Munsey being the principal lecturer, I put in a three-pillar calibration base. The three pillars were constructed by the civil engineering department after soil testing. They proved to be stable and accurately aligned with a total distance apart of 810.5 m. to suit calibration of our Tellurometers at the time and later Wild DI 10s.

The two distances were measured in the classical manner, by invar tape, straining trestles, weights etc much enjoyed by David Munsey who had previously done some work on the arc of the 30th meridian (Cape to Cairo) triangulation in the Sudan.

David Munsey and Brig Guy Bomford were very good friends. Indeed, much of the new material for the great man's forthcoming new edition was sent to David for his comments.

Seemingly word of the availability of the base had filtered through to Dr Froome at NPL. Dr Froome, another great man in his field, had recently determined a more accurate figure for the speed of light in vacuo at NPL, on a shoestring budget. Thereby seeing off a million-dollar effort by American scientists.

Dr Froome had now turned his mind to distance measurement. Together with an electronics wizard by name of Bradsell, they produced the prototype Mekometer.

In February 1972 we at RMCS were delighted to have Dr Froome, Mr Bradsell, and a representative from Kern, come along and use the base to demonstrate and test the instrument. Guy Bomford was invited to attend and witness the event, which of course he did with rather more than passing interest.

It was fascinating listening to these great men, leaders in their fields, in serious discussion. A third-year degree student - J Collins RE - doing a project on the base at the time, was also suitably impressed.

Subsequently, talking to the Brigadier in the officers mess, he made the remark 'In survey using such instruments, surveying ceases at the master station and resumes again at the remote. What goes on in between the two stations is not surveying'! Prophetic words??

Satish Sharma
Before coming to Oxford University, Department of Geodesy, I had known Brig Bomford through his many articles published in various Geodetic Reports of Survey of India. Bomford's Geodesy was followed in the Training Directorate of Survey of India as a textbook. I was looking forward anxiously to meet him when I came to Oxford to spend one year in 1964 to learn Geodesy and Computer methods under Brig Bomford's guidance.

He started giving us lectures based on his Geodesy.

There were four of us attending his lectures, two of them were army officers from Ordnance Survey and the fourth was Vidal Ashkenazi who was doing his DPhil at the time. His ideas were very clear. During his lectures he was prepared to take our comments.

I discussed with him the Indian Geodetic Triangulation and its adjustment. He had left India about 15 years before, but his memory of the geodetic facts about Indian Triangulation were as fresh as they would have been at the time when he adjusted it by his specialised 'Indian Method'.

His treatment of 'Theory of errors' and 'Use of Satellites for Geodesy' was excellent considering that the technology had just started; specially when Vidal Ashkenazi was busy researching his ideas of optimisation and strength of figures and was attending his lectures. Brigadier Bomford was always ready to discuss problems with an open mind and encouraged us to throw new ideas. He was a great source of inspiration.

Many Years later, in the late eighties. I had some officers from Survey of India studying 'Use of Computers for Geodesy and Photogrammetry' at Imperial College. We went to meet Brigadier Bomford at his house in Sutton Courtenay. He discussed changes in Survey of India since his time and specially the 'Geodetic Triangulation of India'. He was a very compassionate and thorough gentleman and all of us enjoyed our meeting and tea with him and Mrs Bomford.

Brigadier Bomford had a large collection of rocks which he collected during his Survey of India field surveying days in the High Himalayas. These were methodically named and stored at his house. We could not but be impressed by his organised manner.

Lt Col P C (Pip) Sherwood
During my, years at Newbury we had acquired Worden gravimeters and were teaching gravity to the Army Survey Courses. I thought it would be a good thing to invite Guy to give lectures on gravity to the students and he agreed to do this. They were a great success, not least for their entertainment qualities. It was wintertime when he first appeared on stage and he was cocooned in a variety of pullovers, sweaters etc, obviously in anticipation of the underheated classrooms typical of the old school before rebuilding. An elaborate routine ensued, he would remark how hot it was and peel off one layer. A short while later off would come the second layer and so on until he was almost down to the buff. He had the endearing habit of wiping his chalky hands on the garments, so he ended up with a pile of chalk impregnated clothing. This was of course highly amusing for the students and, although somewhat camp, contributed greatly to their learning of the subject through mental associations of his antics to the subject matter.

Apart from this I always found him a most endearing person during my monthly visits to his Department at Oxford to see our Geodesy students on the one-year course run by Guy and Alwyn Robbins. A thorough gentleman in the old-fashioned context.

Geodesy
Clarendon Press Oxford
Geodesy has gone to 4 editions and the prefaces and reviews throw some light upon his thinking. Following are extracts from these.
Prefaces
First edition 1952
The literal meaning of 'Geodesy' is 'Dividing the Earth', and its first object is to provide an accurate framework for the control of topographical surveys. Some authors have included almost any kind of triangulation in the subject, but it is now more usual to describe only the main framework as geodetic, and to describe as topographical triangulation the work of breaking down the intervals between widely spaced geodetic stations. There is no need to be precise about the distinction, but the assumption here made is that the reader knows how to use such theodolites as the 5-inch micrometer or 3 inch Wild and can measure angles correctly to within 5 or 10 seconds of arc. Geodesy is then taken to include:
(a) Primary triangulation, and the possible use of radar as a substitute.
(b) The control of azimuth by Laplace stations, and of scale by base measurement, and the closely related process of primary traverse as a substitute for triangulation.
(c) The measurement of height above sea level by primary triangulation or spirit levelling.

This, however, is not the end of the subject. Circumstances have caused geodesy to overlap to some extent with what might reasonably be described as geophysics. Triangulation cannot be computed without a knowledge of the figure of the earth, and from very early days geodesy has included astronomical observations of latitude and longitude, not only to locate detached survey systems, but to enable triangulation to give the length of the degree of latitude or longitude in different parts of the earth, and so to determine the earth's figure. An alternative approach to the same subject has been via the variation of gravity between equator and pole, as measured by timing the swing of a pendulum. But these two operations, the measurement of the direction and intensity of gravity, have led to more than the determination of the axes of a spheroidal earth. They have revealed the presence of irregularities in the earth's figure and gravitation which constitute one of the few available guides to its internal composition. It is impossible to be precise about the dividing line between geodesy and geophysics, but for the present purpose geodesy is held to include:

(d) Observation of the direction of gravity by astronomical observations for latitude and longitude.
(e) Observation of the intensity of gravity by the pendulum or other apparatus.
(f) The use of the above to determine the earth's figure, with some consideration of the geophysical deductions which can thence be made.

This definition of geodesy conforms closely to the range of activity of the International Geodetic Association. Brief reference is also made to the allied subjects of magnetic survey, tidal analysis, latitude variation, and to seismic methods of geophysical prospecting, as although these are separate subjects their technique is such that the geodesist may often be called on to work at them. Earth tides have been excluded.

Restrictions on space have enforced the exclusion of matter which some might like to have seen included, notably: (a) No general historical outline is included. History has been limited to what is needed for the understanding of current practice. (b) Descriptions of the construction and handling of instruments have been confined to general principles, avoiding details which vary in different models, and which would in any case soon get out of date. (c) No worked numerical examples have been given. (d) Proofs of mathematical formulae which have no exclusive reference to geodesy can be found in mathematical textbooks and have been omitted. Proofs of the chief purely geodetic theorems have been included, at least in outline, but where proofs of comparatively unimportant theorems or of alternative formulae are long, reference must be made to the sources quoted.

Third edition 1971
In the second edition (1962) some mention was made of the effect on geodesy of such novelties as electromagnetic distance measurement, electronic computers, and artificial satellites, but it was then too early to assess their effect fully. Now, for the present edition it has been necessary to rewrite the text almost entirely, with those subjects taken as the probable basis of modem work.

Fourth edition 1980

By the last edition he highlights those areas where geodesy overlaps other disciplines. He lists polar motion shared with geophysics and astronomy; earth tides shared with geophysics; separation of the geoid and mean sea level shared with oceanography; engineering surveys and miniature geodesy, where geodetic accuracy is required over a small area for special engineering works shared with engineering and satellite geodesy which is spreading over all other branches of the subject.

In including satellites, he apologised for only devoting 100 pages to it where, he says, even 1000 would be inadequate. He highlights six areas where satellites have had a profound effect - allowing detached datums to be converted to a single geocentric system; the increasing accuracy available on trans-continental schemes; three dimensional fixes to control geoid sections; the necessity of Laplace control becoming obsolete; separation of the geoid and spheroid determined such that Stokes' integral is of lesser value; and a good analysis of the earth's external gravity field.

He highlighted three instances where SI units presented a difficulty. No, not feet versus metres, but the widespread use of the gal, the bar, and the geopotential unit.

Reviews
First edition. 1952 Price 50s.
'As stated on the outside folder, there has been no comprehensive treatise on the subject printed in England since A R Clarke's Geodesy of 1880. This book aims to fill the gap and to include modern developments, some of which have only been published as articles in scientific journals. Geodesy now covers such a wide field that it is difficult to decide exactly how much to include in a textbook. Brigadier Bomford has given in the preface his reasons for excluding history, descriptions of particular instruments, proofs of some mathematical formulae and worked numerical examples. ...

The style of the book is easy and the language as non-technical as possible. At times, the wording is rather loose, and the reader will be left wondering exactly what the author recommends. This is largely due to the omission of almost all practical details of computation.

... Most of the criticisms concern the computational side of the subject which the author, obviously, does not consider as important as the rest. ... There is no doubt, however that the book merits careful study by all who are interested in geodesy. Many of the methods and formulae given were produced by the Survey of India, which has always been to the fore in the advancement of the science of surveying.' HYR (= Hume Rainsford).
Empire Survey Review Vol. XI No 85 July 1952 pp 329-331

Second edition. 1962. Price 90s
'The first edition published in 1952 ... has established the book as the leading work on the subject in English and ... a worthy successor to Col A R Clarke's Geodesy ... published in 1880. Many developments, of course, took place in the seventy years between the publication of 'Clarke' and of the first edition of 'Bomford' but the ten years which have elapsed between the appearance of the first and second editions of 'Bomford' have, perhaps, seen as many important developments as there were during the preceding seventy, if not more. A new edition of 'Bomford' has thus become a real need.

The first edition of 'Bomford' consisted of 452 pages and the new edition consists of 561. ...

Both editions cover the three main branches of geodesy - mathematical or geometrical geodesy, geodetic astronomy, and physical or gravitational geodesy. A number of textbooks exist in which the first two of these branches are treated at some length, but generally from the point of view of the practical surveyor engaged to provide a working framework for topographical or cadastral surveys rather than from that of the geodesist. In 'Bomford' however, the treatment although condensed, is generally much more advanced and contains a great deal of matter ... not to be found elsewhere.

... In the ordinary text book in English on geodesy, apart from 'Clarke', there is very little about gravitational geodesy and, before the publication of the first edition of 'Bomford', one had to go to papers scattered in journals of different kinds in different languages in order to follow recent work on the subject. Altogether, 157 pages in the new edition are devoted to gravitational geodesy against 132 in the first edition.

One criticism of both editions of the book which might be advanced is that in places the treatment is rather condensed and somewhat fuller explanations or details might be thought desirable. However, Brigadier Bomford is a master of compression and manages to get a great deal of matter into a relatively small space. ... The first edition of the book is now so well known that a second edition scarcely requires any recommendation. Suffice to say that it is a book which no serious student of geodesy or practising geodesist can afford to be without.' J.C (= James Clendinning)
Survey Review. Vol XVII No 129 July 1963 pp 150-152

Third edition. 1971 Price £10
'This well-known compendium of geodetic facts and figures may look much the same to those who know the earlier editions, but recent developments in the subject have necessitated extensive re-writing, expansion, contraction, and changes of emphasis. ...

Increases have of course exceeded decreases, and this new edition has 170 more pages. It includes 120 pages of appendices on spheroid geometry, matrix algebra, 3-D coordinates, theory of errors ...

Tight packing of the information, and copious use of those familiar square-bracketed references to 531 sources listed at the end of the book, have enabled the publication to remain in one volume. Inevitably the reader receives impressions of staccato from time to time, but that is the nature of this composition. Frankly, the book is not a students' text, and no student can be expected to buy it at the price; this new edition should, however, be accessible to all students of the subject and should take its place in the libraries of organisations concerned in any way with Geodesy.' J.E.J (= John Jackson).
Survey Review. Vol XXI No 162 October 1971. p 189

Fourth edition. 1980. Reprint with corrections 1983
There were no reviews of these in the Survey Review.
General Comments
The 44 years since the first edition of Geodesy ably illustrates how rapidly the profession has changed not only in that whole period but in the successive increments of ten years or so between each edition. To find that much of what one writes in a major tome of this complexity is out of date within ten years must on the one hand be somewhat depressing yet on the other, a challenge to keep its contents current.

These extracts also raise the further point of the definition of geodesy. Nowadays the European definition incorporates just about every conceivable form of surveying imaginable. Is there an identity problem here? If Bomford had used the present definition, then Geodesy would have needed to be ten times its present size. Maybe it is that since 1952 and Bomford's definition that closely mirrored that of the IAG, we have produced an identity crisis within the profession. A topic on which, I am sure if he were still with us, Bomford would have had much to say.

Without the energy and effort that was put into maintaining the currency of the volume over such a long period, the profession would have been much deprived. It truly deserves its nickname of the geodesists' 'Bible' and will remain so for many years to come. However, the problem of how its influence can be maintained is one that the profession has to face sooner rather than later. Is there any geodesist willing to carry on the tradition by producing his own volume to carry on where Bomford left off? If not, then come the next decade there will be a void in the profession's armoury. Let us hope that there is a geodesist out there open to the challenge of stepping into Bomford's well defined footsteps.

Geodesy, as defined above, involves, among other topics, baselines, figures of the earth, geoidal separation, and the definition of standards of measure. Bomford played a recorded role in the field operations of all of these.

By the beginning of the 1930s there were 10 baselines in India; between 1930 and 1934 a further seven were added and, as will be seen in the paper reprinted from the Survey Review No. 200, Bomford had a hand in these; they were:

In India proper		
Poona	1933-4	In two parts of 4.3 and 2.3 miles
In Baluchistan		
Padag	1933-4	5.3 miles
In Assam & Burma		
Keng Tung	1930-1	7.3 miles
Mergui	1932-3	2.8 miles Remeasure of 1881-82
Amherst	1932-3	8.4 miles
Kalemyo	1932-3	In two parts of 3.7 and 2.8 miles
Namtiali	1933-4	In two parts of 3.7 and 3.5 miles

When these new Indian baselines were being reduced to the Indian foot in 1937 Bomford became involved in the tricky problem of relating the Indian foot to the more modern units. He took the Indian 10-foot bar A at 62° F to be 3.0479841 International metres. Using this Bomford deduced the following versions of Everest's 1st spheroid: -

Semi major axis	Semi minor axis	
20 922 841	20 853 284	British feet of 1865-94
20 922 859	20 853 302	British feet of 1926
6 377 276	6 356 075	International metres.

He said 'It would be wrong to ascribe any of these figures to 'Everest's spheroid'.... It is thought that the best way of viewing this complication without confusion is to regard the original definition of any spheroid as giving the length of its axes in so many units, not necessarily exactly feet or metres, while the length of the unit used is derived from a consideration of the fundamental standard of the country concerned.'

After further comparisons of the standards in 1953 by J S Clarke the most probable value for the International metre to Indian foot was found to be 0.3047995 which differed from that used by Bomford by 0.00000109

This in turn gave a variation in the length of the 10-foot bar of 0.0000036m. As a scale error this was introduced into the 1937 adjustment of the triangulation. Bomford later revised his value of the relationship to agree with the value of Clarke. Obviously a very involved and difficult problem to resolve.

Another area in which Bomford was intimately involved was that of geoidal heights. In the 1910s and 1920s there was much discussion as to the geoidal separation in the Himalayas. In 1929 he proposed an increase in the geoidal separation in the vicinity of Mount Everest from that of 69 ft suggested by de Graaff-Hunter to 100 ft and hence a geoid height there of 29 050 feet (8 854 m).

These examples illustrate just a few of the areas in which Bomford played a major part in the Survey of India, any one of which many geodesists would have been satisfied to have been involved with.

Geodetic Surveys in India 1930-35

Guy Bomford

Survey Review No 200 April 1981 pp 65-78

Brigadier Guy Bomford OBE, MA, DSc

Born 1899 28 June. Son of Surgeon-General Sir Gerald Bomford KCIE of the Indian Medical Service, and Mary Florence Eteson.

Married (1) 1925 in India to Audrey Edith Barclay. They had a son Anthony.

Married (2) 1939 Annette Brown. They had two sons, Christopher, and Rodney.

Died 1996 10 February.

Educated at Marlborough College and RMA Woolwich. He was a keen player of rugby football.

1917	28 February Commissioned as 2nd-Lt. in the Royal Engineers.
1918	After further training he went to France with 94 Field Company.
	28 August Promoted to Lt.
1919	13 October Arrived in India. Posted to Indian Establishment.
	Saw action with the 2nd Queen Victoria's Own Sappers and Miners in India.
1920-21	9 months with 14 Company RE in Wana Column, Waziristan. Mentioned in despatches.
1921-1948	With the Survey of India.
	25 August Asst Superintendent, Trigonometrical Survey Office, Dehra Dun
1922	18 January Asst Superintendent No 7 Party
	5 June Passed higher standard Hindustani
	3 August Returned to England to read Engineering at Queens' College Cambridge
1924	Graduated with First Class Honours

	6 October Asst Superintendent No 8 Party and later No 6 Party Bangalore
1925	21 October Asst Superintendent E Company. Mussoorie
	1 November Asst Superintendent E Company. Quetta
1926	4 March Superintendent No 14 Party. Dehra Dun
	24 September Promoted to Captain
1927	1 July - 22 February 1932 Superintendent in charge of Computing and Tidal Party
1928	Three sources of error in precise levelling. Survey of India Prof Paper 22
1931	Geodetic triangulation. Survey of India
1932	23 February - 24 May In charge of the Survey Party for demarcation of the Persia- Baluchistan border.
	25 May - 31 October 1938 Superintendent in charge of Computing and Tidal Party
1935	18 October Founder member and Fellow of the National Institute of Science in India
1936	13 August Promoted to Major
1939	The readjustment of the Indian triangulation. Survey of India. Prof paper 28
	17 March Due 12 months leave but recalled on 31 August
1940	7 March Assistant Surveyor General. Calcutta
	7 September Assistant Surveyor General. Delhi.
1941	20 June Superintending Officer on special duty under Director, Frontier Circle. Simla
	July - Dec. Assistant Director Survey 4 HQ Iraq
	Served with PAI (Persia and Iraq) Force and responsible for its mapping requirements
1942	Jan - Apr Deputy Director Survey South West Pacific, Java
	April - Sept and Nov - Oct 43 Deputy Director Survey E Army, Burma frontier
	Sept - Nov. Director Survey I Command, Delhi
1942-1945	Deputy Director of Survey for both Eastern and Southern Commands 1942-1945
	Completion of the Survey of Burma
1943	Oct - May 45 Deputy Director Survey 14th Army, Burma Frontier
1945	Oct - Apr 46 Director Survey II Army Group (later ALFSEA), SEAC
1946	Director of Survey in South East Asia Command.
	Awarded the OBE
	Returned to England from Singapore on 22 months leave pending retirement
1948	Retired from the Army and became Reader in Surveying and Geodesy at Oxford
1947-1962	Member of the Royal Society Geodesy & Geophysics Sub-Committee
1950	Fellow of the Royal Institution of Chartered Surveyors. Member of its Land Survey Council 1952-1962
1952	First edition of Geodesy. Subsequent editions in 1962, 1971 and 1980
1961-1968	Chairman of the Royal Society Geodesy & Geophysics Sub-Committee

1963-1967	President of the International Association of Geodesy
1966	Retired from Oxford University
1967	Obituary of Dr J de Graaff-Hunter. Survey Review 144 April pp 50-51 and Bull. Géod. 84 June. pp 83-84
1968	8 January. Honorary Member of the Royal Institution of Chartered Surveyors.
1975	First award of the IAG quadrennium Bomford Award, for outstanding achievement in geodesy by a young scientist, to E W Grafarend.
1981	Geodetic surveys in India 1930-35. Survey Review 200 April pp 65-78
1992	July 10 Building named after him at the Directorate of Military Survey, Feltham

On retirement from the Army, in 1948, he became Reader in Surveying and Geodesy at Oxford, a post he held until 1966. A senior member of Brasenose College, he instructed undergraduates, supervised specialists, and computed all the projections of the Oxford Atlas, some of which were of his own devising.

Publications by Guy Bomford

1926-38	Various sections in Geodetic Reports, Survey of India. particularly 3 of 1926-7; 5 of 1928-9; 1933; 1934; 1937 and 1938. Note, after 7 numbering gave way to the use of the year
1927	Correspondence on the figure of the earth. Geographical Journal. Dec.
1928	Three sources of error in precise levelling. Survey of India Prof. Paper 22
1930-31	Deviation of the vertical. Geodetic Report, Survey of India. 7 pp 49-59
1931	The Indian geoid and gravity anomalies. (with J de Graaff-Hunter). Bull. Géod. 29 Jan/Mar pp 20-21
1931	Construction of the geoid. (with J de Graaff-Hunter). Bull. Géod 29 Jan/Mar pp 22-26
1931	Geodetic triangulation. Survey of India.
1935	Deviation of the Vertical. Geodetic Report for 1934. Survey of India pp 25-45
1936	Deviation of the Vertical; Computing Office & Tidal Section; Observatories and Levelling in Bengal and Bihar. Geodetic Report, Survey of India
1937	Magnetic surveys in Bihar; Computing Office & Tidal Section and Observatories. Geodetic Report. Survey of India.
1938	Several chapters. Geodetic Report, Survey of India
1939	The readjustment of the Indian triangulation. Survey of India Prof Paper 28
1945	The Survey Service. Eastern and 14th Army 1942-45. Report.
1951	General report No 10. Deviations of the vertical. IUGG Brussels.
1952	Geodesy. 2nd Edn 1962. 3rd Edn 1971. 4th Edn 1980, with corrections 1983
1952	Comptes Rendus de l'assemblée Générale de Bruxelles 1951. Bull Géod 23 pp 9-33
1954	General report No 9 Deviation of the vertical. IUGG Rome.
1954	Determination of the European geoid by means of deviations of the vertical. Report of Commission 14. IUGG Rome
1956	European geoid, interim report for period Sept 1954-Dec 1955. IAG
1957	Report for 1954-57. Study Group 10. The geoid. IAG
1957	Determination of the European geoid by means of deviations of the vertical. Bull Géod 42 pp 44-50

1958	Deviations of the vertical. 1954-6. Trav.Ass.int.Géod. 20 (5)
1959	Junctions between triangulation systems of Siam and French Indo China. Unpub.
1960	The figure of the earth. Its departure from an exact spheroid. Geophys, Jnl.R.Astr.Soc.3 (1), 83-95
1960	The junction of the Indian and European triangulation systems. Bull. Géod. 56 June 1960 pp 177-189
1960	Provisional report Commission for the adjustment of the triangulation in South Asia. IAG June 1960
1960	Provisional report on deviation of the vertical and the European geoid. IUGG Study Group 10, Helsinki
1962	The second adjustment of the European triangulation 1963. Spheroid and datum. Symp. on New Adjustment of European Triangulation. Munich. Oct 1962
1963	Report of Study Group 10. The geoid in Europe and connected countries. IAG Conference. Berkeley, California. May 1963
1963	Report on the adjustment of the triangulation in South Asia. Oxford. July 1963 Presented at the General Assembly of IUGG, Berkeley, California.
1964	The geoid in Europe and connected countries. Trav.Ass.int.Géod- 22, 337-340
1964	The adjustment of the triangulation in South Asia. Trav.Ass.int.Géod. 22, 35-49
1967	James de Graaff-Hunter 1881-1967. Obit. Roy. Soc. 13 Nov. 79-88
1967	Determination of the geoid by astro-geodetic deflections. IAG. XIV General Assembly of IUGG Lucerne. Sept 25-Oct 7 1967
1968	Matrix methods and variation of coordinates. Seminar. Nottingham University. Jan
1970	The direction of the minor axis of geodetic reference spheroids. (with A R Robbins). IAU Symposium No 32 Item 2.3 pp 37-43
1970	European Geoid 1970
1971	The geoid in Europe and connecting countries. Trav.Ass.int.Géod. 24 pp 357-71 and addendum
1981	Geodetic surveys in India 1930-5. Sur. Rev. 200 April. 65-78

Banner image is Oliver Bomford's signature and seal on document M 6403/35 in the National Archives of Ireland, photo by Bill Riley, reproduced with kind permission of the National Archives of Ireland