EXHIBITIONS.—Sketches in Burmah, Punjab, Himalayas, and Kashmir, by Captain H. H. Godwin Austen, F.R.G.S.; Sketches of the Scenery, &c., on the Zambesi, by Thomas Baines, Esq., F.R.G.S.; Photographs of Ancient Hindoo Temples, by W. H. Purdon, Esq., F.R.G.S.; Sonnenstern's Map of Central America, &c., were exhibited.

The Papers read were:—

1. *Sun Signals for the Use of Travellers* (*Hand Heliostat*). By FRANCIS GALTON, Esq., F.R.G.S.

A PAPER was read by Mr. Galton in 1858 before the British Association on the principle, explained by a rough wooden model, of the instrument which is the subject of his present communication, but which, in the interim, has been considerably modified and improved. Many matters connected with its use and application have been more thoroughly worked out. The following is an abstract of that part of the paper which bears more immediately on the construction of the hand heliostat. Instruments made for the author by Messrs. Troughton and Simms, were laid on the table.

The principle of the instrument may be shortly recapitulated as follows:—The fact is a well known one, that if a looking glass be held in such a manner that a distant observer can see a portion of the sun's disc reflected in it, it assumes the appearance of a brilliant star, and can be seen at extraordinary distances. Many endeavours have been made, with various success, to utilise this remarkable power for the purpose of telegraphs,—the signals being distinguished by different combinations of flashes,—but no instrument has hitherto been contrived that admits of being carried on the person, held in the hand, and used at will. From experiments detailed by the author, it appears that a mirror whose rays are obstructed by a screen having an aperture of only $\frac{1}{8}$ of an inch in the side, is visible to the naked eye at a distance of ten miles, *if the background be dull and the air perfectly clear*. In other words, a mirror is visible, under those circumstances, if its effective area is a square whose sides subtend one tenth of a second of a degree in angular measurement. But, in practice, some allowance has usually to be made for the opacity of the air traversed by the rays, and a simple formula helps us to collate experiments, made under different circumstances of distance and fine weather. It is necessary in each particular case to make the best estimate possible of the extreme distance which any reflected solar rays could possibly traverse; call this $d$ (the distance at which high lands cease to be visible at the time of experiment gives a good clue towards estimating $d$). Let $x$, less than $d$, be the distance of the signaller. Then, on a perfectly clear day, the side of the effective area of the mirror must subtend

$$x \,.\, \sin. \frac{1''}{10}; \text{ but, on a hazy one, } x \,.\, \sin. \frac{1''}{10} \cdot \sqrt{\frac{d}{d-x}}.$$



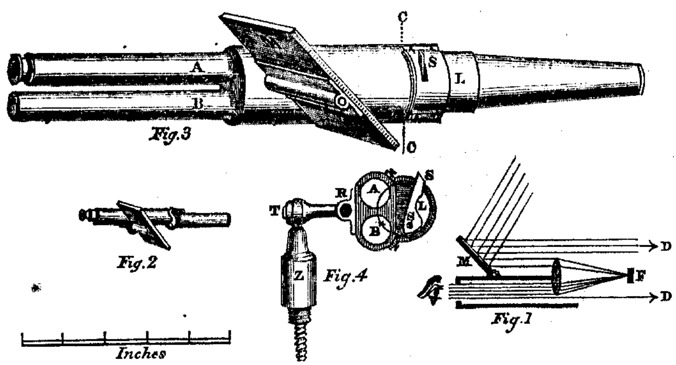
In most cases, a still further increase of size becomes necessary, because the landscape that forms a background to the station of the signaller, when seen through a mass of luminous haze, ceases to be of its natural dull colour, and may assume an appearance, nearly as bright as that of the sky itself.

The degree of brilliancy of the sun above head, has not much influence on the visibility of the flash—for the brighter the day, the more luminous the landscape, and the contrast between the flash and the surrounding tints is but little affected.

It follows from all this,—though we have no space in this abstract to enter into the details,—that a mirror of a few square inches in size, even though considerably inclined, is amply sufficient not only to be seen for distances far exceeding those ever used in ordinary telegraphy, but, also, to attract attention through the brilliancy of its flashes, whenever the high land, distant ship, &c., where the signaller may be standing, is itself, even dimly, visible.

The difficulty is to direct the flash aright, for, as the rays of the sun are reflected from a mirror in a cone precisely similar to that which reaches it, the mirror itself (whose size may be disregarded) being the apex of the cone and the sun's disc its base, it follows that, to the signaller, whose eye is near the mirror, the place where the cone of reflected rays falls on the distant landscape would always appear to him as a disc of simply the same shape and size as the sun itself. In the author's heliostat, an image of the sun is produced, which precisely overlays the area on which the flash of the mirror falls. It is contrived on the following principle. Fig. 1 is a tube with a lens across one of its ends to whose true solar focus a screen of white paper, F, is adjusted; a mirror, M, turns on an axle attached to the tube, which allows it movement in one direction, while the rotation of the entire instrument in the hand gives movement in the other. When the mirror is so adjusted that the reflected (parallel) rays from any one point of the sun's disc impinge on the lens, they are brought by its means to a focus on the screen, and form a minute speck of light. Rays radiate from this in all directions, and those that strike the lower end of the lens are reduced, by its means, back again to parallelism with the rays that originally left the mirror. Consequently an eye, looking down the tube, sees a bright speck of light on the lens, which it refers to the *same* distant point, D, in the landscape seen to the side of it, as that to which the unobstructed rays from the mirror are being flashed. If a telescope be used, the white spot actually appears to overlay the distant point. Now what is true for any one point in the sun's disc is true for every point: therefore the signaller sees a luminous disc, and not a mere point, in the field of view of the instrument, and this exactly overlays the *locus* of the flash. By gently rotating the hand, the image can be made to cover or to forsake any given object that may be desired, and, when that is done, the rays of the mirror will produce an appearance of flashes, as seen from that object.

Very small instruments, of great efficiency, can be made as in Fig. 2. Their tubes should pull out to not less than 4 inches, or it will be difficult to make signals when the sun is low and behind the back, on account of the shadow of the head.




A much more perfect instrument is shown in Fig. 3. (Fig. 4 is a section of Fig. 3 through CC.) The lower tube B is a plain tube, and simply used as a "finder;" the upper tube, A, is a theodolite telescope, and affords means of signalling with the utmost precision. When the sun's image covers the distant station at the time that the latter is seen at X in the plain tube, then, on looking through the telescope above it, the sun's image will be found to overlay the object, whenever the latter is brought into the field of view. The adjustment, by which this result is ensured, is by drilling the eye hole of the plain tube so that a line passing through it and through X shall be parallel to the axis of the telescope. By pushing the slide, S, backwards or forwards, the quantity of light that can reach the lens is regulated at will, and the image of the sun can be toned down to any required shade. A little practice with the instrument makes it exceedingly easy to bring the image of the sun on to the field of view in the first instance. It is done by grasping



the instrument with the left hand across its middle in such a way as to leave a finger and thumb free to move the mirror. Next, holding the right hand, as a screen, against the end of the instrument, the latter is raised nearly to the eye and directed as justly as possible towards the object aimed at. Then, rotating the whole instrument with the hand and moving the mirror backwards and forwards with the fingers, the flash is watched, until it is seen to fall upon the palm of the right hand. Finally, the instrument is rotated carefully, and the mirror gently moved, until the flash falls as full and fairly on the hand as it is possible to direct it: when this is the case, on raising the tube to the eye, the image of the sun is almost sure to be caught on its field. The instrument is fully as easy to work with as a sextant. Without stirring the mirror, there is power of flashing to any desired point within a large area, by slightly rotating the instrument and following the image; also by making contact in different parts of the field of view. Rapid, passing flashes are barely visible, for the mirror must be held steadily during an appreciable time in order to be seen to full advantage.

The heliostat can be mounted on a rest, which may screw at will, either into any piece of wood or into the top of a photograph tripod stand, as shown in Fig. 4. For long continued signalling, a stand is undoubtedly convenient. R gives ample rotatory movement; T allows a sufficient movement in altitude, and Z complete movement in azimuth. No counterpoises are needed for an instrument of ordinary size. The looking glass used for the mirror must have its sides truly parallel. It may have a narrow rim of silvering removed all the way from round its edge, and be cemented on to the top of a shallow glass tray. In this way the silvering is hermetically sealed from danger; and if the common *diamond cement* be employed, no heat or ill usage can separate them.

The instrument may be used simply to attract attention at great distances or to convey a few simple signals, as single flashes for affirmation, doublets for negation, and so forth: for this purpose the small instrument Fig. 2 would fully suffice, or letters and words can be signalled by adopting the well-known notation of Morse's electric telegraph. It is necessary, before beginning, to have some vague general idea where the intended correspondent is situated, then to sweep the distant landscape with the flash, and await his answer. As soon as this has been made, communication can be carried on as long as may be desired. A long line of horizon can be swept, backwards and forwards, with perfect ease, and it is found to be just as easy to attract the attention of a correspondent, whose position is unknown, to 5 or 10 degrees, as when it has been ascertained with perfect accuracy. Where a considerable depth, as well as breadth, of landscape has to be searched, the operation is more tedious. The landscape must be swept in closely parallel bands.

This instrument is of course useless without sunshine, and is intended chiefly for those lands and seasons where sunshine is the rule and not the exception. It is believed that it would be of constant service to a traveller in them. It requires no sky line, as all other signals do, to bring it out into relief, but can be used from any spot where the sun's rays reach it. It works in perfect secrecy to all except those near the line of flash. Its power is enormous as regards the distances across which it can communicate; and lastly, its portability is extreme. Fig. 2 can literally be carried in the waistcoat pocket, and can make a signal visible to the naked eye, under very adverse circumstances of haze and position of the sun, at a distance of 5 or 10 miles. Instruments such as Fig. 3 would probably be of great service to two or three travellers engaged in triangulating a country, or to land parties communicating with a ship.

Sir R. I. Murchison said they were much indebted to Mr. Galton for calling the attention of the Society to this subject. Doubtless many of those who were then assembled may be more gratified by descriptions of foreign travel; but the Society could not be too thankful to those who, from time to time, refer back to the elements of the science and bring to its notice the consideration of instruments of real value to the explorer.

Sir Edward Belcher, F.R.G.S., regretted that General Portlock or Colonel James were not present to speak more decidedly on the use of the heliostadt during the Trigonometrical Survey of Great Britain. But in the year 1835, when he was engaged in the connection of the two surveys of Great Britain and Ireland, for the object of completing the Hydrographic Survey of the Irish Seas, he was informed, as the documents also witnessed, that one shot was obtained from Slieve Donard, in Ireland, to Scawfell, in Cumberland, and *vice versâ*, a distance exceeding 108 miles, and that it was effected by heliostadts, requiring fourteen days' close watching at each station where the parties were encamped.

In the year 1833 a complete set of instruments were supplied to him in order to connect the vessel stationed, and moored in position, on the Skerki Reef, with the positions on shore, at Zembra at the mouth of the Bay of Tunis, and Maritimo on the coast of Sicily; but owing to the motion of the vessel, as well, probably, to defect in directing the flash truly, from the height to an object not visible, it did not prove successful.

He considered under such circumstances—that is, seeking for a flash at very great distances beyond the limit of common vision, unless the calculations of the two positions approximated *very closely* to the truth—that great difficulty would be experienced, and unless the reflecting plates were very perfect and truly fixed with relation to the directing telescopes, success could not be hoped for at such great distances.

He had himself witnessed the effects of the heliostadt used in connection with the survey of the country surrounding St. Paul's, and in particular one distant 40 miles: as seen from the station above the cross of St. Paul's, the object was intensely luminous, too much so to be observed with the precision required, as it occupied the whole system of wires.



In the case of the Irish and English survey, as he before remarked, they were fourteen days intensely occupied in obtaining simultaneous observations, and he believed it resulted only from their very perfect calculations that they were enabled so truly to direct their telescopes and eventually succeed.

Mr. T. Maclear, F.R.G.S., Astronomer Royal at the Cape, was convinced from experiments which had been made at the Cape of Good Hope, that with a five or six inch screen, from 120 to 200 miles a glass might be seen as a star of the fourth or fifth magnitude, through a small telescope. They had very successfully employed signals at a distance of 25 miles.

Mr. Galton remarked, in answer to Sir E. Belcher, that the difficulty of aim was altogether independent of the distance, and that, with his own hand-instrument, the horizon could be swept, and a correspondent sought out, with the utmost facility, as he himself had continual occasion of experiencing. But, on the other hand, without some optical contrivance for knowing accurately where the flash was being sent, it was extremely improbable that the small cone of rays which proceeded from the mirror should be thrown in the desired direction, and still more so, that it should be made to cover the distant station for a sufficient length of time to be properly visible.

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The second Paper read was:—

## 2. *Latest Accounts from* Dr. Livingstone, F.R.G.S., *of the Central African Expedition.*

The numerous papers received from Dr. Livingstone refer to two main points: the one the navigability of the Zambesi, and the other the capabilities of the valley of its affluent, the Shiré, and those of the Shirwa lake, which adjoins it.

The Zambesi has been examined five times over from between Tete to the sea, and Dr. Livingstone's conclusion is, *firstly*, that a navigable entrance has been determined by Captain Berkeley, of H.M.S. *Lynx*, up the Luabo, and by himself up the Kongone. *Secondly*, that a large vessel could be taken up to Tete at any time between January and April. (This is the unhealthy time of the year; but the Zambesi fever has hitherto appeared a far less formidable illness than was feared.) *Thirdly*, that in a season of unusual drought there were found to be only three crossings, from one deep channel to another, over which his little steamer had to be dragged. These were from 24 to 18 inches deep, and from 100 to 150 feet long. The force of the current of the river averages 2½ knots, but never exceeds 4; and Dr. Livingstone considers that a vessel, literally drawing no more than 1½ feet water, could ply at all seasons for the first 300 miles of the Zambesi.

Above Tete the case is different. The long rapids of Kebra-brasa commence 30 miles from that town. They were visited by Dr. Livingstone when the river was still at its lowest, and he describes the appearance of the first part of them as follows:—The river was