

recent years ascended with the modern breed of high angle climbers on their steep walls—may also increasingly take to silent flight. Sky-sailing on mountain waves, their poet might be the airman who gave us these images:<sup>1</sup>

‘Oh, I have slipped the surly bonds of earth, and soared aloft on laughter-silvered wings . . . Sunward I’ve climbed and joined the tumbling mirth of sun-split clouds . . . and chased the shouting wind along . . . through footless halls of air. Up, up the long delirious burning blue, I’ve topped the windswept heights with easy grace . . . wheeled and soared and swung, high in the sunlit silence there’.

(To be concluded)

## Satellite pictures of mountains

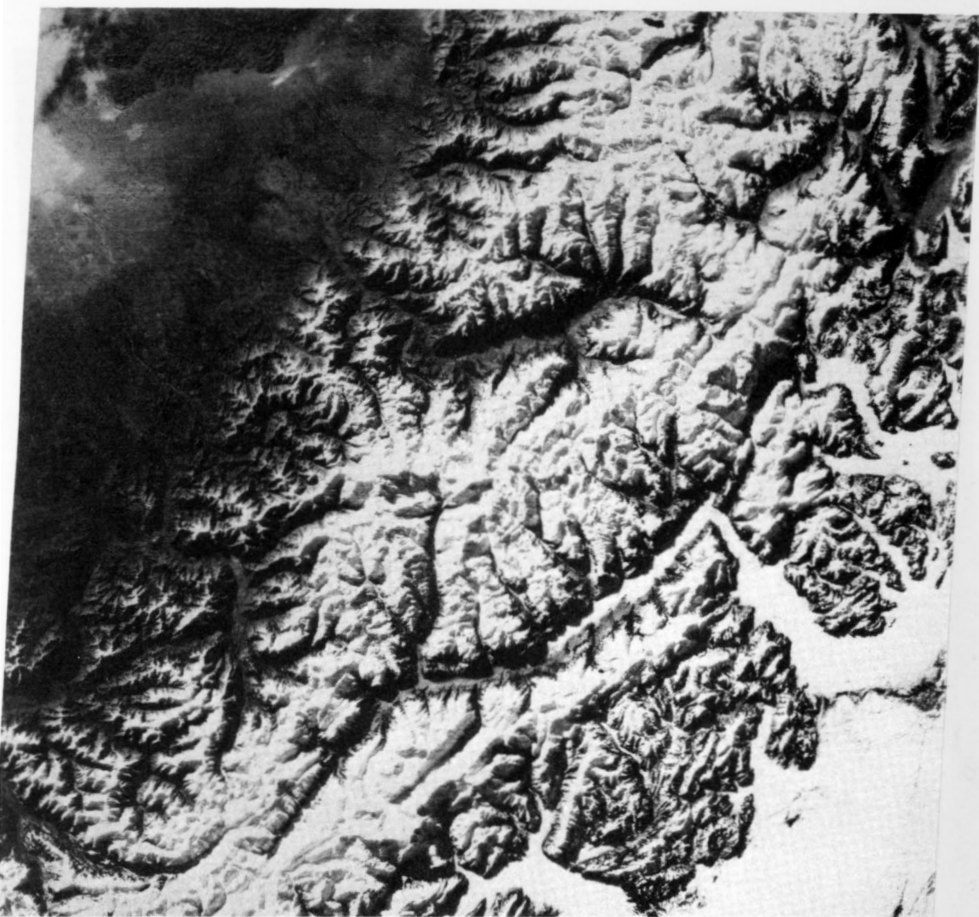
George Bridge

For some years now civilian satellites operated by NASA have been taking pictures of the Earth’s surface. These pictures, along with other data and services, are available from EROS Data Center (EDC) and its branch offices in the US. (EROS = Earth Resources Observation Systems.) The pictures offer virtually complete coverage of the world’s land surface and some adjacent sea areas at a map scale of 1 : 250,000; that is, about  $\frac{1}{4}$  inch to one mile. Only about 20% of the world has been adequately mapped by traditional methods at scales better than this, and indeed it may be doubted whether orthodox mapping will ever attempt such a coverage. One thinks of Shipton’s celebrated expedition to unravel the topography of the River Shaksgam in the Karakoram. On and off and in more ways than one this problem exercised geographers for over 20 years. Satellite photography solves this kind of problem in vastly greater detail in just 20 seconds!

Satellites in the LANDSAT programme circle the Earth in a polar orbit at an altitude of  $920\text{km} \pm 10\text{km}$ , scanning the ground along a path approximately NNE to SSW on each orbit. Each path overlaps its neighbours by 15% at the equator, increasing to 50%, at about  $52^\circ$ , and about 85% overlap at the extreme limits of the path,  $81^\circ$  N and S. The stream of data from each path is processed to give pictures (‘images’ in NASA terminology) with 10% forward overlap. Each image corresponds to a ground ‘scene’ 165km (103 miles) on a side, the slight lozenge shape being caused by a combination of the Earth’s rotation, and the forward motion and any ‘yaw’ or off-axis swing the spacecraft may have.

Two satellites, LANDSAT 1 and 2, are currently functioning, every point in the coverage zones being traversed once every 9 days on the daylight pass. The time of crossing the equator on each daylight pass is 9.30am. In the autumn of 1977 a third craft, LANDSAT C, was planned to join the programme, the orbits being re-arranged to provide 6-day coverage. The paths are numbered from E to W beginning with one just skirting Newfoundland on the E. Similarly each scene is given a number from ‘NNE’ to ‘SSW’. These two figures, for path and row, form a world reference system to EDC’s rapidly accumulating collection of images which must already number well over 7 million.

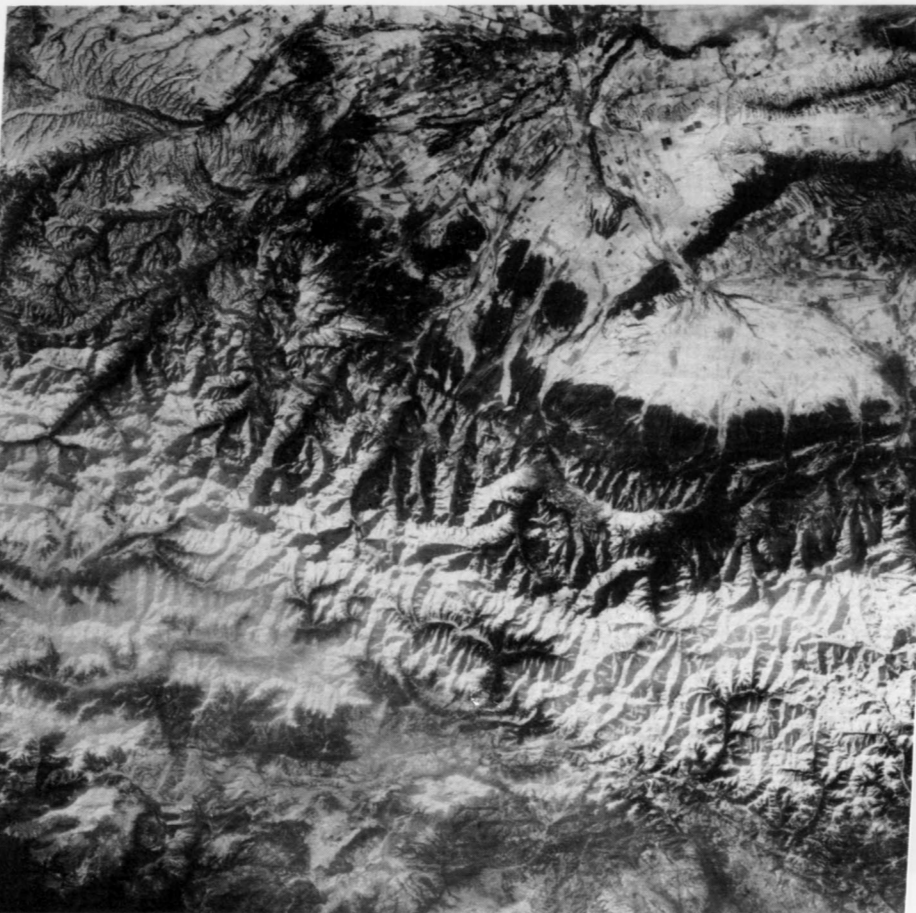
<sup>1</sup> These lines are a slight re-arrangement from *High Flight* by John G. Magee, Jr, American pilot officer in the RCAF killed at 19, over England, 11 December 1941.



*9 Western Alps. The Matterhorn is almost at the exact centre of the picture. Just below it, the very obvious Val d'Aosta leads left to Courmayeur; Chamonix is just inside the deep shadow of Mont Blanc. The long valley in the upper half of the picture is that of the R Rhône. The Jungfrau, Eiger and Wetterhorn are at the top. Id: 811 490 950 45G 000; date 19/12/1972. (This and next five photos: NASA by courtesy of George Bridge)*

The satellite sensors operate in 4 bands of the spectrum. **Band 4** (green, 0.5 to 0.6 $\mu\text{m}$ ) is the best for shallow water detail. **Band 5** (red, 0.6 to 0.7 $\mu\text{m}$ ) is the best for general topographical views, field pattern and urban zoning. Disturbed ground, eg building sites, shows up very well. **Bands 6 & 7** (near infrared, 0.7 to 0.8 to 1.1 $\mu\text{m}$ ) are excellent for haze penetration and show landforms and vegetation well and may also offer the best discrimination for rivers and roads.

Images in any of the 4 bands are available as a matter of routine. Selected images have also been combined to provide 'False-Color Composites' (FCCs); that is, coloured images using Bands 4, 5 and either 6 or 7 to produce a result approximating to the effect of using Kodak Colour Infrared film. In these FCCs, vegetation appears as varieties of orange, red or pink depending on the plant species, shallow water appears pale blue, deep water black and urban areas a



*10 Central Caucasus. Dykh Tau is just left of centre; Kasbek far right. Note the huge size of Russian fields, many of them more than a mile square. ID: 815 190 719 15A 000; date 24/12/1973*

different pale blue. FCCs have usually been produced in response to customer requests.

Satellite pictures are easy to 'read' but like air photographs they are most rewarding to those who are willing to spend a little time in interpretation. Some local knowledge of the ground is invaluable. Serious problems are cloud and snow cover and haze and dust in the atmosphere at the time of data acquisition.

The people to write to for satellite pictures are: User Services Unit, EROS Data Center, Sioux Falls, South Dakota, 57198, USA.

You can order any particular image if you know its ID number; otherwise you can ask what coverage is available for a given path/row; or you can specify your area of interest by latitude and longitude, or failing all else by a sketch map. In all but the first of these you will receive a computer printout listing the imagery

available. The entry for each image will tell you what image quality and cloud cover to expect, and the date of acquisition and whether false-color composites are available. And also, if you originally asked for this, what Skylab and other spacecraft imagery there might be.

When ordering imagery it is necessary to quote the ID number, Band number selected by you, and the Product Code.



*11 Karakoram. K-2 can be seen just below left centre, above the head of the enormous Baltoro glacier. Siachen glacier very obvious running to the right. Other mountains in this picture include Broad Peak, the Gasherbrums, Masherbrum and Chogolisa. The big river crossing the top of the picture is the Yarkand. ID: 811 160 501 15A 000; date 16/11/1972.*



*12 Eastern Nepal. Mount Everest, Cho Uyo, Gauri Sankar and many other peaks are clustered together in the top right hand corner. Kathmandu is left centre. The plains of India begin at the bottom of the picture. ID: 811 980 417 45A 000; date 6/2/1973*

At the time of writing prices, post-free anywhere in the world, are:

Black & White			FCC <sup>1</sup>		
Image size	Scale	Product Code	Price	Product Code	Price
185mm	1 M	23	\$ 8	63	\$12
371 mm	$\frac{1}{2}$ M	24	12	64	25
742 mm	$\frac{1}{4}$ M	26	20	66	50

<sup>1</sup> Where False-color Composites already exist. For the production of new FCCs from existing images, an additional one-time fee of \$50 is charged. Positive film images in both black and white and FCC are available. The FCC ones are \$15, Product Code 53, size 185mm.

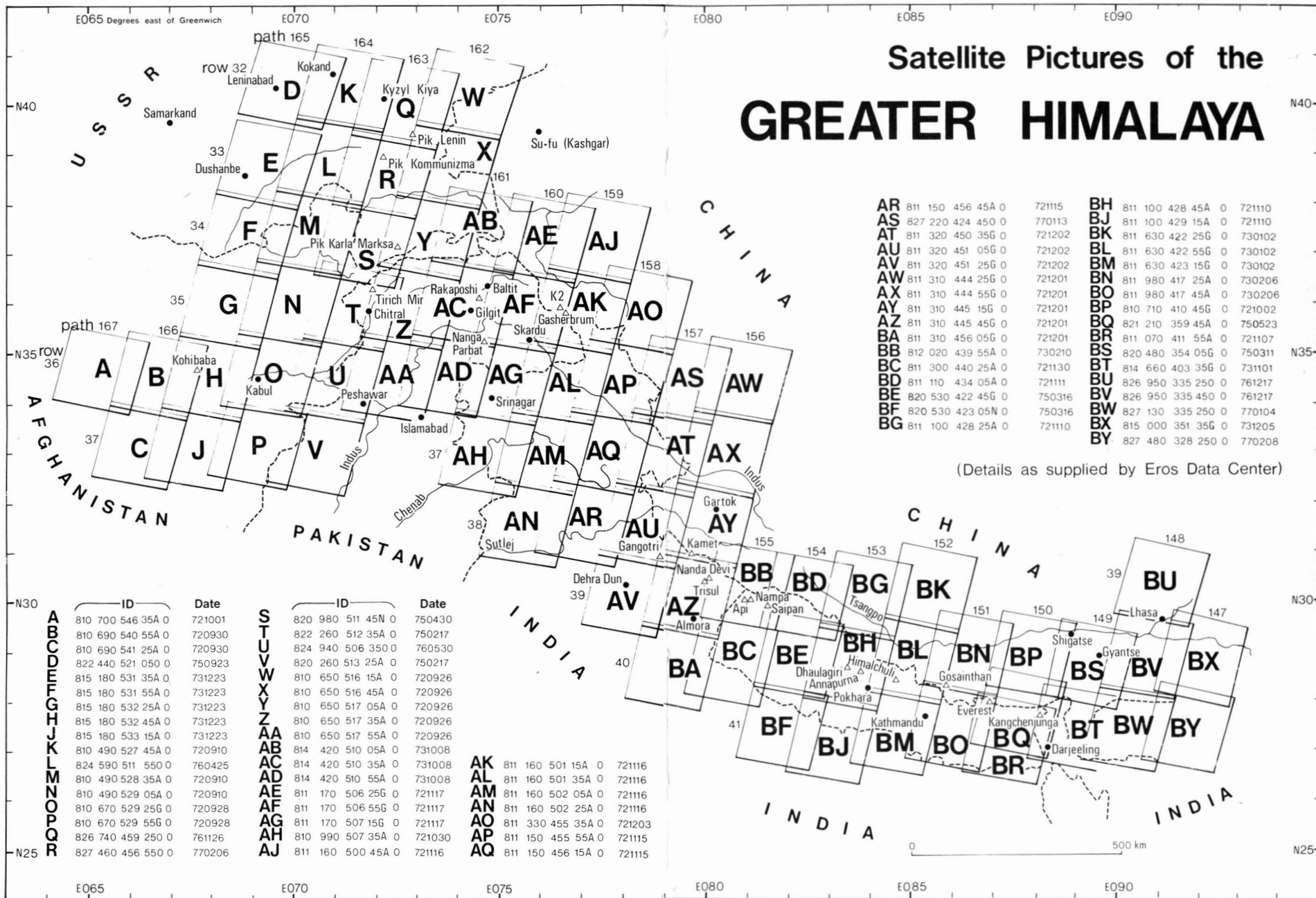


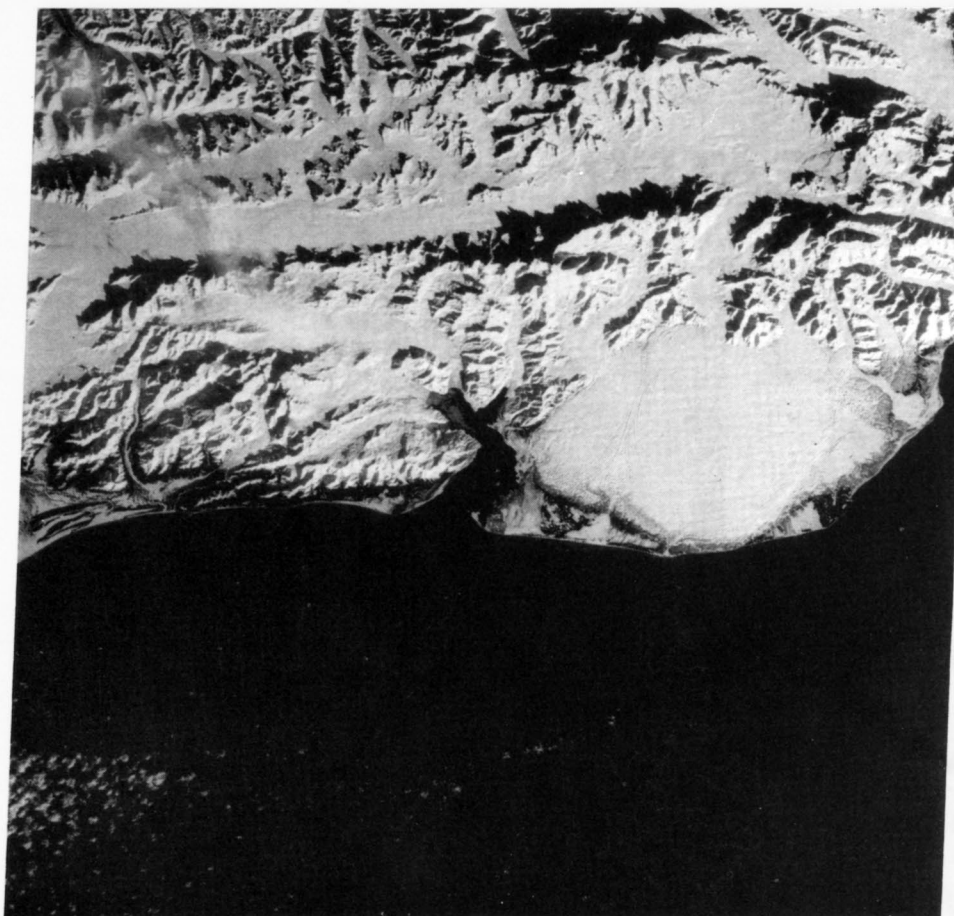
13 Central Alaska. Mount McKinley (Denali) is pin-pointed by its enormous shadow in top right-hand corner. ID: 818 252 050 55A 000; date 26/10/1974

The pictures illustrating this article and indexed in the map were acquired by the National Aeronautics and Space Administration.

A magnificent picture book of satellite images is available: *Mission to Earth: Landsat views the World* by Drs Short, Lowman, Freden and Finch. Supt. of Documents, US Government Printing Office, Washington, D.C., 20402, USA. \$14. Serious users of LANDSAT imagery will want to refer to: *Data Users Handbook*. General Electric Company, Space Division, Attn: Bruce Rogers, 5030 Herzel Place, Beltsville, Maryland, 20705, USA. Price \$10 p.f.

For satellite pictures taken on extra-terrestrial missions, eg images of other planets, contact NASA direct: National Aeronautics and Space Administration, Goddard Space Flight Center, Greenbelt, Maryland, 20771, USA.





14 South-East Alaska. Mounts St Elias and Logan in the upper half of the picture. Notice the enormous avalanche track on the ice field just south of mount St Elias. It measures 22 miles long by about 5 miles wide and was probably triggered by an earthquake. ID: 812 042 012 05A 000; date 12/2/1973  
The scale of the maps reproduced here is 1.5M (1cm = 15km)