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METRIC REMOTE SENSING EXPERIMENTS IN PREPARATION FOR SPACELAB FLIGHTS

G. Galibert

Translation of "Expériences de télédétection métrique dans les Alpes en vue des vols Spacelab", Revue de Geographie Alpine, Vol. 66, No. 1, 1978, pp. 43-63

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METRIC REMOTE SENSING EXPERIMENTS IN PREPARATION FOR SPACELAB FLIGHTS /43*

G. Galibert

SUMMARY:

Preparations for the first Spacelab Experiments aboard the NASA Space Shuttle that will overfly the Alps between 4 and 11 December 1980 with a metric camera aboard led us to conduct photographic experiments in the Western Alps for the purpose of obtaining photographic plates usable for both remote sensing itself and stereophotogrammetry.

In particular, we made aerial and ground photographs of the Zinal Mountain (Overgabelhorn, Blanc de Moming, Zinalrothorn) in the Swiss county of Wallis, and of the Dolomite Alps of Cortina d'Ampezzo (Tre Cime di Lavaredo), using spectrozonal film such as Kodak SO 410 or the standard Ektachrome Infrared and multichannel optical filters.

These techniques are compatible with the specifications of the European Space Agency, Spacelab project manager, and of NASA, owner of the Space Shuttle, which provide for a ground resolution better than 20 meters for stereoscopic photographs taken at one thousandth of a second at a scale of 1/820,000, taking into account a speed relative to the ground of 7755.75 meters/second. Many shapes that make up the relief of high alpine mountains and most snow and ice phenomenon enter into the range of investigations of the first industrial experiment in space cartography.

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16. Abstract

Our experiments of spectrozonal stereophotogrammetry in the Western Alps are related to Spacelab program using a metric camera in the perspective of the first Spacelab flight aboard of NASA Space Shuttle, which will over fly the Alps between 4th and 11th December 1980. We made aerial and ground photographs of Wallis mountains and of Dolomiti di Cortina d'Ampezzo in Italy, using spectrozonal emulsions and optical multichannels filters.

These technics are compatible with European Space Agency and NASA specifications owners respectively of Spacelab and Space Shuttle: final ground resolution better than 20 meters, with exposure speeds of 1/1000 second at the scale of 1/820.000 on the film, in spite of a ground motion of 7.755,75 meters per second.

In that way, several elementary forms of alpine geomorphology and ice— or snow phenomena will be detectable on metric scenes of this first industrial survey from space.

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The installation of a metric camera aboard the removable European "Spacelab" laboratory to be carried aboard the NASA Space Shuttle probably opens new possibilities in the field of combined remote-sensing and cartography of mountains, using photographic means. Indeed, the "Massif des Ecrins", the Haute-Ubaye, Styria and the Eastern Pyrenees will be overflown during the first Spacelab flight (eleventh flight of the Space Shuttle) planned for 4 December 1980 by NASA. Other Space Shuttle flights will bring the Spacelab above the Central Alps at a later date. The object of this /44
study is to report on research in which we are involved through the European Space Agency, Spacelab project manager , with a view toward successful testing of new equipment as new as this [1]. We will recall at this time that the Spacelab prime contractor is the German consortium ERNO assisted by the French company Matra.

We thus have the opportunity to propose several applications for remote-sensing photographic techniques that we recently revealed in this magazine[2] to assist in the development of this new area in geography,"Earth Observation from Space".

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[1] European Space Agency letter dated 26 July 1977: "Use of a Metric Camera on First Spacelab Flight, July 15th 1980". Annex 1 through 4. We can refer to an article in Interavia magazine, author unnamed: "The American Space Shuttle", Interavia, 12, 1976, pp. 1170-1171.

[2] G. Galibert. "The application of Two-Color Remote Sensing Process to Mountains". Revue de Géographie Alpine (Alpine Geography Magazine), LXIV. 1976, pp. 155-165. From the same author: "Very-Low Altitude Aerial Photography Applied to Coastline Ecology and Geotechnology". Bulletin of the French Society for Photogrammetry #61, 1976, pp. 5-13.

1. POSSIBILITIES OFFERED BY SPACELAB IN THE AREA OF COMBINED DIGITAL MAPPING AND PHOTOGRAPHIC REMOTE-SENSING. /45

A) Orbital Parameters of the Space Shuttle and of Spacelab During an Earth Observation Experiment.

Technical data officially provided to us on 26 June 1977 by NASA and the European Space Agency when these agencies were consulting us in the area of photographic technology reveal that stereophotogrammetry experiments will be performed during Space Shuttle Flight 11 during which the Spacelab will be aboard. Originally planned for 15 July 1980, this flight has been postponed to 4 December 1980 because of the need to place in orbit, using the same Space Shuttle, two data-transmitting satellites before this. The type of equipment integrated into the Spacelab makes it possible to have metric remote-sensing similar to that commonly in use from aircraft or ground observation stations.

We will recall on this point that the five Space Shuttles being built or under test are planned to be reused one hundred times each in order to perform a total of five hundred space flights, spaced a minimum of two weeks apart.

The flight program originally planned for 15 July 1980 seems to be, under these conditions, a typical program suitable for a boreal summer. The schedule of the mission planned for 4 December 1980 will differ slightly from this typical program to take into account the differences in the amount of sunlight between the Northern and Southern hemispheres at that time of the year.

Typical Boreal Summer Program (Basic Program for a Spacelab Flight Dedicated to "Earth Observation" from Above the Northern Hemisphere).

Launch Time (information likely to be modified slightly): 9 hours (UMT). This is "H-Hour" from which all times for this Spacelab flight will be measured.

Orbit: circular, maintained at 6628.95 kilometers from the center of the earth. The maximum deviations from this value will have to be less than 5 kilometers.

Inclination of the orbit: 57° relative to the equatorial plane. /46

Speed of the Space Shuttle relative to the ground: 7755.75 meters/second.

Time of orbital injection: H + 0.713 hour

Geographic coordinates of the ground trace for the Space Shuttle trajectory 24 hours after launch:

39.15° North, 74.87° West.

This Spacelab flight is to last 165 hours during which the Space Shuttle will operate at 250 kilometers above sea level. Stereoscopic picture-taking will be possible between 0° and 57° of latitude North, lasting a total of 64 hours, divided into two periods lasting 52 and 12 hours, respectively. Orbital revolutions #18, 49 and 50 will be of particular interest to mountain geography. Spacelab will fly over La Grave and Larche Pass (Col de Larche) during orbit #18, Mariazell in Austria during orbit #49, and Cadaquès in the Spanish Eastern Pyrenees during orbit #50.

Incidence Angle of Sun Rays Relative to Horizontal Ground:

Orbital Revolution Number	Location	Incidence of Solar Rays
18	Oisans	48°
50	Eastern Pyrenees	40°

The high spacecraft speed relative to the ground, 27920.7 kilometers/hour, should not create any major obstacle to the use of a modern metric camera equipped with a shutter operating at 1/1000 of a second.

B) Characteristics of the Zeiss (Oberkochen) Metric Camera Selected for the first Spacelab Flight.

A standard Carl Zeiss, Oberkochen (F.R.G.), Type RMK A30/23, metric camera is to be carried aboard the Spacelab for this flight and integrated to all systems. It will be equipped with a Zeiss "Topar" lens with a 305 mm focal length and a shutter with three speeds: 1/1000, 1/500 and 1/250 of a second, aperture to 5.6. Format size covered: 23 x 23 cm.

Picture characteristics will be the following over the entire field when pictures of fixed objects are taken at 1/1000 of a second with a 5.6 f-stop: /47

Resolution of the photograph: 40 pairs of white and black lines per millimeter when photographing a 1000/I target, using Aviphot Pan 30E film with an ASA speed of 125 when developed with "Perufin".

Maximum "smear" on photographs taken from Spacelab at 1/1000 second: 8 meters.

Final ground resolution: better than 20 meters with film separating 130 black and white lines per millimeter with a 1000/I target, providing contrast differences of at least 4%.

Geometric Distortion: a maximum of 5 microns on the photograph.

Overlap: 60 or 80^{o} as desired by the user.

Photograph Scale: 1:820,000 at the center of the frame.

Ground Surface Covered: 188.5 x 188.5 km.

Minimum Interval Between Two Frames: 2 seconds.

We will also recall that the Spacelab Project is financed at 52% by the German Federal Republic and at 10% by France. The directorship of the project has been entrusted by the European Space Agency to the "Deutsche Forschungs und Versuchanstalt Für Luft und Raumfahrt" (D.F.V.L.R.), the equivalent of the "Centre National d'Etudes Spatiales" (C.N.E.S.). This operation will not take place aboard the Spacelab at the same time as the operation of a high-frequency scatterometer and of side-looking radar. It is possible that different photographic equipment will be carried aboard Spacelab in later flights[3].

C) Capabilities Provided by the Zeiss RMK A30/23 Camera in the Area of Digital Map-Making and Photographic Remote-Sensing.

Number-coding contours and colors on photographs is made indispensable by the enormous quantity of data collected from space, such that only automatic data processing can extract the desired data.

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3 We will refer to "Summaries of the Symposium on the Utilization of Artificial Satellites for Remote-Sensing". Group for the Development of Aerospace Remote-Sensing. National Geographic Institute. Paris-Saint-Mandé, 21-23 September 1977. W. Alpers; "The 2 Frequency Scatterometer for Measuring Ocean Wave Spectra from a Satellite", pp. 44-45.

F.W. Leberl; "Mapping with Satellite Radar", p.50.

Color can be coded in a coordinate system and in three-color diagrams. /48

We know that the visual appearance of the complex coloring Z of an object illuminated with a light source with a color temperature K can be re-created by mixing the proper proportions of monochromatic color radiations z_1, z_2, and z_3 selected arbitrarily. This principle is the basis for color television.

Given:

Z: complex color radiation; for example, the apparent coloring of an object.

(z_1), (z_2) and (z_3); the energy levels-expressed as a percentage of radiation Z- of the three monochromatic radiations, arbitrarily selected, for example, a blue (483 nm), a green (546nm) and a red (633nm).

We have $(z_1) + (z_2) + (z_3) = 100$ = a constant

$$z_1 = 100 - (z_2 + z_3)$$
$$z_2 = 100 - (z_1 + z_3)$$
$$z_3 = 100 - (z_1 + z_2)$$

Total Z being a constant, it is therefore sufficient to know the energy levels of two of the three monochromatic radiations considered in order to define the visual appearance of a complex color radiation: for example z_1 and z_3.

Letting $x = z_1$ and $y = z_3$, we will be able to plot in a system of planar rectangular coordinates, using a representative point P(x,y), the visual appearance of Z.

We will note in this regard that it is a color notation system rather than actual number-coding. The graphical representation of this notation in "colorimetric dimensions" is a "trichromatic diagram".

This operation is performed by installing a selective filter for the desired monochromatic radiation onto a densitometer. The trichromatic notation of a color is performed by making three series of measurements through three different color filters corresponding, for example, to blue (483 nm), green (546 nm) and red (633 nm). It can be performed by using a Joyce-Loebl densitometer commonly used by geographers on the condition that the 3 Wratten or Ilford filters manufactured for the three desired colors selected are installed successively.

Number-coding the contours of pictured objects consists of replacing a /50 line presentation with the compilation of planar rectangular coordinates of each point. It is not necessary to go through the stage of a drawn map in order to number-code the contours of an object that has been photographed and the contours broken-down into a large number of points[4].

We can number-code not only the contours of photographed objects but also of entire dark or light spots that make up a photographic image, that is to say, the optical density[5] of the frame at these same points. If it is a frame recorded on infrared film, we will have completed a number-coding of remote-sensing "signatures" (see Figure 1).

Smear, rather than the reading accuracy of densitometers and coordinate-generators, limits the accuracy of such measurements: the scanning distance of such instruments can be adjusted so as to reach 0.5 micron (Zeiss P05 automatic photometer microscope) while the positioning of frames onto the Matra Trater "stereo-recoverer" is of the same order.

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4 We will be able to consult the following large document: G. Reeves, A. Ansin, D. Landen; "Manual of Remote-Sensing". American Society of Photogrammetry; Falls Church, Virginia (U.S.A.), 1975.

5 Fralit Team, Directed by F. Verger; "Remote-Sensing the Ocean Shores of France". "Ecole Normale Supérieure", 48 Boulevard Jourdan, 75014, Paris; 1977.

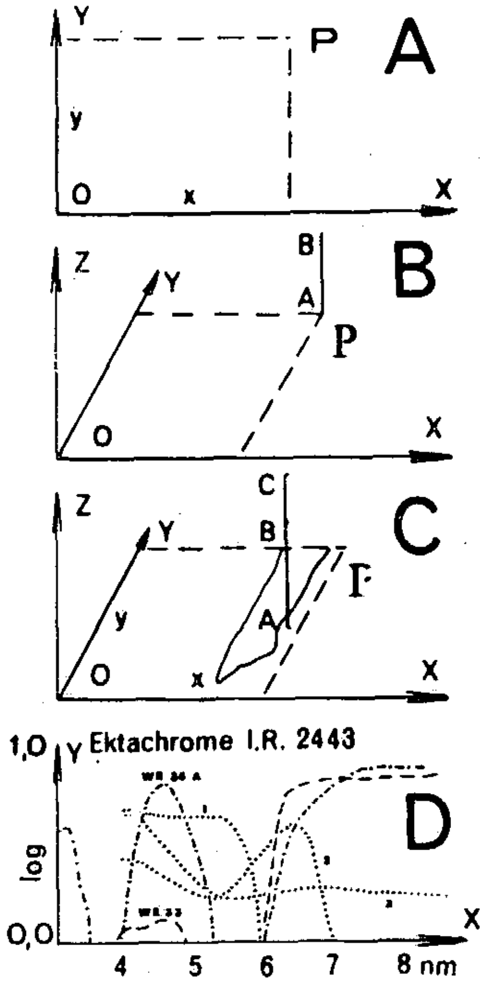

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Figure 1. Trichromatic Notation of Colors and Number-Coding the Outlines of Objects Photographed.

Figure A - Notation , on a trichromatic diagram, of the visual appearance of the coloring of an object illuminated by a light defined by its color temperature. $\vec{O}x$ and $\vec{O}y$ represent (x) and (y) respectively, coordinates of point P representative of the apparent coloring of an object photographed in natural color with lighting defined by its color temperature: for example, grass in a state of chlorophyll assimilation. P', P'' and P''' represent the coloring of the image of such an object on a picture made with Infrared Ektachrome fill (in false colors) using Wratten 12, 33 and 58 filters. Q', Q'' and Q''' represent the coloring of the picture of a puddle of water photographed under the same conditions.

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Caption to Figure 1, continued from page 9.

Multiband filtering (filters 33 and 58) differentiates to the maximum extent the calorimetric dimensions of the pictures of numerous objects on such spectrozonal film.

Figures B and C. - Graphical representation of the coding of color on a frame. The $\vec{AB}$ and $\vec{BC}$ vectors marked on the AC segment show the proportion of red and blue - of predetermined wavelength - that enters into the composition of the color radiation depicted for each point of the frame under study. The set of B points constitutes a representative color surface.

Figure D. - Selection of proper two-color filtering on Infrared Ektachrome 2236 Film (formerly 2443) through superposition of the spectral transmission curve of multiband filters and of the spectral sensitivity curve of photographic emulsion:

Wratten Filter 33 shown with a dashed line.

Wratten Filter 34A shown with dots and dashes.

End of Caption to Figure 1. Text is continued on page 11.

We will make note as a reminder that the sharpness of a contour of a photographic image can be improved-provided it is applied to blurring caused by camera motion- through data processing of the superposed images within the blur. The cost of such processing, currently at 35000 to 40000 francs for a 23 x 23 cm frame, limits the practical possibilities of applying such a process. The processing of 1500 stereoscopic frames likely to be recorded during the first Spacelab flight would reach a prohibitive cost level.

II. THE WESTERN ALPS SLOPES USED AS "TARGETS" FOR PHOTOGRAPHIC REMOTE SENSING IN PREPARATION FOR THE SPACELAB EXPERIMENT.

We have prepared for this Spacelab experiment by photographing, as examples, a certain number of rocky, snow and ice-covered, and grassy slopes[6] in the Western Alps (remote-sensing targets) by using photographic processes that we anticipate to be used aboard Spacelab. The overflight of the National Park of "Les Ecrins" being forbidden at low altitude, we were unable to photograph this area that is to be studied from Spacelab.

A) Grassy slopes of the Alpine Middle Mountains: /51
We have selected the slopes above the valley of the Chagne, around the Vars station (Hautes-Alpes Department) where we had previously performed research (see footnote 2). An altitude range of 1700 to 2300 meters was explored.

B) Wall and Crest Rocky Formations in the Alpine High Mountains:
Our work was mainly done in the Dolomite Alps of Cortina D'Ampezzo, particularly with regard to the faces and crests of the Cima Piccola and of the Spigolo Giallo di Laravedo, between 2500 and 2600 meters. The road to the Auronzo refuge (2405 meters) makes it possible to reach the foot of these features easily.

The gaps across the crests of such a mountain range, as well as the vast "slabs" characteristic of the faces, have dimensions greater than 20 meters, regardless of the mensuration method. Such "objects" therefore enter the possible investigation range of the Spacelab metric camera.

Only the micro-formations of these walls, created by the freeze process or by chemical change phenomena, cannot be photographed from space with a metric camera.

C) Rocky Formations and Ice-Snow Phenomena of Mixed or Iced Faces in Alpine High Mountains:

We have selected the north slopes of the Obergabelhorn and of the Blanc de Moming, in the Zinal cirque (Wallis canton, Switzerland) that we had the opportunity to fly over several times. The Zinalrothorn (4223 meters) and its Blanc de Moming spur, as well as the Obergabelhorn (4062 meters) can also be observed conveniently from the Besso belvedere (3667 meters).

Snow covers and ice apparatus of these mountains have dimensions greater than 20 meters in length or width. It is the same for rocky formations that make up the walls and the peaks. The white peak of the "Blanc de

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6 (page 11) A description of these faces, with conventional panoramic photographs are included in the following work:

G. Galibert, "The Alpine High Mountains", 1965; at the author's, 7 Rue de Vincennes, 35000 Rennes, page 129: Northern Face of the Obergabelhorn, p. 131: Western Face of the Weisshorn; p. 255: the Spigolo and the Cime di Lavaredo.

For the description of a few of the aspects of the water cycle in mountains:

J. Loup. "Terrestrial Waters", Masson & Co., Paris 1974.

R. Vivian. "Western Alps Glaciers", Allier, Grenoble, 1975.

Moming" is 780 meters long, its thickness at the base, at the level of the thick crevasses bordering the ice and snow covers at their lower end, is about 400 meters. Only small formations such as the gap located at 3877 meters on the southwestern crest of the Zinalrothorn have dimensions smaller than 20 meters and escape metric photography. /52

The half-grassy, half-rocky formations of middle mountains visible in this area, such as the grassy ledges and the corridors cutting into the slopes of the Roc de la Vache (Cow's Rock) (2581 meters) above Zinal have minimum dimensions similarly compatible with the ground resolution of the Zeiss RMK A23/30 metric camera.

It is therefore possible to prepare for the combined photogrammetry and remote-sensing experiment considered for this first Spacelab flight by using the above targets.

III. EXPLOITATION OF REMOTE SENSING PHOTOGRAPHS TAKEN IN PREPARATION FOR THE SPACELAB EXPERIMENT.

We have studied three sets of photographs relative to the capture, on a photographic document, of information pertaining to reliefs that make up overall formations characterized by unequal differences in their spectral reflectance.

A) An example of 'heptaphyres' made under conditions of "mono-reflectance": the rocky slopes of the Spigolo Giallo in the Cime de Lavaredo.

We speak of "mono-reflectance" when an object reflects mainly visible or invisible light radiations belonging to a single band of the solar spectrum. This is the case for the walls of dolomitic rocks in the Cime di Lavaredo that reflect mostly red and very little ultra-violet, blue, green or infrared.

By making 'heptaphyres', we can use this property.

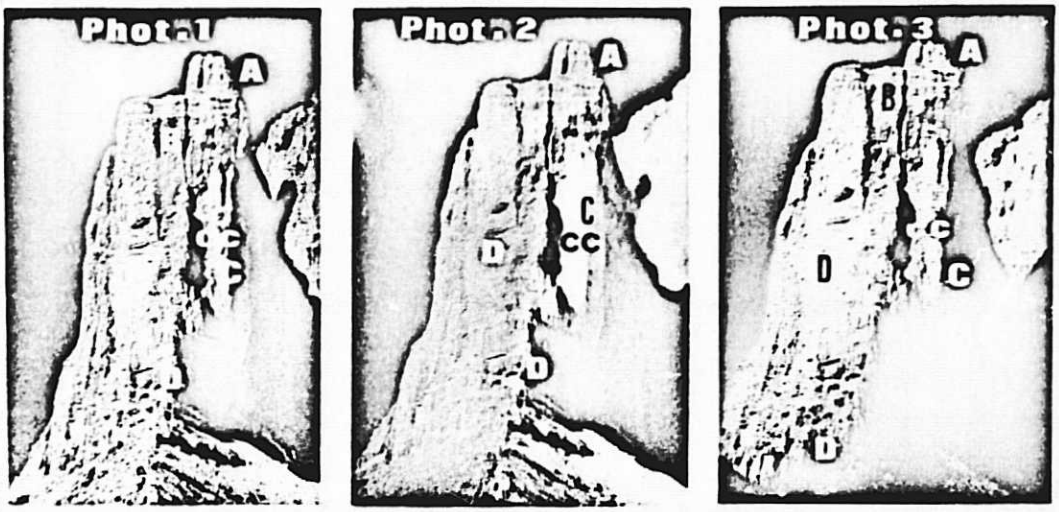
A 'heptaphyre' is a set of seven frames on one or more different films, using seven different filters such that red-sensitive elements can be exposed each time.

We were able to submit for review the results obtained from such a process to the VIIIth International Cartography Conference and to the XXIIIth International Geographic Congress in Moscow, in 1976.[7] /53

It provides contrasting pictures particularly suited for depicting the condition of wall surfaces. We will refer to the set of photographs #1, to Table 1 and to the set of photographs #2.

Here are the films and filters that we used on 8 August 1977: /55
Ilford HP5 (black and white panchromatic; Wratten 25 filter).
Kodak SO-410 (black and white insensitive to green; Wratten 1A filter)
Kodak 2481 (black and white infrared; Wratten 25 filter)
Kodak 2236 (formerly 2443; infrared in false colors; Wratten 12,15,25,& 58 filters).

[7] G. Galibert . "Automatic Cartography and visual remote sensing using bichromatic remote sensing at very low altitude (geo-technical applications." Paper presented to the International Cartography Conference, 2-11 August 1976.
This study was partly re-initiated in the following printed work:
G. Galibert. "Temporary Stagnation of waters on slope surfaces. Fundamental and geo-technical studies through bichromatic remote sensing at very low altitude".
XXIIIth International Geographic Congress, Moscow, 21 July-3 August 1976.
Volume 1 of Summaries: "Geomorphology and Paleogeography", pp. 146-153.
Six figures.



Coverage, with 'heptaphyres' of the relief of the walls of the Spigolo Giallo of the Cime di Lavaredo (G. Galibert photo, 8 August 1977).
Photo 1. - Photo on Ilford HP5 panchromatic film (Wratten 25 filter)
Photo 2. - Photo on Kodak 2481 film, infrared black-and-white (Wratten 25 filter)
Photo 3. - Photo on spectrozonal black-and-white non-infrared Kodak SO410 film (Wratten 1A filter).

These three frames were made on 8 August 1977 in the (3), (2) and (1) order between 6 and 6:30 hours (Universal Time) from the Forcella Lavaredo shelter. The primary differences in photographic appearance are observed to be with regard to surface landslides. The SO140 film highlights these formations because of their gloss reflecting light radiations (rupture shine) and of the absence of brownish patina on the northern exposure (cc) as well as the southern exposure (D). The infrared Kodak 2481 black-and-white film reveals these formations with sidelighting although they are difficult to detect when they are illuminated from the front (D).

This phenomenon is perhaps associated with different rock surface conditions as a function of its exposure which creates differences in the establishment of lichen beds.

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SUMMARY TABLE NUMBER 1

Interpretation of Heptaphyres Pertaining to the Faces of the Spigollo Giallo of the Cime di Lavaredo (Italian Dolomites) performed on 8 August 1977.
Appearance of the return and visual contrast (grey or colors)

Observed Rocky Formations	Symbol used on photos	Photo on B&W infra red Kodak 2481 Film Wratten25	Photo on Panchromatic HP5 Ilford Film Wratten25	Photo on Spectrozonal non-infrared KodakSO410 Wratten 1A	Photos on Infra-Red 2236 Ektachrome (formerly 2443) (color of the return and visual contrast). Filtering used in front of camera:			
					Wratten12	Wratten15	Wratten25	Wratten58
Wall Rivulets	A	grey low contrast	grey low contrast	grey very high contrast	cyan fairly good	cyan very good	yellowish brown average	black or purplish dark grey good
Vertical ice-caused Fissures	B	grey low contrast	grey low contrast	grey very high contrast	bluish cyan good	cyan very good	yellowish brown average	same as above
Horizontal ice-caused Fissures	C	grey	grey	grey	cyan	cyan	yellowish brown average	black or purplish dark grey
Surface Landslide Trace	D	grey low contrast	grey low contrast	grey very high contrast	cyan very good	cyan good	yellowish brown average	black or purplish dark grey
Glacial Return	E	grey low contrast	grey low contrast	grey very high contrast	cyan very good	cyan very good	yellowish brown average	black or purplish dark grey good
Main Wall with Overhangs	F	grey low contrast	grey low contrast	grey very high contrast	cyan fairly good	cyan good	yellowish brown average	black or purplish dark grey good

Maximum details are provided with Kodak SO410 film. On Infrared Ektachrome film with a Wratten 15 filter, the pictures obtained are monochromes with a cyan color. Glacial returns and slabs attacked by icing effects are easily differentiated through simple visual examination. Representation on a trichromatic diagram of the coloring of the pictures of such objects is given by points aligned in the order of greater or lesser saturation of the shades of the same color, the greenish blue called cyan, which reveals the existence of bare rock.

B) Monochromatic Black-and-White Photographs in the Case of "bi-reflectance": macrophotography of melting icing on sun-exposed rock (terrasse of Espécières, near Gavarnie, Central Pyrenees).
We will refer to Picture Set #2, to Summary Table #2 and to Figure Set #2.

Bi-reflectance is the property of some objects studied in remote-sensing by juxtaposing elements likely to be classified into two different categories as a function of their spectral reflectance: highly reflective or, on the contrary, very poorly reflective to blue (400 to 500 nm) for example.

A limestone wall chipped by ice effects is partially covered, at the end of spring, by types of lacework created by the snow cover in the process of melting. The overall object, from the standpoint of remote-sensing, provided by the wall is characterized by the juxtaposition of very small areas either covered or not by snow, either reflecting or not reflecting blue radiations. We can speak of "bi-reflectance". The use of a panchromatic emulsion and of a blue monochromatic filter such as the Wratten 47B filter makes it possible to highlight areas covered with snow as opposed to bare rock flat areas: the latter are seen as dark greys on a positive print (relative under-exposure) while snow will appear as white (relative over-exposure).

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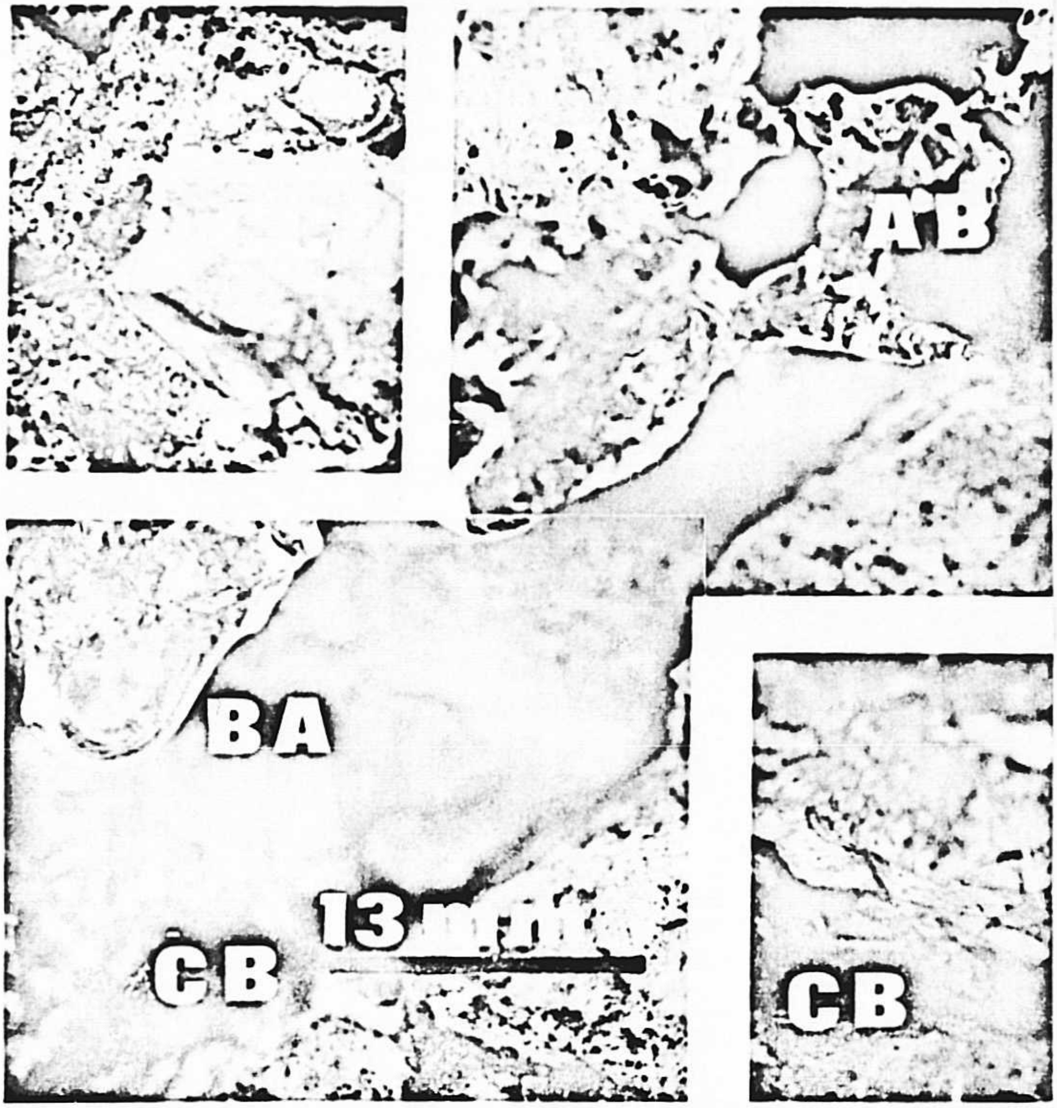


Mosaic of monochromatic photographs on Ilford HP4 panchromatic film (Written 47B Filter) depicting the melting of snow on part of a slope sculptured into white limestone (Espécières Terrace at Gavarnie, Central Pyrenees, at about 2000 meters).

Photos by G. Galibert, recorded on 6 April 1975 with a Medical Nikkor camera (linear enlargement by a factor of 1 on the photographs; see the reference line which is 13mm in length).

Photographs in Picture Set #2 page 19, pertaining to the "truth-terrain" of one of our Pyrenean "targets" show a layering of Dinant limestones visible on the Espécières terrasse at 2005 meters, above Gavarnie, at the time that winter snows melt. The outline of the water droplet from melting snow which is going to fall into an open fissure below is highly detailed relative to the rock. However, the latter is nearly white. /57

Snow is even more detailed by comparison with the rock.

Such a procedure in picture-taking thus provides photographs that are useful for simple visual interpretation as well as for numerical-coding of the contours. A mixed wall of alpine high mountains photographed during the last two weeks of the month of June will be seen in the form of a juxtaposition of dark (the rock) and light (the snow) areas. Mensuration of the snowy area can be performed without any difficulty with a corrected photograph.

C) Problems in Picture-Taking and Interpretation Associated with "Multi-reflectance"; Bi-chromatic frames of the Obergabelhorn and of the Blanc de Moming in the Zinal Cirque.

When geographic objects likely to be studied through photographic remote-sensing are made up by juxtaposing elements with a very diversified spectral reflectance, we speak of "multi-reflectance". That is the case for a large alpine wall such as the North face of the Blanc de Moming and the slopes of /58
the alpine Middle Mountains of the Zinal cirque which stretches downwards.

We will refer to Picture Set #3, Summary Table #3 and to Figure #2.
To the geographical objects with spectral reflectance studied above are added some varieties of snow or ice covers that are different by their reflectivity in the near ultra-violet (370-400 nm) likely to be recorded on conventional photographic optical equipment. The fresh snow that covers, during the month of July, the shelves of the Zinalrothorn at 4100 meters or that accumulates, protected from the wind, at about 3500 meters on the "bridges"

SUMMARY TABLE #2

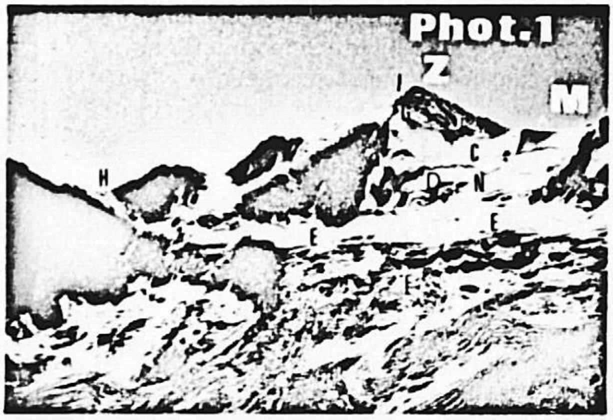
Melting Ice on a Block of Dinant Limestone (Espécières Terrasse, 2005 m), Near Gavarnie in the Central Pyrenees, on 6 April 1975.

Monochromatic Photography in the Blue (400 to 500 nm) Spectrum on Ilford HP4 film with a Wratten 47B Filter (linear enlargement by a factor of 1 on the photograph)

Micro-reliefs and Snow Phenomena Observed	Symbol on Photographs
Snow Lace transformed into Ice	AB
Melt-water Droplet ready to fall into a fissure	BA
Open Fissure	CB
Limestone Fragment Cracked by Freezing	CC

of crevasses on the Mont-Durand (Durand Mountain) glacier, strongly reflects ultra-violet. The rock on the rocky boulders appearing in the northern face of the Blanc de Moming reflects it little. Photographic infrared is strongly reflected by the alpine lawn recovering life in the upper portion of the high mountain meadows in spots where the snow has melted. This /59 meadow hardly reflects the ultra-violet that snow, still a few centimeters away, returns toward the sky. Such a variety of spectral reflectances and of surface conditions is revealed quite well by Infrared Ektachrome 2236 film used in a two-color process.

This same photographic base and the same type of filtering make it possible /60 to finely detail the vegetation of the alpine level when the slopes are almost entirely devoid of spring snows.



Non-infrared Spectrozonal Photographs Made on Kodak SO 410 Film insensitive to green, through a Wratten 1A filter, depicting the North face of the Blanc de Moming, seen from the side (Photo 1) and from above, perpendicular to the crest line (Photo 2).

M: Blanc de Moming; Z: Zinalrothorn.

G. Galibert photographs made on 7 August 1976 from a Cessna 182 aircraft belonging to the Air-Glaciers Company of Sion-Suisse (Switzerland).

On the peaks, in the snow valleys between 2400 and 2900 meters in the Queyras or the Ubaye, the snow dirtied by wind dust slowly gives way to Salicetum herbaceae (grouping of weed willows, golden potentillas, viviparious knotgrass, five-leaf alchemilla, etc.). Bichromatism with a Wratten 33 filter with Infrared Ektachrome clearly separates vegetation in red over a yellowish grey snow background.

SUMMARY TABLE #3

North faces of the Blanc de Moming and of the Obergabelhorn. Comparison of the possibilities offered to gather data on photographs through visual interpretation or measurement of the contrast of optical densities and colored returns.

Legend of Table Columns:

1: Designation of Rock Formations and of Ice-snow Phenomenon

2: Symbols on Photographs

3: Quality of the return on Kodak SO140 Film

4: Wratten Filter for the Best Visual Contrast on Infrared Ektachrome

5: Wratten Filter on Infrared Ektachrome leading to the Lowest Possibilities of Interpretation.

6: Detectability with the Spacelab Metric Camera.

Notations for the Color Return mentioned in (4) and (5) are purely descriptive and without any precise calorimetric significance.

1	2	3	4	5	6
White Crest	A	IA very good	11 green-brown	34A white	Yes
Crest Outlining	B	IA very good	12 blue	33 yellow	Yes
Snow Shield on Wall.....	C	IA very good	11 green-brown	22 yellow	Yes
Wall Glacier	D	IA very good	12 blue	22 yellow	Yes
Cirque Glacier..........	E	IA very good	12 blue	33 yellow	Yes
Fresh Snow Bridges over Crevasses	F	IA very good	58 red	44A brown	No
Snow banks on Walls	G	IA very good	12 blue	22 yellow	No
Corridor Snow Sedimentation	H	IA very good	12 blue	44A pink	Yes
Rock Slabs	I	IA very good	12 blue	44A black	Yes
Ledges	J	IA very good	12 blue	34A black	No
Surface Landslide Traces		IA very good	12 blue	34A black	No
Wall Pseudo-Rivulets ...		IA very good	12 blue	12 blue	No

continued on page 23

From Page 22 - Continuation of Summary Table #3

1	2	3	4	5	6
Androgenic Erosion of Path		IA very good	11 dark grey	12 blue	No
Dry Snow	N	IA average	44A pink	12 blue	Yes
Melting Snow	O	IA average	44A pink	12 blue	Yes
Wind Plate	P	IA very good	44A pink	12 blue	No
Vegetation		IA very bad	58 fluorescent red or black	12 red or blue	Yes

Text continued from Page 21.

The "Curvuletum-elynetosum of windy crests (grouping with colonies of sedges, "Elyna", stemless silene, etc.) is very much brought out on the same film with the standard Wratten 12 yellow filter.

It is the same for the grass-covered terrasses with "Festucero-Trifolietum Thalii" (grouping with the violet fescue-grass, Thal clover, bay clover, etc.).

The sometimes thin vegetation on limestone slopes between 1900 and 2500 meters, such as Seslerietum (grouping with the blue Sesleria, mountain oats, Alps aster, edelweiss sometimes, etc.), appears extremely well when Wratten 58 or Wratten 59 filters are used with infrared Ektachrome. Vegetation stands out, even when it is thin as it appears as a bright red. Such filtering gives fresh snow a beautiful fluorescent mauve color. /61

The numerical coding of object outlines on such photographs is very easy because of density and color contrasts. Color notation on a trichromatic diagram provides very different measurements translated into very distant representative points.

Possibilities for metric usage of these pictures can unfortunately be reduced when they are recorded on infra-red Ektachrome film.

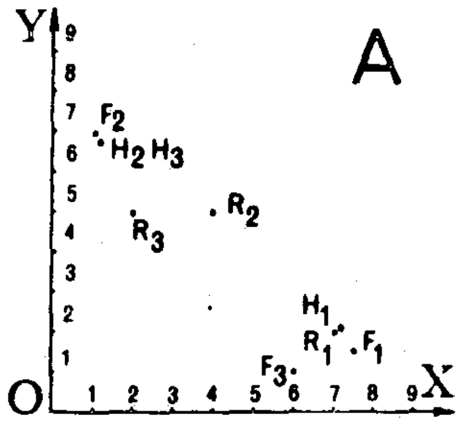


Figure A - Trichromatic representation of the apparent color of certain objects photographed on Infrared Ektachrome 2236 Kodak Film (formerly 2443): faces N of the Blanc de Moming and of the Obergabelhorn.

Planar representation on a trichromatic diagram: Ox: Blue(483nm);Oy: Red(633nm).

F_1, H_1, R_1 respectively depict the color of pictures of dry rock, of fresh snow and of moist nêvé snow obtained with a single-band Wratten 12 filter.

F_2, H_2, R_2 correspond to filtering performed with a two-band Wratten 33 filter passing ultra-violet and blue in one band, and red and infra-red in the other.

F_3, H_3, R_3 correspond to filtering performed with a Wratten 58 filter with two bandpasses, green and infrared.

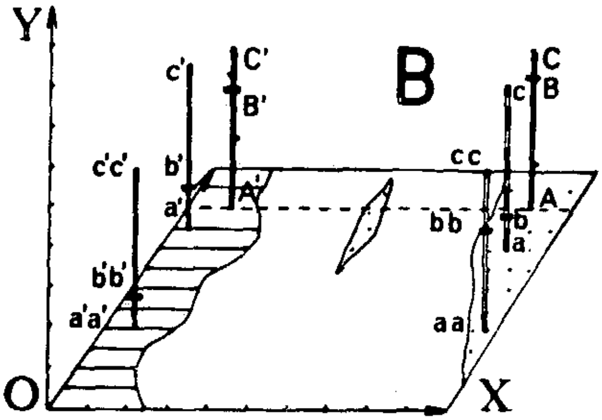


Figure B - Vector presentation in space of the coloring of objects on the photographs:
$\vec{AB} = x$; $\vec{BC} = y$; $\vec{AC}$ = constant; $\frac{\vec{AB}}{\vec{BC}} = \frac{x}{y}$. The length of the $\vec{AC}$ vector is taken as the unit on the figure. The position of B, B', b, b', bb, b'b' is indicated with a crossbar. These points trace a"representative color surface".

We have: for F_1 : $\vec{AB} = x_1$, $\vec{BC} = y_1$; For H_1 : $\vec{A'B'} = x'_1$, $\vec{B'C'} = y'_1$.
for F_2 : $\vec{ab} = x_2$, $\vec{bc} = y_2$; For H_2 : $\vec{a'b'} = x'_2$, $\vec{b'c'} = y'_2$.
for F_3 : $\vec{aabb} = x_3$, $\vec{bbcc} = y_3$; for H_3: $\vec{a'a'b'b'} = x'_3$, $\vec{b'b'c'c'} = y'_3$.

In a pictorial drawing, the simplified representation of a vertical photograph taken from above the Blanc de Moming (North being to the right of the figure); in horizontal hatchings, snow covering the top of this face; in white, névé snow; dotted area, the rock of Ar Pitteta downstream from the Moming glacier.

Taking pictures with the bichromatic process, using multi-band filters /62
with transmission coefficients that can be 5 to 10 times less than that of the Wratten 12 filter, indeed imposes relatively long exposure times, generating smears. We therefore expose film as a function of a fictitious speed that is far greater than its real speed: ASA 1000 instead of ASA 100. It is then necessary to proceed with special processing, performed by most professional laboratories qualified for Ektachrome, that increases film grain size. Picture sharpness on which final ground resolution depends is then not as good as when Ektachrome is used in the standard manner.

Under these conditions, it appears illusory to look for a ground resolution better than 40 meters on Spacelab photographs recorded in such a manner. Nevertheless, this resolution is 50% better than the resolution of ERTS pictures.[8]

The photographs of the North faces of the Obergabelhorn and of the Blanc de Moming recorded on Kodak SO410 film show much contrast when depicting rock and snow.

On the other hand, they are unusable for the analysis of the scenery in grassy middle mountains: vegetation and relief formations are shown on a positive print as very dark spots inside which only the cuts for paths appear. It is the same thing for pictures made with Kodak SO-253 holographic fast film, thus making possible the direct capture of data between 550 and 650 nm with an overall speed equivalent to an ASA of 25.

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[8] We will find the characteristics of the main metric cameras in the following article:
R. Welch, J. Halliday; "Imaging Characteristics of Photogrammetric Camera Systems". Photogrammetria, Volume 29, 1973, pp. 1-43.

CONCLUSION

Three main conclusions come to mind at the conclusion of this survey of experiments performed in preparation for the use of Spacelab above the Alps.

Most of the formations that make up alpine high mountains as well as middle mountains will be photographed with a standard metric camera, their size being greater, in most cases than the ground resolution of such equipment, in the neighborhood of 20 meters. /63

Taking pictures on a single type of film, as is the common practice in the field of photogrammetry, would not make it possible to inventory all geographical facts that are detectable on slope surfaces. The geographical object is not confused with the photographic object shown on a photograph. It will be necessary to plan for magazine changes with different films aboard Spacelab, depending on the different types of scenery overflown: such as 2236 and SO-410 Kodak films. The third conclusion concerns new study possibilities offered by photographic remote-sensing in mountains. We do not think that this method will lead to the discovery of phenomena invisible to the eye of a trained observer moving over the ground surface and equipped with a field microscope and a portable radiometer. Metric remote-sensing provides, on the other hand, irreplaceable data in the areas of localization, of synoptic viewing of problems, and of surface mensuration.

More than anything, it applies to cartography rather than to the overall analysis of the evolution process of the countryside.

Symbols, abbreviations and conventions:

A.S.A. : Speed rating of a photographic emulsion according to the American Standards Association

°K : Degree Kelvin

°C : Degree Centigrade; 0° K = -273.16° C

G.E.T. : Ground Elapsed Time: duration of a phenomenon counted relative to local time, on the Earth surface.

Angles and elapsed time are respectively measured in degrees and hours, expressed in decimal fractions of these units (one hundredth of a degree for angles, and one thousandth of an hour for durations).

Altitudes of summit tops are those indicated in the National Map of Switzerland, 1:50,000 scale.