14th Congress of the International Society of Photogrammetry
Hamburg 1980

Commission 1 - Working Group 1/1

Presented Paper

Giovanna V. TOGLIATTI
Istituto di Topografia, Fotogrammetria e Geofisica
Politecnico di Milano, Italy

Title

Quality Analysis Methods Selecting Film Material for the First Spacelab Mission 1: Photogrammetric Analysis

Abstract

The quality of the different films employed in the Test flights made by IGN and DFVLR, have been tested by means of the determination of residual parallaxes after relative orientation on 100 points per model in several models per flight. For each group of parallaxes the autocovariance diagram has been drawn in function of the distance between the points and the mean square value of the parallaxes has then been splitted into its systematic and random parts (signal and noise). The noise, taken as a measure of the film quality, has allowed an evaluation of the photographic material and the selection of the "best" films, the use of which has to be suggested for Spacelab Mission 1.

a) - One of the five different tests that have been planned in order to evaluate the photographic material among which the three films to be used on Spacelab 1 are to be selected, is based on photogrammetric measures. These tests have been carried out by the Institute of Topography, Photogrammetry and Geophysics of the Politecnico of Milano.

The underlying philosophy is that from the analysis of many residual parallaxes in models taken with various types of films it is possible to detect some information on the amount of error caused by the photographic material. The various steps of the procedure are as follows:

1) - relative orientation of several models with many measured points on each model;
2) - analysis of the correlation existing between the residual parallaxes as a function of the distance between the points taken into consideration and determination of the best basic *lag* for evaluating the amount of "noise" and "signal" present in the m.s.v. of the residual parallaxes;
3) - splitting of the residual parallaxes into their pseudo-systematic and accidental part;
4) - classification of the films according to the elements mentioned in point 3);
5) - analysis of the "signal" present in the residual parallaxes when the orientation is performed on all measured points;

The same procedure has been applied to the material of the test flights taken by IGN-DFVLR in the area of Villefranche sur Cher in September, 1978 and to the subsequent group of test flights taken in June, 1979 by the IGN in the area of Montpellier.

The measures have been performed with a Stereocomparator OMI TA3/P with a uniform distribution of 100 points on each model. For each film a certain amount of models has been selected, in order to improve the reliability of the results. Whenever possible, the area where the measures were to fall was the same in all flights so that the influence of the different photographic textures could be eliminated from the variability of the results.
In the following paragraphs a detailed account is given of the information we have been able to gather on the above mentioned points.

The chronological sequence of the measures has been respected and the results are, therefore, subdivided in two groups: "Villefranche tests" and "Montpellier tests" hereafter called V-tests and M-tests. The V-tests include 12 films, out of the 13 that have been actually used (the last one never arrived to Milan because of difficulties in rotating the material among the experimenters).

After the evaluation of the Villefranche material a comparison of the results of the five experimenters has taken place: the opinions were in very good agreement and on this basis it has been possible to select the films that were going to be used during the Montpellier tests: a total of 8 films, the best ones of the preceeding series and one new IRC.

The V-tests include two different groups of models, those taken with the 30 cm focal length camera and those taken with the 60 cm camera (indicated in the following with C-30 and C-60). The last ones proved to be less reliable for the analysis of the film quality in so far as the camera itself needed a new calibration and, as a whole, has yielded poorer performances. The results acquired with the C-60 camera are given, for sake of comparison, but the choice of the best films has been mainly based on the material of C-30.

b) - The results of the measures are gathered as follows:

- Table 1 : Villefranche tests, C-30;
- Table 2 : Villefranche tests, C-60;
- Table 3 : Summary of Tables 1, 2 : list of m.s.v. of σ noise in increasing order;
- Table 4 : Montpellier tests, C-30 (provisional);
- Table 5 : Summary of Table 4: list of m.s.v. of σ noise in increasing order (provisional).

The measures on the Montpellier material are still going on at the moment because the 8 films under analysis are much more uniform in their quality than those used in the V-tests, which is quite obvious since they have already been selected as the best ones on the market. It follows that, in order to ascertain the difference between them, a much higher number of measures is required. Therefore, after the first results came out, based on three measured models per flight (as we had done in the V-tests), it was evident that it was wiser to double the number of measured models for each film. We intend to add the results of these last measures, that are being performed now, directly at the Hamburg Congress . We think, however, that a preliminary film evaluation can safely be made also on the already available data.

c) - The relative orientation of all the models has been computed on 6 orientation points (a brief comment on this choice follows in paragraph g). Some models have been discarded before orientation for clouds or defective material. A few points out of 100 have been discarded after relative orientation for gross errors: the remaining number of points, never smaller than 96, appears in Col.6 of Tables 1, 2, 4.

The accuracy of the results, evaluated as m.s.v. of the residual parallaxes (σ) goes in the V-tests from a minimum of 4.8 μm (Table 1, flight 1-4/3, model 7-8) to a maximum of 15.0 μm (Table 2, flight 8-1/6, model 10-12) and in the M-tests from a minimum of 5.2 μm (Table 4, flight 24-1, model 23-27) to a maximum of 11.3μm (Table 4, flight 25-6, model 32-36). The whole list of σ's is given in Tables 1, 2, 4 under Column 8, according to the type of film (Col.1), flight conditions (Col.2), filter (Col.3), name of the flight (Col.4), plates of the model (Col.5), numbers of the points in each model (Col.6). The explanation of Columns 9 ÷ 12 will be given later.

The analysis of Columns 8 shows that:

- the σ's in the models taken with C-30 are generally smaller than those taken with C-60 in the same flight conditions;

- the σ's of the M-tests (Table 4) are generally smaller and more uniform than those of the V-tests (Tables 1, 2);
- within the group of models belonging to the same flight there are remarkable variations of σ. See, for instance, flight 7-3/3 (Table 1) in which three consecutive models give σ = 9.7; σ =11.4; σ = 6.5 µm. This fact is rather common, although not always so evident. Its first consequence is that no average σ can be computed for each flight since the σ's of each group are significantly different from each other, the limiting F ratio for non-significance (with 100 and 100 degrees of freedom, 95% level) being F = 1.59 . It follows that it is rather hard to classify the type of film on the basis of these σ's whereas, on the contrary, the purpose of the investigation is mainly the quantification of the film quality from the viewpoint of the measures that will have to be done on them.

d) - The analysis of the correlation between residual parallaxes has been carried out by means of a suitable program which computes the autocovariance function of values scattered on the plate on the basis of their distance from each other. The well-known formulae are:

$$R_{XX}(k \cdot lag) = \frac{1}{N} \sum_{i=1}^{N} \frac{\sum_{j=1}^{\alpha_i} x_i x_j}{\alpha_i} \qquad 0 \leq k \leq 20$$

in which

N = total n. of points in which the residual parallax is known;

x_i = residual parallax in P_i;

x_j = residual parallax in P_j;

α_i = n. of points P_j that can be found in a circular ring of width = lag, internal radius = $k \cdot lag$ centered on point P_i.

The main problem with this type of application is the choice of a suitable basic lag, that is the radius of the basic circle. It is obvious that if the lag is too small, the first points of the covariance function, after the origin, will be zero since no other points (or too few) will be found lying in very small rings centered on each of the 100 points. Therefore, the computation of each covariance function has been repeated several times, starting with a basic lag of 5 mm up to a basic lag of 15 mm, and in very few cases of 20 mm. The number of steps of the autocovariance function (k) has been restricted to 20, even when the function does not clearly vanish within the 20 x lag, since the main ourpose of the computation is to identify the basic lag that allows to separate the fraction of the variance due to pseudo-systematic errors (signal) from that due to accidental errors (noise).

One can see in Fig.1 the whole series of 5 autocovariance functions referring to the same test. It is a V-test, flight 3-1/6, model 10-12, and has been chosen nearly at random, in the sense that all the "curricula" of the remaining autocovariance functions are more or less the same. It can be observed that:

- the first value in 0 is always standardized to 1;

- *lags* 5 mm and 7.5 mm: the diagrams drop to 0 in the points corresponding to 1-*lag*, then sharply increase but are very instable. They do not tend to 0 since they have been cut respectively at 9.75 mm and 14.62 mm;
- *lag* 10 mm: the graph looks better but still shows an anomalous jump between 1·*lag* and 2·*lag*;
- *lag* 12.5 mm; the graph has no more initial downward jump; it can easily be interpolated by a curve that cuts the R_{XX} axis in 0.65, which, according to well-known theories, amounts to saying that 65% of σ^2 is to be ascribed to pseudo-systematic causes (signal). *Lag* 12.5 is considered the optimum, as far as the signal estimation is concerned.
- *lag* 15.0 mm: the graph doesn't add anything to the previous information. In general, with *lags* larger than the optimum the graphs become messy, the signal ratio sometimes becomes slightly smaller.

In all tests one can find for each model the two critical situations, before and after the stabilization of the graph. The optimum *lag* lies somewhere in between, but the evaluation of the signal to noise ratio cannot be remarkably mistaken. As a matter of fact, it has always been estimated on the basis of the graph on the right side of each figure (an example of which is given in Fig.2) and the two percentages appear in Col.9 and 11 of Tables 1,2, 4. They are very variable: see for instance test 7-3/3 or 8-3/3 or 2-1/6 (Tables 1,2).

The typical pattern of the autocovariance functions shows that the correlation between residual parallaxes exists up to a remarkable distance, in other words on the whole dimension of the plate, and that its behaviour is more or less always the same, similar to the one which is very clearly and neatly identifiable in flight 7-3/6, model 11-13 (see Fig.2). Of course not all the graphs are as clear as this one, but the same oscillatory trend can be found in nearly all of them.

e) - On the basis of the σ^2 percentages of Col.9, 11 and of the σ values of Col.8, it has been possible to evaluate the σ's of signal and noise for each test, given in Col.10, 12 of Tab.1,2,4. Tables 1, 4 refer to the C-30 of the V-tests and M-tests and are definitely better in order to understand how the splitting of the variance has the curious effect of stabilizing the σ noise of the same flight to a value that can be actually considered a measure of the accidental error with "that" film (and flight conditions and filter). In other words, the instability that had been previously remarked between the σ's of the same flight ends up in the σ's of the signal, so that we can see (for instance Tab.1, flight 8-3/3) that a rather large σ parallax = 8.9 μm has a very low "noise weight" = 0.30 , whereas the subsequent model with a lower σ parallax = 5.8 μm has a noise weight 0.70 and the two models end up with the same σ noise = 4.8 μm.

Analogously, in flight 25-7 (M-tests, Table 4) we have two σ's of 7.9 and 5.5 μm with noise weights respectively of 0.34 and 0.66, which correspond to σ noise of 4.6 and 4.5 μm.

An analysis of Tables 1, 2, 4 shows that:

1. Eleven, among the twelve flights taken with C-30 in the V-tests (Table 1) that have been analysed (unfortunately with a restricted number of models) show σ's noise which are significantly equal, and that can therefore be averaged, the only exception being flight 4-3/3 which has a very small noise anyway.

2. The V-tests taken with C-60 (Table 2) would show the same behaviour had they not been "blurred" by the very poor quality of the images and resulting measures. Notwithstanding this fact, the mechanism underlying the splitting of the residual parallaxes remains the same (see, as an example, the 3 models of flight 3-1/6). Only two out of ten examined flights have σ noise significantly different (but they have been averaged all the same). Two models had to be eliminated because of very big, and widespread, errors. As a matter of fact, as a by-product of the film investigation, one unquestionable fact has become clear: the C-60 is not suitable, as it is, for photogrammetric taking, either for its large distorsion or for other causes, and the difference between the results of Tables 1, 2 proves it rather definitely.

3. The M-tests of Table 4 show a much higher uniformity, even in the total σ's of Col.8. The σ's noise are significantly equal at 99% level in all tests except one (flight 24-1) but here too the values are so small that they have been averaged anyway.

f) - The results of Col.12 of Tables 1, 2, 4 have been summarized in Tab.3, 5 in which the films have been ranged according to increasing magnitude of the respective m.s.v. of the σ noise. To the first group belong those films whose σ is not significantly different from the smallest one. To the second group belong the remaining films, thus creating a sort of first and second class films.

On the basis of the evaluations of Tab.3, and of the "preference list" of the other four experimenters, it has been possible to select the films to use in the Montpellier test, the names of which are shown in Tab. 5 [1]. In Tab.5 they are listed according to a new preference list based on the results of Table 4. The 2402 Plus X - Français appears three times as it has been analysed in three different flights.

It must be noticed, however, that the "notes" given to the various films of the M-tests in Tab.5 are much more uniform than those given to the V-tests (Tab.3). If the significance level is chosen at 1% = 1 - 99% ($F_{300,300}$ = 1.33) only two films fall in the "second class", the Aviphot 30 and Aviphot 200. If the level is raised to 5% = 1 - 95% ($F_{300,300}$ = 1.22) also the 2405 - Double X has to be put in the second class. Those belonging to the "first class" are significantly equivalent and only a much higher number of measures will allow to obtain information about

---

[1] The film 2645 Plus X -English BW has also been tested at Montpellier but no results on it are still available.

a significant difference (if any).

g) - A comment must be made on the nature of these pseudo-systematic errors, the existence of which is evidenced by the presence of relevant "signals", changing from model to model in the same strip. At first these errors had been ascribed to film deformations and we had hoped to be able to carry out the type of investigation a-5, that is to filter out of the residual parallaxes their noise portion thus leaving a common "signal" pattern. However, a few tentative computations made using all the 100 measured points as orientation points for relative orientation, have shown that the largest part of the σ-signal was due to a defective formation of the model resulting from non-detectable measure errors in the six orientation points. That is why the amount of signal varied so much from model to model whereas in the orientations with 100 points it dropped considerably down. In a few cases the total σ represented directly the σ noise as no signal part was detectable from the autocovariance functions.

The procedure of computing the orientation on 6 points only and of splitting the total σ into its two components has been kept all the same because of the purpose of the investigation, which is to identify in the best possible way the accidental measure errors.

The reasons are two:

1. The splitting was necessary in any case because a signal part ranging from 0 to 30% is always present.

2. The orientations with 100 gave us the feeling that the signal part was "messy" and therefore its evaluation wasn't as reliable as the one based on models oriented on 6 points only.

The comparison was fruitful anyway and may bring a small contribution to the long lasting discussion on the opportunity of using more than the usual six standard points for relative orientation. It has succeeded in "quantifying" the amount of residual parallaxes and, in a way, deformation that is present in a model when there is a too small number of degrees of freedom.

An acknowledgment and many thanks go to Mr A. Vanossi who has taken care of all the measures and to Mr L. Pallottino who has executed the drawing for all the tests.

TABLE 1 : Villefranche tests , C-30

FILM		Flight conditions	Filter	Flight	Model	N. points	*Lag* of estimated signal (mm)	σ parallaxes μm	SIGNAL %σ²	SIGNAL σ (μm)	NOISE %σ²	NOISE (μm)
3411	BW	IIα	B	1-4/3	6-8	100	12.5	6.2	0.38	3.8	0.62	4.9
Plus		pm			7-9	100	12.5	4.8	0.35	2.8	0.65	3.9
X-Aerocon					8-10	100	10.0	6.8	0.60	5.2	0.40	4.3
												4.4
2405	BW	IIα	B	1-5/3	9-11	100	12.5	7.3	0.50	5.1	0.50	5.1
Double X		pm			10-12	100	12.5	7.8	0.58	5.9	0.42	5.0
												5.0
2445	C	IIIβ	NF	2-1/3 (3)	6-8	100	15.0	13.8	0.62	10.8	0.38	8.5
Aerocolor					7-9	99	10.0	10.2	0.50	7.2	0.50	7.2
Neg.					8-10	99	17.5	8.9	0.26	4.5	0.74	7.7
												7.8
2448	C	IIIα	NF	3-1/3	6-8	99	12.5	7.8	0.60	6.1	0.40	4.9
MS Diaposit.		pm			7-9	100	10.0	7.6	0.65	6.1	0.35	4.5
					8-10	99	20.0	6.3	0.30	3.5	0.70	5.3
												4.9
2402	BW	IIIα	B	4-2/3	1-2	100	12.5	10.6	0.60	8.2	0.40	6.7
Plus X USA		am			2-3	100	10.0	9.7	0.45	6.5	0.55	7.2
												6.9
2402	BW	IIIα	B	4-3/3	3-4	100	12.5	5.8	0.58	4.4	0.42	3.8
Plus X USA		am			5-6	100	12.5	8.4	0.58	6.4	0.42	5.4
												4.7 (1)
2443	IRC	Iβ	D	5-3/3	9-11	100	12.5	7.0	0.18	2.9	0.82	6.3
Infrared					10-12	99	10.0	6.4	0.35	3.8	0.65	5.1
Colour												5.7
Pan 30	BW	IIβ	B	6-2/3	19-21	100	12.5	7.5	0.58	5.7	0.42	4.9
Agfa Aviphot					20-22	100	10.0	6.9	0.58	5.3	0.42	4.5
												4.7
2424	IR-BW	IVβ	D	7-1/3	6-8							
Infrared					7-9			eliminated				
					8-10							
3414	BW	IVβ	NF	7-3/3	6-8 (2)	100	12.5	9.7	0.70	8.1	0.30	5.3
High					7-9 (2)	100	10.0	11.4	0.80	10.2	0.20	5.1
Defin.Aerial					8-10	100	15.0	6.5	0.34	3.8	0.66	5.3
												5.2
SO 131	IRC	Vβ	NF	8-1/3	6-8	100	10.0	9.8	0.60	7.6	0.40	6.2
Infrared					7-9	100	17.5	6.9	0.20	3.1	0.80	6.2
Colour					8-10	99	12.5	8.1	0.32	4.6	0.68	6.7
												6.3
2645	BW	Vβ	D	8-3/3	6-8	99	12.5	8.9	0.70	7.4	0.30	4.9
Plus X					7-9	99	12.5	5.8	0.30	3.2	0.70	4.8
English					8-10	100	10.0	8.0	0.68	6.6	0.32	4.5
												4.7
2402	BW	Vβ	D	8-7/3	1-2	100	12.5	7.9	0.30	4.3	0.70	6.6
F Plus X					2-3	98	10.0	9.5	0.60	7.4	0.40	6.0
												6.3

(1) the m.s.v. is not strictly valid as the two σ are significantly different

(2) very regular autocovariance function

(3) very irregular autocovariance function

$F_{100\ ,\ 100}$ = 1.39 (95%) ; 1.59 (99%)

TABLE 2 : Villefranche tests , C-60

FILM		Flight conditions	Filter	Flight	Model	N. points	*Lag* of estimated signal (mm)	σ parallaxes µm	SIGNAL %σ²	SIGNAL σ(µm)	NOISE %σ²	NOISE σ(µm)	
3411	BW	IIα	B	1-4/6	9-11	100	12.5	8.6	0.40	5.4	0.60	6.7	
Plus X		pm			10-12	100	12.5	9.3	0.48	6.4	0.52	6.7	
-Aerocon					11-13	100	12.5	8.2	0.35	4.8	0.65	6.6	
												6.7	
2405	BW	IIα	B	1-5/6	17-19	100	10.0	9.9	0.48	6.8	0.52	7.1	
Double X		pm			23-25	100	12.5	9.1	0.60	7.1	0.40	5.8	
												6.5	
2445	C	IIIβ	KL	2-1/6	9-11	99	12.5	9.4	0.35	5.6	0.65	7.6	
Aerocolor Neg.					10-12	100	10.0	10.8	0.55	8.0	0.45	7.3	
					11-13	99	10.0	6.8	0.10	2.2	0.90	6.5	
												7.1	
2448	C	IIIα	KL	3-1/6	9-11	98	12.5	8.2	0.30	4.5	0.70	6.8	
MS Diaposit.		pm			10-12	100	12.5	11.8	0.65	9.5	0.35	7.0	
					11-13	100	12.5	8.5	0.40	5.4	0.60	6.6	
												6.8	
2443	IRC	Iβ	D	5-3/6	21-23	100	10.0	8.7	0.38	5.3	0.62	6.8	
Infrared Col.					22-24	100	10.0	8.3	0.55	6.2	0.45	5.6	
												6.2	
Pan 30	BW	IIβ	B	6-2/6	35-37	99	12.5	8.8	0.48	6.1	0.52	6.4	
Aviphot Agfa					36-38	100	12.5	6.0	0.48	4.1	0.52	4.3	
												5.4	(1)
2424	IR-BW	IVβ	D	7-1/6	9-11	100	12.5	9.3	0.40	5.7	0.60	7.2	
Infrared					10-12	100	12.5	10.2	0.65	8.2	0.35	6.0	
					11-13	99	15.0	10.7	0.55	7.9	0.45	7.2	
												6.8	
3414	BW	IVβ	NF	7-3/6	9-11	99	10.0	8.9	0.60	6.9	0.40	5.6	
High Defin.					10-12	100	12.5	6.6	0.38	4.1	0.62	5.2	
Aerial					11-13	100	12.5	16.6	0.58	12.2	0.42	(10.4)	(3)
												5.4	
SO 131	IRC	Vβ	NF	8-1/6	9-11				eliminated				
Infrared Col					10-12	99	10.0	15.0	0.45	10.0	0.55	11.1	
					11-13(2)	100	10.0	10.0	0.20	4.5	0.80	8.9	
												10.1	
2645	BW	Vβ	D	8-3/6	9-11	99	12.5	8.2	0.38	5.0	0.62	6.5	
Plus X					10-12	99	12.5	8.3	0.65	6.7	0.35	4.9	
English					11-13	100	12.5	7.9	0.45	5.3	0.55	5.9	
												5.8	(1)

(1) m.s.v. is not strictly valid as two σ are significantly different at 99% level

(2) very regular autocovariance function

(3) eliminated

$F_{100,\ 100}$ = 1.39 (95%) ; 1.59 (99%)

TABLE 3 : Summary of Tables 1, 2: list of m.s.v. of σ noise in increasing order

Camera ZEISS f = 305,035 mm

List of m.s.v. of σ noise in increasing order

3411	Plus X Aerocon	BW	IIα pm	B	4.4μm	
2402	Plus X USA	BW	IIIα am	B	(.) 4.7 "	
Aviphot	Pan 30 Agfa	BW	IIβ		4.7 "	
2645	Plux X English	BW	IVβ	D	4.7 "	(+)
2448	MS Diapos.	C	IIIα pm	NF	4.9 "	
2405	Double X	BW	IIα pm		5.0 "	
3414	High Defin. Aerial	BW	IVβ	NF	5.2 "	
2443	Infrared Colour	IRC	Iβ	D	5.7 "	
SO 131	Infrared Colour	IRC	Vβ		6.3 "	
2402	Plus X Fr.	BW	Vβ		6.3 "	(++)
2402	Plus X USA	BW	IIIα am	B	6.9 "	
2445	Aerocolor Neg.	C	IIIβ	NF	7.8 "	

(.) m.s.v. non strictly valid: σ's significantly different at 99% level

(+) significantly equal to 4.4μm at 99%; m.s.v. = 4.8μm

(++) significantly different from 4.4μm at 99% level

$F_{300\,,\,300}$ = 1.22 (95%) ; 1.33 (99%)

Camera ZEISS f = 611,66

List of m.s.v. of σ noise in increasing order

3414	High Defin. Aerial	BW	IVβ	NF	5.4μm	
Aviphot	Pan 30 Agfa	BW	IIβ	B	5.4 "	
2645	Plus X English	BW	Vβ	D	5.8 "	(+)
2443	Infrared Colour	IRC	Iβ	D	6.2 "	
2405	Double X	BW	IIα pm	B	6.5 "	
3411	Plus X Aerocon	BW	IIα pm	B	6.7 "	
2448	MS Diapos.	C	IIIα pm	KL	6.8 "	
2424	Infrared	IR-BW	IVβ	D	6.8 "	(++)
2445	Aerocolor Negatif	C	IIIβ	KL	7.1 "	
SO131	Infrared Colour	IRC	Vβ	NF	10.1 "	

(+) significantly equal to 5.4μm at 99% level; m.s.v. = 5.7μm

(++) significantly different from 5.4μm at 99% level

TABLE 4 : Montpellier tests , C-30 (provisional)

FILM	Date Time	Filter Aperture Exposition	Flight	Model	N. points	Lag of estimated signal (mm)	σ parallaxes µm	SIGNAL %σ²	SIGNAL σ(µm)	NOISE %σ²	NOISE σ(µm)
Aviphot 200 BW	12/9 9.47	H 8 1/1000	21-1	1- 5	99	12.5	7.6	0.54	5.6	0.46	5.1
				17-21	98	12.5	7.0	0.46	4.8	0.54	5.2
				24-28	98	12.5	6.9	0.34	4.0	0.66	5.6
											5.3
3411 BW Plus X Aerocon	12/9 12.01	D 5.6 1/500	21-8	23-27	99	12.5	6.6	0.46	4.5	0.54	4.8
				30-34	97	12.5	6.3	0.42	4.1	0.58	4.8
											4.8
2476 BW Shellburst	16/9 7.37	D 5.6 1/1000	24-1	8-12	100	12.5	6.5	0.62	5.1	0.38	4.0
				23-27	100	12.5	5.2	0.44	3.5	0.56	3.9
				30-34	98	12.5	5.6	0.14	2.1	0.86	5.2
											4.4
2443 IRC Aerochrome	16/9 7.56	D 5.6 1/500	24-2	9-13	99	12.5	6.7	0.36	4.0	0.64	5.4
				25-29	99	10.0	5.9	0.36	3.5	0.64	4.7
				32-36	94	12.5	6.1	0.50	4.3	0.50	4.3
											4.8 (1)
2402/F BW Plus X Fr.	16/9 10.40	D 5.6 1/500	25-1	7-10	100	12.5	7.0	0.50	5.0	0.50	5.0
				20-23	100	10.0	6.0	0.36	3.6	0.64	4.8
				25-28	96	12.5	5.8	0.34	3.4	0.66	4.7
											4.8
2405 BW Double X Aerographic	16/9 11.30	D 11 1/1000	25-4	9-13	100	12.5	8.2	0.64	6.6	0.36	4.9
				25-29	99	12.5	6.7	0.38	4.1	0.62	5.2
				32-36	100	12.5	7.2	0.56	5.4	0.44	4.8
											5.0
Aviphot BW Pan 30	16/9 12.00	D 5.6 1/1000	25-6	9-13	99	10.0	7.0	0.54	5.2	0.46	4.8
				25-29	99	10.0	10.2	0.76	8.9	0.24	5.0
				32-36	100	12.5	11.3	0.74	9.7	0.26	5.7
											5.2
2402/F BW Plus X Fr.	16/9 12.19	D 5.6 1/500	25-7	7-11	100	12.5	7.9	0.66	6.4	0.34	4.6
				23-27	99	10.0	5.5	0.34	3.2	0.66	4.5
				30-34	97	12.5	6.5	0.52	4.7	0.48	4.5
											4.5
2402/F BW Plus X Fr.	16/9 15.35	D 5.6 1/500	26-1	7-10	99	12.5	6.1	0.30	3.3	0.70	5.1
				20-23	100	15.0	7.1	0.56	5.3	0.44	4.7
				24-27	100	12.5	6.0	0.48	4.1	0.52	4.3
											4.7

(1) m.s.v. is not strictly valid as two σ are significantly different at 99% level

$F_{100\ ,\ 100}$ = 1.39 (95%); 1.59 (99%)

TABLE 5 : Summary of Table 4 : list of m.s.v. of σ noise in increasing order

FILM			Time	Aperture	Exposition	Filter	σ noise	
2476	Shellburst	BW	7.37	5.6	1/1000	D	4.4 μm	
2402	Plus X Fr	BW	12.19	5.6	1/500	D	4.5	
2402	Plus X Fr	BW	15.35	5.6	1/500	D	4.7	
3411	Plus Aerocon	BW	12.01	5.6	1/500	D	4.8	(+)
2443	Aerochrome	IRC	7.56	5.6	1/500	D	4.8	
2402	Plus X Fr	BW	10.40	5.6	1/500	D	4.8	
2405	Double Aerogr.	BW	11.30	11.0	1/1000	D	5.0	
Aviphot 30			12.00	5.6	1/1000	D	5.2	(++)
Aviphot 200			9.47	8.0	1/1000	H	5.3	

(+) significantly equal to 4.4 μm at 95% level; m.s.v. = 4.67 μm

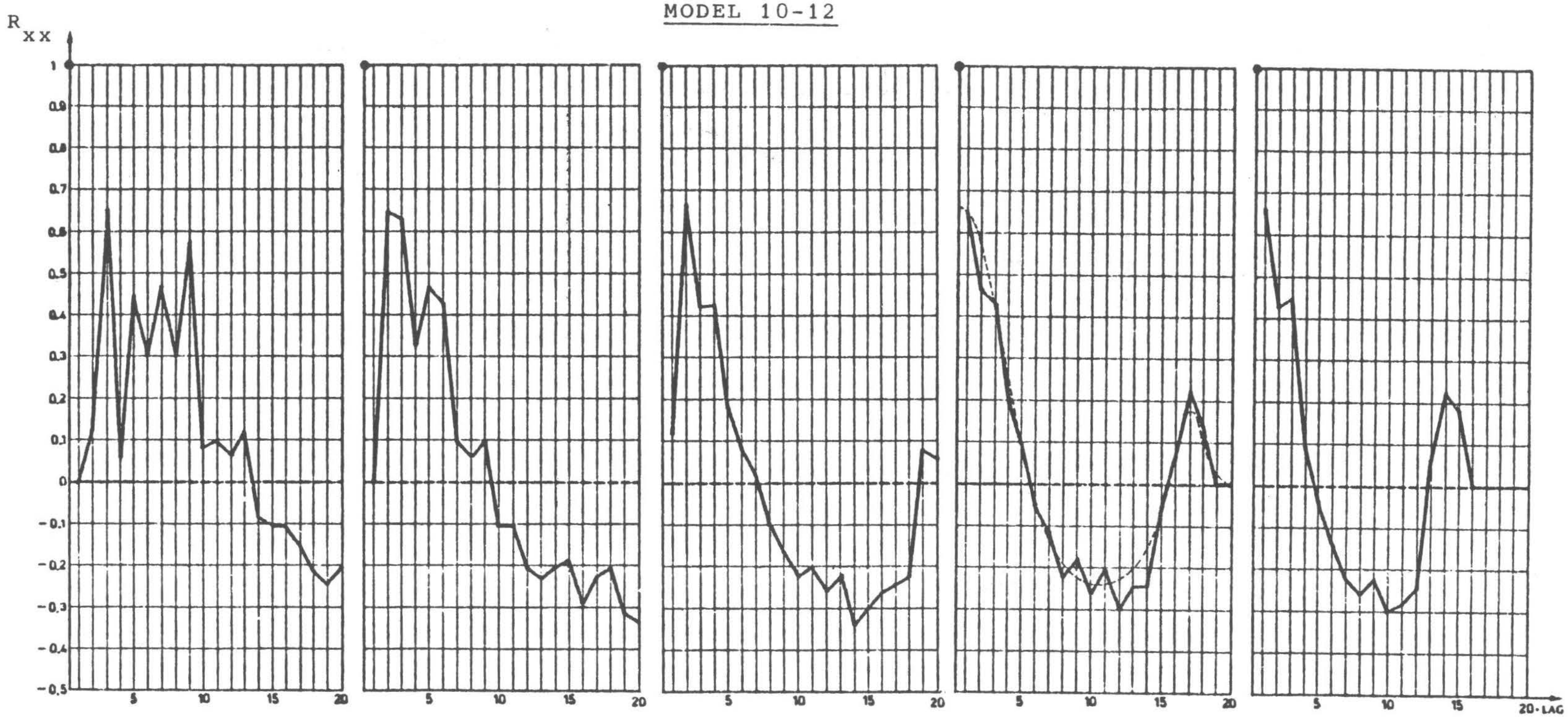
(++) significantly different from 4.4 μm at 95% level

$F_{300\,,\,300}$ = 1.22 (95%) ; 1.33 (99%)

FILM 2448 MS Diapositive C

FLIGHT 3-1/6 (IIIα pm KL)

MODEL 10-12



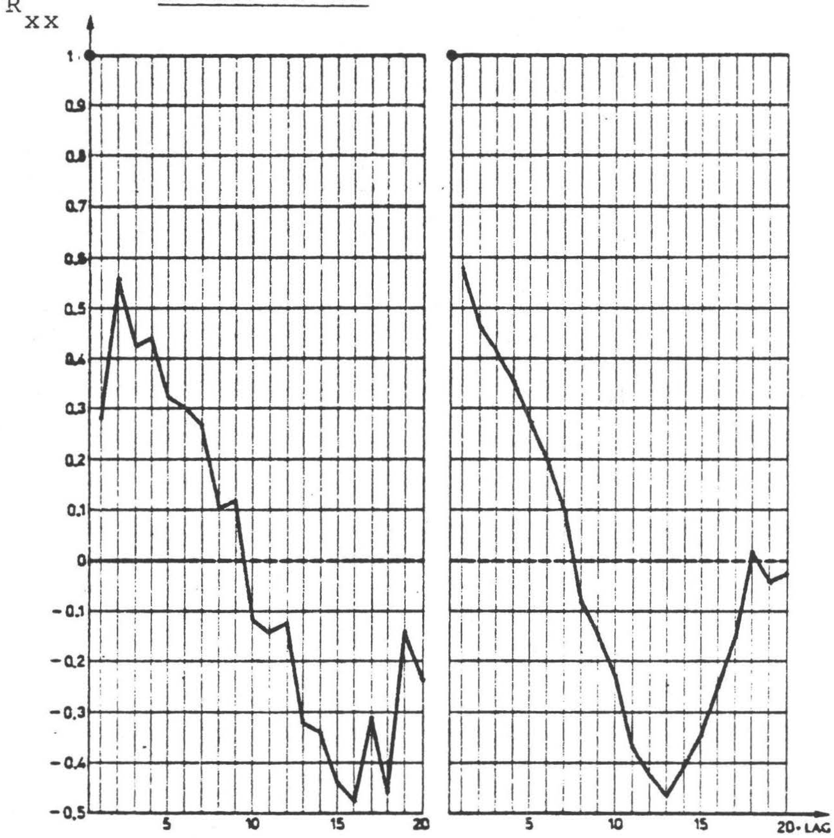
LAG=5mm LAG=7.5mm LAG=10mm LAG=12.5mm LAG=15mm

Fig. 1

FILM 3414 High Defin. Aerial BW

FLIGHT 7-3/6 (IVβ NF)

MODEL 11-13



LAG=10mm

LAG=12.5mm

Fig. 2