Commission of the European Communities
JRC - Ispra Establishment

TELLUS PROJECT

Joint Flight Experiment UK/1977

Report No. 1

Planning and Execution

P. Reiniger

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1. CHRONOLOGICAL SCHEDULE

April 1, 1977	2nd TELLUS meeting, Brussels Announcement of JFE
June 6	1st Meeting Working Group 1: Preparation of prelaunch experiments
June 8	Attribution of credits for JFE
July 1	Credits for JFE available
July 28	Publication of tender for flight campaign

Joint Flight Experiment, UK

July 19, 1977	NERC, London. First meeting of UK Co-investigators for planning of JFE/UK
August 17	Attribution of tender to Spacetec-Flight One
August 25	NERC, London. Second and final meeting of UK co-investigators and Flight One for planning of JFE/UK
September 2	Start of operations fixed for Sept. 10, pending favourable weather forecast
September 6	Weather forecast favourable - operation is launched. Departure of mobile unit
September 8	Arrival of mobile unit and JRC ground team
September 13	Night and day overflight
September 14	Return of mobile unit
September 15	End of campaign
November 8	Delivery of computer-compatible tapes and scanner imagery.

2. INTRODUCTION

The Joint Flight Experiment (JFE) of the TELLUS Project was conceived as a preparation for the EXPLORER-A Heat Capacity Mapping Mission with the purpose of acquiring experience in the interpretation of thermal imagery of agricultural land surfaces.

In particular it was the purpose of the experiment to test the algorithms which should permit an evaluation of soil moisture and evapo-transpiration from remotely sensed surface temperatures. An assessment of the atmospheric influences on these surface temperature measurements was only a secondary objective of the experiment.

Accordingly, the conditions for the experiment were set by the first objective and they were the following:

1. Consecutive night and day flights
2. Overflight at the time of the maximum and minimum of the daily surface temperature cycle
3. Clear night and day, no wind at night
4. Relatively high radiation during the day in order to obtain an important temperature amplitude
5. Bare soil, grassland and other crops in the flight area
6. Contrasts in soil moisture and soil type.

These often conflicting conditions and the time necessary for organizing the campaigns narrowed down the suitable period to the month of September, with the radiative flux from the sun being still rather high and wheat fields having already been harvested and ploughed. Likewise, meteorological statistics showed a fair chance for obtaining suitable weather conditions during this month.

As can be seen from the chronological schedule, only five months lay between the decision to carry out the JFE and the first flight; the responsible for the JFE was designated only two months before the campaign.

It was due to the spirit of cooperation and to the effort devoted by all the persons involved that the operation of the JFE could be carried out. This is true for the personnel of the various institutes and organizations who took part actively in the JFE, as well as for the personnel of the JRC-Ispra, at all levels, administrative, technical and scientific.

On this occasion I should like to thank everyone and all of them for their contribution.

P. Reiniger,

Coordinator JFE

3. INSTITUTES AND ORGANIZATIONS

The following institutes and organizations participated in the campaign, either at the organizational or at the executive stage.

Coordination and Sponsor in the UK:

Natural Environment Research Council
Alhambra House
27-33 Charing Cross Road
London, WC2H OAX — A.E.S. MAYER

Co-investigators participating in the planning of the operation, the execution of ground measurements and data interpretation:

Institute of Hydrology
Crowmarsh Gifford
Wallingford, Oxfordshire OX10 8BB — K. BLYTH, R.T. CLARKE, R.J. GURNEY

University of Reading
Department of Geography
2, Earley Gate, Whiteknights Rd.
Reading RG6 2AU — J. HARDY

University of Leeds
Department of Geography
33, Hydeter 2
Leeds LS2 9JT — M.J. KIRBY, S.F. JAGGER

Commission of the European Communities
Joint Research Centre
Ispra-Establishment
I-21020 Ispra — G. MARACCI, P. REINIGER, G. TASSONE

Contractor for airborne operation and pretreatment of scanner data, aerial photography:

Spacetec Datengewinnung GmbH
Heidehang 17
D-4300 Essen — F. KINDLE (Operator)

Subcontractor for flight:

Flight-One Ltd.
Staverton Airport
Cheltenham, Gloucestershire — P. RAYNER (Chief pilot).

4. TEST AREA AND GROUND INSTRUMENTATION

The test area situated to the west and north-west of London, was composed of two test sites:

Grendon-Underwood (1°W, 51°53′N)
Newbury (1°44′W, 51°20′N)

4.1 Grendon Underwood

Ground operations: Institute of Hydrology, Wallingford (IHW)
Joint Research Centre, Ispra (JRC)

Maps: Ordonnance Survey 1:50,000 First Series, Sheet 165
O.S. 1:10,560 Provisional Edition, Sheets SP 62 SE, SP 72 SW, SP 72 SE.

Soil map 1:10,560

Landscape: Gently sloping land between 60 and 100 m above sea level. Fields bordered by hedges. Size of fields up to 15 ha. Land use is cropland (cereals) and grassland with some forest and market gardening.

The area is part of the Grendon Underwood Experimental Catchment of the river Ray, with one of the longest records established by the Institute of Hydrology.

Soils: Clay soils, alluvium and soils of the sandstone series (Fig. 1)
Grassland - clay of Evensham Series
Cropland - clay of Denchworth Series

Test plots: Two 1 x 1 km plots were delineated on the test site (Fig. 2), one being mainly composed of grassland, the other mainly occupied by cropland. At the time of the flight the cropland was stubble, burnt stubble, or bare soil (ploughed). Ground instrumentation was established on grassland and on bare soil.

Fig. 1 - Soil Map of the Grendon Underwood Experimental Catchment

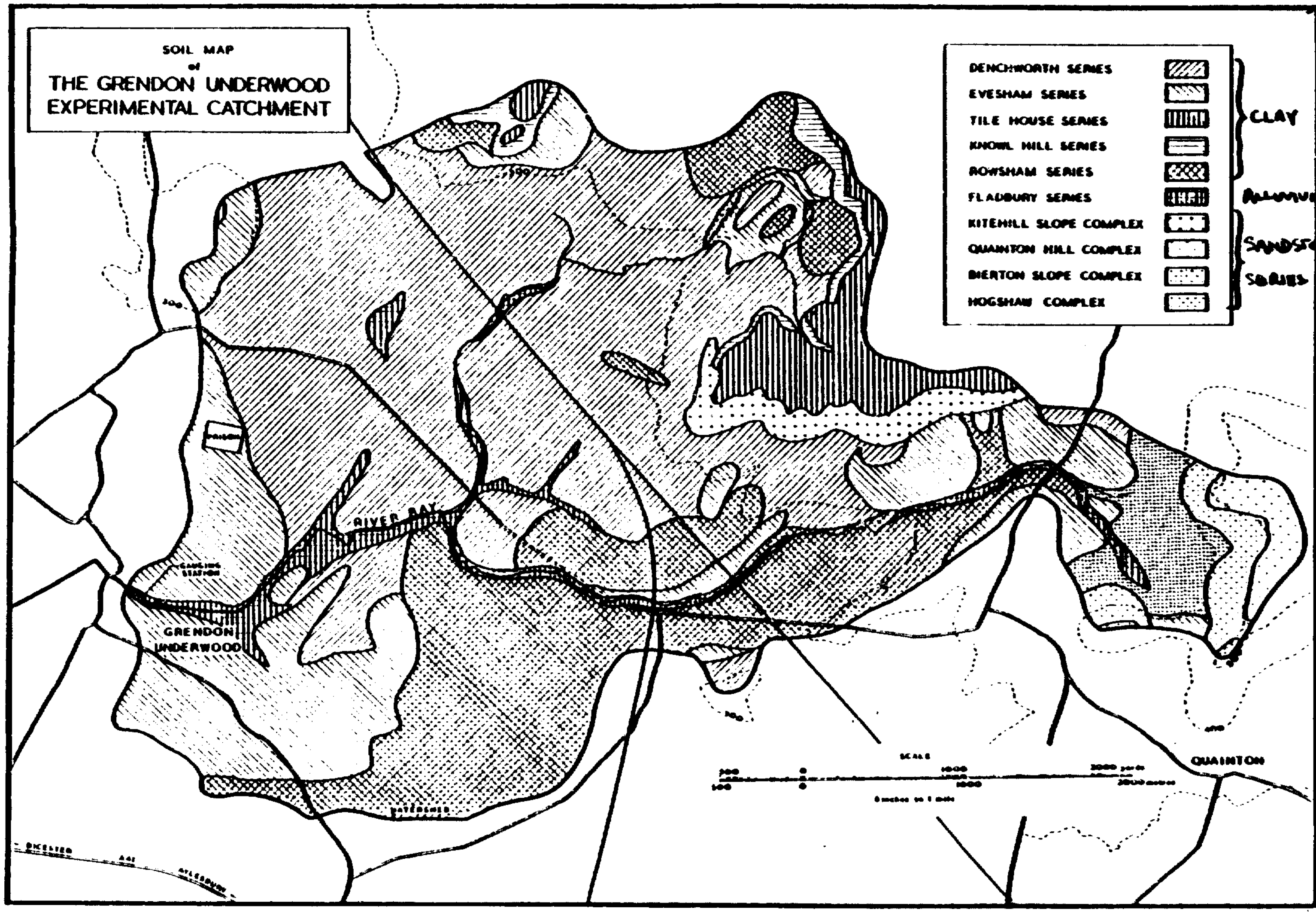
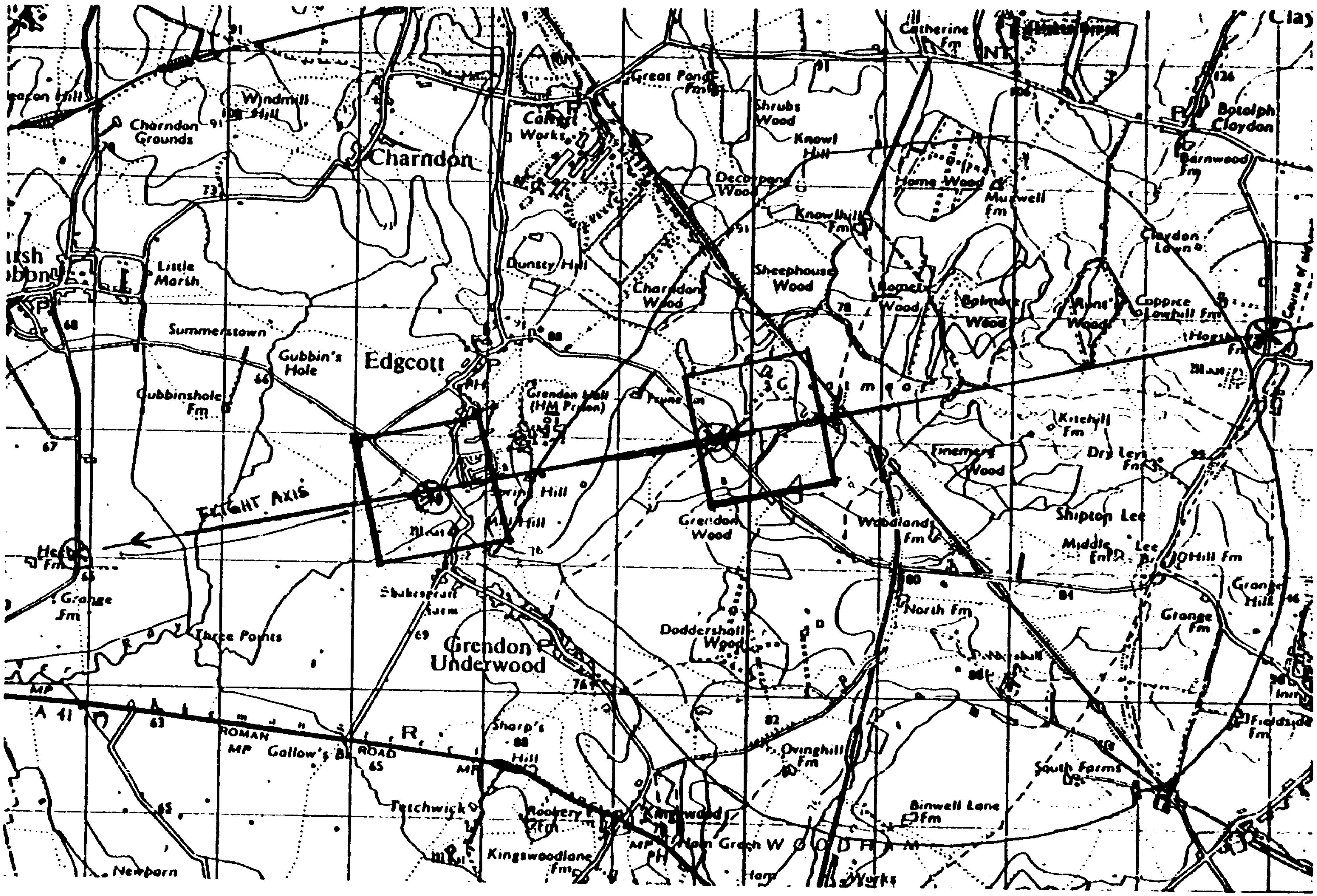


Fig. 2 - Grendon Underwood Test Site

⊕ marker light



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4.1.1 Met Site - Grassland

Stationary Instrumentation and Measurements

Automatic weather station, recording on magnetic tape cassette at five minutes' intervals (Operator: IHW)

Solar radiation	0.3 - 2.5 μm
Net radiation	0.3 - 80 μm
Wind run	
Wind direction	
Rainfall	
Air temperature (wet and dry bulb).	

Grass minimum thermometer	
Earth temperature thermometers	60, 120, 240 cm
Soil surface thermometers	5, 10, 20 cm
Soil heat flux plates	1 in air at 1.5 cm
	2 at 5 cm depth
	1 at 10 cm "
	1 at 20 cm " .

Mobile data collection unit, equipped with data logger and tape punch, recording at five minute intervals (Operator: JRC-Ispra)

Solar radiation	0.3 - 2.5 μm
Reflected radiation	Exotech radiometer, mounted on tripod at 2 m height over ground surface pointed vertically downward.
Four LANDSAT-2 compatible bands:	498 - 596 nm
	580 - 706 nm
	687 - 817 nm
	797 - 974 nm
Reflected radiation from standard panel	LANDSAT-2 compatible radiometer ("Gatelli" radiometer)
Grass surface temperature	Heiman infrared thermometer mounted on tripod at 2 m height pointed vertically downward. Spectral range 8-14 μm, field of view 20°.

Mobile Instrumentation Used on Both Sites

Surface temperature	Barnes infrared thermometer PRT-5. Spectral range 9.5 - 11.5 μm, field of view 2°. The instrument was read via a digital millivoltmeter and was used hand-held at about 1.5 m

	from the soil surface and at an approx. angle of 30° from the vertical (Operator: JRC-Ispra).
Soil moisture	gravimetric (Operator: IHW).

4.1.2 Lower Greatmoor Farm - Bare Soil

Stationary Instrumentation

Data logger with magnetic tape unit (Operator: IHW)

Albedo	0.3 - 2.5 µm	
Wind run	(20 cm above ground level)	
Thermistor soil temperature probes	sub-surface	2 cm
		5 cm
		20 cm
Earth temperature	(manual)	50 cm
Air temperature	(120 cm above ground level, manual)	

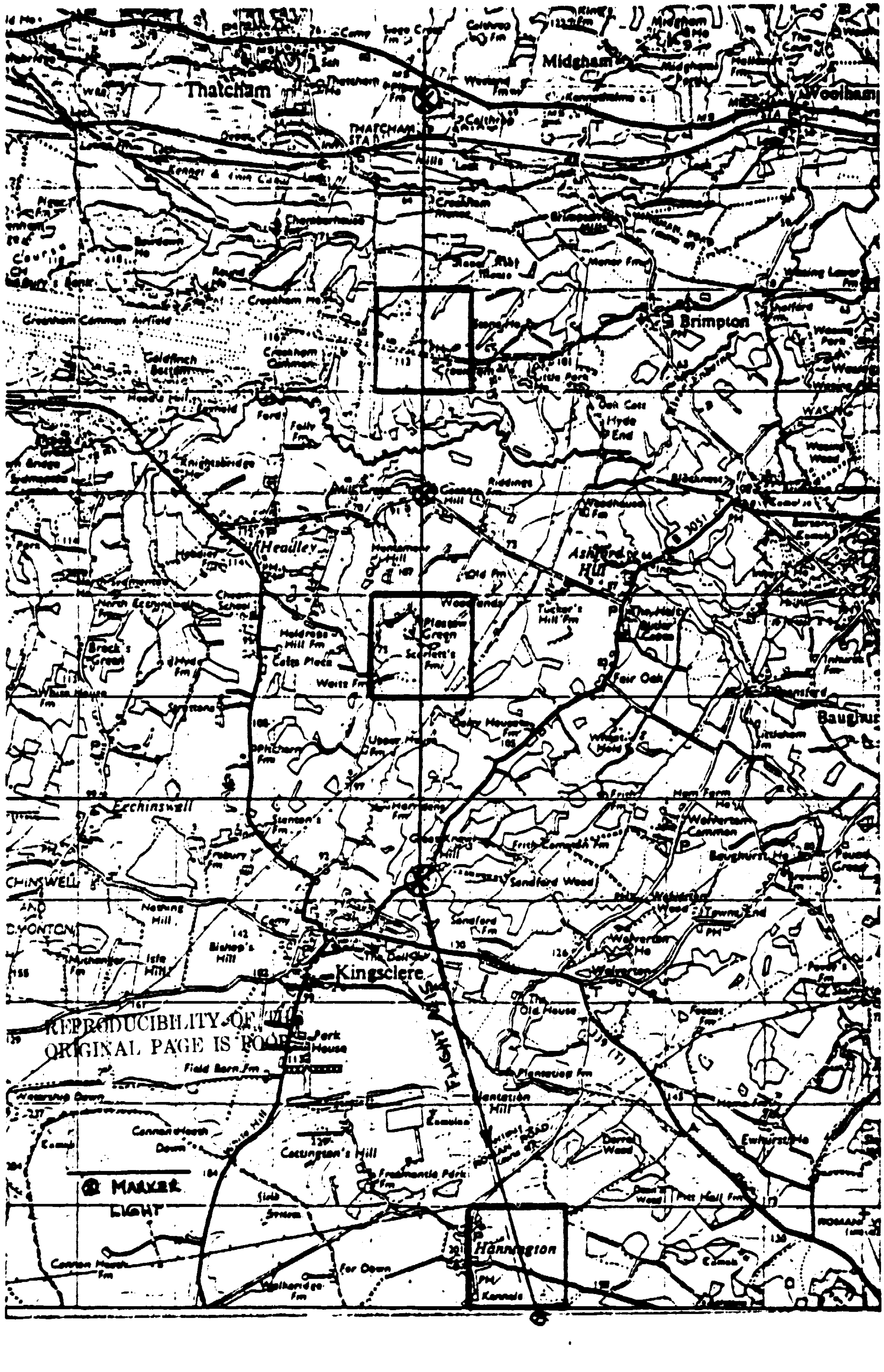
Mobile Instrumentation and Measurements

Surface temperature	Barnes infrared thermometer PRT-5
Spectral range	8-14 µm, field of view 2°. Operated with power generator, 75 cm above ground level (Operator: IHW)
Reflectance	Exotech radiometer, pointed alternatively towards the sun and at the ground (Operator: JRC-Ispra)
Soil moisture	gravimetric (Operator: IHW)

4.2 Newbury

Ground Operators:	University Reading, Dept. Geography (UR/DG) University Leeds, Dept. Geography (UL/DG)
Maps:	Ordonnance Survey 1:50,000 First Series, Sheet 174. O.S. 1:25,000 First Series, Sheets SU 55, SU 56
Landscape:	Sloping land between 70 and 200 m above sea level. Fields bordered by hedges. Size of fields up to 12 ha. Land use is cropland (cereals), grassland and woodland and some market gardening.
Soils:	Brown earth (sol lessivé) on terrace gravel. St. Albans series. Arable soil. Water table > 10 m (Crookham). Surface water gley, on loamy drift, on clay. Wickham Series. Permanent pasture. Water table 1-2 m (Plastow Green).

Fig. 3 - Newbury Test Site



Brown calcareous soil (rendzina) on chalk.
Arable soil (Hannington).

Test plots:	Three 1 x 1 km test plots were delineated on the test site, corresponding to the three different soil types (Fig. 3).

4.2.1 Crookham - Brown earth

SW corner grid point SU 530 640	51°22'30''N 1°14'00''W
Land use	arable land and grassland, instrumentation on arable soil.

Instrumentation

Automatic weather station, data recorded on magnetic tape cassette (supplied by IHW).

Solar radiation	0.3 - 2.5 µm
Net radiation	0.3 - 80 µm
Wind run	
Wind direction	
Rainfall	
Air temperature	(wet and dry bulb)
Soil moisture	gravimetric (Operator: UR/DG)

4.2.2 Plastow Green - Surface water gley

SW corner grid point SU 530 610	51°20'55''N 1°14'00''W
Land use	mostly grassland, cropland wheat stubble. Instrumentation on grassland.

Instrumentation

Solar radiation	0.3 - 2.5 µm
Reflected short wave	0.3 - 2.5 µm
Net radiation	0.3 - 80 µm
Air temperature	(wet and dry bulb)
Wind speed	
Soil temperature	5, 10, 20, 60 cm
Soil heat flux plates	surface, 10 cm
Soil moisture	gravimetric (Operator: UR/DG)

4.2.3 Hannington - Brown calcareous soil

SW corner grid point SU 540 550	$51^{\circ}17'45''$N $1^{\circ}13'00''$W
Land use	arable land, grain wheat, stubble, ploughed. Instrumentation on bare soil.

Instrumentation

Solar radiation	0.3 - 2.5 μm
Reflected short wave	0.3 - 2.5 μm
Net radiation	0.3 - 80 μm
Air temperature and humidity	
Wind run	
Soil temperature	5, 10, 20, 60 cm
Soil heat flux plates	surface, 10 cm
Soil moisture	gravimetric (Operator: UL/DG)

5. AIRCRAFT AND SENSORS

Aircraft:

Twin-Pioneer		
Operating speed -	possible range	140 - 185 km/h
	actual	170 - 185 km/h
Altitude	1000 m	
Crew:	2 (pilot, navigator)	
Airport:	Stavenport, Cheltenham	
Flight time to the test sites:	20 min	

Sensors:

Camera	RC - 883
Lens	I 5 UAG 275
Film	Kodak Aerochrome Infrared 2443, 60% overlap stereo coverage
Infrared thermometer	Barnes PRT-5. Spectral sensitivity 8-14 μm, field of view 2°.

This instrument was mounted vertically aligned with the MSS nadir view and was coupled with a Hasselblad camera (80 mm focal length, 5.6 aperture, 1/500 sec exposure. Ektachrome MS). The signal of the thermometer and of the camera shutter was recorded on two tracks of the MSS tape recorder.

Multispectral scanner (MSS)	Daedalus DS-1250 with 9 channels in the visible and near-infrared and one channel in the thermal range, equipped with a 14-track tape recorder. The operating parameters of the system and the wavelengths of the 10 channels and their possible combination for LANDSAT channels are the following:

Operating parameters for DS-1250 system:

Operating wavelength	.42-14 μm
Aperture	5 inches
Focal length	6 inches
Optical aperture (eff.)	f/2
Scan rate	80 scans/sec
Total field of view	87°20′
Gated field of view	77°20′
Instantaneous field of view	infrared: 2.5 mrad visible : 2.5 mrad
Temp. resolution	infrared: 0.2°C
V/H	.2
Roll correction	total: ± 10°; unvignetted: ± 5°
Reference sources	infrared: 2 controllable thermal blackbodies visible: 1 fixed voltage broadband visible/IR light source
Reference range	infrared: -10°C to + 40°C with respect to scan head heat sink visible: .42 - 1.2 μm

Channel	Wavelength, μm	LANDSAT channels
2	0.42 - 0.45	
3	0.45 - 0.50	
4	0.50 - 0.55)	4 0.50 - 0.60 μm
5	0.55 - 0.60)	
6	0.60 - 0.65)	5 0.60 - 0.70 "
7	0.65 - 0.69)	
8	0.70 - 0.79	6 0.70 - 0.80 "
9	0.80 - 0.89)	7 0.80 - 1.10 "
10	0.92 - 1.10)	
11	8 - 14	

Replay of the tapes could produce a quicklook image immediately after the flight. Pixel size for 1000 m altitude 2.5 x 2.5 m; swath width 1600 m.

Operating crew: 1 photographer
1 scanner operator.

6. ORGANIZATION

6.1 Responsibility

The coordinator of the JFE takes the decision when to carry out the operation. In case of heavy ground fog on one of the two sites, the flight will be carried out over one site only.

6.2 Weather Forecasting

A long range weather forecast was obtained from the Royal Meteorological Service at Bracknell three days before the planned date of the operation.

During the stand-by period a forecast for the next 16 hours was obtained every evening at 20.00 h local time from:

Royal Meteorological Service, Bracknell (contact: IHW)
Royal Airforce Met. Office, Benson (contact: IHW)
Royal Airforce Met. Office, Brize Norton (contact: chief pilot)

The RAF Met. Offices supplied a forecast of local weather conditions such as the formation of ground fog.

6.3 Sequence of Flights

The night flight is carried out first, followed by the day flight.

Arguments in favour:

- conditions for night flight critical - clear night, no wind; those for day flight less limiting as some clouds are permitted.
- only 9 hours from minimum to maximum temperature, 15 hours from maximum to minimum; less chance for change of weather.
- quicklook arrives around noon and allows sampling during daylight.

Arguments against:

- maximum and following minimum form a temperature cycle.
- EXPLORER-A sequence is day, followed by night passage.

The aircraft should be over the test site:

night flight: Grendon 05.30
Newbury 06.00

day flight:	Grendon	14.00
	Newbury	14.30

Flight axis: Grendon: ENE to WSW, length 8 km
Newbury: N to S, from Kingsclerc SSE, length 10 km

Marker lights: The flight axis for the night flight was marked with yellow flashing lights, battery-operated. The lights were positioned to allow for a 3° to 5° viewing angle. The position of the lights was checked on the ground before the operation to ensure an unobstructed field of view.

Grendon site: 3 marker lights (circled crosses on Fig. 2)
Newbury site: 4 marker lights (circled crosses on Fig. 3).

6.4 Time Table

Time indicated is local time (British daylight saving time) = GMT + 1

Sun rise:	approximately 06.30; new moon
20.00 h	Weather forecast is communicated to coordinator JFE. Takes go-decision after consultation with chief pilot. Informs IHW and UR/DG of decision. One on-the-ground observer is sent to each test site to check local weather conditions. In case of adverse conditions, i.e. heavy ground fog, inform coordinator at 03.20 h.
03.30 h	Operation can be cancelled by phoning to chief pilot.
04.30 h	Take-off - 30 min. Last opportunity to cancel flight by phoning to Flight-One, Staverton Airport.
05.00 h	Take-off.
05.00 h	Ground team operational on the test sites. Marker lights in position.
05.30 - 06.00	Overflight.
09.00 h	Car from UR/DG at airfield to pick up and disseminate quicklook to test sites.
12.30 h	Coordinator contacts Flight-One at Staverton Airport for decision on day flight.
13.30 h	Take-off.
13.30 h	Ground team operational on test sites for day flight.
14.00 - 14.30	Overflight.
15.30 h	Contact Flight-One, Staverton Airport for results of the day flight.

7. DESCRIPTION OF THE CAMPAIGN

Thur. Sept. 8	Arrival of JRC mobile unit and ground team. HQ in Aylesbury, 20 km from Grendon site. First visit of Grendon site. Aircraft arrived at Staverton Airport.
Fri. Sept. 9	Set-up of ground instrumentation on test sites. Mobile unit installed on Grendon site. Briefing at Staverton Airfield. Calibration of airborne PRT-5, mounting of PRT-5 and Hasselblad camera in aircraft. Weather forecast negative.
Sat. Sept. 10	Check of ground instrumentation. Weather forecast negative.
Sun. Sept. 11	Cloudy in the morning, getting bright and sunny in the afternoon. Weather forecast predicts clouds coming up in the second half of the night. Possibility of suitable weather conditions for 12/13.
Mon. Sept. 12	Weather forecast was right. Cloudy. Intercalibration of IR-thermometers: Heiman, PRT-5 JRC, PRT-5 IHW. Weather forecast at 20.00 positive. Predicts suitable conditions for flight, possibility of ground fog in low-lying areas later in the morning. Operation is started.
Tue. Sept. 13	No negative reports from on-the-ground observers on test sites at 03.20. Operation continues. Ground teams arrive at test sites on schedule. Marker lights on. On Grendon site most eastern light on late, on Newbury site one light not on all the time. Take-off 04.45 h.

Passes over Grendon:	05.26 h
	05.34 h
	05.43 h
Passes over Newbury:	06.01 h
	06.12 h
Landing:	07.00 h

Landing was made difficult by ground fog.

On Grendon Met site ground fog formed at around 06.00 h, dissipated at 07.20 h.

Measurements with mobile IR-thermometer between 05.15 h and 06.45 h on both Grendon sites.
Failure of one battery of airborne PRT-5 noted by operator during first passage over Grendon site.

Quicklooks ready at Staverton Airport 09.30 h, arrive at Grendon 12.30 h.

Weather clear and sunny, light wind. Operation continues with day flight.

Take-off:	13.15 h
Passes over Grendon:	13.47 h 14.00 h
Passes over Newbury:	14.25 h 14.33 h
Landing:	15.10 h
Contact Staverton Airport	15.30 h

Again battery failure of airborne PRT-5; all other instruments worked correctly, including Hasselblad camera connected to PRT-5. Due to fatigue of operator day flight quicklook will be ready only next morning.

On Grendon site ground measurements with mobile IR-thermometers and Exotech from 12.30 to 17.15 h. Soil moisture samples at both sites until late in the afternoon.

Wed. Sept. 14 Recalibration of airborne PRT-5 at Staverton Airport. Dismantling of Hasselblad camera. Quicklooks ready in late morning, judged satisfactory: operation does not have to be repeated.

Dismantling of instrumentation on test sites. In the afternoon departure of the JRC mobile unit.

Thur. Sept. 15 Departure of JRC ground team. End of campaign.

Tue. Sept. 20 De-briefing of JRC ground team at Ispra.

8. REMARKS AND CONCLUSIONS

8.1 General

A number of conclusions of a general organizational nature could be drawn from this first campaign. Part of these conclusions came up during the debriefing of the JRC ground team.

Transport:

Sufficient transport turned out to be vital for the success of the campaign. The "mobile" unit of the JRC turned out to be stationary once the instruments installed on the site. One station-car hired at the start of the campaign proved to be inadequate, a second car was rented too late the day of the flight.

Lodging:

Not all the members of the JRC ground team found rooms in the same hotel for the whole duration of the campaign. Some of them had to change rooms or hotel. This had a negative effect on the moral and cohesion of the team and should be avoided in future operations.

Communications:

Communications from the Grendon site where the coordinator of the JFE was stationed, with the airport and the other test site, proved to be inadequate. They were in fact assured by a public phone booth about 500 m from the mobile unit.

In future operations a telephone connection directly from the field station should be established. Likewise, walky-talkies should be used for communication between various ground teams on one site. An emergency radio connection with the aircraft would also be advisable, though VHF should not be employed by the aircraft during the overflight so as to avoid disturbing the scanner signal.

8.2 Ground Measurements

Flight campaigns such as the JFE require an important concentration of personnel and instrumentation on the ground to match and properly exploit the wealth of data obtained by the airborne instruments. Though an important effort in this direction had been made, greater means should be deployed on the ground in future campaigns.

The precise layout and execution of the sampling schemes and measurements was left to the competence of the various team leaders, i.e. IHW, JRC-visible, JRC-thermal, etc. A more thorough discussion of the scheme would be recommendable in future operations, though the initiative should remain with the team leaders. Measurements of emissivity should be included in the future.

The precise localization of mobile ground measurements, i.e. soil moisture, radiometric measurements, is a problem to be solved. Numbered markers left on the ground may serve to this purpose as their exact position may be measured beforehand or later and not during the "heat of the action".

While data for atmospheric corrections could be obtained from a tethered balloon not far from the test area, more particular attention should be given to these measurements in future campaigns.

The thermal quicklooks were used only to a limited extent in deciding the sampling of soil moisture. This is partly due to lack of experience and difficulties in handling transparencies in the field. Heliographic prints should be more useful and daytime quicklooks should show more contrasts than nighttime thermal images.

The quicklooks proved extremely valuable, if not indispensable, for establishing an up-to-date landuse map of the test area.

8.3 Weather Forecasting

The weather forecast, both from the Royal Met. Service at Bracknell and from the RAF Met. Offices, proved to be very reliable and accurate.

While the day of the overflight appeared to be bright and clear from the ground, weather-satellite photographies obtained retrospectively by the IHW showed the passage of thin clouds over the test area. While these did not interfere with the measurements from the low-flying aircraft, data from weather satellites should certainly be consulted in future underflight experiments.

8.4 Flight

The execution of the flight operation by a small company employing subcontractors for the aircraft and aerial photography proved on the whole to be very satisfactory. The organization was flexible, there was a direct contact with the people doing the job and there was a complete absence of red tape.

In future operations, the rule that only one person deals with the chief-pilot should be enforced more strictly. This would have avoided some confusion with the format of quicklooks and the delivery of aerial photos.

Operation of airborne instruments:

The operator was apparently not familiar with the PRT-5 infrared thermometer as this instrument is usually not installed in the aircraft. In this case, precise written instruction should, in the future, be given to the operator.

Both the scanner data and the aerial photographies were of high quality.

Execution of the flight:

The precision of the flying was very high and the passages over the test areas were on schedule.

On the Grendon site the flight axis of the day flight was rotated relative to the night flight by 0.6° only. The night axis was shifted to the SE relative to the day axis: 205 m at the entrance to the axis (Hogshaw);
284 m at the exit from the axis (SW of Grendon).

The planned centerline of the flight path lies between the actual day and night flight axes and it intersects the actual day flight axis at the Grendon Met site.

The erroneous position of one marker light on the Grendon site is certainly responsible for part of this slight divergence.

A similar precision was obtained on the Newbury site.

APPENDIX

Aircraft Personnel

P. Rayner	Chief Pilot	Flight-One
J. Allinson	Navigator	Flight-One
R. Wood	Photographer	Fairey Surveys
F. Kindle	Scanner Operator	Spacetec

Ground Team

Grendon Site

F. Bertona	JRC-Ispra
K. Blyth	IHW
E. Gatelli	JRC-Ispra
G. Maracci	" "
P. Reiniger	" "
J. Sentoll	" "
G. Tassone	" "
R. van Wijk	" "
G. Williams	IHW

Newbury Site

P. Brice	UR/DG
G. Goodhind	"
C. Gurney	"
J. Hardy	"
S. Jagger	UL/DG
C. Justice	UR/DG
D. Milton	"
R. A. G. Savigear	"
R. Thompson	"
H. Walkland	"
D. William	"
M. Wooding	"