Fire Management Branch
Department of Conservation & Environment

OPERATIONAL ASPECTS OF THE INFRA-RED LINE SCANNER

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P BILLING
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INTRODUCTION

During the 1983/84 and 1984/85 fire seasons the Department of Conservation, Forests and Lands used the National Safety Council of Australia's (NSCA) Daedulus Thermal Infra Red (IR) Line Scanner for fire mapping.

In the configuration used for fire mapping the Scanner is fitted with two thermal IR detectors. One sensor detects in the 8 - 14 micron band which provides fire edge information and good terrain detail. The other sensor has a response in the 3 - 5 micron band and triggers an event marker on the imagery when heat sources in a preset temperature range are detected.

Scanner output is available in two forms. A "quick look" print is produced from a real time printer as the flight path is flown. Image detail is also recorded on High Density Digital Tape if future computer processing is required.

The Line Scanner was used four times during the 1983/84 fire season to map fires near Lorne and Gellibrand. The imagery obtained was of a good quality and provided valuable information to fire controllers. The location of fire edges and relevant fire behaviour was mapped at times when normal methods of fire detection were not possible.

In January 1985 the Scanner was used extensively to map fires burning in remote areas of Victoria (Map 1). Many of these fires originated from lightning activity. 20 missions (Table 1) were flown between 14 January and 27 January 1985, 18 (104.1 hours) in a Super King Air 200 (Figure 1) and 2 (11.7 hours) in a Nomad 22B. (Figure 2).

As with many new advances in technology the full realisation of a systems ability is not known till it has been tested to its limit. At first the imagery was used solely to map the fire edge and this information was then passed on to the fire control headquarters. It became apparent as techniques developed that better use could be made of information contained on the imagery itself.

This report outlines the uses of IR imagery and gives guidelines for future operations. It also describes the Scanner operations that occured in Victoria during the 1984/85 fires season and examples of imagery are presented as case histories.

MAP 1 : INFRA-RED LINE SCANNING OPERATIONS - JANUARY 1985

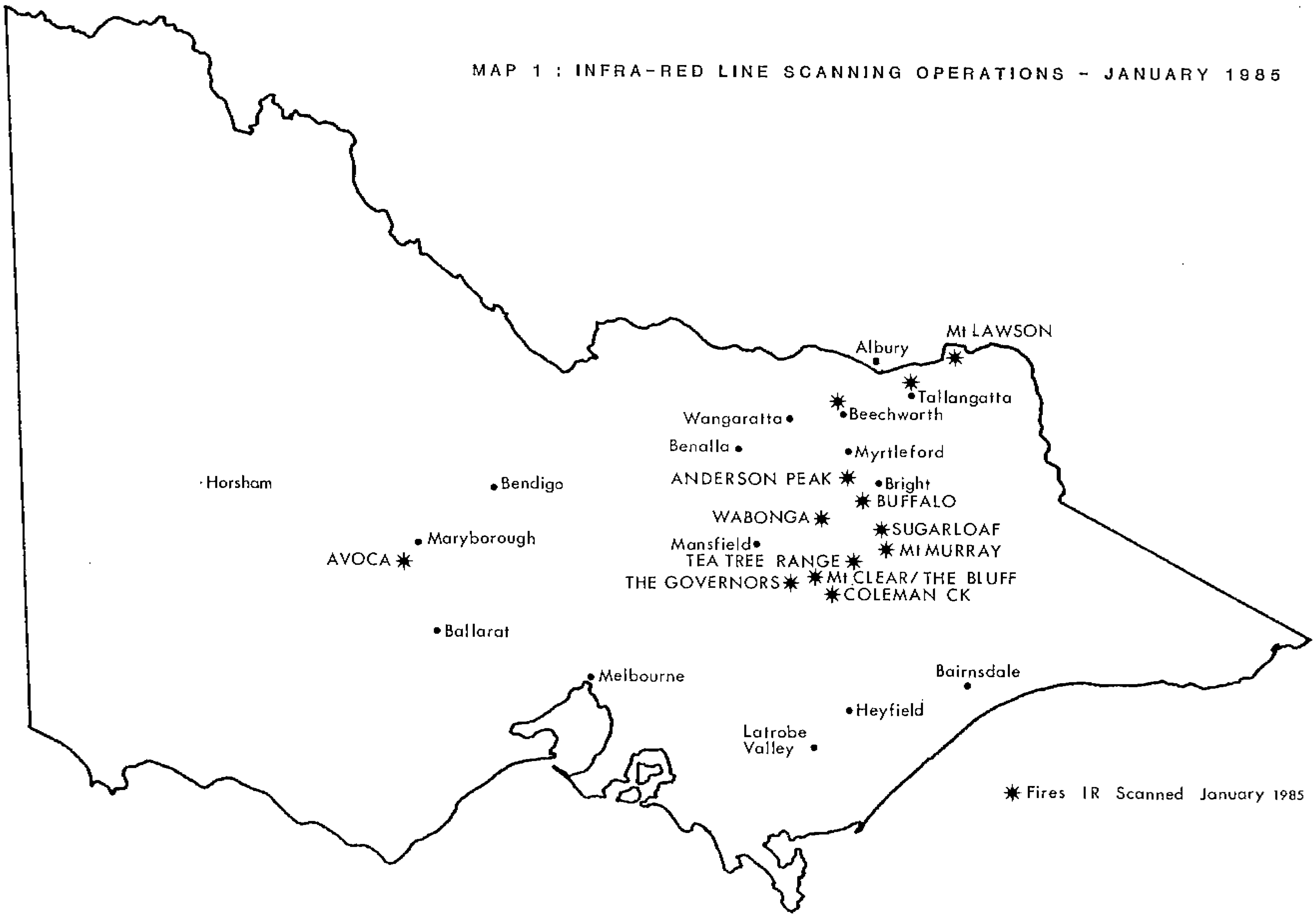


Figure 1 : Super King Air 200

Figure 2 : Nomad 22B

APPLICATIONS OF INFRA RED IMAGERY

There are several uses of line scan imagery at fires.

1. Immediate fire information

By using radio in the aircraft it is possible for key items of fire information to be relayed directly to the fire headquarters or sector boss, increasing the effectiveness of the fire control operation. For this to work smoothly the IR interpreters must be experienced in fire control. They must be briefed on the fire, the areas that are of particular concern, what fire control activities are being conducted if any, and who to contact. Imagery can show the location of the fire, its position in relation to creeks, ridges, roads or settlements, the extent and behaviour of any spot fires and the location and depth of burnt edges on a backburn.

At present this use of IR scanning is under-developed, but as awareness of the value of IR imagery increases information relayed directly from the scanning aircraft will play a more important role in fire control.

2. Fire Mapping

Accurate fire mapping is the main role of this technique. Maps can be prepared in the aircraft and delivered together with imagery by either dropping a message tube or bag at a suitable locality or by landing at a convenient aerodrome. Emphasis on the information mapped, changes with the state of the fire.

2.1 Fire Detection

The imagery can pin point a fire _if_ the general location is known. Known lightning strikes or suspected smoke sightings can be scanned to check if a fire exists. With the King Air scanning at 5000 m a.g.l. each scan is 7 km wide.

3. Fire Development

For a fire which is spreading rapidly and spotting, imagery can be used to accurately map the fire. On a major fire which is spreading a scan may be necessary every five to six hours to maintain a useful fire map. As the fire stabilises and fire control becomes effective, scanning at 12 hourly intervals would be adequate. If other mapping techniques are possible during daylight hours scanning may only be required at night.

3. Fire Control

At this stage the most important aspects are the progress of backburning operations, their effectiveness, the amount of fire activity close to the control lines and the extent and location of unburnt areas within the fire control perimeter. All of these features show up on the imagery. Later, as mopping up takes place scanning can detect hot spots close to the fire perimeter.

3. Imagery

Although maps prepared from IR imagery are extremely useful, the actual imagery is often more valuable as it shows much more detail of the fire behaviour. The imagery not only shows the fire location but also the fire behaviour, the extent of active edges and how these are spreading. This can be valuable for deploying resources, deciding what type of attack to carry out and where it is most likely to be successful. Copies of imagery given to sector bosses at a briefing before their shift shows an up-to-date "picture" of the fire allowing a better appreciation of the fire situation in his sector. They can use this print to brief crews, explain tactics and generally improve fire control operations on the fire line.

This aspect of using imagery will develop as people become more familiar with its use especially if we can produce high quality photocopies or "polariod" type prints of the imagery.

GUIDLINES FOR FUTURE INFRA RED OPERATIONS

The Role of Infra Red Scanning relative to Aerial and Ground Reconnaissance

Experience with IR scanning has proved that it is very accurate, can be carried out relatively quickly, can operate satisfactorily at most times of the day or night and is most useful when normal visibility is reduced by smoke. The effect of cloud can be a limiting factor. Cloud/water vapour produces flat "washed out" imagery making interpretation impossible. Scanning is complementary to existing fire mapping techniques such as conventional aerial and ground reconnaissance. It does not make them obsolete.

Where maps are up to date, aerial and ground reconnaissance can be used to check areas of concern and progress of fire control. Where IR scanned maps of an active fire are several hours old, reconnaissance can be used to up-date the location of fire edges, look at fuel types ahead of the fire and assess the progress of fire control.

Aerial reconnaissance using FLIR (Forward Looking Infra Red is a portable video output sensor), is also very useful, particularly for spot fires or backburns obscured by smoke or where certain sectors of the fire need intense monitoring.

With the considerable improvements in fire information brought about by IR scanning there is a tendency to regard mapping from conventional aerial reconnaissance as being redundant. IR interpreters should ensure that aerial observers review the main features of IR derived maps not only as a check but also to up-date the most important aspects of the fire.

Co-ordination and Liaison

The co-ordination of IR scanning and liaison with fire controllers, and the NSCA is the responsibility of the Central Fire Controller in Melbourne. The Central Fire Controller outlines a priority for scanning from reports by IR interpreters together with demands for additional scanning of other fires from various fire controllers throughout Victoria.

Requests must be considered against any other NSCA operations so the Central Fire Controller or his deputy must have good communication with the NSCA Operations Centre at Morwell as well as a knowledge of the capabilities of NSCA scanning operations. In conjunction with the interpreter the Central Fire Controller may recommend that aerial reconnaissance using FLIR would be more appropriate.

Scanning missions are very demanding and together with other duties, interpreters have to work long shifts. The Aircraft Officer should ensure that there are crew changes or rest periods for interpreters and where possible on-the-job training should be considered for inexperienced interpreters. The interpreter is responsible for maintaining records of scanning missions. Each interpreter keeps a log of every scanning mission, outlining the fires scanned and the aircraft's activities.

Timing

The value of a scanning mission depends on delivering a map or the imagery in time to be useful to fire control. To achieve this it is necessary to consider when is the best time for high quality imagery, what the optimum time is to meet deadlines, and how frequently the fire should be scanned to up-date information.

Meeting deadlines for imagery or maps has the highest priority. When a fire is spreading rapidly it is important to keep the delay between scanning and delivery to a minimum. If the fire changes markedly, imagery can become useless in a few hours. Message tubes dropped at a suitable location close to the fire can speed up the delivery of maps and imagery for both day and night missions.

The frequency of scanning a fire must be balanced against its spread, what changes have developed since the last scan and what other sources of fire information are available. A rapidly spreading fire probably requires to be scanned roughly every six hours. After it stabilises it may need to be scanned on a 12 hour cycle or perhaps only around midnight. As the strength and organisation of fire control increases, the deadline for imagery and maps coincides with the planning period prior to crew changes. When attention is focused on the progress of backburning, scanning around midnight would fit in with command requirements.

For the highest quality imagery, scanning missions are flown from midnight to approximately 0700 hours. Scanning during the day may produce poorer quality imagery although it can still be useful for mapping purposes. Scanning should be avoided during the thermal crossover period (post sunrise and post sunset). Water and land boundaries are difficult to differentiate due to them radiating the same energy at these times.

Mapping

Prior to 1984/85 the mapping of IR imagery took place on the ground from scanning carried out independent of an interpreter. This system was satisfactory for missions scanning one or two small fires such as at Lorne in December 1983. For extensive missions this approach is inefficient and could involve considerable time delays between scanning and mapping.

The mapping system developed in January 1985 relied on a master map up-dated from each scan and a number of plain photocopies used as work maps. The master copy contained the details of every scanning mission outlining the history of the fire. This was particularly valuable for monitoring backburning operations. Work maps, plainimetric photocopies of the previous fire scan are very convenient and simplify the process of transferring current imagery to a map. At least three copies of work maps are necessary for each fire scanned on each mission. One copy is for fire control, one copy for the interpreters for faxing, and the third copy is a spare to be used in case a message tube is damaged or lost.

Each work map is identified by the fire name or number, scale, and time and date of the current and previous scan. Reference to particular aspects of the fire are best emphasised by words, ie. "spot over", "hot spot", "active edge", "unburnt", "cold". Where possible a duplicate of the imagery print should be included with any maps for fire control.

For fire control to operate efficiently there must be an adequate mapping service at the fire. This starts with one or more operations maps, preferably mounted on a wall. These must be updated using the most appropriate information.

Imagery must be displayed in a useful manner together with adequate labelling. The mapping service must also produce multiple copies of up-to-date photocopy type fire maps or sector maps prior to each crew change. These maps are extremely valuable and are used widely, from fire bosses and sector bosses to firebomber pilots and bulldozer operators.

Maps of a convenient scale are the backbone of an efficient scanning operation. The scanning aircraft should be equipped with 1:2 500 000 WAC, 1:250 000 and 1:100 000 topographic maps covering Victoria. Planimetric 1:100 000 maps are much better for faxing, so copies of these maps should be available to the interpreters. All maps must be black and white, good quality dyeline masters.

A light table has now been fitted to the aircraft to aid interpreters.

Crew

The crew for a scanning mission consists of a pilot, co-pilot, Scanner operator and two imagery interpreters. The pilot, co-pilot and Scanner operator are trained NSCA staff.

Two interpreters are required for all but single fire missions. One interpreter is usually occupied with mapping and imagery while the other interpreter can concentrate on navigating, assisting the pilot with maps, grid references, making sure IR scan coverage is adequate, organising map/imagery drops and communications. Even with quite sophisticated navigation aids, visual contact should be maintained with fires which have or have not been scanned, as disorientation can occur when scanning a number of fires.

For each mission to run efficiently the pilot must be briefed. A discussion prior to take off listing the priorities, the location of each fire (latitude and longitude), the scanning height most suitable to obtain a useful imagery scale, arrangements for delivering maps of imagery (drops or landing) and any deadlines for imagery allows the pilot to work out a flight plan to make the best use of flying time and plan for refueling.

Message Tubes

Message tubes are a reliable means of relaying information from an aircraft to the ground anytime of the day. During daylight, provided visibility is satisfactory, drops can be made at any identifiable clear area where the aircraft can get down low enough to drop.

After dark drops can only be made safely at a well lit clearing in relative flat terrain or over a lit airstrip. The lit football oval at Mansfield was quite satisfactory.

Successful message dropping relies on good communication between the aircraft and the ground. The aircraft will usually make one low pass before flying in low to make a drop. People on the ground should stand clear of the flight path to avoid any possibility to being struck by a message tube and when it is recovered this should be acknowledged or arrangements made to make another drop.

Two types of message tube have been used to drop information from aircraft.

The yellow fabric message bags supplied by NSCA performed well on daylight drops, however, the bags tend to be too heavily weighted for their shape. On impact either the bag or its contents were easily damaged. This is being rectified.

At night time, cylindrical drop tubes fitted with a light and beeper performed well. It is essential to have any drop tubes for night work fitted with a light and a length of brightly coloured ribbon.

INFRA RED LINE SCAN OPERATIONS - JANUARY 1985

Use of the Nomad aircraft was limited because the scale of the scanning operation was too extensive to be carried out by this aircraft in the time available. The Nomad was first used to scan the Avoca fire on 14 January 1985 and the next morning (15.1.85) flew a mission over the Mt Buffalo fires.

Because the Avoca fire was too large (50 000 ha) to scan completely with this aircraft, scanning was concentrated on the active fire edges, roughly a triangle between Avoca, Clunes and Carisbrook. Flying at an altitude of 2500 metres the Nomad encountered turbulence from the fire and drift from a strong south easterly wind. This, plus the absence of a clearly defined fire edge in grassland made navigation and scanning extremely difficult. Even though the fire edge was flown twice the scan coverage was incomplete. Some of the imagery quality was very poor, both in the background response, and the sensitivity of the event marker. These problems were caused by the relatively high surface temperatures (maximum temperature on 14.1.85 was 41^{o}C), vegetation in the fire area and heat generated by the fire.

Dry grass in the fire area kept surface temperatures high compared to recently burnt grassland. This made interpreting burnt and unburnt grassland areas difficult.

The large size of the fire combined with the relatively low scan height meant that frequently the IR sensor was so saturated by radiation from the fire that the sensor could not detect background radiation. Saturation of the sensor results in washed out background imagery.

With the event marker not operating at the desired sensitivity, spotfires and burnt areas outside the main fire were not identified on the imagery.

The Nomad mission over the Mt Buffalo fires on 15 January 1985 was flown at an altitude of 3000 metres. Scanning the entire fire required 15 runs over a period of more than 1.5 hours. Turbulence from the fire caused some navigation difficulties and distortion to the imagery. The event marker was not sensitive enough but the background response shown on the quick-look prints was quite good.

Although there were problems with both missions flown by the Nomad, the maps and imagery were extremely valuable.

The first King Air scanning mission was flown over the Mt Buffalo fires late on 14 January 1985. Cloud prevented scanning from an altitude of more than 4000 metres and low level cloud obscured the imagery on some runs.

The next mission on the afternoon of 15 January 1985 was more extensive although the Mt Buffalo fires could not be scanned due to the convection column, general smoke and cloud. Scanning was possible over the Wabonga fire at an altitude of 6000 metres and also over the Beechworth fire. Four, day-time missions were flown during the week because conventional mapping methods were being restricted by an inversion trapping smoke in the valleys.

The night-time missions were more extensive. On the night of 15 - 16 January 1985, eight fires were scanned, accurately mapping many remote lightning strikes. Cloud over Mt Buffalo forced scanning down to an altitude of 4000 metres. Similar missions to this were flown each night until 27 January 1985.

Where possible maps, and in some instances imagery as well, were dropped close to the fire. Day-time drops took place at Tallangatta (1), Bright arboretum (3), Beechworth football oval (1) and the Mansfield football oval (2): Night-time drops were only attempted at Mansfield (3) due to the terrain at Bright. Where drops were not possible the information was either delivered by the interpreters after a mission was completed or relayed to a messenger at an aerodrome. Albury (1), Wangaratta (2).

Table 1. Summary of Infra Red Line Scan Operations - January 1985

Flight Times	Hours	Aircraft Type	Mission Details
14.1.85 2055 15.1.85 0315	5.0	Nomad	Map Avoca fire
14.1.85 2352 15.1.85 0333	3.4	King Air	Map Mt Buffalo fires
15.1.85 0525 15.1.85 1358	6.7	Nomad	Map Mt Buffalo fires
15.1.85 1143 15.1.85 2115	6.0	King Air	Map Mt Buffalo, Wabonga, Beechworth
15.1.85 2229 16.1.85 0617	6.0	King Air	Map Mt Buffalo, Beechworth, Wabonga, Sugarloaf, The Governor, The Bluff, Nelson Creek, Tea Tree Range
16.1.85 1325 16.1.85 2025	5.65	King Air	Map Mt Buffalo, Mt Lawson, Wabonga
16.1.85 2058 17.1.85 0740	8.5	King Air	Map Mt Buffalo, Wabonga, The Bluff The Governor, Tea Tree Range, Nelson Creek
17.1.85 1314 17.1.85 2134	6.8	King Air	Map Mt Buffalo, Wabonga, Mt Sugarloaf
17.1.85 2235 18.1.85 0845	7.9	King Air	Map Mt Buffalo, Wabonga, The Governor, The Bluff, Mt Sugarloaf, Tea Tree Range, Nelson Creek, Murray River fires
18.1.85 1048 18.1.85 1855	7.1	King Air	Map Mt Baffalo, Wabonga, Mt Sugarloaf, Nelson Creek, Tea Tree Range
19.1.85 0025 19.1.85 0613	6.2	King Air	Map Wabonga, Mt Buffalo, Mt Sugarloaf, Nelson Creek
19.1.85 2206 20.1.85 0518	6.6	King Air	Map Mt Buffalo, Mt Sugarloaf, Mt Murray, Tea Tree Range, Coleman Creek
20.1.85 2200 20.1.85 0510	6.4	King Air	Map Wabonga, The Governor, The Bluff, Coleman Creek, Mt Murray, Mt Sugarloaf
21.1.85 1330 21.1.85 1650	3.0	King Air	Map Mt Sugarloaf, Mt Murray

Table 1 (continued)

Flight Times	Hours	Aircraft Type	Mission Details
21.1.85 2208 22.1.85 0415	5.95	King Air	Map Mt Buffalo, Wabonga, The Governor, The Bluff, Coleman Creek
22.1.85 2210 23.1.85 0241	4.7	King Air	Map Mt Buffalo
23.1.85 2202 24.1.85 0337	5.25	King Air	Map Mt Buffalo, Mt Sugarloaf, Mt Murray
24.1.85 2215 25.1.85 0255	4.9	King Air	Map Mt Buffalo, Mt Murray, Sugarloaf
25.1.85 2202 26.1.85 0310	5.4	King Air	Map Mt Buffalo
26.1.85 2158 27.1.85 0220	4.4	King Air	Map Mt Murray, Mt Buffalo, Mt Sugarloaf

Costs

King Air and Nomad	(0 - 3 hours $1250 per engine hour (3 + hours $1095 per engine hour (Fixed daily hire $1500

Both the Nomad and King Air are based in the Latrobe Valley. With the long periods of flying for scanning missions these aircraft made use of Albury, Ballarat, Benalla and Wangaratta aerodromes. Refueling for scanning outside normal hours was a problem except at Latrobe Valley.

Of the two aircraft used in the January 1985 IR missions, the King Air was the most suitable. The King Air is a much faster aircraft than the Nomad and with the pressurised cabin it can fly at a much higher altitude whereas the Nomad is restricted to around 4000m. Scanning operations with the King Air can be flown quicker and at a convenient scale to suit fire operations.

Inside the King Air the passenger compartment is very comfortable. The IR equipment does not interfere with movement or communications between the IR operator, the interpreter and the pilots. There is sufficient room to read maps or to transfer imagery. The King Air's role is more suited to fires larger than 10,000 ha or where a number of fires have to be scanned.

The Nomad is much slower and cannot fly high enough to obtain a useful scale on a large fire. Drift and turbulence have a greater impact on the Nomad, this makes navigation more difficult and it can distort the imagery.

The passenger compartment of the Nomad is noisy and the infra red equipment prevents easy access so it is difficult to communicate with the pilot. Seating is inadequate for long missions. Despite these problems the Nomad is suitable for scanning fires up to 10,000 ha.

CASE HISTORIES OF INFRA RED IMAGERY

Case 1: Mt Sugarloaf Fire

When the fire was first scanned at 0129 hours, 16 January 1985, the only detail known was its approximate location. As can be seen from Figure 3 the scan shows the exact location of the fire, its size (approximately 100 hectares) and the fire behaviour such as the active and inactive edges.

The second scan (Figure 4) flown at 0131 hours 17.1.85, shows the fire burning actively to the east. Its size was now approximately 200 hectares.

The scan flown at 0400 hours 21.1.85 (Figure 5), shows that a tongue of fire has spread rapidly uphill along a spur from the Buckland River toward a weak backburn near the Twins, while there is a large spotfire burning on the eastern edge across the control line.

Case 2: Mt Buffalo Fire - Early Spread

The Mt Buffalo fire started from lightning strikes on 14.1.85. These developed very quickly as shown by the first scans flown at 0122 and 0134 hours, 15.1.85 (Figure 6 and 7). They clearly show the fire shape and mass spotting. Colder areas inside the fire indicate the location of early fire activity, close to the fire origins. The speckled regions represent cooler areas or areas burnt earlier. The images show a large area burnt earlier on the Mt Buffalo plateau but several other fires also have much cooler centres suggesting they originated from lightning strikes rather than from spotting.

Case 3: Mt Buffalo Fire - Backburning

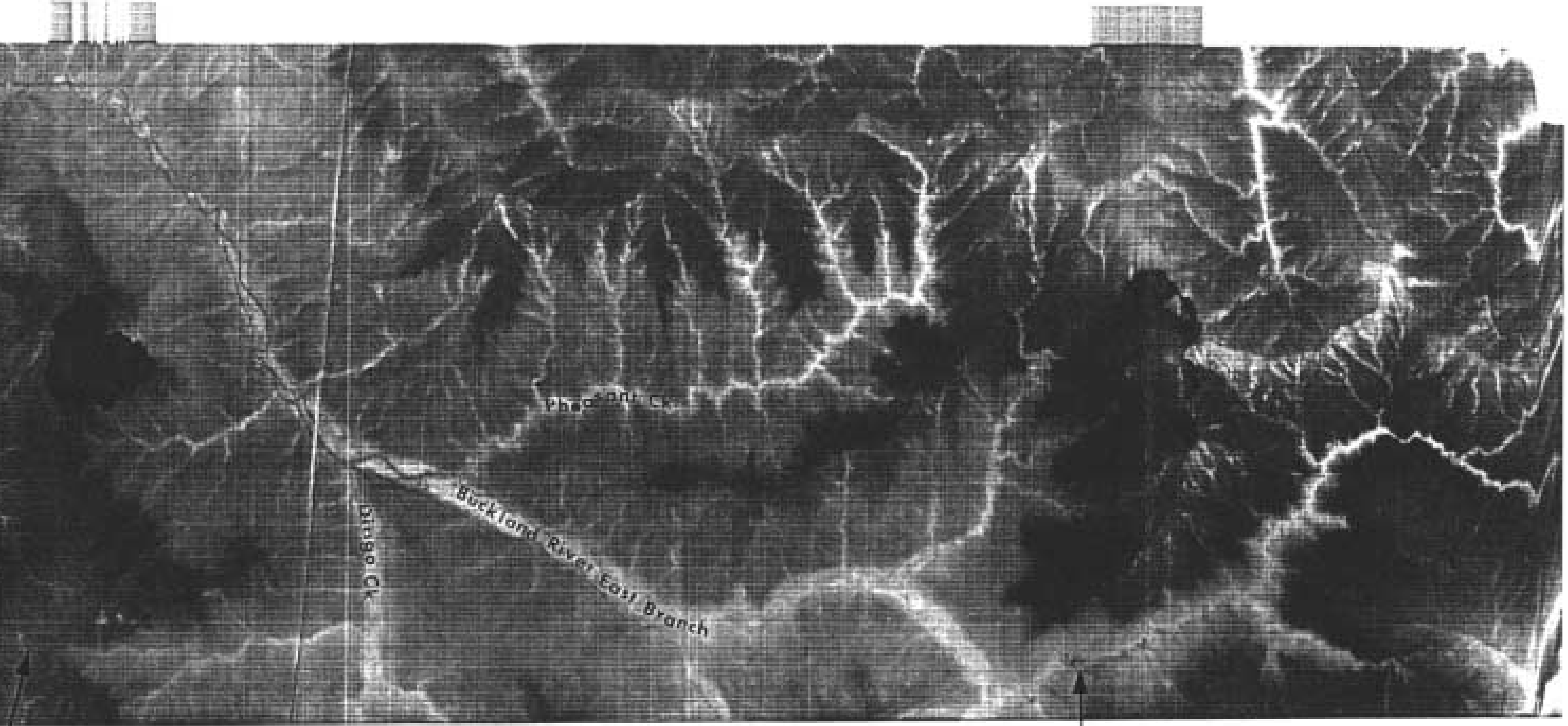
The scan flown at 0405 hours, 16 January 1985 (Figure 8), shows not only fire development but the progress of backburning. The fire has crossed Morses Creek, south of Wandiligong and a backburn has completed along Dingo Ridge, south of Bright. Another backburn was in progress from Eagle Peak along the ridge through Clear Spot.

Backburning, as shown by the scan at 0609 hours, 17 January 1985 (Figure 9), has advanced along the private property to the east while the sector along the spur in forest, south of Smoko has burnt well.

This backburn has progressed well but the scan flown at 1950 hours, 17 January 1985 (Figure 10), shows two indicated points where the burn is quite shallow.

Later scans clearly showed that spotting from unburnt fuels close to the control line at a weak point in the backburn, developed into a troublesome breakaway. This was detected and suppressed quickly. Other weak points were watched closely and strengthened by additional backburning.

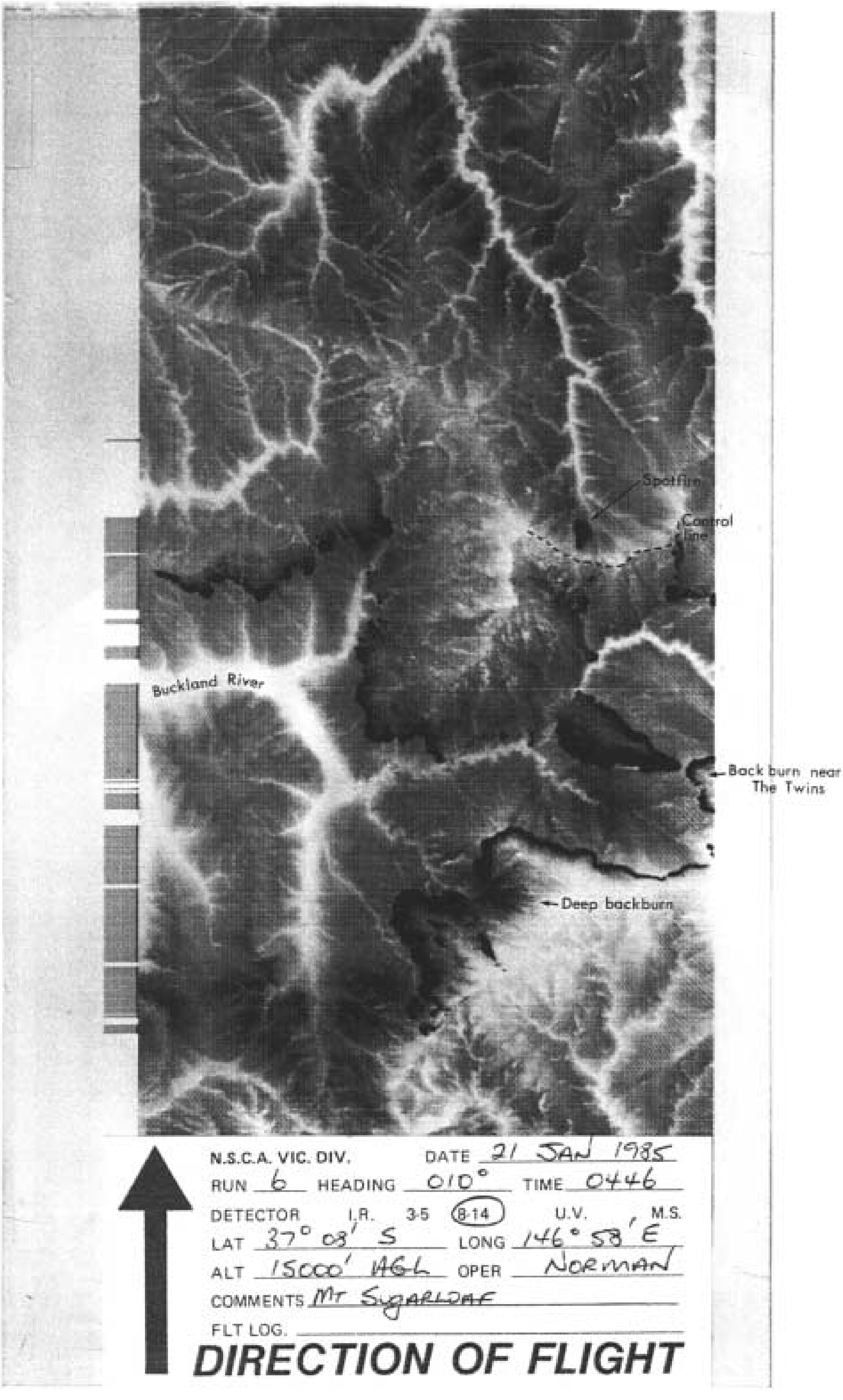
development

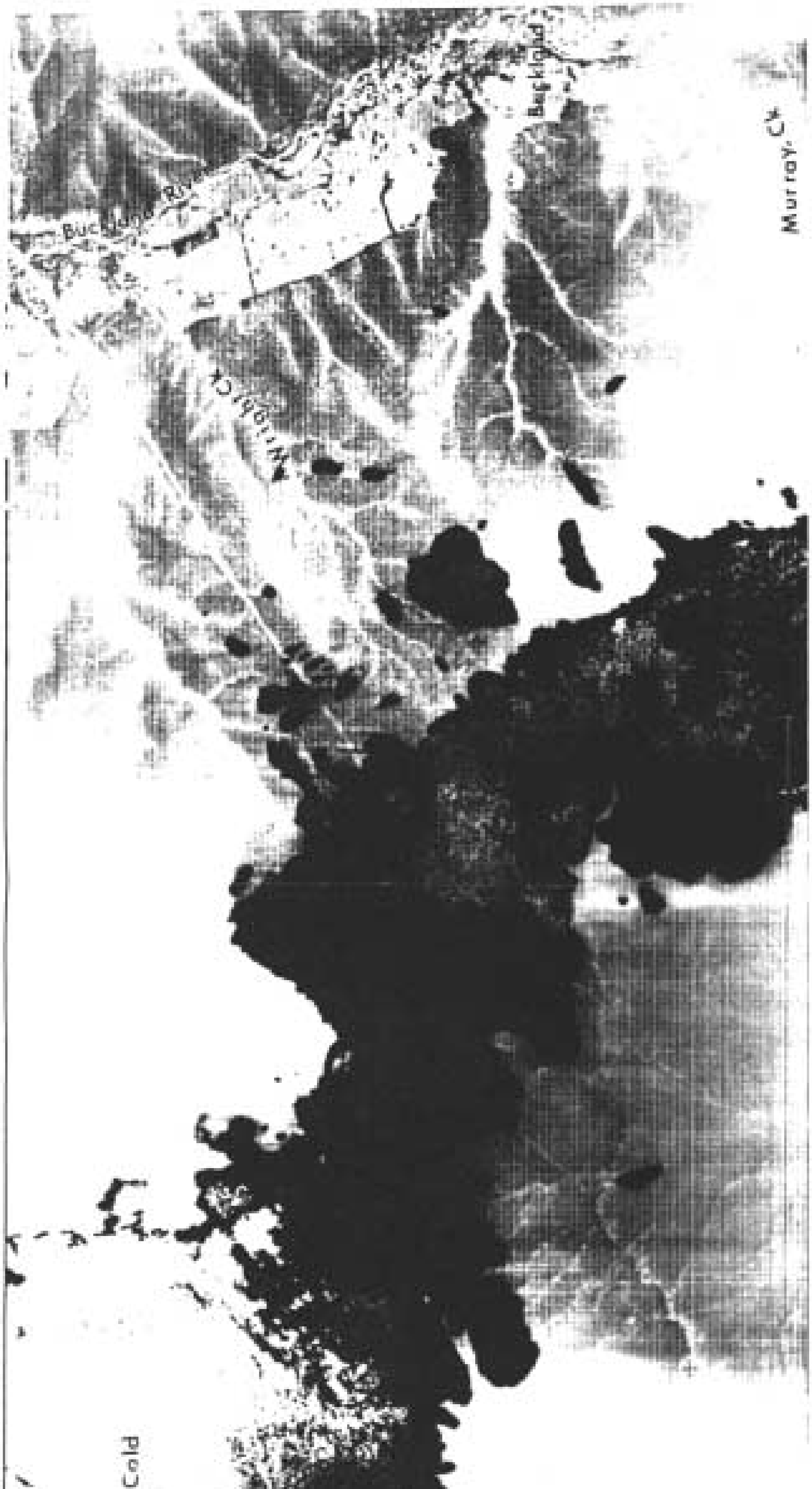


n Ck fire

Mt Sugarloaf fire

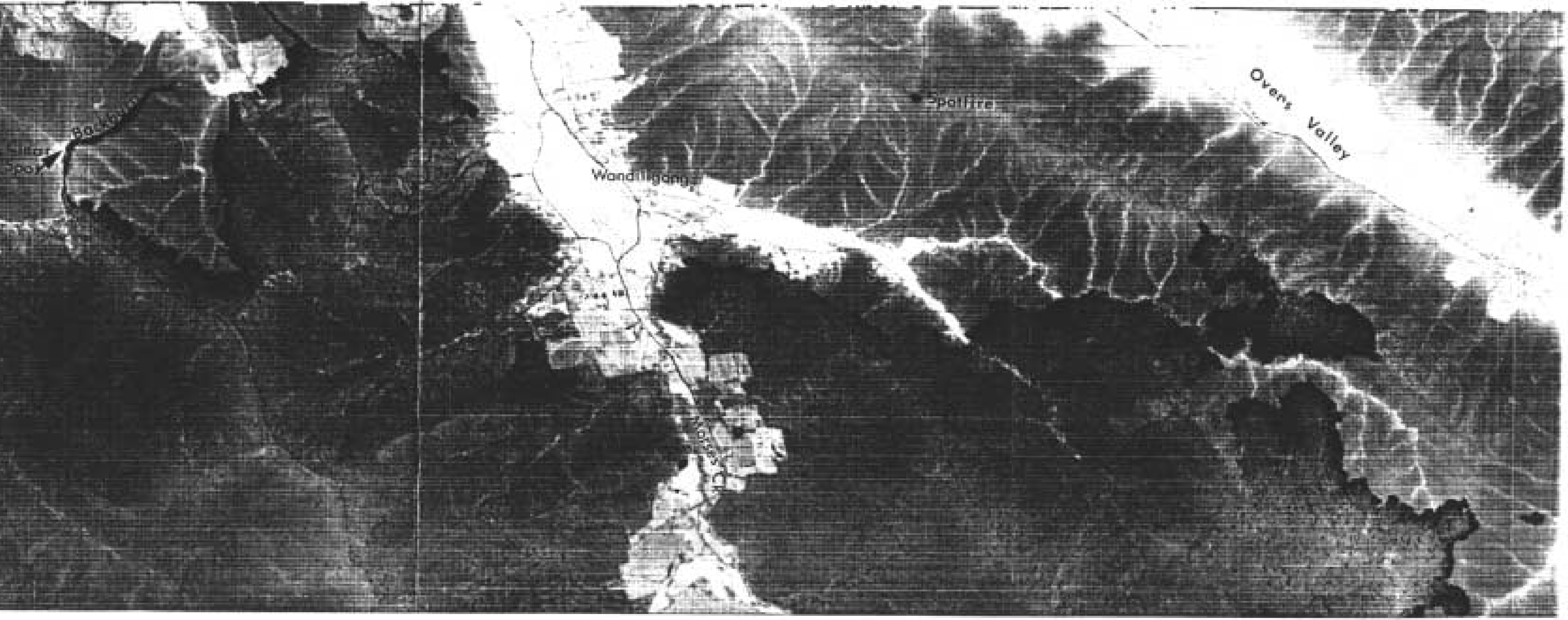
Figure 5 : Mt Sugarloaf fire - 21 January 1985





N.S.C.A. VIC.
RUN 3
DETECTOR
LAT

ckburning


Ovens Valley
Spotfire
Wandiligong
Backburn

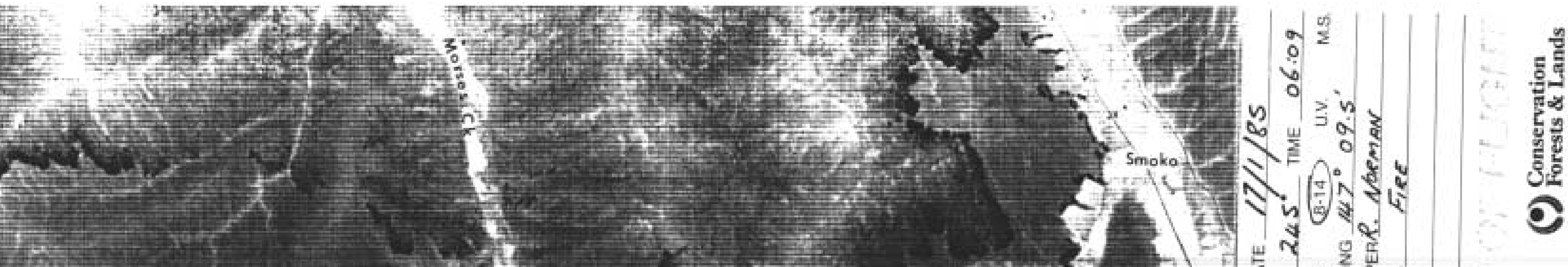

Morses Ck
Smoko
TE 17/1/85
245 TIME 06:09
8-14 U.V. M.S.
NG 147° 09.5'
ER R. Norman
Fire
Conservation Forests & Lands

Figure 10 : Mt Buffalo fire - Backburning

N.S.C.A. VIC. DIV. DATE 17 JAN 1985

RUN 8 HEADING 340° TIME 1950

DETECTOR I.R. 3-5 (8-14) U.V. M.S.

LAT 26° 57' S LONG 147° 02' E

ALT 15000' OPER McMILLAN

COMMENTS

FLT LOG. MT BUFFALO

DIRECTION OF FLIGHT