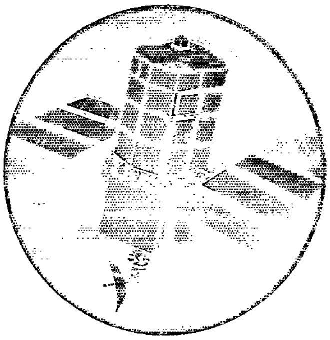
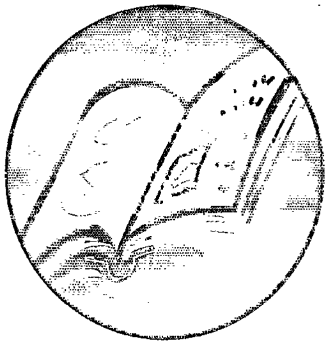
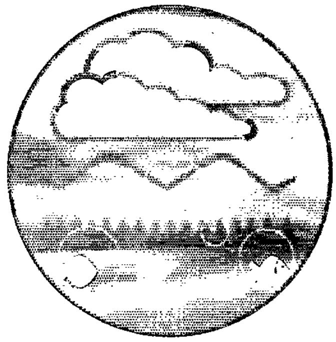
Satellite Alarm Field Evaluation (SAFE) - Field Trials

Research and Development

Technical Report
W129

ENVIRONMENT AGENCY

Satellite Alarm Field Evaluation (SAFE) - Field Trials

Technical Report W129

K Lee and A Bathurst

Research Contractor:
Kennedy & Donkin Ltd

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This document was produced under R&D Project W5A036 by:

Kennedy & Donkin
Westbrook Mills
Godalming
Surrey
GU7 2AZ

Tel: 01483 425900 Fax: 01483 425136

Environment Agency's Project Manager
The Environment Agency's Project Manager for R&D Project W5A036 was:

Malcolm Tyler - Anglian Region
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GLOSSARY

ACPO	Association of Chief Police Officers
C-S	COSPAS-SARSAT
COSPAS	'Cosmicheskaya Sistyema Poiska Avariynich Sudov', Russian meaning Space System for the Search of Vessels in Distress
DF	Direction Finding
ELT	Emergency Locator Transmitter
EPIRB	Emergency Position-Indication Radio Beacon
GPS	Global Positioning System (a constellation of 24 satellites used for a radionavigation system developed by the US Department of Defence)
Ground Segment	The Earth-based part of the C-S system.
LUT	Local User Terminal
LWB	Lone Worker Beacon
MCC	Mission Control Centre
MHz	Megahertz
PLB	Personal Locator Beacon
RF	Radio Frequency
RCC	Rescue Coordination Centre (also known as SPOC)
SARSAT	Search and Rescue Satellite-Aided Tracking
SPOC	Search and Rescue Point of Contact

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- Sullivan Marine Limited
- Sartech

EXECUTIVE SUMMARY

The Environment Agency (Agency) has an interest in providing an increased level of emergency protection for its lone workers and investigations have been conducted under the Satellite Alarm Field Evaluation (SAFE) project.

The assessment of the COSPAS-SARSAT (C-S) satellite system is presented in this report. The C-S system, operational for well over 10 years, gives continuous global coverage from six polar orbiting satellites that are able to detect signals from hand-held distress beacons. These satellites re-transmit beacon signals down to 'Local User Terminals' (LUTs) (of which there are over 30 world-wide). From the beacon signals, the LUTs then obtain beacon identification and two position estimates with associated probabilities (two are obtained as a result of the Doppler frequency shift in the beacon signal). This information is then passed to a Mission Control Centre (MCC) who co-ordinate search and rescue activities. Trials of the system were conducted in October 1997, which confirmed that beacon detection time is highly dependent upon the type of terrain local to the beacon. During typical working hours (7am to 7pm), 87% of beacons were detected within an hour at a flat open site, compared to 51% in a severe valley. All the beacons were detected. At only the 2 most severe trial sites (16 were tested) did it take over 6 hours during typical working hours for all beacons at those sites to be detected.

80% of position estimates were shown to be within a 1.78 kilometre (km) radius of the true location for an open site, compared to 44% at a location at the bottom of a cliff, where sky visibility was severely restricted.

It was found that more satellites detected beacons during daylight hours, hence detection times were slower at night. This is due to the fact that the satellites are sun-synchronous. However, it was concluded from satellite path prediction analysis that coverage gaps of up to 4 hours around midnight, as seen on the trial, are not likely to be exceeded.

Other factors that may effect system performance were also considered, such as satellite signal processing time, propagation delay, beacon warm-up time, decreased satellite visibility and low elevation angles. However, it was concluded that decreased satellite visibility and low elevation angles are the most prominent parameters that will decrease performance. Trials also included the assessment of data from an overseas LUT. It was concluded that beacon information detected by an overseas LUT that has not been detected by the UK LUT will be passed through the C-S ground segment back to the UK, in order to speed up alert response times.

Implementation issues that may effect the Agency are discussed in the report:

- registration of land-based UK beacons, in line with practice overseas, would first need to be sought;
- consideration should be given as to whether the Agency would wish to conduct its own search and rescue activities;
- the format of communication between the UK MCC and the Agency will need to be considered.

Use of the system is considered low risk as international support is considerable and technical developments are continuing, the imminent ones being the full-scale inclusion of geostationary satellite data to provide quicker beacon detections as well as the inclusion of more positional

information utilising satellites from the widely used Global Positioning System (GPS), which is accurate to within 50 metres.

It is recommended that the use of the C-S system by the Agency is given serious consideration, as well as conducting a pilot study within an Agency region. This will give an indication of the organisational issues involved and should include an assessment of direction finding equipment and frequencies of homing signals emitted by the beacons.

Key words

COSPAS, SARSAT, satellite, lone worker, locator beacon, trial, search and rescue

1. INTRODUCTION

1.1 Purpose of Document

The following report presents the evaluation and results from trials of the COSPAS-SARSAT (C-S) satellite system, undertaken in October 1997.

The report firstly discusses the background to the project, the objectives of this study, followed by a brief description of the C-S system. Trials and results are then presented, followed by a discussion of the implementation issues that are anticipated if an organisation were to use the C-S system to provide a lone worker beacon (LWB) facility.

1.2 Background

The Environment Agency (Agency) has an interest in providing an increased level of protection for lone workers, so a worker in distress can raise an alarm in order to summon help in a timely manner. With lone workers often working in remote areas, the reliability of an alarm system in all geographical areas and in different terrain conditions is an essential requirement.

The use of Personal Mobile Radio (PMR) systems has been considered, however not all Agency regions are covered. Cellular systems have also been considered, but as coverage is concentrated on areas with reasonable population densities, many rural areas lack coverage. This has been supported by assessing cellular telephone coverage operation at sites used in the trials presented in this report, which showed that mobile telephones worked at only 4 out of 14 sites (see Appendix II). The Agency has therefore considered the use of a satellite based system which provides global coverage. Initial trials of the C-S system were conducted in October 1994 (NRA, 1994) and although this gave a useful indication of system performance, a need for further investigation of the system was identified.

Additional research has also been conducted as part of this project into emerging satellite telephone technology (Agency, 1998).

1.3 Objectives of Cospas-Sarsat System Study

The main objective of the study was to determine functionality, performance and operational requirements of the C-S system for use by the Agency in the emergency protection of its staff working alone.. The following actions were identified:

(i) Through field trials, assess system functionality and performance. This included:

- verification of the conclusions from the previous trials conducted in October 1994 that detection delay is dependent upon terrain, by deploying beacons at a larger number of geographically varying sites;
- investigation of the accuracy of beacon positional information calculated by the system and whether positional accuracy is dependent on terrain local to the beacon;
- investigation as to whether, if a beacon is turned on whilst a satellite is passing overhead, the beacon is not detected until the next complete satellite pass and if so, at what percentage of a satellite pass this cut-off time occurs;

- investigation as to whether other factors, such as beacon warm up time and processing time, have a significant effect on detection times;

- investigation of the reliability of the data link from the beacon to the ground segment;

- assessment of information from foreign ground segments and determination of whether inclusion of this information gives significantly lower detection times compared to those seen on last trial or whether the foreign terminals generally only, provide information that has already been seen by UK ground segment;

- consideration of performance of the system, as far as possible, with the inclusion of geostationary satellite information.

(ii) Assess the status of the C-S system and its ability to provide a long term LWB facility. The aim was to identify main system participants, financial and technical support and future development of the system.

(iii) Determine the implementation issues involved if an organisation wishes to set up a land based LWB facility within the UK. Aims included:

- identification of regulatory and legislative changes that may be required to enable use of the system on land within England and Wales;

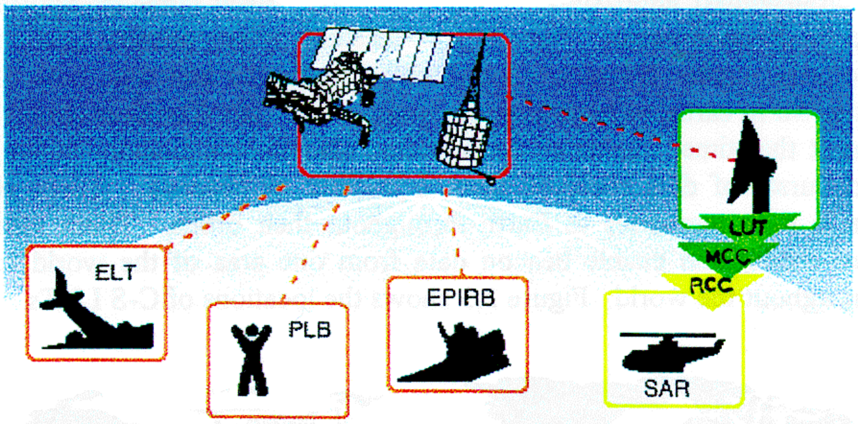
- operational requirements for implementation of such a system within the Agency.

2. COSPAS SARSAT SYSTEM OVERVIEW

2.1 History

In response to a specific search and rescue case in which a United States (US) aircraft was lost, a mandatory beacon system was initially developed in the 1970s for all US aircraft. The beacons transmitted a homing signal (at 121.5 MHz, the international maritime distress frequency) to be detected by search and rescue aircraft. However, after several years, limitations of this system became apparent and a more sophisticated satellite system named SARSAT was developed as a joint effort between the US, Canada and France. The COSPAS system was developed by the former Soviet Union. The four nations then joined forces to form the Cospas-Sarsat system and in 1984, the system became fully operational. The system has been developed for emergency beacons operating on a frequency of 406 MHz, although it is also able to process the original 121.5 MHz beacon signals.

2.2 System Configuration



KEY:	ELT	Emergency Locator Transmitter
	PLB	Personal Locator Beacon
	EPIRB	Emergency Position-Indication Radio Beacons
	SAR	Search and Rescue
	LUT	Local User Terminal
	MCC	Mission Control Centre
	RCC	Rescue Co-ordination Centre

Figure 2.1: The COSPAS-SARSAT System Concept

The purpose of the C-S system is to collect and process alert signals sent from beacon users in distress and inform appropriate organisations of the alert so that rescues can be instigated as quickly as possible. The system operates 24 hours a day, seven days a week.

Six satellites form the space segment of the C-S system: Cospas-4 (C4), C6, Sarsat-2 (S2), S3, S4 and S6. All of the satellites travel in ‘near polar’ orbits and each satellite orbits the Earth in about 100 minutes, with any single spot on the Earth’s surface remaining in view of a satellite for about 15 minutes. Each satellite has a footprint on the Earth’s surface which is over 4000 kilometres (km) wide. Figure 2.2 shows two typical satellites orbiting in near polar orbits.

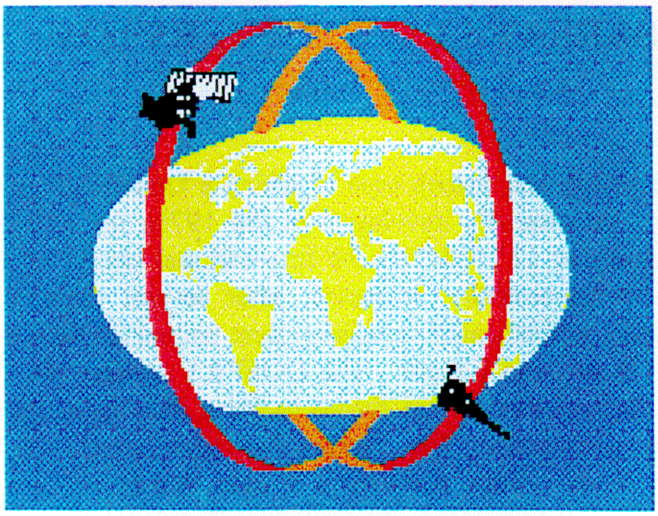


Figure 2.2: Near Polar Orbits

An activated beacon transmits a signal consisting of a burst of information, a few milliseconds (ms) long, which is retransmitted approximately every minute. Each burst of information contains a unique identity code for the beacon. The signal is detected by any passing satellite that 'views' the beacon in its footprint. After the satellite has added frequency and time data to the signal, it is transmitted back down to earth, to be processed by any Local User Terminal (LUT) that is within the satellite footprint at that time. Some of the satellites also have a memory buffer, which can hold several thousand bursts of data received from a number of beacons. These satellites continue transmitting data in their memories to Earth throughout their orbits. These satellites are said to operate in 'global mode' and enable beacon data from one area of the world to be detected by several LUTs throughout the world. Figure 2.3 shows the locations of C-S LUTs.

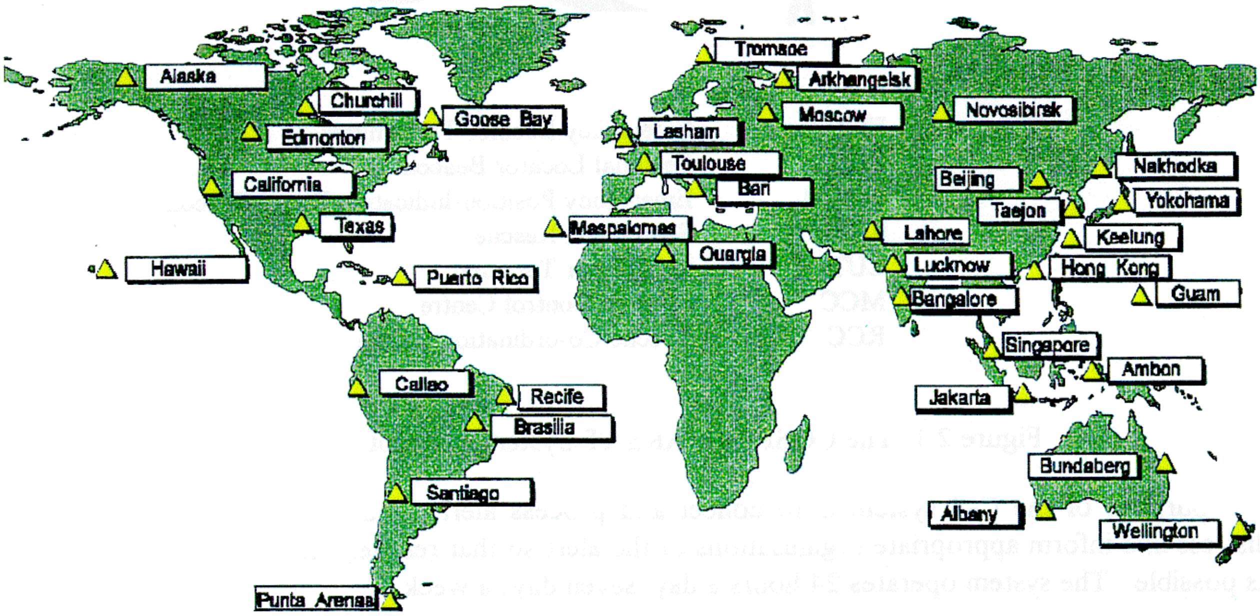


Figure 2.3: Cospas-Sarsat LUT Locations (July 1997)

Once the satellite has passed out of view of the LUT, the resulting alert message processed by the LUT is sent to the local Mission Control Centre (MCC), typically 1-2 minutes after the end of the satellite pass. There are approximately 19 MCCs in the C-S MCC network; the majority of countries with a LUT also have an MCC.

The message transmitted to the MCC includes the identity of the beacon, as well as two positional estimates, each with an associated probability. The positional estimates and probabilities are calculated using 'Doppler frequency shift' information, the apparent change in frequency as a receiver moves with respect to a travelling frequency wave; for example, the apparent change in pitch of a fire engine siren as it approaches. Although two positional estimates are obtained, one has a much higher probability of being right, the other one often being tens of thousands of kilometres in error. In many cases, wrong positional estimates can also be dismissed, either by a telephone call from the MCC to the organisation with whom the beacon is registered, or if the estimate is in the sea and the beacon a land-based type.

Before acting upon the information, the MCC will firstly assess whether the beacon is registered locally or with another MCC. If it is registered with another MCC, the beacon information is passed on to that MCC. Otherwise, the MCC will then contact an appropriate local Search and Rescue Point of Contact (SPOC). In the UK, the LUT is located at Lasham, the MCC at Kinloss and the SPOC for marine beacons is the local Coastguard.

2.3 Beacons

Three types of emergency beacon are used in the C-S system: Emergency Locator Transmitters (ELTs) for aircraft, Emergency Position-Indication Radio Beacons (EPIRBs) for marine use and Personal Locator Beacons (PLBs). The latter type are for land use and were the type used in the trials described in this report.

Although all three types of beacons are used worldwide, land-based PLBs are not currently licensed for use in the UK, although they are registered in other countries such as Russia and Canada. There are also a number of organisations within the UK that are interested the use of PLBs for lone worker safety purposes.

2.4 Future Development of the C-S system

In July 1984, the 'International Cospas-Sarsat Programme Agreement' was signed by all system participants. The agreement has ensured long term continuity of the system, both financially and technically, as well as allowing the opportunity for other states to join on a non-discriminatory basis and has guaranteed the system to be free of charge to the end user (apart from the initial cost of beacons). There are now well over 135,000 406 MHz and 590,000 121.5 MHz beacons registered worldwide. Figure 2.4 indicates the increase in 406 MHz beacon usage that has been seen since 1991.

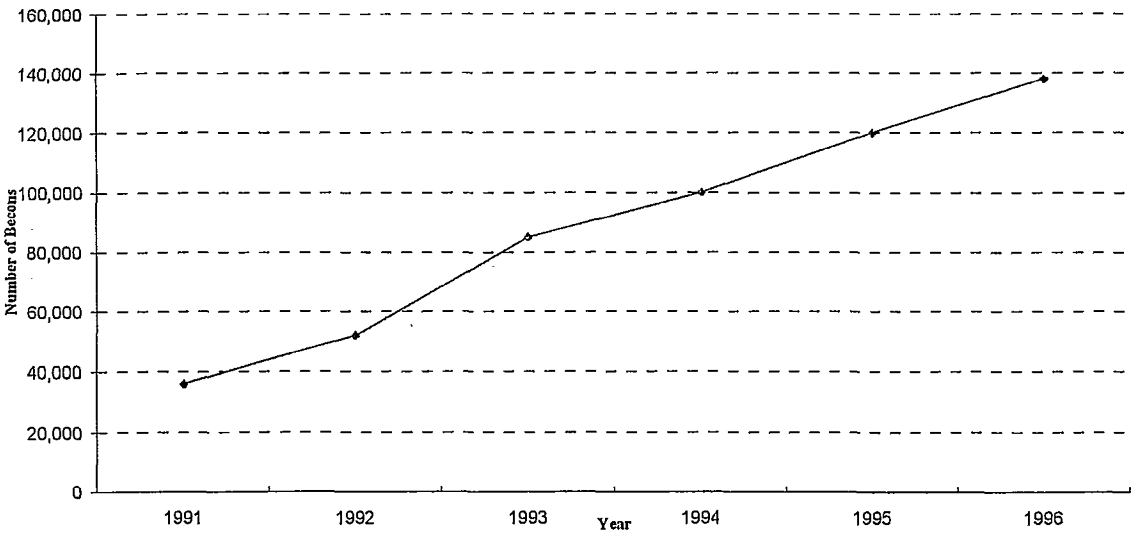


Figure 2.4: Worldwide 406 MHz Beacon Population

System ground segment participation has also continued to grow and there are now 29 nations participating. In July 1997, 19 MCCs in 19 countries and 38 LUTs in 21 countries were operational, with a further 3 MCCs under test. All ground segment providers are supported by government agencies.

Table 2.1 lists current and planned system payloads (C-S WWW) The C-S system has also begun the demonstration and evaluation of incorporation of 'geostationary' satellites (satellites which remain fixed above a single point above the Earth's surface). Canada, France, India, Russia, Spain and the UK are all involved in this phase and data gathered by their geostationary ground stations (GEOLUTs) is being actively used to assist in alerts and being distributed using the MCC network. Figure 2.5 shows the locations of the geostationary satellites and their footprints and the GEOLUTs that are participating in the demonstration and evaluation.

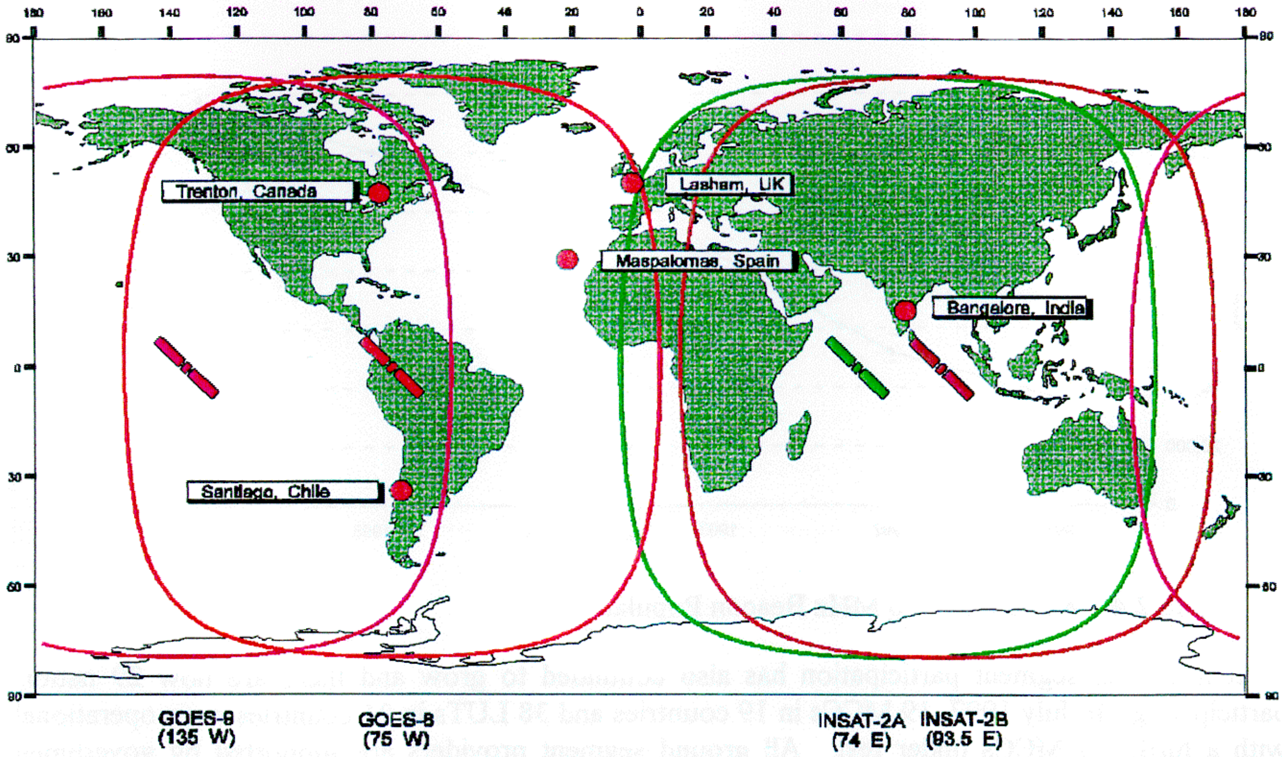


Figure 2.5: 406 MHz GEOSAR Systems (Satellite Coverage and GEOLUTS)

Although geostationary satellites are not able to provide positional information as they do not move with respect to Earth, they are advantageous in the fact that they are at higher altitudes: beacons, particularly nearer the centre of geostationary footprints, will 'see' the satellites higher in the sky. Signals are therefore less likely to be obstructed by local terrain and can be processed more efficiently. Beacon identities can therefore in general be detected more quickly by geostationary satellites.

In addition to this, EPIRBs are currently being developed that incorporate 'Global Positioning System' (GPS) receivers. However, because the beacon protocol used in the C-S system has reserved space for additional positional encoding information, the GPS facility remains an option for all types of users.

The incorporation of GPS and geostationary satellites into the existing system will serve to further reduce alert times and increase positional accuracy, thereby increasing system performance.

Table 2.1: Current and Planned C-S System Payloads

C-S Payload	Spacecraft	Launch Date	Status
C4	Nadezda-1	July 1989	In operation
C6	Nadezda-3	March 1991	In operation
C8	Nadezda-5	Projected 1998	Ready for launch
S2	NOAA-9	December 1984	In operation
S3	NOAA-10	September 1986	In operation
S4	NOAA-11	September 1988	In operation
S6	NOAA-14	December 1994	In operation
S7	NOAA-K	Projected 1998	Ready for launch
S8	NOAA L	Projected 1998	End of test phase
S9	NOAA-M	To be determined	
S10	NOAA-N	To be determined	

3. DESCRIPTION OF TRIALS

Four land-based PLBs (see Appendix III for technical details) were obtained for the C-S trials. Each beacon was test coded and homer frequencies (a separate signal that is transmitted by the beacon to assist in search and rescue) were turned off. The unique beacon identity code for each beacon was supplied to the British LUT, based in Lasham, who agreed to collect all test beacon data from the satellite passes that they tracked (a single LUT is unable to track all satellite passes; a timetable is therefore used to co-ordinate tracking between the LUTs). Lasham was also able to collect samples of overseas LUT and geostationary satellite data. The UK MCC (based at Plymouth at the time of the trials, now relocated to Kinloss) was also consulted before trials commenced; although close liaison with the MCC was achieved and details of trials dates were supplied to them, the MCC was not directly involved in the trials as search and rescue teams were not used.

Two weeks of trials were conducted. As a main objective of this trial was to assess the affect of local terrain on C-S system performance, a number of sites were selected that demonstrated varying local topography. For example, a beacon situated in flat open location is able to view a satellite closer to the horizon and for a longer period than a beacon placed in a valley or at the bottom of a cliff. Figure 3.1 demonstrates this.

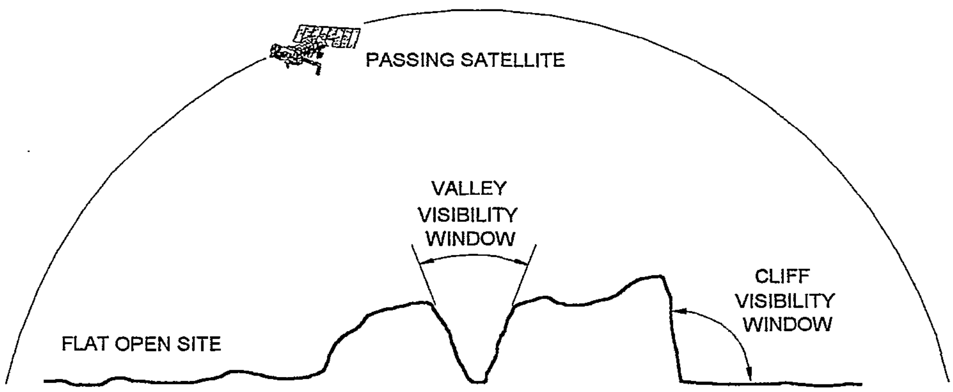


Figure 3.1: Effect of Local Topography on Satellite Visibility.

Eight suitable sites were identified in Wales and a further eight in Yorkshire. A list of sites and a description of local terrain can be found in Appendix I.

The trials were divided into two sets of test:

(i) test 1, '48 Hour Tests': Individual beacons were activated at each site and left transmitting continuously for 48 hours. The purpose of test 1 was to:

- assess the delay that would be seen in different terrain conditions, if a beacon were activated at any time of the day, until an alert message would be output to an MCC;
- assess the effects of terrain on the accuracy of position estimates predicted by the system.

ii) test 2, 'Multiple Trigger Tests'. All four beacons were activated at a particular site at varying percentages of a satellite pass (predictions of satellite pass times were gained from Lasham beforehand) to:

- assess the performance of the system if a beacon is activated during a satellite pass;

- to assess the reliability of data throughput and identify any gaps where detection of the beacon did not occur when expected.

4. ANALYSIS METHOD AND RESULTS

4.1 Data Output Format

An example of the information that was obtained from Lasham LUT during the trials and which would also be supplied by an MCC to a SPOC is contained in Appendix IV.

4.2 Test 1 Data Analysis and Results

4.2.1 Delay Assessment over Periods of 48 Hours

In order to make an assessment of what the delay would be in summoning search and rescue assistance if a beacon were activated at any time during the day, data collected for each beacon over a 48 hour period was assessed in five minute intervals. (Five minutes was considered to give an acceptable time resolution of 0.2%. Increased resolution would have resulted in an impractical amount of data.) For each five minute point throughout the 48 hour period, the time until the next satellite pass which detected the beacon was calculated and added to the duration of that satellite pass (almost immediately after which an alert would be raised) to give the delay that would be experienced between activation of a beacon and an alert message being sent to an MCC.

As some satellites (known as 'global' satellites) store the last few thousand data bursts that they have received (see section 2.2), they continuously transmit their stored data back down to Earth as they travel throughout their orbits. During some satellite passes over Lasham, therefore, data transmitted down to Lasham was that stored on board the satellite from its previous passes and Lasham is likely to have processed it before. This data is known as 'dump' data and is identified as such in the data output from Lasham. For the purposes of analysis, it was necessary to ignore beacon details from dump data (unless it had not been received by Lasham beforehand), as it would give a false impression of how long a beacon would have to wait before it is detected for the first time. For example, figure 4.1 shows that including dump data received at 3.30 pm would indicate that the beacon turned on at 3 pm would be detected after 30 minutes, although it was actually detected after 60 minutes. The 3.30 pm data in this case would therefore be omitted from the analysis.

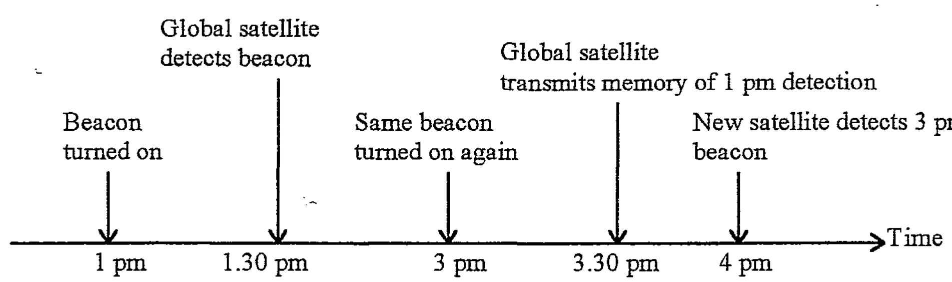


Figure 4.1 Dump Data From Global Satellites

Appendix V contains graphs that show individual detection delays seen throughout of the day at all sites in Wales and Yorkshire. These are saw tooth shaped, as expected, as it is reasonable to assume that delay will decrease linearly until the next satellite pass, after which delay reaches its maximum for the following gap between passes.

Figures 4.2 and 4.3 were generated from the graphs in Appendix 5 and they show the mean (average) detection times calculated for sites in Wales and Yorkshire respectively.

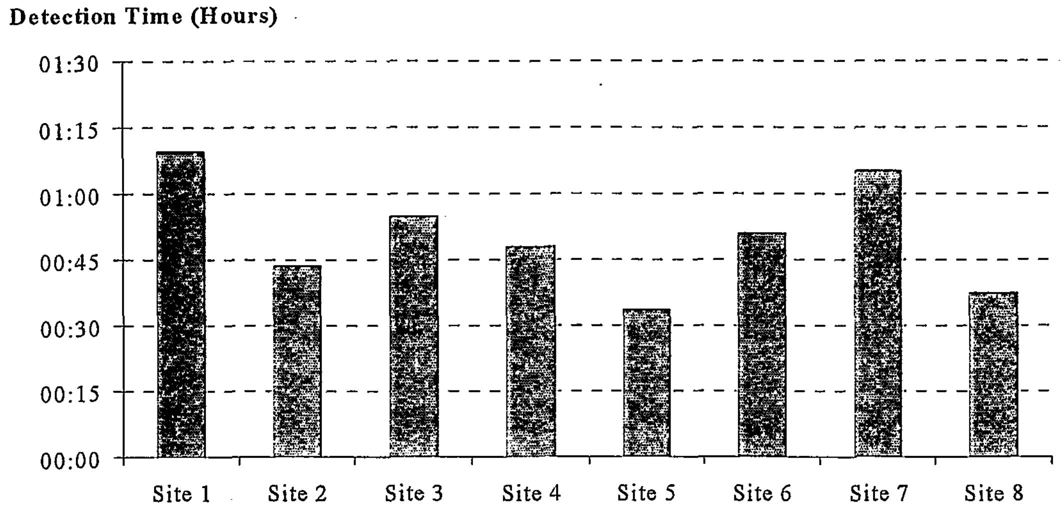


Figure 4.2: Mean Detection Times in Wales (48 Hour Analysis)

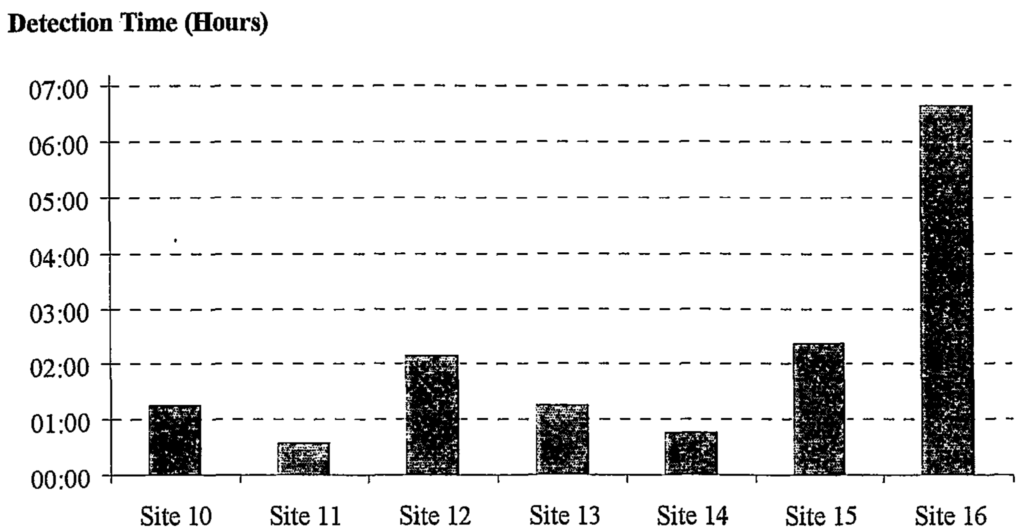


Figure 4.3: Mean Detection Times in Yorkshire (48 Hour Analysis)

Details of local terrain at the sites listed on the figures can be found in Appendix I. It can be seen that, at all but 2 of the sites in Wales, the mean detection time is under an hour. In Yorkshire, sites 15 (Littlebeck), which was a deep wooded valley and 16 (Staithes Lifeboat Station), which was shielded by a cliff on one side and a house on the other, both experienced higher than average delays. However, this was to be expected as the severe local terrain causes multiple reflections of beacon radio signals, a well known phenomenon which produces interference, often rendering the link to the satellite less reliable than in a clear open site, such as site 5, an airport on the West coast of north Wales. It must be noted, however, that the beacon at site 16 had an extremely restricted view of the sky and although workers would not be permitted to work alone under such conditions, the site was selected in order to test the C-S system in extreme circumstances. Nevertheless, performance was far better than had been expected, as it was thought initially that detection may not have been possible at this location.

In order to give an indication of how long, in the majority of cases, a worker in distress would have to wait before a search and rescue team is alerted, depending upon the type of terrain he/she is in, cumulative probability graphs (graphs which show the probability of having to wait up to a certain time period) were generated from the results in Appendix V for each site. These are presented in figures 4.4 and 4.5 for Wales and Yorkshire respectively.

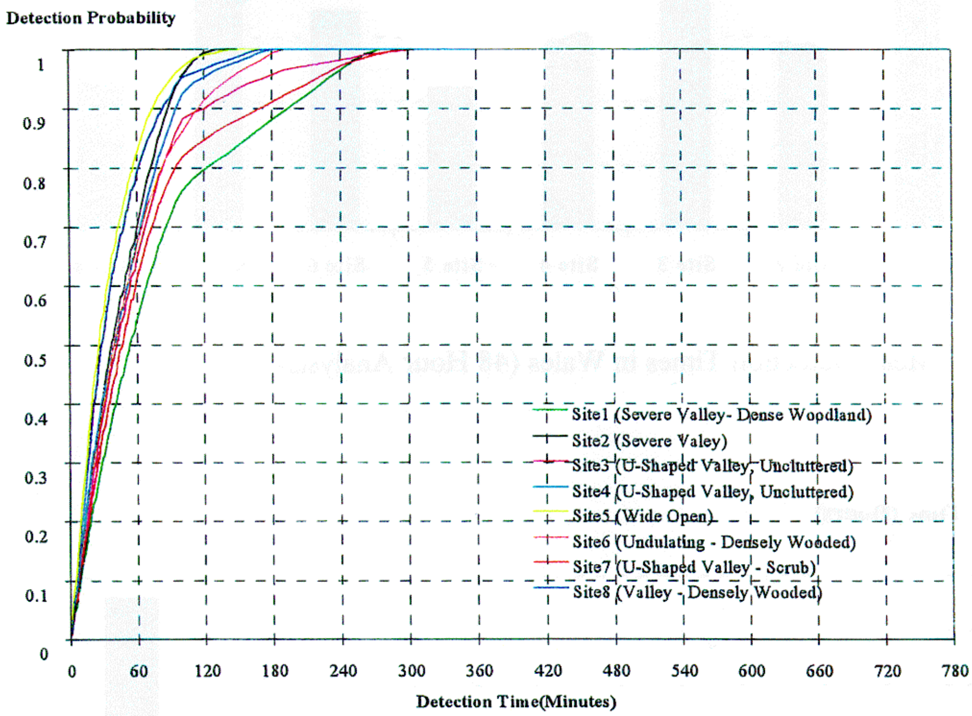


Figure 4.4: Probability of Being Detected within a Certain Time Period at sites in Wales (48 hour Analysis)

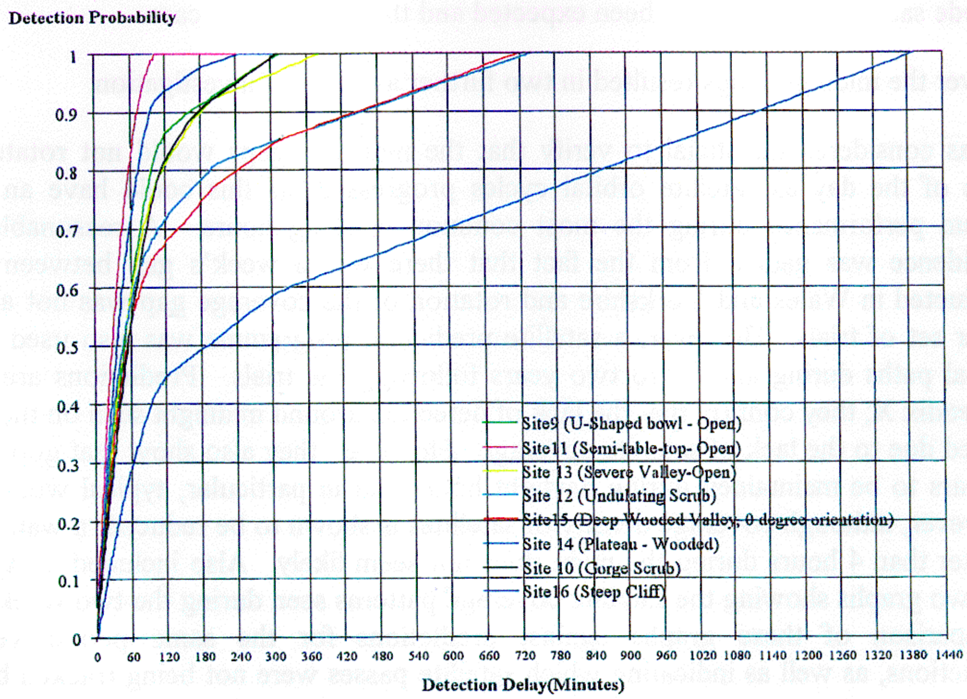


Figure 4.5: Probability of Being Detected within a Certain Time Period at sites in Yorkshire (48 hour Analysis)

It can be seen from figure 4.4 that there is an 82% probability of being detected within an hour at wide open site 5, compared to a 54% probability of being detected within an hour in the severe valley at site 1. However, both sites show that there is a 100% probability of being detected within 4 hours and detection is certain within 5 hours at all sites in Wales. Similar trends were demonstrated in Yorkshire, as probability of detection within a certain time period was less at sites with reduced satellite visibility windows (see Figure 2). Appendix VI presents a summary table of detection probabilities seen at all sites for various waiting periods.

Results also showed that vegetation local to the beacon, such as dense woodland, has a negative effect on system performance, although this is not severe and 100% detection times are largely unaffected.

It is also interesting to note that, at site 1, the Pass of Aberglaslyn, which is a severe wooded valley, results are similar to those conducted in a location close to this in the previous trials conducted in 1994 (NRA, 1994). In 1994, it was shown that 80% of alarms raised at the location were detected within approximately 2.5 hours, compared to these trials which showed 80% were detected in 2 hours.

4.2.2 Delay Assessment within a Working Day

An unexpected anomaly that became apparent from the results presented in Appendix V was that, in several cases, regardless of local terrain, detection times increased at and around midnight. Gaps of up to 4 hours were seen. After careful assessment of system functionality, it was decided that these discrepancies around the midnight hours were likely to be due to the fact that some of the satellites are used as weather satellites and they are therefore sun-synchronous. Previous thoughts were that midnight gaps could be due to the fact that Lasham was not programmed to track certain satellites, as other foreign LUTs were doing so, which would account for an apparent gap in coverage. However, if this was the case, a certain amount of 'dump' data for these midnight hours from global mode satellites would have been expected and this was not the case.

The concern over the midnight gaps resulted in two further avenues of investigation:

i) it was considered beneficial to verify that the midnight gaps would not rotate to other parts of the day as satellite orbital cycles progressed, as this could have an effect on system performance during the most common working hours. A reasonable level of confidence was gained from the fact that there was a week's gap between the trials conducted in Wales and Yorkshire and rotation of the coverage gap was not apparent in either set of trials. However, a satellite prediction programme was also used to predict orbital paths during and up to two years following the trials. Predictions are shown in Appendix X; they confirm that the lack of detection around midnight seen on the trials was indeed due to the lack of satellite coverage. However, they also show that good coverage appears to be maintained during daylight hours and in particular, typical working hours. However, although coverage density of satellites is shown to be reduced, a waiting time of greater than 4 hours during the night does not seem likely. Also included in Appendix X are two graphs showing the satellite coverage patterns seen during the two weeks of trials. Comparison of these graphs against predictions for the same period verifies the predictions, as well as indicating which satellite passes were not being tracked by Lasham LUT;

ii) the analysis described in section 4.2.1 was conducted for a typical working day (taken to be 7 am to 7 pm), to provide a more accurate representation of the probability of being detected during working hours. Figures 4.6 and 4.7 show mean detection times experienced within the working day for sites in Wales and Yorkshire respectively.

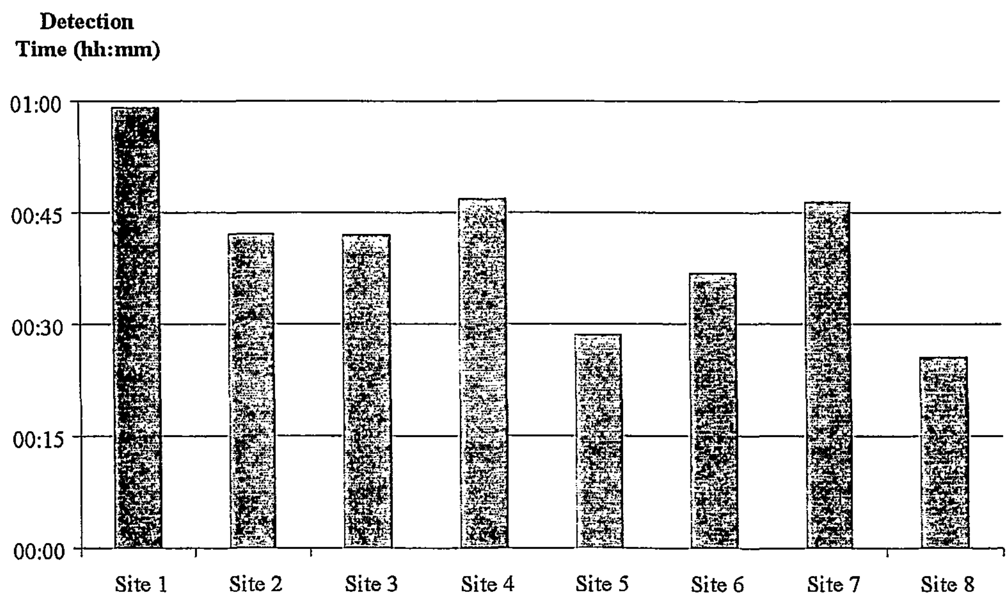


Figure 4.6: Mean Detection Times in Wales (Typical Working Day, 7am to 7pm)

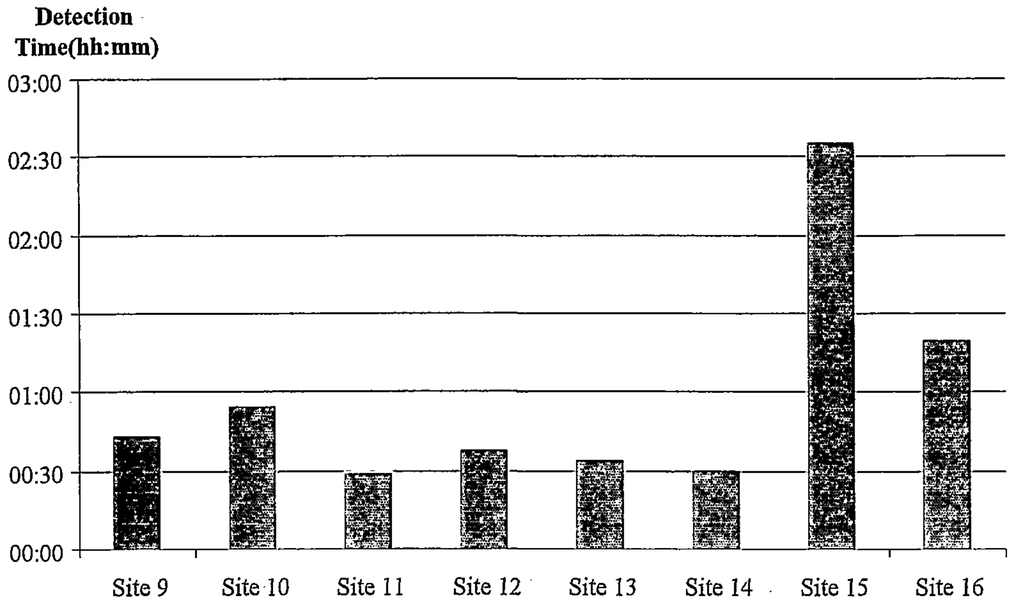


Figure 4.7: Mean Detection Times in Yorkshire (Typical Working Day, 7am to 7pm)

It can be seen that, for sites in Wales, mean detection times are well under an hour and for most cases, less than 45 minutes. Again, detection is on average quicker at the open sites, such as the airfield at site 5, compared to the severe wooded valley at site 1.

Figures 4.8 and 4.9 show the probability of having to wait for a certain time period before being detected within a typical working day at each site. If these are compared to figures 4.4 and 4.5 respectively, it can be seen that the plots have shifted to the left. This shows that it is more likely that an activated beacon will be detected within a shorter time period during the working day. For example, during the working day, 87% of beacons were detected within an hour at open site 5 (compared to 82% for the 48 hour analysis) and 64% of beacons were detected within an hour at the severe valley at site 2 (compared to 54% for the 48 hour analysis). In all but the 3 most severe sites, it was predicted that all beacon alerts at any time during the typical working day would be detected within 4 hours, with the majority being detected within 3 hours.

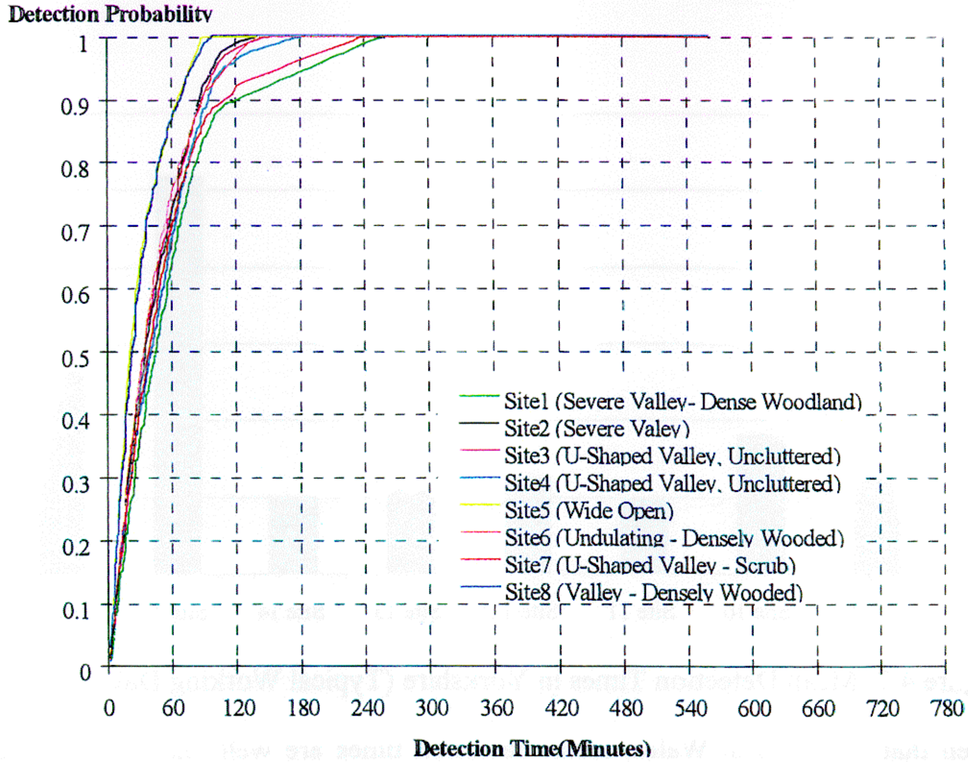


Figure 4.8: Probability of Being Detected within a Certain Time Period at sites in Wales (Typical Working Day, 7am to 7pm)

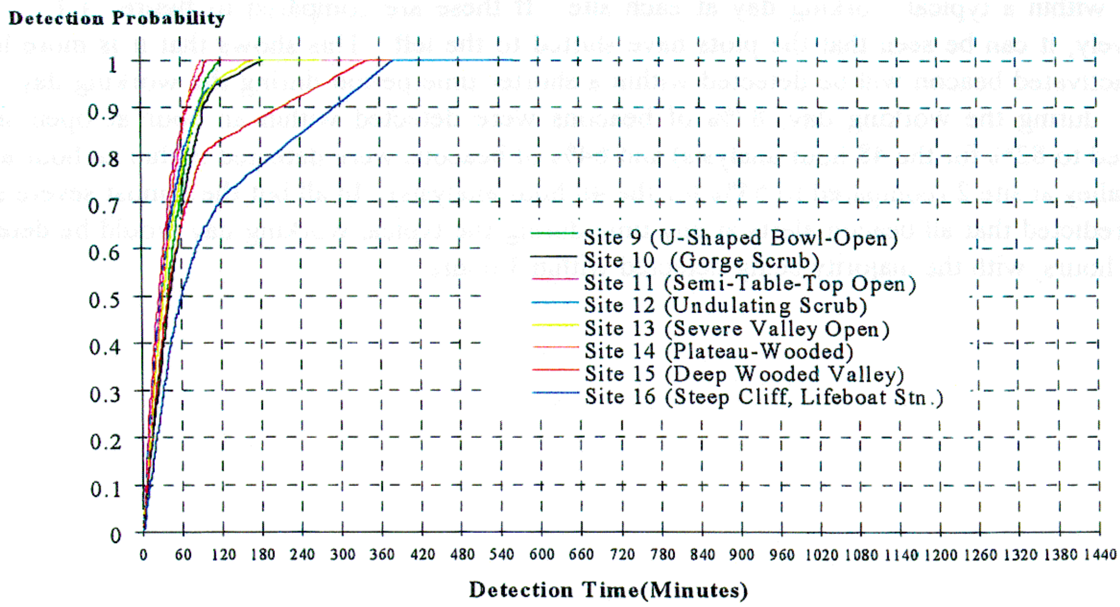


Figure 4.9: Probability of Being Detected within a Certain Time Period at sites in Yorkshire (Typical Working Day, 7am to 7pm)

The analysis presented above that considers typical working hours only gives a better impression of the system performance that most lone workers would expect to see. It is comforting to note that, throughout all of the 48 hour periods in which beacons were activated, all beacon alerts will be detected at some time, regardless of beacon location, with 85% of all alerts (see Appendix VI) predicted to be detected within 3 hours.

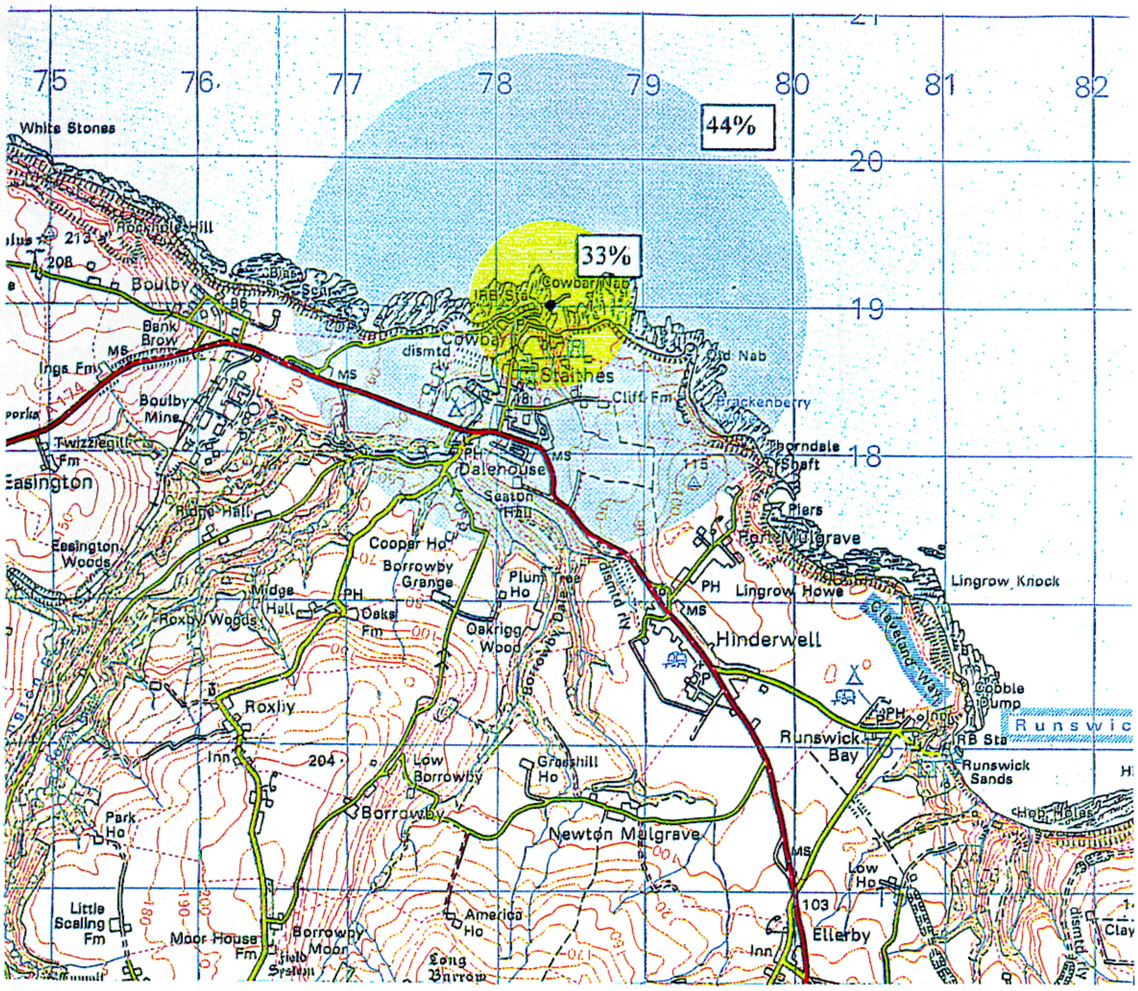
4.2.3 Assessment of Predicted Location Accuracy

At each site a GPS handheld receiver was used to obtain position estimates, accurate to within 50 metres, at each site in the trial. This information was then compared to the location estimates predicted by the C-S system for beacons activated at each site, in order that the accuracy of C-S location predictions could be assessed.

It was found through data analysis that at least three bursts of information from a beacon need to be received by a LUT from a satellite in order that location estimates can be calculated. If less than this are received a 'detection only' solution is produced by the LUT, from which beacon identification can be determined. Although only a small number of satellite passes were unable to produce location estimates, beacon identification information alone will undoubtedly be useful, as MCCs will be able to telephone organisations with whom the beacon is registered. It is likely that organisations will know approximate whereabouts of their staff and SAR teams can be mobilised whilst further positional information is gained from other satellite passes.

As discussed in section 2.2, beacon information processed from each satellite pass will result in 2 location estimates (given at least 3 data bursts were received), each with an associated probability. However, our analysis showed the wrong estimate to be thousands of kilometres in error (demonstrated in Appendix XI) and it is therefore very likely that an organisation will be able to confirm which estimate is right. Furthermore, probabilities in the vast majority of cases clearly indicated which estimate was correct. Only in approximately 1 in 25 cases did the system assign the higher probability to the wrong location, in which case the wrong location could usually be dismissed due to its high inaccuracy.

In order to give an example of the accuracy of position estimates given by the C-S system, the correct of the two position estimates predicted from each satellite pass was used, for reasons explained above, and plotted on maps for sites 5 and 16. Site 5 is an open site with good visibility of the satellite and the latter is a contrasting site with poor visibility of the satellite, as the beacon was located at the foot of a cliff. This shows the distribution of location estimates around the true location. These plots are shown in Figures 4.10 and 4.11.



Scale 1:50,000

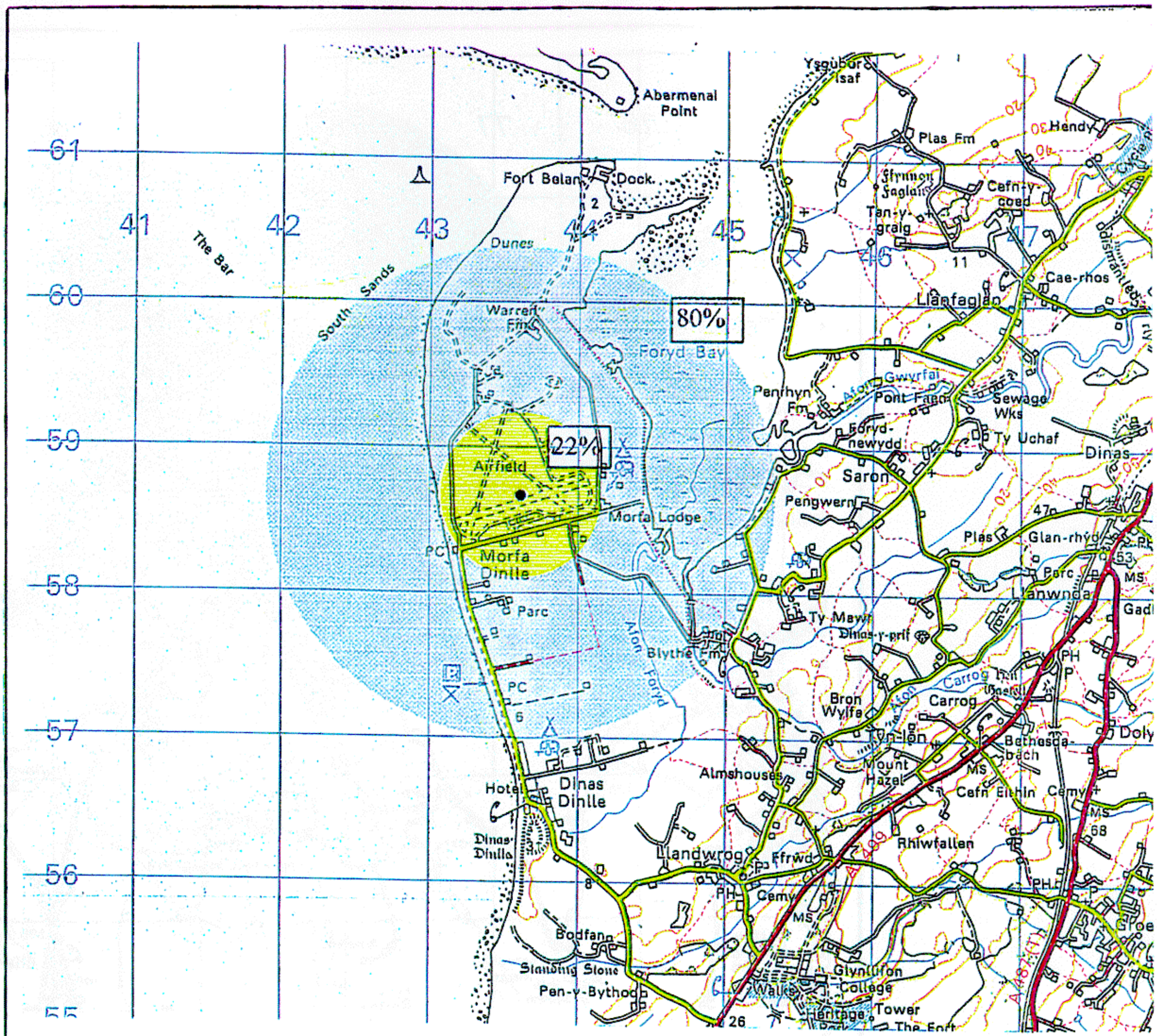
KEY:

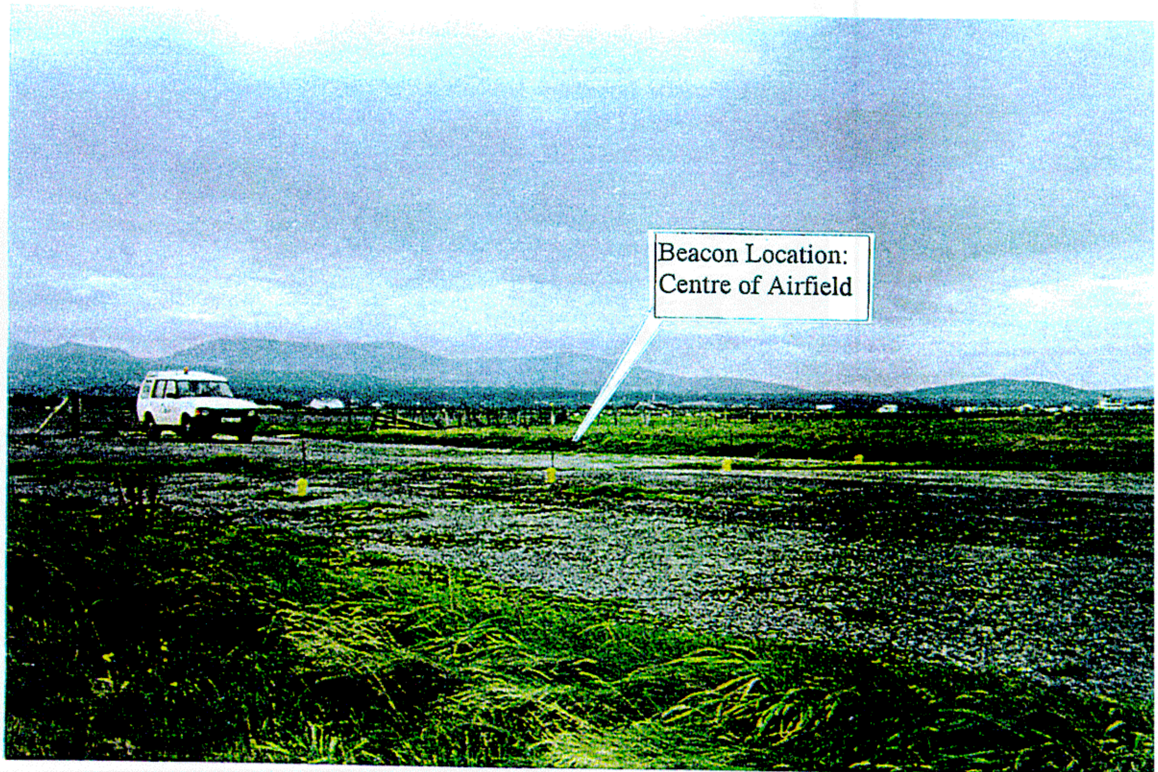
1 km^2

10 km^2

Figure 4.10: Distribution of Position Estimates around Site 5

Extract from Ordnance Survey Landranger Map Number 115





Scale 1:50,000

KEY:

1 km²

10 km²

Figure 4.11: Distribution of Position Estimates around Site 16

Extract from Ordnance Survey Landranger Map Number 94

It can be seen that 80% of the estimates at site 5 were within a 10 square kilometre (sq km) locus (circle) of the true location (a maximum distance of 1.78 km away), with 22% within 1 sq km, compared to 44% of estimates being with 10 sq km of site 16 and 33% with 1 sq km. This shows that a higher majority of position estimates will have increased accuracy at sites with better visibility of the satellites.

Position estimates allow a search and rescue team to search outwards from the predicted location in a locus until the distressed worker is found. For this reason, search areas were predicted for each site. Appendix XI contains the calculation used to gain search area values. Search areas are shown on figures 4.12 and 4.13 for sites in Wales and Yorkshire respectively. Percentage values are grouped into logarithmic ranges, as this clearly indicates that only a small number of predicted locations are very inaccurate, with the majority of predictions requiring search areas of under 10 sq km.

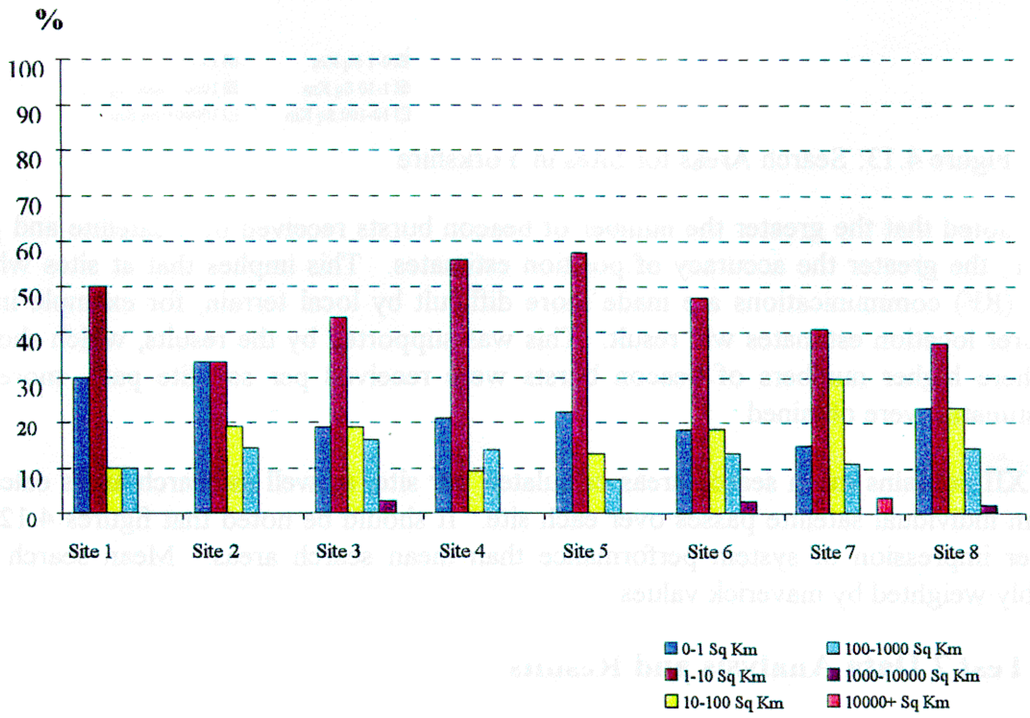


Figure 4.12: Search Areas for Sites in Wales

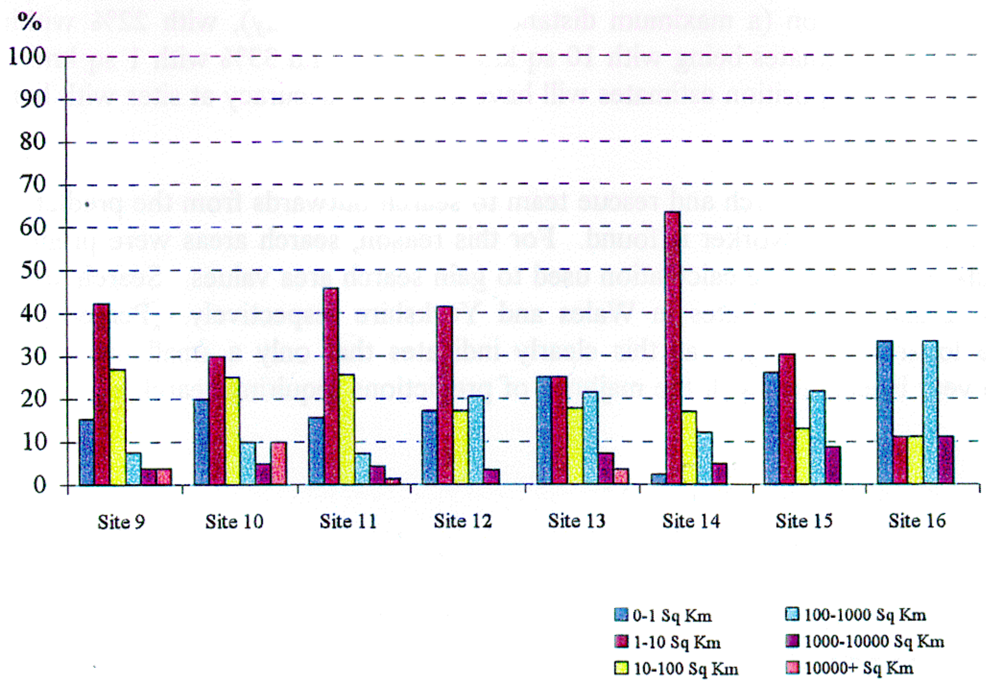


Figure 4.13: Search Areas for Sites in Yorkshire

It was also noted that the greater the number of beacon bursts received by a satellite and processed by the LUT, the greater the accuracy of position estimates. This implies that at sites where radio frequency (RF) communications are made more difficult by local terrain, for example in a severe valley, poorer location estimates will result. This was supported by the results, which showed that, at sites where higher numbers of beacon bursts were received per satellite pass, more accurate location estimates were obtained.

Appendix XII contains mean search areas calculated per site, as well as search areas calculated for results from individual satellite passes over each site. It should be noted that figures 4.12 and 4.13 give a truer impression of system performance than mean search areas. Mean search areas are unfavourably weighted by maverick values.

4.3 Test 2 Data Analysis and Results

The analysis of Test 1 data represents the case where beacons are activated between satellite passes, as the test beacons were already activated when the satellite passes started. To investigate whether the results also hold true if the emergency occurs during a pass, the 'Test 2' trials were conducted.

Test 2 involved:

- determining the durations of any gaps at either end of the satellite pass in which the satellite is unable to detect the beacon and consider factors which may cause this. Assess whether satellite window narrowing has a noticeable effect on overall system performance.
- conducting 'Multiple Trigger' tests, in which beacons were activated at varying percentages of the pass, to determine whether there was a satellite window 'cut-off' point, after which the system would be unable to process signals transmitted up to the satellite and no location predictions are possible.

- assessing the reliability of the data links and whether there were any gaps during the pass where beacon bursts were not processed.

4.3.1 Factors Affecting Satellite Visibility Window

The information collected from Lasham included the times at which individual beacon bursts were received by the C-S system. By comparing the times of the first and last bursts received from a particular beacon within a satellite pass (Time First Seen, TFS and Time Last Seen, TLS,) to the Acquisition of Signal (AOS) (the time at which Lasham first received the satellite signal at the start of a satellite pass overhead) and Loss of Signal (LOS) (the time at which Lasham last received the satellite signal at the end of a satellite pass overhead) respectively, it was possible to assess whether there were gaps at either side of the satellite pass where the system was unable to process beacon information. This concept is demonstrated in figure 4.14.

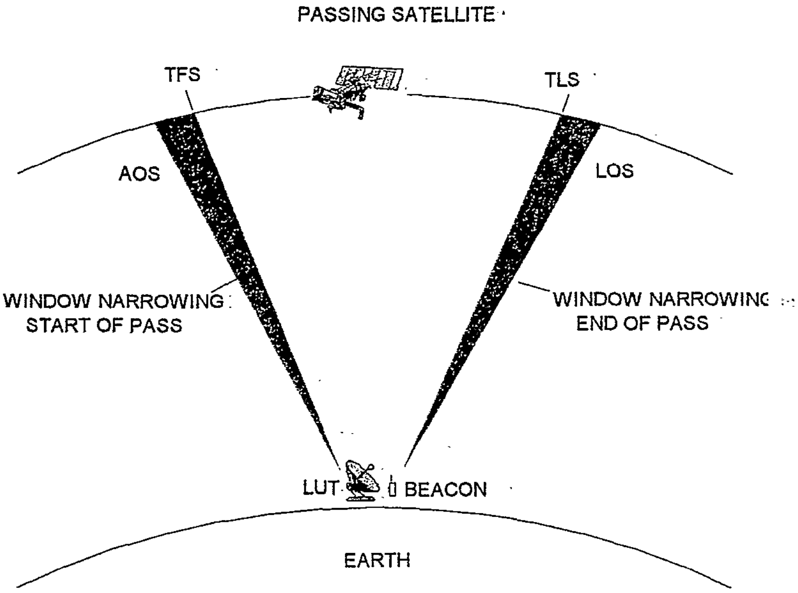


Figure 4.14: Effective Satellite Visibility Window

Results are presented in Appendix XV. It was found that there was often a period of 3 or 4 minutes at either end of satellite passes where bursts were not received, resulting in an effective narrowing of the useful satellite window pass. This is likely to be due to three main factors:

i) terrain local to the beacon will have an effect because if the satellite visibility window by the beacon is narrower (see figure 3.1), less data bursts will be received;

ii) satellite elevation angles will have an effect on satellite visibility. For example, if a satellite pass is low in the sky, clutter and terrain on the Earth's surface is more likely to disrupt the RF signal, causing a reduction in link performance;

iii) it was assumed that the proximity of the beacon to Lasham LUT is very close compared to the distance of the satellite. Therefore, it was assumed that, when Lasham is in a satellite footprint, so is the beacon. In practice, however, there may be a delay of a few minutes as the edge of the footprint moves over the Earth's surface.

Beacon warm-up time will cause a slight delay at the beginning of a pass, although this will be negligible, a matter of seconds at normal operating temperatures. Likewise, propagation delay will cause a negligible delay of a few milliseconds at both ends of the pass. Other factors that are thought to have a slightly bigger impact on satellite pass window narrowing are an average delay of 25 seconds until the next beacon burst is transmitted (bursts are transmitted every 50 seconds) and processing delay on board the satellite, although it is not possible to quantify the latter without a knowledge of satellite processing capabilities.

Having assessed these factors, it was concluded that only satellite visibility (caused by local terrain and satellite elevation angle) will have a significant effect on system performance and this effect has been quantified in Test 1.

4.3.2 Multiple Trigger Tests

Figure 4.15 indicates a typical test scenario, in which beacons were deployed at the same location and turned on at varying percentages of a satellite pass. In order to determine when individual beacons should be activated, it was necessary to obtain pass time predictions from Lasham prior to these tests, in the form of Acquisition of Signal (AOS) and Loss of Signal (LOS).

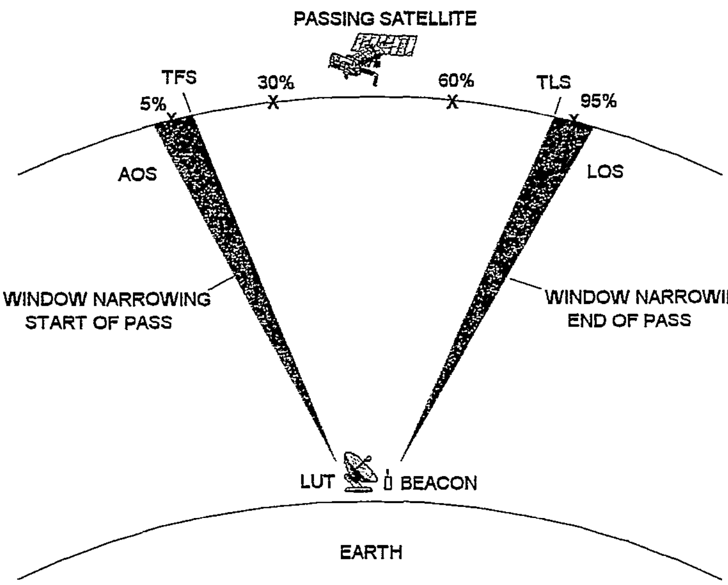


Figure 4.15: Typical Test 2 Scenario

Results can be found in Appendix IV, which showed that if a beacon is switched on later than 90% of the pass, the beacon will either not be detected by the system or 'detect only' solutions are produced, in which beacon identity but no positional information can be obtained.

Having conducted this analysis, it was concluded that, as the cut-off point is late in the pass, it will not have a significantly adverse effect on overall system performance. Therefore, test 1 data represented cases where beacons were activated during, as well as in between satellite passes.

4.3.3 Data Link Reliability

In order to assess the reliability of the RF links to and from the satellites, the number of data bursts were counted between TFS and TLS to determine if any gaps in the transmitted information were apparent. Appendix XVI contains the results of this analysis, which was conducted on data from sites 5 (a wide open site) and 9 (a U-shaped bowl). At site 9, the differences between the number of bursts predicted and the number received was either 0, 1 or 2 and the majority of bursts emitted by the beacon were detected by the system. Site 5 produced similar results, although several passes by C6 missed a greater number of bursts.

It can be concluded that on average link reliability is good and differences in numbers of bursts received from the numbers expected can be put down to satellite visibility. In particular, the poor performance of C6 at site 5 was probably due to the fact that the elevation angle of this satellite over the horizon was reasonably low, thereby reducing the reliability of the link to this satellite.

4.4 Assessment of Foreign LUT and Geostationary Data

4.4.1 Foreign LUT Data

A sample of overseas data was obtained from Spain which is provided in Appendix XVI. As discussed in section 2.2, LUTs co-ordinate their satellite tracking schedules in order that no satellite goes untracked while others are tracked by more than one LUT. As three of the C-S satellites operate in global mode, beacon information that was received by them and then received by the Spanish LUT was later received as dump data by Lasham. As it was possible to identify dump data and establish the time when the beacon was first seen by the global satellites, the inclusion of Spanish global mode data would not have made a change to the results that we have processed from Lasham. However, in some cases where beacon information was received by satellites with no storage on board and was seen by the Spanish LUT prior to the British one, a decrease in response times for those beacons would be expected. This is due to the fact that the Spanish LUT would send its alert data to its local MCC immediately after the end of the pass. It is therefore likely that the British MCC would receive this information and initiate search and rescue activities before another satellite detects signals from the same beacon.

4.4.2 Geostationary Data

A small amount of geostationary data was obtained from the Spanish LUT via Lasham from 5 to 7 October 1997. During this time, 2 test beacons were activated at site 5 and in both cases, the geostationary satellite detected the beacons immediately and viewed them up until the point that they were turned off. As discussed in section 2.4, geostationary satellites are unable to provide positional information, as they remain in a fixed position in the sky and therefore are unable to collect Doppler frequency shift information. However, although the sample of data obtained is small, the test demonstrates the potential of the larger scale inclusion of geostationary satellites into the C-S system. If elevation angles are sufficient and visibility is good, geostationary satellites will be able to detect activated beacons almost immediately. These results are particularly encouraging as it can be seen from figure 2.4 that Spain collects data from GOES-8, the geostationary satellite located above Peru. The UK is on the edge of its footprint, which is where communications to the satellite is more likely to be subject to interference from the Earth's terrain and the elevation angle seen by the UK is only about 1.5°. It can therefore be concluded that the full-scale integration of geostationary data into the C-S system is likely to result in a decrease in beacon detection times by the system and therefore a decrease in the time it will take to provide search and rescue assistance to personnel in distress.

5. IMPLEMENTATION ISSUES

There are a number of issues that the Agency will need to consider, should it wish to utilise the C-S system to provide a lone worker beacon facility. These include:

- registration of land based beacons within the UK;
- beacon procurement;
- co-ordination and responsibility for search and rescue activities for the Agency;
- alert reporting mechanism and system from the C-S system to the Agency.
- training of lone workers and other organisational issues within the Agency;

At present, unlike ELTs and EPIRBs, PLBs are not registered for use in the UK, although they are in a number of other countries throughout the world. The approval of land based beacons will be the first major step to utilising the C-S system. In particular, the use of land based beacons in the UK will require the support of the Association of Chief Police Officers (ACPO), who are concerned that if the use of PLBs is not properly regulated, a large number of untrained users may activate them for minor instances that do not require immediate search and rescue responses. However, problems of this nature have not been reported abroad and considerable success has been seen. In addition, a number of UK organisations have expressed an interest in using PLBs with the C-S system. A co-ordinated effort with the support of the UK Search and Rescue Committee (UKSAR) will be needed to bring about the approval required. Close liaison with UKSAR needs to be achieved should the Agency wish to pursue the path of C-S system usage for emergency protection of its lone workers.

Once land registration is achieved, purchase of a number of beacons from a registered supplier whose beacons are approved by the C-S system (COSPAS-SARSAT, 1997) would be necessary. It is essential that beacons are type approved to ensure compatibility of the 406 MHz beacon signals with the system. The responsibility for type approval lies with individual State. A list of approved suppliers can be gained from (COSPAS-SARSAT, WWW). Beacon costs vary with supplier, but at the time of writing, they are estimated to be £600 each. However, the Agency was able to purchase test beacons at a considerable discount (£400) and it is likely that similar or larger discounts may be possible if the Agency decide to utilise beacons on a larger scale.

All UK beacons must be registered with the UK ground segment. It is an essential requirement that any organisation using the C-S system should provide the MCC with full identification details of all its beacons as well as providing contact numbers and addresses to be used in the event of an alert. At this stage it is thought that, should the Agency wish to use the C-S system, the Agency may well choose to be responsible for the co-ordination of its own search and rescue activities. In this case, it will be necessary to instruct the MCC to bypass its normal SPOCs and provide full alert data directly to an Agency point of contact.

If the Agency were to co-ordinate its own search and rescue activities, consideration should be given to the use of the homer frequency transmitted by the beacons. The Agency may wish to use its own frequency, in which case licenses would be required. Purchase of direction finding (DF) equipment would also be necessary. This would use the homer frequency of the beacon to assist in the search for the activated beacon. It is therefore recommended that, prior to any moves to use the C-S system, further consideration to homer frequencies and the use and study of DF equipment should be given.

The format of the link between the UK MCC will need to be considered, along with the Agency's operational requirements. For example, a direct data link could be used that would provide all alert data, similar to that presented in Appendix IV, directly from the MCC to the Agency's own SPOC.

Finally, it is considered that the risk to the Agency of pursuing the C-S avenue is low. As discussed in section 2.4, the system is well supported and its healthy survival and continual improvement for many years to come is certain. The financial costs to the Agency would include the training of its staff in beacon usage, purchase of beacons, the initial set-up of organisational procedure within the Agency and the co-ordination of its own search and rescue activities.

6. CONCLUSIONS

The trials conducted in October 1997 and the assessment of the C-S system have enabled a firm appreciation of the system's performance and functionality to be obtained, as well as providing a good insight into the operational requirements should the Agency decide to use the system to provide emergency protection for its lone workers in distress.

Results have supported previous findings of the initial C-S trials conducted in 1994 that the time the system took to detect an activated beacon was very dependent upon the type of terrain local to the beacon. It was found that the average time for an activated beacon signal to be detected during typical working hours (7am to 7pm) was under an hour at all but 2 sites in Yorkshire, with the most impressive response times being seen at an airfield (site 5), where there was an 87% probability of being detected within an hour. At site 16, which was at the bottom of a cliff face, the narrow pass window reduces the probability of detection to 72% after a 120 minute period. However, it should be noted that, under the Agency's current practice, single man working would not be permitted in such an area and the site was chosen in order to test the operation of the C-S system in extreme conditions. Furthermore, it was expected that the system would fail to detect beacons in such conditions, however, this was not the case. All beacons were detected.

It was noted from the analysis that, for the majority of sites on most days, there is a decrease in detection performance in the few hours around midnight. Detection times of 4 hours were not uncommon around this time. This is due to the fact that some of the C-S satellites are used as weather satellites and are therefore sun-synchronous. This was supported by predictions performed using a software programme, which showed increased satellite coverage during daylight hours. However, it was encouraging to note that the coverage density during daylight hours is predicted to remain adequate to maintain the system performance seen on our trials. Although coverage gaps of a few hours were seen, it is thought that it would be unlikely to have a significant effect on an organisation using the system whose staff operate in typical working hours.

Additional analysis found that effective satellite visibility windows in which the satellite is able to receive data from beacons can be narrower than the satellite visibility seen by the LUT. This is due to terrain local to the beacon and satellite elevation angles. Delays due to beacon warm up times (at normal operating temperatures) and signal processing on board the satellite are thought to be negligible.

An assessment of accuracy of the location estimates obtained in the trial was undertaken. It was found that location accuracy increased with increased satellite visibility as a greater amount of information bursts from the beacon were received and processed by the C-S system. At an airfield site with good visibility, it was found that 80% of position estimates lie within 1.78 km of the true location, compared to 44% at a site by the side of a cliff, where the visibility window was severely restricted. In addition to this, it was noted that positional accuracy increases as more beacon bursts are received. Therefore, as a search and rescue team is being mobilised, it will be possible to continually update the information passed to the rescue team, thereby reducing the area in which they will need to search.

Data received from a geostationary satellite being evaluated by C-S for full-scale inclusion into the system was assessed in the trial. Although the amount of GEOLUT data we received was small and it included beacon data from a flat open site only, it was encouraging to discover that the geostationary satellite detected the beacon immediately it was turned on and did not lose sight of it until the beacon was deactivated. The detected beacon was on the edge of the satellite's footprint, where the elevation angle is only about 1.5°. It is therefore very likely that the incorporation of additional geostationary satellites into the system on a permanent basis will improve system performance and reduce detection delays.

Consideration of data received by a foreign LUT (Spain) verified that dump data seen by the Lasham LUT is often detected on a previous satellite pass by a foreign LUT and alert messages are passed through the MCC network on the ground, thereby increasing system response to personnel in distress.

The study has enabled a more in-depth appreciation of C-S system operations to be obtained and an understanding of the issues that would need to be considered by the Agency, should it wish to use the C-S for emergency protection of its lone workers. The first stage would be seeking the approval for use of land based beacons within the UK. As other UK organisations also have an interest in achieving this, there will be further support within the UK for obtaining the approval required. Beacons used by the Agency would need to be approved by the C-S organisation and details of contacts in case of activation of Agency beacons would need to be supplied to the UK MCC. The method of information flow from the MCC will need to be considered and in particular, careful consideration will need to be given if the Agency would prefer to conduct search and rescue activities for its own workers.

It has been ascertained that the long term future of the C-S system is promising, as considerable long term support is guaranteed from a number of international government organisations. Technical developments will continue to increase system performance, with the most imminent of these being the inclusion of geostationary and GPS data, to provide decreased response times and increased location accuracy.

7. RECOMMENDATIONS

It is recommended that the use of the C-S system to provide emergency protection for its lone workers is given serious consideration. Initially, should the Agency consider to pursue the system's use, approval for the use of land based beacons within the UK should be sought. A pilot study in a region would then be beneficial to gain an appreciation of the organisational and implementation issues involved, in particular the effective collection of alert information from the C-S network, instigation of search and rescue activities and training of Agency staff. Part of any study should also include the consideration of the use of the homer frequency emitted by beacons, such as whether the Agency would require its own frequency allocation if it is to conduct its own search and rescue activities and the employment of direction finding (DF) equipment to assist in rescues.

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APPENDIX I

DETAILS OF TRIALS SITES

Table I.I List of Trials sites

SITE	NAME	TERRAIN
Wales		
1	Pass of Aberglaslyn	Severe Wooded Valley
2	Pass of Aberglaslyn	Severe Valley
3	Pass of Llanberis	U-Shaped Valley, Clear
4	Drws-y-Coed	U-Shaped Valley, Clear
5	Airfirld-Morfa Dinlle	Wide Open
6	Bryn-y-Fawnog	High Undulating Wooded
7	Hafod-y-Llan	U-Shaped Valley, Scrub
8	PontGethin	Valley - Dense Wood
Yorkshire		
9	Darnholm (Nr Goathland)	U-Shaped Bowl, Open
10	Darnholm	Gorge, Scrub
11	Greenlands Farm	Semi-table-top, open
12	Abbots House Farm	Undulating Scrub
13	Levisham Mill Farm	Severe Valley, Open
14	High Muffles	Wooded Plateau
15	Littlebeck	Deep Wooded Valley
16	Staithes Lifeboat Station	Between cliff and house

APPENDIX II

CELLULAR COVERAGE AT TRIALS SITES

Table II.I Digital Cellphone Reception at Trials Sites

SITE	TERRAIN	DIGITAL CELLPHONE RECEPTION
Wales		
1	Severe valley, dense woodland	Not Tried
2	Severe valley	Yes
3	U-shaped valley, uncluttered	Yes
4	U-shaped valley, uncluttered	Yes
5	Wide open	Yes
6	Undulating - densely wooded	No
7	U-shaped valley - scrub	No
8	Valley - densely wooded	No
Yorkshire		
9	U-shaped bowl - open	No
10	Gorge scrub	No
11	Semi-table-top - open	No
12	Undulating scrub	No
13	Severe valley - open	No
14	Plateau - wooded	No
15	Deep wooded valley, 0° orientation	No
16	Steep Cliff	Not Tried

APPENDIX III

DETAILS OF BEACON

Table III.I Test Beacon Specification

ITEM	SPECIFICATION	
Model:	KANNAD 406M Personal Locator Beacon	
Supplier:	Sullivan Marine Limited, Kent, UK	
Technical Specs:	Frequency:	406.025 MHz ± 0.002 MHz
	Power:	5W ± 2 dB
	Modulation:	Phase modulation of 1.1 ± 0.1 radians
	Short Term Stability:	≤ 0.002 parts/million/minute
	Medium Term Stability:	≤ 0.001 parts/million/minute
	NOTE: 121.5 MHz or other homing frequency (25 mW) available as authorised by national authorities.	
General Packaging:	Case:	High impact resistant plastic
	Colour:	High visibility yellow
	Carrying Case:	Red carrying case with belt loop
	Antenna:	Foldable tape antenna (requires deployment)
	Weight:	490 g
	Diemensions:	160 x 55 x 90 mm
Operation:	Modes:	Switch, Off and Test Two conscious actions required for ON Flashing light indicates correct operation
	Operating life:	Minimum 48 hours at -20°C/ 24 hours at -40°
	Operating temperature:	-40°C to +55°C
	Storage temperature:	-50°C to +70°C
	Battery replacement:	Every 4 years
Test codes used in trial:	9D 1E CC 34 9F 8D0 9D 1E CC 34 9F 9D0 9D 1E CC 34 9F 990 9D 1E CC 34 9F 900	

APPENDIX IV

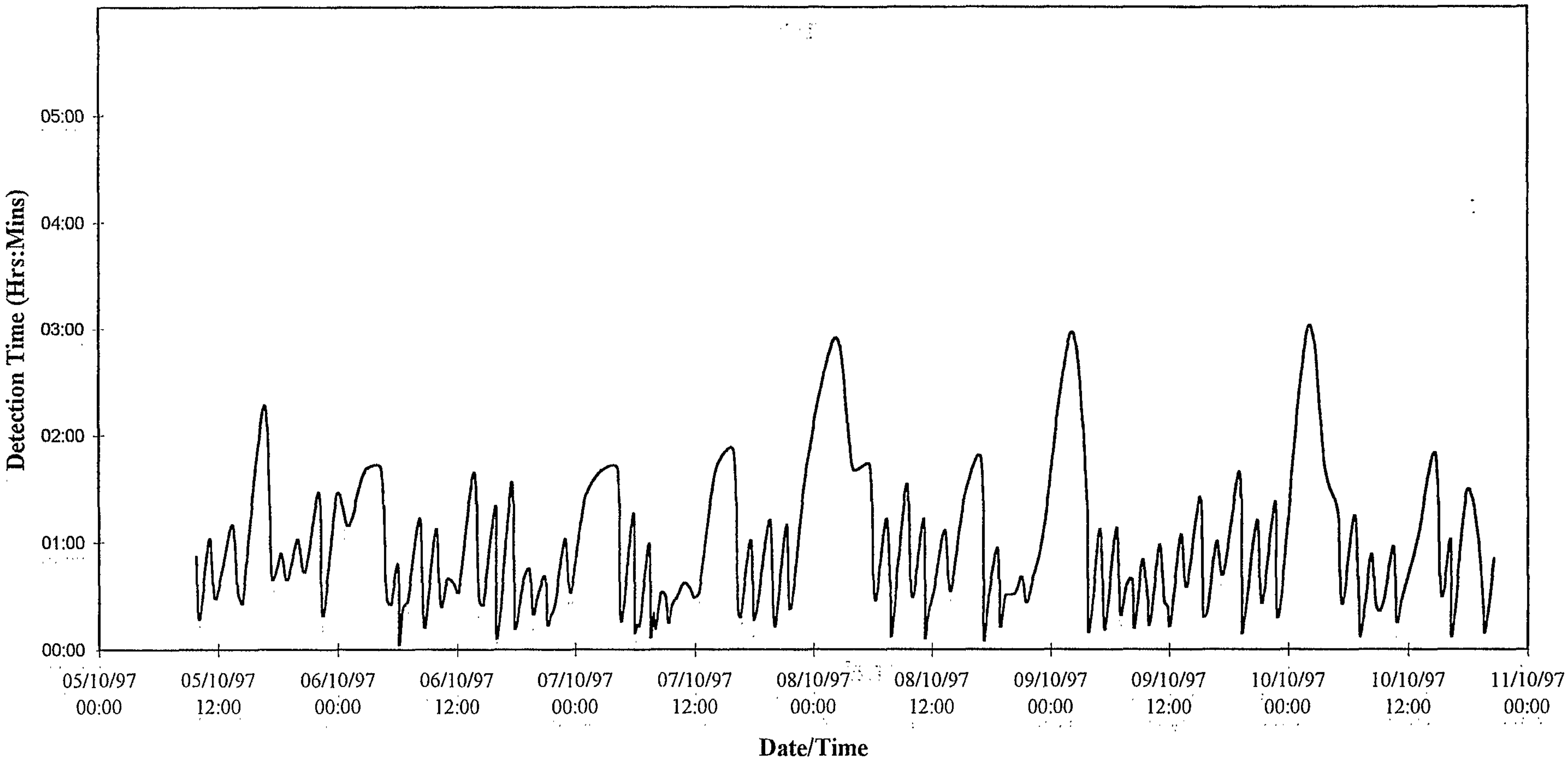
SAMPLE OF DATA OUTPUT FROM LUT AND MCC

Each satellite pass tracked by a LUT results in a solution file containing the following information:

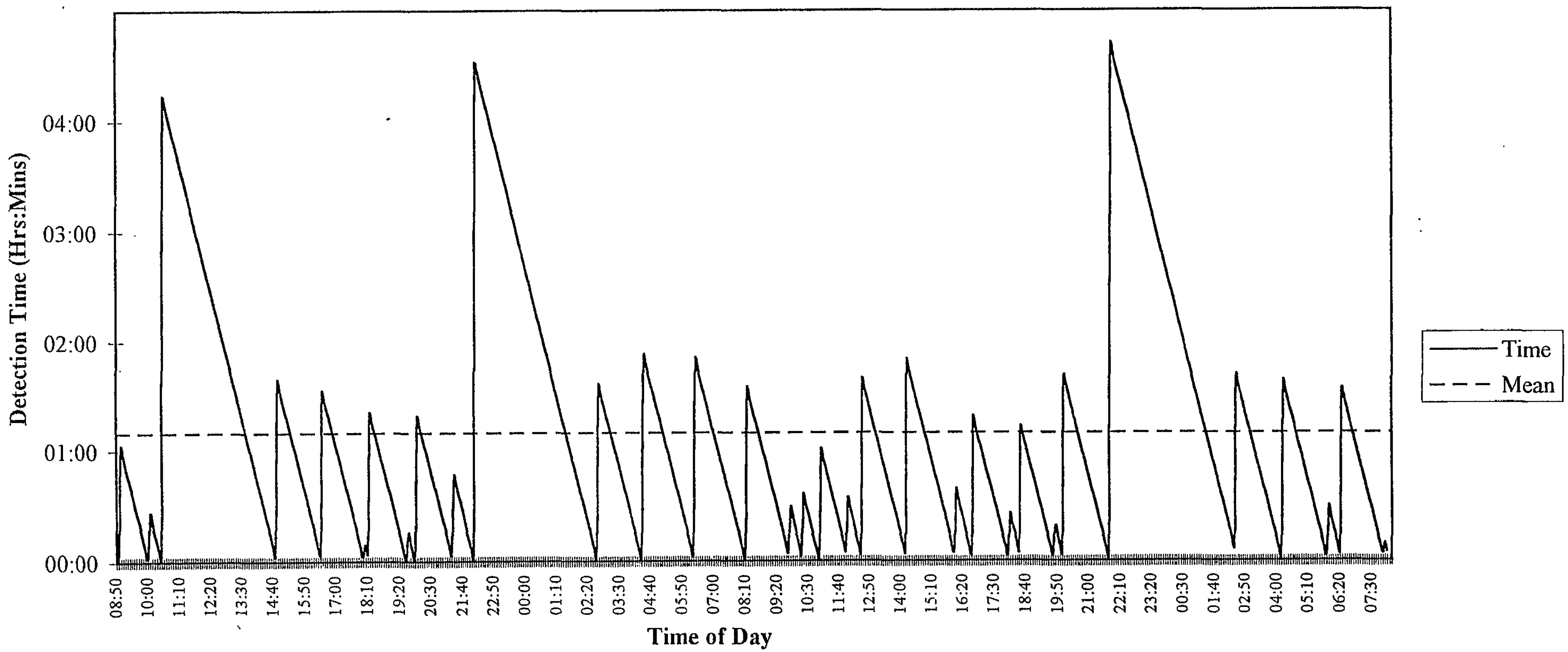
- Pass Number (Each orbit for each satellite has a unique number assigned to it).
- Satellite Identification
- Date
- AOS (Acquisition of Signal; this is the time at which the LUT detects a signal from the satellite, at the start of the satellite pass).
- LOS (Loss of Signal; the time at which the LUT loses the signal from the satellite).
- Beacon identification code (C8D0, C900, C990 or C9D0)
- Number of bursts of data received
- TCA (Time of closest approach to the beacon)
- Lat1 and Long1 (Calculated positional information)
- Prob1 (Confidence factor of the above calculation expressed as percentage)
- Lat2 and Long2 (Calculated alternative positional information)
- Prob2 (Confidence factor of the alternative position expressed as percentage)
- TFS (Time the satellite first 'sees' the beacon)
- TLS (Time the satellite last 'sees' the beacon)

APPENDIX V

DETECTION DELAYS FOR 48 HOUR TRIAL PERIODS

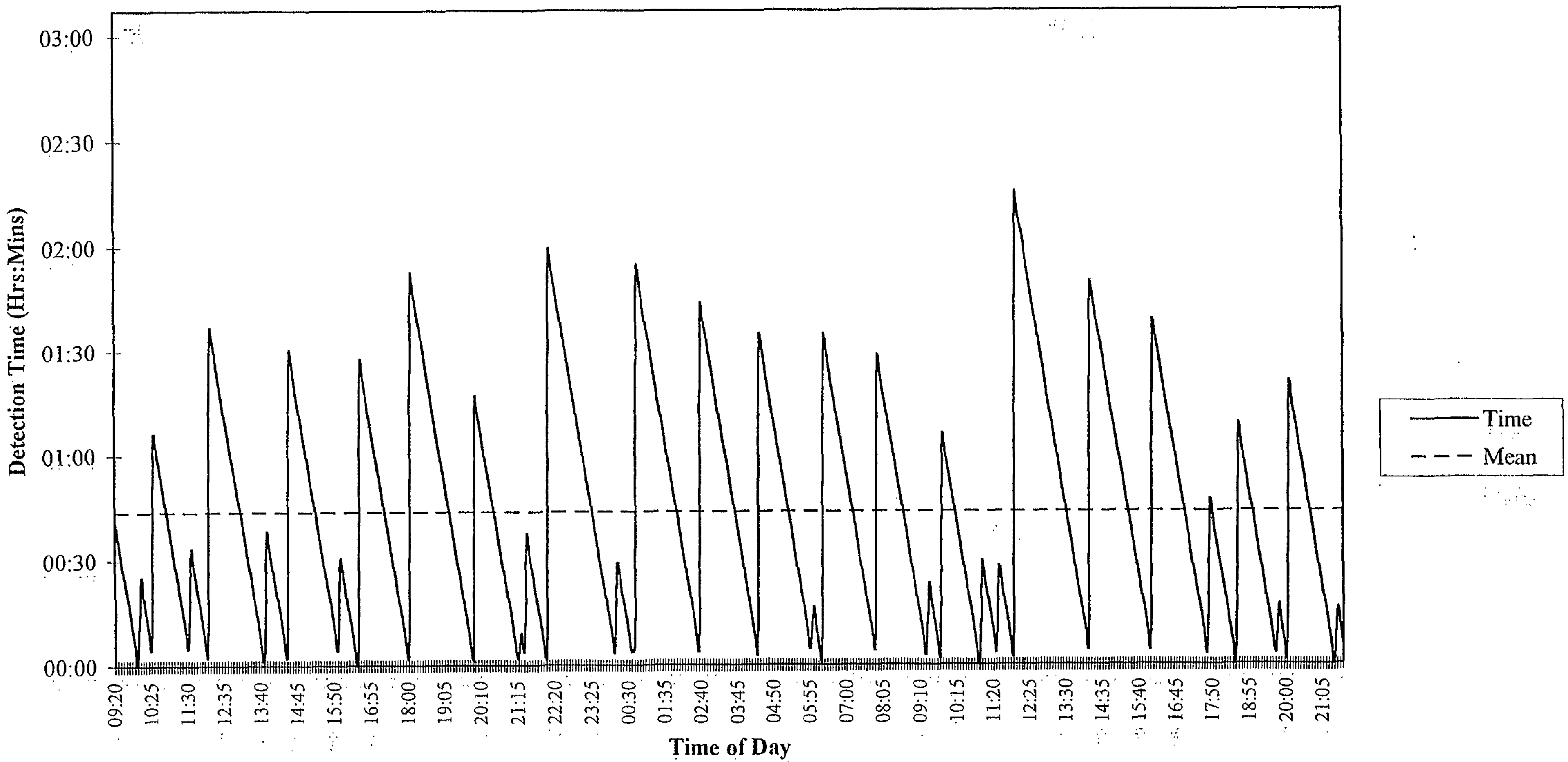


TIME TO BEACON DETECTION: WEEK 1 WALES 5-10 OCTOBER 1997

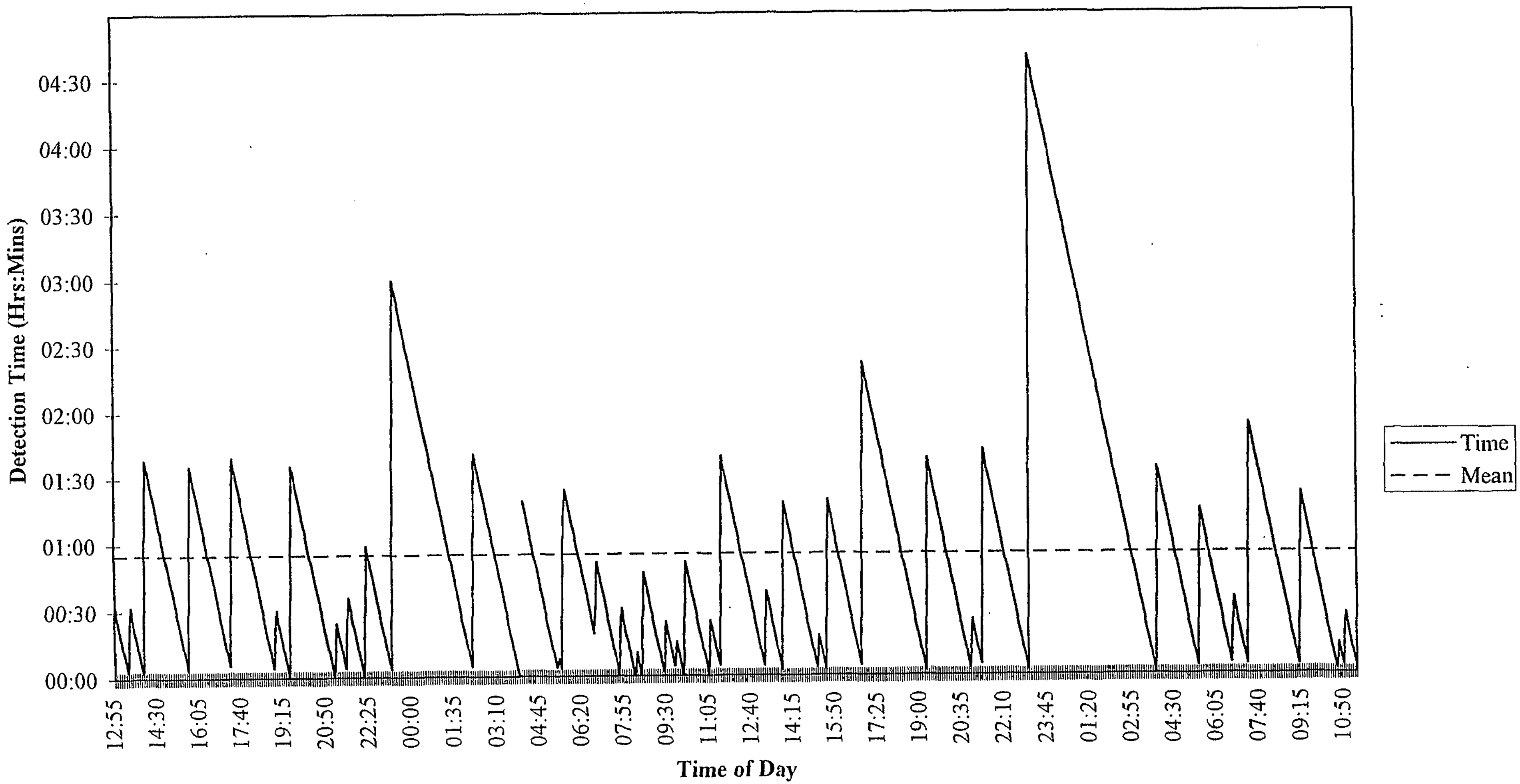


TIME TO BEACON DETECTION

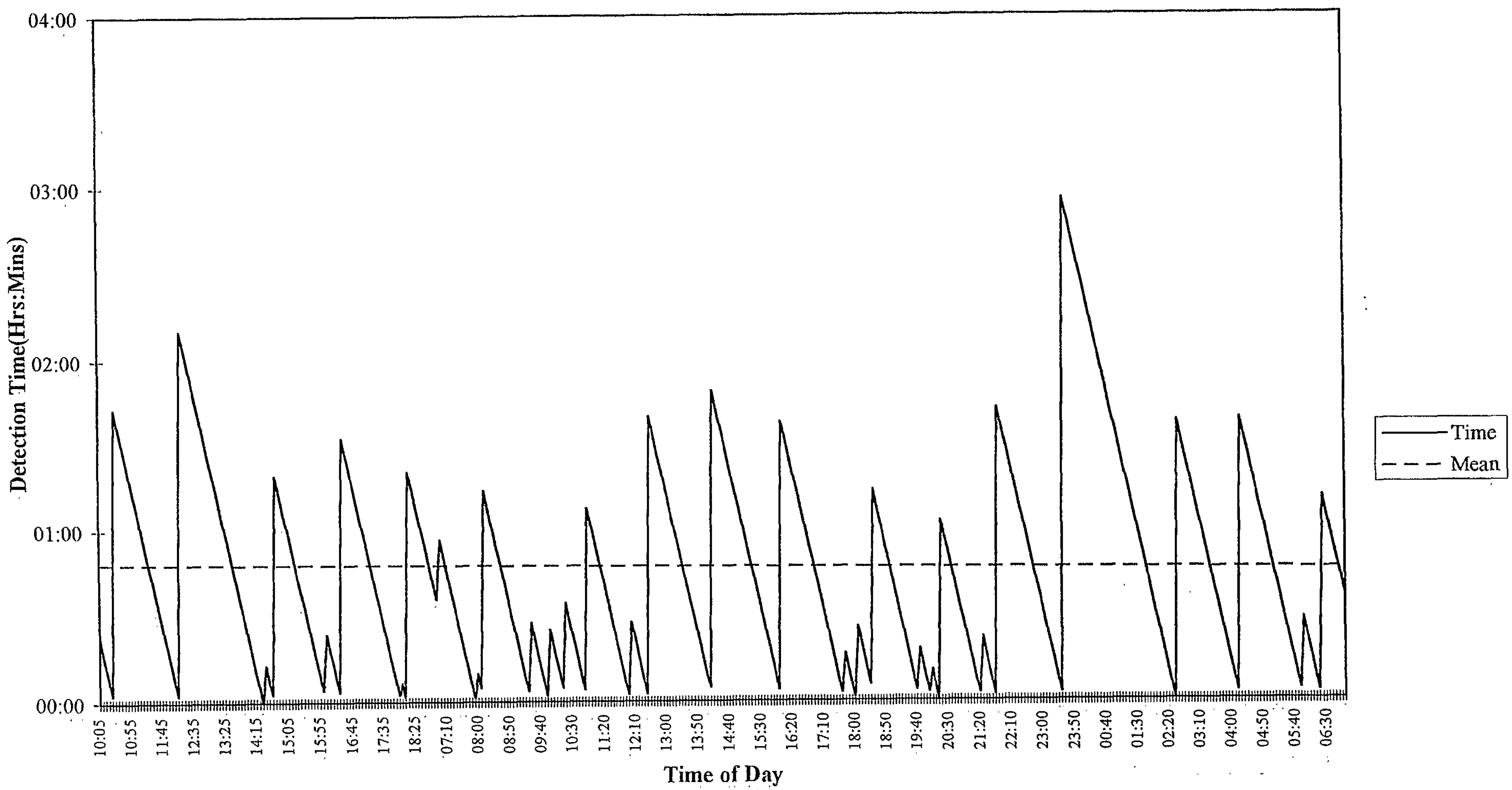
Site 1: Beacon C9D0: On, 6-Oct-97 Off, 8-Oct-97



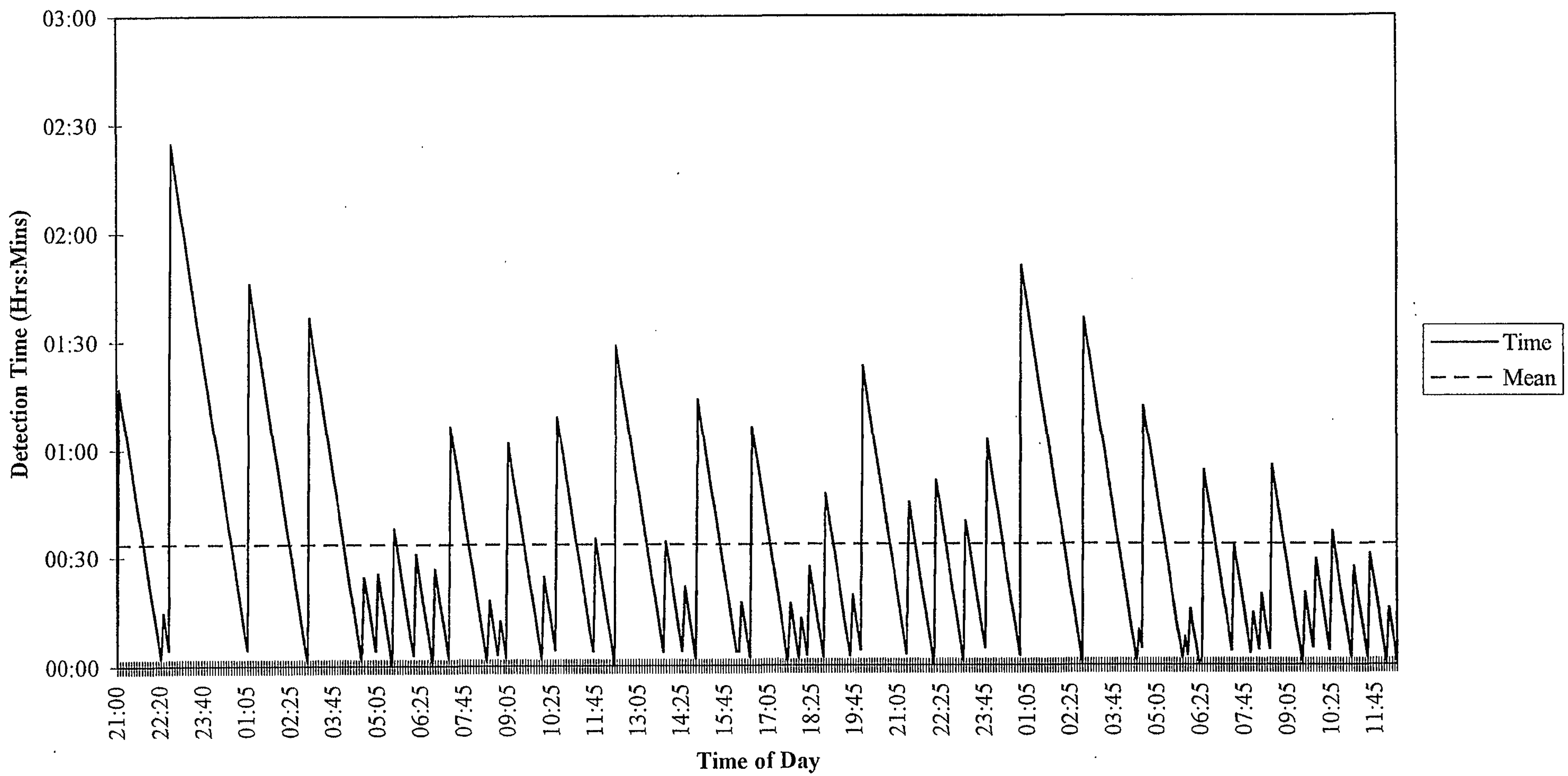
TIME TO BEACON DETECTION
Site 2: Beacon C990: On, 6-Oct-97 Off, 8-Oct-97



TIME TO BEACON DETECTION
Site 3:Beacon C990: On, 8-Oct-97 Off, 10-Oct-97

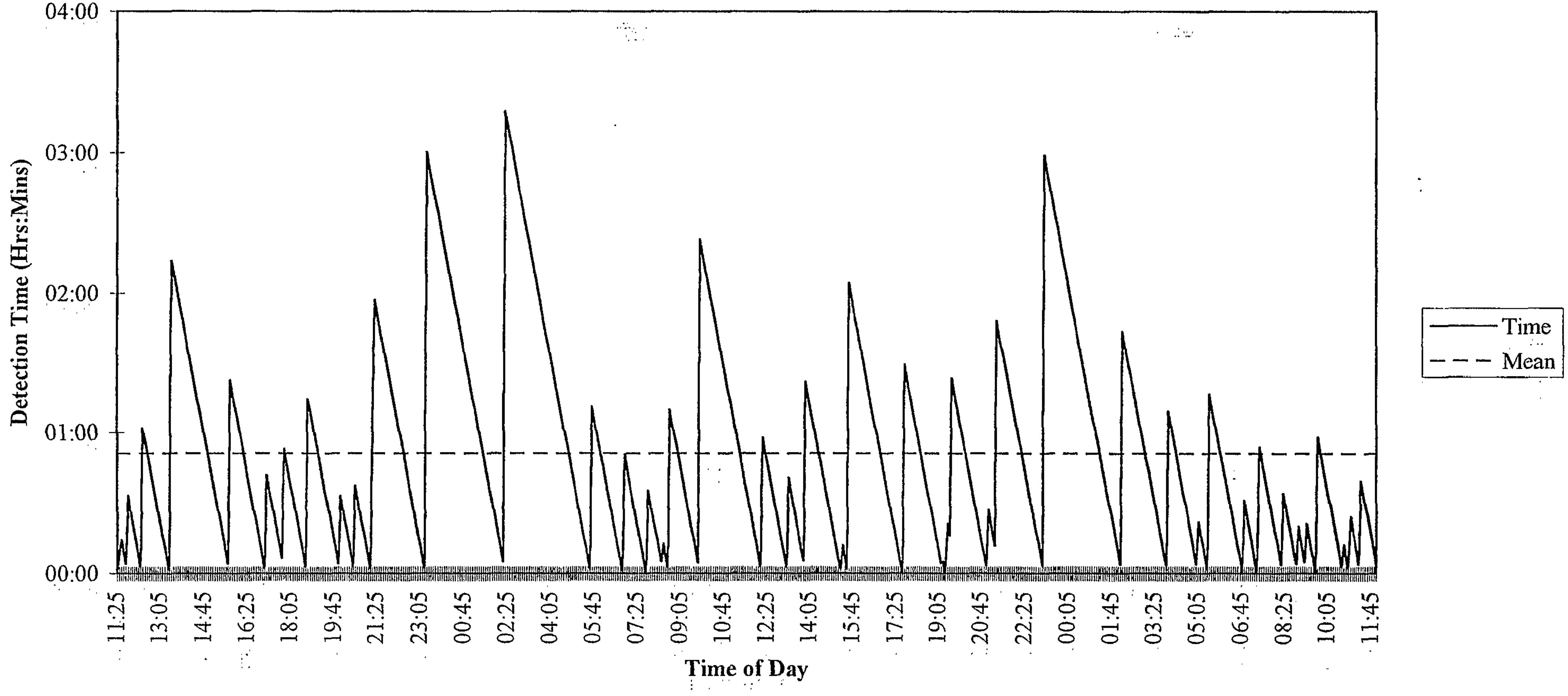


TIME TO BEACON DETECTION
Site 4 Beacon C900: On 6-Oct-97 Off, 8-Oct-97

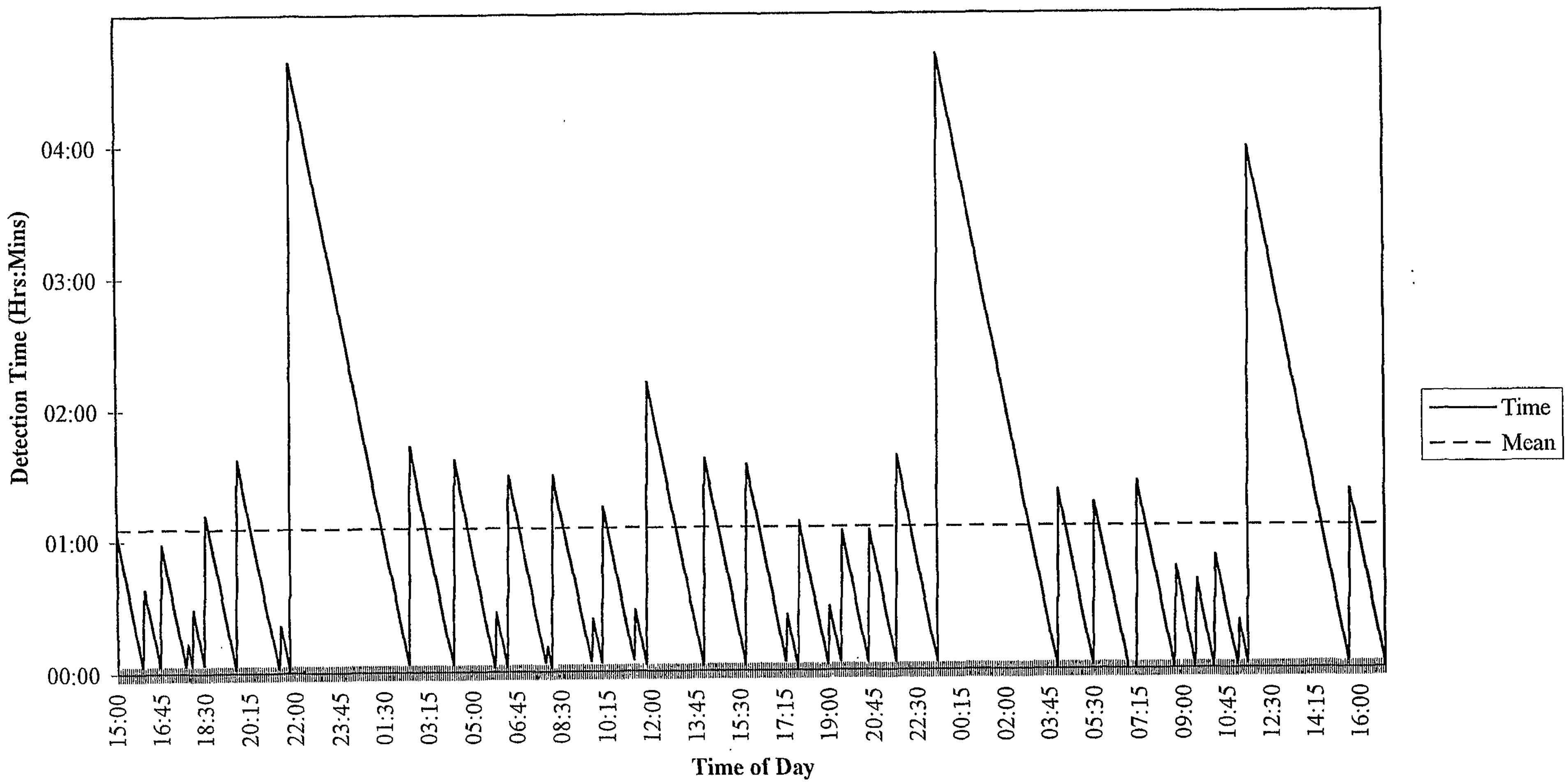


TIME TO BEACON DETECTION
Site5: BeaconC8D0: On, 5-Oct-97 Off, 7-Oct-97

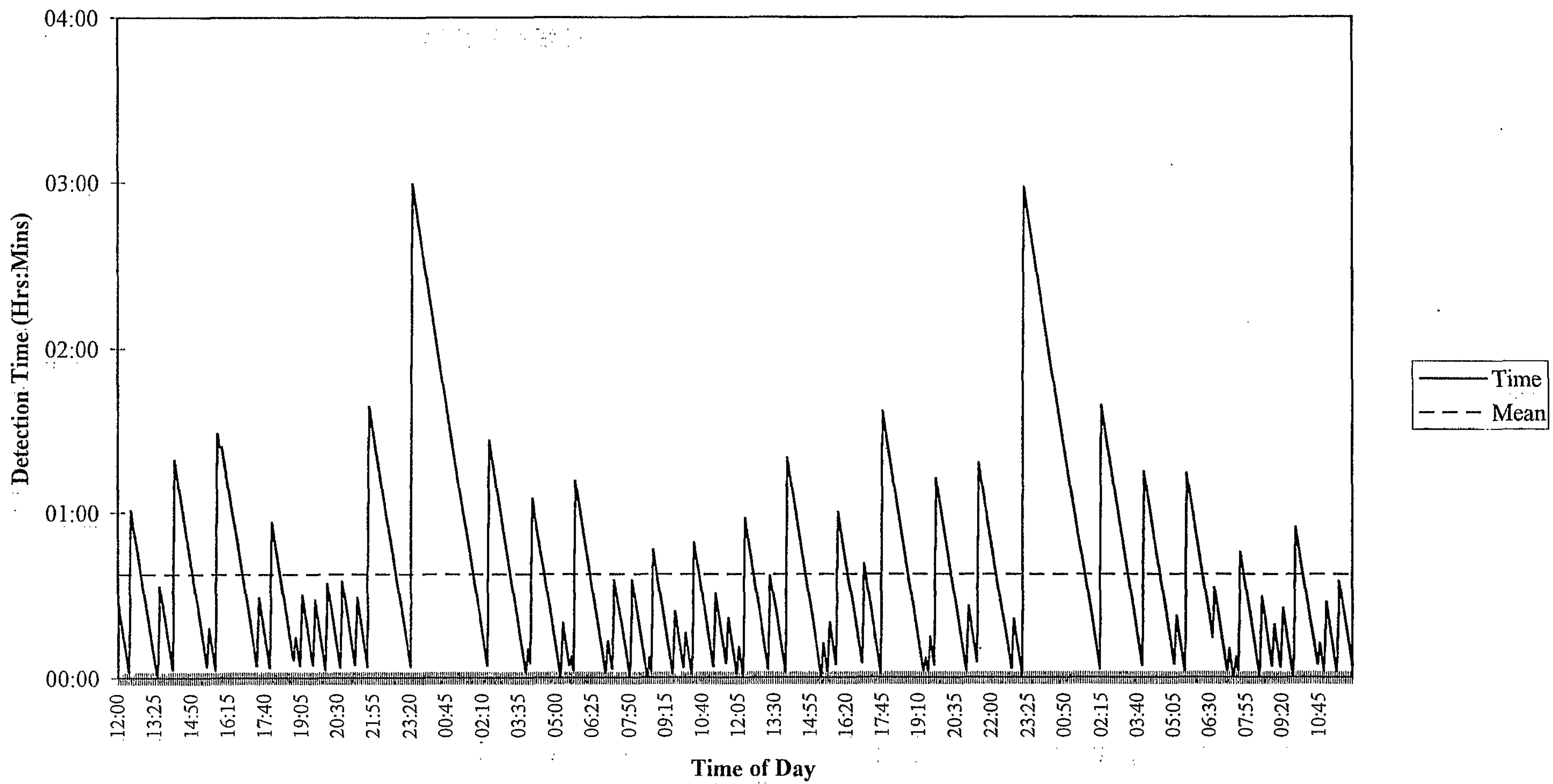
X



TIME TO BEACON DETECTION
Site 6: Beacon C9D0: On,8-Oct-97 Off, 10-Oct-97

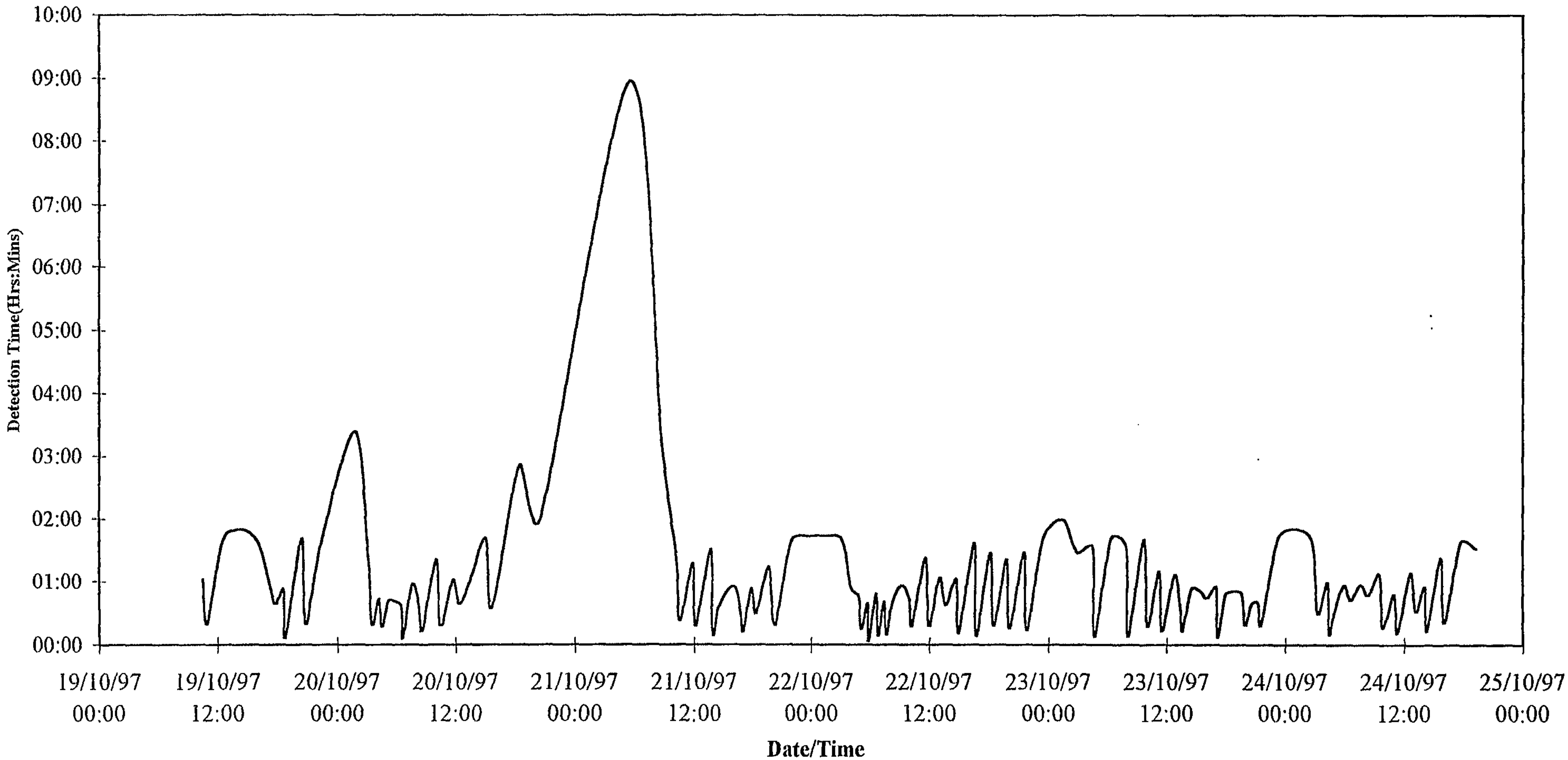


TIME TO BEACON DETECTION
Site 7: Beacon C8D0: On, 7-Oct-97 Off, 9-Oct-97

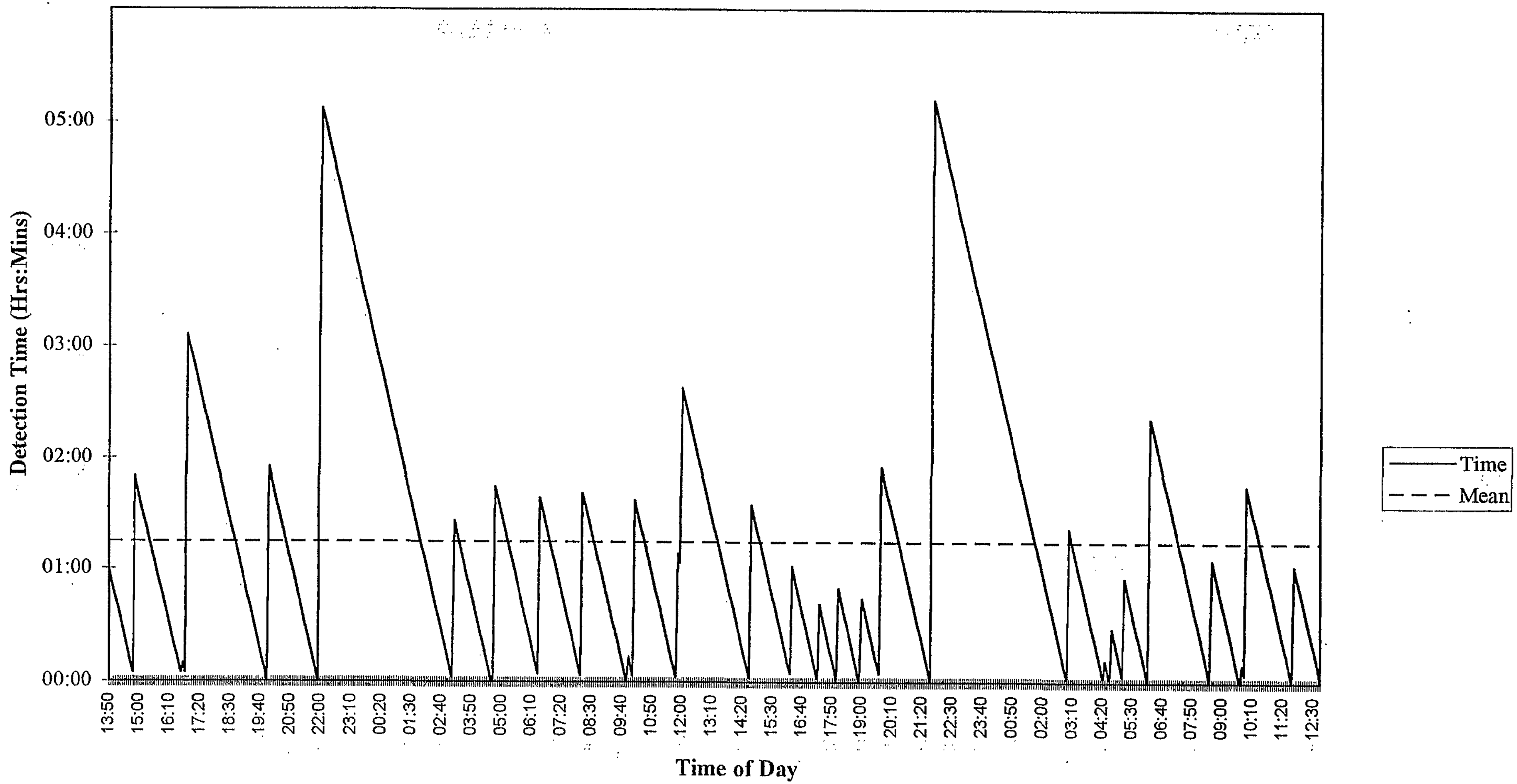


TIME TO BEACON DETECTION

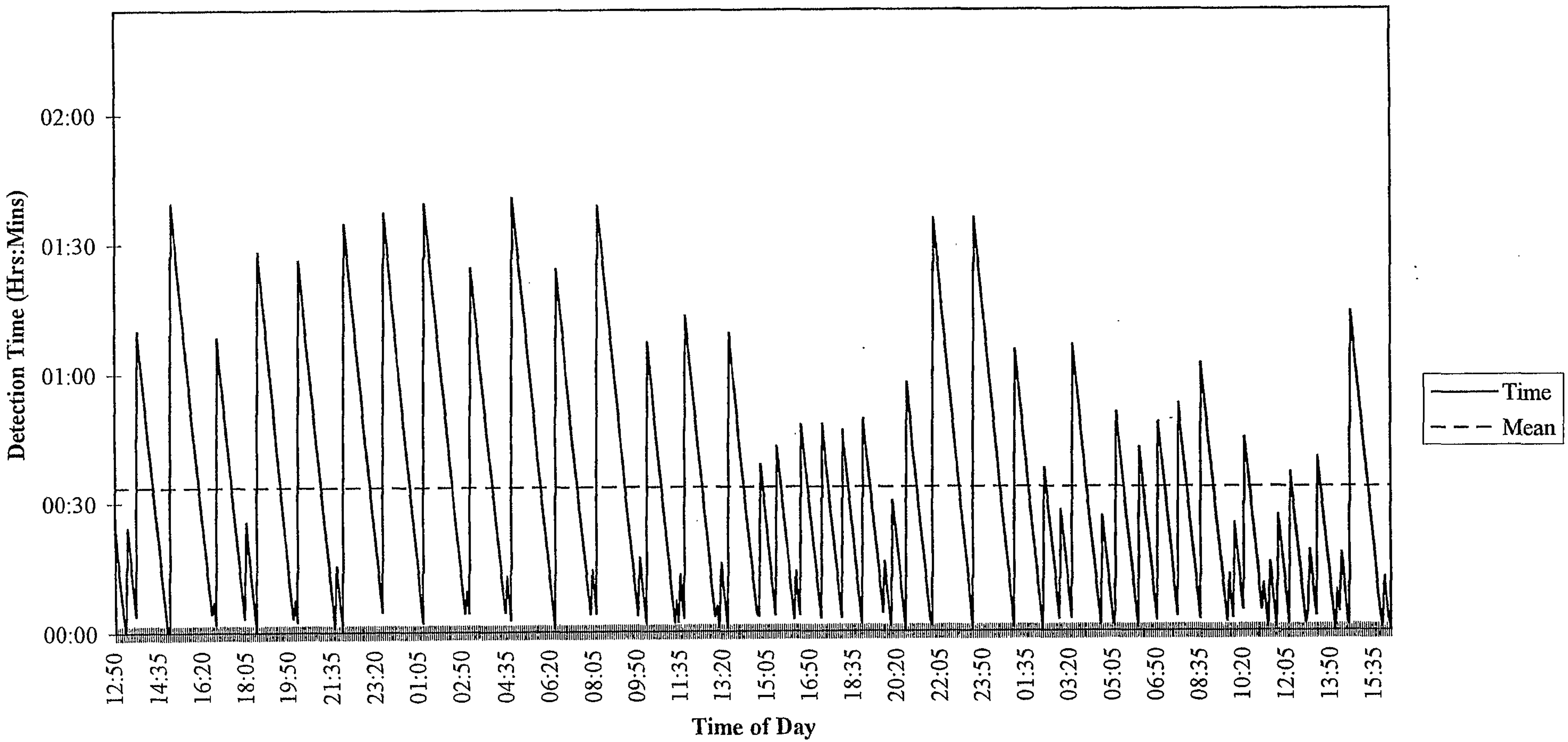
Site 8: Beacon C900: On, 8-Oct-97 Off, 10-Oct-97



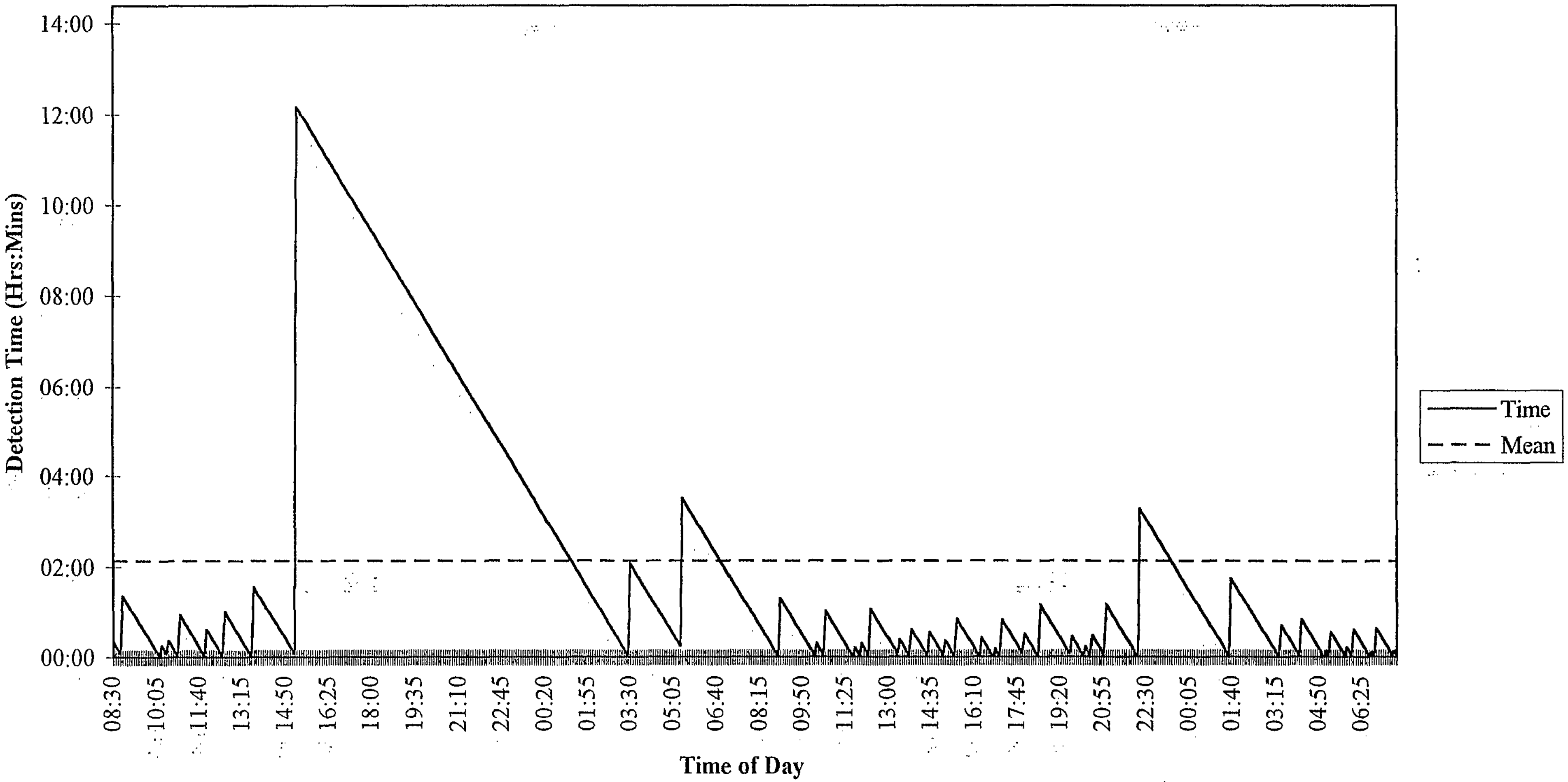
TIME TO BEACON DETECTION: WEEK 2 YORKSHIRE 19-24 OCTOBER 1997



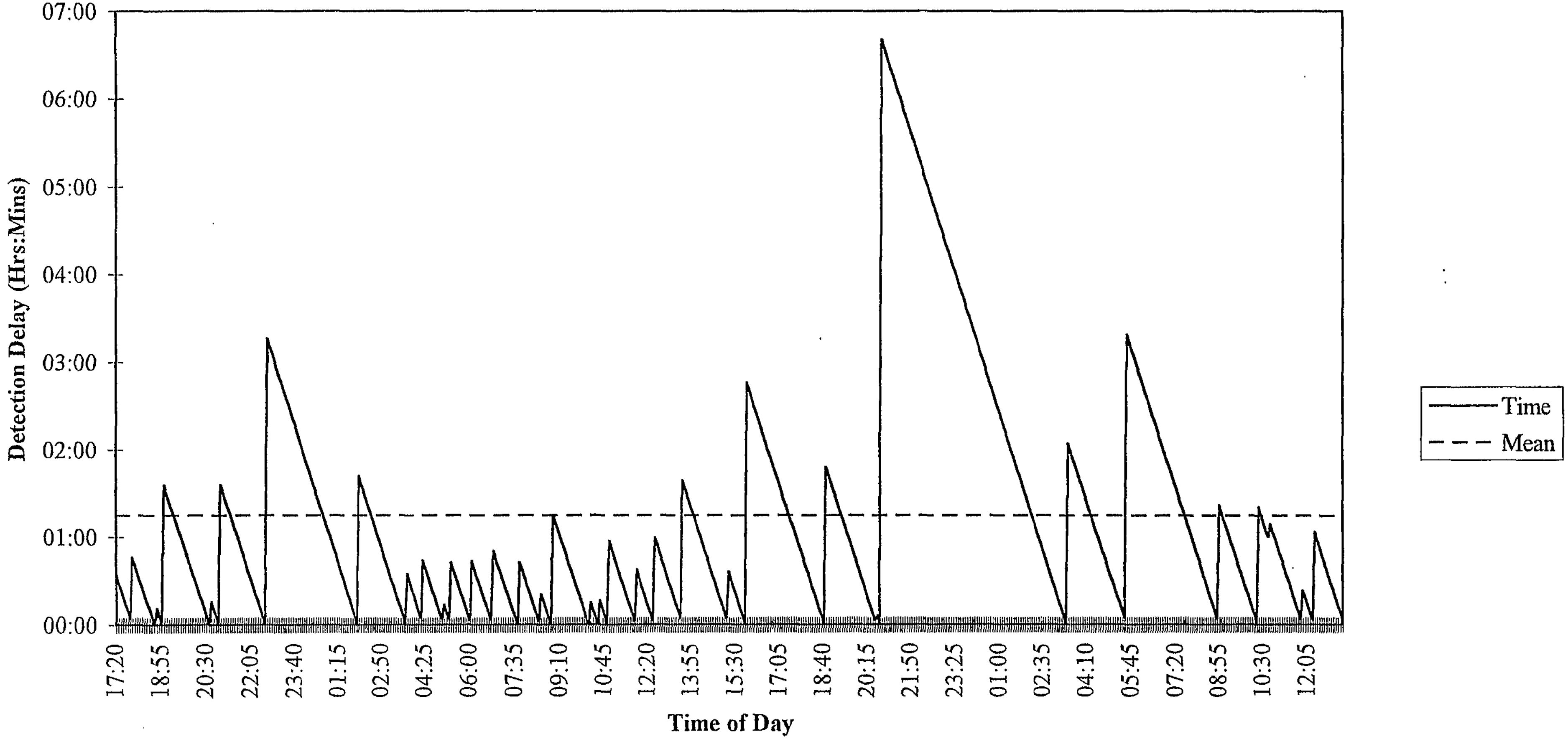
TIME TO BEACON DETECTION
Site 10: Beacon:C900 On, 22-Oct-97 Off, 24-Oct-97



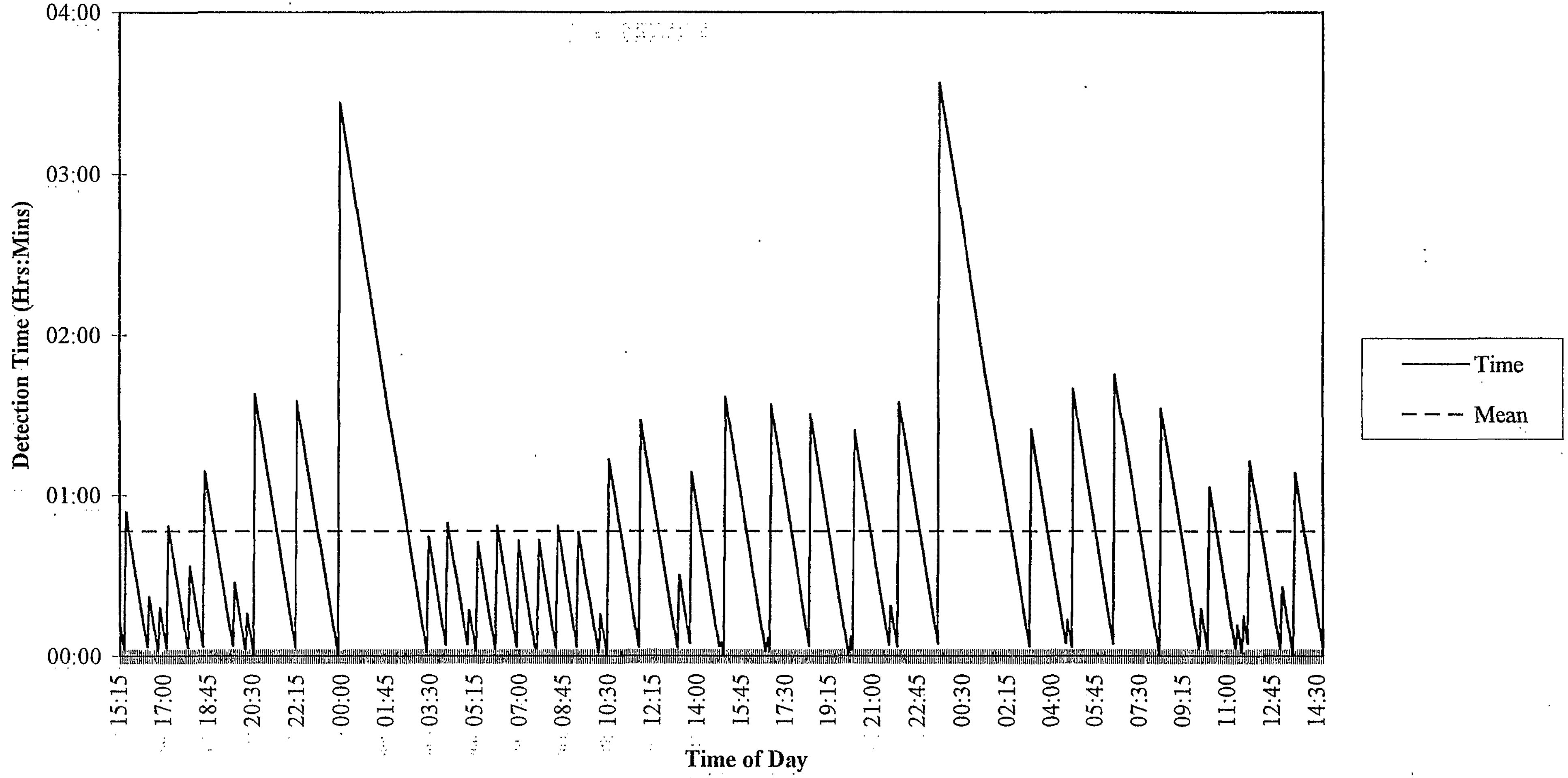
TIME TO BEACON DETECTION
Site 11: Beacon C990: On,22-Oct-97 Off, 24-Oct-97



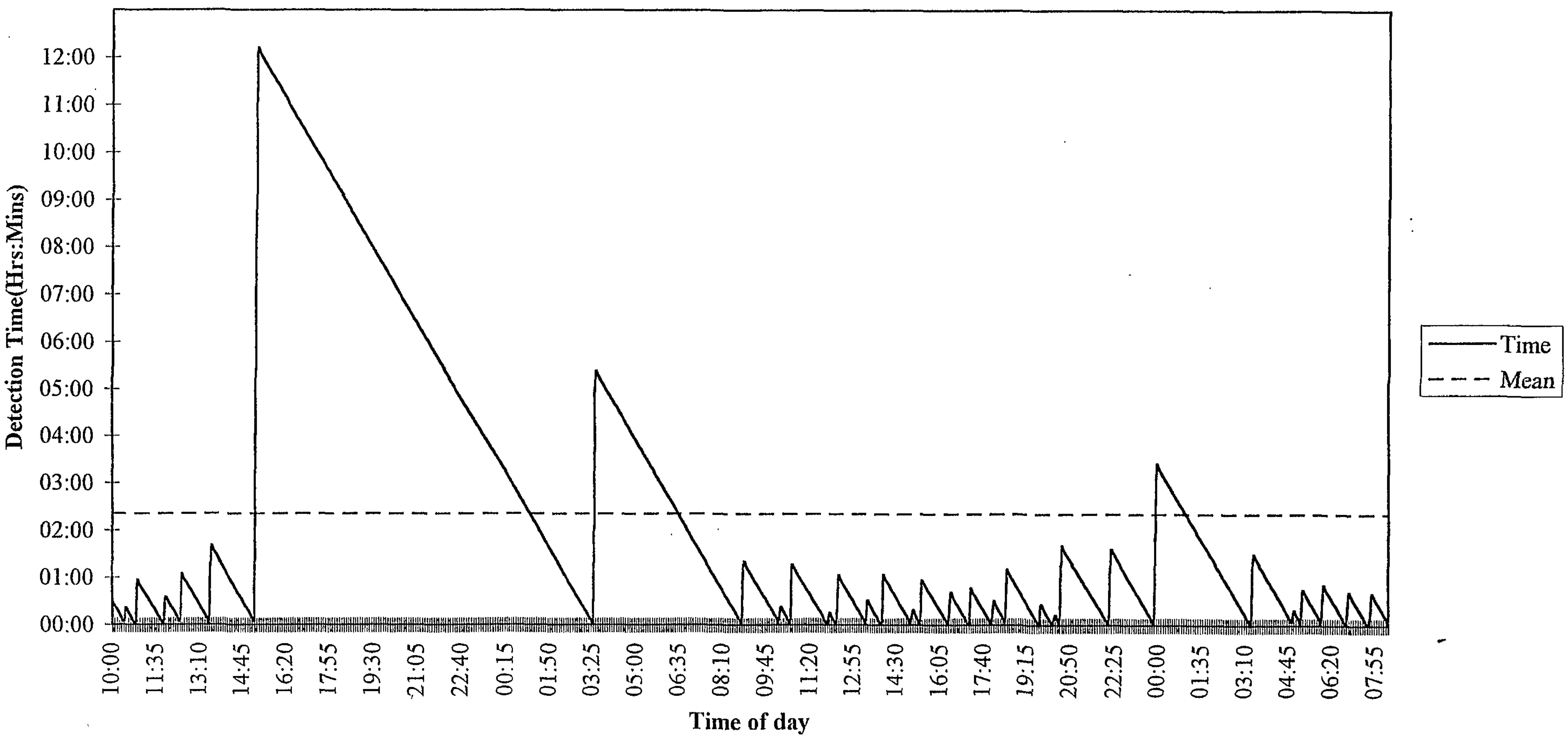
TIME TO BEACON DETECTION
Site 12: Beacon C9D0: On,20-Oct-97 Off 22-Oct-97



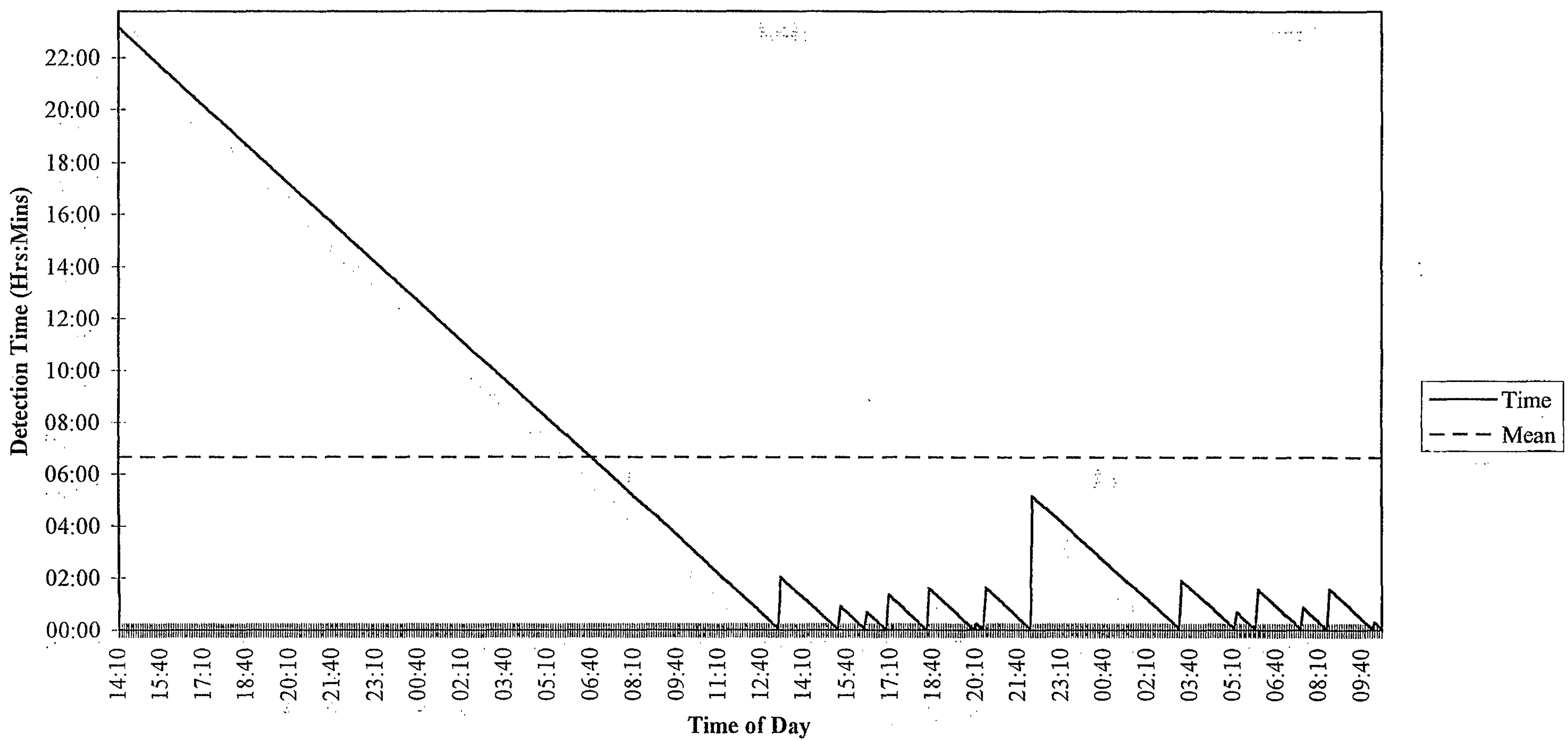
TIME TO BEACON DETECTION
Site 13 Beacon 8D0: On 19-Oct-1997 Off 21-Oct-97



TIME TO BEACON DETECTION
Site14: Beacon C8D0: On, 21-Oct-97 Off,23-Oct-97



TIME TO BEACON DETECTION
Site 15: Beacon C900: On, 20-Oct-97 Off 22-Oct-97



TIME TO BEACON DETECTION
Site 16: Beacon: C990:On,14:08 20-Oct-97 Off, 11:00 22-Oct-97

APPENDIX VI

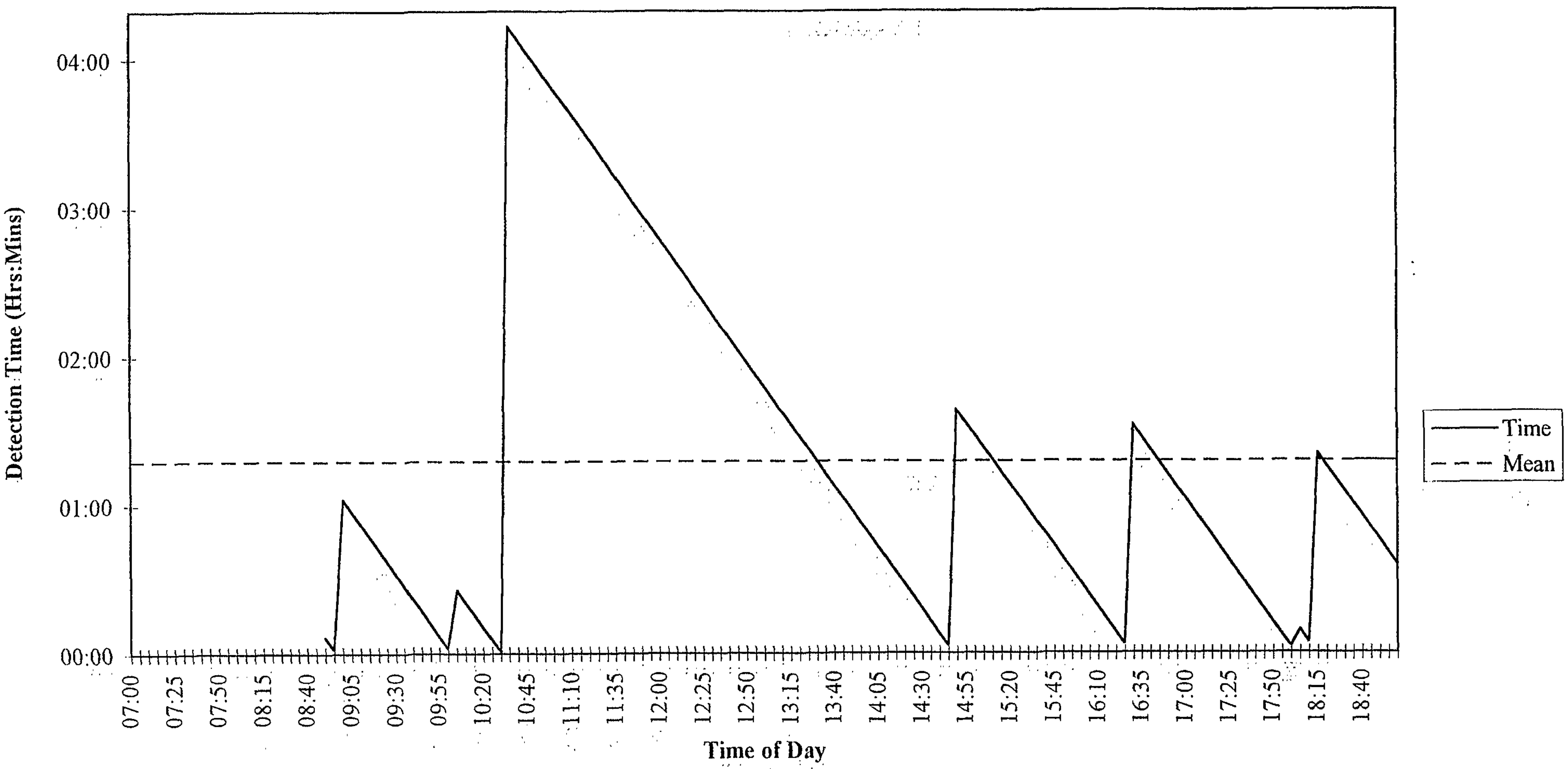
DETECTION PROBABILITIES FOR 48 HOUR TRIAL PERIODS

Table VI: Percentage Probability of Detection within Various Times (48 Hour Trial Period)

Site No	Terrain	30mins	1 hour	2 hours	3 hours	4 hours	5 hours
	Wales						
1	Severe Wooded Valley	31	54	80	88	96	100
2	Severe Valley	42	70	99	100	100	100
3	U-Shaped Valley, Clear	39	65	91	96	99	100
4	U-Shaped Valley, Clear	42	67	95	100	100	100
5	Wide Open	56	82	99	100	100	100
6	High Undulating Wooded	41	67	91	99	100	100
7	U-Shaped Valley, Scrub	36	61	85	91	97	100
8	Valley - Dense Wood	51	76	94	100	100	100
	Yorkshire						
9	U-Shaped Bowl, Open	32	59	86	91	95	99
10	Gorge, Scrub	28	53	82	90	95	99
11	Semi-table-top, open	53	82	100	100	100	100
12	Undulating Scrub	38	57	72	79	83	85
13	Severe Valley, Open	35	58	81	90	94	96
14	Wooded Plateau	44	72	94	98	100	100
15	Deep Wooded Valley	33	53	67	74	79	83
16	Between cliff and house	16	29	45	50	54	59

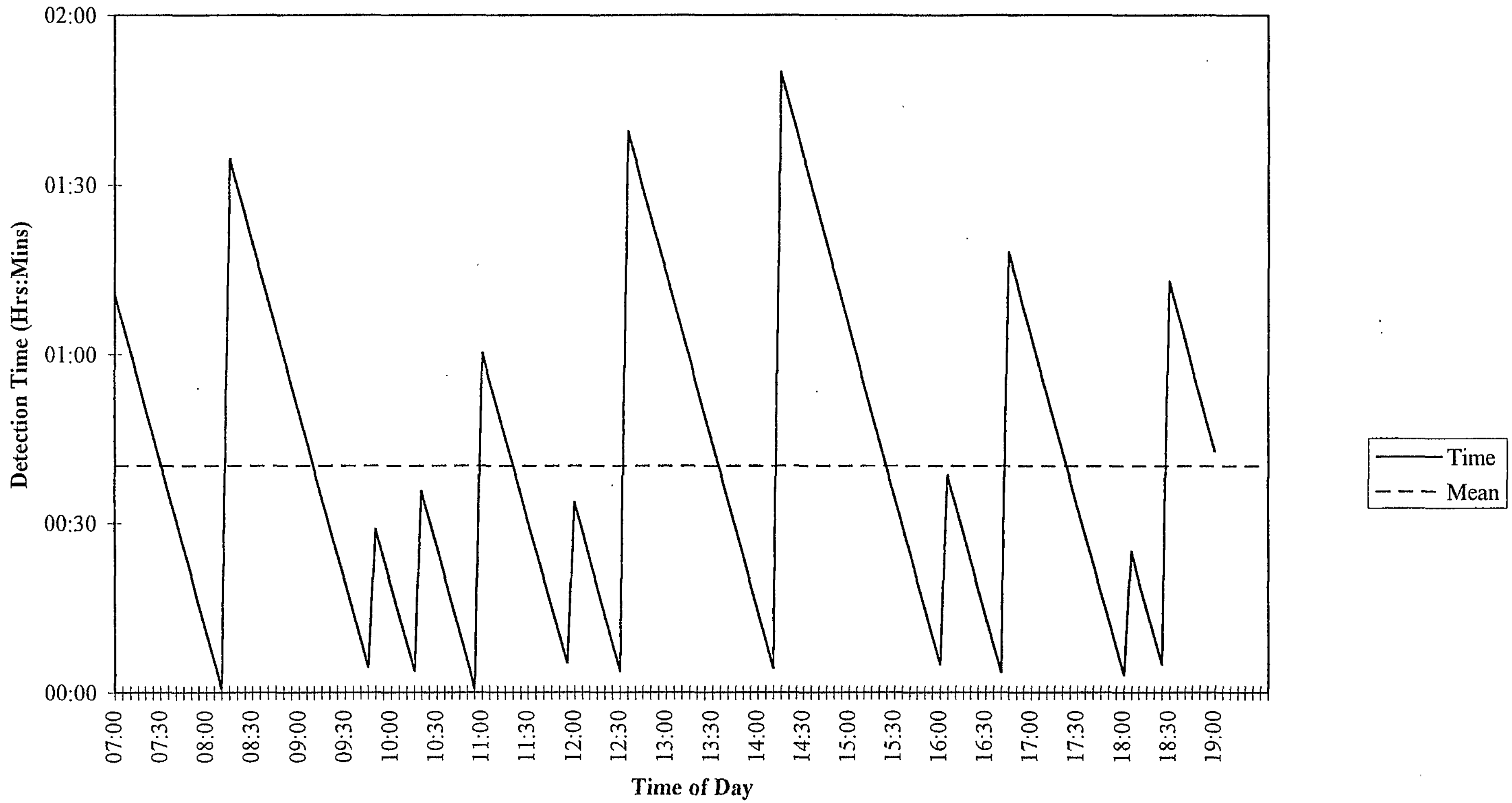
APPENDIX VII

DETECTION DELAYS FOR TYPICAL WORKING DAY (7AM TO 7PM)

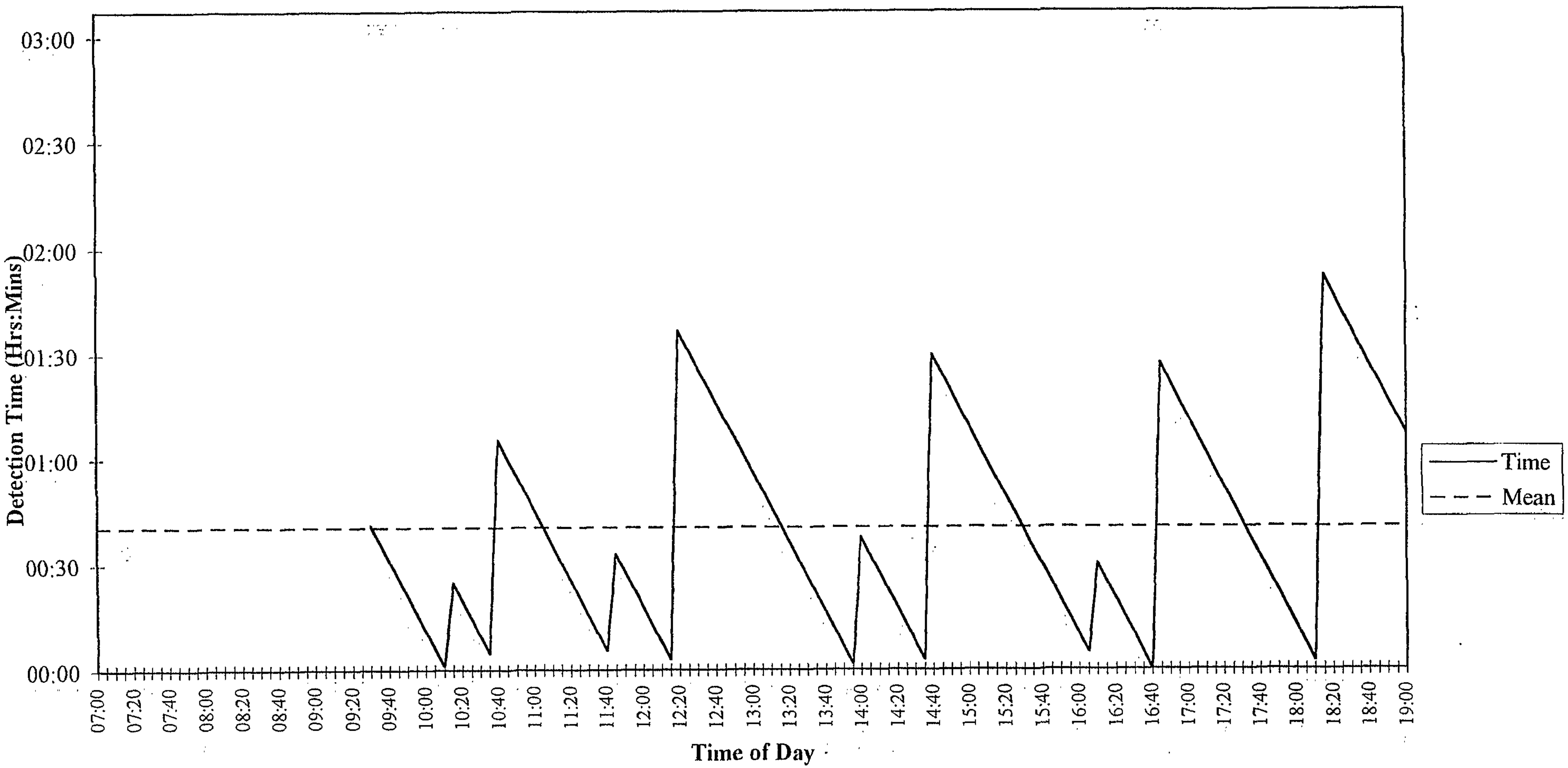


TIME TO BEACON DETECTION

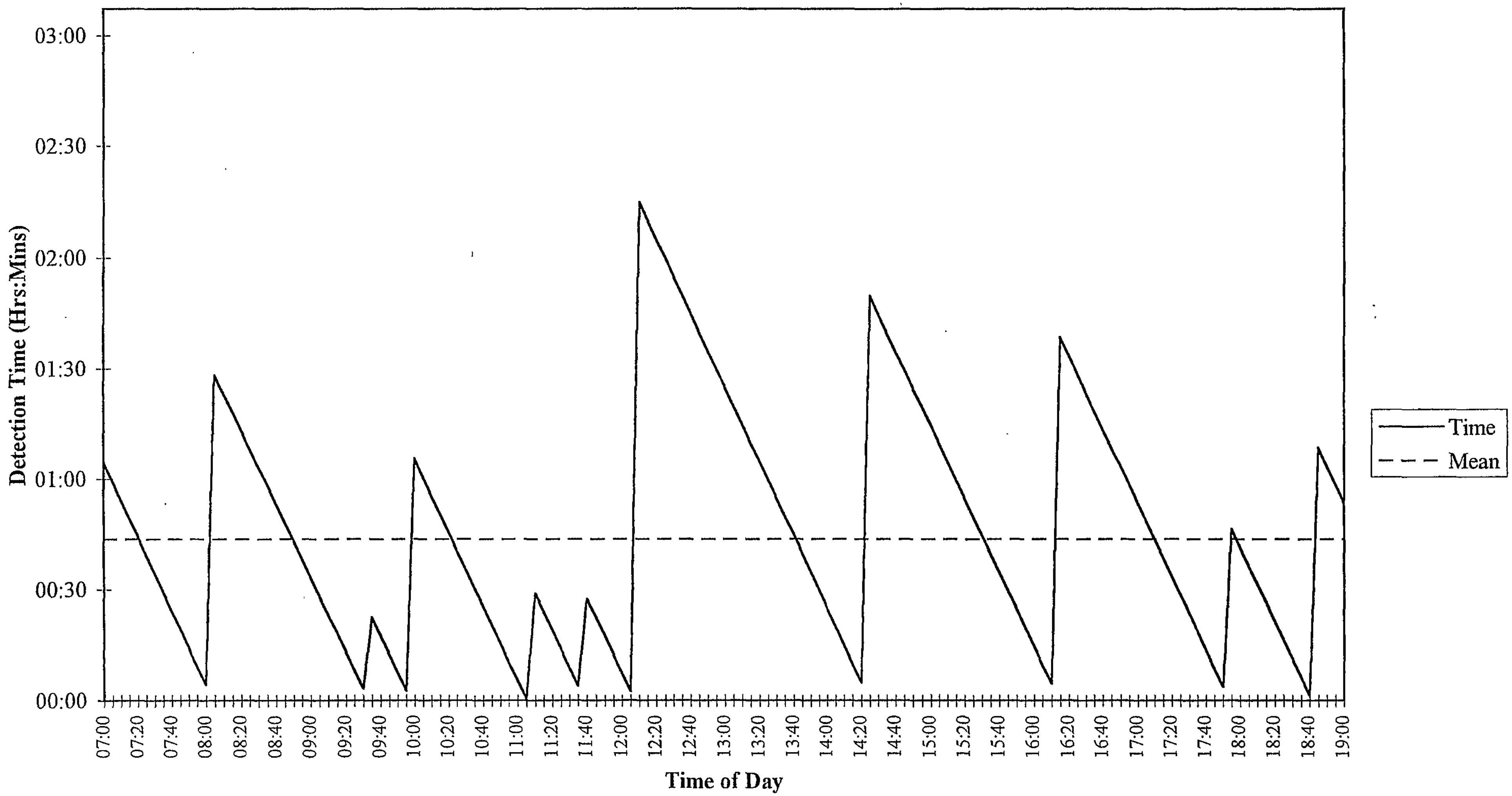
Site 1: Beacon C9D0 6-Oct-97



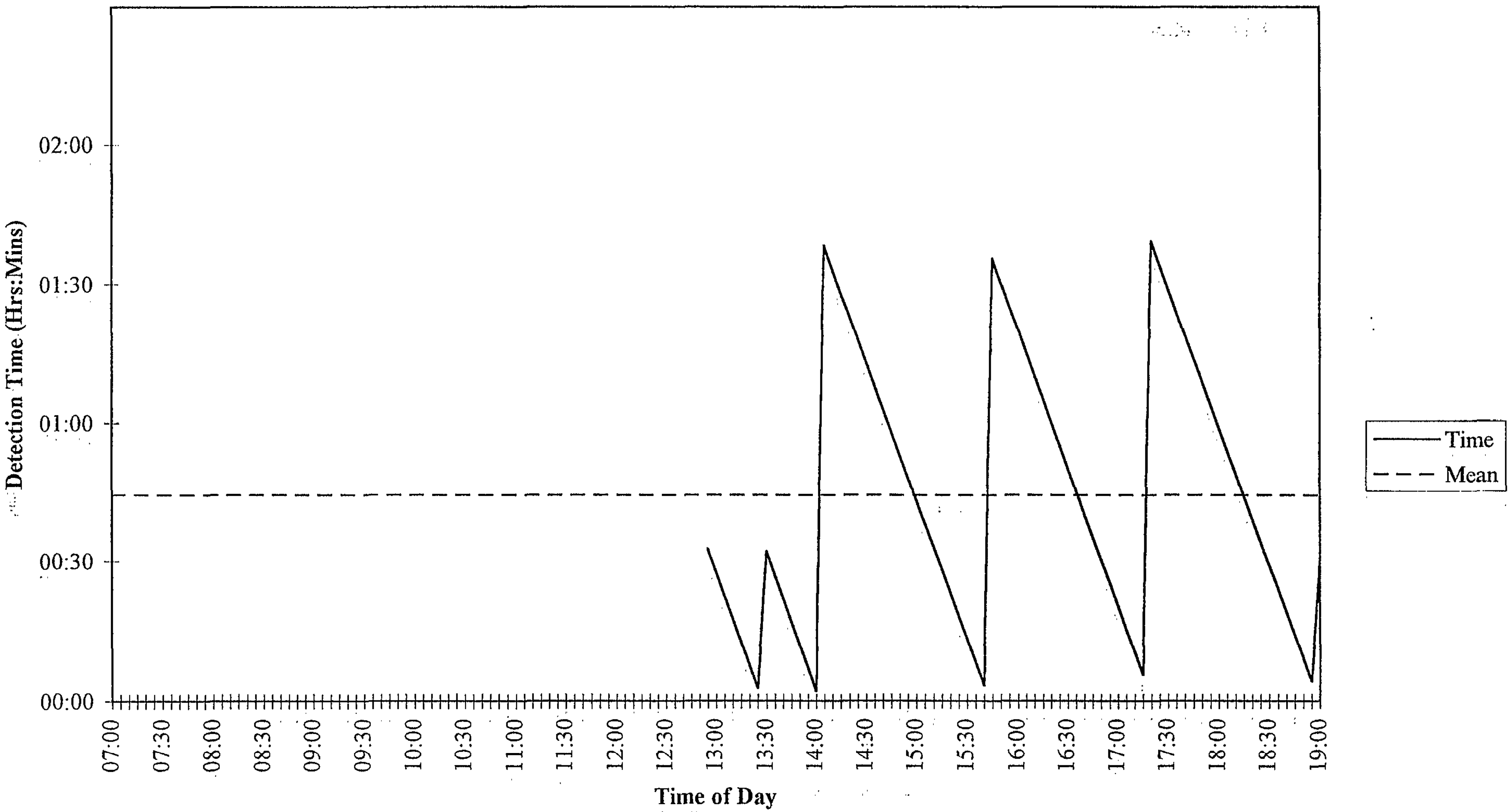
TIME TO BEACON DETECTION
Site 1: Beacon C9D0 7-Oct-97



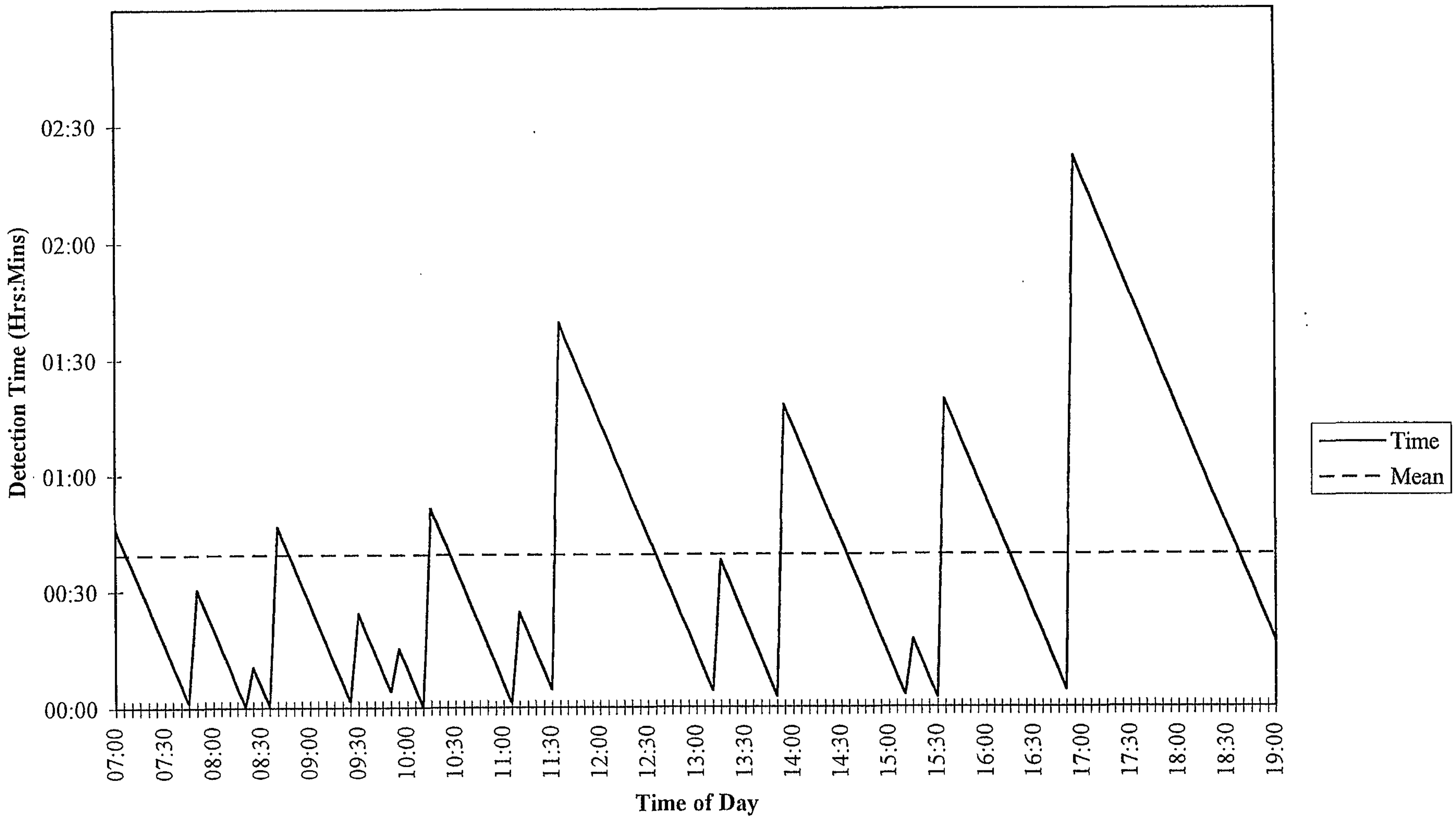
TIME TO BEACON DETECTION
Site 2: Beacon C990: 6-Oct-97



TIME TO BEACON DETECTION
Site 2: Beacon C990: 7 October 1997

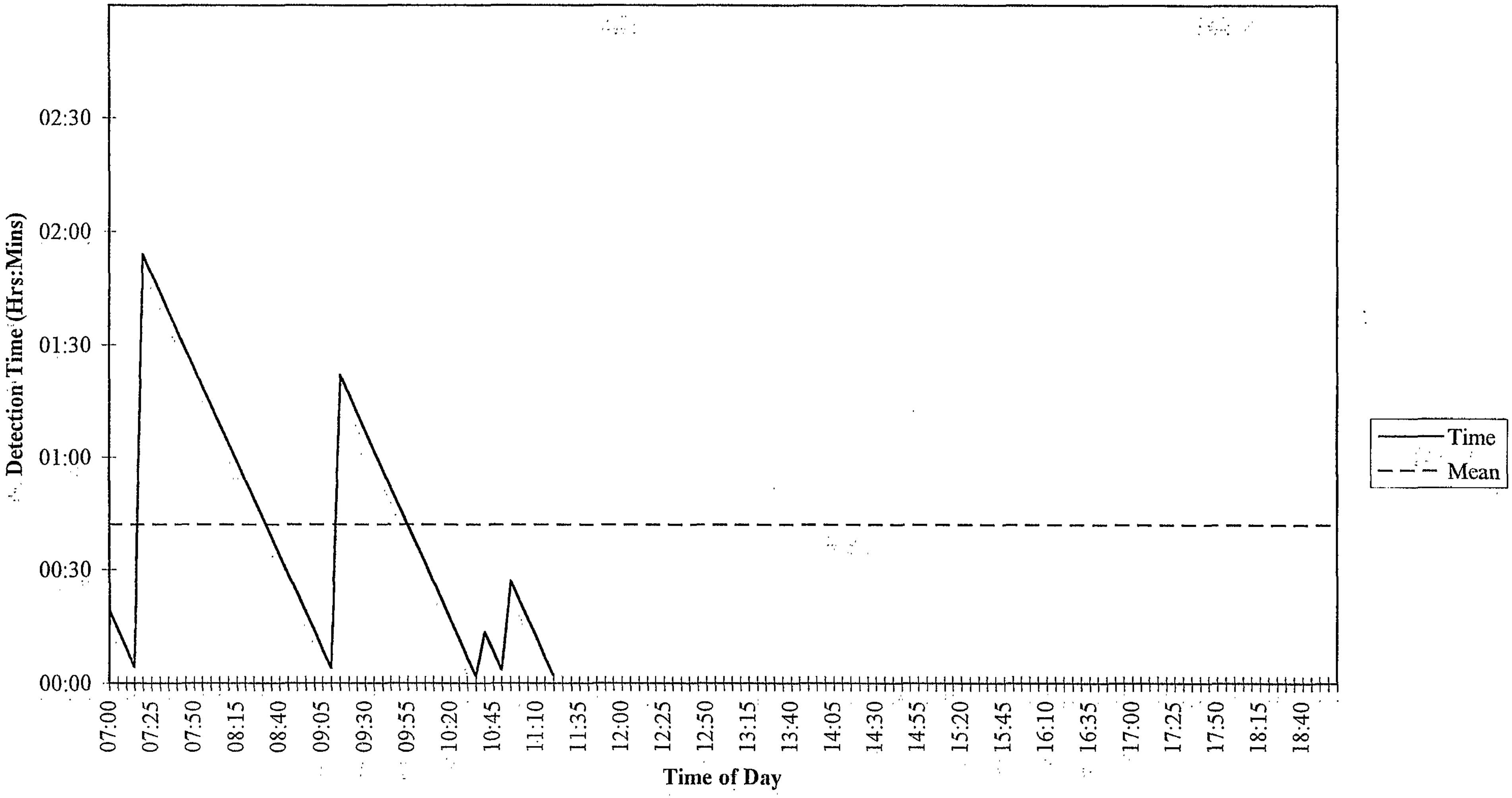


TIME TO BEACON DETECTION
Site 3:Beacon C990: 08-Oct-97

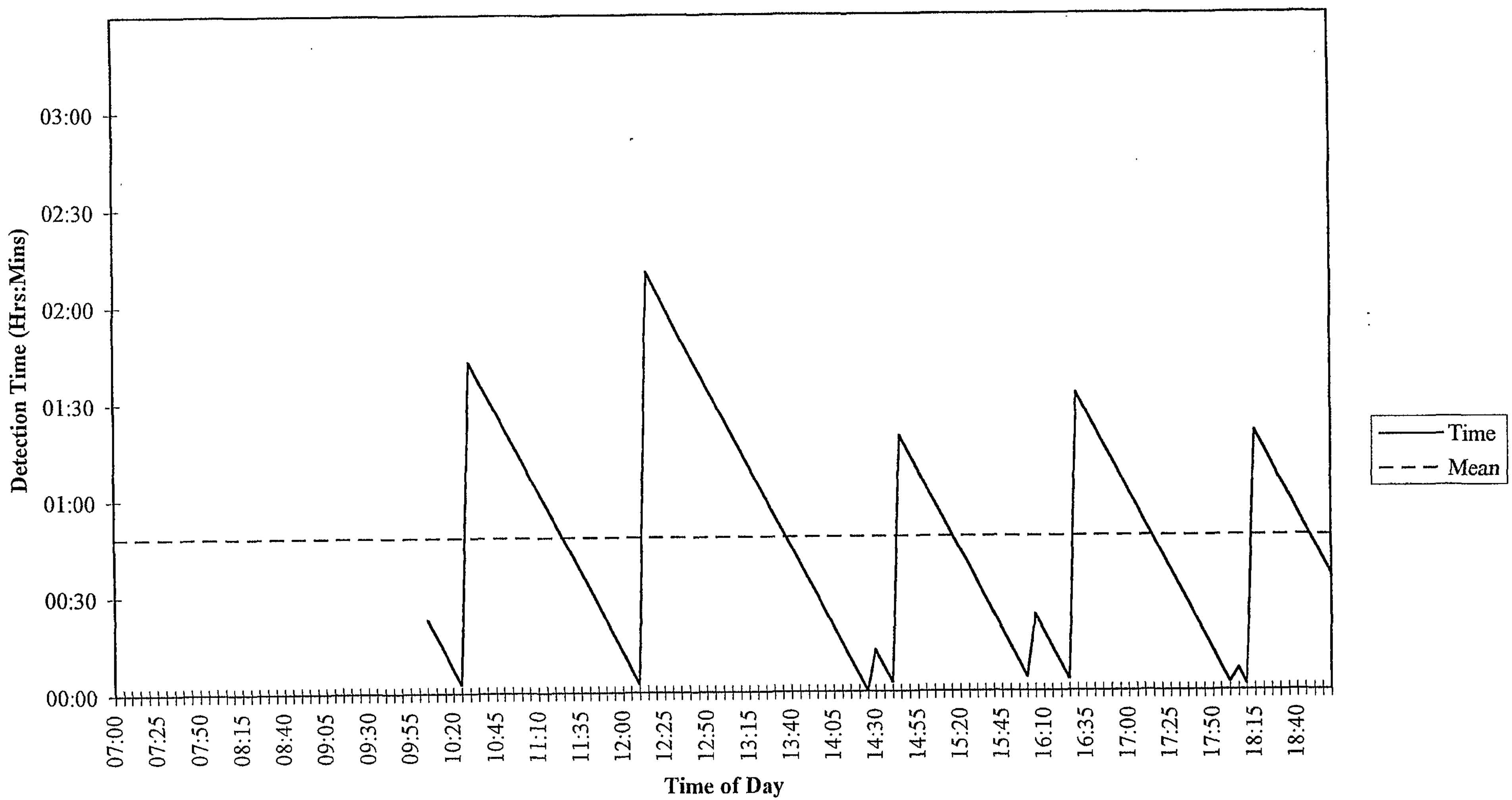


TIME TO BEACON DETECTION

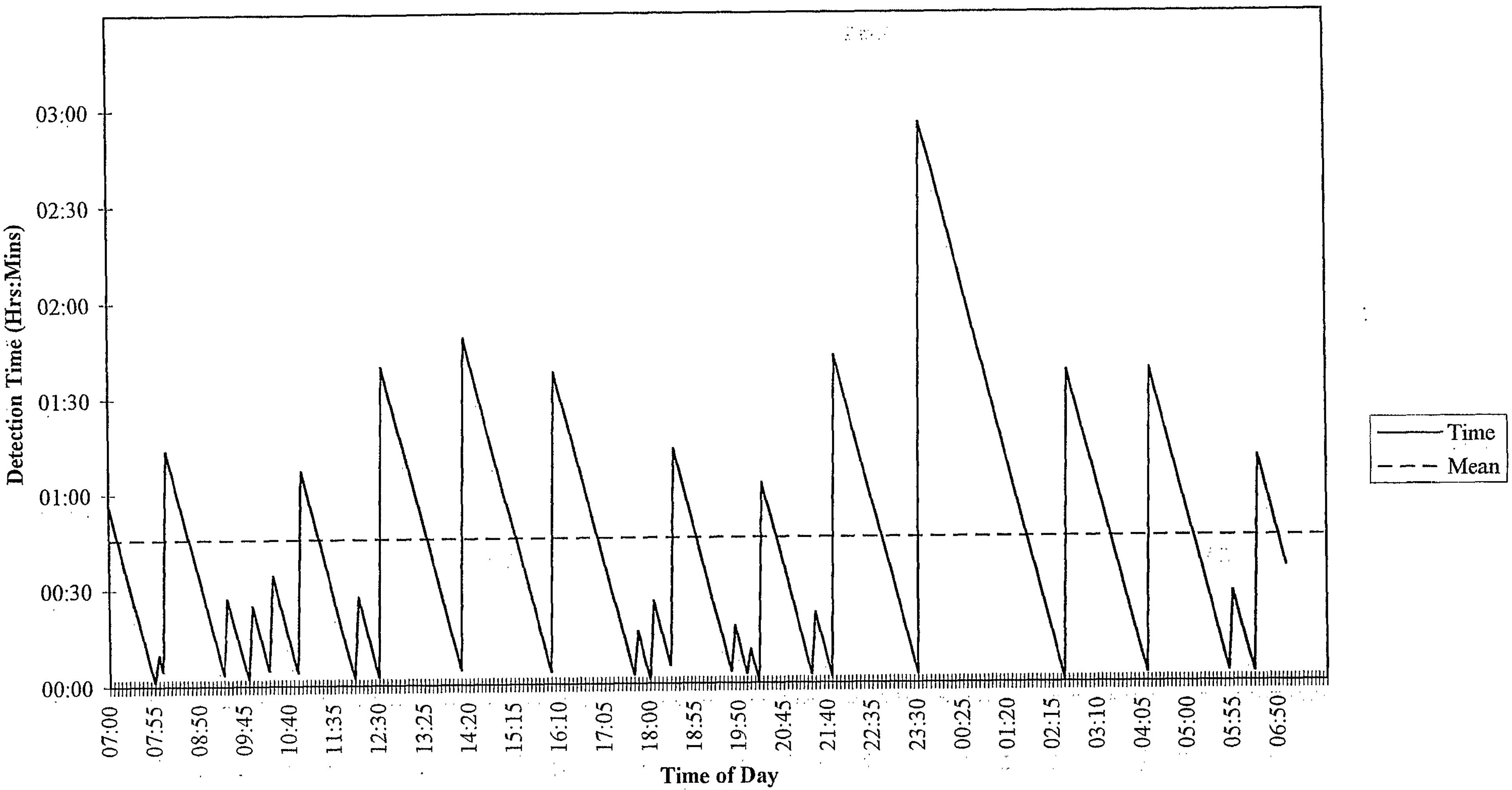
Site 3:Beacon C990: 9-Oct-97



TIME TO BEACON DETECTION
Site 3:Beacon C990: 10 October 1997

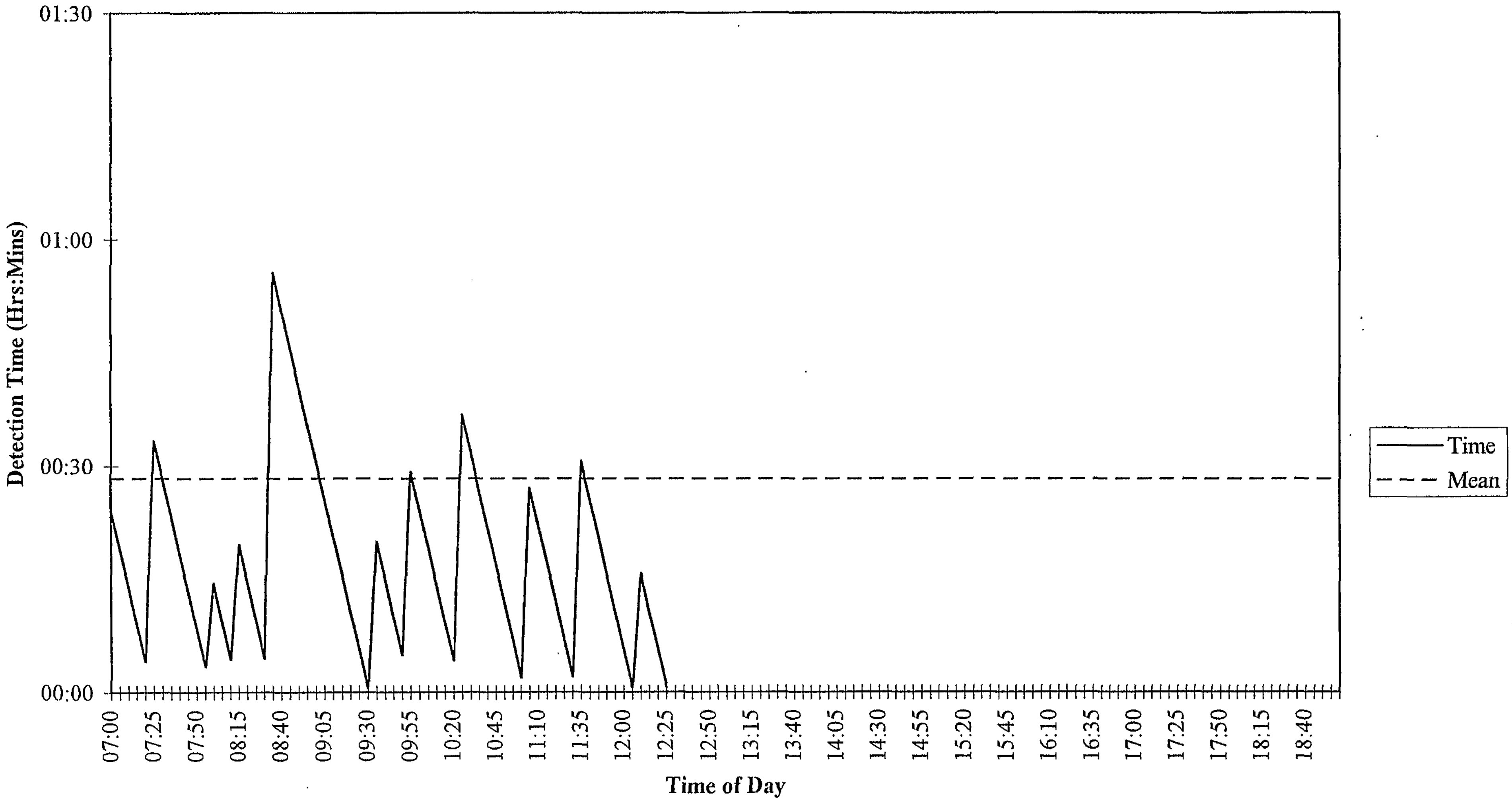


TIME TO BEACON DETECTION
Site4: BeaconC900: 6-Oct-97



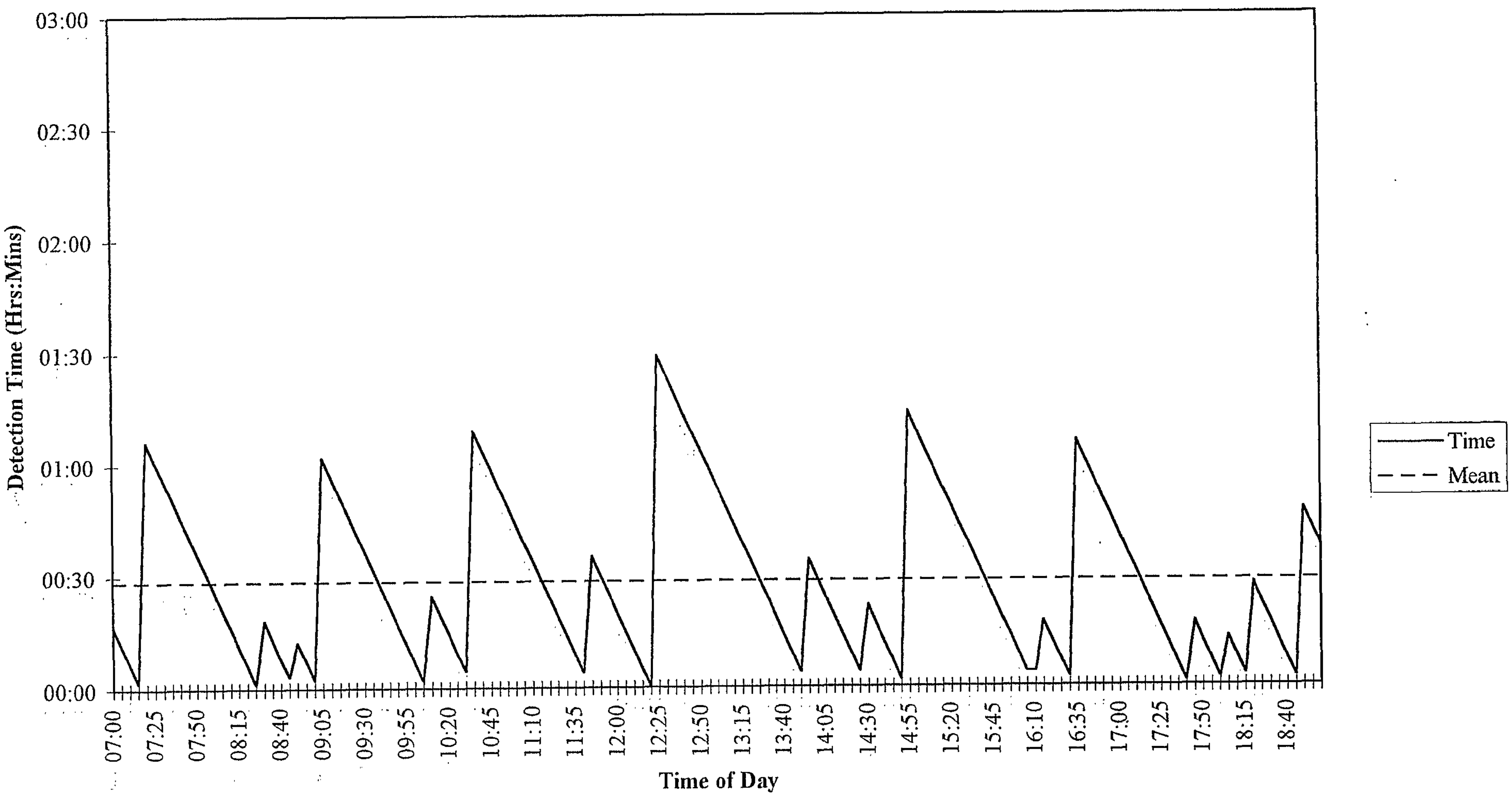
TIME TO BEACON DETECTION

Site4: BeaconC900: 7-Oct-97

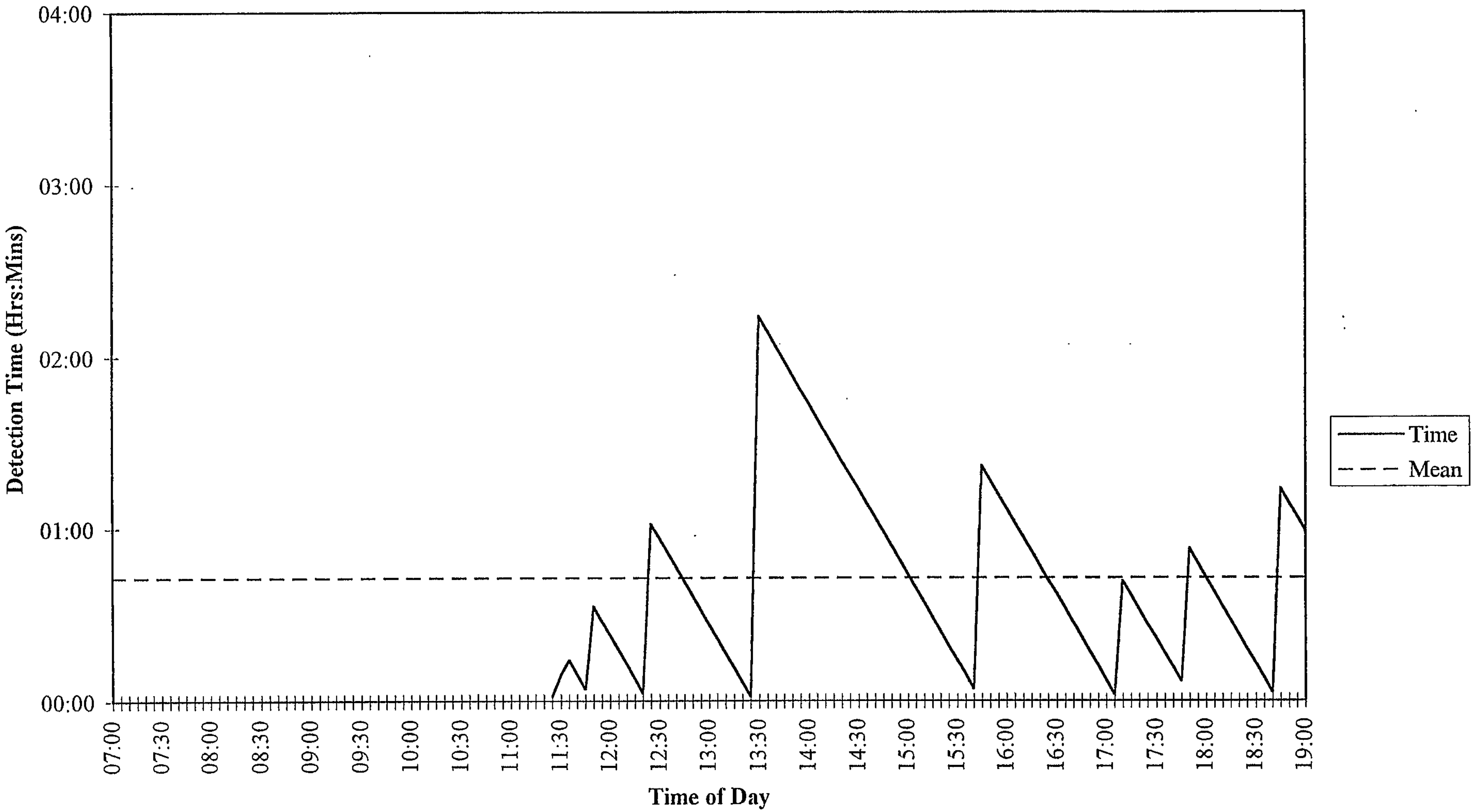


TIME TO BEACON DETECTION

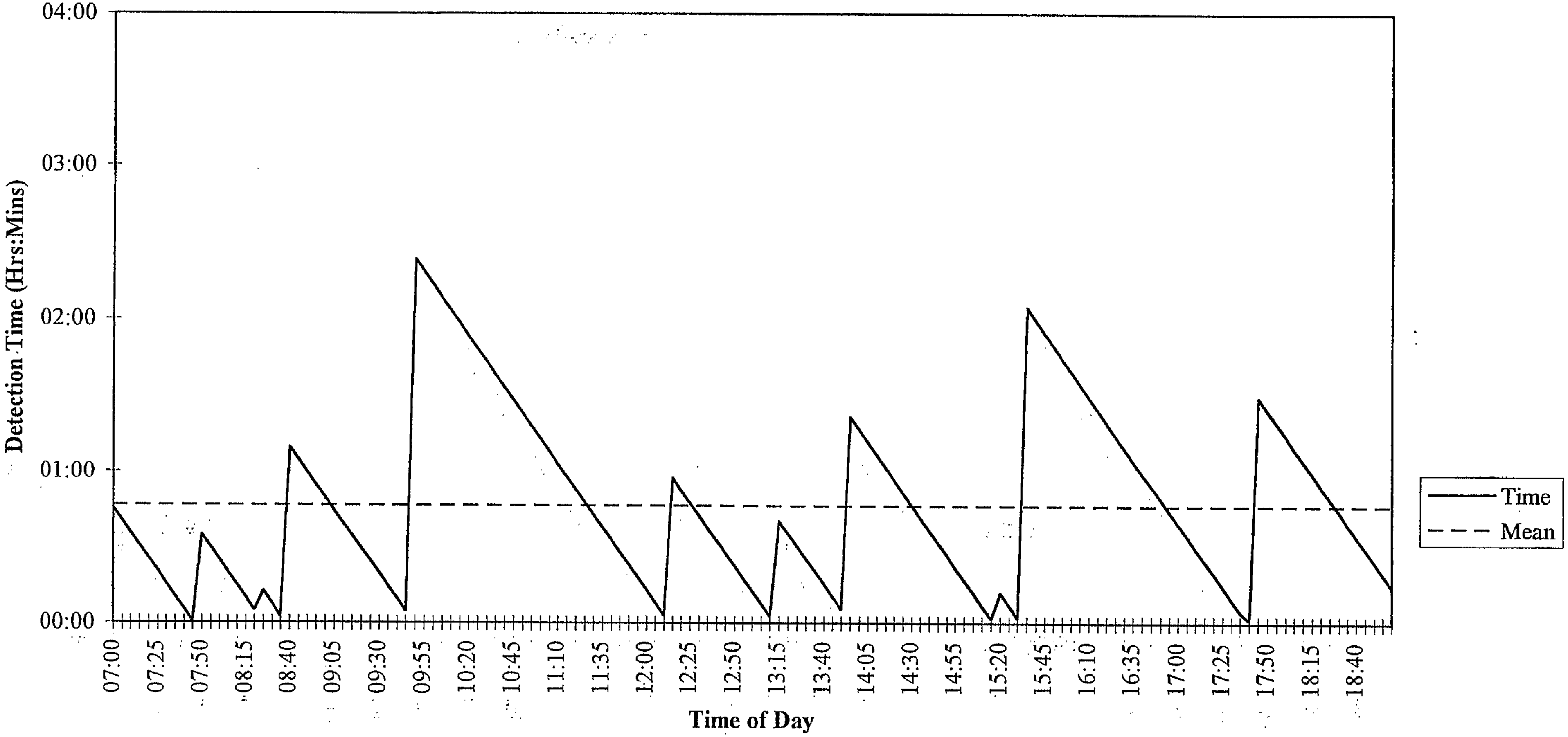
Site5: BeaconC8D0: 6-Oct-97



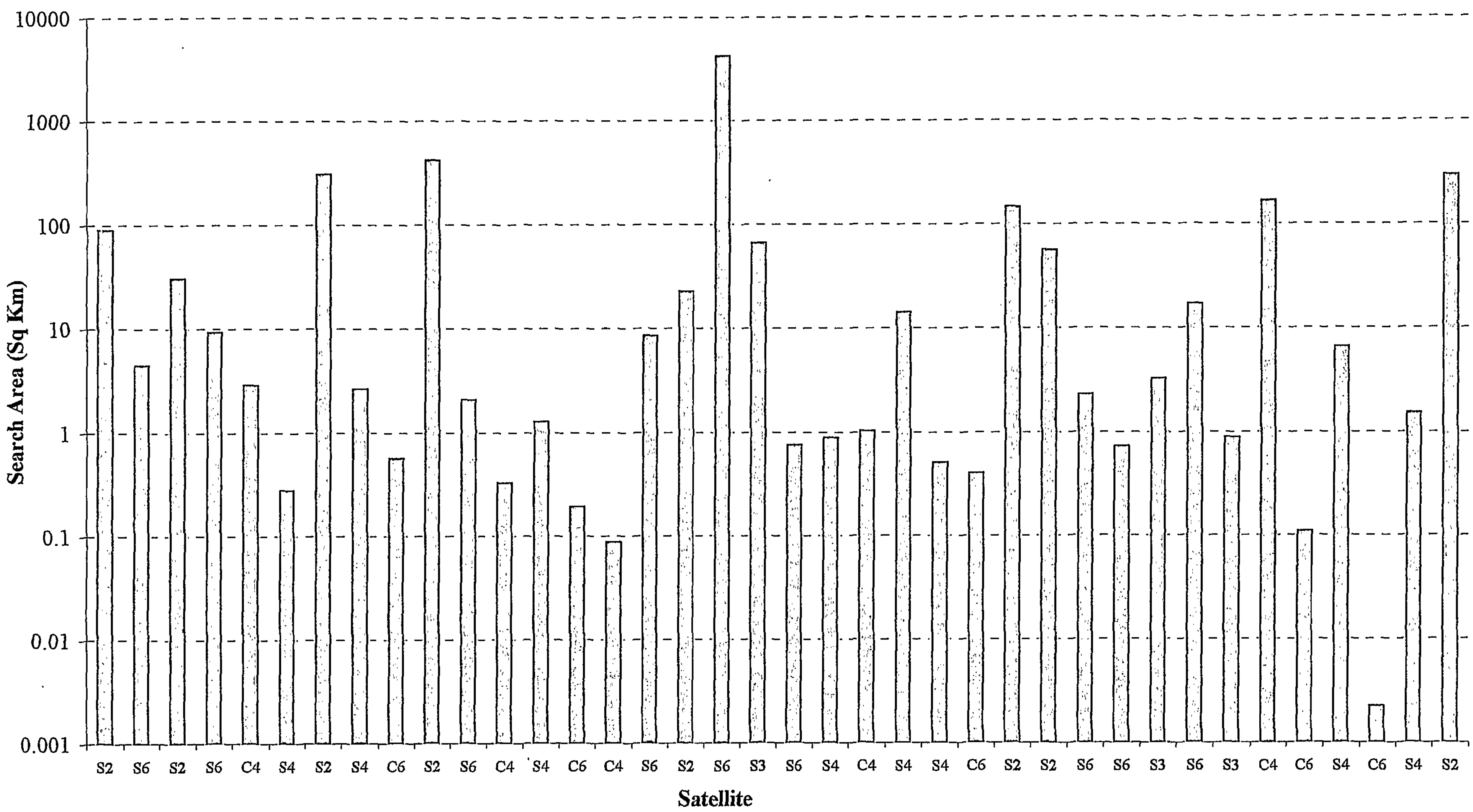
TIME TO BEACON DETECTION
Site 5: Beacon C8D0: 7-Oct-97



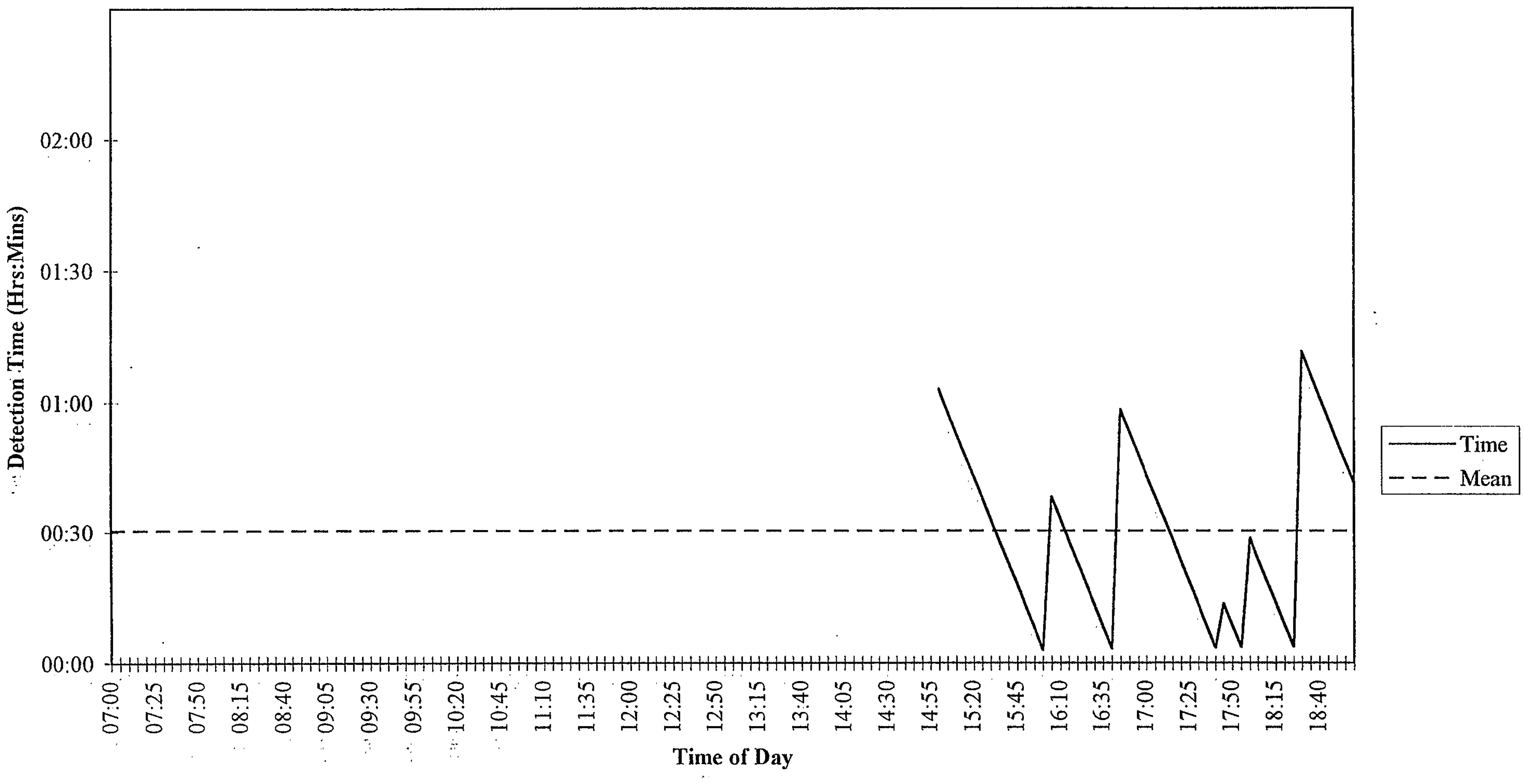
TIME TO BEACON DETECTION
Site 6: Beacon C9D0: 8-Oct-97



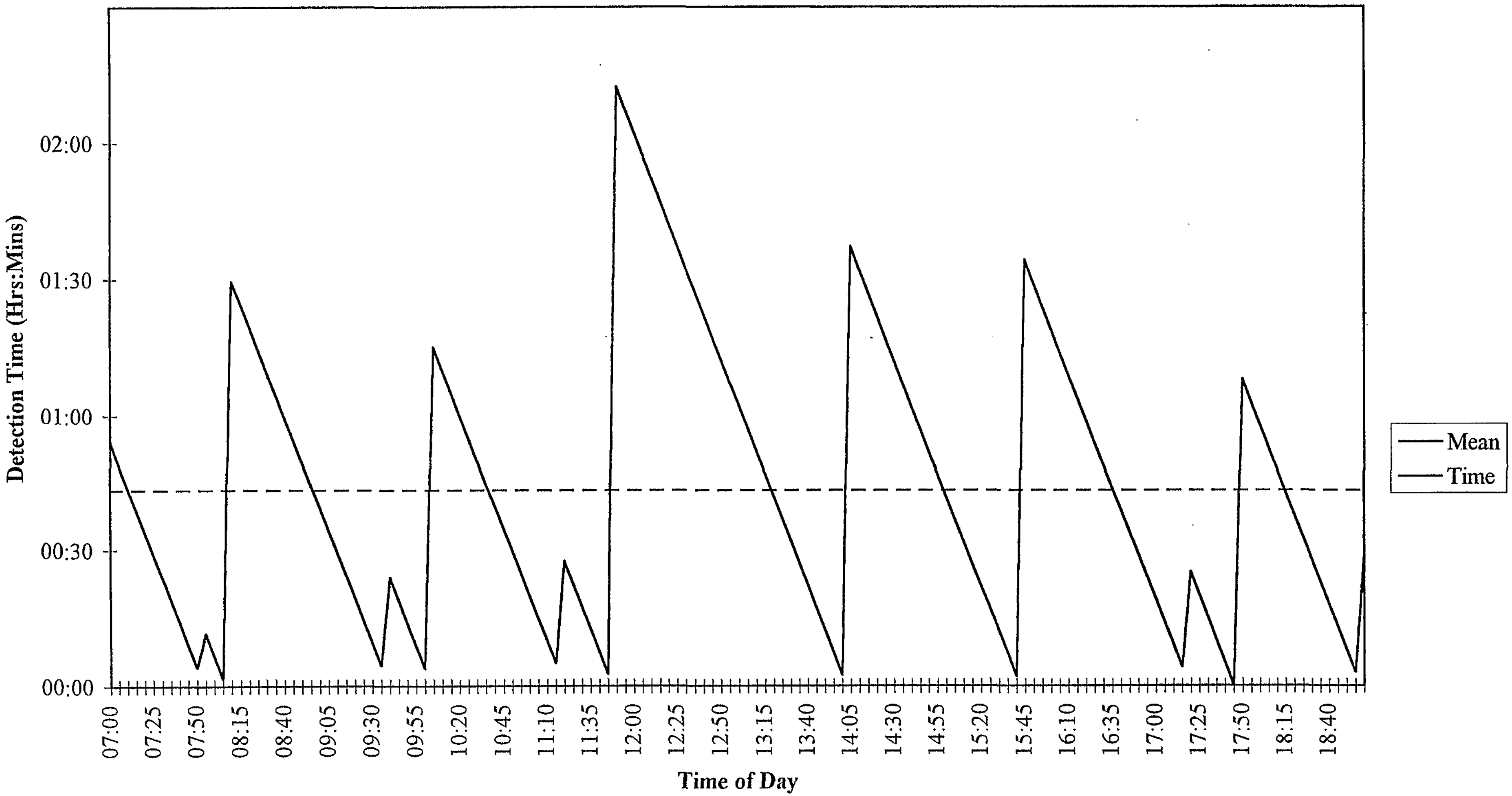
TIME TO BEACON DETECTION
Site 6: Beacon C9D0: 9-Oct-97



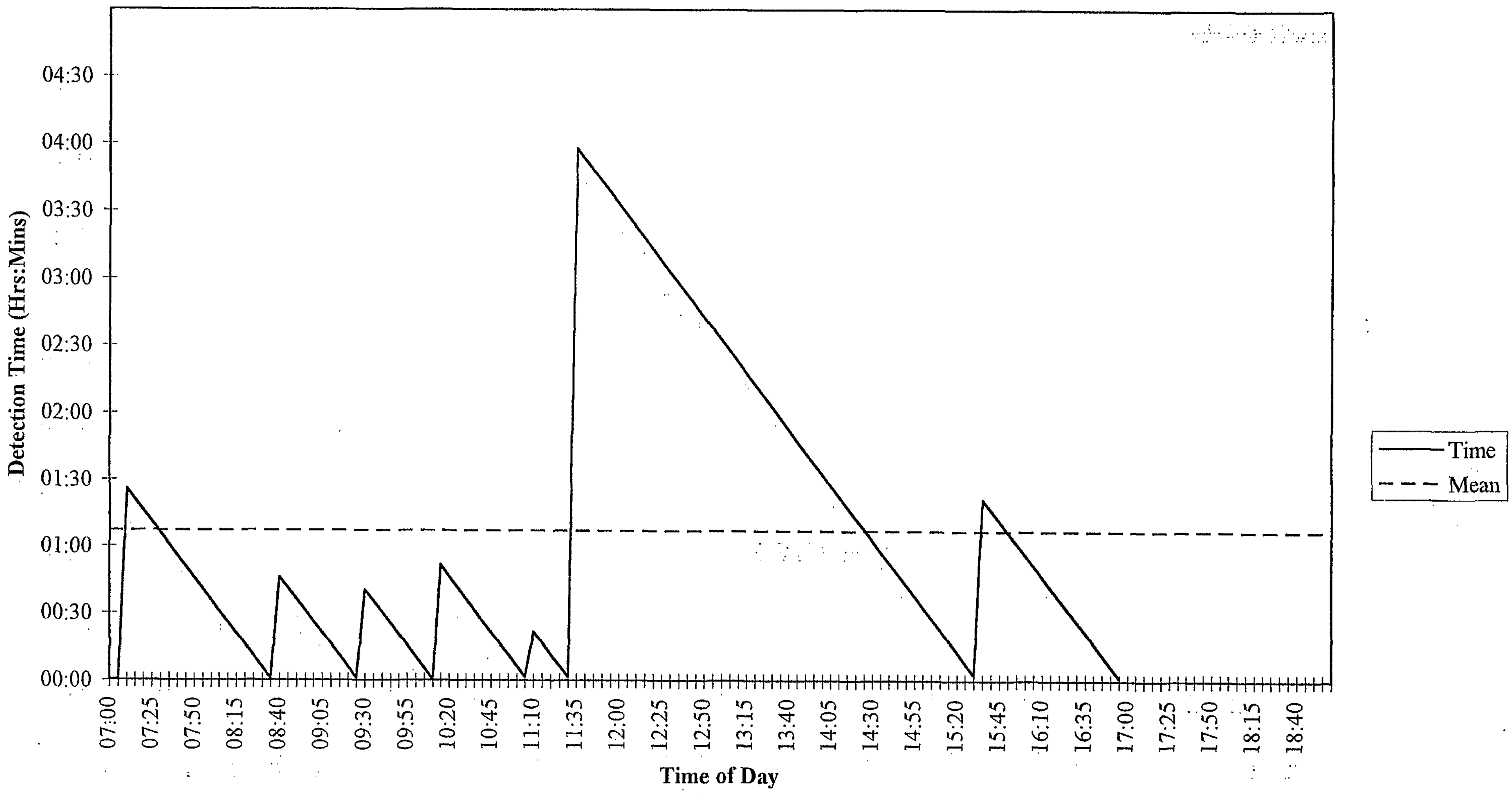
SITE 6 SERACH AREAS



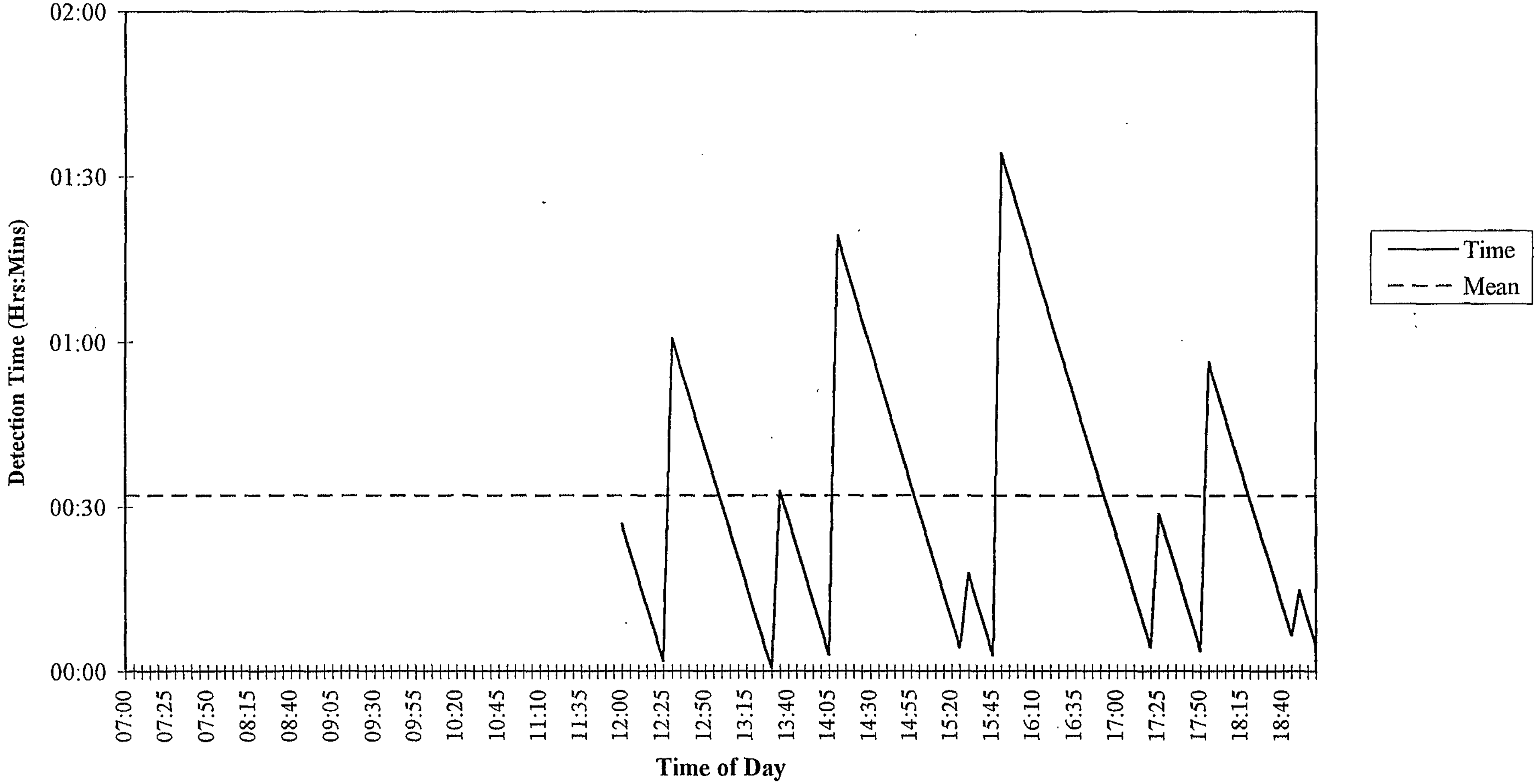
TIME TO BEACON DETECTION
Site 7: Beacon C8D0: 7-Oct-97



TIME TO BEACON DETECTION
Site 7: Beacon C8D0: 8 October 1997

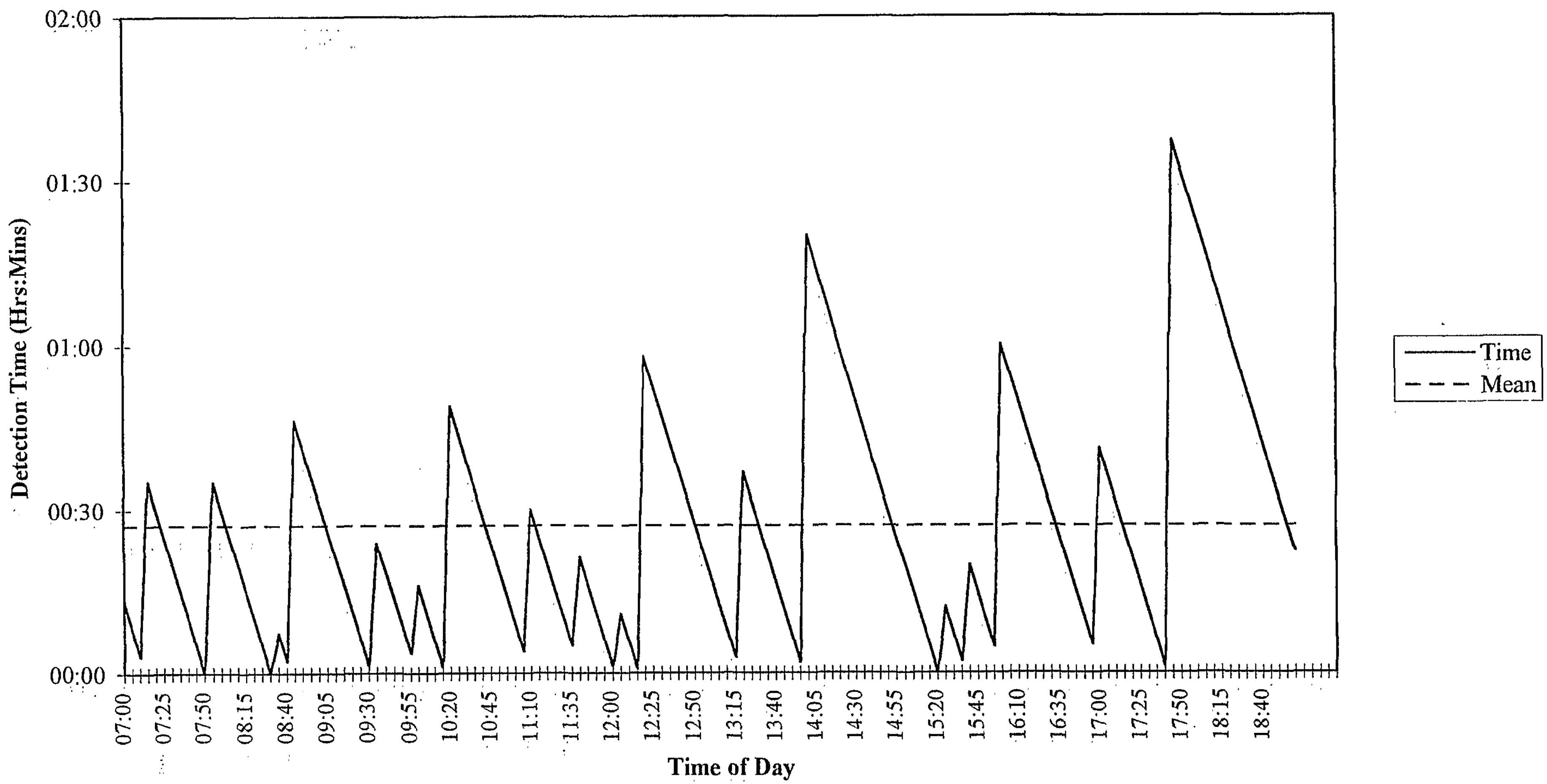


TIME TO BEACON DETECTION
Site 7: Beacon C8D0: 9-Oct-97

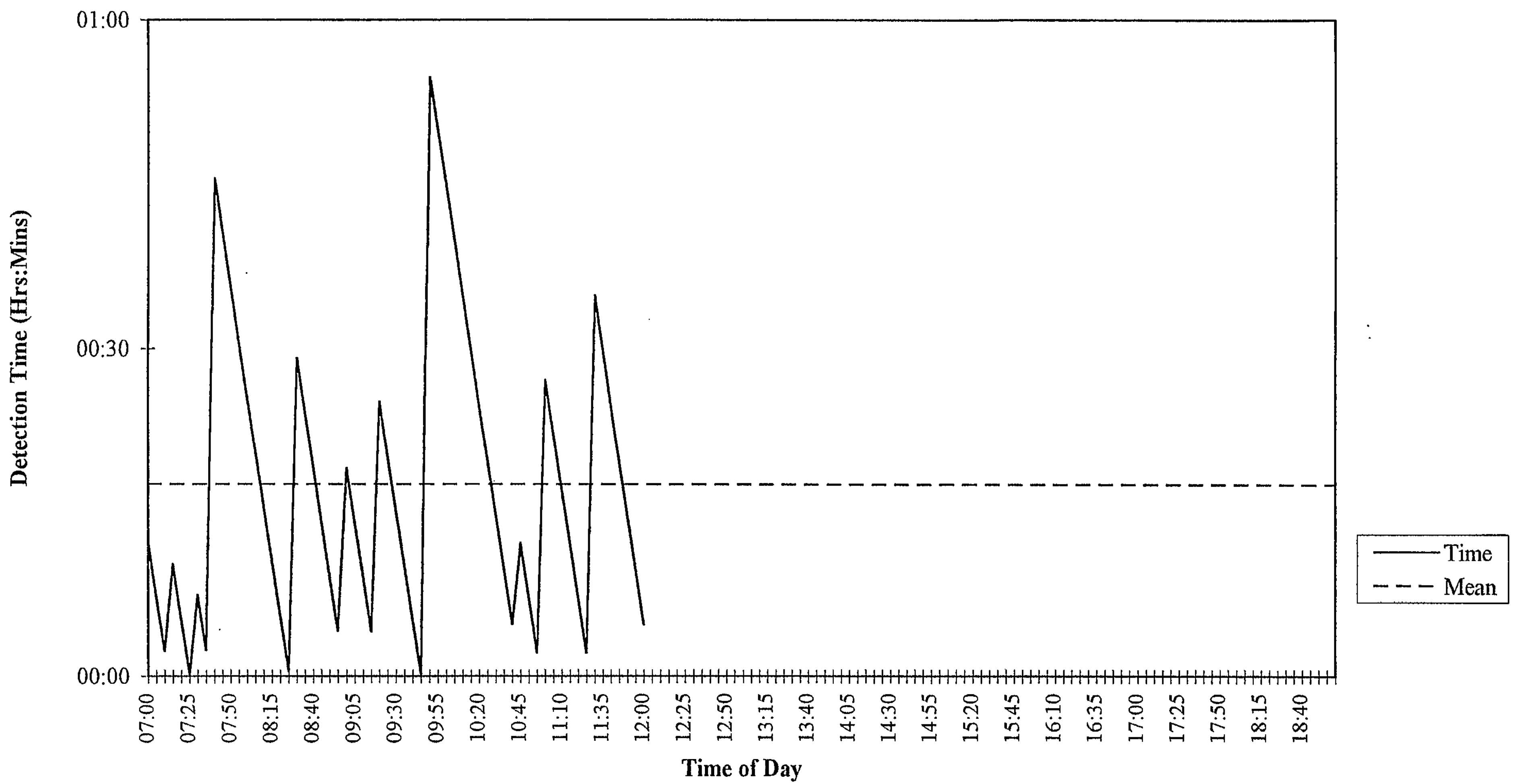


TIME TO BEACON DETECTION

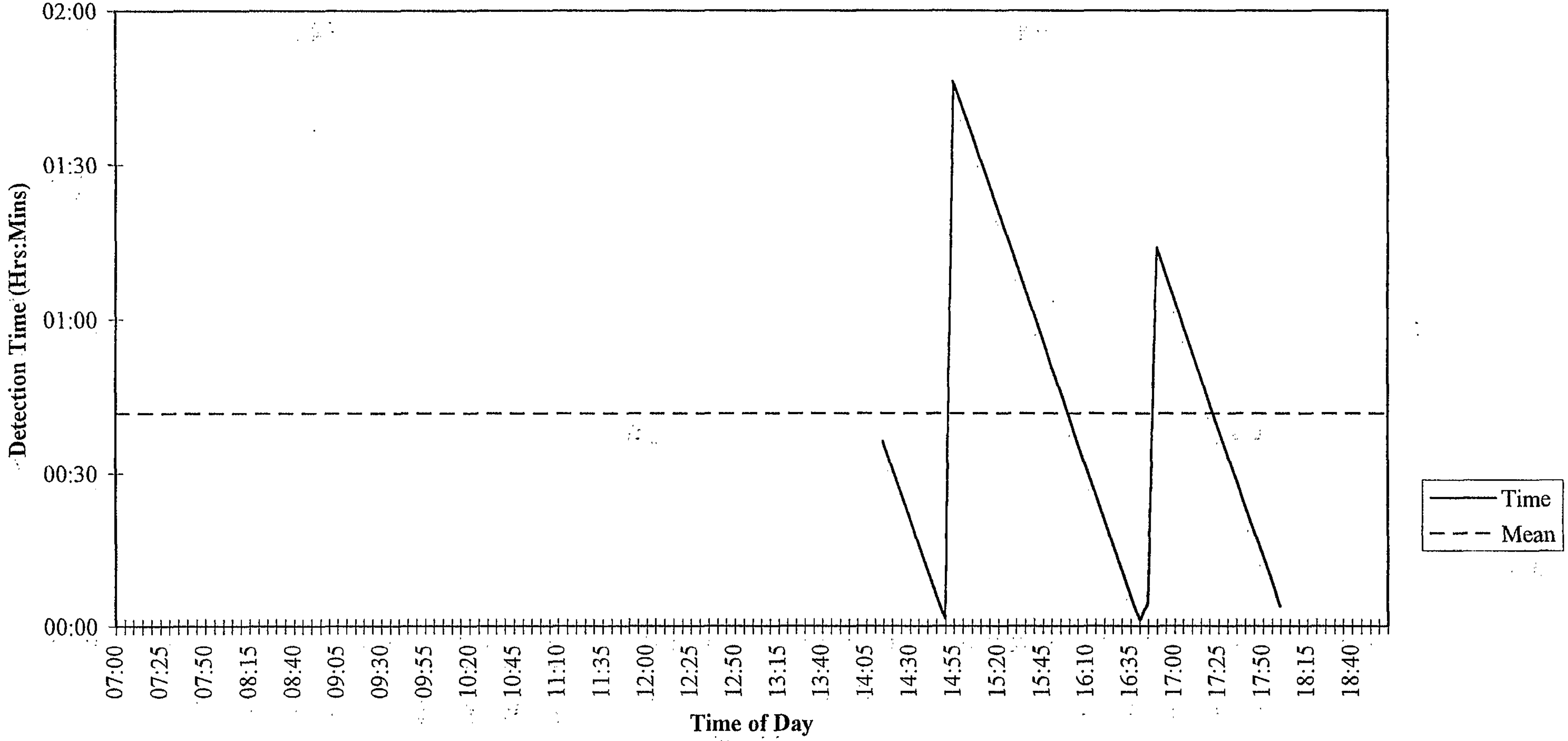
Site 8: Beacon C900: 8-Oct-97



TIME TO BEACON DETECTION
Site 8: Beacon C900: 9-Oct-97

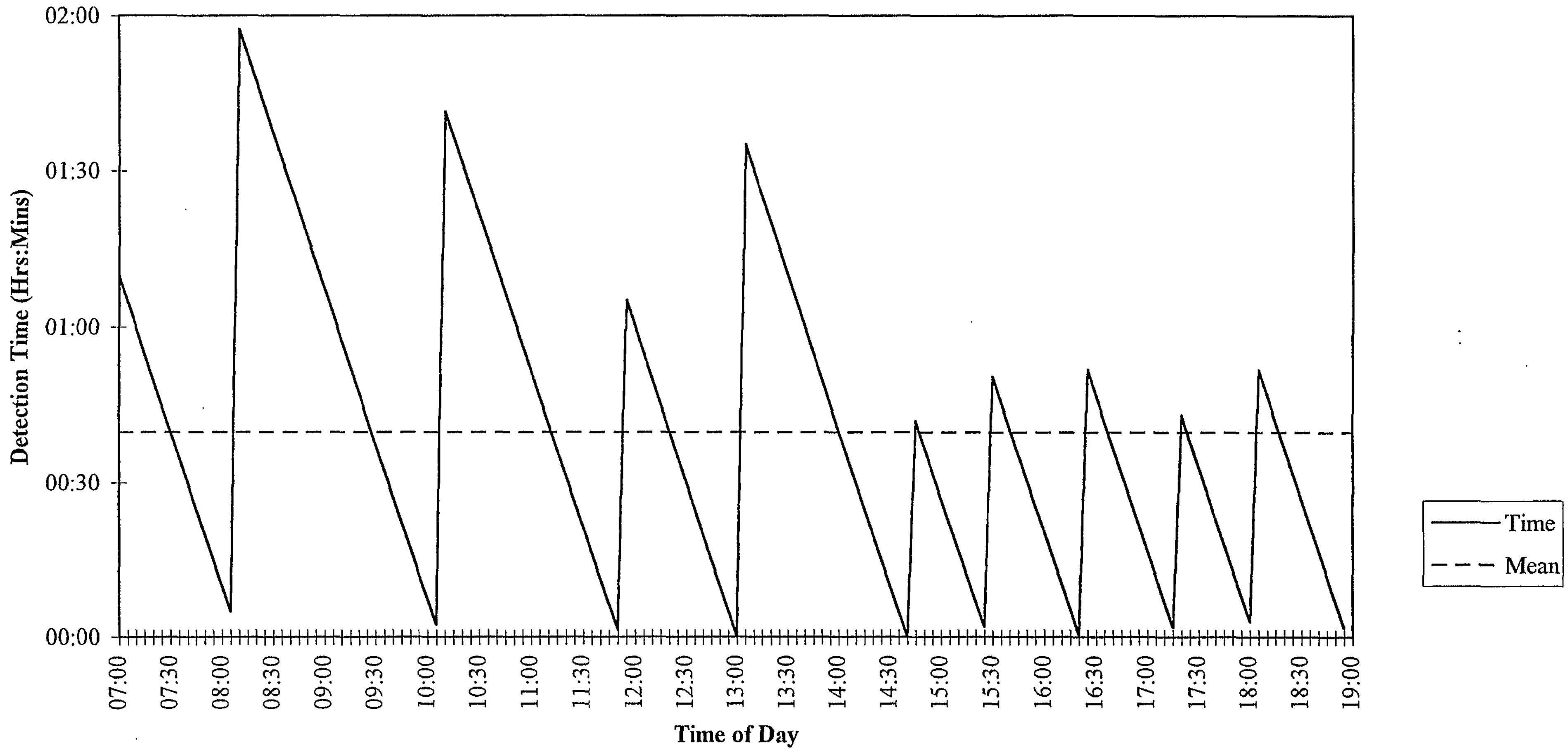


TIME TO BEACON DETECTION
Site 8: Beacon C900: 10 October 1997



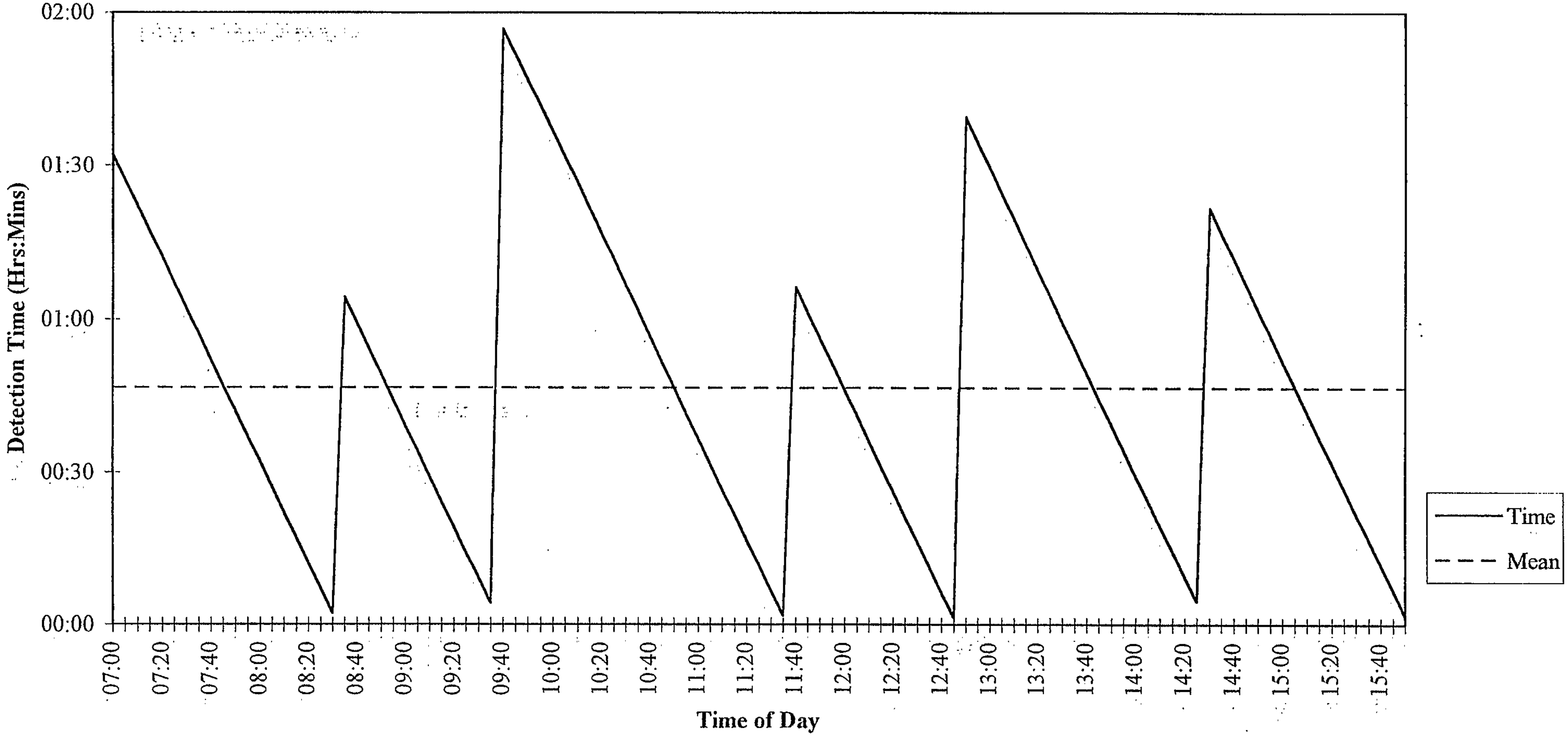
TIME TO BEACON DETECTION

Site 9: Beacon C9D0. Daytime Detections 22-Oct-97



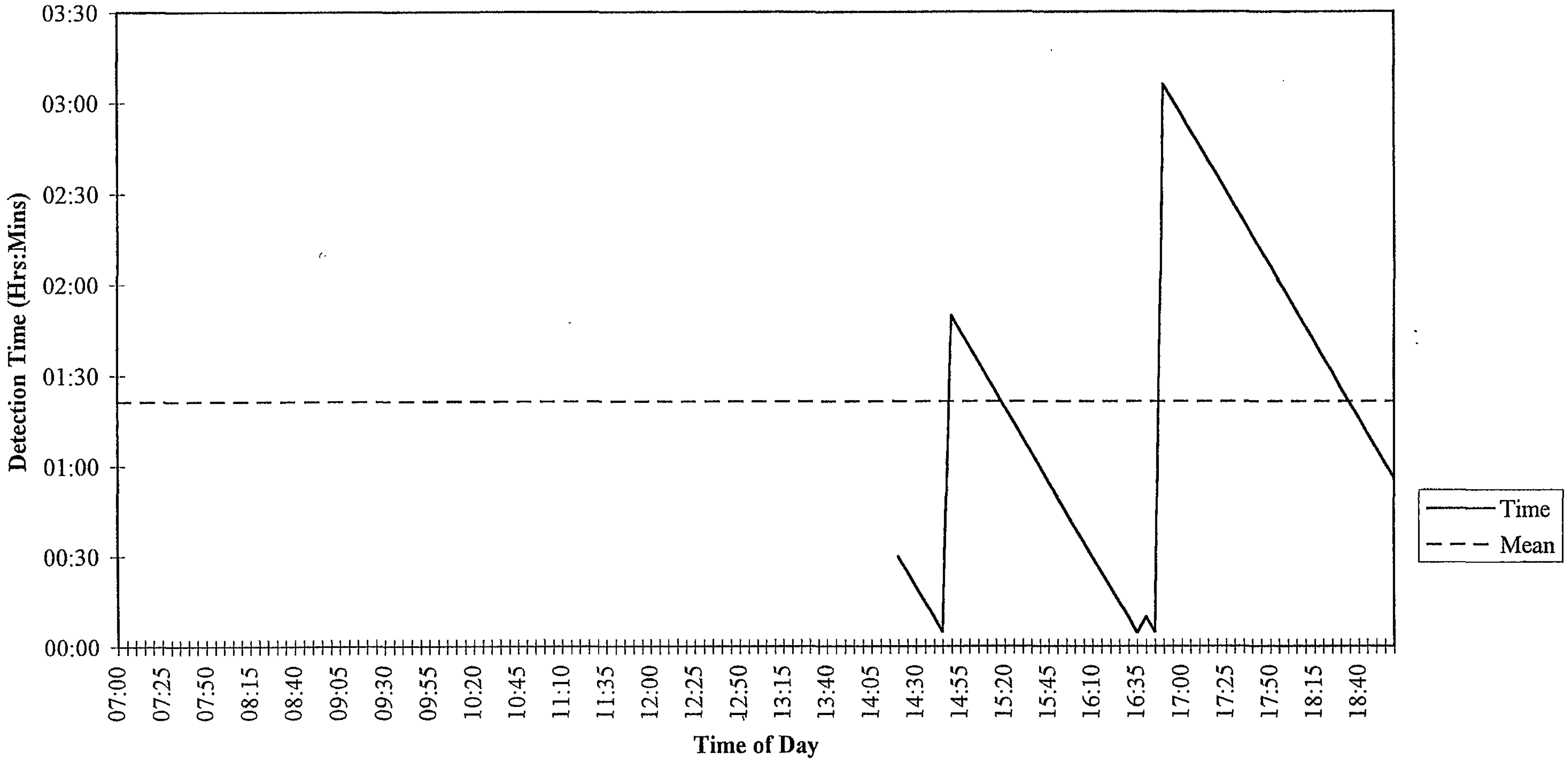
TIME TO BEACON DETECTION

Site 9: Beacon C9D0: 23-Oct-97

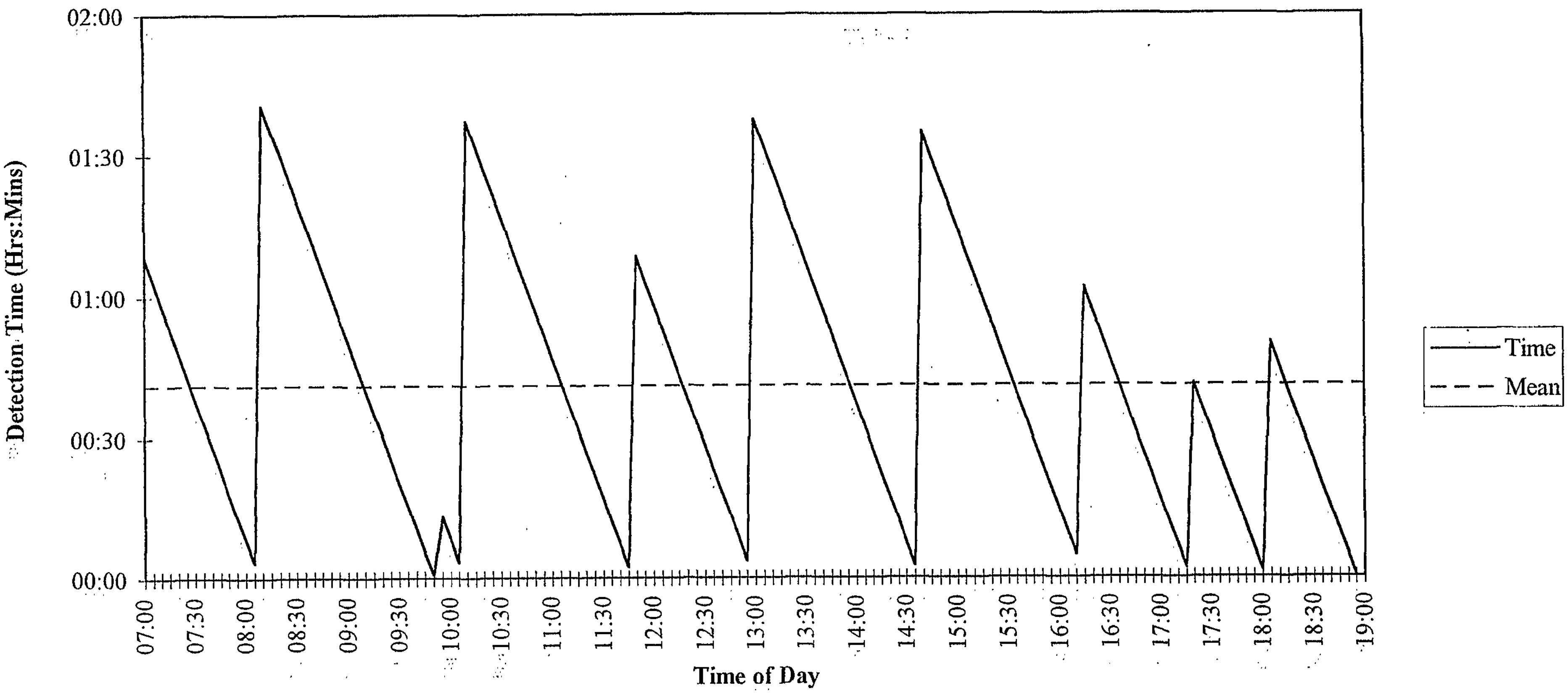


TIME TO BEACON DETECTION

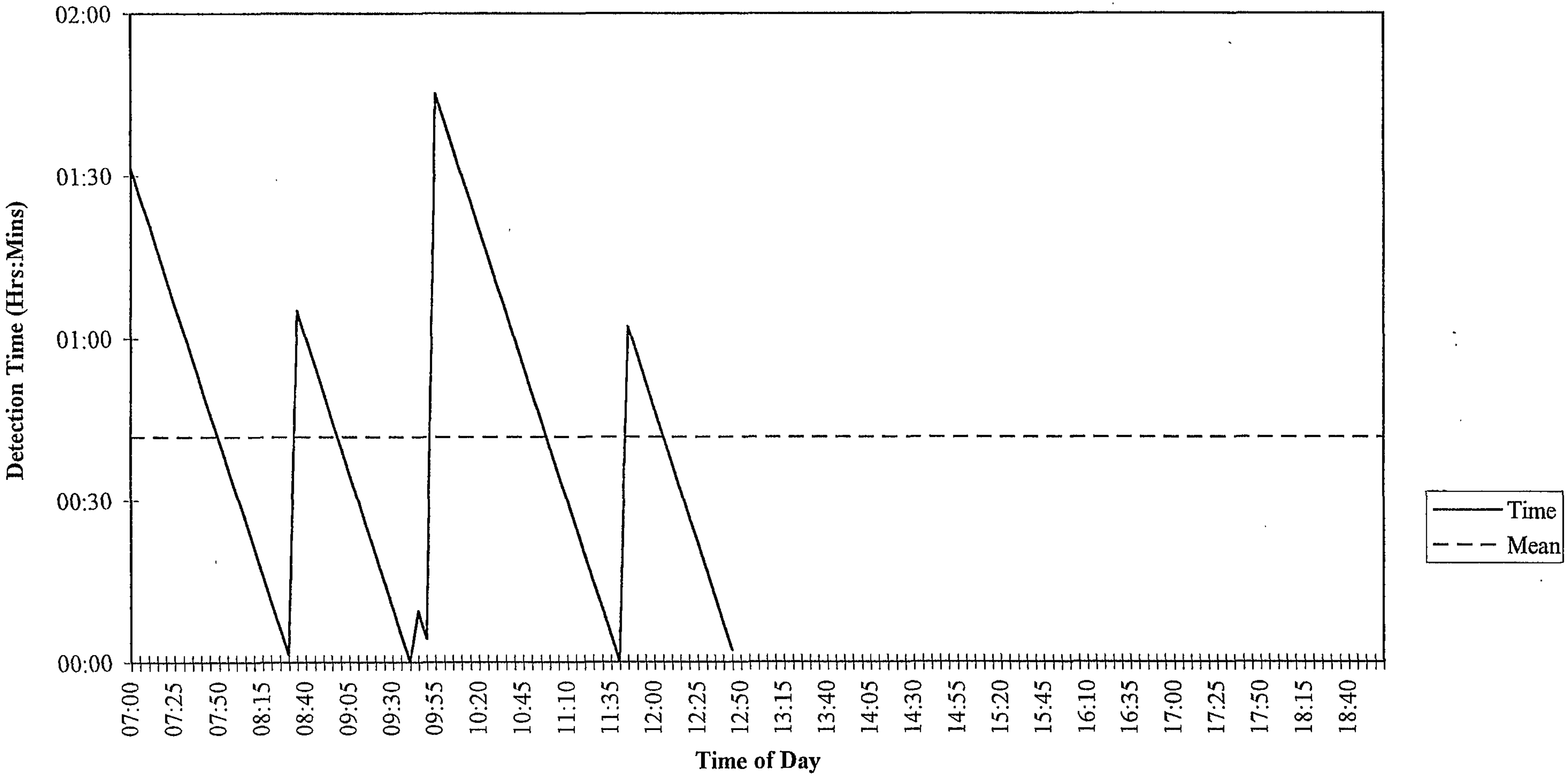
Site 9: Beacon C9D0: 24-Oct -97



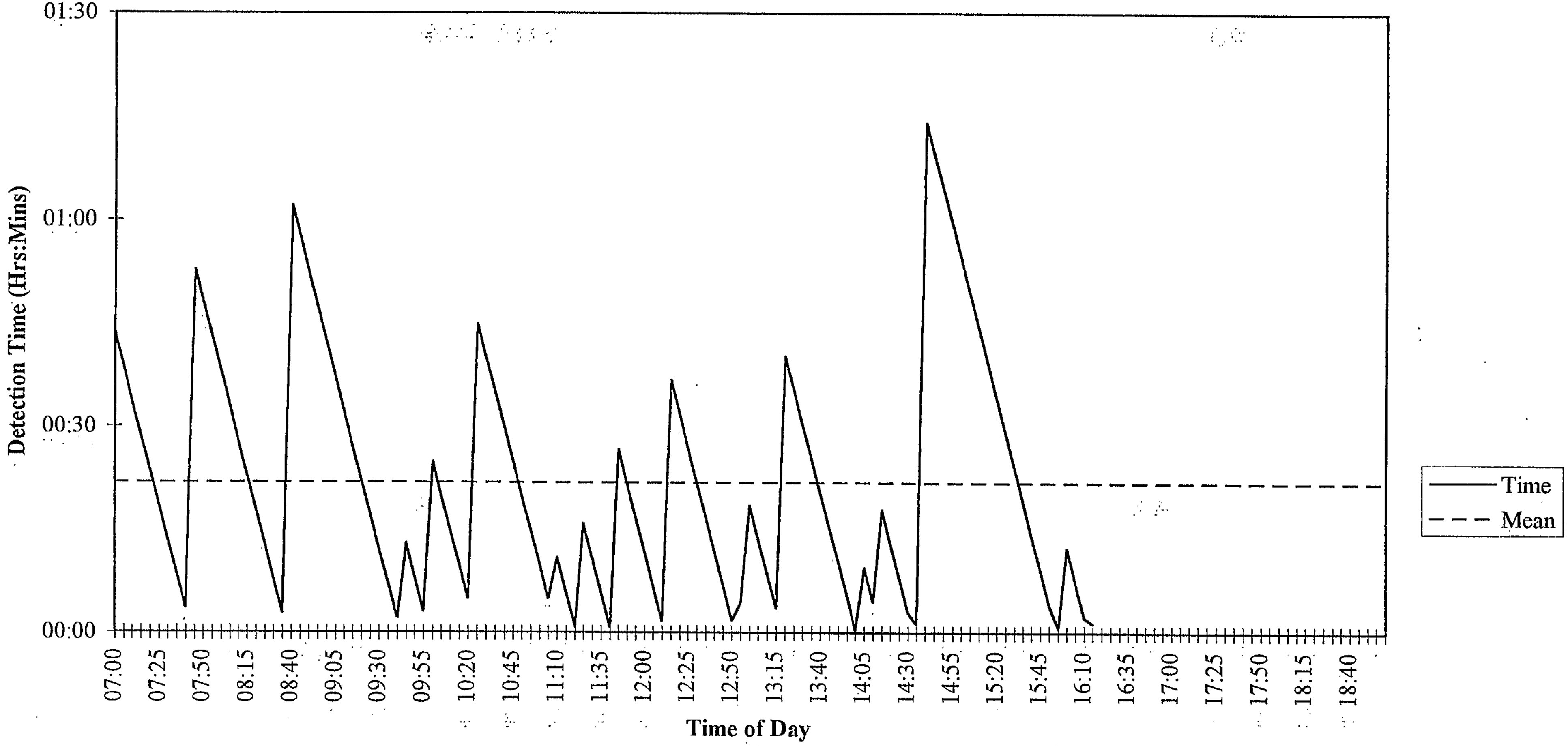
TIME TO BEACON DETECTION
Site 10: BeaconC900: 22-Oct-97



TIME TO BEACON DETECTION
Site 10: Beacon C900: 23-Oct-97

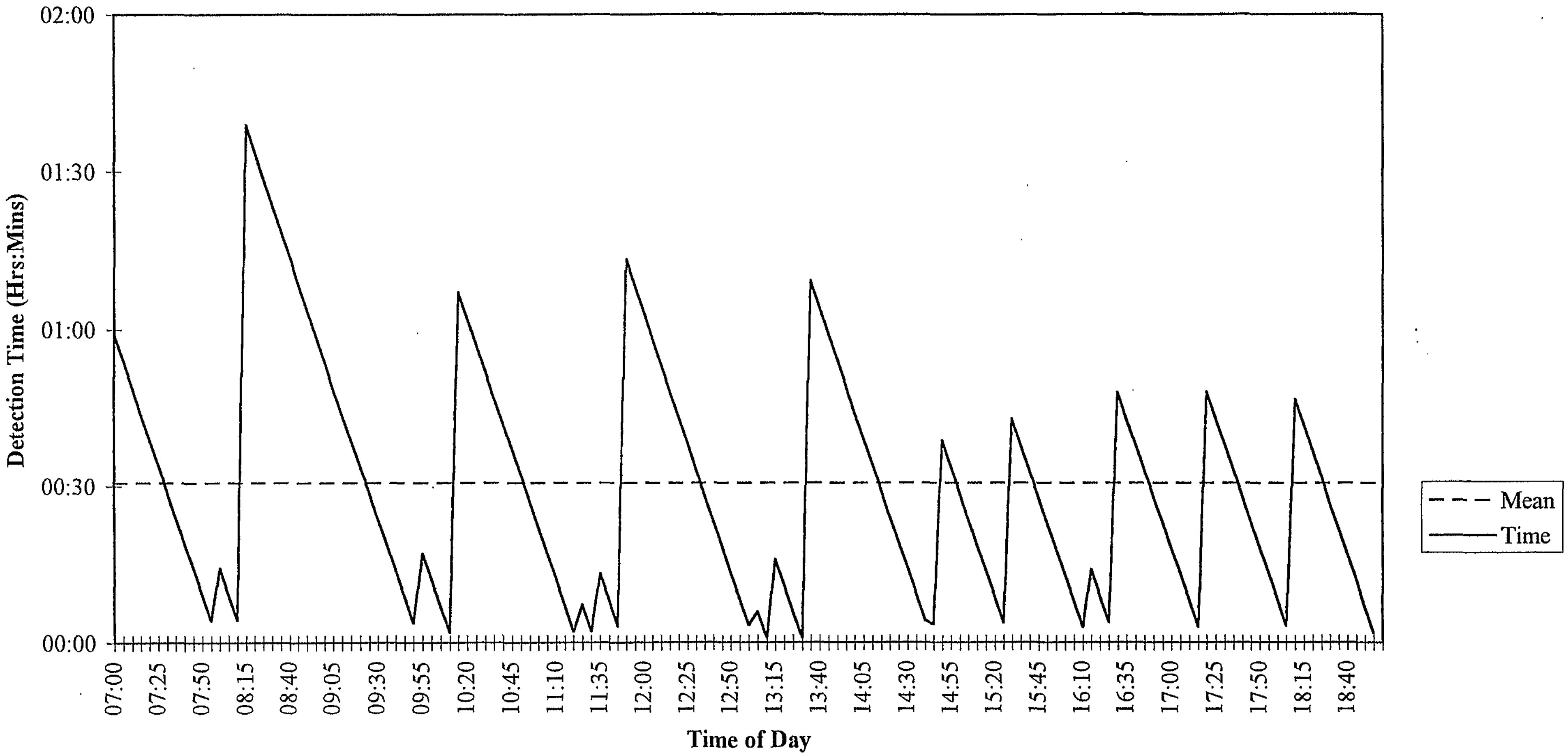


TIME TO BEACON DETECTION
Site 10: Beacon C900: 24-Oct-97

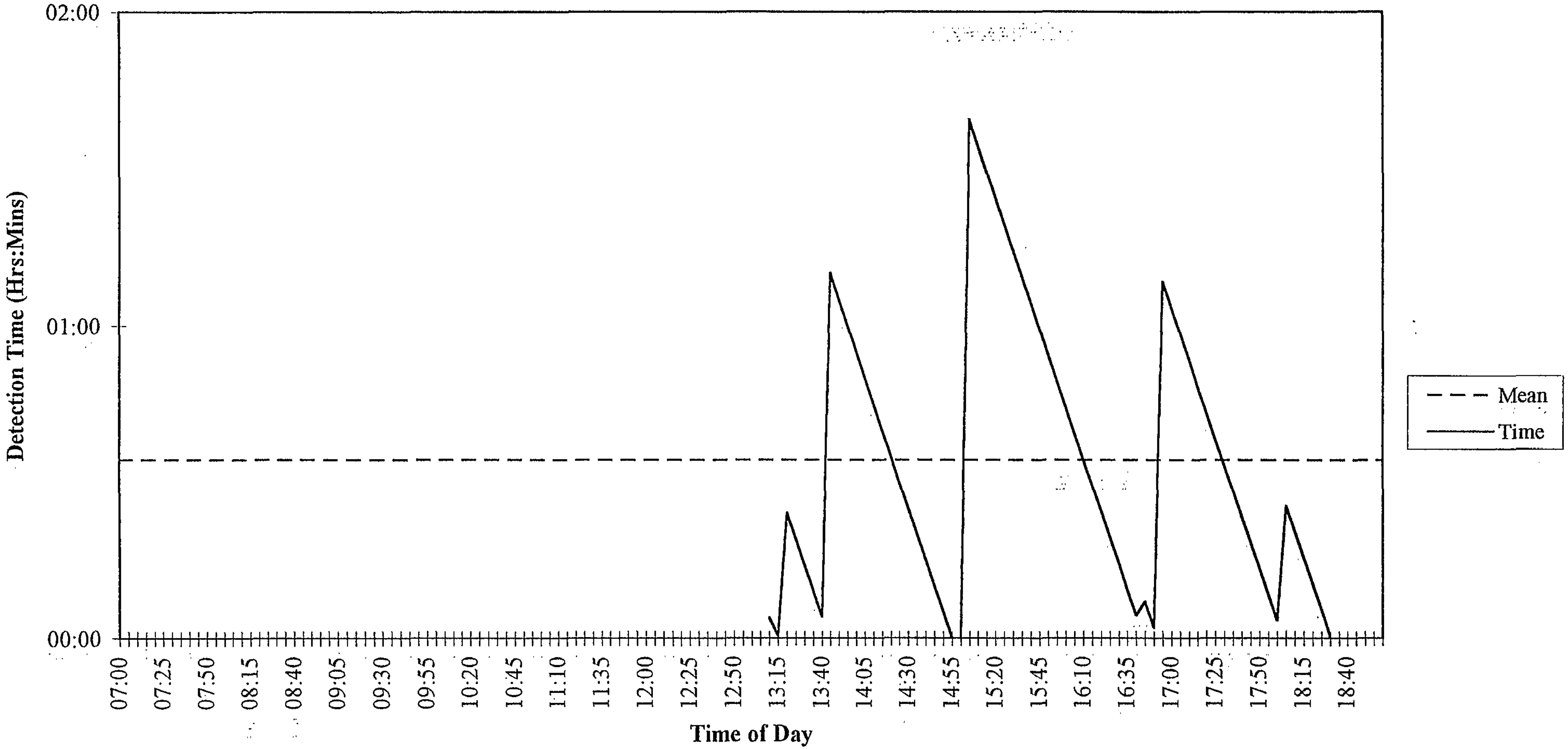


TIME TO BEACON DETECTION
Site 11 Beacon C990: 24-Oct-97

L

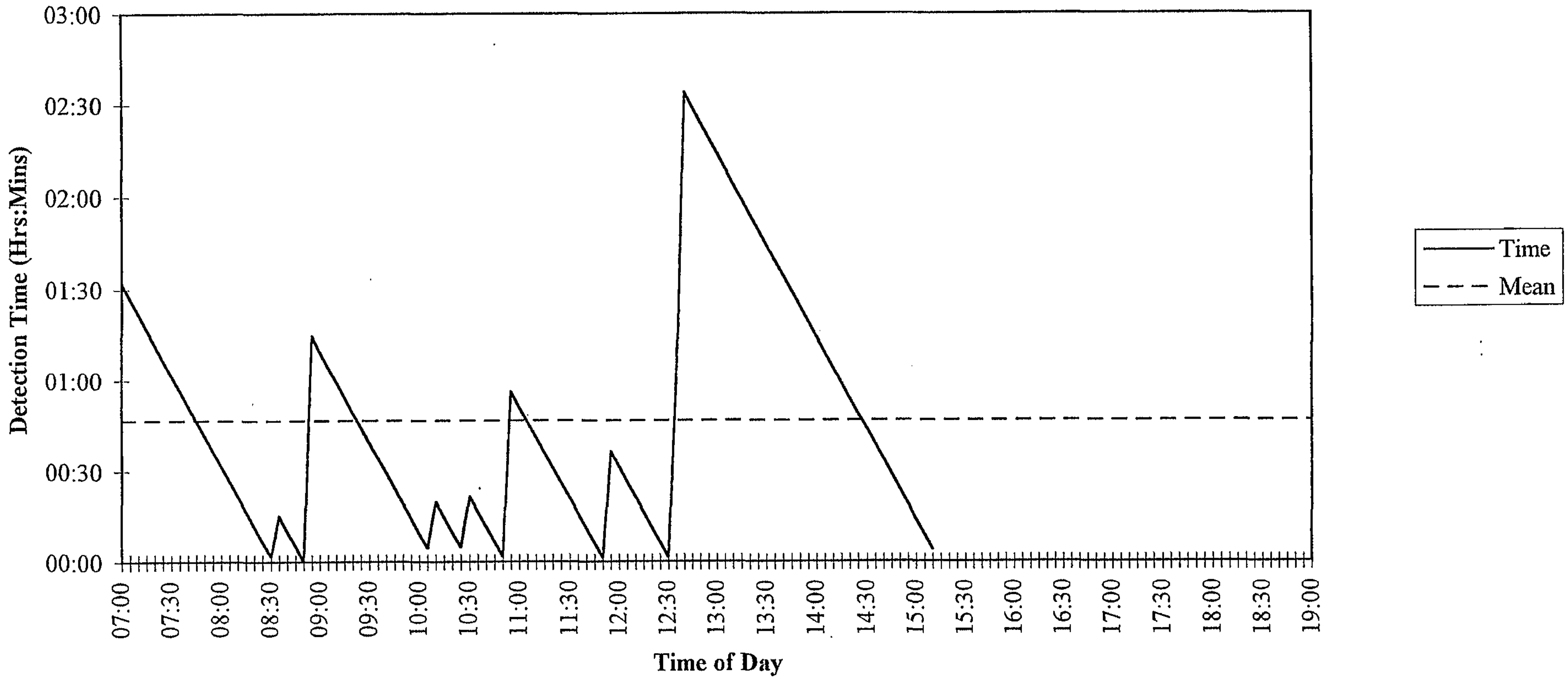


TIME TO BEACON DETECTION
Site 11 Beacon C990: 23-Oct-97



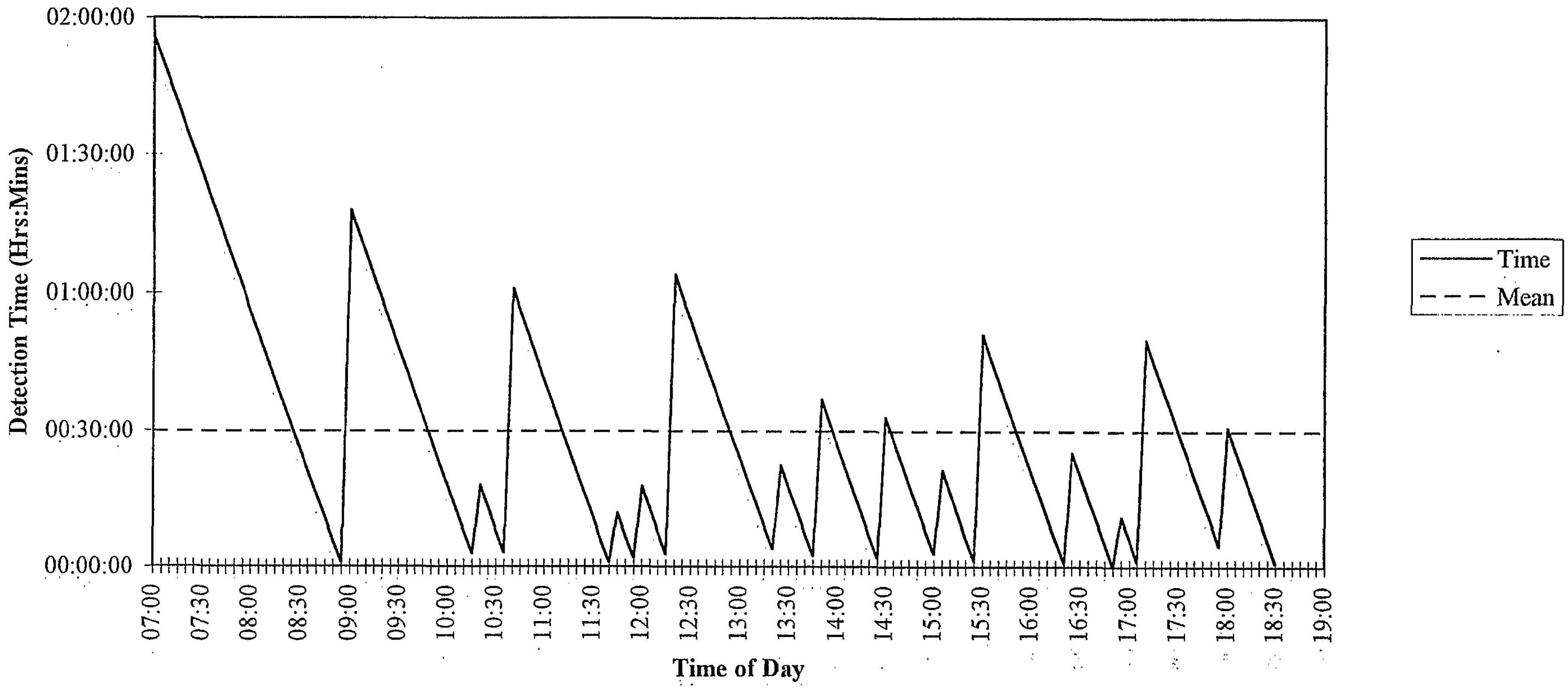
TIME TO BEACON DETECTION

Site 11: Beacon C990: 22-Oct-97



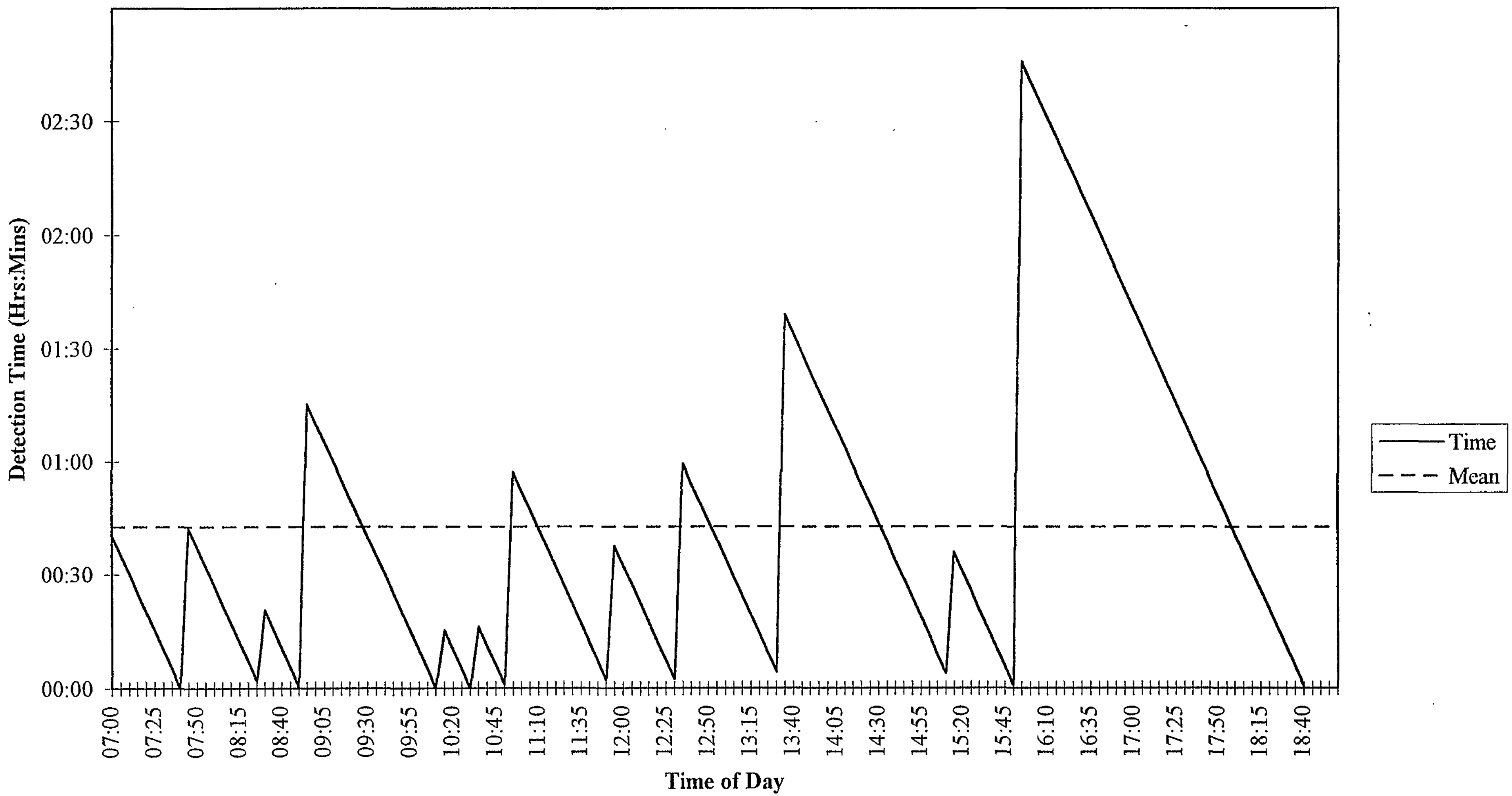
TIME TO BEACON DETECTION

Site 12: Beacon 9D0: 20-Oct-97

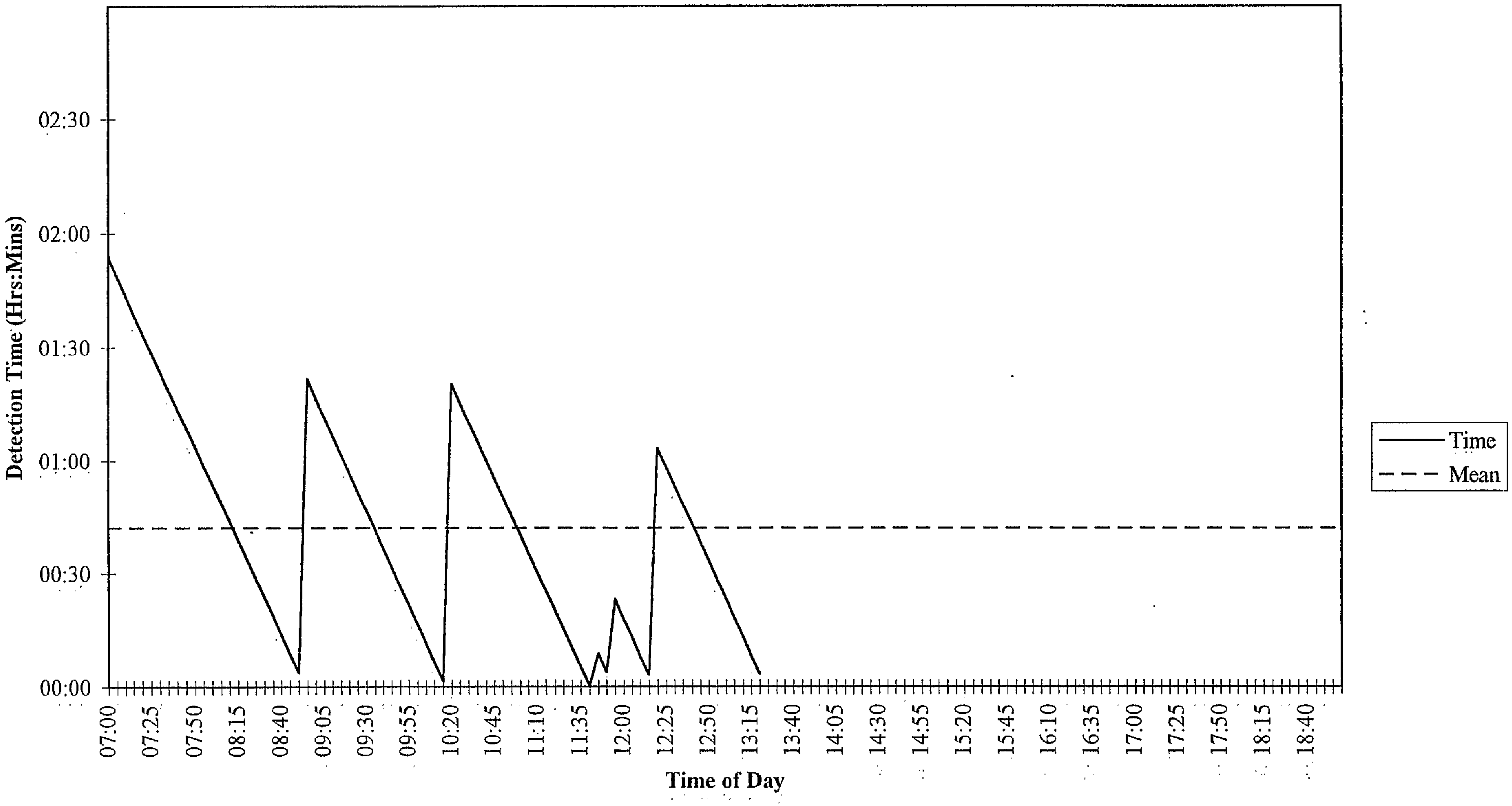


TIME TO BEACON DETECTION

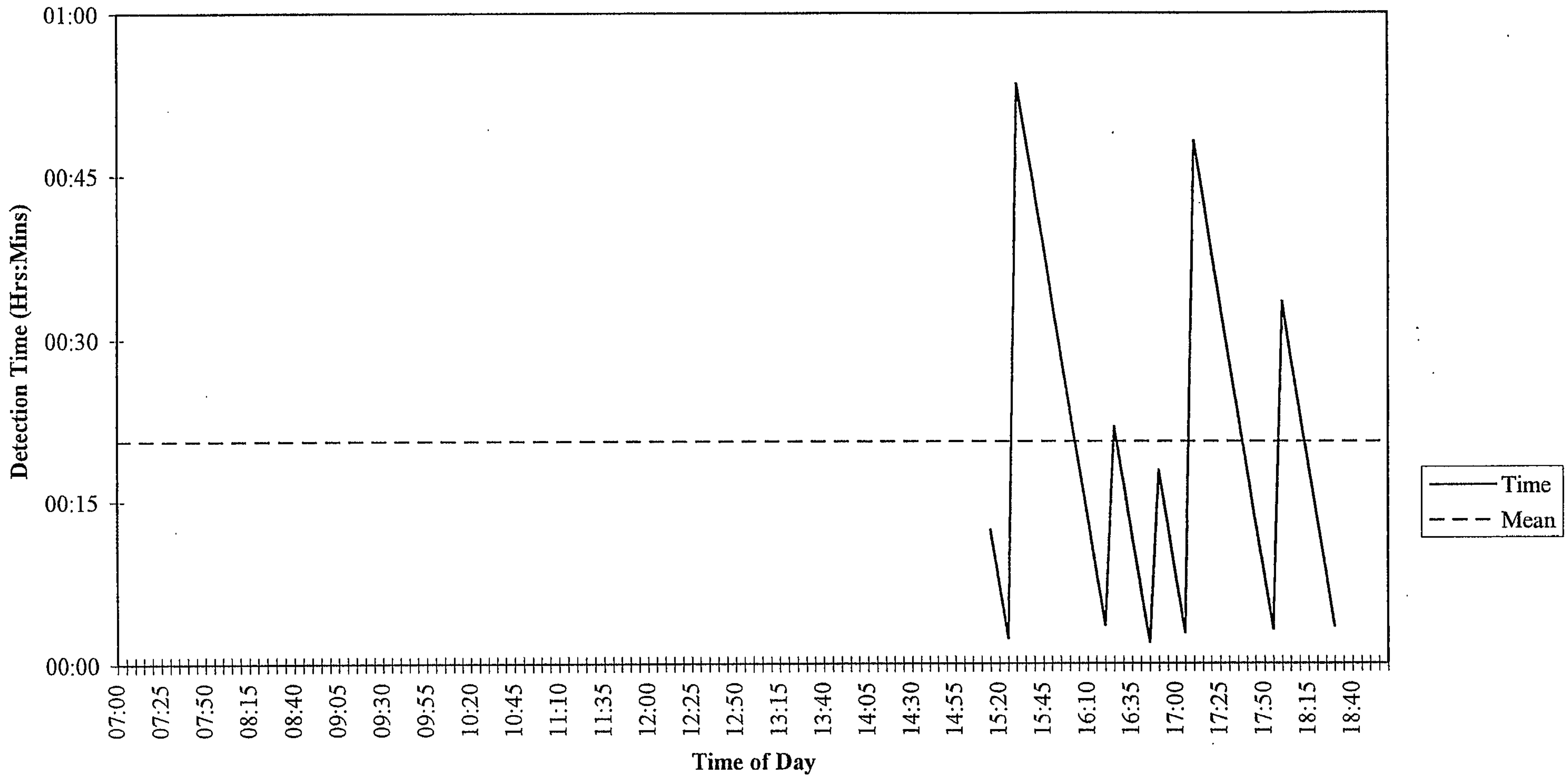
Site 12: Beacon 9D0: 21-Oct-97



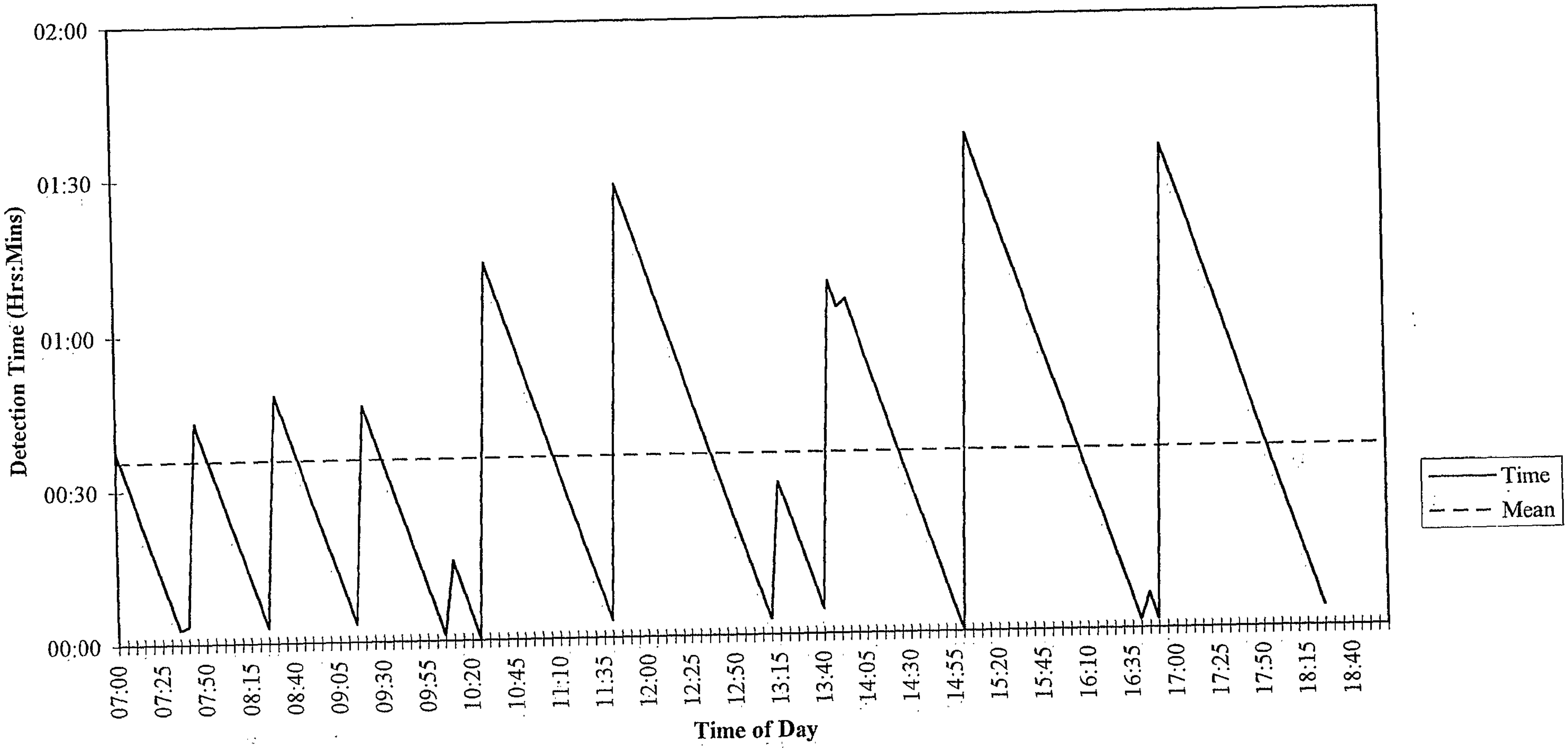
TIME TO BEACON DETECTION
Site 13: Beacon C8D0: 20-Oct-97



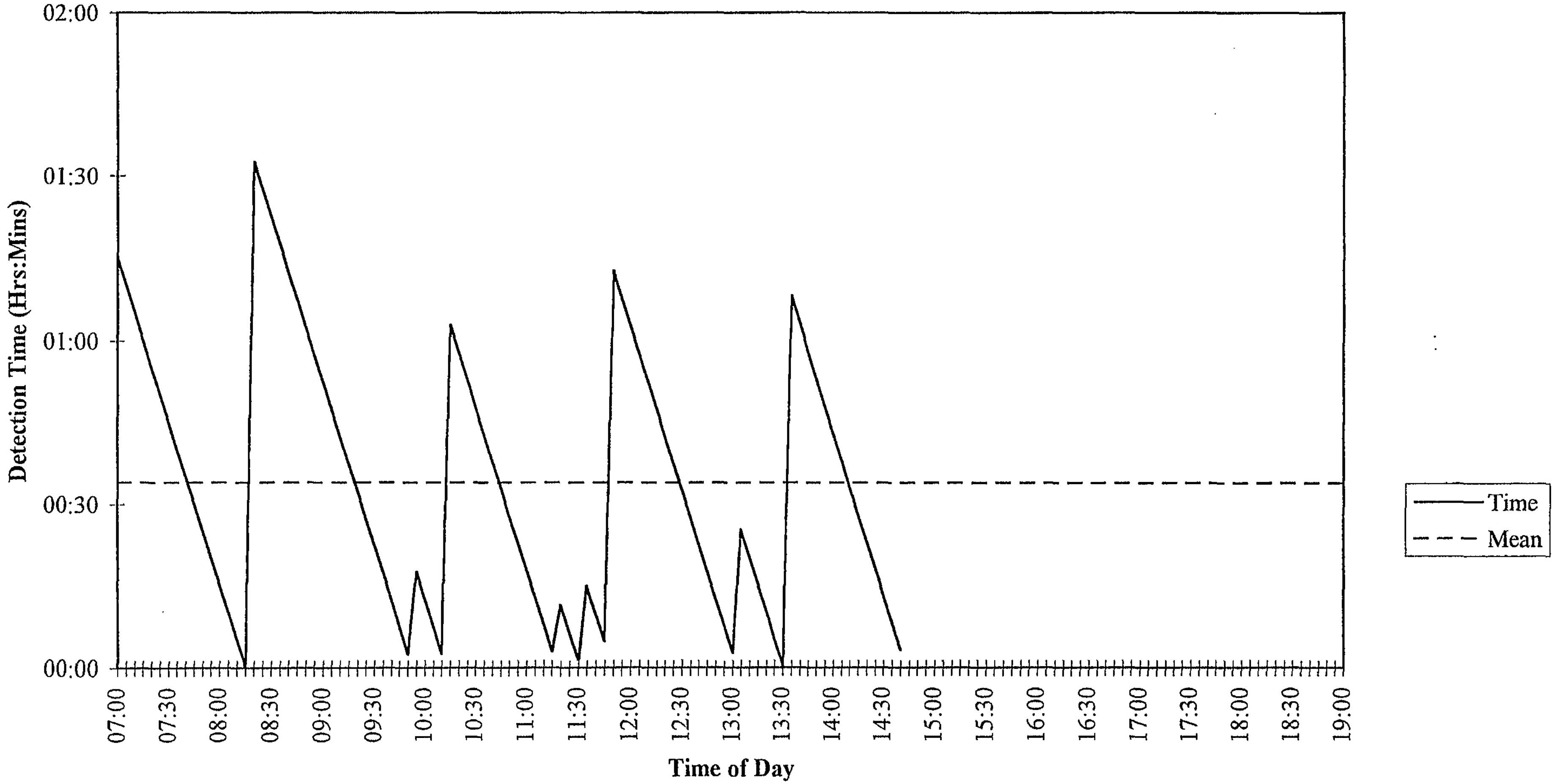
TIME TO BEACON DETECTION
Site 13: Beacon C8D0: 21-Oct-97



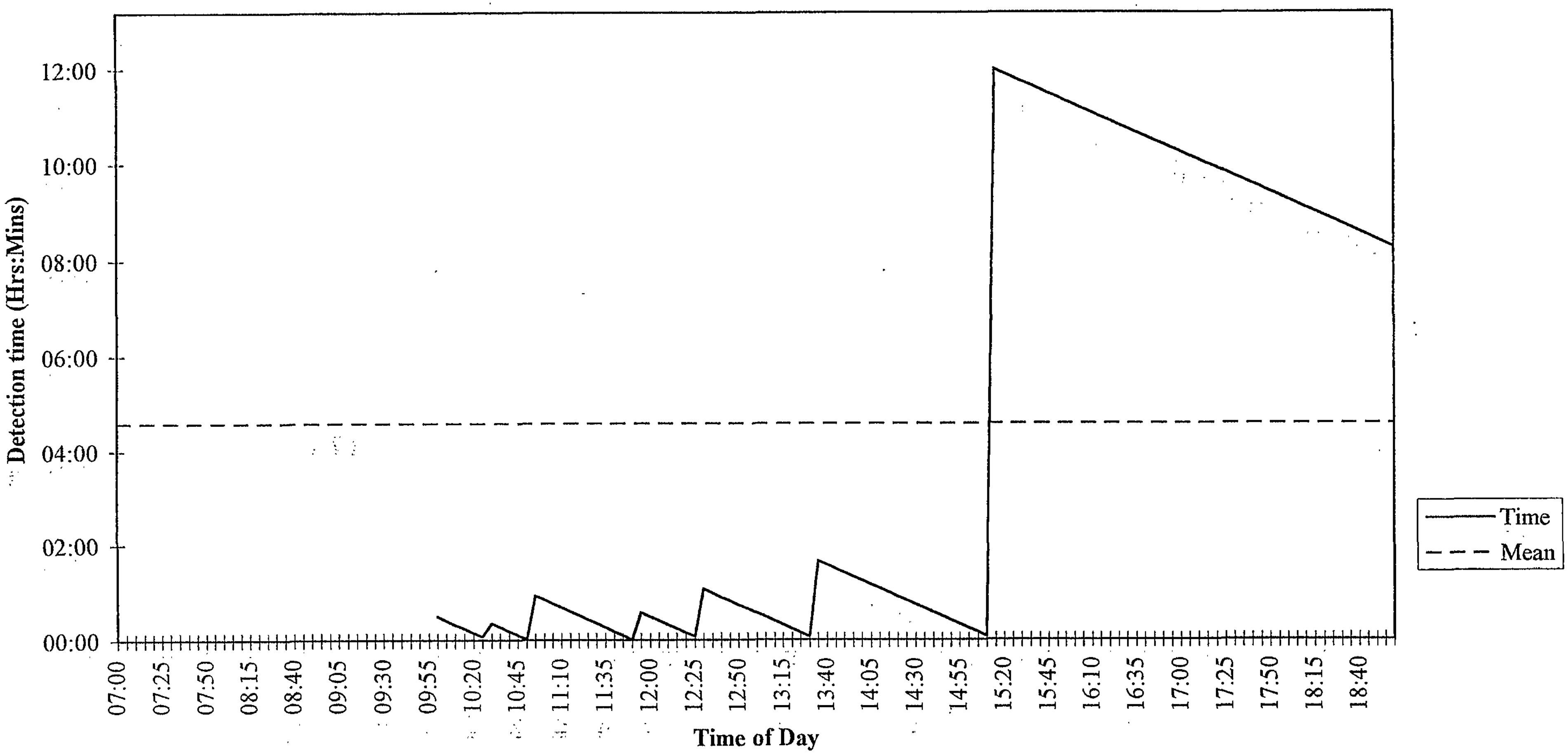
TIME TO BEACON DETECTION
Site 14: Beacon C8D0: 21-Oct-97



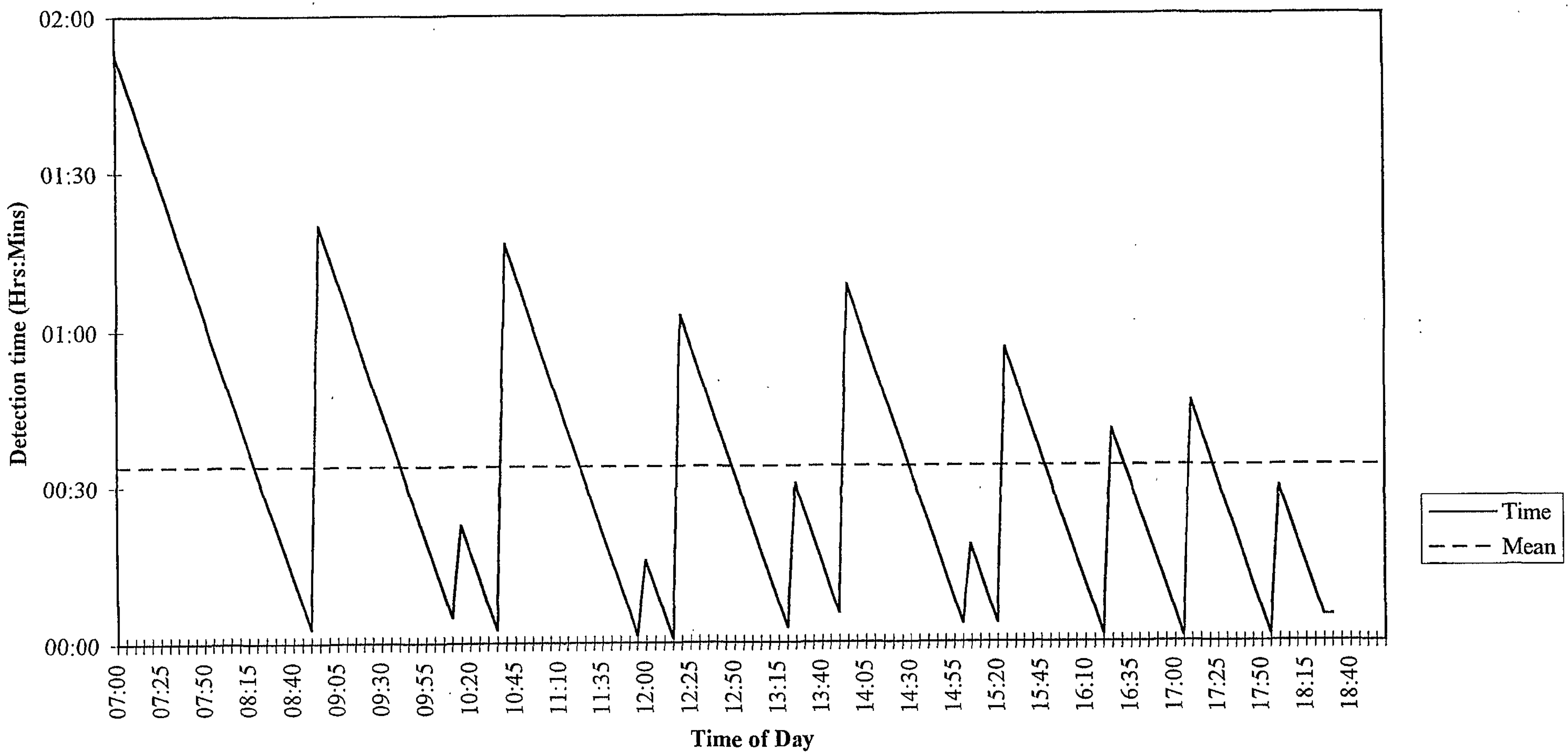
TIME TO BEACON DETECTION
Site 14: Beacon C8D0: 22-Oct-97



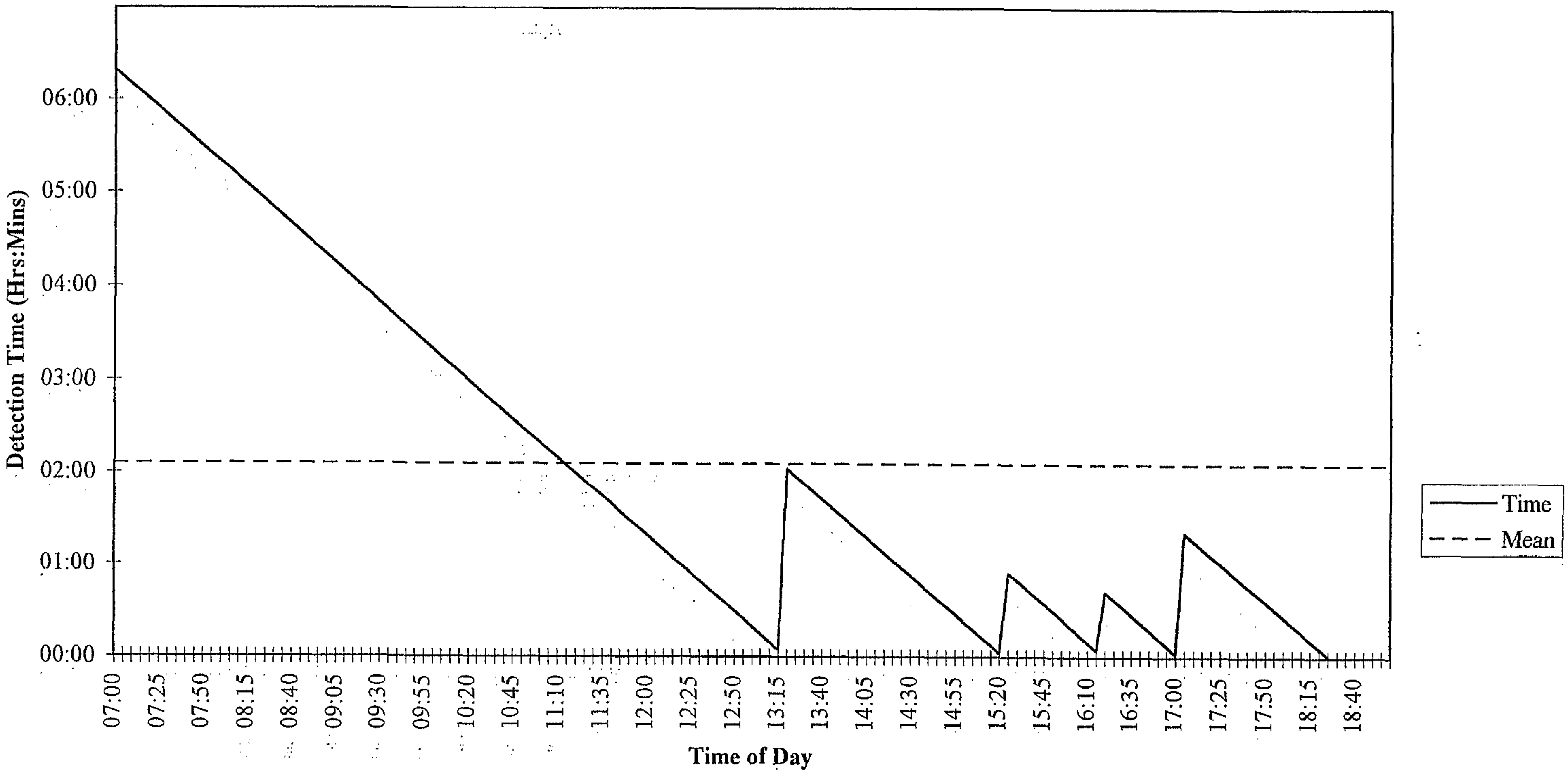
TIME TO BEACON DETECTION
Site 14: Beacon C8D0: 23-Oct-97



TIME TO BEACON DETECTION
Site 15: Beacon C900: 20-Oct-97

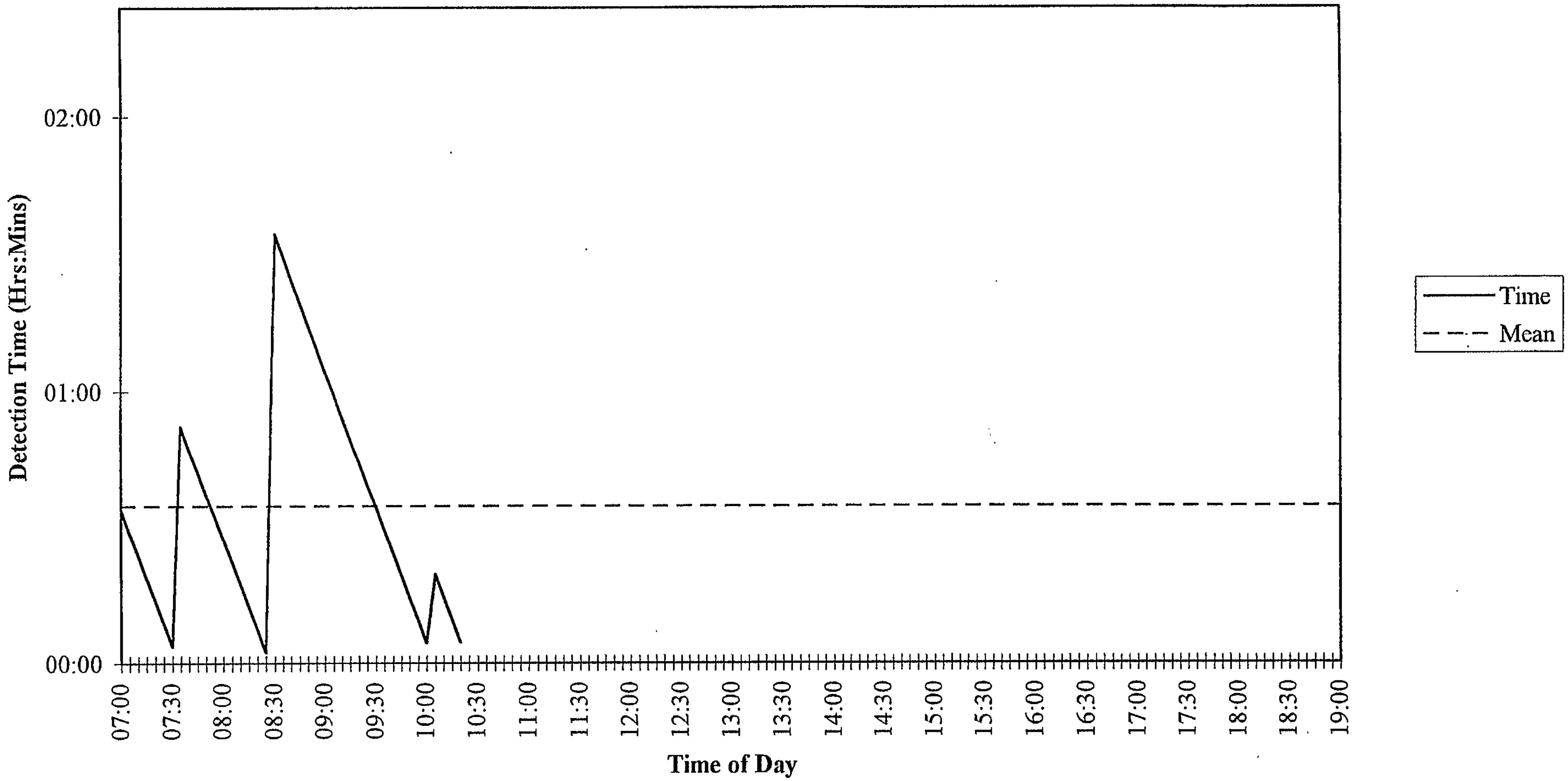


TIME TO BEACON DETECTION
Site 15: Beacon C900: 21-Oct-97



TIME TO BEACON DETECTION

Site 16 Beacon C990: 21-Oct-97



TIME TO BEACON DETECTION
Site 16 Beacon C990: 22-Oct-97

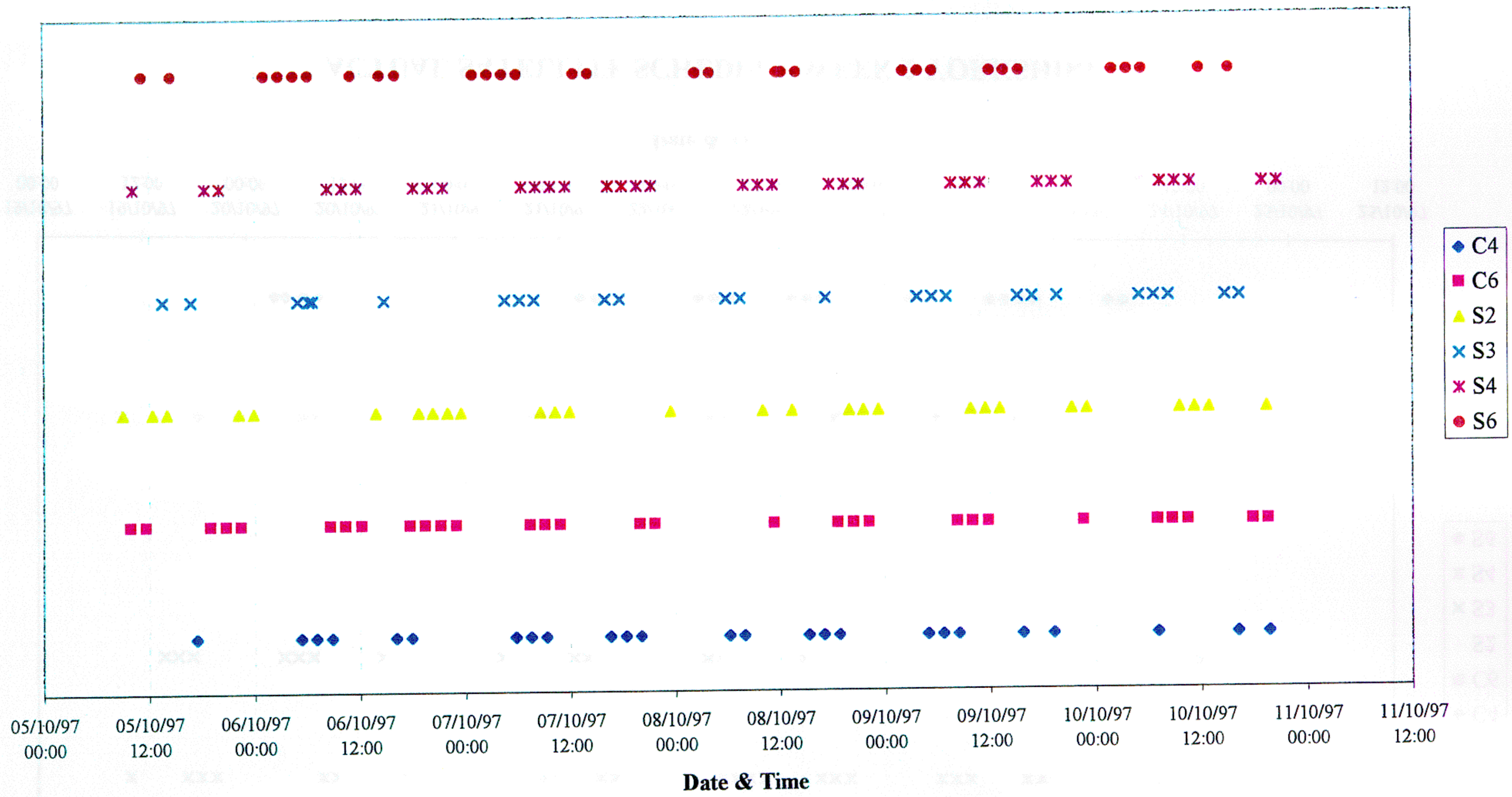
APPENDIX VIII

DETECTION PROBABILITIES FOR TYPICAL WORKING DAY

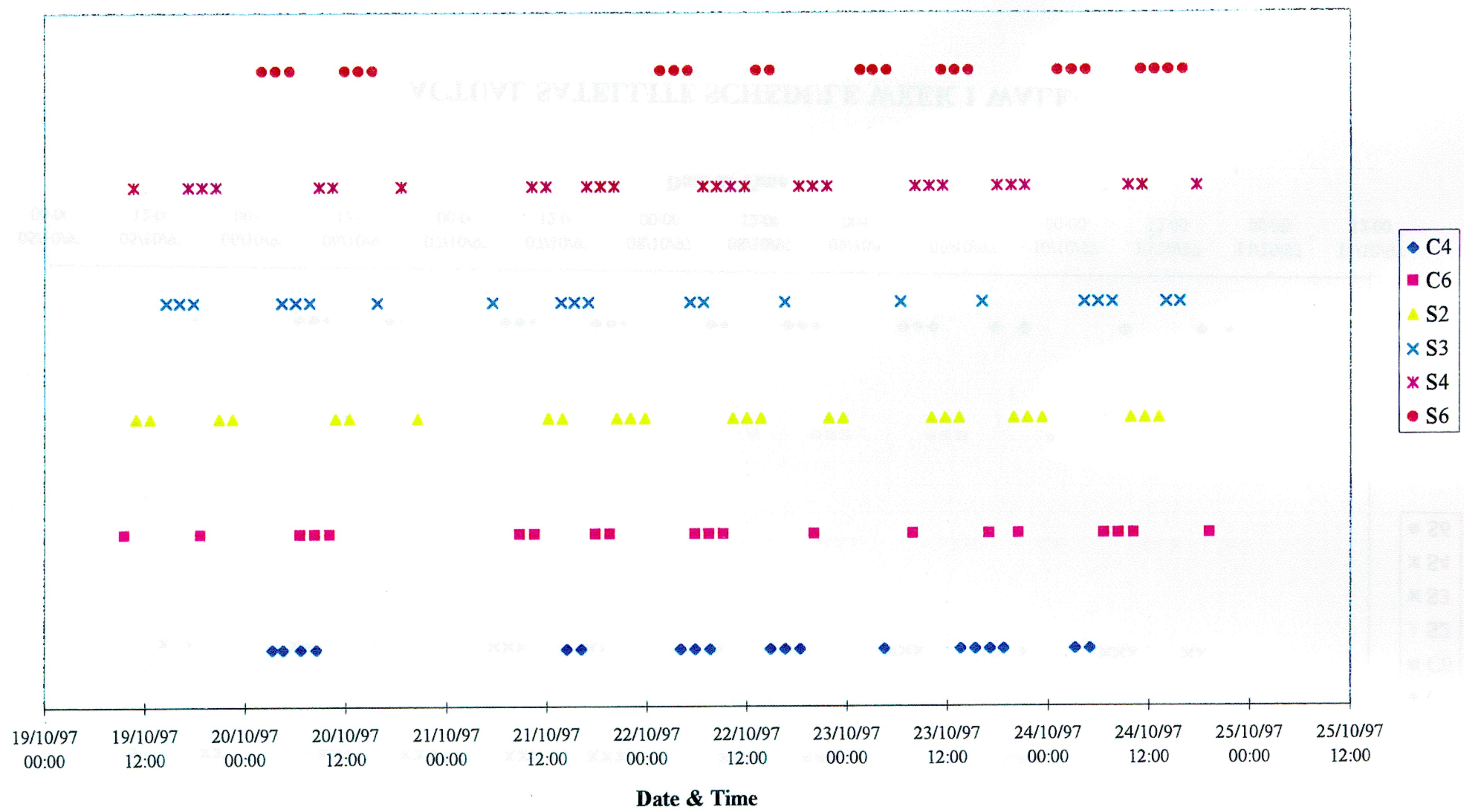
Site No	Terrain	30mins	60mins	120mins	180mins	240mins	300mins
Wales							
1	Severe Wooded Valley	0.37	0.64	0.90	0.94	0.99	1.00
2	Severe Valley	0.44	0.72	0.99	1.00	1.00	1.00
3	U-Shaped Valley, Clear	0.46	0.73	0.98	1.00	1.00	1.00
4	U-Shaped Valley, Clear	0.41	0.68	0.96	1.00	1.00	1.00
5	Wide Open	0.64	0.87	1.00	1.00	1.00	1.00
6	High Undulating Wooded	0.48	0.76	0.97	1.00	1.00	1.00
7	U-Shaped Valley, Scrub	0.42	0.70	0.92	0.96	1.00	1.00
8	Valley - Dense Wood	0.61	0.87	1.00	1.00	1.00	1.00
Yorkshire							
9	U-Shaped Bowl, Open	0.39	0.73	1.00	1.00	1.00	1.00
10	Gorge, Scrub	0.36	0.67	0.95	1.00	1.00	1.00
11	Semi-table-top, open	0.59	0.86	1.00	1.00	1.00	1.00
12	Undulating Scrub	0.52	0.79	0.97	1.00	1.00	1.00
13	Severe Valley, Open	0.47	0.76	0.96	1.00	1.00	1.00
14	Wooded Plateau	0.53	0.84	1.00	1.00	1.00	1.00
15	Deep Wooded Valley	0.42	0.66	0.83	0.88	0.92	0.97
16	Between cliff and house	0.29	0.51	0.72	0.78	0.84	0.91

APPENDIX IX

ACTUAL AND PREDICTED SATELLITE SCHEDULES



ACTUAL SATELLITE SCHEDULE WEEK 1 WALES



ACTUAL SATELLITE SCHEDULE WEEK 2 YORKSHIRE

PREDICTED SATELLITE SCHEDULES

Predicted schedules are shown for trial periods as well as for periods later in 1998 and 1999, in order to demonstrate that satellite coverage remains sufficient during the typical working day. (One satellite pass is represented by either one or two asterisks).

<u>Predicted Satellite Schedule for Trials Week 1: Wales</u>

```
Latitude:    54degrees, 6 mins   Longitude:      -4 degrees, 20 mins

Hrs 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

5 Oct 97
Sat
S2*                         **   **   **   **    *   **   **   **   **   *
S3          **   **   **   **   **        *    *    *    *
S4                    *    **   **   *    *    *    *   **   **    *
S6   **   **   **   **   **   *    *    **   **   **
C4              **   **   **    **    *   *     **    *    **   **
C6                        **   **   **    *          *    **    *    **


6 Oct 97
Sat
S2*                         *    *    *    *    *    *    *   **   **   **
S3         **   **   **   **   *         *    *   **    *
S4                   **   **   **   **   **   *    *    *    **   **
S6   *    *    *    *    *    *   **   **   **    *
C4               **    *    **   **    *     *    *    **   **    *
C6*                   **   **   **    **    *    *    **    **   **   **

7 Oct 97
Sat
S2                         *    **   **   **   *    *    *    *    *    *
S3             **   **   **   *         *   **   **   **    *
S4                   *    *    *    *    *    *   **   **   **   **
S6  **   **   **   **   **   *    *    *    *    **
C4                 **   **   **    *     *    *    **    *    *
C6                      *    *    **   **    *     *    **   **   **    *

8 Oct 97
Sat
S2                         *   **   **   **    *    *   **   **   **   **
S3            *    *    *    *         *   **   **   **   **
S4                  *    **   **   **   *    *    *    *    *    *
S6  *    *    *    *    *    *   **   **   **   **
C4             **   **   **    **   **    *    **    *    **   **
C6                       **   **   **    *          *    **    *    **   *

9 Oct 97
Sat
S2                             *    **   *    *    *    *   **   **   **
S3           *    *    *    *    *        **   **   **   **
S4 *    **   **   **   *    *    *    *    *    *
S6                 **   **   **   **   **   **   **   **   **   **
C4              **    *    **   **    *     *    *    **   **    *
C6                   **   **    *    **    *    *    **    **   **   **

10 Oct 97
Sat
S2  *                         **   **   **   **   *    *    *    *    *
S3         **   **   **   **   **        *    *    *    *
S4                      *    *    *    *    *    *   **   **   **    *
S6 *   **   **    *    *    *   **   **   **   **    *
C4                *    **   **    *     *    *    **   **    *
C6                     *    *    **   **    *     *    **   **   **    *
```

<u>Predicted Satellite Schedule for Trials Week 2: Yorkshire</u>

```
Latitude:    54degrees, 20 mins   Longitude:     0 degrees, 43 mins

Hrs 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

19 Oct 97
Sat
S2 *                         **   **   **   **   *    *    *    **   **
S3        **   **   **   **   **   *    *    *    *    *
S4                *    **   **   **   **   *    *    *    *    **   *
S6 *    *    *    *    *    *   **   **   **   **
C4        *    *    **   **    *     *    *    **   **    *
C6                  *    **   **    *    **    *    **   **    *    *

20 Oct 97
Sat
S2**                         *    *    *    *    *   **   **   **   **   *
S3       *    **   **   **   **   *    *    *    *    *    *
S4                    **   **    *    *    *   **   **   **   **   **
S6*    **   **   **   *    *    *    *    *    *
C4         **   **   **    *    **    *    **    *    **   **
C6              *    **   **    *    **    *    **   **    **   **

21 Oct 97
Sat
S2*                         *    **   **   *    *    *    *    *    *    *
S3           **   **   **   *    *    *   **   **   **    *
S4                    *    **   **   *    *    *    *    *    *    *
S6*   **   **   **    *    *   **   **   **   **    *
C4          **    *    **   **    *    **    *    **   **    *
C6               **   **    **   **    *    **    *    **   **    *

22 Oct 97
Sat
S2                         **   **   **   **   **   *    *    **   **   **
S3        *    *    *    *    *    *   **   **   **   **
S4                   **   **   **   **   **   **   **   **   **   **
S6    **   **   **   *    *    *    *    *    *    *
C4       *    *    **   **    *     *    *    **   **    *
C6                 *    **   **    *    **    *    **   **    *    *

23 Oct 97
Sat
S2                         *    *    *    *    *    *   **   **   **   **
S3         *    *   **    *    *   **   **   **   **   **
S4                   *    *    *    *    *    *   **   **   **   **
S6   **   **   **   **   **   **   **   **   **   **
C4        **   **   **    *    **    *    **    *    **   **
C6             *    **   **    *    **    *    **   **    **   **

24 Oct 97
Sat
S2                        *    **   **   **   *    *    *    *    *    *
S3       **   **   **   **   **   *    *    *    *    *    *
S4                  *    **   **   **   *    *    *    *    *    *
S6   *    **   **   *    *    *    *   **    *    *
C4         **   **    **   **    *    **    *    **   **    *
C6              **   **    **   **    *    **    *    **    **   *
```

Predicted Satellite Schedule: Wales (2nd to 10th November 1997)

Latitude: 54degrees, 6 mins Longitude: -4 degrees, 20 mins

```
Hrs 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

5 Nov 97
Sat
S2  *                         **   **   **   **   *    *    *    *    *    *
S3               *    *    *    *         *   **   **   **   **
S4                       *    *    *    *    *    *   **   **   **    *
S6   **   **   **   **   **   **   **   **   **   **
C4       **   **    **   **    *    **    *    **   **    *
C6             *    *    **   **    *     *    *    **   **    *

6 Nov 97
Sat
S2                           **   **   **    *    *    *   **   **   **   **
S3              *    *    *    *        **   **   **   **   **
S4                      **   **   **   **   *    *    *    *    *    *
S6   *    *    *    *    *    *    *   **   **   **
C4         *    **   **    *          *    **   **    *
C6              **   **   **    *     *    *    **    *    **   **

7 Nov 97
Sat
S2                          *    *    **   *    *    *    *   **   **   **
S3           **   **   **   **   **        *    *    *    *
S4                    **   **   **   **    *   **   **   **   **   **
S6      **   **   **   **   *    *    **   **   **   *
C4    *    **   **    *    **    *    **   **    **   **
C6              **   **    **   **    *    **    *    **   **

8 Nov 97
Sat
S2                         *    **   **   **   **   *    *    *    *    *
S3          **   **   **   **   *         *    *   **    *
S4                    *    *    **   *    *    *    *   **   **    *
S6      *    *    *    *    *    *   **   **   **    *
C4     **   **    **   **    *    **    *    **   **    *
C6           *    *    **   **    *     *    *    **   **    *

9 Nov 97
Sat
S2   *                         **   **    *    *    *   **   **   **   **
S3         *    **   **   **   *         *   **   **   **    *
S4                   **   **   **   **   **   *    *    *    **   **
S6     **   **   **   **   *    *    *    *    *    *
C4       *    **   **    *          *    **   **    *
C6            **   **   **    *     *    *    **    *    **   **

10 Nov 97
Sat
S2  **                         *    **   **   *    *    *    *   **   **
S3             *    *    *    *         *   **   **   **   **
S4                   *    *    *    *    *    *   **   **   **   **    *
S6     *    *    *    *    *    *   **   **   **   **
C4   *    **   **    *    **    *    **   **    **   **
C6             **   **    **   **    *    **    **   **   **
```

<u>Predicted Satellite Schedule: Wales</u> (5th to 10th June 1998)
_Latitude: 53 degrees, 6 mins Longitude: -4 degrees, 20 mins

```
Hrs 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

5 JUN 98
Sat
S2  *                         **   **   **   **   *    *    *    *    *
S3            *    *    *    *        *    **   **   **   **
S4                     *   **   **    *    *    *   **   **   **   **
S6      **   **   **   **   **   *    **   **   **   **
C4      **   **    *    **   *    **   *    **   **   *
C6          *    **   **    *    **   *    **    *    **   **

6 JUN 98
Sat
S2 *                         **   **   **   **    *   **   **   **   **    *
S3          **   **   **   **   **        *    *    *    *
S4                    *    **   **   **   *    *    *    *   **    *    *
S6      *    *    *    *    *    *   **   **   **    *
C4   *   **    **   **    *    **    *    **   **    *
C6           **   **    **   **    *    **    *    **   **    *

7 JUN 98
Sat
S2 *                         *    *    *    *    *    *    *   **   **   **
S3         *    **   **   **   *         *    *   **    *
S4                        **   **   **   **   *    *    **   **   **   **
S6     **   **   **   **   *    *    *    **   **   **
C4    *    **   **    *    **    *    **   **    *    *
C6               *    **   **    *     *    *    **   **    *

8 JUN 98
Sat
S2                          *    **   **   **   **   *    *    *    *    *
S3             **   **   **   *         *   **   **   **    *
S4                        *    *    *    *    *    *   **   **   **    *
S6     *    *    *    *    *    *   **   **   **   **
C4     **   **    *    **    *    **    *    **   **    *
C6         **   **   **    *    **    *    **    *    **   **

9 JUN 98
Sat
S2                          *   **   **   **    *        **   **   **   **
S3            *    *    *    *         *   **   **   **   **
S4                       **   **   **   **   *    *    *    *    *    *
S6    **   **   **   **   *    *    *    *    *    *
C4  *   **    **   **    *    **    *    **   **    *
C6          **    *    **   **    *     *    *    **   **    *

10 JUN 98
Sat
S2    *                         *    **   *    *    *    *   **   **   **
S3           *   **   **   **    *        *    **   **   *
S4                      **   **   **   **    *   **   **   **   **   **
S6    *   **    *    *    *    *   **   **   **   **
C4   *    **   **    *    **    *    **   **    *    *
C6            *    **   **    *          *    **    *    *
```

<u>Predicted Satellite Schedule: Wales</u> (5th to 10th June 1999)
Latitude: 53 degrees, 6 mins Longitude: -4 degrees, 20 mins

```
Hrs 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

5 June 99
Sat
S2 **                         *    **   **   **   *    *    *    *    *
S3        *    **   **   **   *         *   **   **   **    *
S4                        **   **   **   **   **   *    **   **   **   **
S6     **   **   **   **   **   *    **   **   **   **
C4                      *    **   **    *    **    *    **   **    **   **
C6  **                        *    *    **   **    *     *    *    **   **

6 June 99
Sat
S2 *                         **   **   **   **   **   *    **   **   **   *
S3            *    **   *    *         *   **   **   **   **
S4                        *    *    *    *    *    *    *   **   **   **
S6     *    *    *    *    *    *    *   **   **   **
C4                       **   **    *    **    *    **    *    **   **    *
C6    *                        **   **   **    *     *    *    **    *    *

7 June 99
Sat
S2 *                         *    *    *    *    *    *    *   **   **   **
S3           *    *    *    *             **   **   **   **
S4                       *    **   **   **   **   *    *    *    *    *
S6    *    **   **   **   **   *    *    *    **   **
C4                    *    *    **   **    *    **    *    **   **    *
C6 *   **                       **   **    **   **    *    **    *    **

8 June 99
Sat
S2                               **   **   **   *         *    *    *    *
S3         **   **   **   **   **        *    *    *    *
S4                           **   **    *    *    *   **   **   **   **
S6    *    *    *    *    *    *    *   **   **   **    *
C4                     *    **   **    *    **    *    **   **    *    **
C6 **                        *    *    **   **    *    *    *    **   **

9 June 99
Sat
S2    *                         **   **   **   **    *   **   **   **   **
S3        *    **   **   **   *         *    *    *    *    *
S4 *                         *    **   **   *    *    *    *   **   **    *
S6        **   **   **   **   *    *    *    *    *    *
C4                      **   **    *    **    *    **    *    **   **   **
C6   *                        **   **   **    *     *    *    **    *

10 June 98
Sat
S2   **                         *    *    *    *    *    *   **   **   **
S3            **   **   **   *         *   **   **   **    *
S4                          **   **   **   **   *    *    *    **   **   **
S6       **    *    *    *    *   **   **   **   **   **
C4                   *   **    **   **    *    *     *    **   **    *
C6    **                       **    *    **   **    *    **    **   **   *
```

Predicted Satellite Schedule: The Lizard 18 March to 6 April 1998.

```
Lat:  49 degrees 48 Mins,  Long:   -5 degrees

Hrs 0  1  2  3  4  5  6  7  8  9  10 11 12 13 14 15 16 17 18 19 20 21 22 23

19 Mar 1998
Sat
S2  *                         **   **   **   **              *   **   **
S3          **   **   **   **              *    *    *    *
S4                       *    **   *    *         *   **   **   **    *
S6   **   **   **   **              *    *    *    *
C4 **    *                        *    **   **    *          *    **   **
C6   **    **   **                        **   **    *    **         **

20 Mar 1998
Sat
S2 *                          *    *    *    *             **   **   **
S3         *    **   **   **              *   **   **   **
S4                      **   **   **   **              *    *    *    *
S6   *   **    *    *             **   **   **   **
C4   *                             **   **    *    *          **   **     *
C6*    **   **                        *   **    **   **                *

21 Mar 1998
Sat
S2**                         **   **   **   **             *    *   **
S3             *    **   *    *             **   **   **   **
S4                      *    *    *    *             **   **   **   **
S6  *    **   **   **             *    *   **    *
C4*   **                       **   **    *    **                *    **
C6 **   **    *                        *    **   **    *               **

22 Mar 1998
Sat
S2*                         **   **   **   **             *    **   **   *
S3            *    *    *    *             **   **   **   *
S4                     *    **   **   *              *   **   **    *
S6  *   **   **   **    *        **   **   **   **
C4**    *                        *    *    **    *          *    **   **
C6  **    **   **                        **   **    *    **         **   *

23 Mar 1998
Sat
S2*                         *    *    *    *             **   **   **   **
S3          **   **   **   **              *    *    *    *
S4                    **   **   **   **              *    **   **   **
S6      **   **   **   *         *    *   **   **    *
C4  *                             **   **    *    *          **   **    **
C6    **   **                        *    *    **   **               *

24 Mar 1998
Sat
S2                         *    **   **   **   *         *    *    *    *
S3         **   **   **   **              *    *   **    *
S4                    *    *    *    *              *   **   **   **
S6     **   **   **   **             **   **   **   **
C4   **                       **   **    *    **               *    **   *
C6**   **    *                        *    **   **    *               **

25 Mar 1998
Sat
S2                             **   **   **    *        *    **   **   **
S3             **   **   **                 **   **   **    *
S4                   *    **   **   **   *         *    *    *    *
S6     *    **   *    *             **   **   **    *
C4*    *                        *    *    **    *          *    **   **
C6  *    **   **                        **   **    *    **         **    *
```

```
Hrs 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

26 Mar 1998
Sat
S2  *                          *    *    *    *             **   **   **
S3            *    *    *    *             **   **   **   **
S4                       **   **    *    *        **   **   **   **
S6    **   **   **   **             *    *    **   *
C4 *                             **   **    *    *          **   **    **
C6   **   **                        *    *    **   **                *    *

27 Mar 1998
Sat
S2  *                         **   **   **   **             *    *    *
S3           *    *    *    *             *    **   **   *
S4                       *    **   **   *             **   **   **    *
S6    *    *    *    *             **   **   **   **
C4  **                       **   **    *    **               *    **   **
C6*   **    *                        *    **   **    *               **

28 Mar 1998
Sat
S2 *                         **   **   **    *             **   **   **
S3         **   **   **   **             *    *    *    *
S4                      **   **   **   **             *    *    **   *
S6   **   **   **   **             *    *    *    *
C4   **                        *    *    **    *          *    **   **
C6 *    **   **                       **   **    *    **          *    *

29 Mar 1998
Sat
S2**                         *    *    *    *             **   **   **   *
S3             **   **   **                  *   **   **
S4                      *    *    *    *             **   **   **   **
S6   *    *    *    *             **   **   **   **
C4*                             **   **   **    *          **   **    **
C6  **   **                        *    *    **   **               *    **

30 Mar 1998
Sat
S2*                         **   **   **   **             *    *    *    *
S3            **   **   **   *             **   **   **   **
S4                     **   **   **   **             *    *    *    *
S6  *    **   **   **             *    *    *    *
C4 **                       **   **    *    **               *    **   **
C6   **    *                        *    **   **    *               **

31 Mar 1998
Sat
S2                         **   **   **    *             **   **   **   **
S3           *    *    *    *             **   **   **   **
S4                    **   **   **   **             **   **   **   **
S6  *   **   **    *    *        **   **   **   **
C4  **                        *    *    **    *          *    **   **    *
C6*    **   **                       **   **    **   **          *    **

1 Apr 1998
Sat
S2                         *    *    **   *    *         *   **   **   **
S3          *   **   **    *             *    *    *    *
S4                    *    *    *    *              *   **   **   **
S6      **   **   **   *         *    *   **    *    *
C4                             **   **   **    *          **   **    *
C6 **   **                        *    *    **   **               *    **
```

```
Hrs 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

2 Apr 1998
Sat
S2                             **   **   **   *         *    *    *    *
S3        **   **   **   **             *    *    *    *
S4                   *    **   **   **   *         *    *    *    *
S6     **   **   **    *             **   **   **   **
C4**                       **   **   **    **               *    **   **
C6  **    *                        **   **   **    *               **    *

3 Apr 1998
Sat
S2  *                         **   **    *    *             **   **   **
S3            **   **   **   *              *   **   **    *
S4                        *    *    *    *        **   **   **   **
S6     *    **   **   *              *   **   **    *
C4 **                       **    *    **    *          *    **   **    *
C6    **   **                       **   **    **    *          *    **

4 Apr 1998
Sat
S2 **                         *    **   *    *             **   **   **
S3           *    **   *    *             **   **   **   **
S4                       **   **   **   *              *   **   **    *
S6    **   **   **   **              *    **   **   **
C4                            **   **   **    *          **   **    *    *
C6**   **                        *    *    **   **               **   **

5 Apr 1998
Sat
S2 *                         **   **   **   **             *    *    *
S3          *    *    *    *             **   **   **   **
S4                      **   **   **   **             *    **   **   *
S6    *    *    *    *             **   **   **    *
C4*                       **   **   **    **               *    **   **
C6  *    *                        **   **   **    *               **    **

6 Apr 1998
Sat

S2*                          *   **    *    *             **   **   **   *
S3         *   **   **   **             *    *    *    *
S4                      *    *    *    *             **   **   **   **
S6   **   **   **   **             *    *    *    *
C4**                       **    *    **    *          *    **   **    *
C6   **   **                       **   **    **    *          *    **   *
```

Predicted Satellite Schedule: Newcastle 19 March to 6 April 1998.

```
Lat:   55 degrees   Long:   -1degree 36 mins

Hrs 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

19 Mar 98
Sat
S2  *                         **   **   **   **   **   *    **   **   **
S3          **   **   **   **   *    *    *    *    *    *
S4                  *    *    *    *    *    *    *   **   **   **    *
S6   *    **   **   **   *    *    *    *    *    *
C4 **   **                        *    **   **    *    **    *    **   **
C6   **    *    *                   *    **   **    *    **    *    **

20 Mar 98
Sat
S2 **                         *    *    *    *    *   **   **   **   **
S3         *    **   **   **   *    *    *   **   **   **
S4                      **   **   **   **   *    *    *    *    **   *
S6  **   **   **    *    *   **   **   **   **   **
C4   *    *                   *    **   **    *    **    *    **   **    *
C6*    **   **                        *    *    **   **    *    **    *

21 Mar 98
Sat
S2 *                         *    **   **   *    *    *    *    *    *
S3        *    *    *    *    *    *   **   **   **   **    *
S4                     **   **    *    *    *   **   **   **   **   **
S6  *    **   **   **   *    *    *    *    *    *
C4    **                       **   **    *    **    *    **    *    **
C6 **   **    *                        *    **   **    *    **    *    **

22 Mar 98
Sat
S2*                         **   **   **   **   **   **   **   **   **   *
S3            *    *    *    *    *   **   **   **   **   **
S4                     *    **   **   *    *    *    *    *    *    *
S6 **   **   **   **   **   **   **   **   **   **
C4**   **                        *    **   **    *    **    *    **   **
C6  **    *    *                   **   **   **    **   **    *    **    *

23 Mar 98
Sat
S2*                         *    *    *    *    *    *   **   **   **   **
S3          **   **   **   **   **   *    *    *    *    *
S4                    **   **   **   **   **   **   **   **   **   **
S6  *    *                   *    **   **    *    **    *    **   **    *
C4 *    *    **   *    *    *    *   **   **    *    *
C6    **   **                        *    *    **   **    *    **    *

24 Mar 98
Sat
S2                         *    **   **   **   *    *    *    *    *    *
S3         **   **   **   **   *    *    *    *    *    *
S4*    **   **   **   **   **   **   **   **   **   **
S6                    *    *    *    *    *    *   **   **   **   **
C4   **                       **   **    *    **    *    **   **    **   *
C6**   **    *                        **   **   **    *    **    *    **

25 Mar 98
Sat
S2                        **   **   **   **   **   **   **   **   **   **
S3        *    **   **   *    *    *    *   **   **   **    *
S4                   *    **   **   **   *    *    *    *    *    *
S6     *    *    *    *    *    *   **   **   **    *
C4*   **                        *    **   **    *    **    *    **   **
C6 **    **   *                   **   **   **    **   **    *    **    *
```

```
Hrs 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

26 Mar 98
Sat
S2  **                    *    *    *    *    *    *   **   **   **   **
S3            *    *    *    *    *   **   **   **   **   **
S4                  **   **   **   **   **   **   **   **   **   **
S6    **   **   **   **   **   *    *    **   **   **
C4 *    *                   *    **   **    *    **    *    **   **    *
C6   **   **                        *    *    **   **    *    **    *    *

27 Mar 98
Sat
S2  *                         **   **   **   **   *    *    *    *    *
S3          **   **   **   **   **   **   **   **   **   **
S4                  *    *    **   *    *    *    *   **   **    *    *
S6    *    *    *    *    *    *   **   **   **    *
C4  **                       **   **    *    **    *    **   **    **   **
C6*   **    *                        **   **   **    *    **    *    **

28 Mar 98
Sat
S2 *                         **   **   **   **   **   **   **   **   **   **
S3         **   **   **   **   **   *    *    *    *    *
S4                      **   **   **   **   **  *    *    **   **   **
S6   **   **   **   **  *    *    *    *    *    *
C4   **                        *    **   **    *    **    *    **   **   *
C6**    **   **                  **   **   **    **   **    *    **    *

29 Mar 98
Sat
S2**                         *    *    *    *    *    *   **   **   **
S3        *    **   **   **   *    *    *    *   **    *
S4                      *    *    *    *    *   **   **   **   **   **
S6  **   **    *    *    *    *   **   **   **   **
C4*    *                   *    **   **    *    **    *    **   **    *
C6  **   **                        *    *    **   **    *    **    *    **

30 Mar 98
Sat
S2*                         **   **   **   **   *    *    *.   *    *    *
S3       *    *    **   *    *    *    *.  **   **   **    *
S4                     *    **   **   **   *    *    *    *    *    *
S6  *    **   **   **   *    *    *    *    *    *
C4 **                       **   **    *    **    *    **   **    **   **
C6   **    *                        **   **   **    *    **    *    **

31 Mar 98
Sat
S2                         **   **   **   **   **   **   **   **   **   **
S3           *    *    *    *    *   **   **   **   **   **
S4                    **   **   **   **   **   **   **   **   **   **
S6 **   **   **   **    *   **   **   **   **   **
C4  **                        *    **   **    *    *     *    **   **   **
C6*    **   **                  **   **    *    **   **    *    **    *

1 Apr 98
Sat
S2                         *    *    *    *    *    *    *   **   **   **
S3         **   **   **   **   **   **   **   **   **   *
S4                    *    *    *    *    *    *   **   **   **    *
S6 *    **   **   **   *    *    *    *    *    *    *
C4    *                   *    **   **    *    **    *    **   **    *
C6 **   **                        *    *    **   **    *     *    **   **
```

```
Hrs 0  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23

2 Apr 98
Sat
S2                        *    **   **   **   **   *    *    *    *    *
S3        **   **   **   **   **   *    *    *    *    *
S4                   *    **   **   **   **   *    *    *    *    *
S6**   **   **   **   **   **   **   **   **   **   **
C4**                       **   **    *    **    *    **   **    **   **
C6  **    *                        **   **   **    **    *    *    **    *

3 Apr 98
Sat
S2  *                     *   **   **   **   **   **   **   **   **   **
S3       *    **   **   **   *    *    *   **   **   **    *
S4                  **   **   **   **    *   **   **   **   **   **
S6     *    **   *    *    *    *    *   **    *    *
C4 **                        *    **   **    *    *     *    **   **   **
C6    **   **                  **   **    *    **   **    *    **    **

4 Apr 98
Sat
S2 **                         *    *    *    *    *    *   **   **   **
S3           *    *    *    *    *    *   **   **   **   **
S4                  *    *    **   **   *    *    *    *   **    *    *
S6    **   **   **   **   **   **   **   **   **   **
C4   *                   *    **   **    *    **    *    **   **    *    *
C6**   **                        *    **   **   **    *     *    **   **

5 Apr 98
Sat
S2 *                         **   **   **   **   *    *    *    *    *
S3          *    *    *    *    *   **   **   **   **   **
S4                      **   **   **   **   **   **   **   **   **   **
S6    *    *    *    *    *    *   **   **   **    *
C4                        **   **    *    **    *    **   **    **   **
C6 **    *                        **   **   **    **    *    **   **   *

6 Apr 98
Sat
S2*                         **   **   **   **   **   **   **   **   **   *
S3        **   **   **   **   **   *    *    *    *    *
S4                      *    *    *    *    *    *   **   **   **    *
S6   **   **   **   **   **   *    *    **   **   **
C4**                        *    *    **    *    *     *    **   **   **
C6   **   **                  **   **    *    **    *    *    **    **   *
```

APPENDIX X COMPARISON OF ACCURACY OF POSITION ESTIMATE PAIRS

Table X.I Site 5, Airport

Incorrect Position Estimate		Correct Position Estimate	
Resultant(r)/km	Search Area(Sq kM)	Resultant(r)/km	Search Area(Sq kM)
3790	45136950.7	1.3	5.24
845	2244713.6	7.7	185.51
2569	20741755.7	0.6	1.09
3740	43953725.2	0.3	0.28
1072	3612051.7	0.5	0.88
1635	8404944.6	0.8	1.86
1658	8638516.3	0.5	0.70
3620	41180157.1	1.2	4.44
4554	65177960.5	1.0	3.18
1011	3211490.5	0.4	0.61
938	2767944.3	0.2	0.08
1225	4715088.1	0.4	0.58
2205	15276962.3	1.5	6.64
1979	12312440.1	0.6	1.24
1441	6529857.9	0.4	0.63
586	1080990.9	0.4	0.60
4781	71837158.3	2.2	14.92
4364	59863910.0	0.4	0.56
3677	42481330.4	0.6	1.06
4232	56274814.5	5.4	92.76
834	2183849.6	2.7	23.72
2811	24834525.5	0.3	0.34
3512	38763712.6	1.5	7.03
3896	47704277.8	1.2	4.86
63	12439.6	2.2	14.77
776	1891576.6	0.2	0.14
2022	12854706.6	0.4	0.40
5231	85991592.1	10.2	325.24
2186	15017008.7	0.1	0.06
696	1522703.8	0.3	0.32
770	1861853.1	0.2	0.11
696	1524545.8	0.6	1.06
495	769421.6	6.1	118.48
3423	36825054.0	0.9	2.65
3139	30974023.1	5.7	103.79
4023	50866468.9	1.1	3.87
1366	5861528.4	0.5	0.78
1330	5560814.2	0.7	1.66
2294	16533536.3	0.3	0.33
4613	66885669.7	0.4	0.60
4213	55796882.6	0.8	1.94
359	404187.6	0.7	1.62
4216	55851257.0	1.1	3.66
21	1340.3	2.4	18.35
3128	30759132.5	0.7	1.50
1557	7619223.1	0.3	0.38
1292	5243921.1	0.1	0.04
3028	28816633.9	0.5	0.67
1126	3984246.6	0.5	0.72
1690	8977711.3	1.2	4.84
1607	8119294.1	2.2	15.15
3924	48392903.9	0.3	0.27
986	3052800.7	4.8	71.89
Averages:			
2287.6	23035879.3	1.5	19.9

Table X.II Site 9, Darnholm

Incorrect Position Estimate		**Correct Position Estimate**	
Resultant(r)/km	Search Area(Sq kM)	Resultant(r)/km	Search Area(Sq kM)
3289.24	34002808.63	2.53	20.16
1243.83	4862324.74	0.20	0.13
1176.04	4346777.44	0.54	0.90
4373.51	60115297.03	0.96	2.90
1942.47	11858577.40	2.60	21.32
1132.97	4034267.84	45.26	6436.85
698.26	1532373.81	0.78	1.92
3962.51	49347419.62	0.44	0.60
1753.93	9668224.41	0.60	1.13
2134.39	14317634.66	0.51	0.83
1813.00	10330498.16	4.58	65.93
2794.32	24540091.67	2.63	21.82
137.43	59355.44	1.51	7.15
2820.86	25008434.66	0.53	0.87
1383.48	6015482.21	0.44	0.62
458.11	659562.19	97.96	30161.72
1198.23	4512383.52	0.33	0.35
3427.83	36928616.73	1.17	4.32
957.51	2881455.96	0.29	0.26
629.44	1245192.73	0.24	0.18
1886.32	11182979.12	2.51	19.75
1119.72	3940461.70	13.17	545.02
2285.49	16416601.59	3.37	35.72
979.31	3014132.76	0.88	2.41
Averages:			
1677.27	13108507.45	7.49	1445.87

APPENDIX XI

LOCATION ERROR AND SEARCH AREA CALCULATIONS

Position Accuracy

A single beacon detection by a satellite is theoretically all that is required to determine that a worker is in distress, and rescue services should be deployed to his/her aide. This relies on the fact that records are kept of which beacon is held by which worker in which location. An error in this manual record could cause a search to be conducted in completely the wrong location.

If 3 or more bursts are received from the beacon, the LUT calculates 2 latitude and longitude locations by the Doppler shift process. A confidence percentage accompanies the position information. The percentage for Lat1/Long1 increases with the number of bursts received from the beacon. One of the two locations can generally be dismissed immediately as they tend to be many hundreds of kilometres from the work area or in the sea. For this reason, KDSC have taken the best location accuracy of the two samples and ignored the obviously incorrect estimate.

Total Detections In Relation To Accuracy

For each of the sites, the total number of detections is plotted along with the total number of satellite passes that were able to detect the beacon. From this the average number of detections per pass was calculated. Since the positional confidence probability increases with the number of detections, this test aims to show that positional data accuracy improves with the number of detections.

Search Area Calculations - Location Error

At each of the sites where the beacons were left, the location was measured using two GPS receivers. Average lat/long values were calculated and used as the comparison for the locations calculated by the LUT. It is noted that there may be a small error associated with the GPS data, although this will be constant across the sites, and should be reduced by using data from two different receivers.

In order to express differences in Lat and Long in terms of square metres of search area, there are a number of steps in the data analysis as detailed below:

- Convert the GPS data from degrees/minutes to degrees/decimal of degrees for both latitude and longitude.
- Calculate the differences in lat and long in minutes between GPS and LUT data.
- Scale into km from the Ordnance Survey map for each minute. (measured for 5 minutes and divided by five). Note that the scaling factor of longitude changes according to the position of the sites. Latitude scaling is constant across all sites.
- Having calculated the Northing and Easting displacement in Kilometres, the resultant radius r can be determined as follows:

$$r = \sqrt{(LUTlat1 - GPSlat)^2 + (LUTLong1 - GPSLong)^2} \quad \text{Km}$$

$$SearchArea = \Pi r^2 \quad \text{Km}^2$$

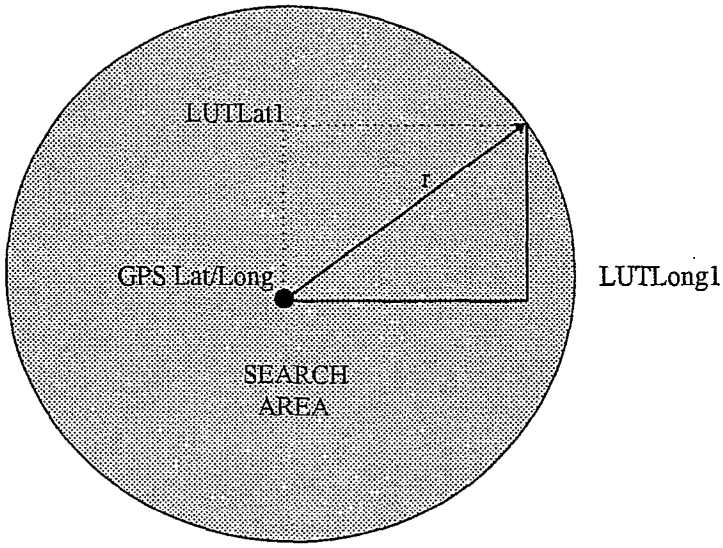


Figure XI.I Search Area Calculation

By applying these equations, the error loci for all detections at each site are determined.

These are plotted against the satellites responsible for the detection, in the sequence in which the detections occurred.

Search Area Assessment

It was anticipated that there will always be a human involvement in the interpretation of the positional data in order to organise a search. Hence any wildly incorrect loci caused by a small amount of corrupted data would cause the mean search area to be increased, when in fact those particular co-ordinates would be dismissed. Hence KDSC decided to group the location errors into logarithmic ranges(0-1sq km, 1-10sq km,10-100sq km,100-1000sq km 1000-10000sq km and >10000km).

This method allows any maverick values to be dismissed and shows what percentage of the data fall within each range, and provides a good assessment of the ability of the system predict the geographical position of the beacon.

If the beacon remains switched on following the initial detection that initiated the search, further data from the LUT should become available and the search area further reduced.

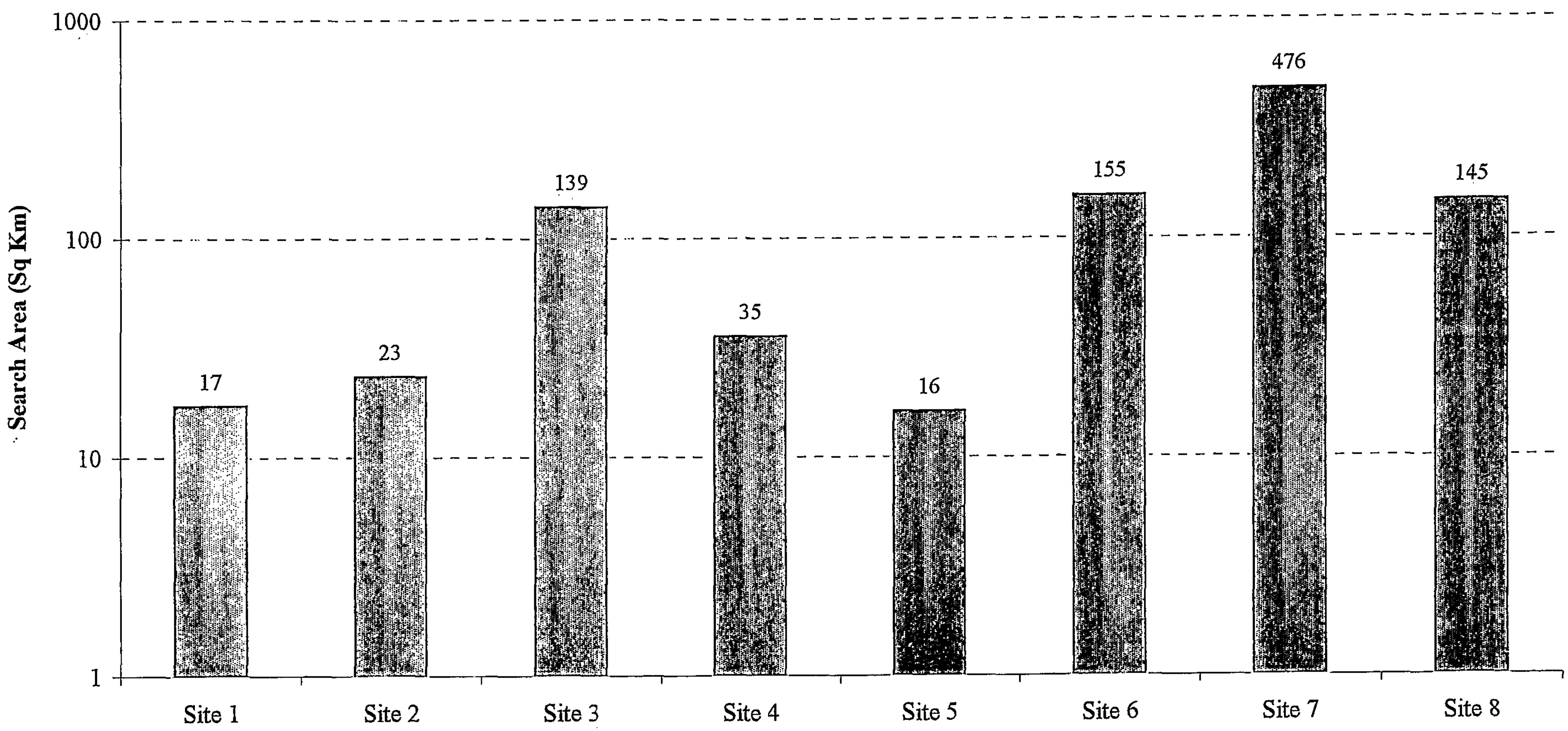
Cumulative Search Area

KDSC have also plotted cumulative percentages of the ranges so that at a glance the graph shows information such as 'At site 14 , 65% of the position estimates are within 10 Sq Km of the actual location of the beacon.

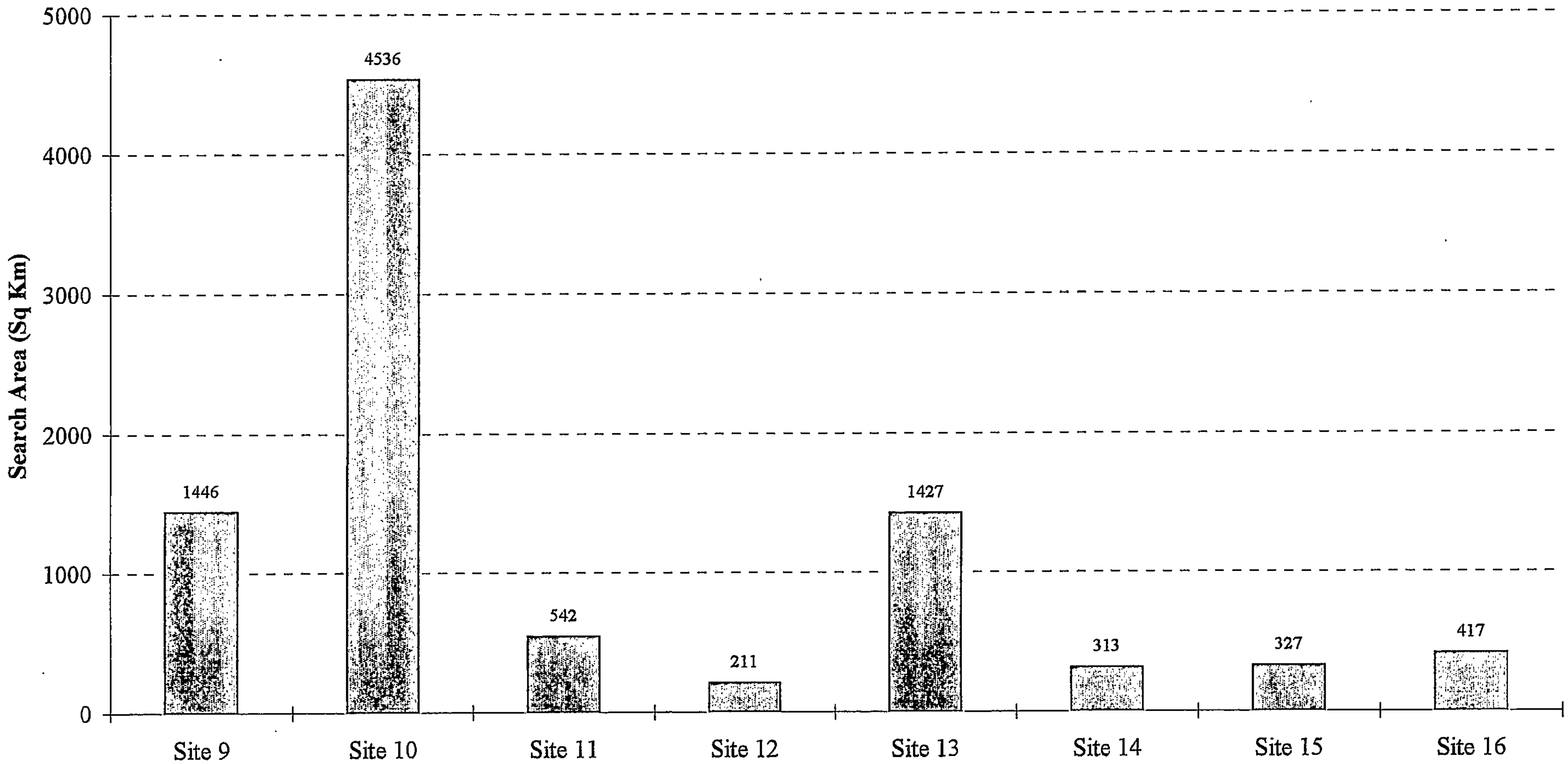
In practice it is recommended that each of the locations are plotted on the map and the search are centred around the most dense area of these plots.

In the event that only one prediction is received from the beacon, it will be necessary to choose one of the two positions calculated by the LUT. The location with the higher confidence factor will usually represent that of the beacon. If two or less bursts are received by the satellite, no positional information can be calculated by the LUT. In this case the search will be centred around the last known position of the worker.

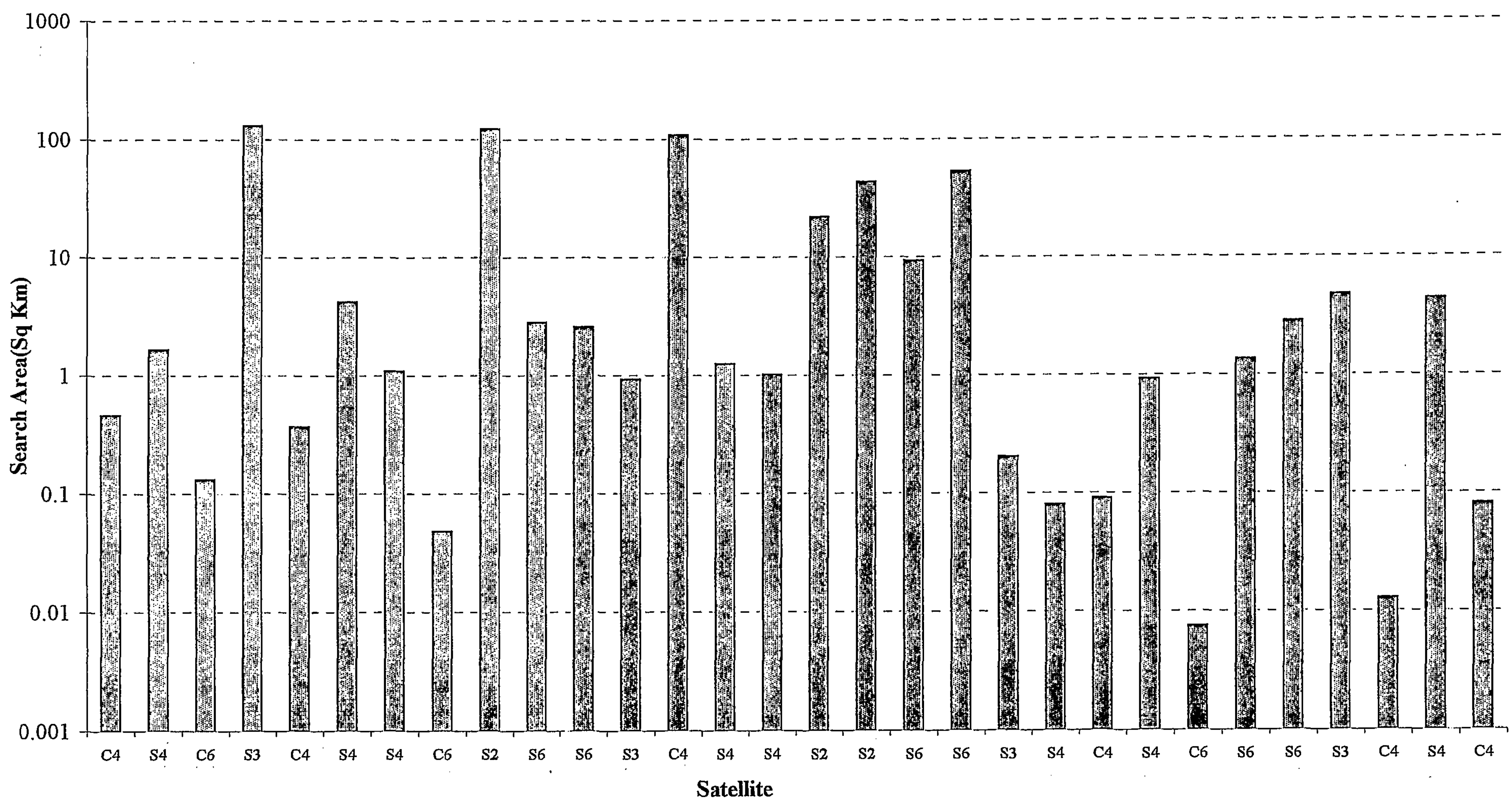
APPENDIX XII
MEAN AND ACTUAL SEARCH AREAS



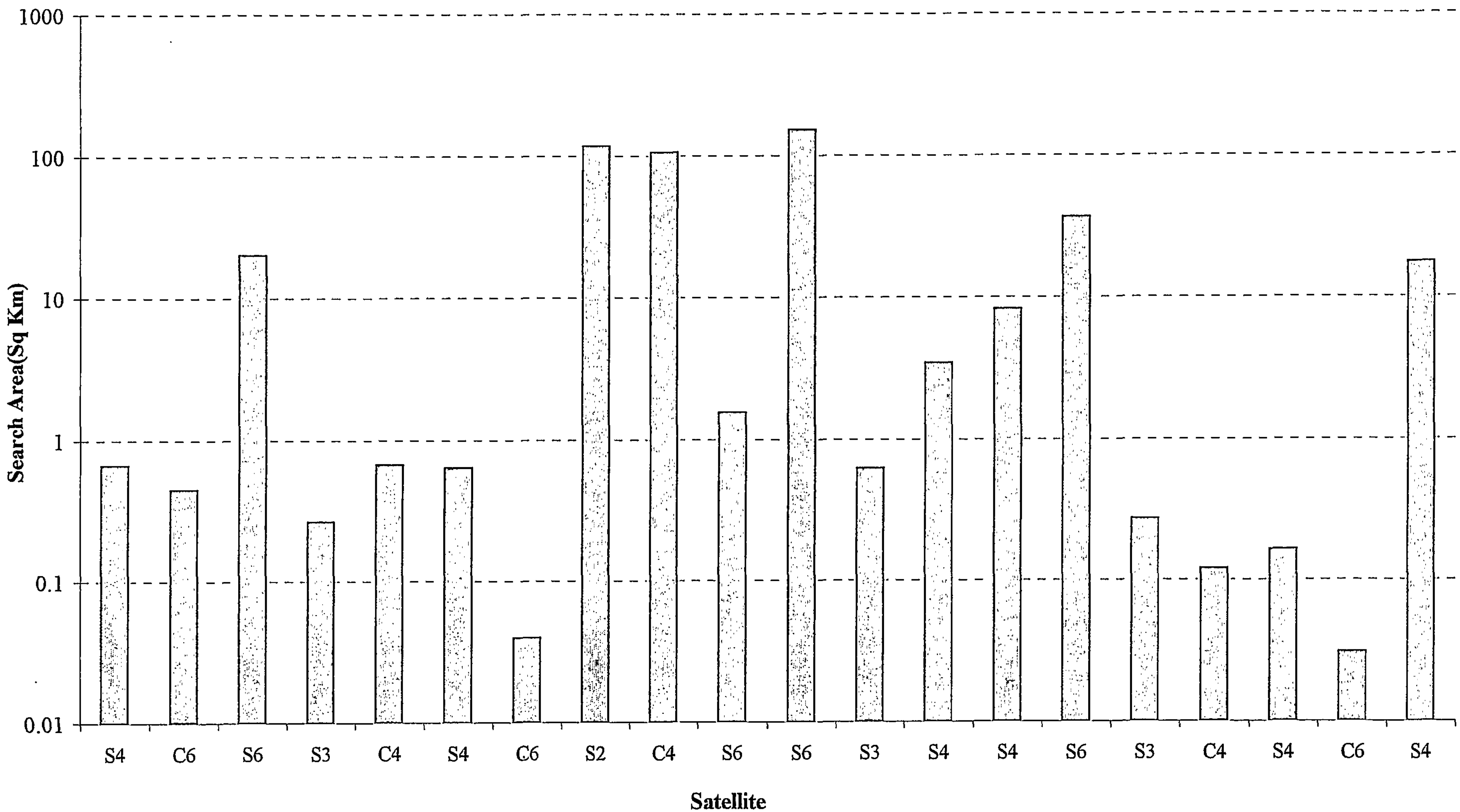
MEAN SEARCH AREAS WEEK 1 WALES



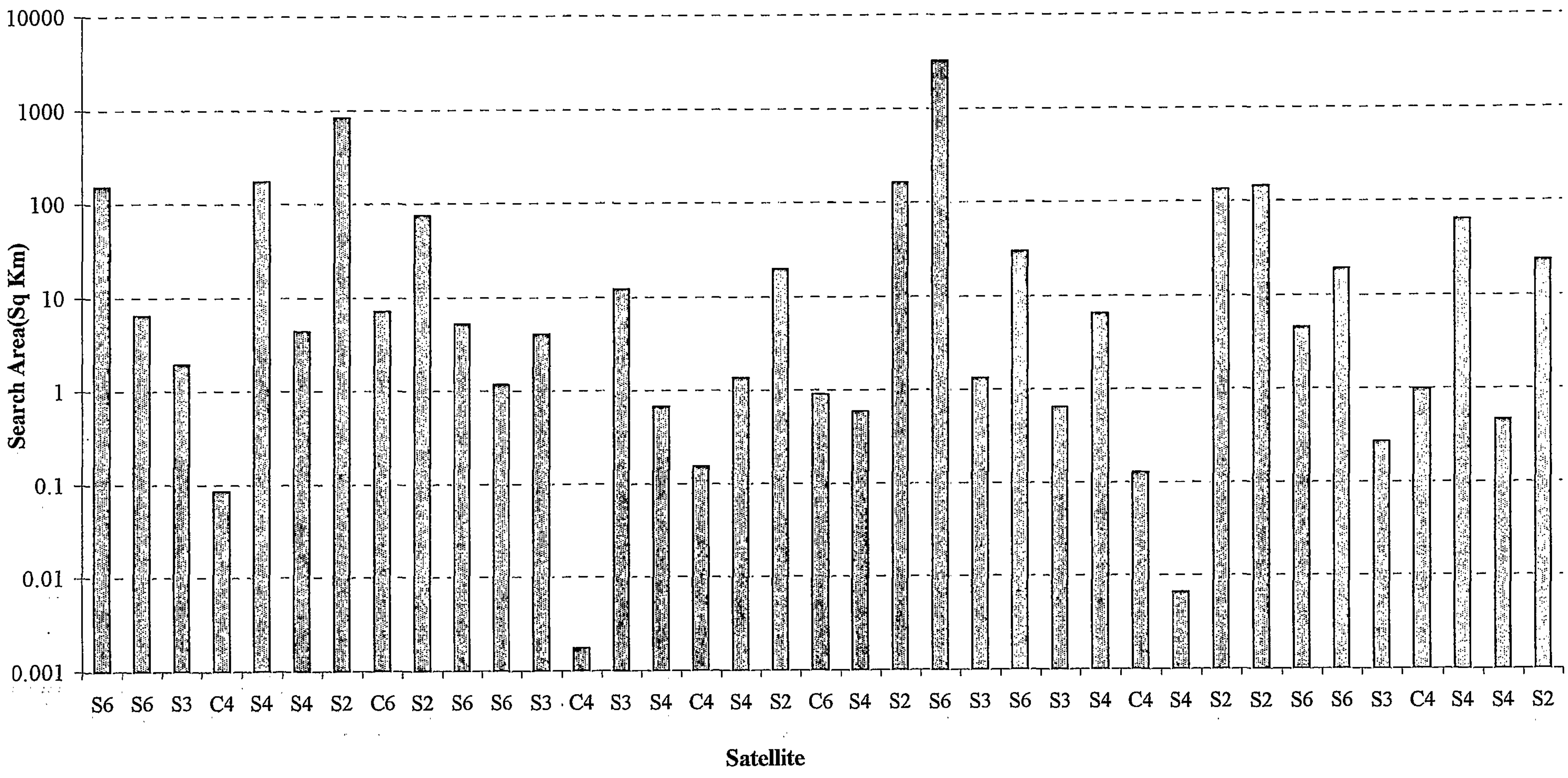
MEAN SEARCH AREAS WEEK 2 YORKSHIRE



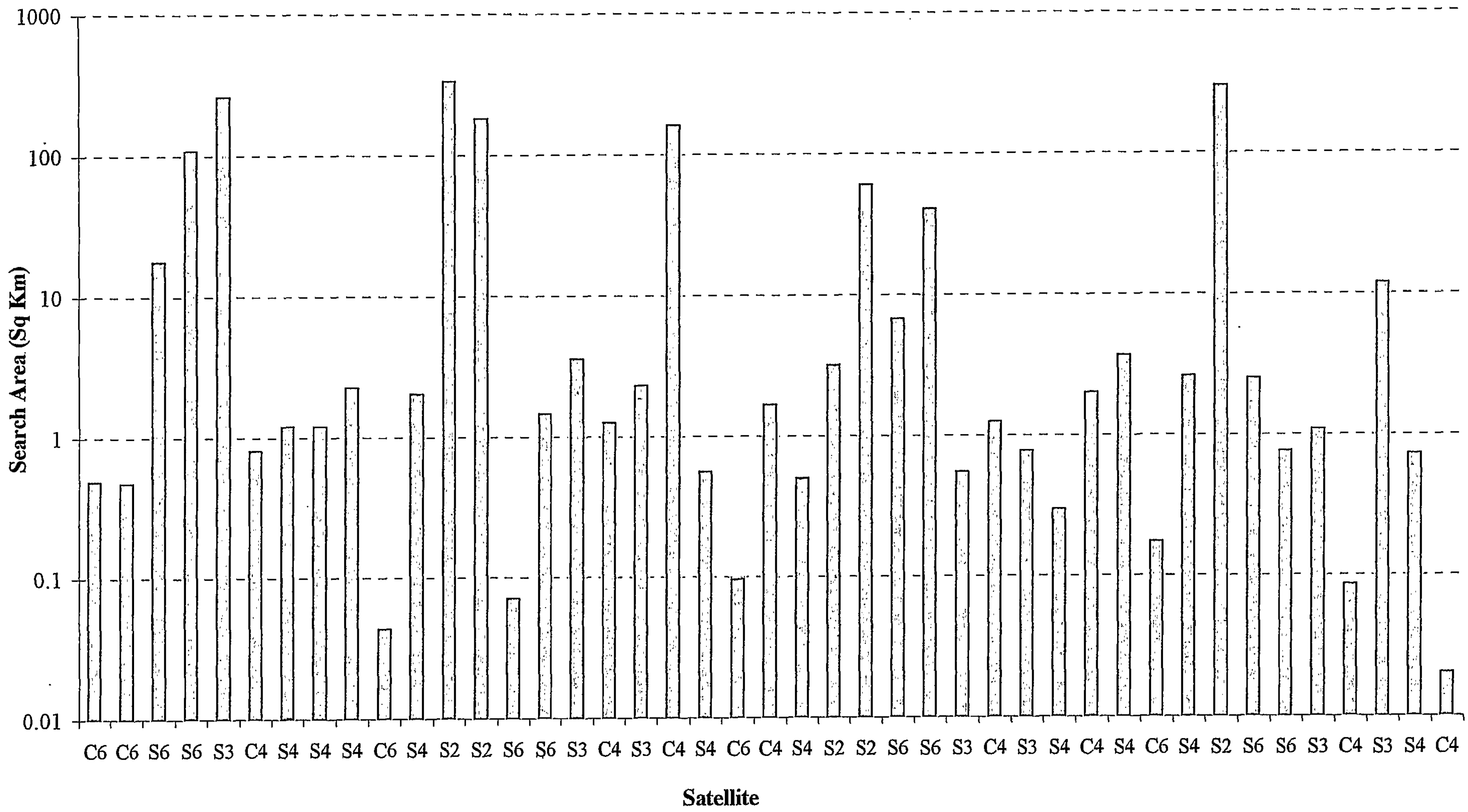
SITE 1 SEARCH AREAS



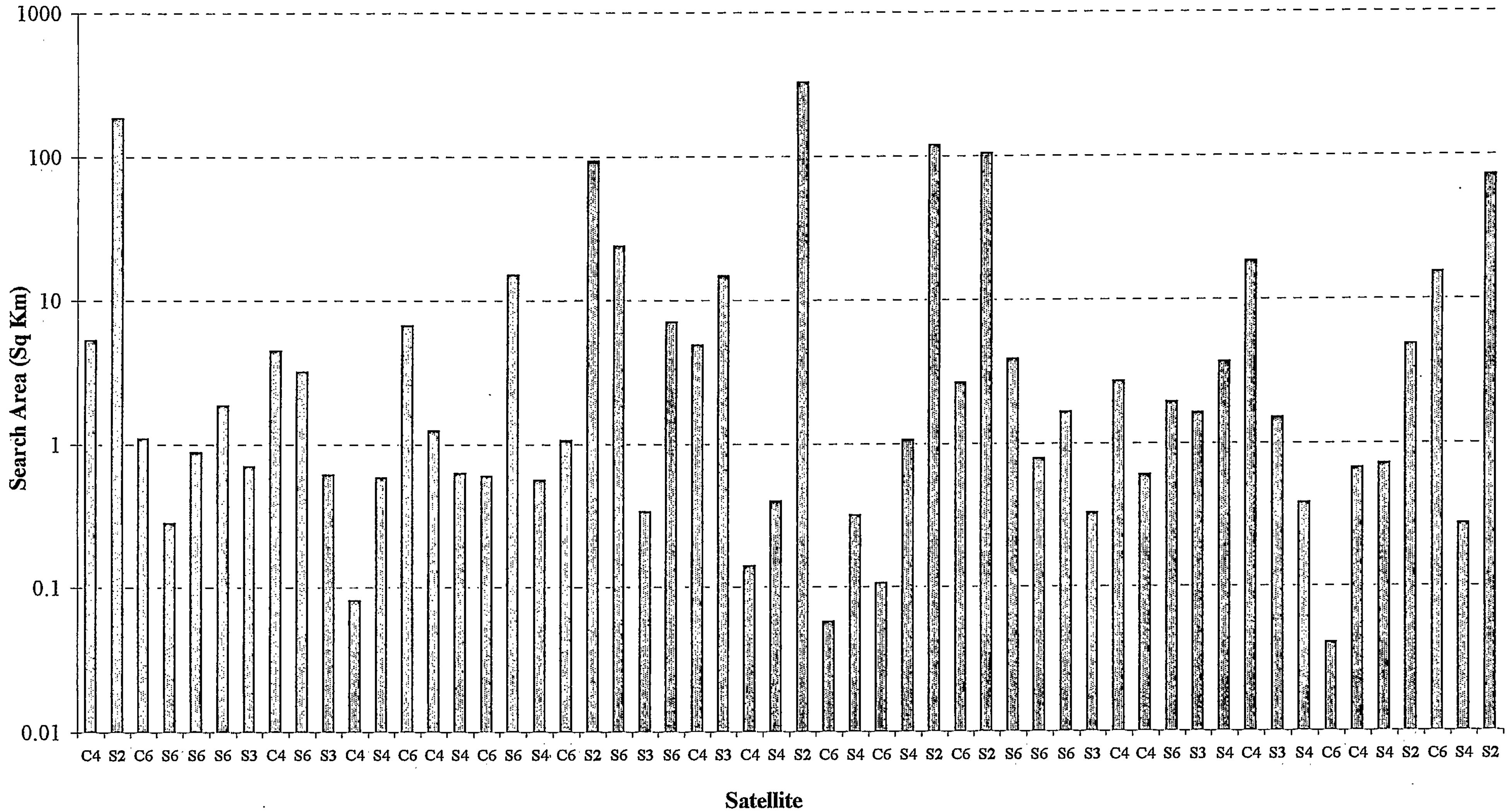
SITE 2 SEARCH AREAS



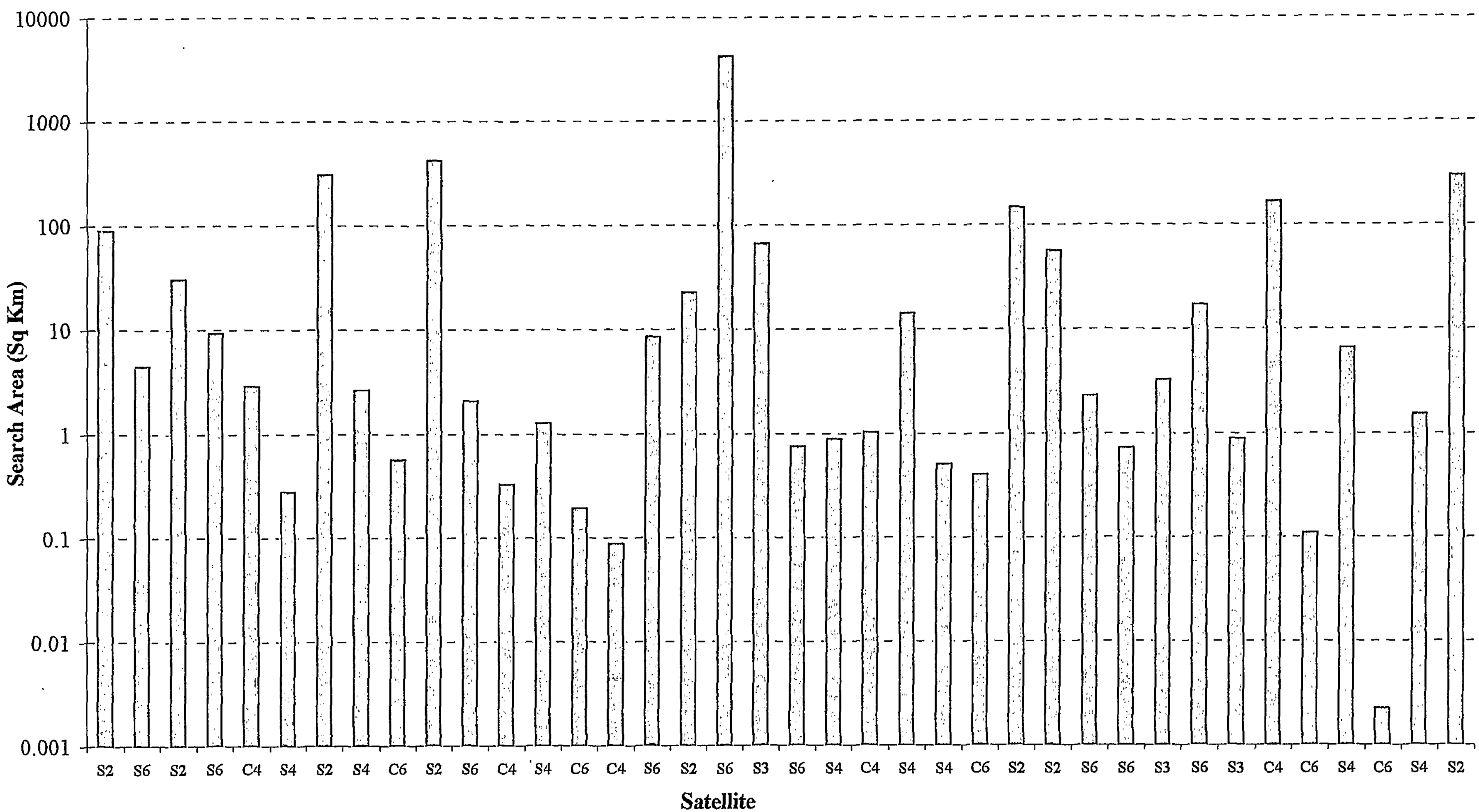
SITE 3 SEARCH AREAS



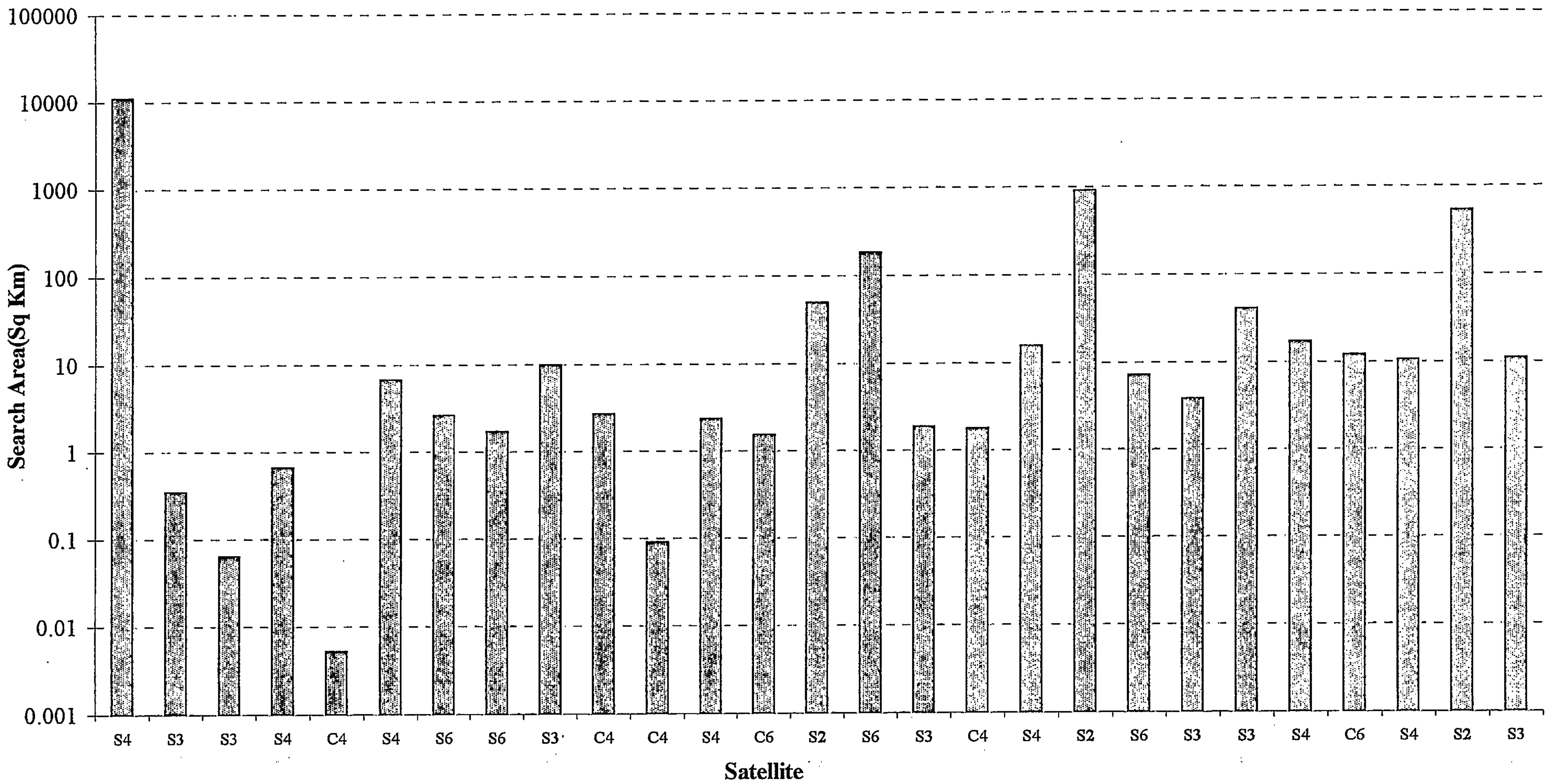
SITE 4 SEARCH AREAS



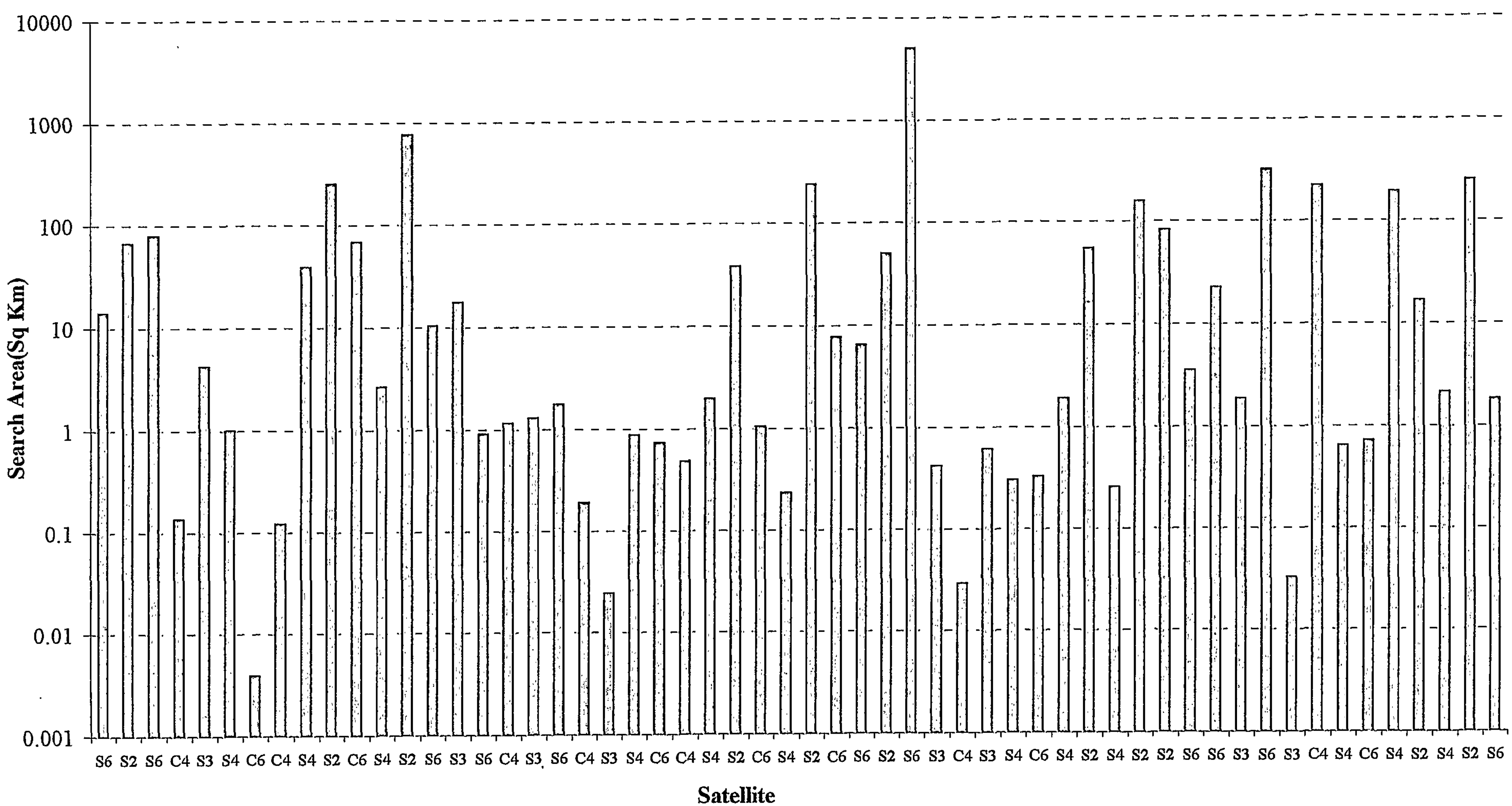
SITE 5 SEARCH AREAS



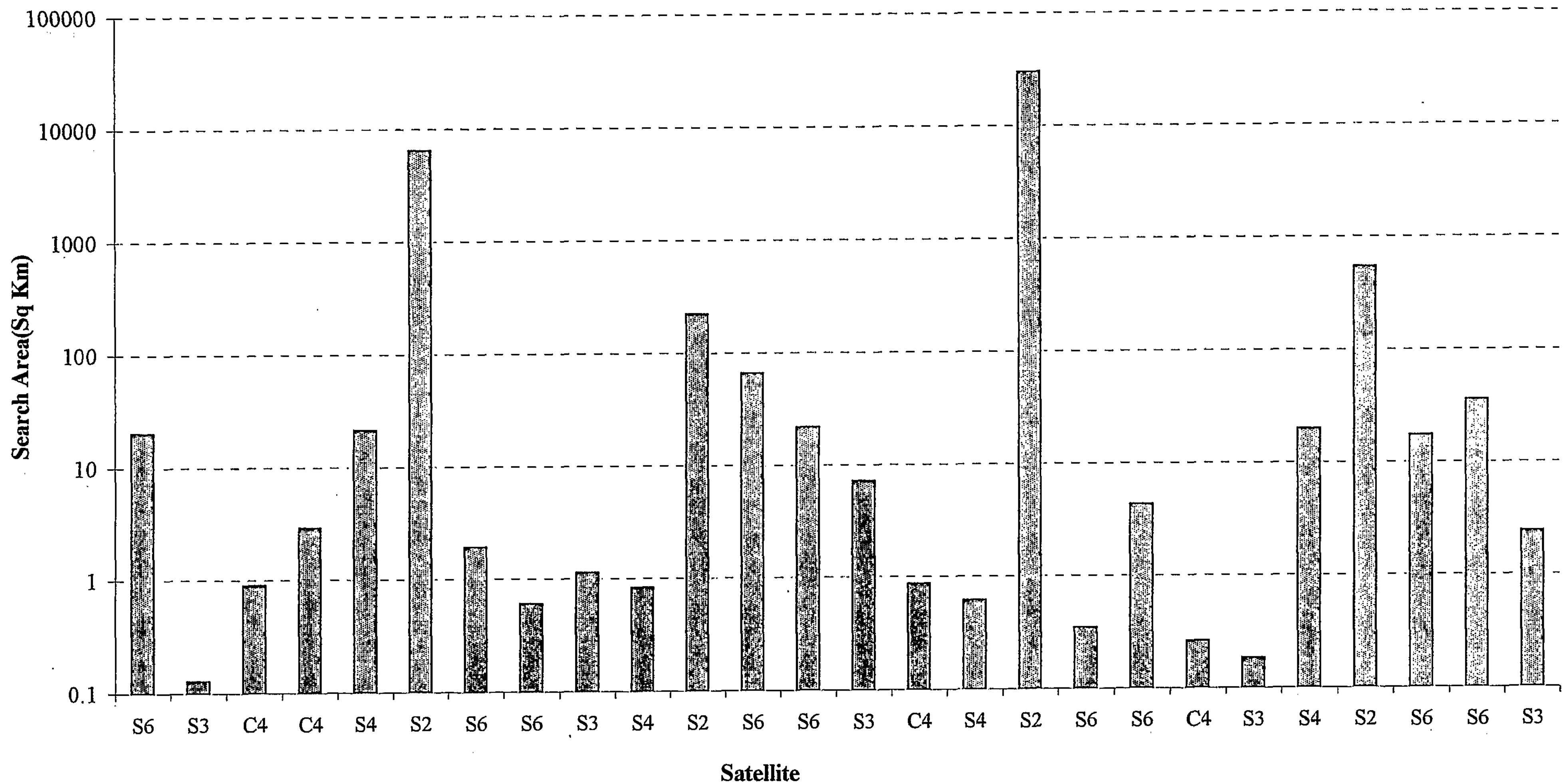
SITE 6 SERACH AREAS



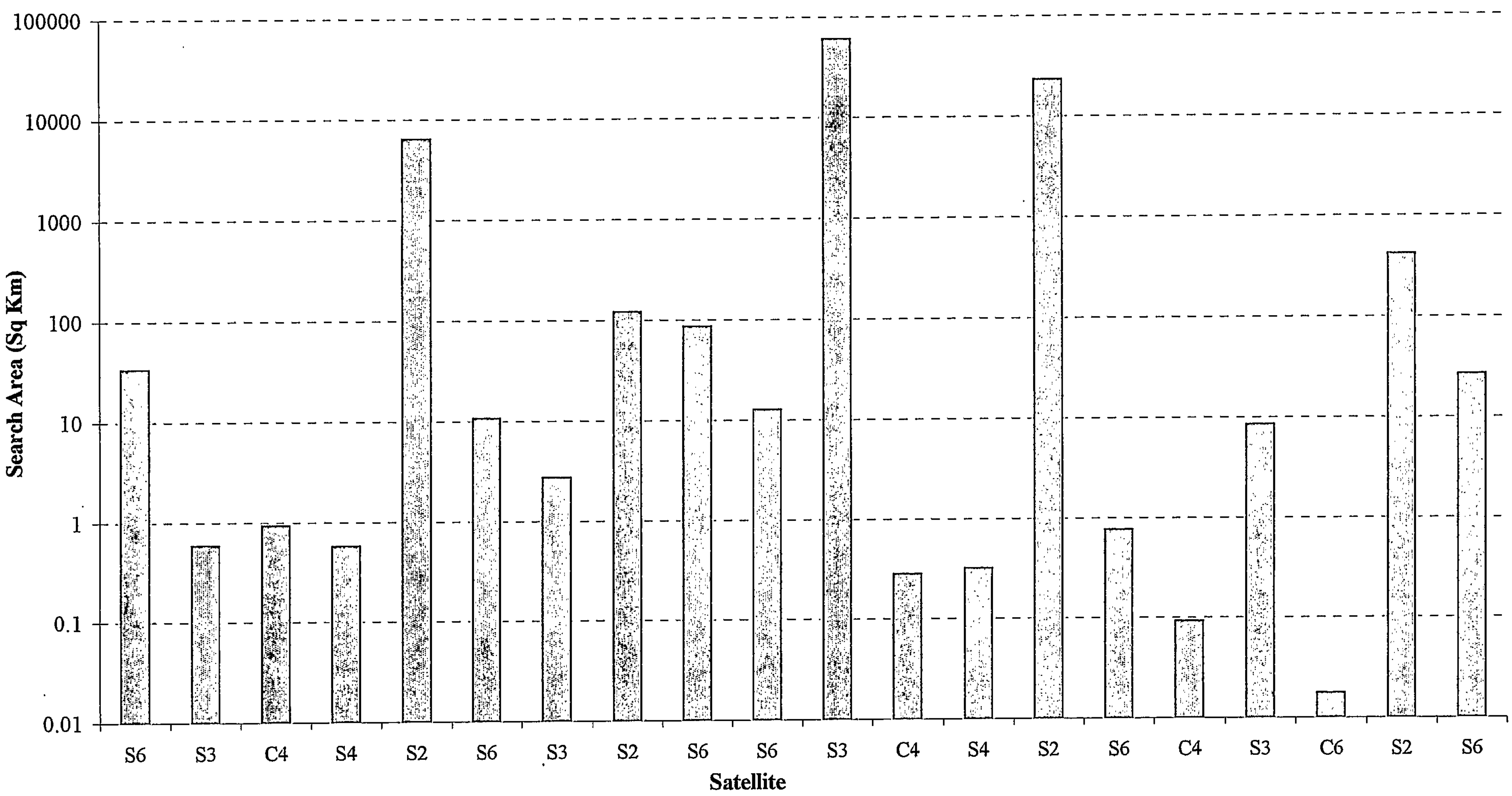
SITE 7 SEARCH AREAS



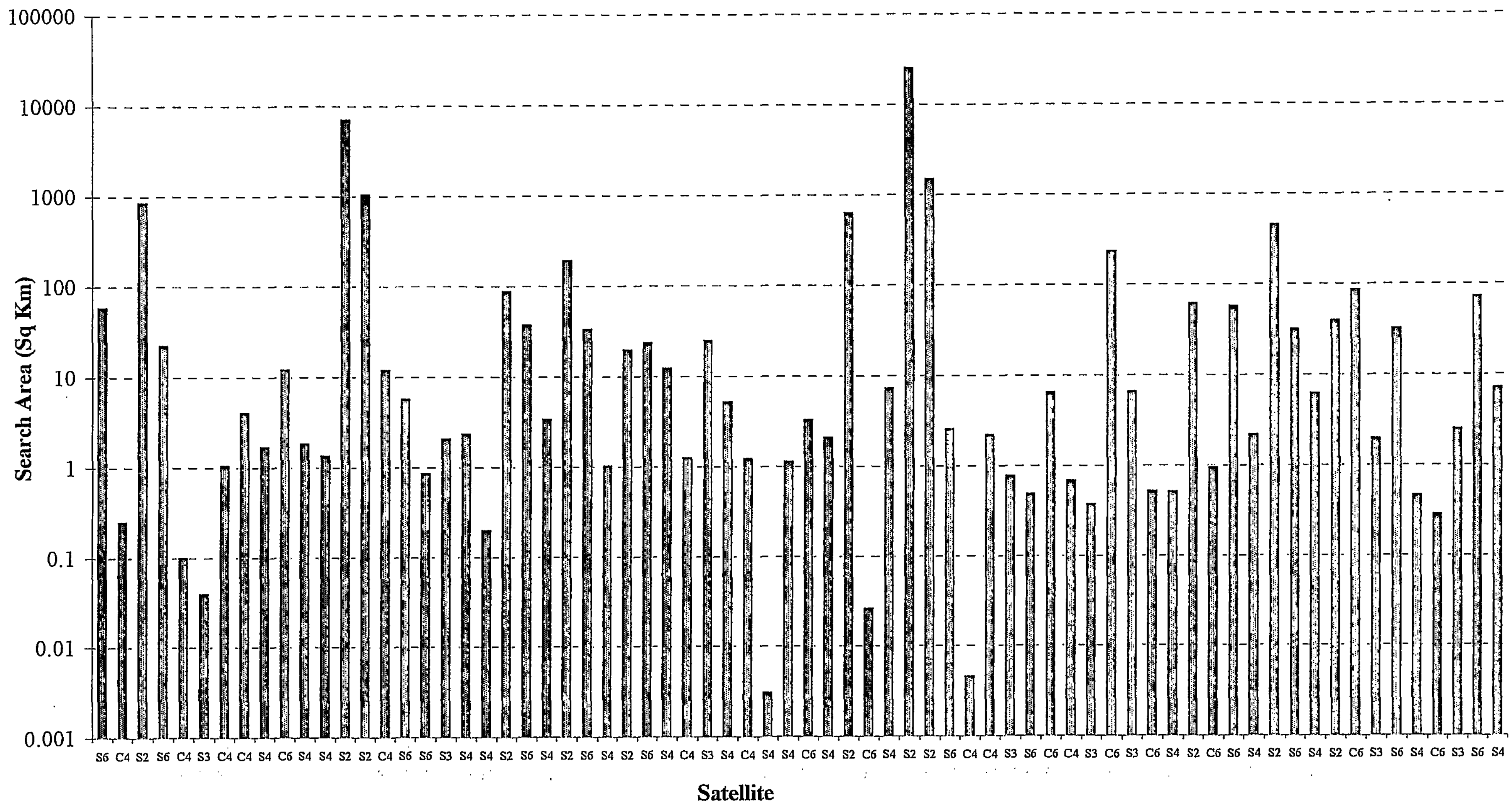
SITE 8 SEARCH AREAS



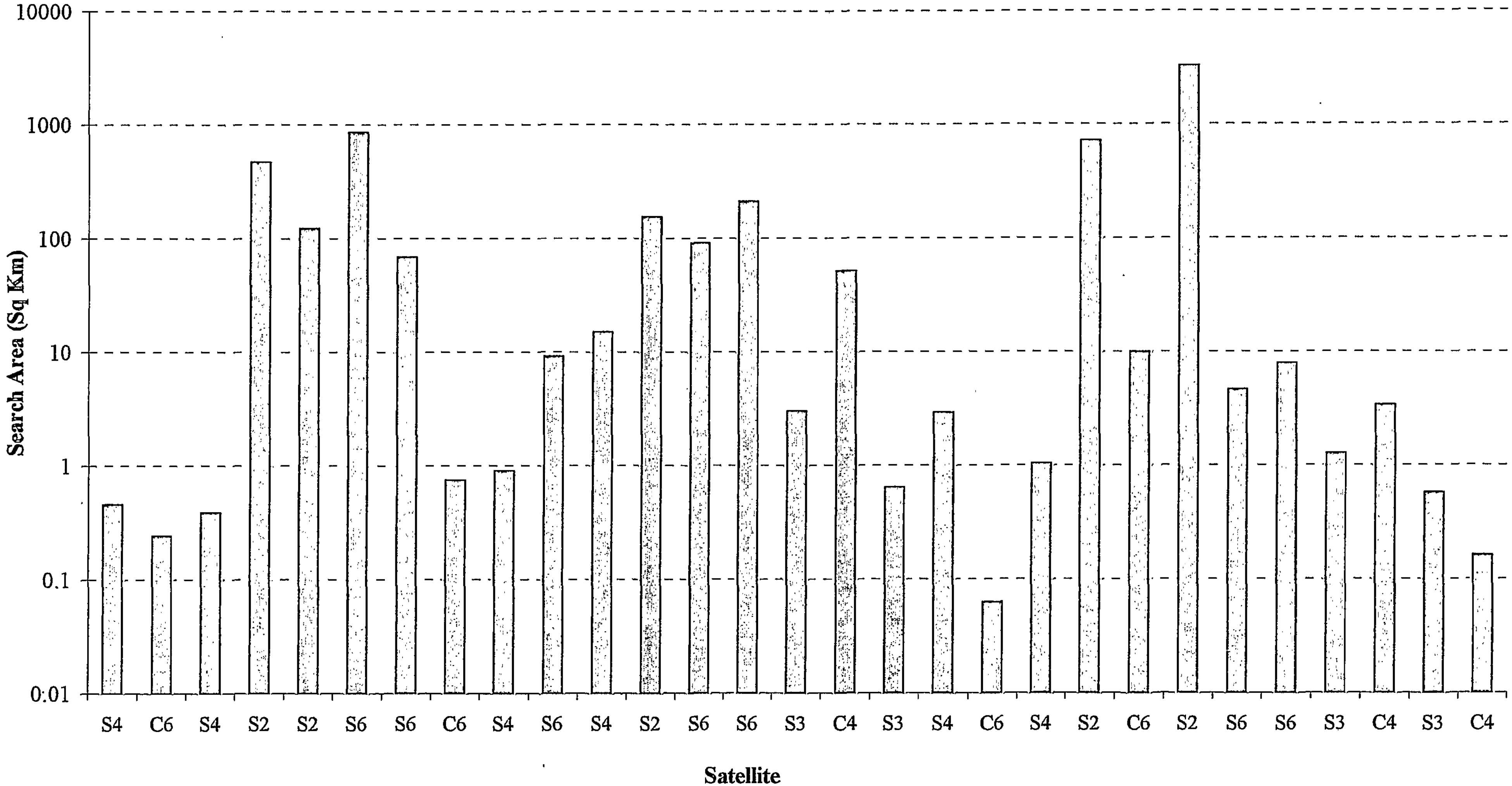
SITE 9 SEARCH AREAS



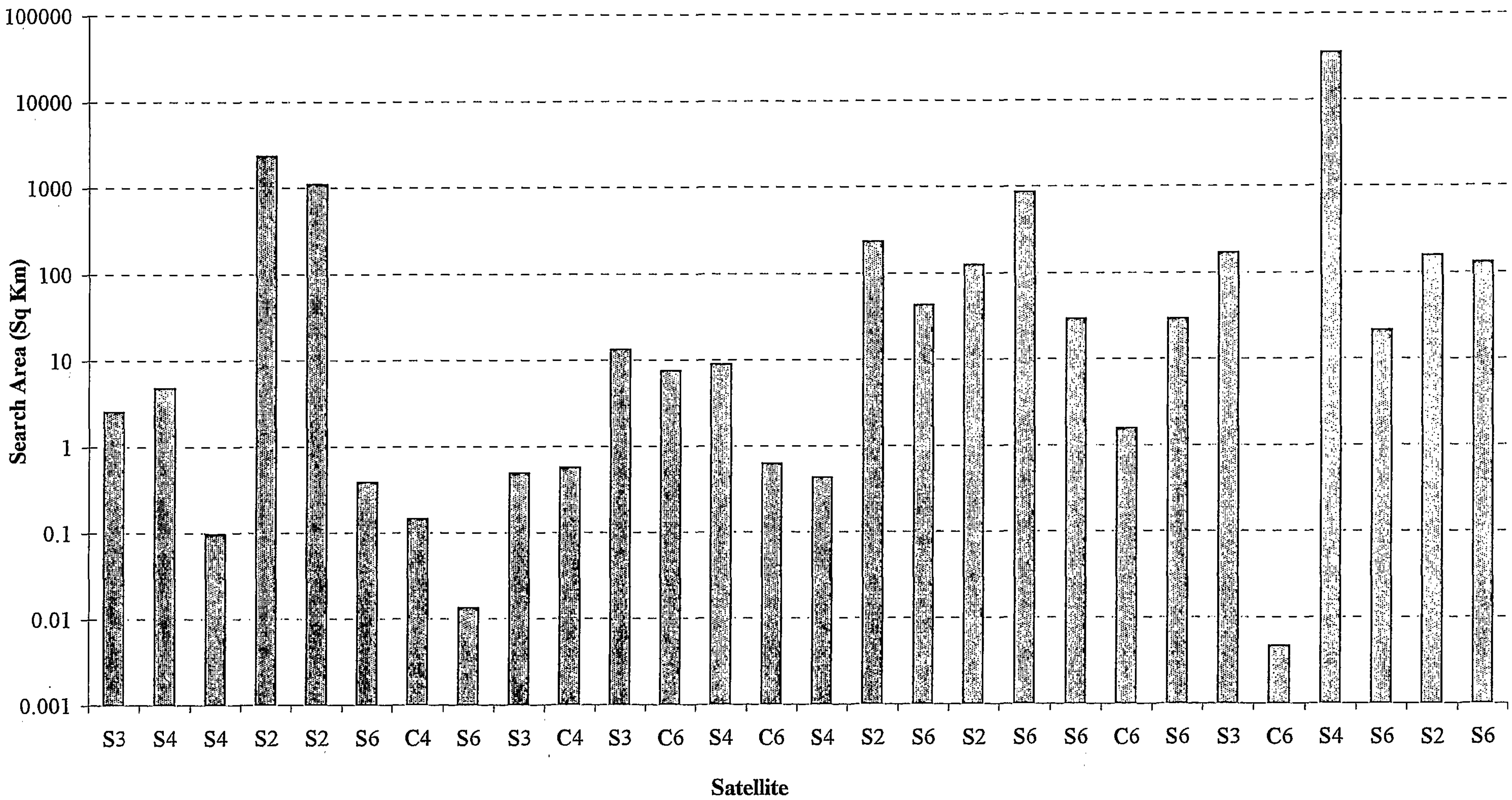
SITE 10 SEARCH AREAS



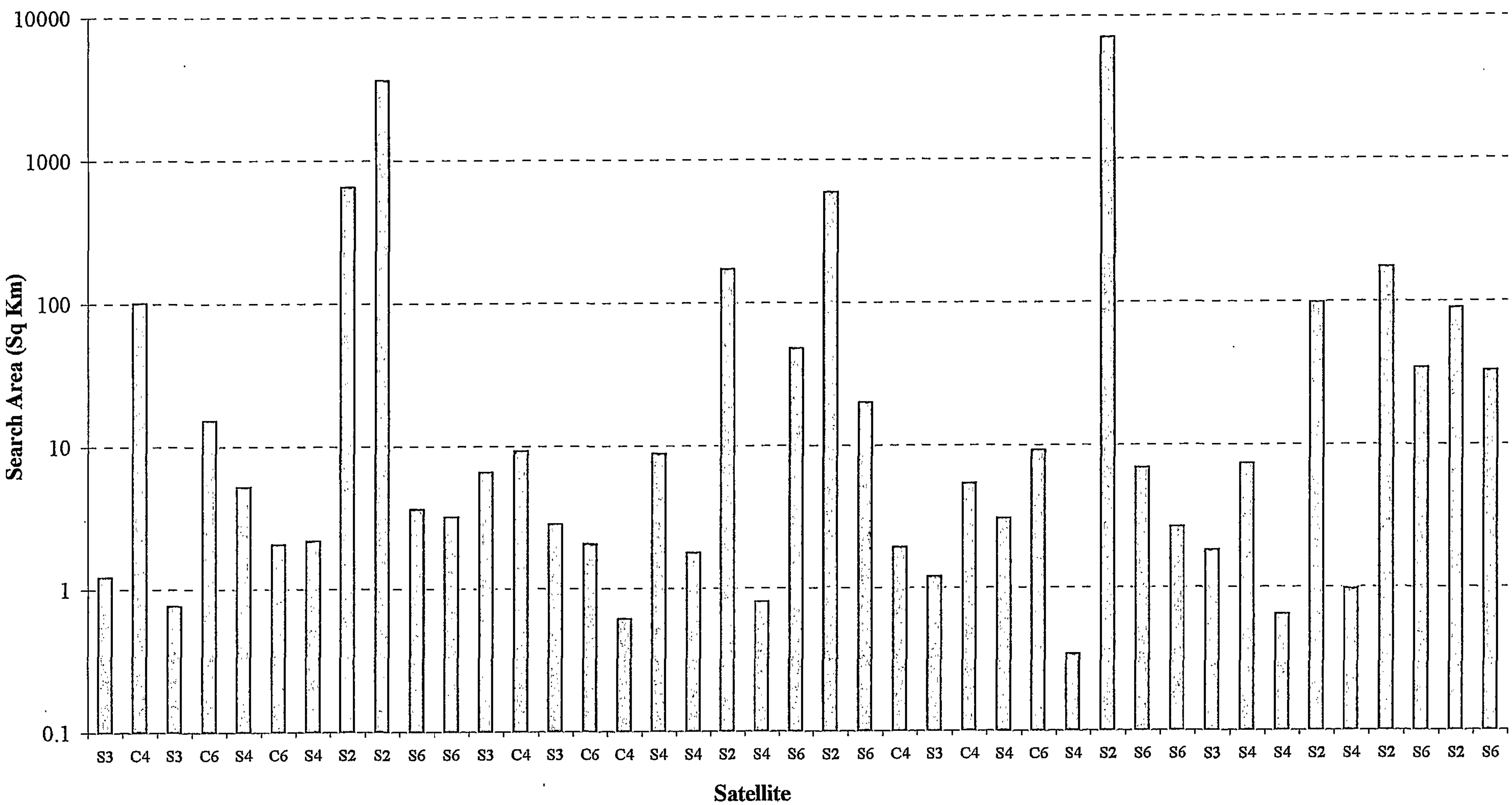
SITE 11 SEARCH AREAS



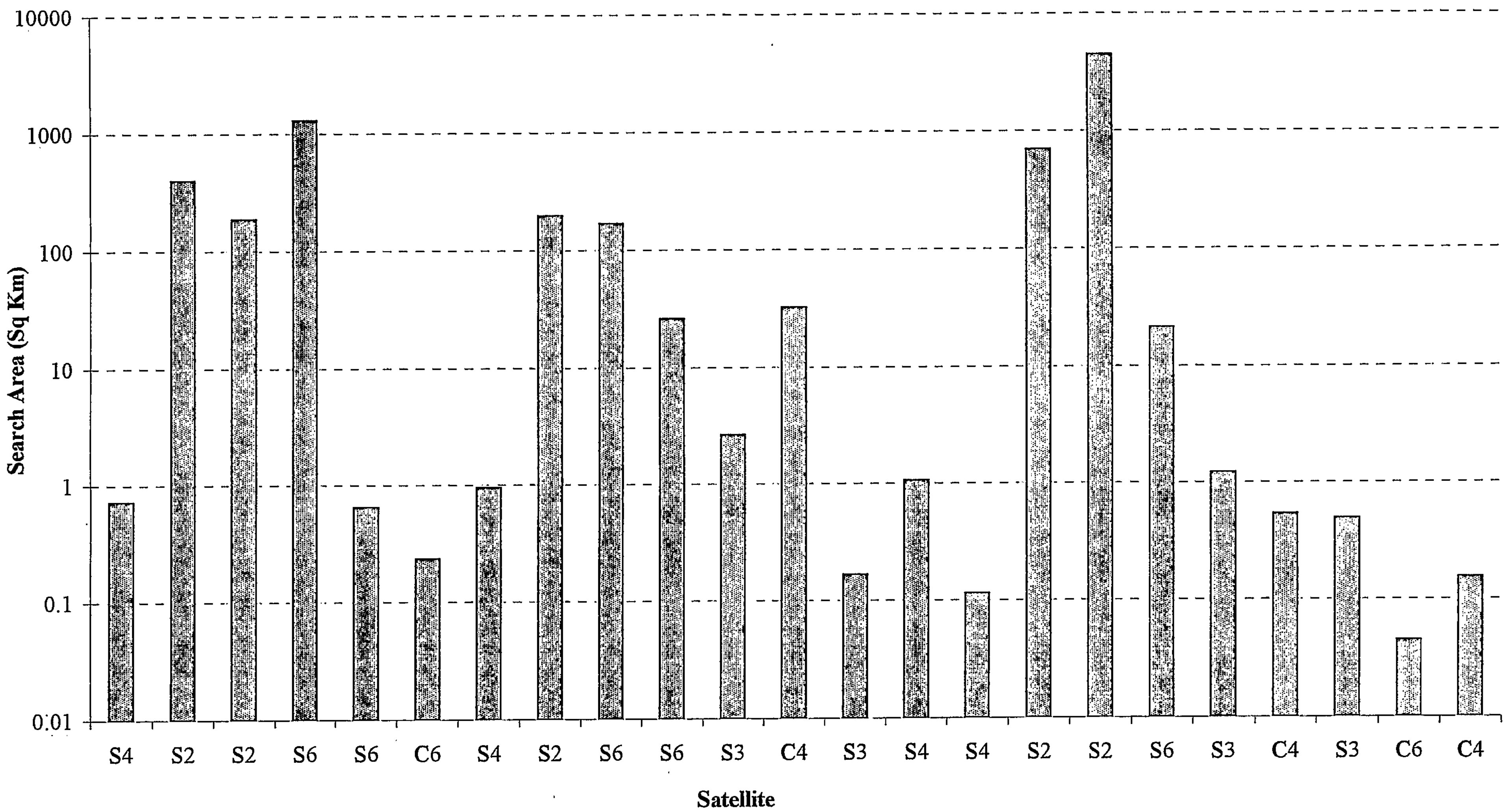
SITE 12 SEARCH AREAS



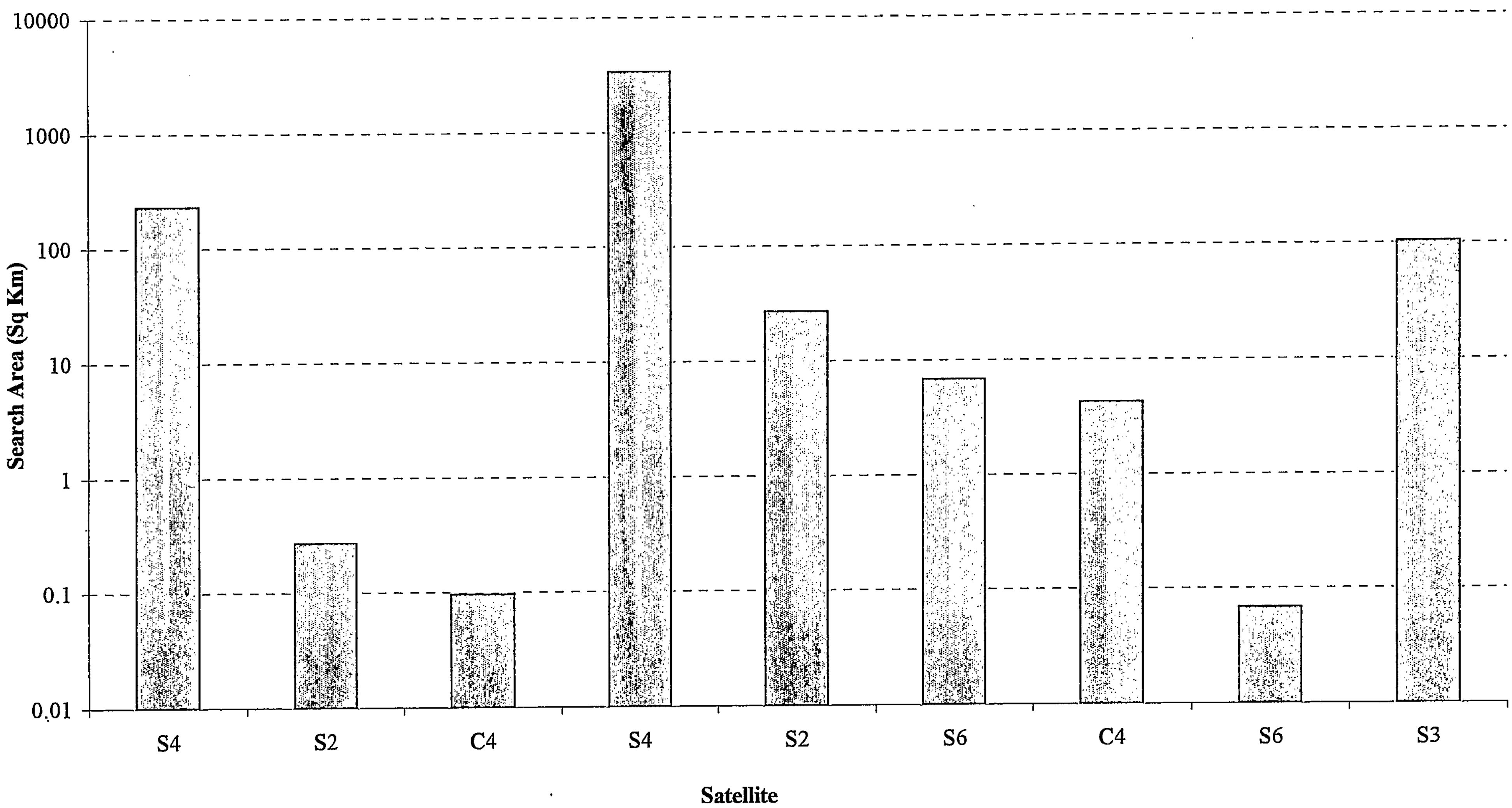
SITE 13 SEARCH AREAS



SITE 14 SEARCH AREAS



SITE 15 SEARCH AREAS



SITE 16 SEARCH AREAS

APPENDIX XIII
MULTIPLE TRIGGER TEST RESULTS

Multiple Trigger Test (Test2)																
						LAT	53.10815							LAT	53.10815	
Site 5: Airport		**Date: 5 October '97**														
						LONG	4.3379375							LONG	4.337938	
Lat1:	53	6.478	**Long1:**	4	20.274											
Lat2:	53	6.51	**Long2:**	4	20.309											
Lat3:	53	6.495	**Long3:**	4	20.232											
Lat4:	53	6.473	**Long4:**	4	20.29											
Lat(Av)	53	6.489	**Long(Av)**	4	20.27625											
Pass No.	***Satellite***	***Date***	***AOS***	***LOS***	***ID No.***	***Time On***	***Bursts***	***TCA***	***Lat1***	***Long1***	***Prob1***	***Lat2***	***Long2***	***Prob2***	***TFS***	***TLS***
6077	Sarsat-2	05-Oct-97	08:57:31	09:08:49	9D1ECC349FEC8D0	**08:58:30**	8	09:02:30	53.1293	-4.3272	89	40.9069	58.704	11	08:58:38	09:05:17
6077	Sarsat-2	05-Oct-97	08:57:31	09:08:49	9D1ECC349FEC900	**08:59:00**	7	09:02:30	53.1359	-4.2756	83.2	41.2268	58.8496	16.8	09:00:03	09:05:05
6077	Sarsat-2	05-Oct-97	08:57:31	09:08:49	9D1ECC349FEC990	**09:03:00**	Detect Only	09:04:04								
6077	Sarsat-2	05-Oct-97	08:57:31	09:08:49	9D1ECC349FEC9D0	**09:06:00**	**Not detected**									
2927	Copsas-6	05-Oct-97	09:49:38	10:06:30	9D1ECC349FEC8D0	**09:48:00**	11	09:58:36	53.1067	-4.3337	96.3	52.4706	2.459	3.7	09:50:45	10:04:06
2927	Copsas-6	05-Oct-97	09:49:38	10:06:30	9D1ECC349FEC900	**09:54:00**	5	09:58:36	53.1096	-4.3173	73.5	52.486	2.5935	26.5	09:57:34	10:03:26
2927	Copsas-6	05-Oct-97	09:49:38	10:06:30	9D1ECC349FEC990	**09:59:00**	5	09:58:37	52.8747	-0.7665	50.4	52.8747	-0.7665	49.6	10:00:04	10:03:21
2927	Copsas-6	05-Oct-97	09:49:38	10:06:30	9D1ECC349FEC990	**10:05:00**										
14250	Sarsat-6	05-Oct-97	11:08:09	11:18:27	9D1ECC349FEC9D0	**11:10:00**	6	11:14:09	53.1043	-4.3573	87.7	66.8388	73.0351	12.3	11:12:44	11:17:46
14250	Sarsat-6	05-Oct-97	11:08:09	11:18:27	9D1ECC349FEC990	**11:13:00**	6	11:14:09	53.0361	-4.389	73.8	66.8959	73.6282	26.2	11:14:05	11:18:11
14250	Sarsat-6	05-Oct-97	11:08:09	11:18:27	9D1ECC349FEC900	**11:15:00**	Detect Only	11:16:03								
14250	Sarsat-6	05-Oct-97	11:08:09	11:18:27	9D1ECC349FEC8D0	**11:17:00**	Detect Only	11:18:05								
2928	Copsas-6	05-Oct-97	11:37:19	11:51:58	9D1ECC349FEC9D0	**11:35:00**	9	11:44:53	53.1049	-4.3375	99.6	57.4468	-51.0447	0.4	11:37:46	11:51:11
2928	Copsas-6	05-Oct-97	11:37:19	11:51:58	9D1ECC349FEC990	**11:40:00**	4	11:44:53	53.0844	-4.3208	97.6	57.1437	-51.1677	2.4	11:43:33	11:50:16
2928	Copsas-6	05-Oct-97	11:37:19	11:51:58	9D1ECC349FEC900	**11:45:00**	3	11:44:50	52.8207	-3.9699	50	57.0169	-50.8479	50	11:46:55	11:51:58
2928	Copsas-6	05-Oct-97	11:37:19	11:51:58	9D1ECC349FEC8D0	**11:51:00**	**Not detected**									
27441	Sarsat-3	05-Oct-97	13:28:06	13:36:09	9D1ECC349FEC8D0	**13:29:00**	5	13:32:53	53.1153	-4.3318	84.6	67.6564	83.8871	15.4	13:32:37	13:35:58
27441	Sarsat-3	05-Oct-97	13:28:06	13:36:09	9D1ECC349FEC900	**13:31:00**	5	13:32:53	53.1605	-4.2072	67.4	67.615	83.5297	32.6	13:32:17	13:35:38
27441	Sarsat-3	05-Oct-97	13:28:06	13:36:09	9D1ECC349FEC990	**13:33:00**	3	13:33:02	**53.089**	**-4.2843**	50	53.089	-4.2843	50	13:34:09	13:35:49
27441	Sarsat-3	05-Oct-97	13:28:06	13:36:09	9D1ECC349FEC9D0	**13:36:00**	**Not detected**									
6080	Sarsat-2	05-Oct-97	13:59:55	14:07:48	9D1ECC349FEC9D0	**14:04:00**	Detect Only	14:06:44								
6080	Sarsat-2	05-Oct-97	13:59:55	14:07:48	9D1ECC349FEC990	**14:05:00**	3	14:04:05	**52.9864**	**-4.1548**	50	52.9864	-4.1548	50	14:06:03	14:07:40
6080	Sarsat-2	05-Oct-97	13:59:55	14:07:48	9D1ECC349FEC900	**14:06:00**	Detect Only	14:07:05								
6080	Sarsat-2	05-Oct-97	13:59:55	14:07:48	9D1ECC349FEC8D0	**14:07:00**	**Not detected**									

Multiple Trigger Test (Continued)

						LAT	53.10815							LAT	53.1082	
Site 5: Airport		Date: 5 October '97														
						LONG	4.3379375							LONG	4.33794	
Lat1:	53	6.478	Long1:	4	20.274											
Lat2:	53	6.51	Long2:	4	20.309											
Lat3:	53	6.495	Long3:	4	20.232											
Lat4:	53	6.473	Long4:	4	20.29											
Lat(Av)	53	6.489	Long(A	4	20.27625											
Pass No.	*Satellite*	*Date*	*AOS*	*LOS*	*ID No.*	*Time On*	*Bursts*	*TCA*	*Lat1*	*Long1*	*Prob1*	*Lat2*	*Long2*	*Prob2*	*TFS*	*TLS*
14252	Sarsat-6	05-Oct-97	14:26:06	14:40:49	9D1ECC349FEC8D0	**14:27:00**	15	14:34:07	53.1152	-4.3025	98.2	49.3834	-23.7028	1.8	14:28:12	14:40:44
14252	Sarsat-6	05-Oct-97	14:26:06	14:40:49	9D1ECC349FEC900	**14:27:00**	14	14:34:07	53.1101	-4.3038	95.9	49.3879	-23.6992	4.1	14:28:14	14:40:48
14252	Sarsat-6	05-Oct-97	14:26:06	14:40:49	9D1ECC349FEC990	**14:39:49**	Not detected									
14252	Sarsat-6	05-Oct-97	14:26:06	14:40:49	9D1ECC349FEC9D0	**14:39:49**	Not detected									
11397	Copsas-4	05-Oct-97	15:37:56	15:49:34	9D1ECC349FEC9D0	**15:39:30**	5	15:42:59	53.1137	-4.3203	92.4	60.5547	87.2672	7.6	15:40:34	15:47:17
11397	Copsas-4	05-Oct-97	15:37:56	15:49:34	9D1ECC349FEC990	**15:42:30**	4	15:43:00	52.9692	-4.4906	51.5	60.9528	87.1771	48.5	15:45:38	15:48:10
11397	Copsas-4	05-Oct-97	15:37:56	15:49:34	9D1ECC349FEC900	**15:45:30**	Detect Only	15:46:34								
11397	Copsas-4	05-Oct-97	15:37:56	15:49:34	9D1ECC349FEC8D0	**15:48:00**	Not detected									
27443	Sarsat-3	05-Oct-97	16:42:47	16:57:15	9D1ECC349FEC990	**16:44:36**	14	16:50:37	53.1122	-4.3393	92.9	51.2678	-14.4572	7.1	16:45:40	16:56:33
27443	Sarsat-3	05-Oct-97	16:42:47	16:57:15	9D1ECC349FEC900	**16:48:13**	10	16:50:37	53.1058	-4.366	78.6	51.2637	-14.4223	21.4	16:49:16	16:56:49
27443	Sarsat-3	05-Oct-97	16:42:47	16:57:15	9D1ECC349FEC8D0	**16:51:50**	6	16:50:36	53.0862	-4.0584	59.9	51.1843	-14.4336	40.1	16:52:54	16:57:06
27443	Sarsat-3	05-Oct-97	16:42:47	16:57:15	9D1ECC349FEC9D0	**16:55:27**	Not detected									
11398	Copsas-4	05-Oct-97	17:23:03	17:39:28	9D1ECC349FEC900	**17:24:42**	11	17:30:40	53.1102	-4.3469	94.6	56.1414	27.5454	5.4	17:25:46	17:34:09
11398	Copsas-4	05-Oct-97	17:23:03	17:39:28	9D1ECC349FEC990	**17:26:20**	11	17:30:40	53.1004	-4.3337	93	56.128	27.6183	7	17:27:24	17:37:23
11398	Copsas-4	05-Oct-97	17:23:03	17:39:28	9D1ECC349FEC9D0	**17:36:11**	Detect Only	17:37:15								
11398	Copsas-4	05-Oct-97	17:23:03	17:39:28	9D1ECC349FEC8D0	**17:37:50**	Not detected									
16562	Sarsat-4	05-Oct-97	18:16:50	18:31:18	9D1ECC349FEC8D0	**18:19:44**	13	18:24:45	53.1123	-4.3292	97.6	58.5742	24.5292	2.4	18:20:49	18:30:49
16562	Sarsat-4	05-Oct-97	18:16:50	18:31:18	9D1ECC349FEC900	**18:21:10**	11	18:24:45	53.097	-4.3166	91.3	58.5618	24.536	8.7	18:22:14	18:30:37
16562	Sarsat-4	05-Oct-97	18:16:50	18:31:18	9D1ECC349FEC990	**18:26:58**	4	18:24:46	52.9537	-4.438	56.2	52.9537	-4.438	43.8	18:28:02	18:30:33
16562	Sarsat-4	05-Oct-97	18:16:50	18:31:18	9D1ECC349FEC9D0	**18:28:24**	3	18:24:42	52.8272	-4.5285	50	58.5524	25.479	50	18:29:27	18:31:08

APPENDIX XIV

VISIBILITY WINDOW NARROWING

By taking the time difference between the beacon switch on and the Time First Seen (TFS) (the time the satellite receives the first beacon burst), we get the time it takes for the satellite to detect a beacon. If a beacon is turned on such that less than this time is left before the satellite goes out of view, then the beacon will not register a detection until the next satellite pass. By subtracting the LOS time (the time that the LUT loses the satellite signal) from the time that the satellite last saw the beacon (TLS), we can show the narrowing of the window at the pass end. Results are presented in Table XIV.I.

Table XIV.I Satellite Detection Gaps at Either End of a Satellite Pass

Beacon	Pass No.	Satellite	Time for satellite to detect beacon	Pass End
8D0	6077	S2	00:00:08	00:03:32
900	6077	S2	00:01:03	00:03:44
990	6077	S2	- (Beacon not seen)	-
9D0	6077	S2	-	-
8D0	2927	C6	00:02:45	00:02:24
900	2927	C6	00:03:34	00:03:04
990	2927	C6	00:01:04	00:03:09
9D0	2927	C6	-	-
8D0	14250	S6	00:02:44	00:00:41
900	14250	S6	00:01:05	00:00:16
990	14250	S6	-	-
9D0	14250	S6	-	-
8D0	2928	C6	00:02:46	00:00:47
900	2928	C6	00:03:33	00:01:42
990	2928	C6	00:01:55	00:00:00
9D0	2928	C6	-	-
8D0	27441	S3	00:03:37	00:00:11
900	27441	S3	00:01:17	00:00:31
990	27441	S3	00:01:09	00:00:20
9D0	27441	S3	-	-
8D0	6080	S2	-	-
900	6080	S2	00:01:03	00:00:08
990	6080	S2	-	-
9D0	6080	S2	-	-
8D0	14252	S6	00:01:12	00:00:05
900	14252	S6	00:01:14	00:00:01
990	14252	S6	-	-
9D0	14252	S6	-	-
8D0	11397	C4	00:01:04	00:02:17
900	11397	C4	00:03:08	00:01:24
990	11397	C4	-	-
9D0	11397	C4	-	-
8D0	27443	S3	00:01:04	00:00:42
900	27443	S3	00:01:03	00:00:26
990	27443	S3	00:01:04	00:00:09
9D0	27443	S3	-	-
8D0	11398	C4	00:01:04	00:05:19
900	11398	C4	00:01:04	00:02:05
990	11398	C4	-	-
9D0	11398	C4	-	-
8D0	16562	S4	00:01:05	00:00:29
900	16562	S4	00:01:04	00:00:41
990	16562	S4	00:01:04	00:00:45
9D0	16562	S4	00:01:03	00:00:10
		Mean:	**00:01:31**	**00:01:18**

Satellite	TFS	TLS	Bursts Received	Visible Pass Length	Bursts Predicted	Difference
Site 5: Airport						
C4	20:55:44	21:04:54	12	00:09:10	10	2
S2	22:10:20	22:22:00	13	00:11:40	13	0
C6	22:27:51	22:39:36	11	00:11:45	13	-2
S6	01:03:47	01:09:39	8	00:05:52	6	2
S6	02:42:39	02:56:02	17	00:13:23	15	2
S6	04:24:55	04:36:38	13	00:11:43	13	0
S3	04:52:35	05:04:16	15	00:11:41	13	2
C4	05:21:03	05:30:17	6	00:09:14	10	-4
S6	06:05:27	06:12:59	10	00:07:32	8	2
S3	06:33:07	06:45:44	16	00:12:37	14	2
C4	07:01:39	07:16:41	16	00:15:02	16	0
C6	08:12:51	08:26:16	17	00:13:25	15	2
C6	08:38:49	08:48:05	4	00:09:16	10	-6
C4	08:47:13	09:02:19	16	00:15:06	16	0
S4	09:54:15	10:06:52	18	00:12:37	14	4
C6	10:23:37	10:34:27	9	00:10:50	12	-3
S6	00:02:08	00:07:12	8	00:05:04	6	2
S4	11:34:51	11:44:02	12	00:09:11	10	2
C6	12:08:21	12:20:05	12	00:11:44	13	-1
S3	13:46:26	13:53:54	9	00:07:28	8	1
S6	14:16:33	14:29:08	16	00:12:35	14	2
S3	14:42:34	14:51:48	11	00:09:14	10	1
S6	16:01:21	16:08:51	10	00:07:30	8	2
C4	16:06:23	16:13:53	9	00:07:30	8	1
S3	16:20:36	16:32:18	15	00:11:42	13	2
C4	17:51:08	18:02:01	14	00:10:53	12	2
S4	18:07:03	18:17:55	14	00:10:52	12	2
S2	18:44:44	18:47:15	3	00:02:31	3	0
C6	19:24:06	19:37:31	5	00:13:25	15	-10
S4	19:45:54	19:59:20	18	00:13:26	15	3
C6	21:10:34	21:23:09	12	00:12:35	14	-2
S4	19:45:54	20:00:11	19	00:14:17	16	3
S2	21:59:07	22:10:03	11	00:10:56	12	-1
C6	23:00:19	23:06:11	6	00:05:52	6	0
S2	23:40:35	23:49:49	12	00:09:14	10	2
S6	02:31:31	02:45:47	18	00:14:16	16	2
S6	04:12:58	04:26:20	17	00:13:22	15	2
S3	04:28:50	04:39:43	10	00:10:53	12	-2
C4	05:46:46	05:51:48	5	00:05:02	5	0
C4	21:25:41	21:29:03	5	00:03:22	4	1
S6	05:54:20	06:02:43	11	00:08:23	9	2
S3	06:08:37	06:20:22	15	00:11:45	13	2
S4	06:22:00	06:27:03	6	00:05:03	6	0
C4	00:29:54	00:45:00	17	00:15:06	16	1
S3	07:49:08	07:58:21	12	00:09:13	10	2
S4	08:00:54	08:14:19	17	00:13:25	15	2
C6	00:07:55	00:17:09	8	00:09:14	10	-2
C4	09:17:09	09:30:34	16	00:13:25	15	1
S4	09:41:29	09:54:55	17	00:13:26	15	2
S2	10:11:37	10:24:11	14	00:12:34	14	0
C6	10:49:21	11:01:52	6	00:12:31	14	-8
S4	11:22:50	11:32:03	12	00:09:13	10	2
S2	11:55:35	12:05:37	12	00:10:02	11	1

Satellite	TFS	TLS	Bursts Received	Visible Pass Length	Bursts Predicted	Difference
Site 9: Darnholm						
S6	14:47:56	14:51:17	5	00:03:21	4	1
S3	16:35:18	16:41:11	8	00:05:53	6	2
C4	16:44:31	16:49:33	7	00:05:02	5	2
C4	18:00:33	18:03:53	5	00:03:21	4	1
S4	19:53:18	19:57:30	4	00:04:12	5	-1
S2	21:51:34	21:56:37	7	00:05:03	6	1
S6	03:01:58	03:07:03	7	00:05:05	6	1
S6	04:43:29	04:47:42	6	00:04:12	5	1
S3	06:24:10	06:28:23	6	00:04:14	5	1
S4	08:07:22	08:09:52	4	00:02:30	3	1
S2	11:49:46	11:51:27	3	00:01:41	2	1
S6	12:53:25	13:00:08	8	00:06:43	7	1
S6	14:36:37	14:40:00	5	00:03:23	4	1
S3	16:14:36	16:20:27	8	00:05:52	6	2
C4	17:11:49	17:16:51	5	00:05:02	5	0
S4	19:36:55	19:45:20	9	00:08:24	9	0
S2	21:37:46	21:41:56	6	00:04:10	5	1
S6	02:49:51	02:55:42	8	00:05:51	6	2
S6	04:32:11	04:37:11	6	00:05:00	5	1
C4	05:04:54	05:09:06	5	00:04:12	5	0
S3	06:00:16	06:04:29	6	00:04:14	5	1
S4	09:35:51	09:39:14	4	00:03:23	4	0
S2	11:33:20	11:36:42	4	00:03:21	4	0
S6	12:44:37	12:46:18	3	00:01:41	2	1
S6	14:21:57	14:29:29	8	00:07:32	8	0
S3	15:47:30	15:51:41	6	00:04:11	5	1

APPENDIX XVI

GEOSTATIONARY AND FOREIGN DATA

The following geostationary information was received from the Spanish LUT for beacons placed at site 5 in Wales. The beacons were viewed continually throughout the periods listed below.

Table XVI.I Geostationary Information Received from the Spanish LUT

Beacon	Time First Seen	Time Last Seen	Beacon Site
8D0	5/10/97, 08:50:24	7/10/97, 12:25:39	5 - Airport Test 1
9D0	5/10/97, 11:13:35	5/10/97, 18:34:30	5 - Airport Test 2
990	5/10/97, 11:14:56	5/10/97, 18:28:51	5 - Airport Test 2
900	5/10/97, 17:27:28	7/10/97, 17:49:31	5 - Airport Test 1

Foreign data received from the Spanish LUT when it tracked the C-S near polar satellites is presented on the following pages.

Figure XVI.I Geostationary Raw Data Received

2.4 KBPS Data
Satellite: S2 66326 processed at: 1997-10-22 23:36:17.94
Pass AOS: 1997-10-22 23:20:27.15 pass LOS: 1997-10-22 23:35:58.72
Satellite elements at epoch: 1997-10-22 23:36:17.36
sx = 3495.8000 km, sy = -2248.1558 km, sz = 5894.8042 km
svx= -6.16666 km/s, svy= 1.23396 km/s, svz= 4.12977 km/s

```
1 lat: 0.00  lon: 0.00  freq: 869   1997-10-22 23:34:51.93
    TCA: 864.8  CTA: 0.00  drft: 0.0  9D1ECC349FEC8D0 bentpipe
    error ellipse:  rad: 0.0  hd: 0.0  mjr: 0.0  mnr: 0.0
  lat: 0.00  lon: 0.00  freq: 869   TCA: 1997-10-22 23:34:51.93
    TCA: 864.8  CTA: 0.00  drft: 0.0  npts: 1  prob: 0.000
    error ellipse:  rad: 0.0  hd: 0.0  mjr: 0.0  mnr: 0.0
    1st: 0, len: 0, conf: 4, wndw: 0  G_B IESM TEST
```

2.4 KBPS Data
Satellite: S6 14499 processed at: 1997-10-23 03:20:10.37
Pass AOS: 1997-10-23 03:04:09.13 pass LOS: 1997-10-23 03:19:45.00
Satellite elements at epoch: 1997-10-23 03:20:09.82
sx = 7007.0020 km, sy = -1779.7595 km, sz = -340.8068 km
svx= -0.74913 km/s, svy= -1.55299 km/s, svz= -7.32163 km/s

```
1 lat: 0.00  lon: 0.00  freq: -8745  1997-10-23 03:08:34.04
    TCA: 264.9  CTA: 0.00  drft: 0.0  9D1ECC349FEC8D0 bentpipe
    error ellipse:  rad: 0.0  hd: 0.0  mjr: 0.0  mnr: 0.0
  lat: 0.00  lon: 0.00  freq: -8745  TCA: 1997-10-23 03:08:34.04
    TCA: 264.9  CTA: 0.00  drft: 0.0  npts: 2  prob: 0.000
    error ellipse:  rad: 0.0  hd: 0.0  mjr: 0.0  mnr: 0.0
    1st: -200, len: 201, conf: 4, wndw: 0  G_B IESM TEST

2 lat: 0.00  lon: 0.00  freq: -5355  1997-10-23 03:05:21.78
    TCA: 72.7  CTA: 0.00  drft: 0.0  9D1ECC349FEC9D0 bentpipe
    error ellipse:  rad: 0.0  hd: 0.0  mjr: 0.0  mnr: 0.0
  lat: 0.00  lon: 0.00  freq: -5355  TCA: 1997-10-23 03:05:21.78
    TCA: 72.7  CTA: 0.00  drft: 0.0  npts: 1  prob: 0.000
    error ellipse:  rad: 0.0  hd: 0.0  mjr: 0.0  mnr: 0.0
    1st: 0, len: 0, conf: 4, wndw: 0  G_B IESM TEST

3 lat: 0.00  lon: 0.00  freq: -6967  1997-10-23 03:06:00.64
    TCA: 111.5  CTA: 0.00  drft: 0.0  9D1ECC349FEC990 bentpipe
    error ellipse:  rad: 0.0  hd: 0.0  mjr: 0.0  mnr: 0.0
  lat: 0.00  lon: 0.00  freq: -6967  TCA: 1997-10-23 03:06:00.64
    TCA: 111.5  CTA: 0.00  drft: 0.0  npts: 1  prob: 0.000
    error ellipse:  rad: 0.0  hd: 0.0  mjr: 0.0  mnr: 0.0
    1st: 0, len: 0, conf: 4, wndw: 0  G_B IESM TEST
```

2.4 KBPS Data
Satellite: C4 11638 processed at: 1997-10-23 04:39:17.13
Pass AOS: 1997-10-23 04:25:56.11 pass LOS: 1997-10-23 04:38:16.36
Satellite elements at epoch: 1997-10-23 04:39:16.62
sx = 4351.8926 km, sy = 998.5206 km, sz = 5834.8242 km
svx= -5.86782 km/s, svy= -0.15456 km/s, svz= 4.36089 km/s

1 lat: 0.00 lon: 0.00 freq: 6763 1997-10-23 04:35:17.49
TCA: 561.4 CTA: 0.00 drft: 0.0 9D1ECC349FEC990 regional
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
lat: 0.00 lon: 0.00 freq: 6763 TCA: 1997-10-23 04:35:17.49
TCA: 561.4 CTA: 0.00 drft: 0.0 npts: 2 prob: 0.000
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
1st: -51, len: 52, conf: 3, wndw: 9 G_B IESM TEST

2 lat: 48.80 lon: 72.68 freq: -568 1997-10-23 02:55:50.28
TCA: -5405.8 CTA: -20.88 drft: 0.0 9D1ECC349FEC990 global
error ellipse: rad: 0.0 hd: 62.1 mjr: 0.0 mnr: 0.0
lat: 71.71 lon: 50.27 freq: -7457 TCA: 1997-10-23 03:00:08.87
TCA: -5147.2 CTA: 0.02 drft: 0.0 npts: 3 prob: 0.500
error ellipse: rad: 32767.0 hd: -68.9 mjr: 371623.2 mnr: 161.1
1st: -93, len: 353, conf: 4, wndw: 0 G_B IESM TEST

3 lat: 0.00 lon: 0.00 freq: 5848 1997-10-23 04:36:29.49
TCA: 633.4 CTA: 0.00 drft: 0.0 9D1ECC349FEC8D0 regional
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
lat: 0.00 lon: 0.00 freq: 5848 TCA: 1997-10-23 04:36:29.49
TCA: 633.4 CTA: 0.00 drft: 0.0 npts: 2 prob: 0.000
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
1st: -98, len: 99, conf: 3, wndw: 9 G_B IESM TEST

4 lat: 0.00 lon: 0.00 freq: 6674 1997-10-23 04:36:03.57
TCA: 607.5 CTA: 0.00 drft: 0.0 9D1ECC349FEC900 regional
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
lat: 0.00 lon: 0.00 freq: 6674 TCA: 1997-10-23 04:36:03.57
TCA: 607.5 CTA: 0.00 drft: 0.0 npts: 1 prob: 0.000
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
1st: 0, len: 0, conf: 3, wndw: 9 G_B IESM TEST

2.4 KBPS Data
Satellite: C4 11639 processed at: 1997-10-23 06:26:23.67
Pass AOS: 1997-10-23 06:07:56.14 pass LOS: 1997-10-23 06:25:47.42
Satellite elements at epoch: 1997-10-23 06:26:23.12
sx = 3594.1064 km, sy = -689.6899 km, sz = 6365.7373 km
svx= -5.80894 km/s, svy= 2.69047 km/s, svz= 3.53618 km/s

1 lat: 56.96 lon: -25.47 freq: -533 1997-10-23 06:25:13.21
TCA: 1037.1 CTA: 7.26 drft: 0.0 9D1ECC349FEC990 regional
error ellipse: rad: 0.0 hd: -88.0 mjr: 0.1 mnr: 0.0
lat: 54.43 lon: -0.71 freq: -444 TCA: 1997-10-23 06:25:11.62
TCA: 1035.5 CTA: -6.91 drft: 0.0 npts: 4 prob: 0.683
error ellipse: rad: 0.0 hd: -71.5 mjr: 0.1 mnr: 0.0
1st: -274, len: 201, conf: 3, wndw: 1 G_B IESM TEST

2 lat: 54.42 lon: -0.70 freq: -445 1997-10-23 04:39:37.06
TCA: -5299.1 CTA: 8.20 drft: 0.0 9D1ECC349FEC990 global
error ellipse: rad: 0.0 hd: -80.6 mjr: 0.1 mnr: 0.1

lat: 52.11 lon: 25.19 freq: -503 TCA: 1997-10-23 04:39:38.66
TCA: -5297.5 CTA: -7.43 drft: 0.0 npts: 13 prob: 0.995
error ellipse: rad: 24.0 hd: -82.2 mjr: 20.6 mnr: 13.1
1st: -310, len: 752, conf: 4, wndw: 0 G_B IESM TEST

3 lat: 56.86 lon: -25.44 freq: -440 1997-10-23 06:25:11.38
TCA: 1035.2 CTA: 7.24 drft: 0.0 9D1ECC349FEC8D0 regional
error ellipse: rad: 0.0 hd: -79.7 mjr: 0.1 mnr: 0.0
lat: 54.34 lon: -0.81 freq: -352 TCA: 1997-10-23 06:25:09.77
TCA: 1033.6 CTA: -6.89 drft: 0.0 npts: 3 prob: 0.500
error ellipse: rad: 0.0 hd: -79.9 mjr: 0.1 mnr: 0.0
1st: -281, len: 150, conf: 3, wndw: 1 G_B IESM TEST

4 lat: 54.33 lon: -0.80 freq: -352 1997-10-23 04:39:35.53
TCA: -5300.6 CTA: 8.26 drft: 0.0 9D1ECC349FEC8D0 global
error ellipse: rad: 0.0 hd: -84.3 mjr: 0.1 mnr: 0.1
lat: 51.95 lon: 25.29 freq: -384 TCA: 1997-10-23 04:39:36.22
TCA: -5299.9 CTA: -7.54 drft: 0.0 npts: 10 prob: 0.992
error ellipse: rad: 19.0 hd: -78.2 mjr: 16.1 mnr: 11.3
1st: -284, len: 603, conf: 4, wndw: 0 G_B IESM TEST

5 lat: 0.00 lon: 0.00 freq: 2664 1997-10-23 06:24:09.87
TCA: 973.7 CTA: 0.00 drft: 0.0 9D1ECC349FEC9D0 regional
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
lat: 0.00 lon: 0.00 freq: 2664 TCA: 1997-10-23 06:24:09.87
TCA: 973.7 CTA: 0.00 drft: 0.0 npts: 2 prob: 0.000
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
1st: -50, len: 51, conf: 3, wndw: 9 G_B IESM TEST

6 lat: 54.41 lon: -0.71 freq: -138 1997-10-23 04:39:36.77
TCA: -5299.4 CTA: 8.21 drft: 0.0 9D1ECC349FEC9D0 global
error ellipse: rad: 0.0 hd: -15.8 mjr: 0.1 mnr: 0.1
lat: 51.97 lon: 25.43 freq: -155 TCA: 1997-10-23 04:39:37.08
TCA: -5299.1 CTA: -7.62 drft: 0.0 npts: 5 prob: 0.989
error ellipse: rad: 8.0 hd: 34.0 mjr: 7.0 mnr: 4.3
1st: -118, len: 252, conf: 4, wndw: 0 G_B IESM TEST

7 lat: 56.93 lon: -25.48 freq: -52 1997-10-23 06:25:12.57
TCA: 1036.4 CTA: 7.26 drft: 0.0 9D1ECC349FEC900 regional
error ellipse: rad: 0.0 hd: -89.1 mjr: 0.7 mnr: 0.1
lat: 54.39 lon: -0.74 freq: 35 TCA: 1997-10-23 06:25:10.97
TCA: 1034.8 CTA: -6.91 drft: 0.0 npts: 5 prob: 0.512
error ellipse: rad: 0.0 hd: -70.4 mjr: 0.7 mnr: 0.1
1st: -306, len: 252, conf: 3, wndw: 1 G_B IESM TEST

8 lat: 54.39 lon: -0.74 freq: 34 1997-10-23 04:39:36.53
TCA: -5299.6 CTA: 8.22 drft: 0.0 9D1ECC349FEC900 global
error ellipse: rad: 0.0 hd: 60.7 mjr: 0.2 mnr: 0.1
lat: 51.83 lon: 25.52 freq: 95 TCA: 1997-10-23 04:39:35.11
TCA: -5301.0 CTA: -7.72 drft: 0.0 npts: 6 prob: 0.958
error ellipse: rad: 5.0 hd: -43.0 mjr: 5.3 mnr: 1.7
1st: -212, len: 252, conf: 4, wndw: 0 G_B IESM TEST

2.4 KBPS Data
Satellite: C8 03173 processed at: 1997-10-23 08:04:58.07
Pass AOS: 1997-10-23 07:47:18.12 pass LOS: 1997-10-23 08:04:08.95
Satellite elements at epoch: 1997-10-23 08:04:57.52
sx = 3765.9346 km, sy = -35.2355 km, sz = 6285.9087 km
svx= -6.14122 km/s, svy= 1.55509 km/s, svz= 3.68591 km/s

1 lat: 54.78 lon: -4 14 freq: -454 1997-10-23 08:03:34.98
TCA: 976.9 CTA: 1.17 drft: 0.0 9D1ECC349FEC990 regional
error ellipse: rad: 0.0 hd: -76.5 mjr: 0 2 mnr: 0.0
lat: 54.42 lon: -0.56 freq: -441 TCA: 1997-10-23 08:03:34.74
TCA: 976.6 CTA: -0.95 drft: 0.0 npts: 3 prob: 0.500
error ellipse: rad: 1.0 hd: -83.4 mjr: 1.1 mnr: 0.0
1st: -265, len: 101, conf: 3, wndw: 1 G_B IESM TEST

2 lat: 50.50 lon: 45.56 freq: -659 1997-10-23 06:18:46.03
TCA: -5312.1 CTA: -13.62 drft: 0.0 9D1ECC349FEC990 global
error ellipse: rad: 0.0 hd: -83.3 mjr: 0 1 mnr: 0.0
lat: 54.43 lon: -0.70 freq. -445 TCA: 1997-10-23 06:18.39.70
TCA: -5318.4 CTA: 14.44 drft: 0.0 npts: 3 prob: 0.500
error ellipse: rad: 0 0 hd: -82.0 mjr: 0.1 mnr: 0.0
1st: 61, len: 152, conf: 3, wndw: 1 G_B IESM TEST

3 lat: 0.00 lon: 0.00 freq: 5049 1997-10-23 08.01:50.65
TCA: 872.5 CTA: 0.00 drft: 0.0 9D1ECC349FEC8D0 regional
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
lat: 0.00 lon: 0.00 freq: 5049 TCA: 1997-10-23 08:01:50.65
TCA: 872.5 CTA: 0.00 drft: 0.0 npts: 2 prob: 0.000
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
1st: -51, len: 52, conf: 3, wndw: 9 G_B IESM TEST

4 lat: 0.00 lon: 0.00 freq: 3975 1997-10-23 08:02:27.15
TCA: 909.0 CTA: 0.00 drft: 0.0 9D1ECC349FEC900 regional
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
lat: 0.00 lon: 0.00 freq: 3975 TCA: 1997-10-23 08:02:27.15
TCA: 909.0 CTA: 0.00 drft: 0.0 npts: 2 prob: 0.000
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
1st: -50, len: 51. conf: 3, wndw: 9 G_B IESM TEST

2.4 KBPS Data
Satellite: S4 46810 processed at: 1997-10-23 08:25:54.30
Pass AOS: 1997-10-23 08:10:29.16 pass LOS: 1997-10-23 08:24:31.50
Satellite elements at epoch: 1997-10-23 08:25:53.73
sx = 7160.3735 km, sy = -855.2106 km, sz = -563.0814 km
svx= -0.76953 km/s, svy= -1.62802 km/s, svz= -7.30616 km/s

1 lat: 54.41 lon: -0.71 freq: -425 1997-10-23 08:09:23.89
TCA: -65.3 CTA: -6.68 drft: 0.0 9D1ECC349FEC990 regional
error ellipse: rad: 0.0 hd: -68.3 mjr: 0.2 mnr: 0.1
lat: 50.11 lon: 21.03 freq: -473 TCA: 1997-10-23 08:09:25.04
TCA: -64.1 CTA: 7.29 drft: 0.0 npts: 14 prob: 0.991
error ellipse: rad: 21.0 hd: -76.5 mjr: 17.7 mnr: 12.4
1st: -413, len: 701, conf: 4, wndw: 0 G_B IESM TEST

2 lat: 54.41 lon: -0.69 freq: -427 1997-10-23 06:27:18.60
TCA: -6190.6 CTA: -21.48 drft: 0.0 9D1ECC349FEC990 global
error ellipse: rad: 0.0 hd: -58.3 mjr: 0.0 mnr: 0.0

lat: 41.23 lon: 65.52 freq: -703 TCA: 1997-10-23 06:27:30.52
TCA: -6178.6 CTA: 23.23 drft: 0.0 npts: 3 prob: 0.500
error ellipse: rad: 0.0 hd: 87.3 mjr: 0.1 mnr: 0.0
1st: -198, len: 151, conf: 3, wndw: 1 G_B IESM TEST

3 lat: 54.43 lon: -0.70 freq: -433 1997-10-22 21:37:11.62
TCA: -37997.5 CTA: -20.90 drft: 0.0 9D1ECC349FEC990 global
error ellipse: rad: 0.0 hd: 49.4 mjr: 0.9 mnr: 0.3
lat: 41.51 lon: -65.48 freq: -214 TCA: 1997-10-22 21:37:01.73
TCA: -38007.4 CTA: 22.80 drft: 0.0 npts: 10 prob: 0.947
error ellipse: rad: 20.0 hd: -77.8 mjr: 19.0 mnr: 7.0
1st: -117, len: 452, conf: 4, wndw: 0 G_B IESM TEST

4 lat: 54.32 lon: -0.80 freq: -333 1997-10-23 08:09:25.56
TCA: -63.6 CTA: -6.72 drft: 0.0 9D1ECC349FEC8D0 regional
error ellipse: rad: 0.0 hd: 75.9 mjr: 0.2 mnr: 0.1
lat: 50.17 lon: 20.96 freq: -293 TCA: 1997-10-23 08:09:24.45
TCA: -64.7 CTA: 7.22 drft: 0.0 npts: 10 prob: 0.984
error ellipse: rad: 11.0 hd: -40.7 mjr: 10.1 mnr: 6.3
1st: -152, len: 503, conf: 4, wndw: 0 G_B IESM TEST

5 lat: 54.35 lon: -0.80 freq: -338 1997-10-22 21:37:09.86
TCA: -37999.3 CTA: -20.86 drft: 0.0 9D1ECC349FEC8D0 global
error ellipse: rad: 1.0 hd: 21.1 mjr: 1.0 mnr: 0.2
lat: 41.68 lon: -65.59 freq: -223 TCA: 1997-10-22 21:37:04.85
TCA: -38004.3 CTA: 22.77 drft: 0.0 npts: 4 prob: 0.917
error ellipse: rad: 14.0 hd: -50.4 mjr: 14.6 mnr: 2.4
1st: -76, len: 198, conf: 4, wndw: 0 G_B IESM TEST

6 lat: 54.39 lon: -0.72 freq: -118 1997-10-23 08:09:24.15
TCA: -65.0 CTA: -6.69 drft: 0.0 9D1ECC349FEC9D0 regional
error ellipse: rad: 0.0 hd: -43.0 mjr: 0.0 mnr: 0.0
lat: 50.18 lon: 20.72 freq: -187 TCA: 1997-10-23 08:09:25.41
TCA: -63.7 CTA: 7.08 drft: 0.0 npts: 4 prob: 0.989
error ellipse: rad: 3.0 hd: 77.7 mjr: 3.8 mnr: 1.2
1st: -121, len: 150, conf: 4, wndw: 0 G_B IESM TEST

7 lat: 0.00 lon: 0.00 freq: 1964 1997-10-22 21:35:38.63
TCA: -38090 5 CTA: 0.00 drft: 0.0 9D1ECC349FEC9D0 global
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
lat: 0.00 lon: 0.00 freq: 1964 TCA: 1997-10-22 21:35:38.63
TCA: -38090.5 CTA: 0.00 drft: 0.0 npts: 1 prob: 0.000
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
1st: 0, len: 0, conf: 3, wndw: 9 G_B IESM TEST

8 lat: 0.00 lon: 0.00 freq: 3480 1997-10-23 08:08:18.91
TCA: -130.2 CTA: 0.00 drft: 0.0 9D1ECC349FEC900 global
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
lat: 0.00 lon: 0.00 freq: 3480 TCA: 1997-10-23 08:08:18.91
TCA: -130.2 CTA: 0.00 drft: 0.0 npts: 1 prob: 0.000
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
1st: 0. len: 0, conf: 3, wndw: 9 G_B IESM TEST

2.4 KBPS Data
Satellite: S4 46811 processed at: 1997-10-23 10:06:32.17
Pass AOS: 1997-10-23 09:50:25.10 pass LOS: 1997-10-23 10:05:54.92
Satellite elements at epoch: 1997-10-23 10:06:31.64
_sx = 6185.5239 km, sy = -3749.4192 km, sz = 18.5087 km_
svx= -0.86798 km/s, svy= -1.46859 km/s, svz= -7.32906 km/s

1 lat: 54.33 lon: -0.82 freq: -333 1997-10-23 09:50:02.67
TCA: -22.4 CTA: 7.33 drft: 0.0 9D1ECC349FEC8D0 regional
error ellipse: rad: 0.0 hd: -86.1 mjr: 0.1 mnr: 0.1
lat: 59.01 lon: -25.12 freq: -279 TCA: 1997-10-23 09:50:01.49
TCA: -23.6 CTA: -6.79 drft: 0.0 npts: 9 prob: 0.993
error ellipse: rad: 11.0 hd: -57.2 mjr: 9.9 mnr: 6.5
1st: -254, len: 403, conf: 4, wndw: 0 G_B IESM TEST

2 lat: 54.32 lon: -0.81 freq: -333 1997-10-23 08:09:25.53
TCA: -6059.6 CTA: -6.73 drft: 0.0 9D1ECC349FEC8D0 global
error ellipse: rad: 1.0 hd: -68.0 mjr: 1.4 mnr: 0.1
lat: 50.26 lon: 20.72 freq: -255 TCA: 1997-10-23 08:09:24.21
TCA: -6060.9 CTA: 7.04 drft: 0.0 npts: 6 prob: 0.689
error ellipse: rad: 3.0 hd: -78.5 mjr: 3.2 mnr: 0.3
1st: 101, len: 250, conf: 3, wndw: 1 G_B IESM TEST

2.4 KBPS Data
Satellite: S2 66333 processed at: 1997-10-23 12:04:57.30
Pass AOS: 1997-10-23 11:48:41.10 pass LOS: 1997-10-23 12:04:31.30
Satellite elements at epoch: 1997-10-23 12:04:56.73
_sx = 6437.9648 km, sy = -3306.5684 km, sz = -83.8415 km_
svx= -0.83333 km/s, svy= -1.45289 km/s, svz= -7.32770 km/s

1 lat: 57.65 lon: -18.51 freq: -538 1997-10-23 11:48:31.17
TCA: -9.9 CTA: -5.11 drft: 0.0 9D1ECC349FEC990 bentpipe
error ellipse: rad: 0.0 hd: -90.0 mjr: 0.0 mnr: 0.0
lat: 54.44 lon: -0.73 freq: -466 TCA: 1997-10-23 11:48:30.23
TCA: -10.9 CTA: 5.34 drft: 0.0 npts: 3 prob: 0.500
error ellipse: rad: 0.0 hd: -66.7 mjr: 0.0 mnr: 0.0
1st: 75, len: 101, conf: 3, wndw: 1 G_B IESM TEST

2 lat: 0.00 lon: 0.00 freq: -4731 1997-10-23 11:49:49.06
TCA: 68.0 CTA: 0.00 drft: 0.0 9D1ECC349FEC8D0 bentpipe
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
lat: 0.00 lon: 0.00 freq: -4731 TCA: 1997-10-23 11:49:49.06
TCA: 68.0 CTA: 0.00 drft: 0.0 npts: 1 prob: 0.000
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
1st: 0, len: 0, conf: 4, wndw: 0 G_B IESM TEST

2.4 KBPS Data
Satellite: S6 14506 processed at: 1997-10-23 14:39:32.48
Pass AOS: 1997-10-23 14:23:49.11 pass LOS: 1997-10-23 14:39:09.96
Satellite elements at epoch: 1997-10-23 14:39:31.92
sx = 3646.5747 km, sy = -1206.5282 km, sz = 6124.7998 km
svx= -6.48081 km/s, svy= -0.45538 km/s, svz= 3.76745 km/s

3 lat: 54.43 lon: -0.71 freq: -281 1997-10-23 14:37:56.14
TCA: 847.0 CTA: -8.80 drft: 0.0 9D1ECC349FEC990 bentpipe
error ellipse: rad: 0.0 hd: -80.3 mjr: 0.2 mnr: 0.0
lat: 49.22 lon: -28.74 freq: -371 TCA: 1997-10-23 14.37:57.90
TCA: 848.8 CTA: 9.23 drft: 0.0 npts: 5 prob: 0.918
error ellipse: rad: 3.0 hd: 47.3 mjr: 3.0 mnr: 0.6
1st: -213, len: 194, conf: 3, wndw: 1 G_B IESM TEST

4 lat: 54.34 lon: -0.82 freq: -196 1997-10-23 14:37:54.77
TCA: 845.7 CTA: -8.72 drft: 0.0 9D1ECC349FEC8D0 bentpipe
error ellipse: rad: 0.0 hd: -80.4 mjr: 0.0 mnr: 0.0
lat: 49.18 lon: -28.57 freq: -285 TCA: 1997-10-23 14:37:56.47
TCA: 847.4 CTA: 9.15 drft: 0.0 npts: 3 prob: 0.500
error ellipse: rad: 0.0 hd: 47.4 mjr: 0.0 mnr: 0.0
1st: -181, len: 151, conf: 3, wndw: 1 G_B IESM TEST

5 lat: 54.40 lon: -0.74 freq: 194 1997-10-23 14:37:55.62
TCA: 846.5 CTA: -8.78 drft: 0.0 9D1ECC349FEC900 bentpipe
error ellipse: rad: 0.0 hd: -76.8 mjr: 0.0 mnr: 0.0
lat: 49.19 lon: -28.71 freq: 111 TCA: 1997-10-23 14:37:57.27
TCA: 848.2 CTA: 9.22 drft: 0.0 npts: 3 prob: 0.500
error ellipse: rad: 0.0 hd: 43.6 mjr: 0.0 mnr: 0.0
1st: -172, len: 152, conf: 3, wndw: 1 G_B IESM TEST

6 lat: 0.00 lon: 0.00 freq: 1410 1997-10-23 14:37:26.84
TCA: 817.7 CTA: 0.00 drft: 0.0 9D1ECC349FEC9D0 bentpipe
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
lat: 0.00 lon: 0.00 freq: 1410 TCA: 1997-10-23 14:37:26.84
TCA: 817.7 CTA: 0.00 drft: 0.0 npts: 2 prob. 0.000
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
1st: -49, len: 50, conf: 4, wndw: 0 G_B IESM TEST

2.4 KBPS Data
Satellite: C4 11644 processed at: 1997-10-23 15:40:33.98
Pass AOS: 1997-10-23 15:31:06.14 pass LOS: 1997-10-23 15:39:46.25
Satellite elements at epoch: 1997-10-23 15:40:33.50
sx = 6809.3472 km, sy = 1889.7573 km, sz = 2000.7729 km
svx= 1.83484 km/s, svy= 0.94959 km/s, svz= -7.03403 km/s

1 lat: 54.30 lon: -0.95 freq: -423 1997-10-23 15:28:51.17
TCA: -135.0 CTA: -6.49 drft: 0.0 9D1ECC349FEC990 global
error ellipse: rad: 0.0 hd: -90.0 mjr: 0.0 mnr: 0.0
lat: 56.50 lon: 21.80 freq: -565 TCA: 1997-10-23 15:28:52.66
TCA: -133.5 CTA: 6.61 drft: 0.0 npts: 3 prob: 0.500
error ellipse: rad: 0.0 hd: -63.9 mjr: 0.6 mnr: 0.0
1st: -408, len: 200, conf: 3, wndw: 1 G_B IESM TEST

2 lat: 54.43 lon: -0.71 freq: -442 1997-10-23 13:41:31.39
TCA: -6574.7 CTA: -19.42 drft: 0.0 9D1ECC349FEC990 global
error ellipse: rad: 0.0 hd: -58.2 mjr: 0.2 mnr: 0.1

lat: 61.02 lon: 80.42 freq: -553 TCA: 1997-10-23 13:41:36.97
TCA: -6569.2 CTA: 21.76 drft: 0.0 npts: 9 prob: 0.993
error ellipse: rad: 47.0 hd: 42.6 mjr: 41.5 mnr: 23.7
1st: -391, len: 700, conf: 4, wndw: 0 G_B IESM TEST

3 lat: 54.43 lon: -0.71 freq: -447 1997-10-23 08:12:35.87
TCA: -26310.3 CTA: -19.87 drft: 0.0 9D1ECC349FEC990 global
error ellipse: rad: 6.0 hd: -79.5 mjr: 5.9 mnr: 2.0
lat: 61.06 lon: -83.26 freq: -185 TCA: 1997-10-23 08:12:23.78
TCA: -26322.4 CTA: 21.89 drft: 0.0 npts: 5 prob: 0.779
error ellipse: rad: 26.0 hd: -85.2 mjr: 25.5 mnr: 8.5
1st: -57, len: 455, conf: 3, wndw: 0 G_B IESM TEST

2.4 KBPS Data
Satellite: C4 11645 processed at: 1997-10-23 17:31:22.10
Pass AOS: 1997-10-23 17:13:14.10 pass LOS: 1997-10-23 17:30:44.04
Satellite elements at epoch: 1997-10-23 17:31:21.54
sx = 7227.0566 km, sy = -1243.2075 km, sz = -575.5450 km
svx= -0.46841 km/s, svy= 0.45671 km/s, svz= -7.29252 km/s

1 lat: 54.41 lon: -0.72 freq: -139 1997-10-23 17:14:20.40
TCA: 66.3 CTA: 8.83 drft: 0.0 9D1ECC349FEC9D0 regional
error ellipse: rad: 0.0 hd: 23.9 mjr: 0.1 mnr: 0.1
lat: 51.80 lon: -28.79 freq: -128 TCA: 1997-10-23 17:14:20.22
TCA: 66.1 CTA: -8.18 drft: 0.0 npts: 5 prob: 0.988
error ellipse: rad: 9.0 hd: -43.8 mjr: 7.4 mnr: 6.1
1st: -151, len: 302, conf: 4, wndw: 0 G_B IESM TEST

2.4 KBPS Data
Satellite: S3 57700 processed at: 1997-10-23 17:55:51.24
Pass AOS: 1997-10-23 17:40:06.12 pass LOS: 1997-10-23 17:55:28.59
Satellite elements at epoch: 1997-10-23 17:55:50.71
sx = 3566.9326 km, sy = -1857.9601 km, sz = 5942.9585 km
svx= -6.32841 km/s, svy= 0.73438 km/s, svz= 4.02945 km/s

1 lat: 0.00 lon: 0.00 freq: 1447 1997-10-23 17:53:55.54
TCA: 829.4 CTA: 0.00 drft: 0.0 9D1ECC349FEC990 bentpipe
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
lat: 0.00 lon: 0.00 freq: 1447 TCA: 1997-10-23 17:53:55.54
TCA: 829.4 CTA: 0.00 drft: 0.0 npts: 1 prob: 0.000
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
1st: 0, len: 0, conf: 4, wndw: 0 G_B IESM TEST

2.4 KBPS Data
Satellite: C6 03179 processed at: 1997-10-23 19:10:16.73
Pass AOS: 1997-10-23 18:52:24.13 pass LOS: 1997-10-23 19:08:56.73
Satellite elements at epoch: 1997-10-23 19:10:16.19
sx = 7374.8701 km, sy = 104.8859 km, sz = -459.0396 km
svx= -0.42709 km/s, svy= 0.36093 km/s, svz= -7.26653 km/s

1 lat: 54.41 lon: -0.73 freq: -138 1997-10-23 18:53:19.26
TCA: 55.1 CTA: 2.63 drft: 0.0 9D1ECC349FEC9D0 regional
error ellipse: rad: 0.0 hd: 87.3 mjr: 0.3 mnr: 0.1
lat: 53.60 lon: -8.91 freq: -150 TCA: 1997-10-23 18:53:19.54
TCA: 55.4 CTA: -2.26 drft: 0.0 npts: 5 prob: 0.960
error ellipse: rad: 7.0 hd: 73.6 mjr: 6.9 mnr: 2.0
1st: -100, len: 304, conf: 4, wndw: 0 G_B IESM TEST

2 lat: 0.00 lon: 0.00 freq: -4488 1997-10-23 08:04:50.11
TCA: -38854.0 CTA: 0.00 drft: 0.0 9D1ECC349FEC9D0 global
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
lat: 0.00 lon: 0.00 freq: -4488 TCA: 1997-10-23 08:04:50.11
TCA: -38854.0 CTA: 0.00 drft: 0.0 npts: 2 prob: 0.000
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
1st: -252, len: 253, conf: 3, wndw: 9 G_B IESM TEST

3 lat: 54.39 lon: -0.76 freq: 33 1997-10-23 18:53:19.53
TCA: 55.4 CTA: 2.61 drft: 0.0 9D1ECC349FEC900 regional
error ellipse: rad: 0.0 hd: -70.2 mjr: 0.0 mnr: 0.0
lat: 53.57 lon: -8.98 freq: 17 TCA: 1997-10-23 18:53:19.84
TCA: 55.7 CTA: -2.31 drft: 0.0 npts: 3 prob: 0.500
error ellipse: rad: 0.0 hd: 51.0 mjr: 0.1 mnr: 0.0
1st: -43, len: 149, conf: 4, wndw: 0 G_B IESM TEST

4 lat: 54.71 lon: -4.02 freq: 26 1997-10-23 08:03:34.16
TCA: -38930.0 CTA: 1.08 drft: 0.0 9D1ECC349FEC900 global
error ellipse: rad: 0.0 hd: -89.8 mjr: 0.0 mnr: 0.0
lat: 54.39 lon: -0.78 freq: 35 TCA: 1997-10-23 08:03:34.01
TCA: -38930.1 CTA: -0.83 drft: 0.0 npts: 3 prob: 0.500
error ellipse: rad: 0.0 hd: -70.2 mjr: 0.0 mnr: 0.0
1st: -117, len: 152, conf: 4, wndw: 0 G_B IESM TEST

2.4 KBPS Data
Satellite: S4 46817 processed at: 1997-10-23 19:44:56.26
Pass AOS: 1997-10-23 19:29:54.11 pass LOS: 1997-10-23 19:43:38.53
Satellite elements at epoch: 1997-10-23 19:44:55.72
sx = 3439.3286 km, sy = -767.6874 km, sz = 6308.0049 km
svx= -6.56311 km/s, svy= -1.27651 km/s, svz= 3.42339 km/s

1 lat: 51.83 lon: -14.50 freq: -492 1997-10-23 19:42:40.31
TCA: 766.2 CTA: 4.43 drft: -2.8 9D1ECC349FEC990 regional
error ellipse: rad: 0.0 hd: 54.1 mjr: 0.9 mnr: 0.1
lat: 54.42 lon: -0.76 freq: -429 TCA: 1997-10-23 19:42:39.52
TCA: 765.4 CTA: -4.23 drft: -1.6 npts: 6 prob: 0.682
error ellipse: rad: 1.0 hd: -88.8 mjr: 1.8 mnr: 0.2
1st: -303, len: 253, conf: 3, wndw: 1 G_B IESM TEST

2 lat: 54.43 lon: -0.70 freq: -419 1997-10-23 18:02:15.73
TCA: -5258.4 CTA: 9.45 drft: 0.0 9D1ECC349FEC990 global
error ellipse: rad: 0.0 hd: 72.0 mjr: 0.2 mnr: 0.2

lat: 60.60 lon: 31.26 freq: -493 TCA: 1997-10-23 18:02:17.70
TCA: -5256.4 CTA: -8.66 drft: 0.0 npts: 15 prob: 0.988
error ellipse: rad: 22.0 hd: 70.9 mjr: 19.0 mnr: 12.8
1st: -298, len: 751, conf: 4, wndw: 0 G_B IESM TEST

2.4 KBPS Data
Satellite: C6 03180 processed at: 1997-10-23 20:55:12.90
Pass AOS: 1997-10-23 20:37:48.15 pass LOS: 1997-10-23 20:54:38.82
Satellite elements at epoch: 1997-10-23 20:55:12.35
sx = 6654.6924 km, sy = -3178.0828 km, sz = -476.5605 km
svx= -0.23824 km/s, svy= 0.52056 km/s, svz= -7.26536 km/s

1 lat: 54.43 lon: -0.72 freq: -435 1997-10-23 20:37:50.28
TCA: 2.1 CTA: 17.89 drft: 0.0 9D1ECC349FEC990 regional
error ellipse: rad: 0.0 hd: 5.5 mjr: 0.7 mnr: 0.3
lat: 49.58 lon: -57.20 freq: -410 TCA: 1997-10-23 20:37:49.35
TCA: 1.2 CTA: -16.41 drft: 0.0 npts: 5 prob: 0.935
error ellipse: rad: 9.0 hd: -18.5 mjr: 8.7 mnr: 3.3
1st: -106, len: 252, conf: 4, wndw: 0 G_B IESM TEST

2.4 KBPS Data
Satellite: S4 46818 processed at: 1997-10-23 21:25:29.39
Pass AOS: 1997-10-23 21:09:13.25 pass LOS: 1997-10-23 21:24:50.54
Satellite elements at epoch: 1997-10-23 21:25:28.85
sx = 3309.8723 km, sy = -2302.2903 km, sz = 5996.1387 km
svx= -6.22369 km/s, svy= 1.39591 km/s, svz= 3.97126 km/s

1 lat: 43.21 lon: -60.22 freq: -492 1997-10-23 21:24:31.64
TCA: 918.4 CTA: 20.54 drft: 0.0 9D1ECC349FEC990 regional
error ellipse: rad: 0.0 hd: 6.7 mjr: 0.0 mnr: 0.0
lat: 54.42 lon: -0.73 freq: -419 TCA: 1997-10-23 21:24:28.95
TCA: 915.7 CTA: -19.06 drft: 0.0 npts: 3 prob: 0.500
error ellipse: rad: 0.0 hd: -37.7 mjr: 0.0 mnr: 0.0
1st: -154, len: 97, conf: 3, wndw: 1 G_B IESM TEST

2 lat: 54.42 lon: -0.72 freq: -418 1997-10-23 19:42:39.46
TCA: -5193.8 CTA: -4.25 drft: 0.0 9D1ECC349FEC990 global
error ellipse: rad: 0.0 hd: 75.7 mjr: 0.3 mnr: 0.1
lat: 51.63 lon: -14.89 freq: -387 TCA: 1997-10-23 19:42:38.81
TCA: -5194.4 CTA: 4.73 drft: 0.0 npts: 16 prob: 0.984
error ellipse: rad: 17.0 hd: 68.4 mjr: 16.3 mnr: 7.1
1st: -302, len: 756, conf: 4, wndw: 0 G_B IESM TEST

3 lat: 54.39 lon: -0.75 freq: 53 1997-10-23 19:42:39.03
TCA: -5194.2 CTA: -4.23 drft: 0.0 9D1ECC349FEC900 global
error ellipse: rad: 0.0 hd: 79.7 mjr: 0.2 mnr: 0.1
lat: 51.65 lon: -14.78 freq: 70 TCA: 1997-10-23 19:42:38.71
TCA: -5194.5 CTA: 4.66 drft: 0.0 npts: 6 prob: 0.987
error ellipse: rad: 19.0 hd: 64.8 mjr: 17.1 mnr: 8.9
1st: -235, len: 505, conf: 4, wndw: 0 G_B IESM TEST

2.4 KBPS Data
Satellite: C4 11652 processed at: 1997-10-24 05:09:06.86
Pass AOS: 1997-10-24 04:52:14.12 pass LOS: 1997-10-24 05:07:56.55
Satellite elements at epoch: 1997-10-24 05:09:06.33
sx = 3863.3074 km, sy = 395.9571 km, sz = 6231.8477 km
svx= -6.21813 km/s, svy= 0.79682 km/s, svz= 3.76809 km/s

1 lat: 54.42 lon: -0.70 freq: -431 1997-10-24 05:07:51.69
TCA: 937.6 CTA: 3.06 drft: 0.0 9D1ECC349FEC990 regional
error ellipse: rad: 1.0 hd: -78.1 mjr: 1.2 mnr: 0.1
lat: 53.43 lon: 9.13 freq: -393 TCA: 1997-10-24 05:07:51.13
TCA: 937.0 CTA: -2.83 drft: 0.0 npts: 5 prob: 0.712
error ellipse: rad: 2.0 hd: -82.5 mjr: 2.9 mnr: 0.2
1st: -335, len: 250, conf: 3, wndw: 1 G_B IESM TEST

2 lat: 54.43 lon: -0.71 freq: -432 1997-10-24 03:23:24.80
TCA: -5329.3 CTA: 18.30 drft: 0.0 9D1ECC349FEC990 global
error ellipse: rad: 0.0 hd: -36.8 mjr: 0.5 mnr: 0.2
lat: 49.89 lon: 57.12 freq: -585 TCA: 1997-10-24 03:23:32.04
TCA: -5322.1 CTA: -16.60 drft: 0.0 npts: 6 prob: 0.989
error ellipse: rad: 40.0 hd: 49.9 mjr: 37.3 mnr: 15.8
1st: -229, len: 604, conf: 4, wndw: 0 G_B IESM TEST

3 lat: 0.00 lon: 0.00 freq: 4481 1997-10-23 18:53:20.27
TCA: -35933.8 CTA: 0.00 drft: 0.0 9D1ECC349FEC990 global
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
lat: 0.00 lon: 0.00 freq: 4481 TCA: 1997-10-23 18:53:20.27
TCA: -35933.8 CTA: 0.00 drft: 0.0 npts: 1 prob: 0.000
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
1st: 0, len: 0, conf: 3, wndw: 9 G_B IESM TEST

2.4 KBPS Data
Satellite: S3 57707 processed at: 1997-10-24 06:18:34.26
Pass AOS: 1997-10-24 06:02:41.13 pass LOS: 1997-10-24 06:18:15.07
Satellite elements at epoch: 1997-10-24 06:18:33.72
sx = 6738.2632 km, sy = -2527.9524 km, sz = -179.2956 km
svx= -0.73786 km/s, svy= -1.46484 km/s, svz= -7.35281 km/s

1 lat: 0.00 lon: 0.00 freq: -7894 1997-10-24 06:04:59.68
TCA: 138.6 CTA: 0.00 drft: 0.0 9D1ECC349FEC990CFC52 bentpipe
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
lat: 0.00 lon: 0.00 freq: -7894 TCA: 1997-10-24 06:04:59.68
TCA: 138.6 CTA: 0.00 drft: 0.0 npts: 2 prob: 0.000
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
1st: -47, len: 48, conf: 4, wndw: 0 G_B IESM TEST

2 lat: 0.00 lon: 0.00 freq: -6865 1997-10-24 06:04:34.76
TCA: 113.6 CTA: 0.00 drft: 0.0 9D1ECC349FEC90073AFD bentpipe
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
lat: 0.00 lon: 0.00 freq: -6865 TCA: 1997-10-24 06:04:34.76

TCA: 113.6 CTA: 0.00 drft: 0.0 npts: 1 prob: 0.000
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
1st: 0, len: 0, conf: 4, wndw: 0 G_B IESM TEST

2.4 KBPS Data
Satellite: C4 11653 processed at: 1997-10-24 06:54:28.42
Pass AOS: 1997-10-24 06:36:46.12 pass LOS: 1997-10-24 06:53:56.05
Contents: 14 records, 14 located beacons, 0 unlocated beacons
Satellite elements at epoch: 1997-10-24 06:54:27.87
sx = 3482.9153 km, sy = -1256.3729 km, sz = 6339.8364 km
svx= -5.30841 km/s, svy= 3.53436 km/s, svz= 3.58215 km/s
Frame count: 1898

1 lat: 58.81 lon: -43.98 freq: -566 1997-10-24 06:54:04.42
TCA: 1038.3 CTA: 12.27 drft: 0.0 9D1ECC349FEC990CFC52 regional
error ellipse: rad: 0.0 hd: 79.8 mjr: 0.0 mnr: 0.0
lat: 54.43 lon: -0.70 freq: -430 TCA: 1997-10-24 06:54:01.21
TCA: 1035.1 CTA: -11.61 drft: 0.0 npts: 3 prob: 0.500
error ellipse: rad: 0.0 hd: -59.7 mjr: 0.1 mnr: 0.0
1st: -235, len: 99, conf: 3, wndw: 1 G_B IESM TEST

2.4 KBPS Data
Satellite: C6 03187 processed at: 1997-10-24 08:34:10.85
Pass AOS: 1997-10-24 08:15:36.10 pass LOS: 1997-10-24 08:33:09.07
Contents: 44 records, 34 located beacons, 10 unlocated beacons
Satellite elements at epoch: 1997-10-24 08:34:10.30
sx = 3479.2861 km, sy = -516.5559 km, sz = 6428.7666 km
svx= -5.95590 km/s, svy= 2.54311 km/s, svz= 3.42919 km/s
Frame count: 1453

1 lat: 0.00 lon: 0.00 freq: 6154 1997-10-24 08:29:27.87
TCA: 831.8 CTA: 0.00 drft: 0.0 9D1ECC349FEC990CFC52 regional
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
lat: 0.00 lon: 0.00 freq: 6154 TCA: 1997-10-24 08:29:27.87
TCA: 831.8 CTA: 0.00 drft: 0.0 npts: 2 prob: 0.000
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
1st: -50, len: 51, conf: 3, wndw: 9 G_B IESM TEST

2 lat: 51.80 lon: 28.47 freq: -526 1997-10-24 06:47:02.70
TCA: -5313.4 CTA: -8.37 drft: 0.0 9D1ECC349FEC990CFC52 global
error ellipse: rad: 0.0 hd: 77.1 mjr: 0.0 mnr: 0.0
lat: 54.45 lon: -0.62 freq: -449 TCA: 1997-10-24 06:47:01.88
TCA: -5314.2 CTA: 9.23 drft: 0.0 npts: 3 prob: 0.500
error ellipse: rad: 0.0 hd: -60.1 mjr: 0.1 mnr: 0.0
1st: -117, len: 450, conf: 4, wndw: 0 G_B IESM TEST

3 lat: 54.42 lon: -0.69 freq: -430 1997-10-24 05:03:13.96
TCA: -11542.1 CTA: 24.12 drft: 0.0 9D1ECC349FEC990CFC52 global
error ellipse: rad: 1.0 hd: -38.7 mjr: 1.0 mnr: 0.3
lat: 48.59 lon: 76.00 freq: -564 TCA: 1997-10-24 05:03:20.77
TCA: -11535.3 CTA: -21.76 drft: 0.0 npts: 5 prob: 0.952
error ellipse: rad: 16.0 hd: 50.5 mjr: 15.8 mnr: 4.6
1st: -110, len: 302, conf: 4, wndw: 0 G_B IESM TEST

2.4 KBPS Data
Satellite: S4 46825 processed at: 1997-10-24 09:55:07.77
Pass AOS: 1997-10-24 09:37:51.10 pass LOS: 1997-10-24 09:53:38.90
Contents: 60 records, 53 located beacons, 7 unlocated beacons
Satellite elements at epoch: 1997-10-24 09:55:07.22
sx = 6310.0469 km, sy = -3498.9055 km, sz = -507.9524 km
svx= -1.27866 km/s, svy= -1.24374 km/s, svz= -7.31056 km/s
Frame count: 1747

1 lat: 54.41 lon: -0.72 freq: -119 1997-10-24 09:37:39.09
TCA: -12.0 CTA: 5.69 drft: 0.0 9D1ECC349FEC9D011478 regional
error ellipse: rad: 0.0 hd: 8.9 mjr: 0.4 mnr: 0.4
lat: 57.98 lon: -19.35 freq: -101 TCA: 1997-10-24 09:37:38.73
TCA: -12.4 CTA: -5.28 drft: 0.0 npts: 4 prob: 0.903
error ellipse: rad: 4.0 hd: 42.6 mjr: 3.5 mnr: 3.4
1st: -108, len: 203, conf: 4, wndw: 0 G_B IESM TEST

2 lat: 0.00 lon: 0.00 freq: -171 1997-10-24 07:56:52.86
TCA: -6058.2 CTA: 0.00 drft: 0.0 9D1ECC349FEC9D011478 global
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
lat: 0.00 lon: 0.00 freq: -171 TCA: 1997-10-24 07:56:52.86
TCA: -6058.2 CTA: 0.00 drft: 0.0 npts: 1 prob: 0.000
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
1st: 0, len: 0, conf: 3, wndw: 9 G_B IESM TEST

2.4 KBPS Data
Satellite: C6 03188 processed at: 1997-10-24 10:17:00.41
Pass AOS: 1997-10-24 10:04:40.15 pass LOS: 1997-10-24 10:16:31.79
Contents: 15 records, 11 located beacons, 4 unlocated beacons
Satellite elements at epoch: 1997-10-24 10:16:59.91
sx = 3392.4597 km, sy = -2596.2583 km, sz = 5954.2622 km
svx= -3.90247 km/s, svy= 4.56153 km/s, svz= 4.20797 km/s
Frame count: 1242

1 lat: 54.43 lon: -0.71 freq: -429 1997-10-24 08:32:30.56
TCA: -5529.6 CTA: -5.89 drft: 0.0 9D1ECC349FEC990CFC52 global
error ellipse: rad: 0.0 hd: -63.5 mjr: 0.1 mnr: 0.0
lat: 56.43 lon: -22.37 freq: -388 TCA: 1997-10-24 08:32:28.99
TCA: -5531.2 CTA: 6.57 drft: 0.0 npts: 8 prob: 0.996
error ellipse: rad: 17.0 hd: 81.7 mjr: 15.9 mnr: 8.5
1st: -233, len: 550, conf: 4, wndw: 0 G_B IESM TEST

2.4 KBPS Data
Satellite: S2 66347 processed at: 1997-10-24 11:52:00.61
Pass AOS: 1997-10-24 11:35:29.13 pass LOS: 1997-10-24 11:51:30.12
Contents: 6 records, 4 located beacons, 2 unlocated beacons
Satellite elements at epoch: 1997-10-24 11:52:00.04
sx = 6599.6436 km, sy = -2960.6584 km, sz = -262.0468 km

svx= -0.92124 km/s, svy= -1.42097 km/s, svz= -7.32329 km/s
Frame count: 0

1 lat: 54.43 lon: -0.71 freq: -457 1997-10-24 11:35:22.53
TCA: -6.6 CTA: 3.57 drft: 0.0 9D1ECC349FEC990CFC52 bentpipe
error ellipse: rad: 0.0 hd: -76.2 mjr: 1.0 mnr: 0.1
lat: 56.55 lon: -12.32 freq: -503 TCA: 1997-10-24 11:35:23.12
TCA: -6.0 CTA: -3.36 drft: 0.0 npts: 5 prob: 0.718
error ellipse: rad: 2.0 hd: -68.6 mjr: 2.5 mnr: 0.2
1st: 78, len: 246, conf: 3, wndw: 1 G_B IESM TEST

2 lat: 0.00 lon: 0.00 freq: -6703 1997-10-24 11:37:30.35
TCA: 121.2 CTA: 0.00 drft: 0.0 9D1ECC349FEC9D011478 bentpipe
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
lat: 0.00 lon: 0.00 freq: -6703 TCA: 1997-10-24 11:37:30.35
TCA: 121.2 CTA: 0.00 drft: 0.0 npts: 2 prob: 0.000
error ellipse: rad: 0.0 hd: 0.0 mjr: 0.0 mnr: 0.0
1st: -48, len: 49, conf: 4, wndw: 0 G_B IESM TEST

3 lat: 54.39 lon: -0.69 freq: 4 1997-10-24 11:35:23.08
TCA: -6.0 CTA: 3.59 drft: 0.0 9D1ECC349FEC90073AFD bentpipe
error ellipse: rad: 0.0 hd: -72.3 mjr: 0.0 mnr: 0.0
lat: 56.53 lon: -12.42 freq: -46 TCA: 1997-10-24 11:35:23.65
TCA: -5.5 CTA: -3.41 drft: 0.0 npts: 3 prob: 0.500
error ellipse: rad: 0.0 hd: -72.4 mjr: 0.0 mnr: 0.0
1st: 82, len: 103, conf: 3, wndw: 1 G_B IESM TEST

2.4 KBPS Data
Satellite: S6 14520 processed at: 1997-10-24 14:28:23.28
Pass AOS: 1997-10-24 14:13:08.13 pass LOS: 1997-10-24 14:28:00.59
Contents: 5 records, 5 located beacons, 0 unlocated beacons
Satellite elements at epoch: 1997-10-24 14:28:22.74
sx = 3704.7700 km, sy = -1026.2809 km, sz = 6123.1553 km
svx= -6.44848 km/s, svy= -0.77291 km/s, svz= 3.77046 km/s
Frame count: 0

1 lat: 54.43 lon: -0.70 freq: -266 1997-10-24 14:26:50.74
TCA: 822.6 CTA: -7.18 drft: 0.0 9D1ECC349FEC990CFC52 bentpipe
error ellipse: rad: 0.0 hd: 87.4 mjr: 0.3 mnr: 0.0
lat: 50.16 lon: -23.68 freq: -350 TCA: 1997-10-24 14:26:52.14
TCA: 824.0 CTA: 7.50 drft: 0.0 npts: 5 prob: 0.810
error ellipse: rad: 1.0 hd: 59.4 mjr: 1.3 mnr: 0.2
1st: -240, len: 204, conf: 3, wndw: 1 G_B IESM TEST