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Cold Regions Performance of Optical-Fiber and Pulsed Near-Infrared Intrusion Detection Systems

Lindamae Peck

May 1994

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Abstract

Four optical-fiber intrusion detection systems (IDSs) and one pulsed near-infrared IDS were operated from October 1992 through July 1993 during conditions of snowfall and rainfall, unfrozen and frozen ground, snow as deep as 80 cm, wind gusts >20 m/s, and air temperatures ranging from –30°C to 35°C. The optical-fiber IDSs were installed in both buried and fence-mounted configurations. The detection capability of the IDSs was determined with controlled intrusions on a regular basis. Long-term monitoring identified causes of nuisance alarms.

For conversion of SI metric units to U.S./British customary units of measurement consult ASTM Standard E380-89a, *Standard Practice for Use of the International System of Units*, published by the American Society for Testing and Materials, 1916 Race St., Philadelphia, Pa. 19103.

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Special Report 94-11

US Army Corps of Engineers
Cold Regions Research &
Engineering Laboratory

Cold Regions Performance of Optical-Fiber and Pulsed Near-Infrared Intrusion Detection Systems

Lindamae Peck

May 1994

Prepared for
OFFICE OF THE CHIEF OF ENGINEERS
and
U.S. AIR FORCE ELECTRONIC SECURITY AND
COMMUNICATIONS CENTER FOR EXCELLENCE

PREFACE

This report was prepared by Dr. Lindamae Peck, Geophysicist, of the Geophysical Sciences Branch, Research Division, U.S. Army Cold Regions Research and Engineering Laboratory. This project was funded by the U.S. Army Corps of Engineers and the U.S. Air Force Electronic Security and Communications Center for Excellence at Hanscom AFB, Massachusetts.

This report was reviewed by James Morse and James Lacombe. James Morse designed the circuitry (rectifier/integrator) that made it possible to monitor the proximity-to-alarm status of the M106 IDSs. Bonnie Jones of CRREL maintains the SOROIDS alarm data acquisition system and was the intruder for the IPID and buried optical-fiber IDSs.

The contents of this report are not to be used for advertising or promotional purposes. Citation of brand names does not constitute an official endorsement or approval of the use of such commercial products.

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LINDAMAE PECK

INTRODUCTION

This report summarizes the results of controlled intrusions and long-term monitoring of four optical-fiber intrusion detection systems (IDSs) and one pulsed near-infrared IDS during the period 3 October 1992 to 27 July 1993 at the CRREL IDS site (SOROIDS) in South Royalton, Vermont. The optical-fiber IDSs are the Mason and Hanger Fiber Optic Intelligence and Detection System (FOIDS) and the Fiber Sens Sys M106; each system is in operation in both a fence-mounted and a buried configuration. The near-infrared IDS is ECSI-EAG International's Infrared Perimeter Intrusion Detection System (hereafter referred to as the IPID). The locations of the IDSs are shown in Figure 1.

A third optical-fiber IDS, Stellar Systems' Sabreline Outdoor Buried Fiber Optic System, generated numerous alarms during the first two weeks of the evaluation period. The manufacturer attributed the problem to a faulty laser or to a break in the sensor cable. This IDS was shut down on 15 October 1992.

All the optical-fiber IDSs were installed by contractors of the Air Force Electronic Security and Communications Center, Hanscom AFB. The IPID was installed by CRREL personnel following a site visit by the manufacturer.

The fence-mounted optical-fiber cable IDSs are attached to the chain-link fence with plastic tie-wraps. The chain-link fence is described in Appendix A. The FOIDS and the M106 cables make a single loop along the length of their separate detection zones. Each cable is positioned slightly (~8 cm) above the lowest stiffening cable on the fence and, after looping at the end of its zone, returns approximately 48 cm below the top of the fence fabric.

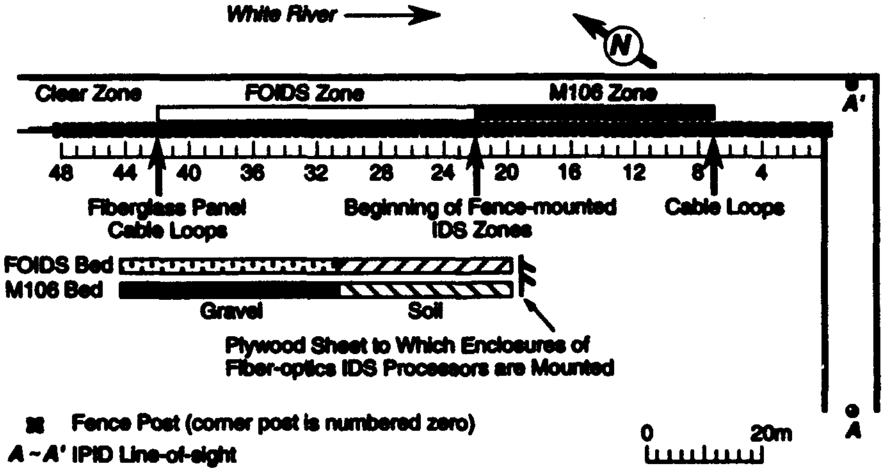

Figure 1. Location of IDSs at SOROIDS. Each panel is numbered according to the number of the fence post to its north. Panel 42 is of fiberglass instead of chain-link, and panels 41 and 43 have horizontal pipes as stiffeners near the top of each panel.

The buried optical-fiber cables are covered either with gravel or soil in beds approximately 2.5 m wide. A single cable loops the entire length of the IDS zone in a serpentine pattern, passing from the soil portion near the processor into the gravel portion, looping back at the far end of the gravel portion, passing into the soil portion again, then looping at the end of the soil portion (by the processor) to repeat the soil–gravel–soil sequence. An unfortunate consequence of this cable configuration is that it is not possible to distinguish between nuisance alarms arising in the soil portion and those arising in the gravel portion. Both burial media comprise the same alarm zone.

The M106 buried cable is attached to orange plastic webbing and is covered with 8 cm (3 in.) of gravel or 10–13 cm (4–5 in.) of soil. The FOIDS buried cable is also attached to orange plastic webbing and is covered with 5 cm (2 in.) of gravel or 5–6 cm (2–2.5 in.) of soil. These depth determinations were made in October 1992 by CRREL personnel at two locations in the gravel and soil portions of each bed. They do not agree with the intended bed profiles, which were 5 cm (2 in.) of soil or gravel on 5 cm (2 in.) of sand.

EQUIPMENT AND INSTALLATION EFFECTS ON DETECTABILITY

Mason and Hanger FOIDS

The system processor in use at SOROIDS is a two-zone unit that handles both the fence-mounted and the buried optical-fiber cables. There is a sensitivity adjustment for each zone but no other operator-selectable parameters. Because newer versions have more selectable parameters and because the manufacturer considers the SOROIDS unit to be a prototype, results obtained at SOROIDS are not necessarily representative of the performance of the commercially available FOIDS.

Fiber Sens Sys M106

There are two system processors in use at SOROIDS, one for the fence-mounted optical fiber cable and one for the buried cable. Both are versions of the manufacturer's commercially available systems. The cable is buried deeper in both the soil and the gravel portions of its test bed than the manufacturer recommends. During a site visit in May 1993, a Fiber Sens Sys representative found locations where the M106 cable was as deep as 18 cm (7 in.), whereas

Table 1. Site conditions during controlled intrusions.

Date	*Time*	*Air temperature (°C)**	*Wind speed (m/s)**	*Wind gust (m/s)*	*Snow depth (cm)*
6 Oct 92	1330–1530	11.8 to 14.1, increasing	2.5 to 2.7	4.9 to 7.3	0
15 Oct 92	1330–1530	8.3 to 8.7	0.4 to 0.7	1.4 to 1.7	0
3 Nov 92	1330–1600	4 to 4.2	1.6 to 2.6	5 to 7.3	0
17 Nov 92	1100–1430	–0.4 to 0.4	0.4 to 2.3	1.3 to 5.1	1
24 Nov 92	1200–1600	4.6 to 5.2	1.1 to 2.1	2.7 to 4.8	0
8 Dec 92	1030–1500	–7.2 to –6.8	3.3 to 4.7	7.1 to 10.5	3 to 10
15 Dec 92	1200–1500	0.2 to 2.9	0.2 to 0.6	0.8 to 2.9	Discontinuous; 0 to 5
22 Dec 92	1100–1400	0.4 to 4.2	0.8 to 1.7	2.3 to 4.9	0
12 Jan 93	1030–1430	–3.2 to –2.4	0.3 to 1.8	1 to 2.6	1 to 4
19 Jan 93	1030–1700	–10.8 to –8.8	1.3 to 6.8	2.7 to 13	12 to 17
2 Feb 93	1230–1630	–11.7 to –8.5	2.4 to 4.4	3.5 to 8	10* to 25; *basal ice layer present
9 Feb 93	1000–1530	–14.1 to –4.4, increasing	0.5 to 2.6	2.2 to 3.9	9 to 20
16 Feb 93	1030–1430	–4.2 to –1.4	0.4 to 5.2	1.8 to 14	26 to 35
23 Feb 93	1130–1600	–2.8 to –1	0.7 to 1.4	1.7 to 6.4	47 to 65
2 Mar 93	1000–1600	–9.1 to 4.9	0.4 to 2	1 to 4.2	42 to 57
9 Mar 93	1100–1630	3.3 to 4.9	2.4 to 4.5	4 to 9.4	33 to 46
16 Mar 93	1030–1630	–2.3 to 7.5	3.6 to 6.5	7.8 to 12	50 to 75
6 Apr 93	1030–1500	6.4 to 13.3	0.7 to 2.1	1.9 to 8.2	20 to 35
13 Apr 93	0945–1330	4.9 to 7.4	2.3 to 3.8	3.7 to 7.1	0
20 Apr 93	0930–1300	7 to 17	0.7 to 5	2 to 11.1	0
27 Apr 93	1000–1200	5.4 to 8.6	3.9 to 4.3	7.6 to 10.8	0
18 May 93	1000–1330	11.3 to 15.7	0.6 to 3.4	1.8 to 8.5	0
1 Jun 93	0945–1330	10.6 to 14.4	0.3 to 1.2	0.9 to 3.7	0
29 Jun 93	1130–1500	21.3 to 23.5	2 to 2.9	5.1 to 7.4	0
13 Jul 93	0930–1315	22.6 to 25.9	1.7 to 3.2	5.2 to 8.0	0
27 Jul 93	0930–1430	17.1 to 20.4	2.3 to 3.6	5.7 to 8.2	0

*2 m height; 30 min average.

the recommended depths are 5 cm (2 in.) in soil and 8–15 cm (3–6 in.) in gravel. For this reason, results obtained with the buried M106 system at SOROIDS are not necessarily representative of its achievable detection capability.

ECSI-EAG International Infrared Perimeter Intrusion Detection System

The IPID at SOROIDS is commercially available. During the evaluation period, there were instances of nuisance alarms that the manufacturer felt were inconsistent with the typical performance of an IPID. Subsequently the manufacturer discovered that some fielded units have a defective resistor that could account for the SOROIDS unit generating alarms when small birds walk in front of the receiver and could also account for the SOROIDS unit's protracted alarms during hot weather. The receiver unit at SOROIDS was first exchanged by the manufacturer on 22 July 1993, before the resistor problem became known. A second replacement receiver unit was installed on 5 October 1993 as part of the manufacturer's effort to replace all potentially defective receiver units. It is not known by CRREL personnel whether the original receiver had the defective resistor, and thus whether the SOROIDS record of IPID nuisance alarms is representative of IPIDs in general or of defective IPIDs only.

All optical-fiber IDSs

The processors of all the optical-fiber IDSs are mounted to an upright sheet of plywood that is oriented broadside to the wind. The plywood is freestanding, attached to two wooden posts that are set in concrete. Its only other support is two 2×4s that extend outward from the back side of the plywood and downward to the ground, where they are held in place by short sections of 2×4s driven into the ground. The optical-fiber cables run from the ground surface through PVC conduit into the processor enclosures. The M106 cables from the ground surface to the processor are inactive signal transmission cables, but the FOIDS cables are active sensor cables.

Both the fence-mounted and the buried FOIDS IDSs are prone to alarms during windy periods, which is probably due in part to movement of the plywood and/or conduit. The M106 IDSs do not show the same sensitivity to wind conditions. It is not known to what extent the low number of wind-induced nuisance alarms with the M106 IDSs is due

Precipitation	*Soil bed*	*Gravel bed*
None	Dry	Gravel loose
Intermittent drizzle	Damp	Gravel loose
Rain in morning	Damp	Gravel loose
Snowing	Damp	Gravel loose
Rain in morning	Damp	Gravel loose
None	Shallow (< 5.5 cm) frozen layer. 3 to 7 cm snow.	0 to 1 cm snow. Hard frozen.
None	Frozen layer > 5.5 cm deep. 4 to 5 cm snow	Gravel loose
None	Frozen layer > 5.5 cm deep.	Gravel loose
None	Frozen layer > 5.5 cm deep. 2 to 3 cm snow.	1 to 2 cm snow. Gravel loose.
None	Frozen layer > 5.5 cm deep. 13.5 to 15 cm snow.	13.5 to 15 cm snow. Gravel loose.
None	Hard frozen (> 5.5 cm). 18 to 20 cm snow with basal ice layer.	Gravel loose but packed with snow. 18 to 20 cm snow. No basal ice layer
None	Hard frozen (> 5.5 cm).	M106 gravel loose. FOIDS gravel frozen in ice.
Snowing	11 to 13 cm snow with basal ice layer.	11 to 15 cm snow. No basal ice layer.
Snowing	—	—
None	—	—
None	Frozen layer > 5.5 cm deep. 41 to 44 cm snow.	43 to 46 cm snow.
None	Hard frozen (> 5.5 cm). 31 to 33 cm snow.	Gravel hard frozen. 32 to 33 cm snow.
None	Hard frozen (> 5.5 cm). Snowcovered.	Snowcovered
	Hard frozen (> 5.5 cm). Crossing made where soil exposed by running water.	Snowcovered
None	FOIDS wet slippery; footprints visible. M106 damp; firm.	Bare; loose
None	Damp, firm	—
None	Firm	—
None	Dry	—
Intermittent light rain	Wet	—
None	Dry	—
None	Very dry, hard	—
None	Dry	—

to their electronic exclusion of characteristic wind-related signals and how much is due to the standard use of inactive cable leading from the ground surface to the processor. In May 1993, following a season of freeze–thaw action, one of the 2×4 braces was loose to the touch. It was possible to cause the buried M106 to alarm by hitting the plywood backplane. The fence-mounted IDS did not alarm then, which is consistent with the buried unit being operated at a higher sensitivity. Once the plywood's 2×4 braces were stabilized, neither M106 unit alarmed when the plywood was pushed or struck.

It is impossible to isolate unquestionably the FOIDS alarms that were due to wind-induced motion of the fence from those due to wind-induced motion of the plywood. A reasonable criterion, however, is whether only the fence-mounted FOIDS is experiencing nuisance alarms. If both FOIDSs alarm, it is likely to be related to movement of the plywood. If only the fence-mounted FOIDS alarms, particularly as that is operated at a lower sensitivity than the buried FOIDS, then it is likely that wind-induced motion of the fence is the cause of the nuisance alarms.

CONTROLLED INTRUSIONS

The site conditions during the days on which controlled intrusions were conducted are given in Table 1. The reported air temperatures and wind speeds are 30-min averages. The wind gust is the maximum wind speed during a 30-min period. Wind and temperature data are acquired at a meteorological tower at a height of 2 m and processed by a data logger into 30-min intervals. Snow depth measurements were made continuously by an acoustic snow depth sensor at a representative location. They were supplemented by hand measurements on days of controlled intrusions.

Controlled intrusions for the fence-mounted IDSs were single taps to the fence with a metal rod. Each fence panel was tapped at its center (panel data). Each panel was also tapped near one of its fence posts (post data) at a distance of approximately 25–30 cm from the post. The post taps were made variously at three heights along the post, which are designated as high (H), middle (M), and low (L). The high location is between the top two stiffening wires. The low location is between the lowest stiffening wire and the bottom rail of the fence. For both the FOIDS and the M106 a single tap constituted an intrusion. (The FOIDS has no provision for selecting the number of events that must occur to satisfy the alarm condition; the M106 was set for a count of one.) If the first tap did not produce an alarm, taps were repeated with increasing force until an alarm occurred. The number of taps required to cause an alarm is given in Tables 2 and 3 for the FOIDS and M106, respectively. If no alarm occurred after five taps, the table entry is 0 (5), preceded by the location designation (H, M, or L). For example, two separate intrusions (taps) were made at post 25 at the low location on 12 Jan 93, and both events were detected following a single tap (L, L). At post 25 on 2 Mar, there were two separate intrusions, one at the low location and one at the high location. The former required two taps (L2) before an alarm occurred, the latter required a single tap (H).

For the buried IDSs, a controlled intrusion was a person crossing an IDS's bed at a walk on a path perpendicular to the length of the bed. The intruder was a 1.7-m-tall female who took 4–5 steps during a crossing. The intruder's characteristics varied during the reporting period in terms of more clothing and heavier footwear in the winter months. The intrusions were conducted in two series along the length of the IDS beds. First, the intruder crossed the soil portion of the bed 12 times on east–west paths as she proceeded northward from the processor end of the bed to the boundary between the soil and gravel portions of the bed. She then continued northward, crossing the gravel portion 12 times on east–west paths. For the second series, the intruder proceeded southward, from the farthest end of the gravel portion toward the processor end. She first crossed the gravel portion 12 times on east–west paths, and then crossed the soil portion 12 times on east–west paths. This resulted in 24 crossings each of the soil and gravel portions at locations that span the length of each portion of an optical-fiber bed. The results of the intrusions are given in Tables 4 and 5 for the FOIDS and M106, respectively.

For the IPID, a controlled intrusion was a person walking upright on a path perpendicular to the line-of-sight of the IPID beams. The crossings were made at 3-m increments between the transmitter and receiver units. The results of the intrusions are given in Table 6.

Fence-mounted FOIDS

The only operator-adjustable setting of the FOIDS is its sensitivity. For 15 Oct 1992 through 13 Apr 1993 the fence-mounted FOIDS was operated at a sensitivity of 4.5 on a scale of 0 to 9+ (the larger the number, the higher the sensitivity). The slight reduction from the initial 4.75 sensitivity on 6 Oct was made to reduce the number of nonintruder

Table 2. FOIDS fence intrusions.

Sensitivity	*Date*	*Panel 23*	*Post 23*	*Panel 24*	*Post 24*	*Panel 25*	*Post 25*	*Panel 26*	*Post 26*
4.75	6 Oct 92	1	H, M	1	M, H	1	L, L	1	H, M
4.75, 4.5	15 Oct 92			1, 1	H, H			1, 1	M, M
4.5	3 Nov 92	1, 1	H	1	M, M	1, 1	L	1	H, L
4.5	17 Nov 92	1	M, H	1	L, L	1	H, M	1	M, H
4.5	24 Nov 92	1	L, M	1	H, M	1	M, L	1	L, H
4.5	8 Dec 92	2	L, L	1, 1	H2	1, 1	M	1	L, H
4.5	15 Dec 92	5	H	1	M	1	L	1	H
4.5	22 Dec 92	1	L, H	1	H, H	1	M, L	1	L, L
4.5	12 Jan 93	1	H, H	1	M, L	1	L, L	1	H, M
4.5	19 Jan 93	1	L, H	1	H, L	1	M, L	1	L, M
4.5	2 Feb 93	1	H, M	1	M, H	1	L, H	1	H, L
4.5	9 Feb 93	1	M, H	1	L, L	1	H, L	1	M, M
4.5	23 Feb 93	1	H, M, L	1	H, M, L	1	H, M, L	1	H, M, L
4.5	2 Mar 93	1	H, M2	2	M, H	5	L2, H	2	H, L
4.5	9 Mar 93	1	H, H	2	M, L	1	L, L	1	H, M
4.5	16 Mar 93	1	M, H	1	L, L	1	H, L	1	M, M2
4.5	6 Apr 93	1	H, H	1	M, L	1	L, L	1	H, M
4.5	13 Apr 93	1	M, H	1	L, L	1	H, L	1	M, M
3.0	20 Apr 93	1	L, H	1	H, L	1	M, L	1	L, M
2.5	27 Apr 93	1	L, H	1	H, L	1	M, L	1	L, M
2.5	18 May 93	1	L, H	1	H, L	1	M, L	1	L, M
2.5	1 Jun 93	1	H, H	1	M, L	1	L, L	1	H, M
2.5	29 Jun 93	1	H, H	2	M, L2	1	L, L	1	H, M
4.5	29 Jun 93	1	H, H	1	M, L	1	L, L	1	H, M
4.5	13 Jul 93	2	M2, H2	2	L, H2	1	H, L	2	M, L
6.0	13 Jul 93		H		L		L		M
4.5	27 Jul 93	1	H, H	1	M, L	1	L, L	1	H, M

Sensitivity	*Date*	*Panel 27*	*Post 27*	*Panel 28*	*Post 28*	*Panel 29*	*Post 29*	*Panel 30*	*Post 30*
4.75	6 Oct 92	1	M, H	1	H	1	H, L	1	M, M
4.75, 4.5	15 Oct 92			1, 1				1, 1	H, H
4.5	3 Nov 92	1, 1	M	1, 1			H, M	1, 1	M2
4.5	17 Nov 92	1	L, L	1	H, M	1	M, H	1	L, L
4.5	24 Nov 92	1	H, H	1	M, M	1	L, M	1	H, M
4.5	8 Dec 92	1	H, H	1, 1	M	1, 1	L	1	H, L
4.5	15 Dec 92	1	M	1	NA	2	H	1	M
4.5	22 Dec 92	2	H, M	1	M, M	1	L2, H	1	H, H
4.5	12 Jan 93	1	M, M	1	L, H	1	H, H	1	M, L
4.5	19 Jan 93	1	H, M	1	M, H	1	L, H	1	H, L
4.5	2 Feb 93	1	M, L	1	L, M	1	H, M	1	M, H
4.5	9 Feb 93	1	L, M	1	H, H	1	M, H	1	L, L
4.5	23 Feb 93	1	H, M, L	1	H, M, L2	1	H, M, L	1	H, M, L
4.5	2 Mar 93	2	M3, L	1	L2, M2	2	H2, M4	2	M4, H
4.5	9 Mar 93	1	M, M	1	L, H	1	H, H	1	M, L
4.5	16 Mar 93	1	L, M	1	H, H	1	M, H	1	L, L
4.5	6 Apr 93	1	M, M	1	L, H	1	H, M	1	M, L
4.5	13 Apr 93	1	L, M	1	H, H	1	M, H	1	L, L
3.0	20 Apr 93	1	H, M	1	M, H	1	L, H	1	H, L
2.5	27 Apr 93	1	H, M	1	M, H	1	L, H	1	H, L
2.5	18 May 93	1	H, M	1	M, H	1	L, H	1	H, L
2.5	1 Jun 93	1	M, M	1	L, H	1	H, H	1	M, L
2.5	29 Jun 93	2	M, M	1	L, H	1	H, H2	1	M, L
4.5	29 Jun 93	1	M, M	1	L, H	1	H, H	1	M, L
4.5	13 Jul 93	2	L2	2	H2	3	M3	2	L3
6.0	13 Jul 93		M		H		H2		L2
4.5	27 Jul 93	1	M, M	1	L, H	1	H, H	1	M, L

Table 2 (cont'd). FOIDS fence intrusions.

Sensitivity	*Date*	*Panel 31*	*Post 31*	*Panel 32*	*Post 32*	*Panel 33*	*Post 33*	*Panel 34*	*Post 34*
4.75	6 Oct 92	1	L, H	1	H, L	1	M, M	1	L, H
4.75, 4.5	15 Oct 92			1, 1	M, M			1, 1	L, L
4.5	3 Nov 92	1	L, H	1, 1	H	1	M, M	1, 1	L
4.5	17 Nov 92	1	H	1	M, H	1	L, L	1	H, M
4.5	24 Nov 92	1	L	1	L, L	1	H, H	1	M, H
4.5	8 Dec 92	1	L	1, 1	L	1, 1	H	2	M, M
4.5	15 Dec 92	1	L	1	H	1	M	1	L2
4.5	22 Dec 92	1	L	2	L, L	1	H, M	2	M, M
4.5	12 Jan 93	1	L, L	1	H, M	1	M, M	1	L, H
4.5	19 Jan 93	1	M, L	1	L, M	1	H, M	1	M, H
4.5	2 Feb 93	1	L, H	1	H, L	1	M, L	1	L, M
4.5	9 Feb 93	1	H, L	1	M, M	1	L, M	1	H, H
4.5	23 Feb 93	1	H, M, L	1	H, M, L	1	H, M, L	1	H, M, L
4.5	2 Mar 93	5	L3, H2	0 (5)	H, L3	2	M, L3	5	L0 (5), M0 (5)
4.5	9 Mar 93	2	L2, L	2	H, M2	1	M, M	1	L, H
4.5	16 Mar 93	1	H, L	1	H, M2	1	M, M	1	L, H2
4.5	6 Apr 93	1	L, L	1	H, M	1	M, M	1	L, H
4.5	13 Apr 93	1	H, L	1	M, M	1	L, M	1	H, H
3.0	20 Apr 93	1	M, L	1	L, M	1	H, M	1	M, H
2.5	27 Apr 93	1	M, L	1	L, M	1	H, M	1	M, H
2.5	18 May 93	1	M, L	1	L, M	1	H, M	1	M, H
2.5	1 Jun 93	1	L, L	1	H, M	1	M, M	1	L, H
2.5	29 Jun 93	1	L2, L2	1	H, M2	1	M, M	1	L, H
4.5	29 Jun 93	1	L, L	1	H, M	1	L, M	1	H, H
4.5	13 Jul 93	1	H2	3	M3, M2	3	L4, M3	5	H, H
6.0	13 Jul 93		L		M2		M		H
4.5	27 Jul 93	1	L, L	1	H, M	1	M, M	1	L, H

Sensitivity	*Date*	*Panel 35*	*Post 35*	*Panel 36*	*Post 36*	*Panel 37*	*Post 37*	*Panel 38*	*Post 38*
4.75	6 Oct 92	1	H, L	1	M	1	L, M	1	H, M
4.75, 4.5	15 Oct 92			1, 1	H, H			1, 1	M, M
4.5	3 Nov 92	1	H, H	2, 1	M2	1	L2, L	1	H, M
4.5	17 Nov 92	1	M, H	1		1	H, M	1	M, H
4.5	24 Nov 92	1	L, M	1	H, M	1	M, L	1	L, H
4.5	8 Dec 92	1	L, M	1, 1	H	1	M3, H	2, 1	L
4.5	15 Dec 92	2	H	3	M4	4	L2	1	H
4.5	22 Dec 92	1	L, H	2	H, H2	1	M3, L	1	L, M
4.5	12 Jan 93	1	H, H	1	M, L	1	L, L	1	H, M
4.5	19 Jan 93	1	L, H	1	H, L	1	M, L	1	L, M
4.5	2 Feb 93	1	H, M	1	M, H	1	L, H	1	H, L2
4.5	9 Feb 93	1	M, H	1	L, L	1	H, L	1	M, M
4.5	23 Feb 93	1	H, M, L	1	H, M, L	2	H, M, L	1	H, M, L
4.5	2 Mar 93	4	H3, M3	1	M2, H0 (5)	1	L0 (5), H4	3	H, L3
4.5	9 Mar 93	2	H, H	1	M, L	1	L, L4	1	H, M
4.5	16 Mar 93	1	H, H	1	M, L	1	L, L	1	H, M
4.5	6 Apr 93	1	H, H	1	M, L	1	L, L	1	H, M
4.5	13 Apr 93	1	M, H	1	L, L	1	H, L	1	M, M
3.0	20 Apr 93	1	L, H	1	H, L	1	M, L	1	L, M
2.5	27 Apr 93	1	L, H	1	H, L	2	M2, L2	1	L, M
2.5	18 May 93	1	L, H	2	H, L	2	M, L	1	L, M
2.5	1 Jun 93	1	H, H	1	M, L	1	L3, L	1	H, M
2.5	29 Jun 93	1	H, H	1	M, L	1	L, L	1	H, M
4.5	29 Jun 93	1	M, H	1	L, L	1	H, L	1	M, M
4.5	13 Jul 93	0 (5)	M0 (5), H5	0 (5)	L0 (5), L0 (5)	0 (5)	H2, L0 (5)	0 (5)	M0 (5), M3
6.0	13 Jul 93		H2		L3		L4		M
4.5	27 Jul 93	1	H, H	1	M, L	1	L, L	1	H, M
4.75	6 Oct 92	1	M, H	1	L, H	1	H, M	1	H, M, L

Table 2 (cont'd).

Sensitivity	*Date*	*Panel 39*	*Post 39*	*Panel 40*	*Post 40*	*Panel 41*	*Post 41*	*Panel 42*	*Post 42*
4.75, 4.5	15 Oct 92			1, 1	L, L			1, 1	H, M, L, H, M, L
4.5	3 Nov 92	1, 1	M	1	L2, H2	2, 1	H2	1	H, M, L2
4.5	17 Nov 92	1	L, L	1	H, M	2	M, H	2	H, M, L2
4.5	24 Nov 92	1	H, H	1	M, M	1	L, M	1	H, M, L2
4.5	8 Dec 92	2	H, H	3, 1	M3	3, 4	L0 (6)	2	H, M2, L2
4.5	15 Dec 92	3	M2	3	L	3	H0 (4)	2	H, M, L3
4.5	22 Dec 92	1	H, M	1	M, H3	2	L2	1	H, M, L3
4.5	12 Jan 93	1	M, M	1	L, H	2	H, H	2	H, M,L
4.5	19 Jan 93	1	H, M	1	M, H	1	L, H	1	H, M, L
4.5	2 Feb 93	1	M, L	1	L, M	1	H, M	1	H, M, L
4.5	9 Feb 93	1	L, M	1	H, H	1	M, H	1	H, M3, L
4.5	23 Feb 93	1	H, M, L	1	H, M, L	1	H2, M, L2	1	H, M, L
4.5	2 Mar 93	5	M0 (5), L	4	L0 (5), M2	0 (5)	H0 (5), M0 (5)	0 (5)	H, M0 (5), L0 (5)
4.5	9 Mar 93	1	M, M	1	L, H	2	H, H	1	H, M2, L
4.5	16 Mar 93	1	M, M	1	L, H	1	H, H	1	H, M, L2
4.5	6 Apr 93	1	M, M	1	L, H	1	H, H	1	H, M, L
4.5	13 Apr 93	1	L, M	1	H, H	1	M, H	1	H, M2, L
3.0	20 Apr 93	1	H, M	1	M, H	1	L, H	1	H, M3, L
2.5	27 Apr 93	1	H, M	1	M, H	1	L, H	2	H, M, L3
2.5	18 May 93	1	H, M	2	M, H	1	L, H	2	H, M3, L3
2.5	1 Jun 93	1	M, M	1	L, H	1	H, H2	1	H, M, L4
2.5	29 Jun 93	1	M, M	1	L, H	1	H, H	1	H, M2, L3
4.5	29 Jun 93	1	L, M	1	H, H	1	M, H	1	H, M, L
4.5	13 Jul 93	5	L0 (5), M3	0 (5)	H0 (5), H2	4	M0 (5), H0 (5)	5	H2, M0 (5), L0 (5)
6.0	13 Jul 93		M		H		H		
4.5	27 Jul 93	1	M, M	1	L, H	1	H, H	1	H, M, L

Table 3. M106 fence intrusions.

Date	*Post 7*	*Panel 8*	*Post 8*	*Panel 9*	*Post 9*	*Panel 10*	*Post 10*
6 Oct 92	H	1	M	1	L	1	H
15 Oct 92		1				5	M
3 Nov 92	H	1	M	1, 1	L	1	H, H
17 Nov 92	M, M	1	L, M	1	H, L3	1	M, M
24 Nov 92	L, M	1	H, L	1	M3, L2	1	L, H
8 Dec 92	L, H	2	H4, H2	1, 1	M	1, 1	L
15 Dec 92	H, M	1	M2, H	1	L2, H	1	H, L
22 Dec 92	M2, L	1	L, M	2	H, M2	2	M, H2
12 Jan 93	H, M	1	M, M	2	L3, H	1	H, H
19 Jan 93	L, M	1	H, M2	2	M2, H	1	L, H
2 Feb 93	H, M	2	M2, M	1	L2, H	1	H, H
9 Feb 93	M, M	1	L, M	1	H, H	1	M, H
23 Feb 93	H, M, L0*	1	H, M, L0	1	H, M, L0	2	H, M, L
2 Mar 93	H, M	2	M4, M	1	L2, H	1	H, H2
9 Mar 93	H, M	1	M, M2	1	L, H	1	H, H
16 Mar 93	M,M	1	L, M4	1	H, H	1	M, H2
6 Apr 93	H, M	2	M2, M	1	L2, H	1	H, H
13 Apr 93	M, M	1	L2, M	1	H, H	3	M, H
20 Apr 93	L, M2	1	H, M2	1	M, H	2	L, H
27 Apr 93	L, M	2	H, M	1	M2, H	3	L, H
18 May 93	L, M	1	H, M	1	M, H	2	L, H
1 Jun 93	H, M	2	M2, M	1	L, H	1	H,H
29 Jun 93	H, M	1	M, M	1	L, H	1	H, H
13 Jul 93	M2, M	1	L, M	1	H, H	2	M, H
27 Jul 93	H, M2	1	M, M2	1	L2, H	2	H, H

*Tapped once, no alarm.

Table 3 (cont'd). M106 fence intrusions.

Date	*Panel 11*	*Post 11*	*Panel 12*	*Post 12*	*Panel 13*	*Post 13*	*Panel 14*	*Post 14*
6 Oct 92	1	M	1	L	1	H	NA	M
15 Oct 92			0*				NA	
3 Nov 92	1, 1	M	1	L2, M	1, 1	H	NA	M, L
17 Nov 92	1	L2, H	1	H, L3	1	M, M	NA	L2, H
24 Nov 92	1	H, M	1	M	1	L, M	NA	H
8 Dec 92	1	H2, H	2, 2	M2	1	L, H	NA	H
15 Dec 92	1	M, L	1	L, M	1	H2, M	NA	M2, H
22 Dec 92	1	L2, H	1	H, L	1	M, L	NA	L, M
12 Jan 93	1	M, L	1	L, L	1	H, M	1	M, M
19 Jan 93	1	H, L3	1	M, L	1	L2, M	3	H, M
2 Feb 93	1	M, L	1	L, L	1	H, M	1	M, M
9 Feb 93	1	L, L	1	H, L	1	M, M	1	L, M
23 Feb 93	1	H, M2, L	1	H, M, L0	1	H, M2, L0	1	H, M, L
2 Mar 93	1	M, L	1	L2, L	1	H, M3	1	M, M
9 Mar 93	1	M, L2	1	L, L2	1	H, M	1	M, M
16 Mar 93	1	L, L2	1	H, L	1	L, M	2	H2, M
6 Apr 93	1	M, L	2	L, L	1	H, M	1	M, M
13 Apr 93	1	L, L	1	H, L	1	M, M	1	L, M
20 Apr 93	1	H, L2	1	M, L	1	L, M2	1	H, M
27 Apr 93	1	H, L2	2	M, L	1	L, M	1	H, M2
18 May 93	1	H, L2	1	M, L	1	L3, M	1	H, M2
1 Jun 93	1	M, L	1	L4, L	1	H, M	1	M, M
29 Jun 93	1	M, L	1	L, L	1	H, M	1	M, M
13 Jul 93	1	L, L	1	H, L	1	M, M	1	L, M
27 Jul 93	1	M, L	1	L, L2	1	H, M2	1	M, M

Date	*Panel 15*	*Post 15*	*Panel 16*	*Post 16*	*Panel 17*	*Post 17*	*Panel 18*	*Post 18*
6 Oct 92	1	L	1	H	1	M	1	L
15 Oct 92			1	H			1	M
3 Nov 92	1, 1	L	1	H, H	1, 1	M	1,1	L2
17 Nov 92	1	H, L	6	M, M	1	L, H	1	H, L
24 Nov 92	1	M, H	1	L3, M3	1	H, L	1	M2, L
8 Dec 92	1	M, H	1, 1	L3	1	H2, L	1, 1	M
15 Dec 92	2	L, H	1	H2, L	2	M, L	1	L3, M
22 Dec 92	1	H, M	1	M2, H	1	L4, H	1	H, L
12 Jan 94	1	L, H	1	H, H	1	M, L	1	L, L
19 Jan 94	1	M, H	1	L, H	1	H, L	1	M, L
2 Feb 94	1	L2, H	1	H, H2	1	M, L	1	L, L
9 Feb 94	1	H, H	1	M, H	1	L, L	1	H, L
23 Feb 94	1	H, M2, L0	1	H, M, L	1	H, M, L	1	H, M, L
2 Mar 93	1	L, H	2	H, H	1	M, L	1	L2, L
9 Mar 93	1	L, H	1	H, H	1	M, L	1	L, L
16 Mar 93	1	M, H	2	L, H2	1	H, L2	3	M, L
6 Apr 93	1	L, H	1	H, H	1	M, L	1	L, L
13 Apr 93	1	H, H	1	M, H	1	L, L	1	H2, L
20 Apr 93	1	M, H	1	L, H2	1	H, L	2	M, L
27 Apr 93	1	M2, H	1	L, H	2	H, L2	1	M2, L
18 May 93	1	M, H	1	L3, H	1	H, L2	1	M, L
1 Jun 93	1	L, H	1	H, H	2	M, L	1	L3, L2
29 Jun 93	1	L, H	1	H, H	1	M, L2	1	L, L2
13 Jul 93	3	H, H	1	M, H	1	L, L	1	H, L
27 Jul 93	1	L, H	1	H, H	1	M, L	2	L, L

Table 3 (cont'd).

Date	*Panel 19*	*Post 19*	*Panel 20*	*Post 20*	*Panel 21*	*Post 21*	*Panel 22*	*Post 22*
6 Oct 92	1	H	1	M	1	L	1	L
15 Oct 92			1	L			1	H
3 Nov 92	2, 1	H2	1	M, L	1, 1	L	1	H, M
17 Nov 92	1	M, M	1	L, H	1	H, L2	1	M
24 Nov 92	1	L2, M	1	H	1	M, L	1	L
8 Dec 92	1	L, M	1, 1	H	1	M, H	1	L, L2
15 Dec 92	2	H, M	1	M, H	1	L , H2	3	H
22 Dec 92	1	M, M	1	L2, M, M	2	H, H	1	M, H
12 Jan 93	1	H, M	1	M, M	1	L, H	1	H, H
19 Jan 93	1	L, M	1	H, M	2	M, H	3	L, H
2 Feb 93	1	H, M	1	M, M	1	L, H	2	H, H2
9 Feb 93	1	M, M	1	L, M	2	H, H	1	M3, H
23 Feb 93	1	H, M2, L	2	H, M, L	1	H, M, L	1	H, M, L
2 Mar 93	1	H, M2	1	M, M	2	L, H	1	H, H
9 Mar 93	1	H, M	1	M, M	1	L, H	1	H, H
16 Mar 93	1	L, M2	1	H, M3	1	M3, H	1	L, H
6 Apr 93	1	H, M	1	M, M	1	L, H	2	H, H
13 Apr 93	1	M3, M	1	L, M	3	H, H2	1	M, H
20 Apr 93	2	L, M	1	H, M	1	M, H	1	L, H
27 Apr 93	2	L2, M	1	H, M	1	M, H	1	L3, H
18 May 93	1	L, M	1	H, M	1	M2, H	2	L, H
1 Jun 93	1	H, M	1	M, M	1	L, H	1	H, H
29 Jun 93	1	H, M	1	M, M	1	L2, H	1	H, H
13 Jul 93	1	M, M	1	L, M	1	H, H	1	M, H
27 Jul 93	1	H, M	2	M, M	1	L, H	1	H, H

Table 4. FOIDS buried intrusions.

Date	*Soil, S to N*	*Soil, N to S*	*Sensitivity*
6 Oct 92	0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0	—	7.5
6 Oct 92	1, 0, 0, 1, 1, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0	9.0
15 Oct 92	0, 1, 1, 1, 0, 1, 1, 0, 0, 0, 1, 1	0, 0, 1, 0, 0, 0, 0, 0, 1, 1, 1, 1	7.5
3 Nov 92	0, 1, 1, 1, 0, 0, 0, 0, 1, 0, 1, 0	1, 0, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1	7.5
17 Nov 92	0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0	0, 0, 0, 0, 0, 0, 0, 1, 1, 1, 0	7.5
24 Nov 92	0, 1, 0, 0, 1, 0, 1, 1, 0, 0, 1, 0	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 0	7.5
8 Dec 92	1, 0, 0, 0, 0, 0, 1, 1, 1, 1, 1, 1	0, 0, 1, 1, 1, 1, 1, 1, 1, 0, 0, 1	7.5
15 Dec 92	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	7.5
22 Dec 92	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	7.5
12 Jan 93	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	7.5
19 Jan 93	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	7.5
2 Feb 93	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	7.5; 9.0+
9 Feb 93	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	9.0+
2 Mar 93	0 (E to W)	0 (W to E)	9.0+
9 Mar 93	0 (E to W)	0 (W to E)	9.0+
6 Apr 93	1 (E to W)		9.0+
13 Apr 93	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	9.0+; 7.5
13 Apr 93	1, 1, 1		5.0
13 Apr 93	1, 1, 1		2.5
13 Apr 93	0, 0, 0		1.0
13 Apr 93	1, 1, 1		2.0 (left at 7.5)
20 Apr 93	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1	6.5
27 Apr 93	1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1	1, 1, 1, 0, 0, 1, 1, 1, 1, 1, 1, 1	5.5
18 May 93	1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1,	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	5.5
1 Jun 93	1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1, 1	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,	5.5
29 Jun 93	1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1	0, 0, 1, 0, 0, 0, 0, 0, 1, 1, 1, 1	4.5
29 Jun 93	1, 1, 0, 1, 1, 1, 1, 1, 0, 0, 1, 1	0, 0, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1	7.5
13 Jul 93	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,	0, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1	7.5
27 Jul 93	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	1, 1, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1	7.5

Table 4 (cont'd). FOIDS buried intrusions.

Date	*Gravel, S to N*	*Gravel, N to S*	*Sensitivity*
6 Oct 92	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	—	7.5
6 Oct 92	—	—	—
15 Oct 92	1, 1, 1, 1, 1, 1, 1, 1, 1,1, 1, 1	1, 1, 1, 1, 1, 1, 1, 1, 1,1, 1, 1	7.5
3 Nov 92	1, 1, 1, 1, 1, 1, 1, 1, 1,1, 1, 1	1, 1, 1, 1, 1, 1, 1, 1, 1,1, 1, 1	7.5
17 Nov 92	0, 1, 1, 1, 1, 0, 0, 1, 0, 1, 1, 1	0, 0, 1, 0, 0, 0, 0, 1, 0, 0, 1, 0	7.5
24 Nov 92	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	7.5
8 Dec 92	0, 0, 0, 1, 0, 1, 0, 0, 0, 1, 0, 0	0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0	7.5
15 Dec 92	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	7.5
22 Dec 92	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	7.5
12 Jan 93	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	7.5
19 Jan 93	0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1	1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1, 1	7.5
2 Feb 93	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	7.5; 9.0+
9 Feb 93	0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 1, 0, 1, 0, 0, 0	9.0+
2 Mar 93	0 (E to W)	0 (W to E)	9.0+
9 Mar 93	0 (E to W)	0 (W to E)	9.0+
6 Apr 93	0 (E to W)		9.0+
13 Apr 93	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	9.0+; 7.5
13 Apr 93	1, 1, 1		2.0 (left at 7.5)
20 Apr 93	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	6.5
27 Apr 93	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	5.5
18 May 93	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	5.5
1 Jun 93	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	5.5
29 Jun 93	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	4.5
29 Jun 93	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	7.5
13 Jul 93	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	7.5
27 Jul 93	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	7.5

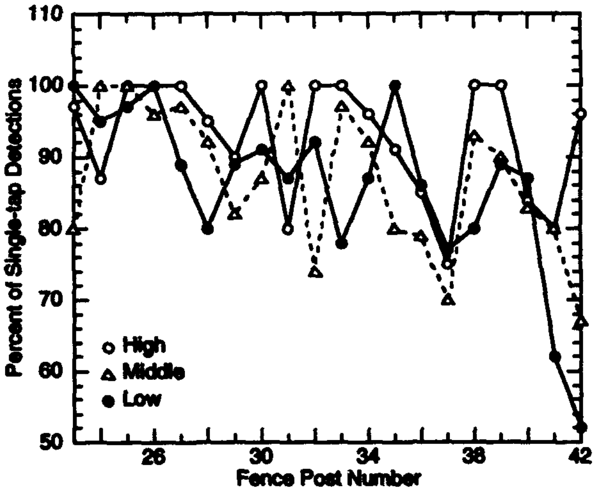

Figure 2. FOIDS single-tap detections: Posts.

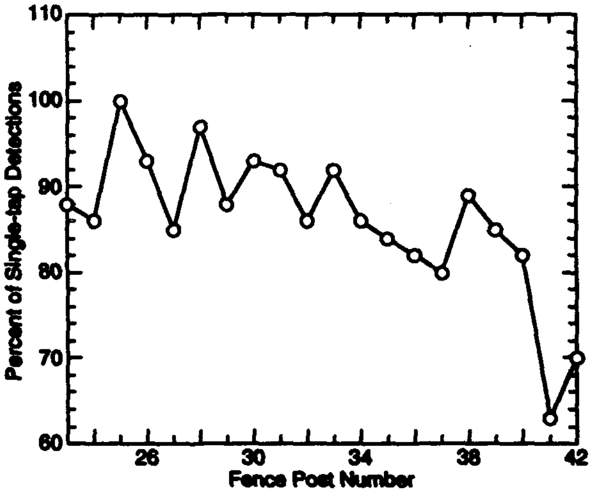

Figure 3. FOIDS single-tap detections: Panels.

(nuisance) alarms. Detection generally occurred at the first tap at all locations (Table 2). Exceptions are panel 41 and post 41, which are more extensively braced because they border a fiberglass panel (panel 42). A metal pipe extends horizontally between posts 40 and 41 near the top of panel 41.

Table 7 gives a breakdown by location of the percentage of detections of a single tap. This is plotted in Figures 2 and 3 for post and panel locations, respectively. The lower detection rates at post 41 and panel 41 are evident. Excluding posts 41 and 42, there is still an indication that the percentage of single-tap detections decreases with distance from the processor, which is indicated by increasing post number. This is seen more clearly in Figure 3, which shows a clear trend of decreasing detection rate of

Table 5. M106 buried intrusions.

Date	*Soil, S to N*	*Soil, N to S*
17 Nov 92	1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1
24 Nov 92	0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 1	0, 0, 0, 1, 1, 0, 1, 0, 0, 0, 0, 0
8 Dec 92	1, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1
15 Dec 92	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1
22 Dec 92	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
12 Jan 93	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
19 Jan 93	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
2 Feb 93	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
9 Feb 93	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
2 Mar 93	0 (E to W)	0 (W to E)
9 Mar 93	0 (E to W)	0 (W to E)
6 Apr 93	0, 0 (E to W)	
13 Apr 93	0, 0, 0, 1, 0, 0, 1, 1, 1, 0, 1, 1	1, 0, 1, 1, 1, 1, 1, 0, 0, 0, 0, 1
20 Apr 93	0, 0, 0, 1, 0, 0, 1, 1, 0, 1, 1, 1	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 1
27 Apr 93	0, 0, 0, 0, 0, 0, 1, 1, 1, 0, 0, 1	1, 0, 0, 0, 1, 0, 0, 0, 0, 0, 1, 1
18 May 93	1, 0, 0, 0, 1, 1, 1, 1, 0, 0, 0, 0	0, 1, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0
1 Jun 93	0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0	0, 0, 1, 1, 1, 0, 0, 0, 0, 0, 0, 1
29 Jun 93	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
13 Jul 93	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
27 Jul 93	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0

Date	*Gravel, S to N*	*Gravel, N to S*
17 Nov 92	0, 0, 1, 0, 1, 1, 1, 1, 0, 0, 0, 1	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
24 Nov 92	0, 1, 0, 1, 1, 0, 1, 1, 1, 0, 1, 1	1, 0, 1, 1, 1, 1, 1, 0, 1, 1, 1, 1
8 Dec 92	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
15 Dec 92	1, 1, 0, 0, 1, 1, 0, 0, 1, 0, 0, 1	1, 0, 0, 1, 1, 1, 1, 0, 1, 0, 1, 1
22 Dec 92	0, 0, 1, 0, 1, 1, 1, 1, 1, 1, 0, 0	1, 0, 0, 1, 1, 0, 1, 1, 0, 0, 0, 0
12 Jan 93	0, 0, 1, 1, 0, 1, 0, 1, 0, 1, 0, 1	1, 0, 1, 1, 0, 1, 0, 0, 0, 0, 0, 0
19 Jan 93	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
2 Feb 93	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
9 Feb 93	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0	0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0
2 Mar 93	0 (E to W)	0 (W to E)
9 Mar 93	0 (E to W)	0 (W to E)
6 Apr 93	0 (E to W)	
13 Apr 93	1, 1, 1, 1, 1, 1, 1, 1, 1, 0, 1, 1	1, 1, 1, 0, 1, 1, 1, 1, 1, 0, 1, 1
20 Apr 93	0, 0, 1, 1, 1, 1, 0, 1, 0, 1, 0, 0	1, 1, 1, 1, 1, 1, 1, 0, 1, 1, 0, 1
27 Apr 93	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	1, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1, 0
18 May 93	1, 1, 1, 1, 1, 0, 1, 1, 0, 1, 1, 1	1, 0, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1
1 Jun 93	0, 0, 1, 0, 1, 0, 1, 1, 1, 1, 1, 0	1, 1, 1, 0, 1, 1, 1, 0, 1, 0, 0, 0
29 Jun 93	1, 1, 1, 1, 0, 1, 1, 0, 0, 0, 0, 0	1, 1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 1
13 Jul 93	0, 0, 1, 1, 1, 0, 1, 1, 1, 0, 1, 1	1, 1, 1, 0, 0, 0, 1, 0, 1, 1, 0, 1
27 Jul 93	0, 1, 0, 1, 0, 1, 1, 1, 1, 0, 0, 1	1, 1, 1, 1, 0, 1, 1, 0, 1, 0, 1, 0

panel taps with increasing distance from the processor.

On 23 Feb the snow along the chain-link fence was deep enough to cover the lower FOIDS cable by 1 to 6 cm from post 34 to post 40. Taps at the "low" post location were made by swinging the metal rod through the snow. Although this must have reduced the impact to the fence by slowing the rate of movement of the rod, each tap was detected. A similar result was obtained on 16 Mar when the lower FOIDS cable was covered by 1–16 cm along its length and taps were again made through the snow; all "low" taps except that at the fiberglass panel were detected.

The worst record of FOIDS detections during the winter is that of 2 Mar 1993, a day characterized by rapidly increasing air temperature (–18° to 5°C in 8 hours). At three panel locations and five post locations (excluding posts 41 and 42), there were no detections even after five taps of increasing force. This was a remarkable situation for the FOIDS, particularly as tap 5 qualified as a bashing impact. It suggested that the FOIDS processor was adversely affected by the rapid rise in temperature. The FOIDS had previously been reliable in the range of temperatures it experienced on that day, but it had not been subjected to such a high rate of temperature change during prior controlled intrusions. Mason and Hanger should be queried as to whether they have subjected their electronics to thermal shock testing and the outcome.

Beginning on 20 Apr 1993, the sensitivity of the FOIDS was progressively reduced, to decrease the number of nuisance alarms. The sensitivity was changed to 3 on 20 Apr and to 2.5 on 27 Apr; it remained at 2.5 until 29 Jun. A consequence of the reduction in sensitivity is that fewer alarms occurred after a single tap to the fence (Table 2).

On 29 Jun the regular series of fence taps was done with the FOIDS at a sensitivity of 2.5. The sensitivity was then increased to 4.5, the value typical for the winter months, and the series of fence taps was repeated. The detection capability improved markedly, from 90 to 100% alarms at a single tap at the center of the fence panels and from 83% to 100% alarms at a single tap near the fence posts (Table 2). This reliable detection capability was, however, accompanied by an unacceptable increase in the number of nuisance alarms each day. (Refer to *Nonintruder Alarms* below.)

At the time, the larger number of nuisance alarms in summer vs. winter, at the same FOIDS sensitivity, was attributed to a change in the coupling between the sensor cable and the fence fabric. At the higher summer temperatures, the fence fab-

Table 6. IPID intrusions.

Date	*3 m**	*6 m*	*9 m*	*12 m*	*15 m*	*18 m*	*21 m*	*24 m*	*27 m*	*30 m*	*33 m*	*36 m*	*39 m*	*41 m*	*45 m*	*48 m*
8 Dec 92	1	1,1	1,1	1	1	1,1	1	1,1	1	1	1,1	1	1,1	1	1	1,1
15 Dec 92	1,1	1	1,1	1	1,1	1	1,1	1	1,1	1	1,1	1	1	1,1	1	1
22 Dec 92	1	1	1,1	1	1	1,1	1,1	1	1	1,1	1,1	1	1,1	1	1,1	1
12 Jan 93	1	1,1	1	1,1	1	1,1	1	1,1	1	1,1	1	1,1	1	1,1	1	1
19 Jan 93	1	1	1,1	1	1,1	1,1	1	1,1	1,1	1	1	1,1	1	1	1	1,1
2 Feb 93	1	1	1,1	1,1	1	1	1,1	1,1	1	1	1	1,1	1,1	1	1,1	1
9 Feb 93	1	1,1	1	1,1	1	1,1	1	1,1	1	1,1	1	1,1	1	1,1	1	1
16 Feb 93	1	1,1	1	1,1	1	1,1	1	1,1	1	1,1	1	1,1	1	1,1	1	1
23 Feb 93	1	1	1,1	1,1	1	1,1	1	1,1	1,1	1	1	1,1	1	1	1,1	1
2 Mar 93	1	1	1	1,1	1	1,1	1,1	1	1	1,1	1,1	1,1	1	1,1	1	1
9 Mar 93	1,1	1	1,1	1	1,1	1	1,1	1	1,1	1	1,1	1	1	1,1	1	1
6 Apr 93	1	1	1,1	1	1,1	1	1	1,1	1,1	1	1,1	1	1	1,1	1	1,1
13 Apr 93	1	1	1,1	1	1	1,1	1	1	1,1	1	1,1	1,1	1	1,1	1,1	1
20 Apr 93	1	1,1	1	1,1	1	1,1	1	1,1	1	1,1	1	1,1	1,1	1	1	1
27 Apr 93	1	1	1,1	1	1	1,1	1	1	1,1	1	1	1,1	1,1	1	1,1	1,1
18 May 93	1	1	1,1	1	1,1	1	1,1	1	1,1	1	1,1	1	1	1,1	1	1,1
29 Jun 93	1	1	1	1,1	1	1,1	1,1	1,1	1	1,1	1	1,1	1	1,1	1	1
13 Jul 93	1	1	1	1	1,1	1	1,1	1,1	1	1,1	1,1	1	1,1	1	1	1,1
27 Jul 93	1	1,1	1	1,1	1	1,1	1	1,1	1	1,1	1	1,1	1	1,1	1	1

*Distance from east unit.

Table 7. FOIDS single-tap detections.

	High		*Middle*		*Low*			*Center*	
Post	*Ratio*	*%*	*Ratio*	*%*	*Ratio*	*%*	*Panel*	*Ratio*	*%*
23	30/31	97	8/10	80	9/9	100	23	23/26	88
24	13/15	87	15/15	100	21/22	95	24	24/28	86
25	8/8	100	9/9	100	31/32	97	25	26/26	100
26	16/16	100	23/24	96	13/13	100	26	25/27	93
27	11/11	100	28/29	97	8/9	89	27	22/26	85
28	21/22	95	12/13	92	8/10	80	28	28/29	97
29	26/29	90	9/11	82	8/9	89	29	23/26	88
30	13/13	100	13/15	87	21/23	91	30	26/28	93
31	8/10	80	5/5	100	27/31	87	31	23/25	92
32	15/15	100	17/23	74	12/13	92	32	25/29	86
33	9/9	100	31/32	97	7/9	78	33	24/26	92
34	23/24	96	12/13	92	13/15	87	34	24/28	86
35	29/32	91	8/10	80	9/9	100	35	21/25	84
36	11/13	85	11/14	79	18/21	86	36	23/28	82
37	6/8	75	7/10	70	24/31	77	37	20/25	80
38	15/15	100	25/27	93	8/10	80	38	24/27	89
39	11/11	100	27/30	90	8/9	89	39	22/26	85
40	21/25	84	10/12	83	13/15	87	40	23/28	82
41	24/30	80	8/10	80	5/8	62	41	17/27	63
42	26/27	96	18/27	67	14/27	52	42	19/27	70

ric, the sensor cable, and the tiewraps attaching the cable to the fence are probably all somewhat less stiff. No further changes in detection capability were anticipated.

On 13 Jul, however, the FOIDS's detection capability was significantly worse, becoming almost nonexistent at the far range of its detection zone (Table 2). Its sensitivity was increased to 6, and there was great improvement in the number of alarms at a single fence tap. On 27 Jul, a cooler day, the detection capability of the FOIDS was excellent despite its sensitivity having been reduced to 4.5 again. It was not possible to do controlled intrusions (fence taps) on 27 Jul while maintaining the sensitivity at 6 because the FOIDS alarmed too frequently when the wind was blowing.

It is reasonable to conclude that two temperature-related effects determined the changes in detec-

Table 8. M106 Single-tap detections.

	High		*Middle*		*Low*			*Center*	
Post	*Ratio*	*%*	*Ratio*	*%*	*Ratio*	*%*	*Panel*	*Ratio*	*%*
7	13/13	100	22/26	85	7/8	88	—	—	—
8	7/9	78	20/30	67	6/8	75	8	19/25	76
9	24/24	100	4/8	50	5/14	36	9	22/25	88
10	28/31	90	9/9	100	8/8	100	10	17/26	65
11	9/10	90	12/13	92	16/24	67	11	25/25	100
12	7/7	100	8/9	89	23/30	77	12	21/26	81
13	12/13	92	21/25	84	6/9	67	13	25/25	100
14	9/10	90	26/29	90	6/7	86	14	15/17	88
15	25/25	100	7/9	78	11/13	85	15	23/25	92
16	27/31	87	6/8	75	6/9	67	16	23/26	88
17	9/10	90	12/12	100	20/25	80	17	22/25	88
18	5/6	83	8/10	80	25/31	81	18	24/27	89
19	11/12	92	23/27	85	6/8	75	19	21/25	84
20	10/10	100	29/30	97	7/8	88	20	24/26	92
21	23/25	92	6/8	75	12/14	86	21	20/25	80
22	28/29	97	6/7	86	8/10	80	22	20/25	80

tion capability of the fence-mounted FOIDS over the period 2 Oct to 27 Jul. There is an overall seasonal contrast related to the stiffness of the fence fabric, the rigidity of the fence posts (frozen ground anchors posts very well, provided they are not heaved by frost action), and thermal contraction or expansion of the FOIDS cable and tiewraps. The seasonal contrast essentially represents differences in the fence motion induced by fence taps or by wind loading and differences in the coupling between the sensor cable and the fence. The very poor detection capability on 13 Jul is attributed to heat-related effects on the FOIDS electronics.

There was one episode of icing during the controlled intrusions. It was a direct consequence of the additional horizontal bracing of the panels abutting the fiberglass panel (panel 42). Snow had apparently accumulated on the horizontal pipes spanning panels 41 and 43. When it melted as the pipe warmed, the meltwater ran down the aluminum wraps holding the chain-link fabric to each horizontal pipe and onto the fence fabric, where it froze. On 23 Feb the aluminum tiewraps and a 7- to 9-in.-square section of fence fabric (below where the tiewrap was attached to the fabric) were coated in ice perhaps 2 mm thick. Taps to the ice-coated portion of the fence fabric were not detected by the FOIDS. After the continuity of the ice coating was broken by cracking it, taps to the fabric (still ice-coated, but with ice of reduced rigidity) were reliably detected.

Fence-mounted M106

The M106 has several adjustable parameters. The initial settings were:

• Frequency window	100–327 Hz
• Sensitivity	30%
• Threshold	48%
• Event window	13 s
• Mask time	5 s
• Count	1
• Alarm relay	2 s

This means that signals in the frequency range of 100–327 Hz were integrated to an energy representation over a time period determined by a sensitivity setting of 30% (a high sensitivity prolongs the integration time, whereas a low sensitivity minimizes the amount of signal that is converted to an energy representation). The output of the integrator qualified as an event whenever its magnitude exceeded 48% (threshold) of full scale. Since the selected count was 1, an alarm should have occurred each time the optical detector generated a signal that exceeded the threshold value of the integrator. The sensitivity was increased to 40% on 3 Nov to increase the number of single-tap alarms. This lengthened the time period over which signal (or energy) was accumulated. The same parameter settings were used for the winter, post-winter transitional, and summer periods with no significant change in detection capability.

The M106 fence zone is shorter than that of the FOIDS and does not include a fiberglass panel. The M106 processor is located slightly north of post 22 (with this fence-mounted IDS, the higher the post or panel number is, the closer it is to the processor). A breakdown of single-tap alarms by location is given in Table 8 and plotted in Figures 4 and 5 for posts and panels, respectively. The percentage of single-

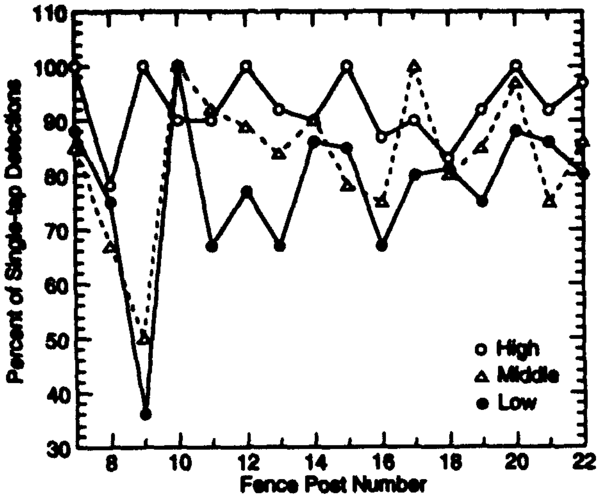

Figure 4. M106 single-tap detections: Posts.

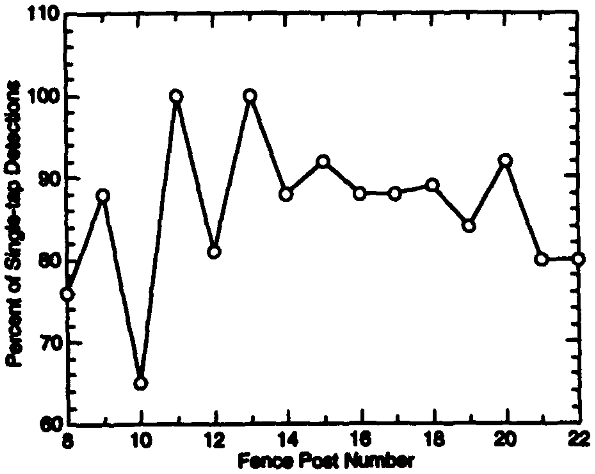

Figure 5. M106 single-tap detections: Panels.

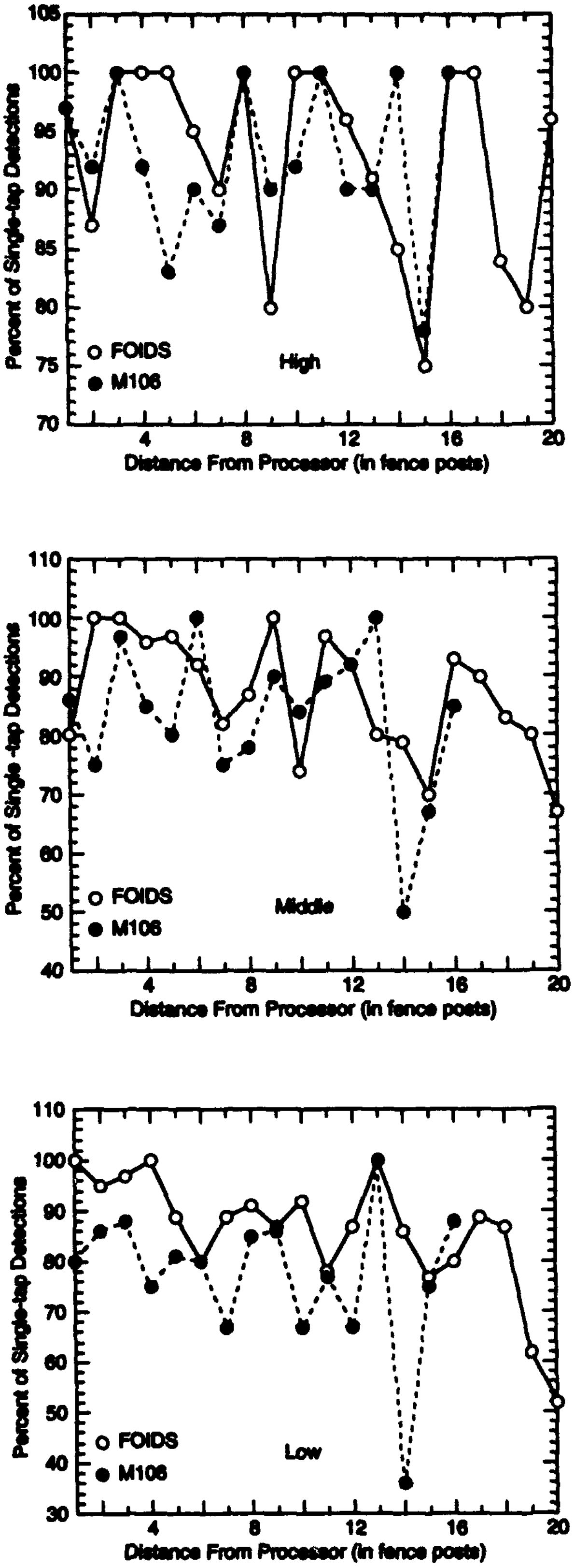

Figure 6. Dependence of single-tap detections at posts on distance.

tap detections at panel centers appears to be higher away from both the processor (panel 22) and the cable loop (panel 7). Taps at the "low" location adjacent to posts generally are the least reliable in producing alarms. However, on 16 Mar, when the M106 cable was 2–16 cm below the surface of the snow, a single tap caused an alarm at 8 of 10 "low" locations. There was no ice formation on the fence fabric within the M106 zone during the controlled intrusions.

Location-dependence of FOIDS and M106 detections

The percentage of single-tap detections as a function of distance from the processor is shown in Figures 6 and 7 for post and panel locations, respec-

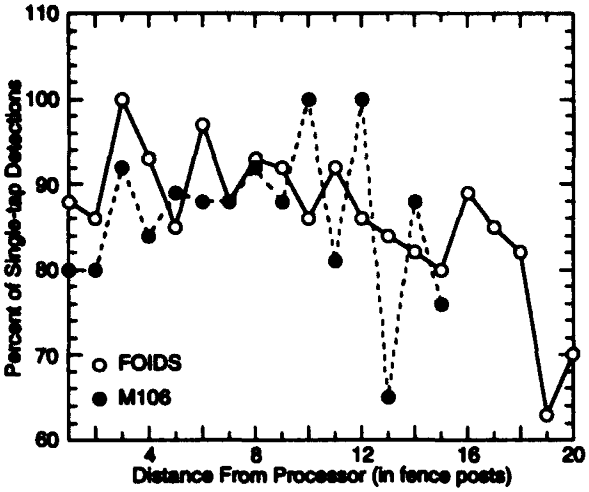

Figure 7. Dependence of single-tap detections at panels on distance.

tively. One difficulty in isolating a dependence on cable length (i.e., distance from the processor) is that the FOIDS zone is longer than the M106 zone. There is no consistency as to which IDS has a higher percentage of single-tap detections at fence panels. The FOIDS generally detects single taps at post locations more reliably than does the M106.

Buried FOIDS

Controlled intrusions with this IDS show a strong seasonal dependence (Tables 4 and 9). Detections of a person walking across the soil portion of the bed decreased as the soil froze, until eventually (mid-December) the intruder was never detected. The FOIDS continued to detect a person walking across the gravel portion of the bed despite the presence of a shallow snowcover as long as the gravel was not firmly bonded by ice. The poor detection results on 8 Dec 1992 were a direct consequence of the gravel layer being hard-frozen. Once the ice bonding the gravel had melted, good detectability resumed, even under conditions of deeper snowcover (19 Jan 1993). Eventually detection capability was lost as the snowcover deepened and as freeze-thaw snow layers of high rigidity formed. Both of these occurrences changed the characteristics (amplitude, frequency content) of the motion imparted to the snowcover by the intruder's footsteps. In turn, the motion induced in the gravel generated a signal in the sensor cable that no longer met the IDS processor's criteria for alarm generation.

On 9 Feb 1993 the snow on the gravel portion of the bed was removed to create a narrow clear path. The exposed gravel was hard-frozen. The intruder stomped across the cleared area four times and was detected twice. Earlier the intruder had walked across the snow-covered gravel at 24 locations and had been detected three times. Although snow removal seems to increase detectability, it also exposes the gravel to the cold winter air, which may lead to increased ice formation (if water is retained within the gravel) and eventually a reduction in system detectability.

The initial sensitivity of the FOIDS was 7.5. Two series of intruder crossings of the soil portion of the FOIDS bed were made at a sensitivity of 9 on 6 Oct; the higher sensitivity did not appreciably increase the system's detection rate, so the sensitivity was returned to 7.5. The sensitivity was increased to full range (9+) on 2 Feb 1993 following the system's failure to detect any of 12 crossings on the gravel portion of the bed. This did not improve the system's detectability.

On 2 and 9 Mar the intrusions were limited to two crossings of the gravel portion and two crossings of the soil portion. This was done to confirm that the intruder remained undetectable under the current site conditions. Crossings were resumed on 6 Apr while the ground was still snow-covered and frozen. There was no detection of a person walking across the gravel bed, and the only detection of a person crossing the soil bed occurred at a location where running meltwater had removed the snowcover and the person stepped directly on the soil.

By a week later (13 Apr), the snowcover was completely melted, and crossings left footprints in the damp soil. Detection of a walking intruder was excellent for both the gravel and soil portions of the FOIDS bed and at sensitivities of both 9+ and 7.5, its early winter value. Because nuisance alarms became too numerous, the sensitivity was subsequently decreased to 6.5 (20 Apr), 5.5 (27 Apr to 29 Jun), and 4.5 (29 Jun). The FOIDS reliably detected a person crossing the gravel bed despite the reductions in sensitivity, but the detections of crossings on soil were significantly lower in June. This is probably due to the combined effects of reduced sensitivity and the increased hardness of the dryer soil in summer.

On 29 Jun, crossings were made at sensitivities of 4.5 and 7.5. All crossings on gravel were detected. The detection of soil crossings improved from 25–42% to 75% at the higher sensitivity. Detections of gravel crossings remained excellent for the remainder of the evaluation period. FOIDS detection of crossings on soil was slightly less reliable. There was no occurrence of severely diminished detection capability on 13 Jul, the hottest day on which controlled intrusions were made.

Table 9. FOIDS vs. M106 detections of a walking intruder.

a. Ratio

Date	*FOIDS, soil*	*FOIDS, gravel*	*M106, soil*	*M106, gravel*
6 Oct 92	1/12	12/12	—	—
6 Oct 92	1/12, 3/12	—	—	—
15 Oct 92	7/13, 5/12	12/12, 12/12	—	—
3 Nov 92	5/12, 10/12	12/12, 12/12	—	—
17 Nov 92	1/12, 3/12	8/12, 3/13	1/12, 1/12	6/12, 0/12
24 Nov 92	5/12, 11/12	12/12, 12/12	2/12, 3/12	8/12, 10/12
8 Dec 92	7/12, 8/12	3/12, 1/12	2/12, 1/12	0/12, 0/12
15 Dec 92	0/12, 0/12	12/12, 12/12	0/12, 1/12	6/12, 8/12
22 Dec 92	0/12, 0/12	12/12, 12/12	0/12, 0/12	7/12, 5/12
12 Jan 93	0/12, 0/12	12/12, 12/12	0/12, 0/12	6/12, 4/12
19 Jan 93	0/12, 0/12	10/12, 11/12	0/12, 0/12	0/12, 0/12
2 Feb 93	0/12, 0/12	0/12, 0/12	0/12, 0/12	0/12, 0/12
9 Feb 93	0/12, 0/12	1/12, 2/12	0/12, 0/12	0/12, 0/12
2 Mar 93	0/1, 0/1	0/1, 0/1	0/1, 0/1	0/1, 0/1
9 Mar 93	0/1, 0/1	0/1, 0/1	0/1, 0/1	0/1, 0/1
6 Apr 93	1/1	0/1	0/0	0/0
13 Apr 93	12/12, 12/12	12/12, 12/12	6/12, 7/12	11/12, 10/12
20 Apr 93	12/12, 10/12	12/12, 12/12	6/12, 2/12	6/12, 10/12
27 Apr 93	10/12, 10/12	12/12, 12/12	4/12, 4/12	12/12, 9/12
18 May 93	11/12, 12/12	12/12, 12/12	5/12, 2/12	10/12, 10/12
1 Jun 93	11/12, 12/12	12/12, 12/12	1/12, 4/12	7/12, 7/12
29 Jun 93	3/12, 5/12	12/12, 12/12	0/12, 0/12	6/12, 11/12
29 Jun 93	9/12, 9/12	12/12, 12/12	—	—
13 Jul 93	12/12, 10/12	12/12, 12/12	0/12, 0/12	8/12, 7/12
27 Jul 93	12/12, 10/12	12/12, 12/12	0/12, 0/12	7/12, 8/12

b. Percentage

Date	*FOIDS, soil*	*FOIDS, gravel*	*M106, soil*	*M106, gravel*
6 Oct 92	8	100	—	—
6 Oct 92	8, 25	—	—	—
15 Oct 92	54, 42	100, 100	—	—
3 Nov 92	42, 83	100, 100	—	—
17 Nov 92	8, 25	67, 23	8, 8	50, 0
24 Nov 92	42, 92	100, 100	17, 25	67, 83
8 Dec 92	58, 67	25, 8	17, 8	0, 0
15 Dec 92	0, 0	100, 100	0, 8	50, 67
22 Dec 92	0, 0	100, 100	0, 0	58, 42
12 Jan 93	0, 0	100, 100	0, 0	50, 33
19 Jan 93	0, 0	83, 92	0, 0	0, 0
2 Feb 93	0, 0	0, 0	0, 0	0, 0
9 Feb 93	0, 0	8, 17	0, 0	0, 0
2 Mar 93	0, 0	0, 0	0, 0	0, 0
9 Mar 93	0, 0	0, 0	0, 0	0, 0
6 Apr 93	100	0	0	0
13 Apr 93	100, 100	100, 100	50, 58	92, 83
20 Apr 93	100, 83	100, 100	50, 17	50, 83
27 Apr 93	83, 83	100, 100	25, 25	100, 75
18 May 93	92, 100	100, 100	42, 17	83, 83
1 Jun 93	92, 100	100, 100	8, 25	58, 58
29 Jun 93	25, 42	100, 100	0, 0	50, 92
29 Jun 93	75, 75	100, 100	—	—
13 Jul 93	100, 83	100, 100	0, 0	66, 58
27 Jul 93	100, 83	100, 100	0, 0	58, 66

Buried M106

This IDS became available on 6 Nov 1992 following the replacement of its electronic module (removed 2 Oct). The initial processor settings were:

• Frequency	1–100 Hz
• Sensitivity	100%
• Threshold	17%
• Event window	5 s
• Mask time	0 s
• Count	2
• Alarm relay	1 s

(See *Fence-mounted M106* above for an explanation of the settings.) Its detection of a walking intruder on either the soil portion or the gravel portion of the bed was poor (Tables 5 and 9), but the gravel detections were more numerous and persisted later into the winter. When no intruder crossings on gravel were detected on 19 Jan 1993, the threshold was reduced to 8%, thereby allowing a smaller quantity of integrated signal energy to qualify as an event. Detection capability did not improve.

Intrusions resumed on 13 Apr with the settings unchanged since 19 Jan. Detection of a person walking on the gravel bed was good although rarely 100%, but detection of a person walking on the soil bed was usually less than 50%. On 21 May the manufacturer visited SOROIDS and adjusted the settings of the buried M106 to:

• Frequency	2–100 Hz
• Sensitivity	62%
• Threshold	50%

The percentage of gravel detections was now lower, mostly 50–66%. A person walking across the soil bed on 1 Jun was detected, when the ground was wet, but all crossings on later days when the soil was dry and hard went undetected.

IPID

The IPID at SOROIDS has detected every intrusion by a walking person since it became operational on 25 Nov 1992 (Table 6). It is configured as a vertically stacked set of two banks of four sensors each. One set of eight sensors transmits pulsed beams (930 nm wavelength), which are received by the opposite set of eight sensors. Interruption of one or more beams, so that transmission falls below 1.5% (as by blocking more than 98.5% of a sensor), causes the IPID to alarm. If the IPID is in continuous alarm because some of the sensors closest to the ground are blocked by the snowcover, as happened several times, the clear sensors cannot render an independent alarm. Consequently, during periods of continuous alarm there is no indication of when or whether the other beams were interrupted sufficiently (by animals, blowing snow, etc.) to have caused alarms.

There are, however, independent alarm LEDs for the upper and lower set of four sensors. This allowed IPID detectability to be determined during periods of continuous alarm that were due to blockage of a lower sensor. At the IPID electronics box the alarm LED associated with the upper set of four sensors was observed. If that LED lighted as the intruder walked through the IPID detection zone, then it was recorded as a detection.

An individual sensor is ~9 cm (3.5 in.) in diameter. The four sensors of one bank are arrayed vertically with 10-cm spacing between each adjacent sensor. The transmitter and receiver units, at a separation of 50 m, are mounted on tripods standing on the ground. At the transmitter unit, the base of the lowest sensor was initially about 13 cm above the soil; at the receiver unit, the base of the lowest sensor was initially 16 cm above the soil. The units were not raised as the snowcover developed, so with deepening of the snow, successively higher sensors became blocked.

The electronic configuration for alarm condition of the SOROIDS IPID imposes severe limitations on the usefulness of this system. Once the IPID has gone into continuous alarm because one sensor is blocked, the remaining suite of seven sensors is useless. Although security personnel might intend to never permit blockage of one sensor to occur, it is unrealistic to expect that such a blockage can be avoided entirely, particularly if the lowest sensor is located close to the ground to detect a crawling intruder. For example, on windy days at SOROIDS when there is no snow crust, windblown snow fills 20-cm-deep footsteps in a few minutes. On such days it would be impossible to keep a clear path between the IPID transmitter and receiver units without extensive snow removal to eliminate the supply of loose snow. It was possible to return the IPID to use during the winter by electronically bypassing first the lowest sensor and then the lowest four sensors as the snow deepened. This involved time-consuming modifications that were not easily done in the field during cold weather. If the IPID normally were configured with selectable sensor input to the alarm electronics, then it would be feasible to maintain the usefulness of all the sensors except the ones that were temporarily blocked.

Because the IPID line-of-sight is nearly perpendicular to the prevailing wind direction, snow did not accumulate in the recess in front of each sensor face plate. Subsequent experience with IPID units mounted on top of the chain-link fence and oriented parallel to the wind showed that often enough snow filled the recess to cause alarms. This blockage could be prevented by eliminating the recess at each sensor.

NONINTRUDER ALARMS

Nonintruder or nuisance alarms are those that occur independently of the controlled intrusions. They are listed by daily occurrence in Table 10.

It is a safe conclusion that any alarms by the buried FOIDS or the buried M106 that occurred when those systems were not detecting the controlled intrusions were not due to displacement of the soil or gravel by a crossing person or animal. The possibility that thermal cracking of the soil may have been occurring is under investigation. A complication in assessing the cause of the nonintruder alarms is that it is not possible to distinguish alarms originating in the gravel portion of each bed from those originating in the soil portion.

One cause of both fence-mounted and buried FOIDS alarms is wind-induced motion of the plywood panel to which the enclosure containing the FOIDS processor is mounted. Because the FOIDS cable is active from the ground surface to the processor, any motion of the enclosure causes alarms, as has been demonstrated by pushing on the plywood panel. When there are both buried and fence-mounted FOIDS alarms in the same period, they are reasonably attributed to movement of the sensor cable independently of fence or ground motion.

The 12 FOIDS fence alarms on 23 Nov 1992 occurred on a day of intermittent rain and light winds. There were no alarms during the period of maximum gust (5.3 m/s), three alarms during the period when the gust was 4.7 m/s, seven alarms during periods of 2–3 m/s gusts, and two alarms during periods of 1.5–1.8 m/s gusts (Figure 8). The precipitation quantity plotted is the amount of rainfall (mm) over the preceding 30 min. Although the combination of relatively high wind and high precipitation rate clearly causes FOIDS fence alarms (1330 hr), the controlling factor(s) during the rest of the day is less evident.

The only FOIDS fence alarm on 17 February 1993 occurred at 0648 hr. No other IDS alarmed until 1141 hr or later. This occurred during the first occurrence of high winds (11.8 m/s gust) since the overnight snowfall had stopped. The video record initiated by the alarm shows snow being blown off the chain-link panels in the FOIDS zone. At least six panels had snow falling through the fabric. There were several closely spaced occurrences of snow coming off the fence, but they were contained within the alarm reset time of the alarm annunciator. Had the annunciator reset time (20 s) been equal to the FOIDS internal reset time (5–8 s), there would have been more than one FOIDS fence alarm.

Note that, prior to 19 Jan 1993, the annunciator alarm reset times had been determined by the individual IDSs. On that day the reset times were standardized to 20 s to eliminate video recording problems during periods of high alarm rates. The reported number of nonintruder alarms on subsequent days should be considered a minimum during high alarm rate periods as there was the potential for twice as many alarms to occur as were reported.

The buried M106 system became unreliable when the air temperature approached –25°C. At lower temperatures there were as many as 31–33 alarms over a 30-min period. The number of alarms

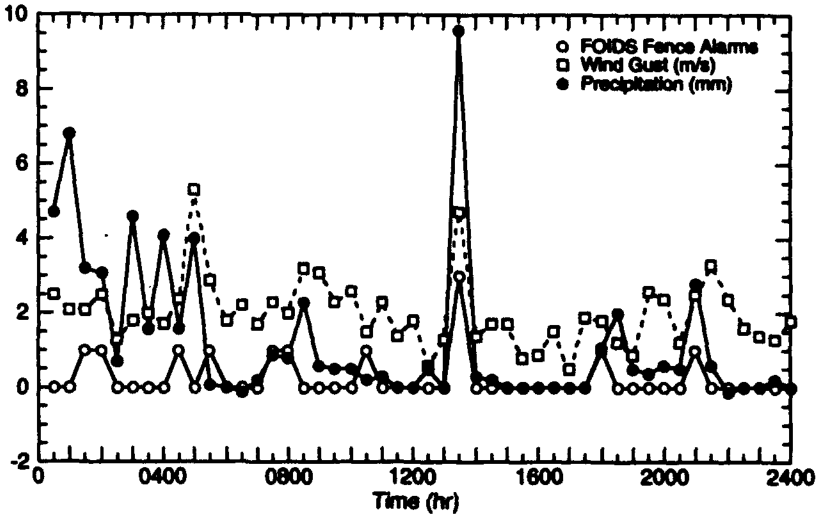

Figure 8. Fence-mounted FOIDS alarms, wind gusts, and rainfall on 23 November 1992.

Table 10. Daily count of nuisance alarms, by IDS.

Month/year	*Date*	*Day*	*FOIDS fence*	*FOIDS buried*	*M106 fence*	*M106 buried*	*IPID*
Oct 92	3	1	9	0	0	n/a	n/a
	4	2	1	2	0	n/a	n/a
	5	3	0	2	0	n/a	n/a
	6	4	3	2	0	n/a	n/a
	7	5	5	2	0	n/a	n/a
	8	6	1	1	0	n/a	n/a
	9	7	78	0	0	n/a	n/a
	10	8	180	2	0	n/a	n/a
	11	9	1	0	0	n/a	n/a
	12	10	1	0	0	n/a	n/a
	13	11	10	2	0	n/a	n/a
	14	12	2	1	0	n/a	n/a
	15	13	13	0	0	n/a	n/a
	16	14	12	1	1	n/a	n/a
	17	15	0	0	0	n/a	n/a
	18	16	0	1	0	n/a	n/a
	19	17	3	0	0	n/a	n/a
	20	18	0	0	0	n/a	n/a
	21	19	0	0	0	n/a	n/a
	22	20	0	0	0	n/a	n/a
	23	21	0	0	0	n/a	n/a
	24	22	15	0	0	n/a	n/a
	25	23	0	0	0	n/a	n/a
	26	24	0	0	0	n/a	n/a
	27	25	0	0	0	n/a	n/a
	28	26	0	1	0	n/a	n/a
	29	27	0	3	0	n/a	n/a
	30	28	0	0	0	n/a	n/a
	31	29	0	0	0	n/a	n/a
Nov 92	1	30	0	0	0	n/a	n/a
	2	31	0	0	0	n/a	n/a
	3	32	0	0	0	n/a	n/a
	4	33	0	0	0	n/a	n/a
	5	34	—	—	—	—	n/a
	6	35	—	—	—	—	n/a
	7	36	0	0	0	0	n/a
	8	37	1	3	0	0	n/a
	9	38	0	2	0	0	n/a
	10	39	0	0	0	1	n/a
	11	40	0	0	0	2	n/a
	12	41	27	0	0	0	n/a
	13	42	317	0	9	0	n/a
	14	43	0	0	0	0	n/a
	15	44	1	0	0	0	n/a
	16	45	1	0	0	0	n/a
	17	46	0	0	0	0	n/a
	18	47	0	0	0	0	n/a
	19	48	0	0	0	0	n/a
	20	49	0	0	0	0	n/a
	21	50	0	2	0	4	n/a
	22	51	7	0	0	0	n/a
	23	52	12	0	0	0	n/a
	24	53	0	0	0	0	n/a
	25	54	1	1	0	0	0
	26	55	4	0	0	0	0
	27	56	0	3	0	0	0
	28	57	0	1	0	0	0
	29	58	0	0	0	0	0
	30	59	0	0	0	0	9

Table 10 (cont'd). Daily count of nuisance alarms, by IDS.

Month/year	*Date*	*Day*	*FOIDS fence*	*FOIDS buried*	*M106 fence*	*M106 buried*	*IPID*
Dec 92	1	60	0	0	0	0	0
	2	61	0	0	0	0	0
	3	62	0	0	0	0	0
	4	63	0	0	0	0	0
	5	64	1	2	0	0	0
	6	65	0	0	0	0	0
	7	66	0	0	0	0	0
	8	67	0	0	2	0	0
	9	68	0	1	1	0	0
	10	69	0	0	0	0	0
	11	70	0	0	0	0	1
	12	71	0	0	0	0	0
	13	72	0	0	0	0	0
	14	73	0	3	0	0	0
	15	74	0	0	0	0	0
	16	75	0	0	1	0	5
	17	76	1	0	0	0	0
	18	77	1	0	0	1	0
	19	78	0	0	0	0	0
	20	79	1	13	1	0	0
	21	80	0	1	0	0	0
	22	81	0	0	0	1	6
	23	82	n/a	0	n/a	0	2
	24	83	n/a	10	n/a	0	0
	25	84	n/a	7	n/a	0	0
	26	85	n/a	9	n/a	0	0
	27	86	n/a	7	n/a	0	0
	28	87	n/a	5	n/a	0	0
	29	88	n/a	3	n/a	0	0
	30	89	n/a	5	n/a	2	0
	31	90	n/a	4	n/a	0	0
Jan 93	1	91	n/a	4	n/a	0	0
	2	92	n/a	3	n/a	0	0
	3	93	n/a	0	n/a	0	0
	4	94	n/a	3	n/a	0	0
	5	95	n/a	3	n/a	0	0
	6	96	n/a	1	n/a	0	0
	7	97	0	0	0	0	0
	8	98	0	0	0	0	0
	9	99	0	1	0	0	0
	10	100	0	3	0	0	0
	11	101	0	1	0	0	0
	12	102	0	0	0	0	0
	13	103	0	1	0	0	5
	14	104	0	1	0	0	n/a
	15	105	0	0	0	0	n/a
	16	106	0	1	0	0	n/a
	17	107	0	0	0	0	n/a
	18	108	10	1	0	0	n/a
	19	109	4	0	0	0	n/a
	20	110	0	1	0	0	0
	21	111	1	0	0	0	0
	22	112	3	0	1	0	0
	23	113	0	0	0	0	0
	24	114	0	0	0	0	0
	25	115	21	6	1	0	0
	26	116	0	8	0	0	0
	27	117	0	0	0	0	0
	28	118	1	4	0	0	0
	29	119	20	22	0	0	8

Table 10 (cont'd).

Month/year	*Date*	*Day*	*FOIDS fence*	*FOIDS buried*	*M106 fence*	*M106 buried*	*IPID*
	30	120	2	5	0	0	1
	31	121	0	1	0	0	1
Feb 93	1	122	16	1	0	0	n/a
	2	123	0	0	0	0	n/a
	3	124	0	2	0	0	n/a
	4	125	7	2	0	0	n/a
	5	126	0	0	0	0	n/a
	6	127	4	4	0	47	n/a
	7	128	0	3	0	241	n/a
	8	129	0	0	0	0	n/a
	9	130	1	3	1	0	n/a
	10	131	0	2	0	0	0
	11	132	0	0	0	0	0
	12	133	0	0	0	0	1
	13	134	21	2	1	1	n/a
	14	135	1	1	0	0	n/a
	15	136	1	3	0	0	n/a
	16	137	0	1	0	0	n/a
	17	138	1	2	1	1	n/a
	18	139	0	3	0	2	n/a
	19	140	0	4	0	29	n/a
	20	141	0	2	0	230	n/a
	21	142	2	5	4	99	n/a
	22	143	0	0	0	0	n/a
	23	144	0	1	0	0	n/a
	24	145	0	0	0	0	n/a
	25	146	0	3	0	77	n/a
	26	147	0	0	0	184	n/a
	27	148	0	2	0	183	n/a
	28	149	1	1	0	5	n/a
Mar 93	1	150	0	0	0	1	n/a
	2	151	0	0	0	0	n/a
	3	152	0	1	0	0	0
	4	153	0	1	1	1	0
	5	154	1	2	0	0	0
	6	155	0	0	0	0	0
	7	156	0	0	0	0	0
	8	157	0	1	0	0	0
	9	158	0	0	0	0	0
	10	159	0	1	0	0	0
	11	160	3	1	0	0	0
	12	161	0	1	0	1	0
	13	162	0	0	0	0	n/a
	14	163	0	50	0	4	n/a
	15	164	0	3	0	2	n/a
	16	165	0	1	0	0	n/a
	17	166	30	3	1	1	3
	18	167	1	12	17	0	0
	19	168	0	9	0	15	0
	20	169	0	1	0	0	0
	21	170	0	0	0	0	0
	22	171	2	0	0	0	6
	23	172	0	1	1	1	0
	24	173	36	0	7	0	0
	25	174	0	1	0	1	0
	26	175	0	2	0	3	0
	27	176	0	4	0	4	0
	28	177	1	1	0	0	0
	29	178	57	1	0	0	0
	30	179	32	3	0	2	0

Table 10 (cont'd). Daily count of nuisance alarms, by IDS.

Month/year	*Date*	*Day*	*FOIDS fence*	*FOIDS buried*	*M106 fence*	*M106 buried*	*IPID*
	31	180	6	3	1	0	0
Apr 93	1	181	30	7	1	0	0
	2	182	7	0	0	0	0
	3	183	0	0	0	0	0
	4	184	1	0	0	0	0
	5	185	5	1	0	1	0
	6	186	1	0	0	0	n/a
	7	187	1	8	0	2	n/a
	8	188	1	3	0	3	n/a
	9	189	13	3	0	0	n/a
	10	190	59	13	0	0	n/a
	11	191	68	46	1	0	n/a
	12	192	50	12	0	0	n/a
	13	193	5	35	0	1	4
	14	194	19	115	1	6	1
	15	195	40	38	0	0	0
	16	196	220	76	1	4	0
	17	197	405	213	0	3	1
	18	198	7	77	0	0	2
	19	199	56	96	0	1	0
	20	200	15	33	0	3	0
	21	201	4	26	0	6	0
	22	202	34	56	0	0	2
	23	203	82	91	2	3	0
	24	204	1	24	0	9	0
	25	205	18	24	0	4	8
	26	206	5	38	0	1	0
	27	207	1	19	0	0	2
	28	208	1	31	0	2	3
	29	209	4	43	1	23	0
	30	210	0	38	0	3	1
May 93	1	211	1	63	0	6	0
	2	212	0	43	0	7	0
	3	213	0	29	0	5	2
	4	214	1	1	0	2	1
	5	215	1	1	0	10	4
	6	216	4	32	3	14	3
	7	217	0	23	0	5	2
	8	218	2	31	0	13	8
	9	219	0	35	2	18	7
	10	220	0	2	0	29	6
	11	221	4	61	8	30	16
	12	222	4	23	0	62	93
	13	223	2	21	0	57	n/a
	14	224	1	33	0	27	n/a
	15	225	1	7	6	20	n/a
	16	226	1	22	0	5	n/a
	17	227	2	25	0	2	n/a
	18	228	0	13	1	1	n/a
	19	229	0	3	0	0	0
	20	230	39	14	3	0	1
	21	231	1	22	0	2	0
	22	232	19	54	2	0	6
	23	233	11	17	1	0	6
	24	234	16	10	0	0	10
	25	235	13	12	2	0	12
	26	236	2	21	1	0	n/a
	27	237	4	14	0	0	n/a
	28	238	2	8	1	0	n/a
	29	239	10	44	1	0	n/a

Table 10 (cont'd).

Month/year	*Date*	*Day*	*FOIDS fence*	*FOIDS buried*	*M106 fence*	*M106 buried*	*IPID*
	30	240	5	46	1	0	n/a
	31	241	9	30	1	0	n/a
Jun 93	1	242	14	23	2	0	n/a
	2	243	—	—	—	—	n/a
	3	244	5	30	0	0	2
	4	245	5	15	0	0	0
	5	246	—	—	—	—	5
	6	247	54	30	1	0	11
	7	248	32	38	1	0	3
	8	249	7	21	1	0	> 71
	9	250	53	10	7	0	n/a
	10	251	38	17	5	0	n/a
	11	252	1	7	0	0	n/a
	12	253	—	—	—	—	n/a
	13	254	15	59	4	n/a	4
	14	255	0	0	3	n/a	8
	15	256	30	9	9	n/a	4
	16	257	2	5	1	0	8
	17	258	3	1	2	0	10
	18	259	8	2	2	0	> 75
	19	260	—	—	—	—	n/a
	20	261	3	11	0	0	7
	21	262	2	10	1	0	11
	22	263	—	—	—	—	—
	23	264	2	12	3	0	4
	24	265	—	—	—	—	—
	25	266	15	0	6	0	2
	26	267	11	5	0	0	2
	27	268	40	3	4	1	2
	28	269	10	1	1	0	9
	29	270	14	2	1	0	9
	30	271	75	5	1	0	8
Jul 93	1	272	—	—	—	—	—
	2	273	58	4	1	0	5
	3	274	18	34	5	0	12
	4	275	2	4	2	0	7
	5	276	4	3	3	n/a	3
	6	277	0	0	2	n/a	3
	7	278	0	0	2	n/a	9
	8	279	—	—	—	n/a	—
	9	280	0	1	0	n/a	3
	10	281	0	0	1	n/a	20
	11	282	0	0	1	n/a	5
	12	283	0	0	1	n/a	1
	13	284	3	1	2	n/a	0
	14	285	0	0	2	n/a	6
	15	286	0	0	8	n/a	7
	16	287	0	0	2	n/a	9
	17	288	0	0	2	n/a	7
	18	289	0	0	3	n/a	0
	19	290	0	0	3	n/a	5
	20	291	0	0	1	n/a	9
	21	292	0	0	3	n/a	7
	22	293	—	—	—	—	—
	23	294	—	—	—	—	—
	24	295	—	—	—	—	—
	25	296	—	—	—	—	—
	26	297	—	—	—	—	—
	27	298	—	—	—	—	—

Table 11. Temperature-related nuisance alarms with buried M106.

Date	*Period*	*Air temperature (°C)*	*Alarm count*
6–7 Feb	2300–0900	–26.8 to –31.2	282
19–20 Feb	2200–0830	–21.9 to 28.8	253
21 Feb	0230–0900	–21.0 to –27.9	98
25 Feb	0630–0800	–22.2 to –23.7	22
25–26 Feb	2100–0900	–20.9 to –27.2	232
27 Feb	0230–0800	–22.3 to –26.5	263

alarms over a 30-min period. The number of alarms during cold periods, notably when the air temperature was below –25°C, is summarized in Table 11. The actual temperature inside the enclosure that houses the processor during these periods is not known. It must be warmer than the air temperature, because the electronics generate some heat. Regardless, the M106 is specified to operate to –30°C ambient. The manufacturer agrees that the occurrence of multiple alarms during cold periods is indicative of cold-related component failure.

The fence-mounted FOIDS is prone to alarming during wind-induced motion of the chain-link fence. Table 12 compares the number of fence-mounted FOIDS alarms and the number of fence-mounted M106 alarms with the gust wind speed. Under the same wind conditions, the number of FOIDS alarms greatly exceeds the number of M106 alarms. Although the FOIDS sensitivity is a different parameter from the M106 parameter, both systems were set at approximately 40% of their sensitivity range on these days.

On 15 Jul, five early-morning (0556–0601 hr) fence-mounted M106 alarms were caused by birds of robin size on the chain-link fence in the M106 zone. A large group of birds was perched on the top of the fence fabric as well as on the strands of barbed wire. The M106 alarms seemed to occur when the birds stirred and fluttered their wings.

The count of IPID nonintruder alarms is valid only for periods when the IPID was not in continuous alarm. The alarms on 13 Jan, 31 Jan, and 12 Feb were all due to the blockage of a sensor by the snowcover and mark the beginning of a period of continuous alarming. The nine alarms on 30 Nov followed an alarm by a colocated passive infrared (PIR) IDS by intervals of 9 s to 8 min 14 s. At least one of these alarms may reasonably be attributed to a small animal crossing the clear zone in which the two IDSs are located. The site lights were not on at this time; the video record showed no obvious activity. The IPID alarm on 11 Dec coincided with a corn leaf blowing through the IPID zone. As it passed the lowest sensor it may have flipped so as to block the sensor temporarily. Of the five IPID alarms on 16 Dec, two occurred 4 s after alarms by the PIR and are attributed to animals. The other three were closely spaced to the second occurrence of joint PIR/IPID alarms, occurring 22 s to 3 min 6 s later. Of the six alarms on 22 Dec, three occurred within 2, 3, or 7 s of a PIR alarm, and three occurred within 13–35 s of one of the joint PIR/IPID alarms. The IPID alarms on 23 Dec occurred 5 s and 1 min 10 s after a PIR alarm.

The eight IPID alarms on 29 Jan spanning a 2.5-hr period and the one alarm on 30 Jan were not associated with any PIR alarms. These nine alarms all occurred during episodes of blowing snow. Wind gusts during the alarm period on 29 Jan were 13.1 to 21 m/s. After the last IPID alarm on 29 Jan, the high winds persisted (gusts of 12.9 to 17 m/s) with consequent alarms from both the buried and fence-mounted FOIDS, but there was no blowing snow, and the IPID did not alarm. The 30 Jan alarm occurred during a high wind (16.7 m/s gust); although this was not the windiest period of the day, it coincided with the only occurrence of blowing snow indicated by the video record. In contrast, there were no IPID alarms on days of snowfall until enough snow accumulated on the ground to block a sensor. Two differences between falling snow and blowing snow are the dominant direction of motion (vertical vs. horizontal) and the particle size, with wind-blown snow particles (snow dust) generally being smaller so that there can be a larger concentration of airborne snow mass per given air volume. Consequently, windblown snow may more completely scatter the near-infrared beams than does falling snow. Prominent episodes of blowing snow also occurred on 14 March, but as the IPID on that day was in continuous alarm due to previous snow accumulation, it is not known whether the airborne snow would have caused the IPID to alarm.

The IPID went into continuous alarm on 13 Jan when the snow depth exceeded the height of the lowest sensor. This had followed three closely spaced alarms when the blockage was intermittent. The lowest sensor was electronically bypassed on 19 Jan, and the alarm condition cleared. The IPID next went into continuous alarm on 31 Jan due to snow buildup over the height of the second highest sensor. It was possible to conduct controlled intrusions on 2 Feb despite the continuous alarm status because the alarm LED for the highest four sensors (5–8), which were unaffected by the snowcover, was

Table 12. Fence alarms vs. wind.

Date	*Time*	*2 m ave wind speed**	*2 m gust speed**	*FOIDS fence***	*M106 fence***
18 Jan 93	0:30:00	2.8	8.9	0	0
	1:00:00	5.1	12.5	3	0
	1:30:00	4.5	9.6	0	0
	2:00:00	5.1	10.4	1	0
	2:30:00	4.7	13.9	0	0
	3:00:00	4.3	10.3	0	0
	3:30:00	5.1	11.4	1	0
	4:00:00	4.5	11.2	0	0
	4:30:00	4.0	8.3	1	0
	5:00:00	3.9	9.9	0	0
	5:30:00	3.2	7.9	0	0
	6:00:00	2.5	5.9	0	0
	6:30:00	3.8	8.8	0	0
	7:00:00	4.1	9.6	0	0
	7:30:00	4.2	8.0	0	0
	8:00:00	3.9	7.7	0	0
	8:30:00	3.3	7.1	1	0
	9:00:00	5.5	11.4	0	0
	9:30:00	4.4	9.6	0	0
	10:00:00	4.8	10.3	0	0
	10:30:00	5.7	10.1	1	0
	11:00:00	6.2	13.3	0	0
	11:30:00	5.6	12.4	0	0
	12:00:00	4.6	8.8	0	0
	12:30:00	4.0	7.7	0	0
	13:00:00	4.4	9.5	0	0
	13:30:00	4.9	9.0	0	0
	14:00:00	4.4	10.0	0	0
	14:30:00	3.7	8.9	0	0
	15:00:00	1.9	5.5	0	0
	15:30:00	3.2	7.3	0	0
	16:00:00	3.5	12.7	0	0
	16:30:00	4.0	11.0	0	0
	17:00:00	3.2	9.4	0	0
	17:30:00	1.6	6.6	0	0
	18:00:00	0.8	2.7	0	0
	18:30:00	0.7	2.1	0	0
	19:00:00	1.0	2.2	0	0
	19:30:00	1.3	4.3	0	0
	20:00:00	1.9	7.4	0	0
	20:30:00	1.7	4.7	0	0
	21:00:00	1.5	2.4	0	0
	21:30:00	1.0	2.1	0	0
	22:00:00	1.1	2.3	1	0
	22:30:00	0.7	1.9	0	0
	23:00:00	0.4	1.3	0	0
	23:30:00	0.4	1.5	1	0
	0:00:00	0.3	1.7	0	0
19 Jan 93	0:30:00	1.0	2.1	0	0
	1:00:00	0.6	1.6	0	0
	1:30:00	0.5	1.4	0	0
	2:00:00	0.5	2.3	0	0
	2:30:00	0.4	1.3	0	0
	3:00:00	0.7	2.3	0	0
	3:30:00	0.6	2.1	0	0
	4:00:00	0.7	1.6	0	0
	4:30:00	0.4	1.5	0	0
	5:00:00	0.7	1.7	0	0
	5:30:00	0.4	1.3	0	0
	6:00:00	0.9	1.5	0	0
	6:30:00	0.8	1.4	0	0
	7:00:00	0.8	1.6	0	0
	7:30:00	0.8	1.9	0	0
	8:00:00	0.3	1.4	0	0
	8:30:00	0.4	1.0	0	0
	9:00:00	1.1	2.6	0	0
	9:30:00	1.5	11.1	0	0
	10:00:00	6.8	15.9	2	0
	10:30:00	6.8	13.0	2	0
	11:00:00	5.8	12.0	11	46
	11:30:00	5.0	11.2	61	2
	12:00:00	4.9	10.8	4	3
	12:30:00	4.3	8.5	0	0
	13:00:00	5.6	9.8	0	0
	13:30:00	4.6	10.7	0	0
	14:00:00	4.3	8.3	0	0
	14:30:00	4.1	8.3	0	0
	15:00:00	3.9	7.0	0	0
	15:30:00	3.5	5.5	0	0
	16:00:00	3.2	5.8	9	5
	16:30:00	2.4	3.5	0	1
	17:00:00	1.3	2.7	0	0
	17:30:00	1.2	2.4	0	0
	18:00:00	0.7	1.8	0	0
	18:30:00	0.4	1.4	0	0
	19:00:00	0.2	0.7	0	0
	19:30:00	0.5	1.7	0	0
	20:00:00	0.5	1.5	0	0
	20:30:00	0.5	1.2	0	0
	21:00:00	0.5	1.6	0	0
	21:30:00	0.7	1.8	0	0
	22:00:00	0.8	1.9	0	0
	22:30:00	0.5	2.1	0	0
	23:00:00	0.8	2.1	0	0
	23:30:00	0.7	2.7	0	0
	0:00:00	0.9	2.2	0	0
25 Jan 93	0:30:00	1.2	4.7	0	0
	1:00:00	1.4	5.7	0	0
	1:30:00	1.6	5.2	0	0
	2:00:00	1.8	9.7	0	0
	2:30:00	1.8	7	0	0
	3:00:00	3.2	9.4	0	0
	3:30:00	3.3	11.5	3	0
	4:00:00	3.6	15.7	2	1
	4:30:00	4.9	14.3	1	0
	5:00:00	4.3	17.9	1	0
	5:30:00	5.1	13.4	0	0
	6:00:00	5.1	11.8	3	0
	6:30:00	4.6	15.7	3	0
	7:00:00	4.5	14.0	1	0
	7:30:00	7.4	18.4	5	0
	8:00:00	5.8	15.3	0	0
	8:30:00	5.9	15.2	1	0
	9:00:00	4.8	12.6	0	0
	9:30:00	5.5	13.7	0	0
	10:00:00	3.0	9.3	0	0
	10:30:00	3.7	8.0	0	0
	11:00:00	4.9	11.7	0	0

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* m/s

** number of alarms in preceding 30 minutes

Table 12 (cont'd). Fence alarms vs. wind.

Date	Time	2 m ave wind speed*	2 m gust speed*	FOIDS fence**	M106 fence**
	11:30:00	2.8	6.0	0	0
	12:00:00	3.3	12.4	0	0
	12:30:00	3.6	9.1	0	0
	13:00:00	4.2	9.4	0	0
	13:30:00	4.7	14.8	0	0
	14:00:00	4.3	14.4	0	0
	14:30:00	4.9	11.2	1	0
	15:00:00	5.1	14.6	0	0
	15:30:00	3.3	11.3	0	0
	16:00:00	4.5	13.3	0	0
	16:30:00	3.0	11.9	0	0
	17:00:00	3.0	6.8	0	0
	17:30:00	3.1	7.5	0	0
	18:00:00	2.9	7.0	0	0
	18:30:00	3.5	7.8	0	0
	19:00:00	3.6	8.2	0	0
	19:30:00	2.5	4.6	0	0
	20:00:00	3.0	5.4	0	0
	20:30:00	2.7	4.7	0	0
	21:00:00	1.7	3.4	0	0
	21:30:00	2.0	5.1	0	0
	22:00:00	2.1	3.9	0	0
	22:30:00	2.4	4.6	0	0
	23:00:00	2.4	5.3	0	0
	23:30:00	2.3	4.1	0	0
	0:00:00	2.3	4.6	0	0
28 Jan 93	0:30:00	2.6	5.0	0	0
	1:00:00	2.5	6.7	0	0
	1:30:00	2.9	8.5	0	0
	2:00:00	2.9	7.9	0	0
	2:30:00	3.1	6.6	0	0
	3:00:00	2.7	5.0	0	0
	3:30:00	2.9	5.3	0	0
	4:00:00	2.5	5.5	0	0
	4:30:00	3.4	8.2	0	0
	5:00:00	4.5	9.6	0	0
	5:30:00	3.2	9.1	1	0
	6:00:00	2.8	5.5	0	0
	6:30:00	2.4	4.2	0	0
	7:00:00	2.2	4.0	0	0
	7:30:00	2.6	4.3	0	0
	8:00:00	1.9	2.5	0	0
	8:30:00	2.1	4.6	0	0
	9:00:00	2.6	4.1	0	0
	9:30:00	3.3	5.5	0	0
	10:00:00	4.2	9.5	0	0
	10:30:00	3.4	7.1	0	0
	11:00:00	3.9	8.9	0	0
	11:30:00	4.2	9.8	0	0
	12:00:00	3.8	7.3	0	0
	12:30:00	3.2	6.5	0	0
	13:00:00	2.7	6.4	0	0
	13:30:00	2.3	4.9	0	0
	14:00:00	2.6	4.7	0	0
	14:30:00	1.7	4.6	0	0
	15:00:00	1.9	4.8	0	0
	15:30:00	1.6	4.2	0	0
	16:00:00	0.9	2.8	0	0
	16:30:00	1.3	2.7	0	0
	17:00:00	1.2	1.7	0	0
	17:30:00	1.1	1.9	0	0
	18:00:00	0.5	1.3	0	0
	18:30:00	0.4	1.2	0	0
	19:00:00	0.5	1.8	0	0
	19:30:00	0.4	1.1	0	0
	20:00:00	0.2	0.9	0	0
	20:30:00	0.5	1.8	0	0
	21:00:00	0.5	3.8	0	0
	21:30:00	2.5	4.2	0	0
	22:00:00	1.5	2.9	0	0
	22:30:00	2.3	5.1	0	0
	23:00:00	2.7	5.3	0	0
	23:30:00	3.4	7.0	0	0
	0:00:00	3.7	8.0	0	0
29 Jan 93	0:30:00	3.6	8.1	0	0
	1:00:00	3.3	6.7	0	0
	1:30:00	2.9	5.9	0	0
	2:00:00	2.7	6.8	0	0
	2:30:00	2.7	5.3	0	0
	3:00:00	2.4	4.8	0	0
	3:30:00	2.1	4.4	0	0
	4:00:00	1.7	3.8	0	0
	4:30:00	1.2	3.4	0	0
	5:00:00	1.1	3.4	0	0
	5:30:00	1.1	2.4	0	0
	6:00:00	0.7	1.8	0	0
	6:30:00	1.1	4.5	0	0
	7:00:00	1.0	4.2	0	0
	7:30:00	1.5	6.2	0	0
	8:00:00	1.6	4.3	0	0
	8:30:00	1.8	7.2	0	0
	9:00:00	2.5	9.0	0	0
	9:30:00	4.6	12.4	0	0
	10:00:00	3.5	8.3	0	0
	10:30:00	1.9	9.9	0	0
	11:00:00	2.1	9.9	0	0
	11:30:00	4.8	13.5	2	0
	12:00:00	4.7	21.0	6	0
	12:30:00	4.0	15.0	4	0
	13:00:00	4.8	18.1	1	0
	13:30:00	5.8	13.1	1	0
	14:00:00	5.7	18.1	1	0
	14:30:00	5.5	13.6	1	0
	15:00:00	5.3	12.9	0	0
	15:30:00	4.9	17.0	0	0
	16:00:00	5.8	15.7	1	0
	16:30:00	5.2	13.0	1	0
	17:00:00	5.2	13.9	0	0
	17:30:00	4.3	8.6	0	0
	18:00:00	4.4	10.7	0	0
	18:30:00	4.8	11.1	0	0
	19:00:00	5.8	11.0	0	0
	19:30:00	4.2	10.8	0	0
	20:00:00	4.2	9.9	0	0
	20:30:00	4.6	10.1	1	0
	21:00:00	4.6	10.9	0	0
	21:30:00	4.1	11.5	1	0
	22:00:00	3.8	10.4	0	0

Table 12 (cont'd).

Date	*Time*	*2 m ave wind speed**	*2 m gust speed**	*FOIDS fence***	*M106 fence***
	22:30:00	2.2	5.1	0	0
	23:00:00	0.5	1.7	0	0
	23:30:00	1.4	7.8	0	0
	0:00:00	2.3	7.8	0	0
30 Jan 93	0:30:00	1.9	5.3	0	0
	1:00:00	1.5	4.3	0	0
	1:30:00	2.0	5.2	0	0
	2:00:00	2.3	4.9	0	0
	2:30:00	2.1	4.2	0	0
	3:00:00	0.8	2.7	0	0
	3:30:00	1.2	2.0	0	0
	4:00:00	1.0	1.8	0	0
	4:30:00	1.0	1.7	0	0
	5:00:00	1.0	1.8	0	0
	5:30:00	0.7	1.3	0	0
	6:00:00	0.5	3.1	0	0
	6:30:00	5.0	15.4	0	0
	7:00:00	5.1	11.5	0	0
	7:30:00	5.3	11.6	0	0
	8:00:00	5.0	10.1	0	0
	8:30:00	4.6	9.1	0	0
	9:00:00	5.3	11.9	0	0
	9:30:00	6.5	12.4	0	0
	10:00:00	6.7	16.7	0	0
	10:30:00	5.3	12.8	0	0
	11:00:00	6.3	15.6	0	0
	11:30:00	6.9	13.6	0	0
	12:00:00	7.8	15.6	0	0
	12:30:00	7.7	17.6	0	0
	13:00:00	7.3	14.2	0	0
	13:30:00	6.6	12.8	0	0
	14:00:00	6.0	16.2	0	0
	14:30:00	5.0	9.6	0	0
	15:00:00	5.4	11.6	0	0
	15:30:00	5.2	9.2	0	0
	16:00:00	5.0	10.3	0	0
	16:30:00	4.6	7.8	1	0
	17:00:00	2.9	6.1	1	0
	17:30:00	2.3	4.5	0	0
	18:00:00	2.6	4.8	0	0
	18:30:00	3.3	5.6	0	0
	19:00:00	2.7	4.5	0	0
	19:30:00	2.2	4.0	0	0
	20:00:00	2.6	4.6	0	0
	20:30:00	2.6	4.1	0	0
	21:00:00	2.2	4.2	0	0
	21:30:00	2.2	3.5	0	0
	22:00:00	1.3	2.3	0	0
	22:30:00	1.4	2.5	0	0
	23:00:00	1.0	2.3	0	0
	23:30:00	0.9	2.3	0	0
	0:00:00	0.7	2.1	0	0
1 Feb 93	0:30:00	1.6	3.1	0	0
	1:00:00	0.9	2.7	0	0
	1:30:00	2.0	2.9	0	0
	2:00:00	1.6	3.4	0	0
	2:30:00	2.0	4.3	0	0
	3:00:00	5.0	9.1	0	0
	3:30:00	6.6	15.1	2	0
	4:00:00	7.5	13.0	2	0
	4:30:00	6.3	11.4	1	0
	5:00:00	5.1	11.1	0	0
	5:30:00	5.0	11.1	0	0
	6:00:00	3.8	7.5	0	0
	6:30:00	3.5	6.6	0	0
	7:00:00	4.0	9.7	0	0
	7:30:00	3.4	8.4	0	0
	8:00:00	3.0	7.0	0	0
	8:30:00	3.3	8.2	0	0
	9:00:00	4.7	12.5	0	0
	9:30:00	5.3	9.4	0	0
	10:00:00	5.5	11.4	0	0
	10:30:00	6.4	11.2	0	0
	11:00:00	7.0	14.1	1	0
	11:30:00	6.4	13.4	1	0
	12:00:00	5.9	11.9	0	0
	12:30:00	6.6	12.7	1	0
	13:00:00	6.8	13.2	0	0
	13:30:00	6.8	13.0	0	0
	14:00:00	7.3	13.3	0	0
	14:30:00	7.7	14.3	2	0
	15:00:00	6.2	13.1	3	0
	15:30:00	6.8	13.9	1	0
	16:00:00	5.6	11.3	1	0
	16:30:00	5.9	13.1	1	0
	17:00:00	6.3	12.8	0	0
	17:30:00	5.2	11.3	0	0
	18:00:00	4.0	8.9	0	0
	18:30:00	3.7	7.8	0	0
	19:00:00	3.8	6.5	0	0
	19:30:00	3.5	7.3	0	0
	20:00:00	3.3	8.7	0	0
	20:30:00	3.3	5.9	0	0
	21:00:00	3.4	5.2	0	0
	21:30:00	3.8	10.1	0	0
	22:00:00	3.6	6.5	0	0
	22:30:00	3.1	6.5	0	0
	23:00:00	3.0	7.1	0	0
	23:30:00	3.1	6.1	0	0
	0:00:00	4.1	9.6	0	0
4 Feb 93	0:30:00	0.7	1.5	0	0
	1:00:00	2.0	6.9	0	0
	1:30:00	1.5	3.7	0	0
	2:00:00	2.3	4.7	0	0
	2:30:00	4.0	11.5	0	0
	3:00:00	3.6	7.2	0	0
	3:30:00	4.5	9.6	0	0
	4:00:00	5.1	10.5	0	0
	4:30:00	7.6	15.4	4	0
	5:00:00	6.1	12.4	1	0
	5:30:00	6.0	14.2	1	0
	6:00:00	5.3	11.7	1	0
	6:30:00	5.3	12.4	0	0
	7:00:00	5.2	11.0	0	0
	7:30:00	4.3	8.9	0	0
	8:00:00	5.0	9.3	0	0
	8:30:00	4.4	11.1	0	0
	9:00:00	5.4	11.5	0	0

Table 12 (cont'd). Fence alarms vs. wind.

Date	*Time*	*2 m ave wind speed**	*2 m gust speed**	*FOIDS fence***	*M106 fence***
4 Feb 93	9:30:00	5.2	12.4	0	0
	10:00:00	5.3	11.0	0	0
	10:30:00	4.6	8.1	0	0
	11:00:00	4.1	9.6	0	0
	11:30:00	6.1	11.8	0	0
	12:00:00	5.2	10.4	0	0
	12:30:00	3.7	7.7	0	0
	13:00:00	5.2	9.4	0	0
	13:30:00	5.6	13.5	0	0
	14:00:00	5.5	9.8	0	0
	14:30:00	5.0	9.8	0	0
	15:00:00	4.1	7.8	0	0
	15:30:00	3.7	7.9	0	0
	16:00:00	3.3	6.3	0	0
	16:30:00	3.0	5.0	0	0
	17:00:00	2.9	4.6	0	0
	17:30:00	2.5	4.2	0	0
	18:00:00	2.4	3.9	0	0
	18:30:00	2.0	2.7	0	0
	19:00:00	2.1	2.8	0	0
	19:30:00	1.9	3.1	0	0
	20:00:00	0.5	2.0	0	0
	20:30:00	0.7	2.1	0	0
	21:00:00	0.4	1.2	0	0
	21:30:00	0.5	1.5	0	0
	22:00:00	0.5	1.7	0	0
	22:30:00	0.6	1.6	0	0
	23:00:00	0.5	1.3	0	0
	23:30:00	0.5	1.7	0	0
	0:00:00	0.5	1.4	0	0

* m/s

** number of alarms in preceding 30 minutes

alarm LED for the lowest four sensors was lighted continuously. The IPID went out of alarm when the snow depth decreased sufficiently. It next went into continuous alarm on 12 Feb due to snow buildup. That alarm lasted until 2 Mar when the lowest stack of four sensors was electronically bypassed. The IPID again went into continuous alarm following the blizzard of 13 Mar; this lasted into 16 Mar.

Although the snow along the IPID line-of-sight is generally deep relative to other site locations, probably because of the influence of the east–west chain-link fences on the dominantly north–south wind pattern, the greatest snow depth in that area occurs on the leeward side of a field distribution box. It was that local snow accumulation that first put the IPID into continuous alarm.

The six IPID alarms on 22 Mar occurred within 7 minutes of each other and were caused by a crow walking through the IPID detection zone.

The bypass of the lower stack of four sensors was reversed on 6 Apr, leaving only the lowest sensor bypassed. The IPID immediately went into continuous alarm, which was attributed to the second lowest sensor being blocked by snow at two or three locations along the IPID line-of-sight (determined by stretching a string between the transmitter and receiver units). The cause of that alarm ceased naturally during the next week as the snow melted, yet the continuous alarm continued. It was found on 13 Apr that one of the rewiring connections made the previous week (to reverse the electronic bypass of the lowest stack of sensors) had not made good contact. The manufacturer advised where to open the IPID to have better access for checking the connections. This highlights the difficulty of the present means of bypassing sensors, rewiring, and the need for an expedient, reliable means to select which sensors can generate alarms. Beginning 13 Apr, all eight IPID sensors were configured to be capable of generating alarms.

This marked the beginning of numerous IPID alarms related to birds. Although not all alarm causes could be identified by referring to the alarm-initiated video recording, the known sources of nuisance alarms are identified here. Between 13 Apr and 22 Jul (when the video cassette recorder was removed for cleaning), there were a total of 19 alarms caused by a crow on 6 days, 65 alarms caused by birds of robin size or smaller on 27 days, one alarm caused by an unidentified animal, and one alarm caused by a corn leaf blowing across the IPID zone.

A continuous alarm extended from 12 to 18 May, when the grass along the IPID's line-of-sight was cut down with a weedwhacker. (The first grass mowing of the season was on 2 Jun.) Visual inspection indicated that the grass should not have been causing alarms because it did not block the lowest sensor as much as 98.5%. Another contributing factor was that frost heave of the soil during the winter had accentuated the terrain undulations along the IPID line-of-sight. On 21 May the manufacturer visited SOROIDS and documented that, first, the high ground along the IPID line of sight was partially (40%) blocking the reception of the lowest sensor, (40%) blocking the reception of the lowest sensor, and second, one of the support legs of the receiver unit was partially blocking the lowest sensor. In the manufacturer's assessment, the nuisance alarms due to birds and grass would not have occurred if there were not already partial blockage of the lowest sensor by the soil mounds and support leg. (The technician maintaining the IPID had situated the leg there during the course of aligning the units and had allowed it to remain there because she believed its blockage, being so much less than 98.5%, should not make a difference.)

To demonstrate that seasonal variation in small-scale topography is a natural consequence of soil heave, the IPID units were left at their present height while the soil mounds gradually subsided. Periods of continuous alarms did occur: 25 May–2 Jun (grass mowed on 2 Jun), 8–9 June (grass most recently mowed on 5 Jun), 9–12 Jun (grass mowed on 12 Jun), and 18–19 Jun (grass mowed on 19 Jun).

By 29 Jun the lowest sensor was not at all blocked by a soil mound. This was demonstrated by progressively blocking the lowest sensor from its top toward its base. The IPID did not alarm until the lowest sensor was almost completely covered, with a very small arc of lens remaining uncovered. If the soil had been extending into the lowest sensor's field of view, that portion of lens would have been already blocked by the ground, and the IPID would have alarmed while more of the lens remained uncovered.

Beginning on 8 Jul a different type of IPID alarm began occurring. There would be several alarms during the midmorning to late afternoon portion of each day (8–11 Jul), and an individual alarm would last from several minutes to several hours. No alarm continued later than 1700 hr. This was the first prolonged hot period of the summer, with air temperatures of 30–35°C during much of the day. On 9 Jul the temperature inside the enclosure of one stack of IPID receivers, measured with a copper-constantin (Type T) thermocouple, was 40.5°C (105°F). The manufacturer was consulted about these alarms, as it seemed probable that they were the result of a temperature effect on the IPID electronics.

That the IPID continued to have nuisance alarms caused by small (chickadee-sized) birds walking through its detection zone together with individual alarms on hot days lasting minutes or hours led the manufacturer to investigate potential electronic causes of the IPID alarms. This was when the defective resistor in the circuitry of the lowest sensor of an IPID at the manufacturer's was discovered. The manufacturer feels that the performance of the resistor explains the alarms at birds that, according to the IPID operating specifications, should be too small to block the lowest sensor sufficiently to cause alarms. The manufacturer also attributes the protracted alarms during hot weather to the defective resistor. It should be noted that CRREL personnel do not know if the receiver unit of the SOROIDS IPID, upon its return to the manufacturer, was found to have one of the defective resistors.

EQUIPMENT-RELATED ALARMS

On 12 Feb 1993 the fence-mounted M106 went into continuous alarm. The cause was traced to the processor's transient protection board, which was sent to the manufacturer for troubleshooting. They found that all the components were burned out.

There were periods of continuous alarms by the buried M106 during the summer. These were cleared by resetting the ground fault circuit interrupter outlet.

PROXIMITY-TO-ALARM MONITORING

The most informative method of investigating the interaction between the environment and an IDS is to monitor the proximity-to-alarm status of the IDS. Generally, the alarm condition of an IDS is based on a comparison of two voltages, one derived from the sensor's output and one typically determined by the sensitivity setting of the IDS. If the alarm threshold is known, then by monitoring the processed sensor voltage it is possible to correlate variation in the IDS's proximity to alarm with changes in site conditions.

The proximity to alarm of one IPID sensor, the fifth up from the ground, has been monitored since 12 Jan 1993. The voltage is sampled every 125 ms and recorded as the average and minimum values for each 30 minutes. The manufacturer advised that the voltage should normally be 5 V, that it should begin dropping when the sensor is 90% blocked, and that an alarm should occur at a voltage of ~1 V, which corresponds to about 98% blockage. Because of the height of the sensor, birds on the ground, animals, or accumulating snow are not candidates for blocking the sensor. The monitoring has shown that the sensor's average voltage is 5 V, but that the half-hour minimum is typically 4.8 to 4.9 V and occasionally as low as 4.65 V. Some voltage drops coincided with rainfall, but there is no consistency to the amount of voltage drop per quantity of rainfall, nor are voltage drops associated with each rainfall event.

The two M106 IDSs have also been monitored, beginning on 29 May 1992 for the fence-mounted M106 and 26 Feb 1993 for the buried M106. Because the M106s process the output of the laser detector into an energy representation, there is no sensor voltage equivalent to that of the IPID. A CRREL engineer designed an integrator circuit that mimics the later stages of the M106 processor. The integrator circuit is fed the signal from the processor's audio jack, which is the filtered output of the laser detector; the circuit accumulates the audio jack signal for 10 s, then resets to zero and repeats the sequence. This is similar to the subsequent action of the M106 processor, which integrates the filtered signal over a time period determined by the sensitivity setting and compares the output of its integrator with a threshold value to determine if an event has occurred. The output of the CRREL integrator is sampled every 125 ms, and its average, minimum, and maximum values over 30 min are recorded.

Unlike IDSs for which the alarm criterion is a specific (although perhaps sensitivity-dependent) threshold voltage, the M106 alarm condition had to be estimated by comparing alarm occurrences with voltage values of the CRREL integrator circuit. This was possible because the time of each half-hour's voltage maximum is also recorded. Most of the time the two coincided, but there were numerous occasions when an M106 alarm did not coincide with the highest voltage of the integrator circuit in that half-hour. In addition, the same level of voltage on the CRREL integrator circuit did not always coincide with an alarm. Overall, however, the diurnal variation in the output of the CRREL integrator circuit was similar to the proximity-to-alarm record of the two Stellar Systems E-Flex II Perimeter Protection Systems mounted to the same fence. The E-Flex processors have a well-defined alarm threshold and test point access to the sensor signal, so there is no ambiguity to their proximity-to-alarm status.

The environmental effects on the detection capability of a fence-mounted IDS are the temperature-dependent stiffness of the fence, the diurnal cycles of wind activity, and precipitation-induced fence motion. These are discussed in Appendix A.

CONCLUSIONS AND RECOMMENDATIONS

The four optical-fiber IDSs and one pulsed near-infrared IDS have been in operation at SOROIDS during conditions of snowfall and rainfall, unfrozen/frozen soil and gravel, snow as deep as 80 cm, wind gusts of >20 m/s, and air temperatures ranging from −30°C to 35°C over the period 3 October 1992 to 27 July 1993. Controlled intrusions were done on 25 days, approximately weekly during the winter.

Both the FOIDS and the M106 are unusable in a buried configuration under conditions of frozen soil or gravel and/or the presence of a deep snowcover. The M106 in a fence-mounted configuration has a superior (lower) nuisance alarm rate, but it may have a lower detection rate than the fence-mounted FOIDS. The IPID reliably detects a walking intruder, but its usefulness is often severely limited or nonexistent if its sensors are electronically connected in the standard configuration for alarm annunciation.

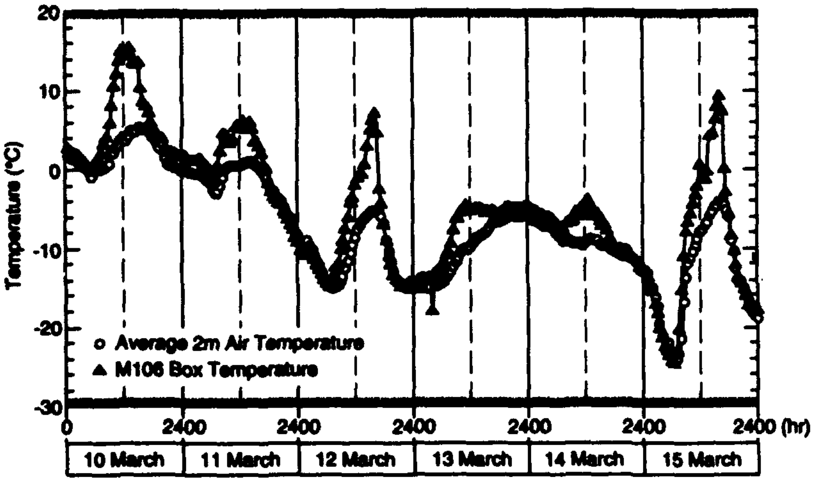

Figure 9. Outside air temperature vs. temperature inside the enclosure housing the processor for the buried M106 system.

The following recommendations are made:

1) Mason-Hanger should be queried as to whether they have subjected their electronics to thermal shock testing, and the outcome.
2) The two Fiber Sens Sys processors should be subjected to low-temperature testing to identify the source (apparently component-related) of the numerous alarms by the buried unit at air temperatures below –25°C and to determine why the fence-mounted system does not alarm under the same conditions. Figure 9 shows that the interior temperature of the enclosure for the buried system's processor varies substantially with changes in air temperature. The air temperature during the periods of high alarm rate in February, however, did not fall below the minimum operating temperature (–30°C) specified by the manufacturer.
3) If the fabric of a chain-link fence becomes sufficiently ice-coated to prevent FOIDS alarms at fence taps, the continuity of the coating should be broken by striking the ice until it cracks. Very limited results with the FOIDS on locally ice-coated sections of the SOROIDS fence suggest that it is not necessary to remove the ice coating to restore FOIDS detectability. Presumably, similar results would have been obtained with the M106 if a portion of the chain-link fence in its zone had become ice-coated. Leaving the cracked ice on the fence, however, raises the possibility of nuisance alarms if segments of the ice fall or are blown through the fabric. That is potentially similar to the situation that occurred when snow, which had been clinging to the fence fabric, fell through the fence to the ground and caused several FOIDS alarms.
4) The IPID should not be located near objects that may induce localized snow drifting or deposition of snow on the ground. There is a potential problem due to frost heaving of soil along the IPID line-of-sight if the IPID is mounted close to the ground. This would not be experienced with an IPID located on asphalt or concrete. Those surfaces would also make it easier to orient the IPID since they would provide a flatter, more stable surface than does soil. The recess in front of each sensor lens should be eliminated to prevent accumulation of snow there.
5) Twice the IPID at SOROIDS has been returned to use by electronically bypassing the lowest sensors (one sensor the first time, four the second time) as they became blocked by snow on the ground. This involved time-consuming modifications that are not easily done in the field during cold weather. If the IPID normally were configured with selectable sensor input to the alarm electronics, then it would be feasible to maintain the usefulness of all the sensors except the ones that were temporarily blocked. It should be recommended to ECSI-EAG International that such an option be standard with the IPID.

APPENDIX A: ENVIRONMENTALLY INDUCED VARIATION IN THE DETECTABILITY OF FENCE-MOUNTED INTRUSION DETECTION SYSTEMS

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Scottsdale, Arizona, July 1993, p. 122–130

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ABSTRACT

Seasonal differences in the normal stiffness of the chain-link fence panels at CRREL's intrusion detection system (IDS) research facility have been determined using a CRREL-developed fence characterization kit. These results quantify changes in the fence panels' response to loading that result from thermal contraction or expansion of the fence elements. To assess seasonal differences in IDS response to fence motion, the proximity-to-alarm status of three fence-mounted IDSs has been continually monitored. Weather-related diurnal patterns in the likelihood of occurrence of nuisance alarms have been determined. This information allows security personnel to anticipate when the detectability of fence-mounted IDSs will vary because of wind-induced motion of chain-link fences and temperature-dependent differences in fence stiffness

INTRODUCTION

Intrusion detection systems (IDSs) are attached to a chain-link fence to detect when someone is cutting or climbing the fence. They analyze the fence motion for changes indicative of intruder activity. The fence also moves because of wind loading and the impact of precipitation. Whether such non-intruder motion causes IDS alarms depends on the characteristics of the fence motion to which the IDS processor is designed to respond. This paper presents examples of precipitation- and wind-induced fence motion in the context of possible seasonal changes in the resistance to motion of a chain-link fence.

FENCE DESCRIPTION

The chain-link fence at the CRREL IDS research site (known as SOROIDS) is 2.4 m high, with 3 m-wide panels. (A fence panel is that portion of the chain-link fabric between two adjacent posts.) It was installed in 1987. The fence posts (4.9-cm diameter) are set 0.9 m deep in concrete. The galvanized steel strands of the fabric are 3.5 mm in diameter. Originally, the fabric was braced with five horizontal stiffening cables spaced at ~0.6 m intervals from the base to the top of the fence fabric. The fabric was removed from the posts in 1990, retensioned, and reattached to the fence posts; the lowest stiffening cable was replaced with a metal pipe. A 150 m-long, straight section of the fence, extending from a heavily braced corner to the termination of the fence, is used with fence-mounted IDSs.

The IDS site in South Royalton, Vermont, is located in a river valley. The dominant wind direction is down-river, nearly parallel to the orientation of the chain-link fence, and typically varies by less than 15° (except during frontal weather changes). Consequently, the severity of wind-related effects on fence-mounted IDSs is low compared to the extreme situation of a fence oriented broadside to the wind.

FENCE MOTION UNDER CONTROLLED LOADING

The fence's normal stiffness and transverse stiffness (displacements of the fence fabric under loading applied perpendicular to and parallel to the plane of the fabric, respectively, at the panel center), together with the rigidity and plumbness of its posts, were measured in July 1989 using the fence characterization kit developed at CRREL (Walsh and Peck, 1990). Every fifth panel was measured in the section where fence-mounted IDSs are now located. Excluding the corner panel and the end panel, the normal stiffness (millimeters of displacement under 132-N [30-lbf] loading) of the 11 panels varied from 38 to 77 mm, with an average of 57 mm. The larger the value, the more the fence fabric displaced under the standard applied load. The normal stiffness of the corner panel, which was braced with a horizontal pipe near its top and a metal rod running diagonally across it, was 51 mm; three of the interior panels (without bracing pipes or rods) displaced less under the same load. The rigidity (deflection in millimeters at 1.5-m height with 226-N force) of one of the two posts adjacent to each panel was also measured; it ranged from 4–6 mm.

The normal stiffness of two of the panels was measured again in February 1990. There had been no structural changes to the fence, but the air temperature was 32°C lower (24 vs. –8° C). When cold, the two panels each displaced 22 mm less than they did under the same loading in July 1989.

The normal stiffness of selected panels was measured in September 1990, prior to the retensioning of the fabric, and in November 1990. Air temperatures were comparable (~13°C). The increased stiffness of the fence caused by the retensioning is evident (Table I) as smaller displacements (by 18–48 mm) under the same loading. By June 1991, the fence panels were less stiff, probably because of the combined effects of long-term relaxation, thermal cycling during the past winter, and thermal expansion at the higher summer temperature. Measurements of the normal stiffness of four other panels during April 1992–June 1993 suggest that 1) relaxation of the fence eventually becomes negligible, and 2) as the tension of the chain-link fence decreases with time, the magnitude of the difference in stiffness attributable to the fence panels being relatively cold or hot also is less.

The above examples show that the resistance to motion of chain-link fence panels is quite changeable. The stiffness of the panels varies over time due to loss of tension, with a superimposed seasonal variation caused by thermal contraction and expansion of the fabric. This suggests that assessments of fence suitability for an IDS should be made during warm weather when the full looseness of the fence should be evident, and after a year of thermal cycling. As the fence stiffness varies, the differences in fence motion due to wind loading or precipitation impact probably take the form of different vibration spectra as well as different displacement maxima.

A second fence parameter that may affect the apparent stiffness of the fence is the post rigidity. Soil that is hard because of being frozen in winter

Table I. Normal stiffness* of SOROIDS chain-link fence.

	Air temp.	*Displacement (mm)*			
	(°C)	*Panel 15†*	*Panel 20*	*Panel 40*	*Panel 60*
1990					
September	14	50	70	52	70
November	12	10	50	34	22
Difference		40	20	18	48
1991					
June	20	29	65	—	—

*Displacement (mm) perpendicular to the plane of the fabric, under a load of 132-N (30-lbf) push or pull at the center of the panel.
†Panel 15 is a heavily braced corner.

or dry in summer will anchor the fence posts more stably than will deeply saturated soil or thawing, frost-heaved soil.

IDS RESPONSE TO FENCE MOTION

The responses of three IDSs to environmentally caused fence motion were obtained through proximity-to-alarm monitoring. An IDS processor typically converts the output of the system's sensor to a voltage that is compared with a threshold level (dependent upon the sensitivity setting of the IDS) to determine whether an alarm should be generated. By electronically monitoring that voltage, a time series record of the IDS's proximity-to-alarm is obtained. At SOROIDS the IDS voltages are sampled at 8-Hz frequency, and maximum, minimum and average values for each half hour period are recorded. This information is compared with extensive site characterization data to determine what change in site conditions may have caused a change in IDS proximity-to-alarm.

All of the monitored fence-mounted systems have sensors in the form of a looped cable that is attached to the fence fabric with tie-wraps. Two of them are triboelectric (deformation of the cable by fence motion produces a transfer of charge between the conductors in the cable), with test point access to the sensor voltage that made proximity-to-alarm monitoring straightforward. The detection zone of one is 100 m long, that of the other is a different 50-m section of the fence. The third fence-mounted IDS uses optical fiber in its cable and a laser detector at the end of the cable to respond to changes in the incident laser light. The processor of this IDS did not have test point access to a voltage indicative of its proximity-to-alarm, so an integrator box was designed to sample the audio output (representative of the post-filtering output of the laser detector) of the processor, rectify that to DC level, and integrate it. The sampled output of the integrator was used to monitor the sensor's activation. This IDS has a 45-m-long detection zone that is within the 100-m detection zone of the triboelectric IDS.

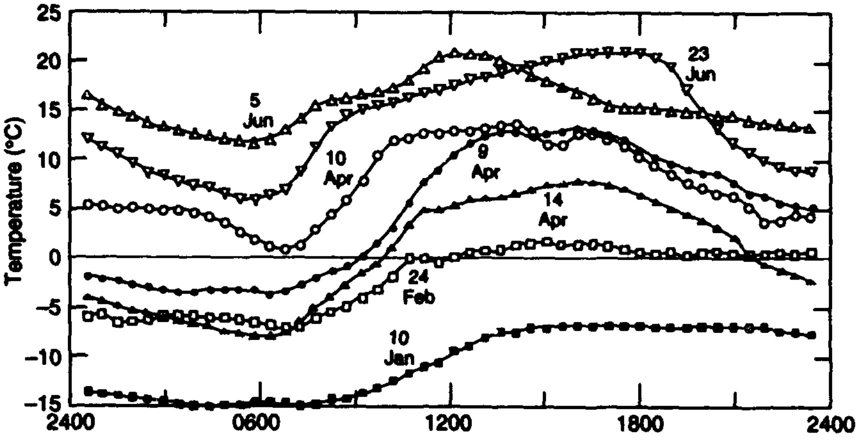
Because there is some uncertainty regarding the match between the output of the integrator box used to monitor the optical fiber IDS and its internally processed signal, examples of environmental effects on fence-mounted IDSs are drawn primarily from the monitoring of the triboelectric IDSs. The triboelectric IDS's voltage threshold for alarms is 3.2 V.

ENVIRONMENTALLY INDUCED VARIATION IN PROXIMITY-TO-ALARM

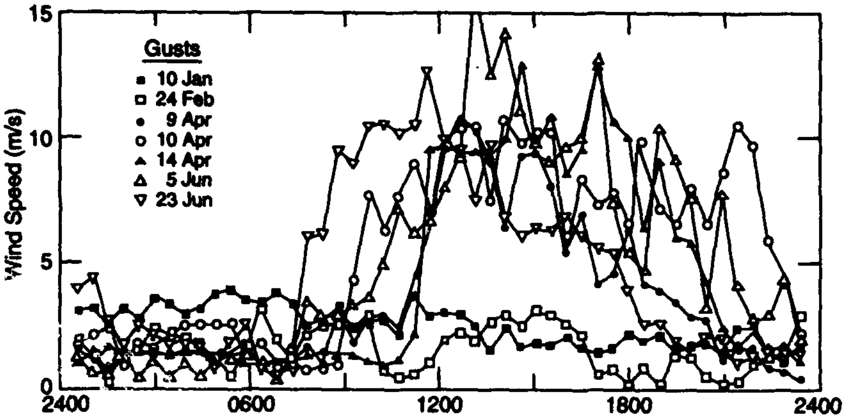
The events assessed for their effect on the IDSs are wind loading, rainfall and snowfall. The wind-induced IDS response is examined for seasonal differences because of the expected temperature dependence of the characteristics of the fence motion.

Wind and Temperature. The proximity-to-alarm status of the IDSs on 7 days was analyzed for seasonal differences in response to wind loading. The days are a selection of winter (January, February), transitional (April) and summer (June) conditions. Daily records of air temperatures (30-minute average at 2-m height) and wind gusts (maximum speed during the half hour) are shown in Figure 1. Air temperatures rose during the winter mornings because of high incident solar radiation locally and remained high after sunset because changing regional conditions brought warm air to the site. On the April days, the fence and IDSs experienced a 14–17°C range in air temperature in the course of a typical clear-sky diurnal cycle; solar heating of the ground led to radiational heating of the air during the morning and early afternoon, followed by radiational cooling through the afternoon and evening, with the lowest temperatures around sunrise (Rosenberg, 1974). The summer days were characterized by higher maximum air temperatures but not necessarily larger diurnal temperature ranges (as on 5 June), so the magnitude of temperature-related differences in fence stiffness over 24 hours was comparable to or less than that on the April days.

There are seasonal differences in wind activity that lead to greater likelihood of significant wind during the transitional and summer days. Synoptic conditions, such as weather fronts moving through the area, are the primary cause of variable site winds during the winter when the ground is snow covered. In the late spring and summer there are also local winds generated by convective systems (air heated by the ground rises, a pressure difference is created, and cooler air flows in along



a. Air temperature.



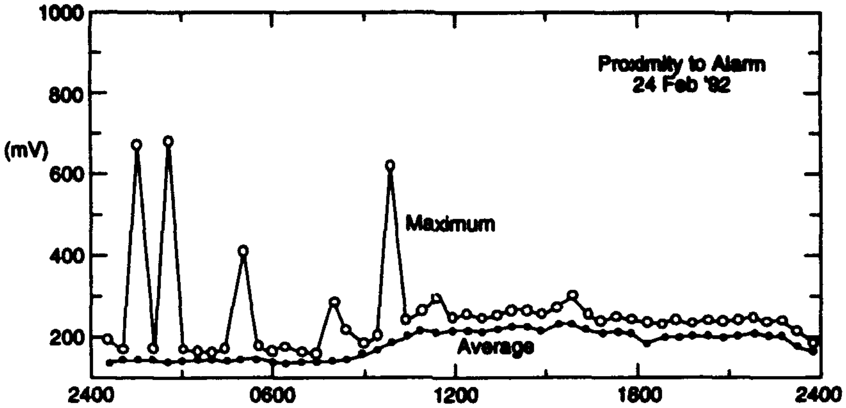
b. Wind speed.

Figure 1. Daily record of average air temperature and maximum wind speed on selected winter (January, February), transitional (April) and summer (June) days. Values are reported every half hour. The maximum wind speed on 5 June was 15.7 m/s.

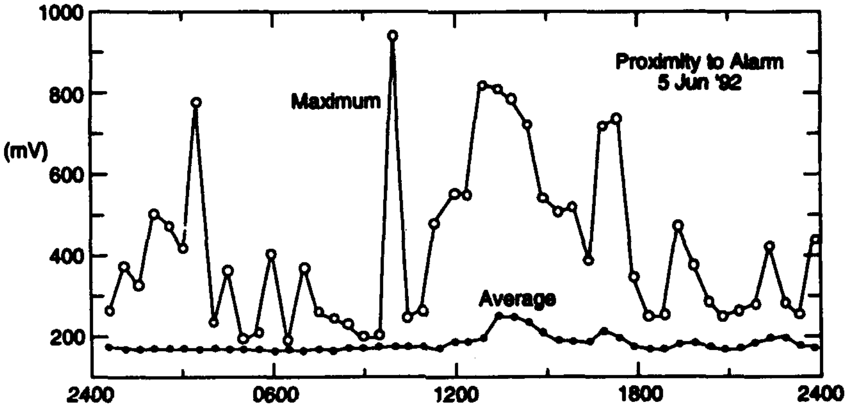
the ground). The winds on the winter days selected (Fig. 1b) were low (<3.5 m/s) and unchanging, probably because of stable regional conditions. The April and June winds showed strong diurnal cycles, with high wind speeds following dawn as the ground surface was warmed by the sun and radiated heat to the air. Wind activity fell noticeably after dusk on 9 April and 23 June as the ground radiationally cooled, but high winds persisted on 10 April and 5 June as a consequence of changing regional weather conditions.

The proximity-to-alarm status of the triboelectric IDS (100-m-long zone) is shown for 24 February and 5 June 1992 in Figure 2. Although the overall proximity-to-alarm is low (<300 mV) on the calm winter day, both maximum and average proximity-to-alarm values are higher after 0930, corresponding to air temperatures higher than -4°C. This is consistent with a temperature dependence of the wind-induced fence motion. Earlier, there are isolated occurrences of proximity-to-alarm status as high as ~700 mV that are not numerous enough to raise the half hourly average.

On the warmer, windier June day, there is sustained high proximity-to-alarm (>500 mV) from midday to dusk that coincides with the maximum wind speeds on that day (>10 m/s). Again, there are isolated high maxima during predawn, low wind speed conditions. The night-



a. 24 February.

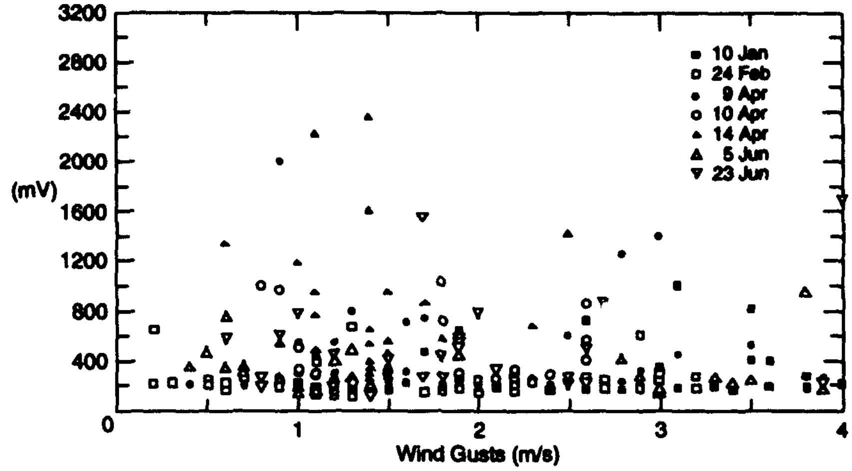


b. 5 June.

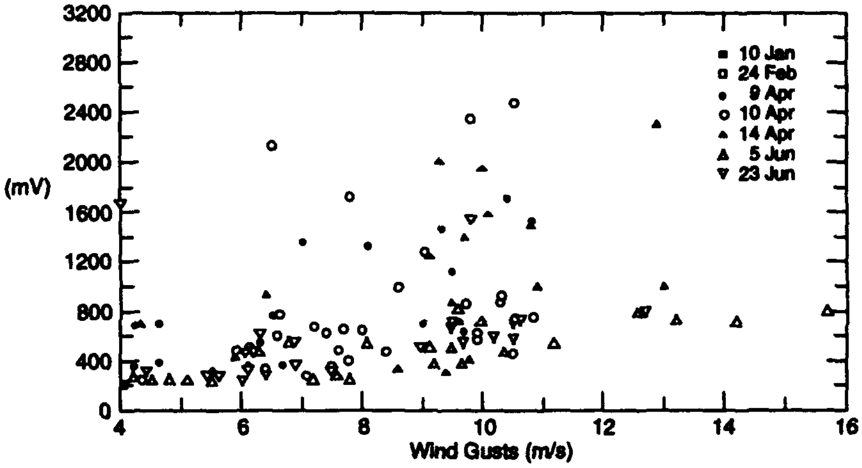
Figure 2. Proximity-to-alarm voltage of the 100-m triboelectric IDS on two days in 1992. Average and maximum values are reported every half hour. The alarm threshold is 3.2 V.

time wind speeds, ascribable to regional weather conditions, cause sufficiently numerous incidents of high proximity-to-alarm between 2130 and 2300 that the average values are also high then.

The IDS's proximity-to-alarm status is plotted versus wind speed in Figure 3 with all the selected days represented at wind speeds of ≤4 m/s (Fig. 3a), but only on the April and June days were wind speeds >4 m/s (Fig. 3b). The greatest ranges of air temperatures (–15 to 20°C) and fence stiffnesses are associated with the low wind speeds, but there is no clear-cut division by season (equivalently, air temperature) in the data. This may in part be due to the associated wind directions being ignored (although the variation in wind direction is atypically low at the IDS site owing to the river valley channeling the wind). Also, the occurrence of isolated high voltage maxima (Fig. 2) that are apparently unrelated to wind speed may obscure a temperature dependence. The proximity-to-alarm at a given wind speed often is highest for the April days, suggesting that the transitional period may be more troublesome with regard to nuisance alarms. This may be due to a combination of factors such as 1) in winter, when the fence is stiffer because of thermal contraction of the fence panels and rigid anchoring of the fence posts in frozen ground, the amount of fence motion from wind loading is smaller, and 2) in summer coupling between the sensor cable and the fence may be reduced by thermal expansion of the fence panels, the tie-



a. Low wind.



b. High wind.

Figure 3. Proximity-to-alarm voltage of 100-m triboelectric IDS during low wind (≤4 m/s) and high wind (>4 m/s) conditions on selected winter (January, February), transitional (April) and summer (June) days. Maximum IDS voltages and maximum wind speeds are reported every half hour. The alarm threshold, 3.2 V, was exceeded in the half hour ending 0530 on 14 April under calm wind conditions (1.5 m/s gust). The voltage, 4.8 V, did not cause an alarm because the event count criterion was not satisfied.

wraps attaching the cable to the fence, or the cable itself, or all three.

The IDS's proximity-to-alarm during windier periods (>4 m/s; Fig. 3b) also is highest on the transitional days. The half hourly maxima that are greater than 1200 mV are almost exclusively those of the April days. There is a trend of increasingly higher IDS voltages at wind speeds of >8 m/s. The densest band of IDS voltage maxima is ~200–700 mV at wind speeds of 4–8 m/s; it is ~300–900 mV at wind speeds of ~9 m/s; and it is ~500–900 mV at wind speeds of ~10 m/s.

The IDS response to wind loading in the above examples is for an optimum situation, that

Table II. Proximity-to-alarm (PTA) voltage and site conditions during rainfall, 22 September 1992.

Time	*PTA, max (mV)*	*PTA, ave (mV)*	*Precip.* (mm)*	*Wind gusts (m/s)*	*Air temp. (°C)*
1830	334	176	0	2.6	22.9
1900	1118	251	16.1	2.9	21.8
1930	2916	317	23.0	20.9	20.9
2000	593	205	4.8	2.1	19.5

*Millimeters of rainfall during each half hour.

of a well-installed and well-maintained fence. If the fence were poorly anchored in the ground, if the fence fabric were inadequately secured to the posts, or if there were loose parts, then the proximity-to-alarm would be higher because wind-induced motion of the fence would be large and vibrations due to impacts would be numerous.

The actual wind force on a fence is the product of the velocity pressure, a gust response factor (which accounts for the additional loading effects due to wind turbulence), a force coefficient (which depends on the ratio of solid area to gross area of a fence panel), and the area of all exposed fence members projected on a plane normal to the wind direction (ASCE 7-88, 1990). The velocity pressure, which is proportional to the square of the wind speed, varies directly with a parameter called the exposure coefficient, which depends upon the terrain and obstructions in the vicinity of the fence. If the terrain or obstructions vary seasonally, as for example due to changes in vegetation height or fullness, then this imparts an environmental difference to the wind loading of the fence that is not related to weather.

Rainfall. There are two difficulties in quantifying the effect of rainfall on the proximity-to-alarm status of the fence-mounted IDS. First, rainfall is often accompanied by wind, which itself induces fence motion. Second, rain drops directly strike the sensor cable as well as the fence, so there is both direct cable vibration and cable motion coupled to fence motion. The example of changes in proximity-to-alarm (Table II) presents the net effect of rainfall and wind on fence motion.

Prior to the onset of rainfall (period ending 1830), the wind was calm and the maximum proximity-to-alarm voltage was one-tenth of the alarm condition. During the next half hour, 16 mm of rain fell while winds remained calm; the maximum proximity-to-alarm voltage more than tripled. The following half hour (period ending 1930) was marked by an additional 23 mm of rainfall but also very strong winds (20.9 m/s maximum gust), and the maximum proximity-to-alarm voltage was 8.7 times higher than its value before the storm. During the final half-hour considered, winds were calm, rainfall was low (~5 mm) and the proximity-to-alarm was much closer to its value before rainfall. The average proximity-to-alarm value also showed increases during rainfall, which indicates frequent high values.

Snowfall. Fence motion caused by the impact of snowflakes is expected to be less than that during rainfall because the weight of the particles typically would be less. Instead, snowfall is potentially troublesome for fence-mounted IDSs because snow can accumulate on the fence wherever there are components that are not vertical, such as horizontal or diagonal pipes or cables used to brace fence panels. Wet snow may cling to the fence fabric. Either when displaced by wind-induced motion of the fence or under its own weight, such accumulated snow will fall off (often through) the fence. Fence motion results as the fence fabric rebounds and as the snow piles strike the fence during their descent. Such motion occurred in the detection zone of one of the other fence-mounted IDSs at SOROIDS and did cause alarms.

Icing. The formation of an ice coating on a chain-link fence potentially has two detrimental effects on alarm occurrences by fence-mounted

IDSs. The first is a reduction in probability of detection if the ice coating sufficiently changes the vibration characteristics of the fence panels so that fence motion caused by cutting or climbing activities does not result in alarms. The second is an increase in nuisance alarms while the fence sheds the ice coating, similar to the nuisance alarms that occurred as accumulated snow fell through the fence.

During the winter of 1993, there was an episode of icing on the SOROIDS chain-link fence. Melt water from snow that had accumulated on a horizontal pipe (used to brace a fence panel) froze onto the fabric. Taps to the fence (the standard controlled intrusion event for fence-mounted IDSs at SOROIDS) in the ice-coated location produced no alarms until the rigidity of the ice coating had been reduced by manually cracking it.

RELATIVE RESPONSE TO ENVIRONMENTAL CHANGES

All three IDSs that were monitored to determine their variations in proximity-to-alarm as site conditions changed showed similar overall behavior. Diurnal variations correlating with wind activity were evident in their responses. The two triboelectric IDSs had isolated occurrences of high proximity-to-alarm during calm wind conditions that were not evident with the optical fiber IDS. It is not known if this is attributable to the difference in detection phenomenologies, or to differences in the stage of the processing of the sensor output at which the monitoring is done.

Initially, the triboelectric IDS with the 100-m detection zone experienced many more wind-related nuisance alarms than did the triboelectric IDS with the 50-m zone, so the sensitivity of the former was reduced until nuisance alarm activity was comparable (without reducing the 50-m IDS's probability of detecting fence taps). It was thought that the larger fence area protected by the 100-m IDS, and consequently the greater likelihood that disturbances of the fence along its length would cumulatively satisfy its alarm criteria, was responsible for the more numerous alarms with the 100-m IDS (Peck, 1992). Other factors are differences inherent to the sensor cable and variability in response to wind loading among the fence panels in each zone.

Comparison of wind-related nuisance alarm occurrences with the three monitored IDSs, all of which have a count feature, and a fourth, an optical fiber IDS that does not, emphasizes the usefulness of fence-mounted IDSs having an operator-selected count feature, such that a specified number of events (voltage levels equivalent to the alarm threshold) must occur in a certain time interval for the alarm conditions to be met. Primarily because the triboelectric IDSs were set for a count greater than one, they had few nuisance alarms during windy periods when the IDS response voltage intermittently exceeded the alarm threshold.

CONCLUSIONS

Fence-mounted IDSs are susceptible to both environmental- and time-related changes in detection capability. The dominant environmental influence is wind-loading of the fence, but there is also a temperature-dependence to the resultant fence motion because of differences in the stiffness of a thermally contracted or thermally expanded fence fabric. Whether fence posts are rigidly anchored in frozen or dry ground, or are weakly anchored in deeply saturated or thawing frost-heaved soil, also influences the motion induced by such applied loads as wind action or an intruder. Rainfall increases the proximity-to-alarm status of fence-mounted IDSs, while limited results indicate that an ice coating on the fence reduces IDS response to fence taps (a non-destructive substitute for cutting the fence fabric). Snowfall in itself typically does not cause nuisance alarms, but accumulated snow that falls off (through) the fence does.

There is an obvious time-dependence to the proximity-to-alarm status of fence-mounted IDSs because there are diurnal and seasonal variations in wind activity and air temperatures. A more subtle time-dependence arises from the gradual change in stiffness of a chain-link fence. An overall decrease in stiffness, i.e., less resistance to deflection under loading, occurs with time as the fence components relax due to thermal cycling. This may be seasonally offset by thermal contraction of the fabric during cold weather.

Proximity-to-alarm monitoring is a reliable means of determining changes in IDS detection capability caused jointly by environmental factors and by variations in the stiffness of the fence.

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Four optical-fiber intrusion detection systems (IDSs) and one pulsed near-infrared IDS were operated from October 1992 through July 1993 during conditions of snowfall and rainfall, unfrozen and frozen ground, snow as deep as 80 cm, wind gusts >20 m/s, and air temperatures ranging from –30°C to 35°C. The optical-fiber IDSs were installed in both buried and fence-mounted configurations. The detection capability of the IDSs was determined with controlled intrusions on a regular basis. Long-term monitoring identified causes of nuisance alarms.

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