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FOREST FIRE MAPPING USING AN 8-13 MICRON PYROELECTRIC VIDICON

by

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ABSTRACT

A relatively inexpensive, portable, 8-13 micron infrared vidicon system was field tested to evaluate its potential for forest fire mapping. Preliminary results indicate that such systems could play an important role in future Canadian forest fire mapping.

SOMMAIRE

Un systeme vidicon a infrarouge, relativement peu couteux a ete mis a l'essai en vue d'evaluer son potentiel pour la cartographie des feux de forets. Les resultats preliminaires indiquent qu'un tel systeme pourait desormais, jouer un role important dans la cartographie des incendies forestiers au Canada.

FOREST FIRE MAPPING

USING AN 8-13 MICRON PYROELECTRIC VIDICON

Vidicon tubes employing an uncooled bolometric pyroelectric target and capable of imaging in the 3 to 70 micron infrared region of the electromagnetic spectrum have recently become available to civilian users. The cameras containing the tubes are normally designed to operate in the 8 to 13 micron infrared region, well beyond the 1 micron long wavelength limit of conventional near infrared photography. Hirsch (1965) has shown that long wavelength infrared radiation emitted by terrain and fires penetrates thick smoke palls. These "Pyricon" cameras thus have the potential for mapping perimeters of large forest fires through thick smoke.

Because Pyricon tubes respond to the time rate of change of image temperature, they share with infrared line scanners the ability to discard the very large dc component of 8 to 13 micron thermal imagery. Hence, like scanners, they produce on the viewing screen a relatively high contrast ac, or differential, image of the thermal scene.

A field test of such an airborne Pyricon system was carried out by the Forest Fire Research Institute in August 1974. This report describes the test, the results, and discusses the potential future of this equipment in fire control.

Need for Forest Fire Mapping

Large, fast-spreading forest fires produce smoke in sufficient quantities that aerial observation or conventional photography of perimeter positions frequently are impossible. Without a fire mapping system, control activity by ground forces of a fast spreading fire must either be curtailed or proceed at a cautious pace. Otherwise, suppression crews and equipment risk encirclement with little hope of rescue.

Another closely related and frequently occurring situation involves the decision as to when communities in the potential path of a large fire should be evacuated. Without accurate fire perimeter locations, this decision is difficult, particularly when fire behaviour conditions are such that the fire can run many miles in a single hour.

After a fire line has been constructed around a fire, there is a need to appraise the security of that line. A fire mapping system flown along the fire line would provide information concerning the extent and intensity of remaining fire activity in the vicinity of the line. Once the line is secure, the process of "mopping-up" or extinguishing the remaining, often hidden and smouldering fires must begin. This can be a long and costly process in some cases. A fire mapping system could be used to locate many of these fires, thus reducing the mop-up time.

The U.S. Forest Service's project "Fire Scan" first demonstrated in 1962 that an infrared line-scanner system could be used to map fire perimeters through thick smoke (Hirsch 1965). Several such systems were built and have proven most useful since that time. However, Canadian fire control agencies, to date, have been unwilling to invest the necessary funds required for a quality fire-mapping line-scanner. Such a scanner would likely cost in the neighbourhood of $100,000.

Since 1970 the Forest Fire Research Institute has investigated several alternatives to line scanners including microwave scanners (Kavadus, 1974) and semi-conducter infrared photography (Pinson, 1973). The present paper witnesses the expansion of this interest to infrared camera tubes of the vidicon type.

Description of the Airborne Pyricon System

The Pyricon system used in the tests, together with field personnel, were provided, under contract, by Philips Labs.*

A photo of this system, including camera and support equipment, is provided in Fig. 1. The support equipment includes a nine-inch T.V. monitor, a video recorder with 30-minute tape reels, and a 200-watt dc/ac converter which provides 110V, 60 cps power for the system. This converter is protected against ±50 volt surges from the aircraft power supply. System weight is in the 50 to 100 pound range, depending on the make of converter. An inexperienced operator can learn to operate the equipment quickly.

For tests, the system was installed in a light Cessna 185 aircraft. The camera was suspended over the open 18-inch wide rear floor hatch by means of rubber straps attached to a ring on a horizontal bar secured to the window-sills. The forward motion of the aircraft caused the image of the scene to move across the target of the camera tube at a few mm/sec so that no additional panning of the camera or chopping of the radiation was required. Panning or chopping is normally required because the time rate of change of the thermal pattern, and not the thermal pattern itself, is responsible for the pyroelectric target of the tube forming an image. The T.V. monitor displayed the moving scene, as observed by the camera, and the video-recorder stored the information for later viewing.

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Fig. 1 Camera, Recorder and Monitor as Mounted in a Cessna 185 Aircraft

The camera is suspended over the 18" camera hatch of the aircraft.

Philips Labs had modified a good quality standard portable vidicon camera for use with their "off-the-shelf" pyricon tube. The completed camera weighs 14 pounds and incorporates all controls within its 8" x 10" x 12" volume. A F/1.0 germanium or Irtran 2 lens attached to the front of the camera focuses the termal scene onto the faceplate and target of the camera tube. The faceplate is made of germanium or an Irtran material. Both the faceplate and lens are anti-reflection coated for maximum transmission in the 8-13 micron region.

The lens used was a 120 mm F.L, F/1.0 high quality 2-element aspherical germanium lens made by Rank Taylor Optics**. The 18 mm wide target limited the angular aperture of the lens to about 10 degrees so that for an aircraft altitude of 2000 feet, the instantaneous image on the monitor was of a patch of ground 350 feet in diameter.

The system had a temperature resolution of approximately 0.5 degrees C at a spatial resolution of 100 T.V. lines per picture diameter.

This camera is similar in its operation to the common 1-inch vidicon T.V. camera. However, the use of a pyroelectric target distinguishes the pyricon from other vidicon tubes. Where the usual vidicon tube typically employs a 1-inch diameter photoconductive target whose electrical resistance is modulated by the incident visible radiation pattern, the pyricon instead employs an 18 mm diameter non-conductive pyroelectric target with a built-in surface polarization charge which may be spatially modulated by the target absorbing a thermal infrared radiation pattern. This thermally modulated surface charge pattern is detected and read out by the scanning electron beam of the Pyricon tube to produce a corresponding output video signal across the load resistor. This video signal produces on the screen of a T.V. monitor a black and white picture which is the real time visible analog of the thermal infrared pattern.

The Pyricon system that was tested was a research prototype. No specific package has been developed to date for fire mapping. It is difficult, therefore, to quote a precise cost figure. It appears that a fire mapping system might be marketed for less than $12,000. The Pyricon tubes currently sell for about $3,500 and are guaranteed for a few hundred operational hours. The camera and support equipment might be bought for under $4,500 and an acceptable lens for perhaps $3,500.

** Chelmsford, England

A special test was carried out to show that a modified Pyricon tube with a faceplate transmitting only 3.4 to 4.8 micron radiation could form images of hot objects. The image was focused onto the vidicon target by a single element 50 mm F.L., F/1.0 Irtran 2 lens, having one aspheric surface, which had been anti-reflection coated for use in the 8 to 13 micron range. Ground tests showed that this sytem had a temperature resolution better than 6 degrees C at a spatial resolution of 100 TV lines per picture diameter. The test carried out with this special tube is described at the end of the following section.

Description of the Test and Results

The test of the standard 8-13 micron Pyricon system consisted of a series of flights at different altitudes over:

a) the city, forest, lakes and farmland to assess the ability of the Pyricon to map terrain background, using thermal radiation originating in these objects;

b) a cluster of five two-foot diameter charcoal fires, with variable spacing of five to 25 feet between fires, to determine the Pyricon's ability to image small targets (Fig. 2) for the mop-up role; and

c) small forest fires and a smoky sawdust burner to assess the Pyricon's capability for large fire mapping in the presence of smoke. (During the period of the test no large forest fires were burning in Eastern Canada.)

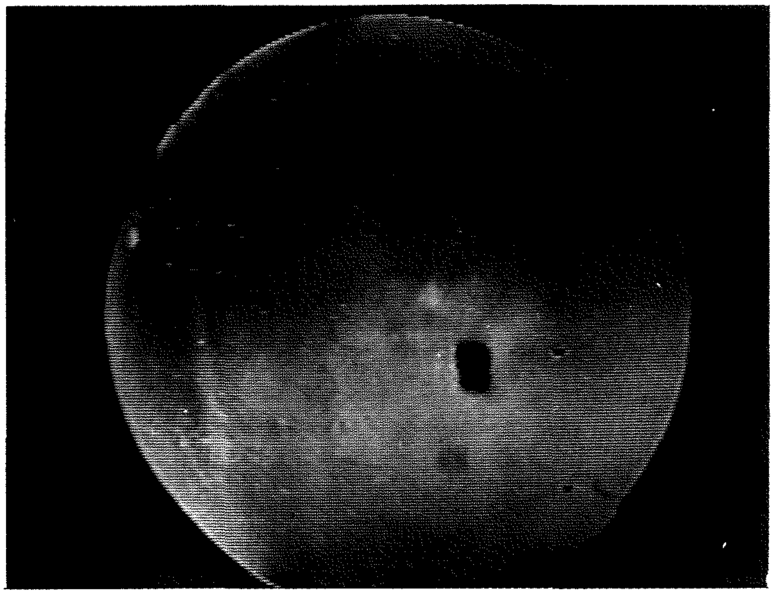
Flights over suburban and industrial areas showed that acceptable low contrast terrain imagery could be made. Roads, houses, warehouses and factories appeared undistorted. Roads ran straight and corners were at right angles. At altitudes up to 2000 feet individual trees, cars, locomotives and bulldozers could be distinguished from the background (Fig. 3).

Flights over lakes and forests showed that lake boundaries, rock outcrops and forest clearings could usually be recognized.

The charcoal test fires as a group could be distinguished from the background up to an altitude of 4,000 feet (Fig. 2). Above this height, the fire imagery could be confused with that of objects such as parked cars and tin roofs. Even at 4000 feet the widely separated charcoal pots could be recognized as separate from the group.

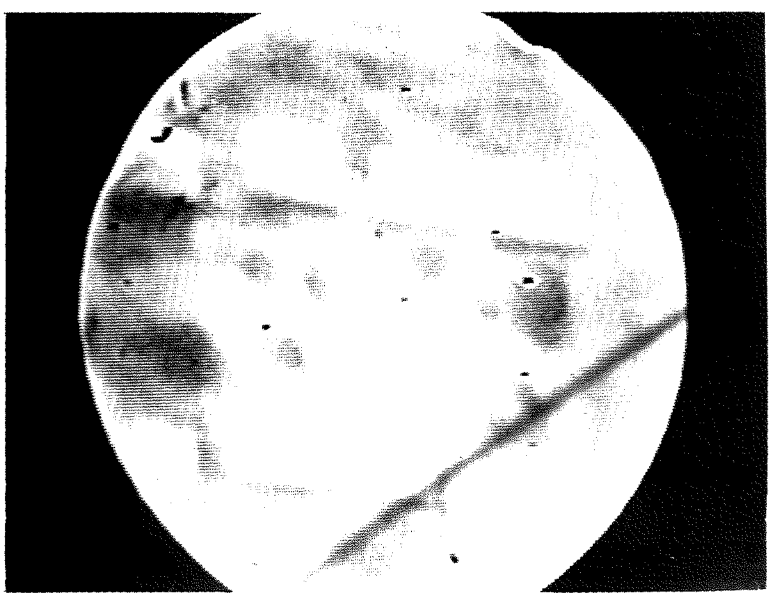
A flight over a large sawdust burner in a mill yard showed the ability of the system to image through smoke. Figure 4 shows the burner from an altitude of 1,000 feet through about 20 feet of thick smoke. Individual lumber piles in the yard surrounding the burner could be seen at the same time the burner was in view.

Fig. 2. Example of Imagry Obtained Over the Charcoal Fire Cluster at 2000' Altitude



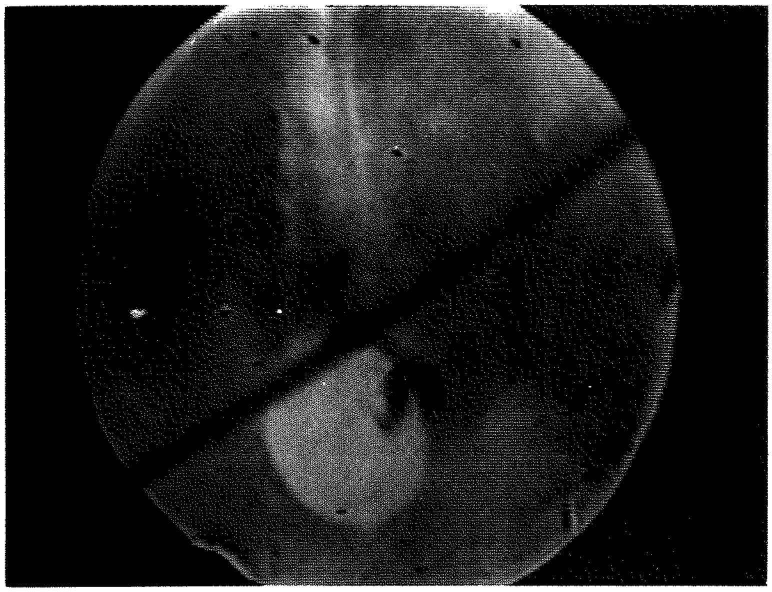
The black rectangle represents the cold metal roof of a building. The cluster of fires is located 1/2 inch above and slightly to the left of this building. These fires were easily distinguished on the video monitor however, most detail has been lost in attempting to photograph the T.V. screen.

Fig. 3. Image of a Suburban Area



On the original video output each house, car, tree and road showed clearly.

Fig. 4. Sawdust Burner Imagery



The large white circle represents the sawdust burner. In the original video imagery each individual lumber pile in the surrounding yard could be seen.

Fig. 5. Burning Slash Pile Imagery

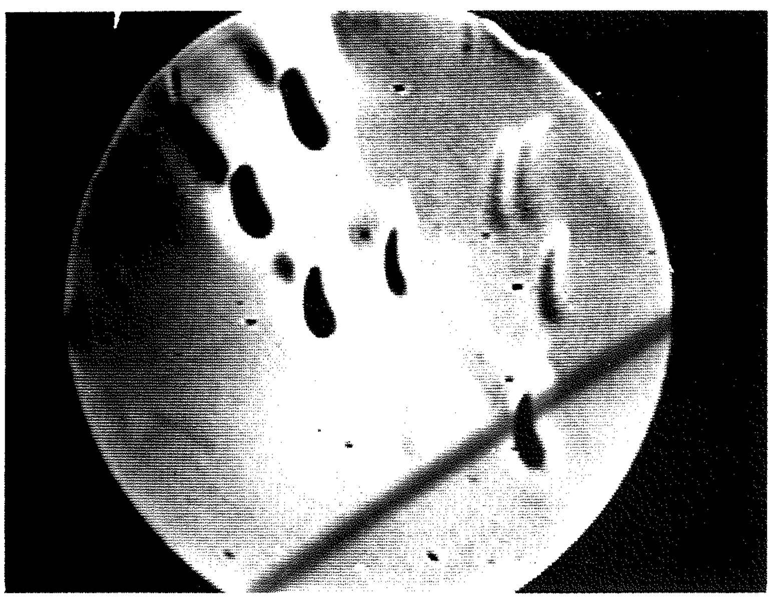


Image "saturation" caused by high temperatures of the slash fires.

A flight over 12 burning slash piles (Fig. 5) caused the target of the Pyricon tube to saturate so that much of the background and perimeter information was lost momentarily. In such cases, insertion of either a long pass filter or of an iris, or both, between lens and camera faceplate would have reduced the radiant power density on the target and eliminated saturation. When such hot objects are observed, the necessary insertion could be made and a return flight made over the hot target. From Fig. 6, which shows the radiant emission spectrum of black bodies at ambient (300 degrees K) and at 1000 degrees K, it is evident that most of the radiant energy emitted by the 1000 degrees K object is on the short wavelength side of 8 u. Thus by choosing a long pass filter with a cut-off somewhere between 8 and 11 microns, it should be possible to get both acceptable fire and background imagery.

A flight over a small forest fire recently ignited from a burning garbage dump clearly showed the extent of the new fire relative to the original garbage fire. The video recorder proved its usefulness in this case. The operator was not looking for the small forest fire so he was not quite sure he had seen it on the monitor. A replay of the video tape, which could have been done immediately in the aircraft, showed the location and extent of the fire.

Referring again to Fig. 6, the intensity of reflected solar radiation in this 8-13 micron range is seen to be well below the intensity of radiation self-emitted by objects at ambient temperature. All the test results are in agreement with this prediction. Thus similar imager would be observed whether the flights were carried out by day or night.

The test of the Pyricon tube modified for use in the 3.4 to 4.8 micron region consisted of observing the cluster of burning charcoal pots from altitudes between 1000 and 4000 feet. The cluster was observable but individual pots unresolved at all these altitudes, while no terrain imagery was observable at any altitude. This absence of background is understandable in view of the narrow 3.4 to 4.8 micron spectral width employed, the strong atmospheric absorption at 4.1 micron, (Fig. 7), the use of an Irtran 2 lens anti-reflection coated for the 8-13 micron range, and the relatively small amounts of both reflected sunlight and ambient self-emitted radiation in the 3.4 to 4.8 micron range (See Fig. 6).

The charcoal pot group can be seen as there is considerable energy in this 3.4 to 4.8 micron range from even a charcoal fire (700 degrees K) (Fig. 6). The inability of the Irtran 2 lens and Pyricon to resolve the individual pots results most likely from scattering within the lens of the 3.4 to 4.8 micron radiation by the sintered Irtran material.

FIG. 6

Radiant Emission Spectrum of Black Bodies at Ambient (300°K) and at 1000° K Temperature.

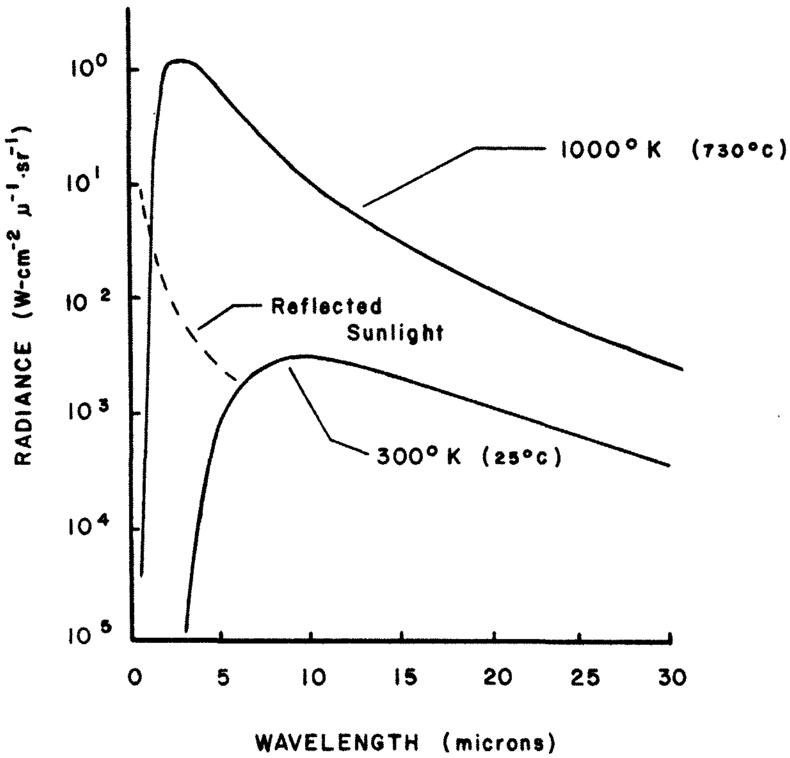
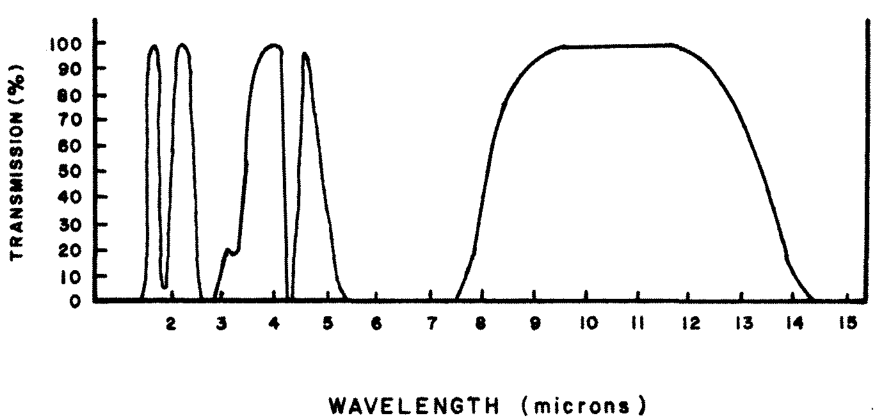


FIG. 7

Atmospheric Transmission and Wavelength Relation.
(2000' altitude)



Conclusion

In view of the modest cost, portability, and ease of operation of Pyricon systems relative to quality infrared line scanners and of the success of this test, it seems safe to conclude that such systems will have a role to play in future forest fire mapping operations. Although no large forest fires were mapped during this test, it was demonstrated that the Pyricon can image small targets similar to those encountered in mop-up conditions. Terrain detail of sufficient contrast is produced that fire perimeters and hot spots can be readily located on the ground.

Some modifications of the present system which might improve its fire mapping efficiency are listed below:

a) A lens with an angular field of view of 30 degrees, making it easier to recognize the background and to see at a glance the position of small fires widely scattered within it.

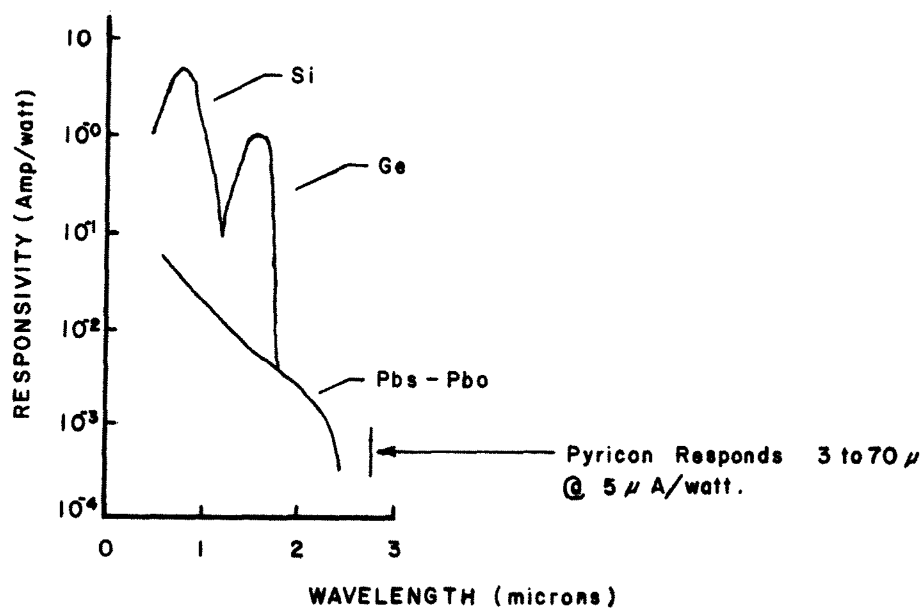
b) An iris and long pass filter to provide acceptable background along with unsaturated images of hot fires.

c) A built-in small TV monitor in the camera itself.

d) A light weight power supply, designed to run on batteries.

FIG. 8

Responsivity of Several Target Materials



Tests are planned for the immediate future to determine the fire mapping ability of two near infrared vidicons, one having an uncooled PbS-PbO target with long wavelength limit of 2.4 microns, the other a cooled germanium target having the very high responsivity of 1 amp/watt at 1.55 microns (Fig. 8).

The PbS-PbO vidicon camera is particularly attractive because of its low price (less than $2,000.), its compatibility with the Pyricon support equipment, its use of inexpensive quality glass lenses, its spatial resolution exceeding 500 T.V. lines per picture diameter, and its operation at ambient temperature. With this system reflected solar radiation should provide excellent terrain imagery. The literature available on these vidicons suggests that only fires with temperatures exceeding approximately 250 degrees C will be seen. Little information is available on the ability of radiation in the 1.1 to 2.4 micron range to penetrate smoke.

A list of available Pyricons and near infrared vidicons and a technical discussion related to their use and operation is contained in a report prepared by one of the authors and is available from the FFRI.

The FFRI plans to proceed with testing of such vidicon systems in the continuing search for improved, low cost fire mapping and detecting systems.

References

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