DETECTION AND IDENTIFICATION OF UNIDENTIFIED FLYING OBJECTS (UFO) USING EXISTING TECHNOLOGY
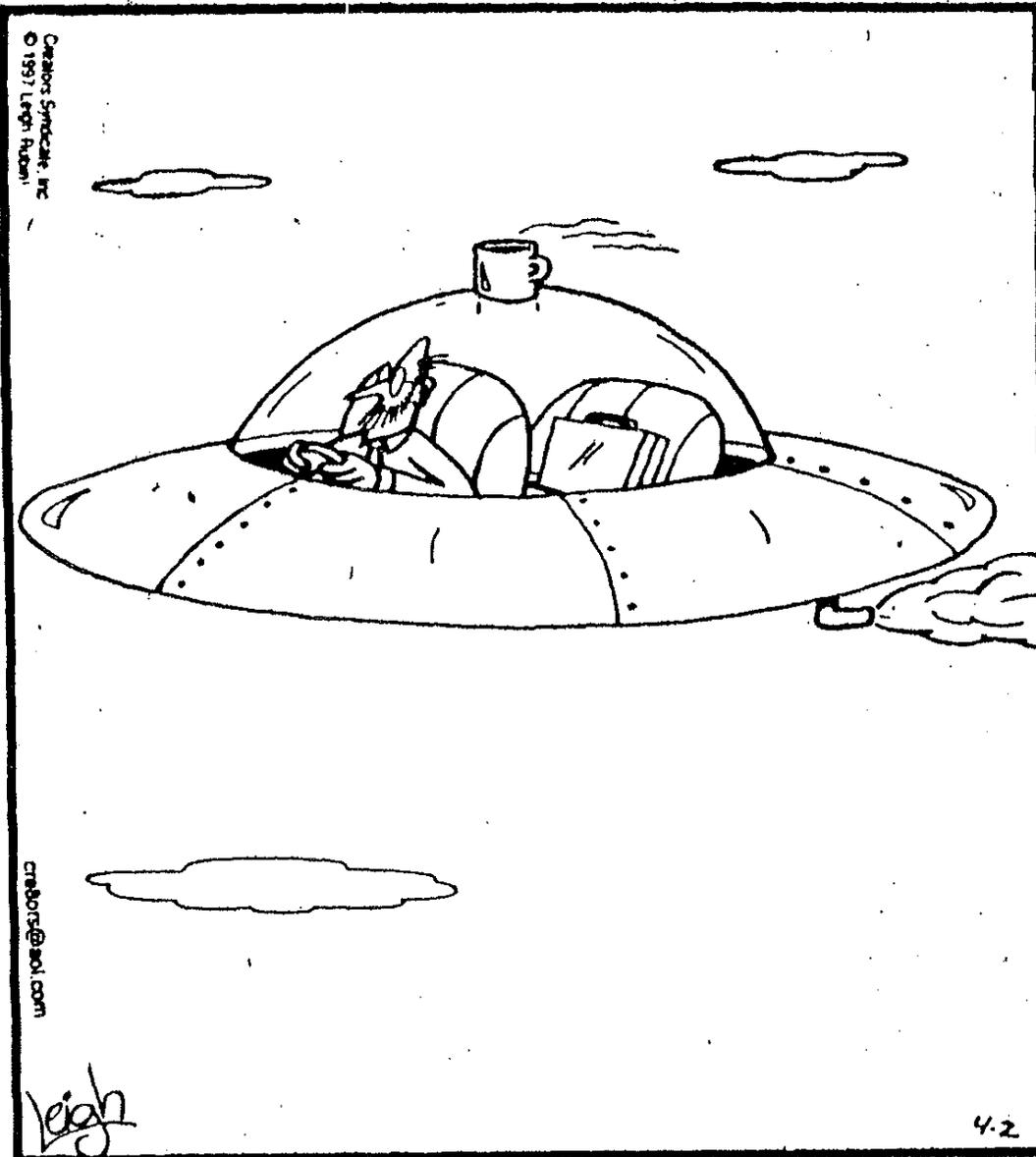
September 2000

John F. Schuessler
P.O. Box 369
Morrison, CO 80465-0369

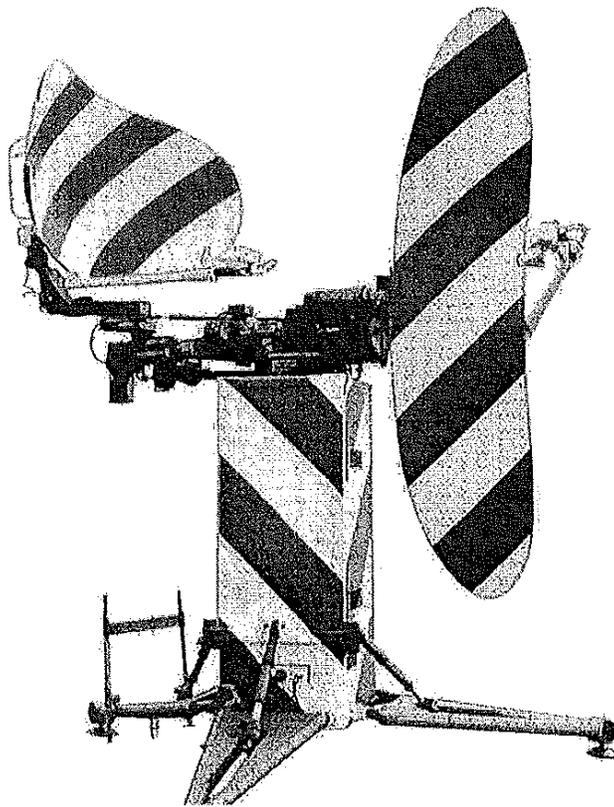# Rubes

4.2

Technology advances; people stay the same.

PORTABLE RADAR
GROUND CONTROLLED APPROACH

GCA RADAR FPN-36

HELICOPTER PORTABLE-ITT-GILFILLAN

SPECIFICATIONS

FREQUENCY	9000 to 9160 MHz, TUNABLE
PULSE WIDTH	0.18 to 0.6 usec.
RECEIVER BANDWIDTH	4 mhz minimum at half power point
PULSE REPETITION	1500 pulses per second
PEAK POWER OUTPUT	160 kw
RECEIVER SENSITIVITY	Not less than 90 db below 1 mw.

	Resolution (at 1 mile)	Accuracy:
Range	170 ft	±1% of true range (search)
Azimuth	0.75°	±0.35°
Elevation	0.6°	±0.175°

AZIMUTH ANTENNA:

Vertical beam width	Cosecanted to 30°
Horizontal beam width	Not more than 0.95°

ELEVATION ANTENNA:

Vertical beam width	Not more than 0.85°
Horizontal beam width	Not less than 2.5°

SURVEILLANCE FUNCTION

DISPLAY	PPI
RANGES	5, 10, 20, and 40 nmi
ANTENNA COVERAGE	360°

FINAL APPROACH FUNCTION

AZIMUTH AND ELEVATION

Display	Beta scan
Ranges	1 to 3, 10, 20, and 40 nmi
Range marks	1-mile spacing on 1-to 20-mile ranges; 5-mile spacing on 40-mile range

HEIGHT FINDER FUNCTION

DISPLAY	Beta scan
RANGE	40-mile slant range at a 30° angle
RANGE MARKS	1-mile spacing on 5-10 mile range; 5-mile spacing on 40-mile range

PORTABLE RADAR
S BAND SURVEILLANCE
& X BAND AUTO-TRACK SYSTEM

## M-33 S BAND SURVEILLANCE & X BAND AUTO-TRACK SYSTEM

S BAND ACQUISITION
Acquisition Antenna:
Type:	Parabolic

Beam Width:
Horizontal	25 mils
Vertical	Variable Scan
Gain:	29 db
Polar:	Horizontal

Transmitting Group:
Frequency	3.1 to 3.5 MHz
Peak Power	1 mw
PRF	1000 pps @ 1.3 usec
IF Frequency	60 mc
IF Bandwidth	2.3 mc

Presentation Group:
Range	120,000 yds.

X BAND TRACKING
Antenna:
Beam Width	1.2°
Gain	39 db

Transmitting Group:
Frequency	8.5 to 9.6 GHz
Power	250 kw
PRF	1000 pps @ .25 usec

Receiver:
IF Freq	60 mc
IF Bandwidth	10 mc
Indicators	5-in, 3 ea.

Periscope:
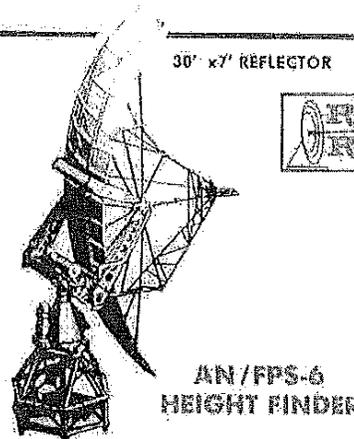|	
Field of view	100 mils
Magnification	8 pwr

Tracking Rates:
Range	600 yds per sec
Azimuth	700 mils per sec
Elevation	500 mils per sec

COMPUTER
General:
Modes   Linear, tangential and quadratic

ACQ ANTENNA ASSY

TRK ANTENNA
6' DIA

TRK CONSOLE ASSY

TACTICAL-CONTROL
CONSOLE

COMPUTER ASSY
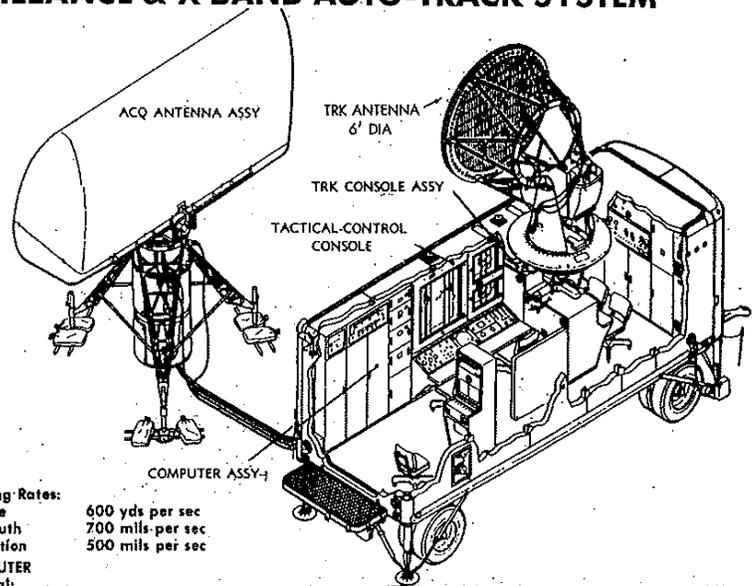
NIKE HERCULES AND AJAX ALSO IN STOCK

PORTABLE RADAR –HEIGHT FINDER

30' x7' REFLECTOR

AN/FPS-6 HEIGHT FINDER

The FPS-6 radar is capable of height determination of targets flying between elevation angles of −2 and +32 degrees for any azimuth throughout 360°. The transmitter develops a peak power of 5 Megawatts at a frequency range of 2.7 to 2.9 GHz. The pulse width is 2 usec at a PRF of 400 PPS. Maximum indication range is 200 nautical miles with height measurement capability to 75,000 feet. Both ranges are readily expandable. Data is displayed on two 12' RHI indicators and mechanical counter assemblies. The antenna type is a truncated semiparabolic reflector with associated waveguide feed sections. Input power requirements are 208V, 3Ø, 60 Hz. This radar is also suited for very high power search functions.

Frequency:	2700 to 2900 mc
Power Output:	5 megw, peak
Power Source:	QK-338A
Range:	300 naut mi
Vertical Coverage:	Minus 2 to plus 32 deg angular
Vertical Scanning Rate:	20 or 30 cpm
Azimuth Resolution:	3.2 deg
Elevation Accuracy:	1000 ft
Horizontal Beam Width:	3.2 deg

4 SYSTEMS IN STOCK

## 5000 MILE "PRELORT" PRECISION LONG RANGE TRACKER
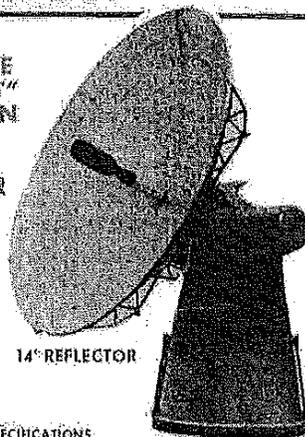
14' REFLECTOR

TECHNICAL SPECIFICATIONS

Frequency Range	2700 to 2900 MHz
Peak power output	250 kw minimum
Pulse width	0.8 usec
PRF	410, 512, 585 or 630 pps
Antenna beam width	1.8 degrees
Polarization	Selectable horiz, vert, right circular, left circular
Noise Figure	3.5 db
Tracking Range	9,965,000 yds. (4982.5 nmi)
Accuracy	plus or minus 25 yds.
Azimuth coverage	360 degrees
Elevation coverage	minus 1½ to 89 deg tracking 181½ degrees plunged
AZ and EL accuracy	plus or minus 0.1 mil
Data transmission	Shaft-to-digital encoders

PORTABLE RADAR – AUTOTRACK

SCR-584 AUTOTRACK

6' REFLECTOR
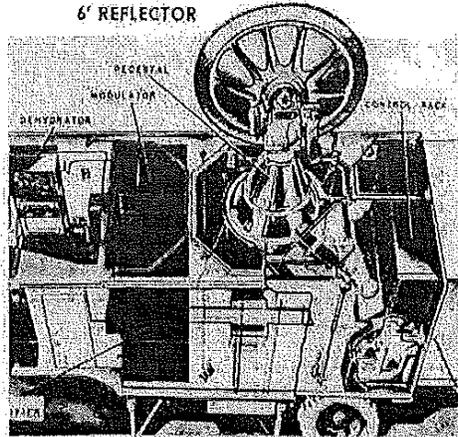
SCR-584 AUTOTRACK. Radar type: SCR-584. Freq. band 2700-2900 mHz. Pwr. output 250 KW. Indicator: PPI J Scope. Magnetron type: 2J32. Rep. rate: .8 microsec., 1707 PPS. Pwr. input 115V 60 Hz. AC. Antenna: 6' parabola with conical scan. Mfr. G.E.

Designed at MIT Radiation Labs, and still considered one of the finest automatic tracking radars ever built. It is now being used in hundreds of installations in its original form and in various modifications. We have them in stock for immediate delivery complete in their own 20 ft. trailer van containing the entire system. We have both the 10cm and 3cm versions of this radar. Read some of its nominal original capabilities in the MIT Radiation Lab. Series Vol. 1 pps 207-210, 228, 284-286.

# HYBRID MULTI-APERTURE RADAR SYSTEM
MARS

MARS integrates bistatic and phased array radar technology to combine multiple track-while-scan technology with single-beam, search-and-track technology. MARS offers simultaneous detection of 1,500 targets, including incoming, outgoing, and crossing artillery projectiles, rockets, missiles, cruise missiles, unmanned aerial vehicles and other aircraft. Using extensive high-speed information processing, MARS prioritizes all targets at the radar.

The U.S. Army's bistatic artillery locating radar advanced technology demonstration transmitter uses off-the-shelf hardware at a Yuma, Arizona,

MARITIME SURVEILLANCE RADAR

A heliborne surveillance radar designed for maritime patrol also serves as part of a sensor suite that identified, optically tracks and targets vessels.
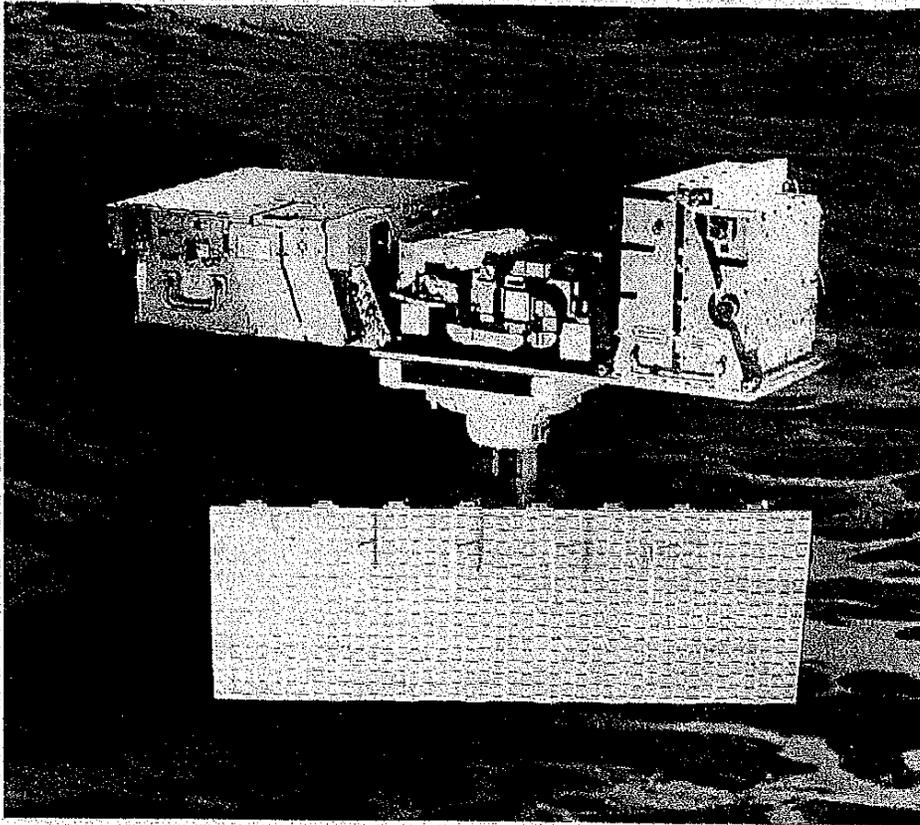
The EL/M2022A airborne maritime surveillance radar from IAI's ELTA Electronics Industries Limited can be mounted under a helicopter to detect, track and identify multiple targets in rough seas.

NAVAL SPACE SURVEILLANCE SYSTEM
NAVSPASUR

NAVSPASUR is a unique multistatic radar system that detects orbital objects passing over the contiguous United States. It can detect objects as small as 10cm diameter at orbital heights up to 15,000 nautical miles, and measure the positions and velocity vectors of detected objects as they pass through its detection plane.
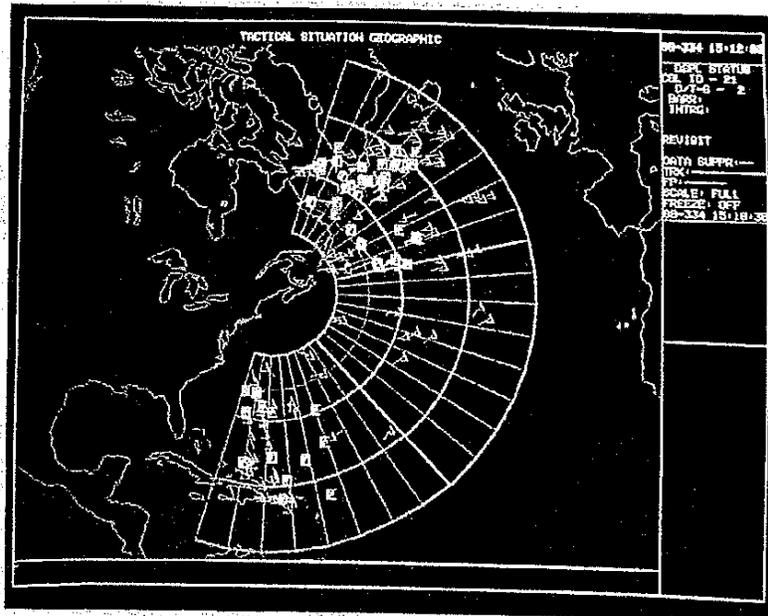
North antenna section

AIRBORNE WARNING AND CONTROL SYSTEM
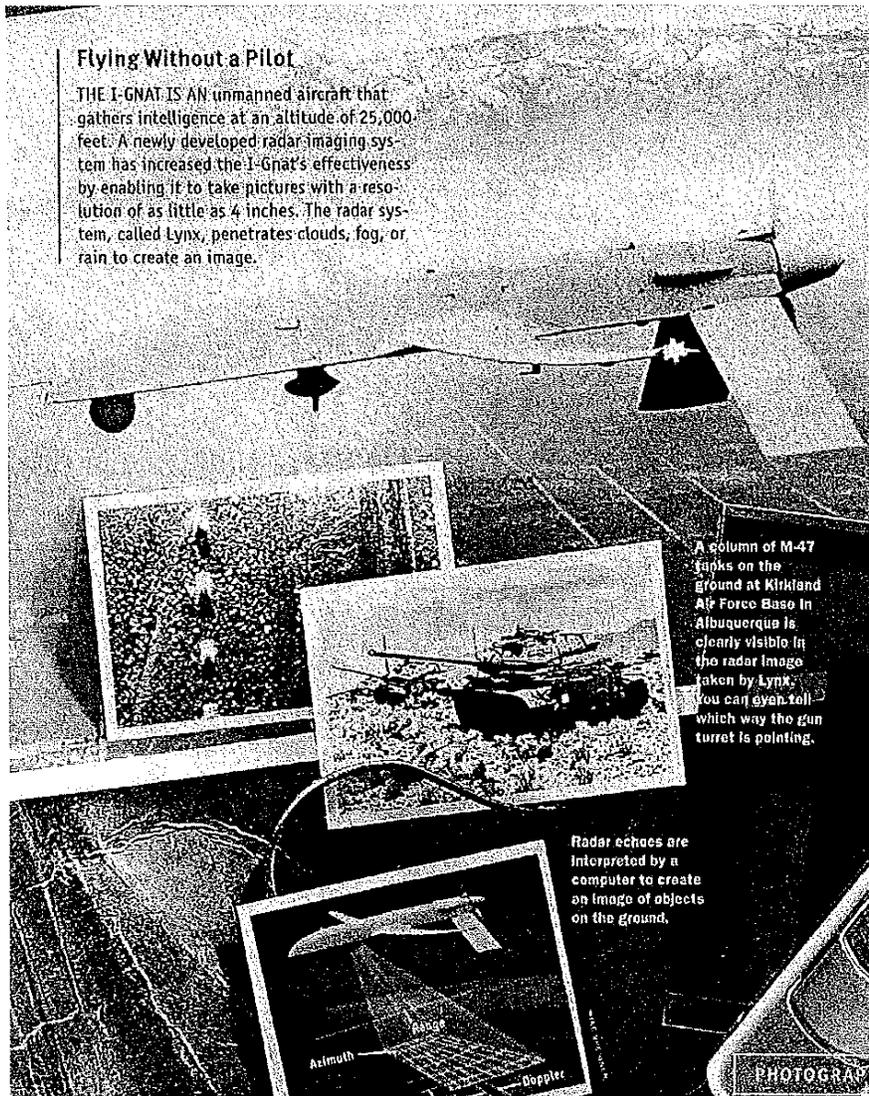# AWACS
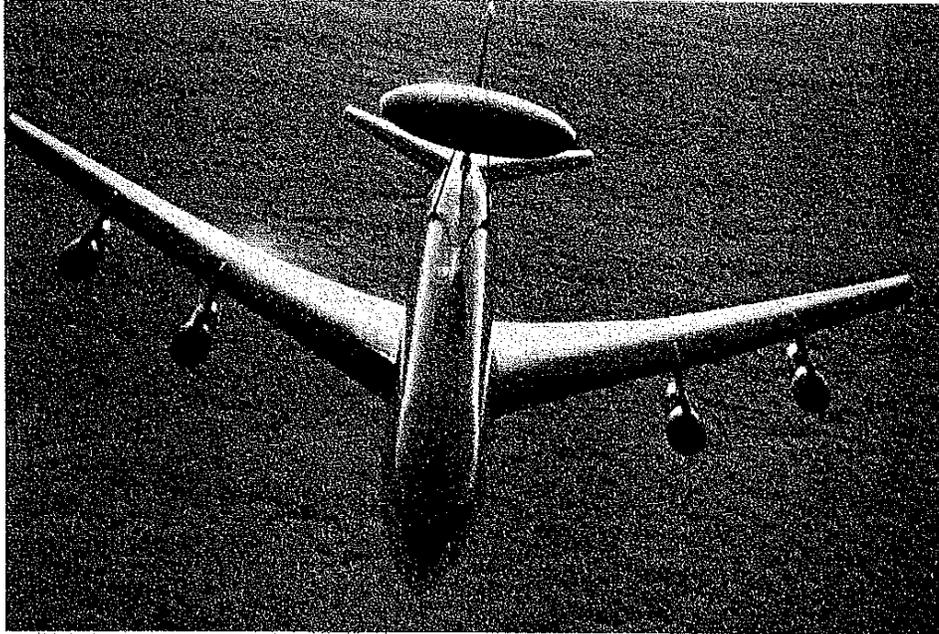
The Boeing E-3 is being upgraded to provide improved detection of small airborne targets.

An over-the-horizon radar system display can show any aircraft approaching the East Coast of North America from Greenland to Cuba. The symbols indicate aircraft targets as well as all known flight plans. The system automatically correlates targets with flight plans. Any aircraft that does not correlate is investigated and reported to the appropriate agency of the North American Aerospace Defense Command (NORAD) for further action.

I-GNAT UNMANNED AIRCRAFT SYSTEM

The I-Gnat is equipped with a synthetic aperture radar, dubbed Lynx, that has a resolution of 4 inches. Lynx produces photo-like images day or night – through clouds, for, or rain at a distance of up to 15 miles, from an altitude of 25,000 feet. Lynx operates in the Ku-band.

Flying Without a Pilot

THE I-GNAT IS AN unmanned aircraft that gathers intelligence at an altitude of 25,000 feet. A newly developed radar imaging system has increased the I-Gnat's effectiveness by enabling it to take pictures with a resolution of as little as 4 inches. The radar system, called Lynx, penetrates clouds, fog, or rain to create an image.

A column of M-47 tanks on the ground at Kirkland Air Force Base in Albuquerque is clearly visible in the radar image taken by Lynx. You can even tell which way the gun turret is pointing.

Radar echoes are interpreted by a computer to create an image of objects on the ground.

USAF SPACE TRACKING SYSTEM

The Ground-Based Electro Optical Deep Space Surveillance System (GEODSS) is a network of telescopes around the world that track satellites and space objects using optical telescopes, laser beam director/trackers, low-light level television cameras, and a variety of infrared sensors.
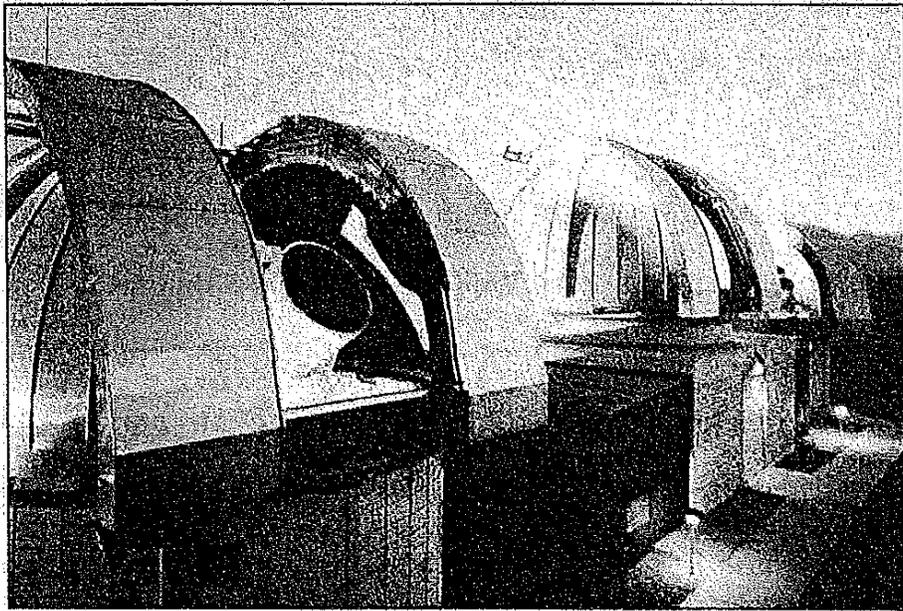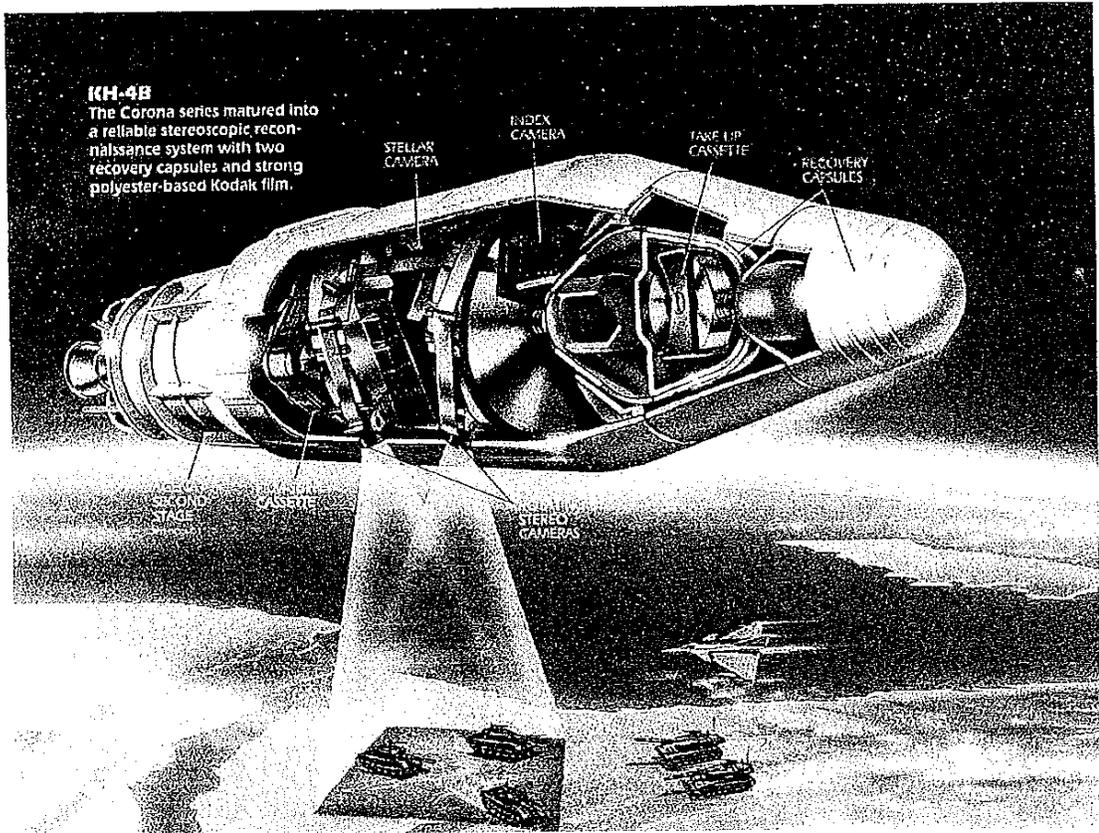
The Army recently tested the Rapid Optical Beam-steering System (ROBS) at Ft. Bliss. It is powered by 110 VAC, and draws 1-2 kw. All the electronics are in the box partially visible to the left of the system (below).
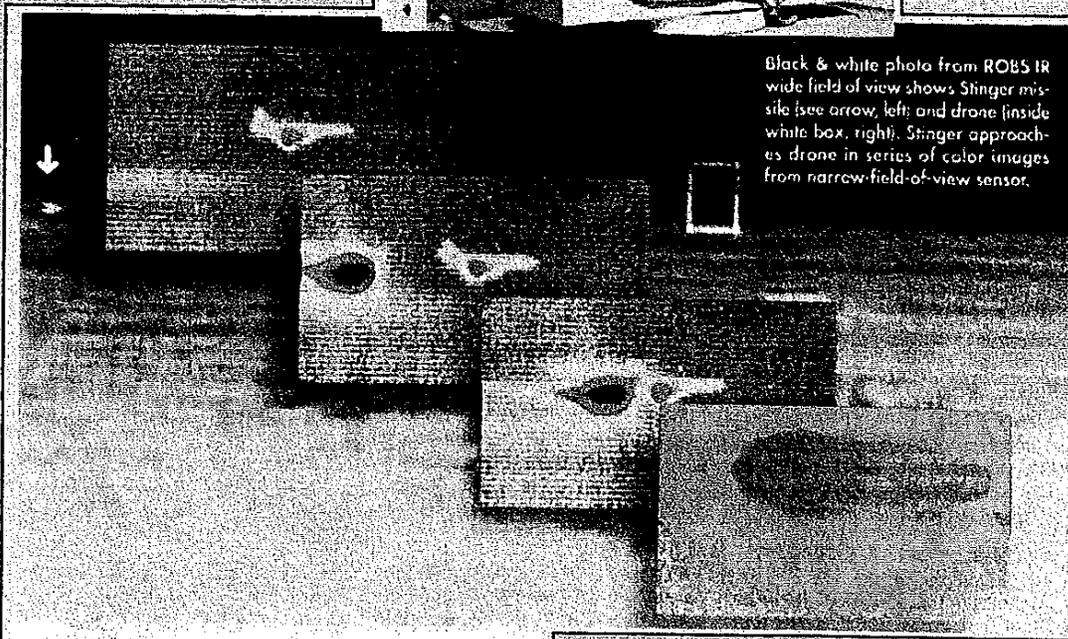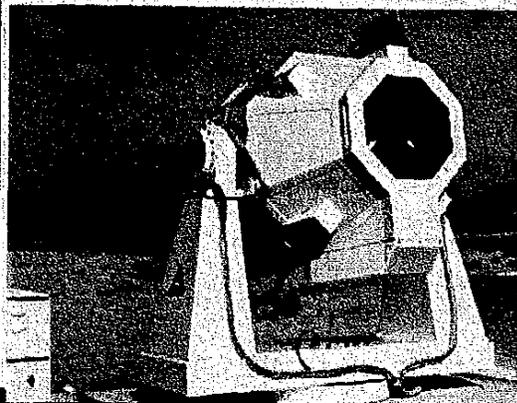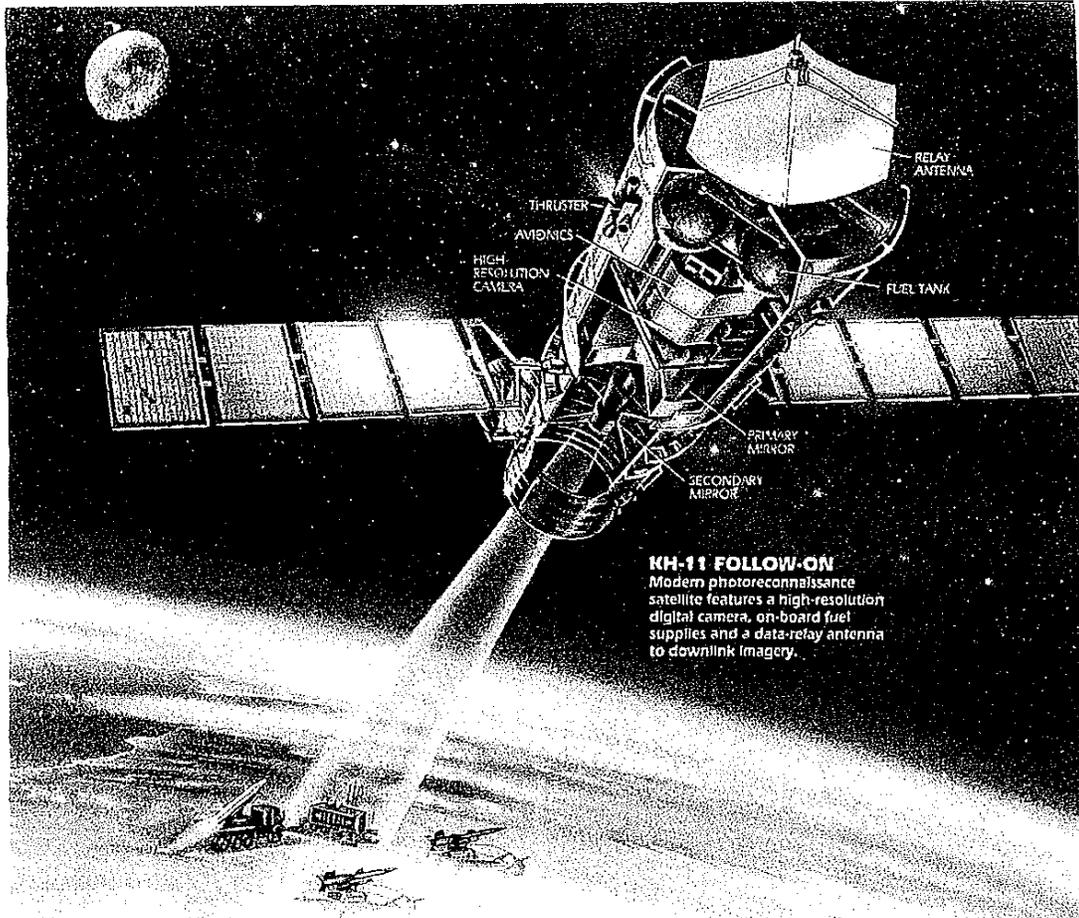
Black & white photo from ROBS IR wide field of view shows Stinger missile (see arrow, left) and drone (inside white box, right). Stinger approaches drone in series of color images from narrow-field-of-view sensor.

KH-4B SATELLITE

KH-4B
The Corona series matured into a reliable stereoscopic reconnaissance system with two recovery capsules and strong polyester-based Kodak film.

KH-11 SATELLITE

THRUSTER

AVIONICS

HIGH-
RESOLUTION
CAMERA

RELAY
ANTENNA

FUEL TANK

PRIMARY
MIRROR

SECONDARY
MIRROR

KH-11 FOLLOW-ON
Modern photoreconnaissance
satellite features a high-resolution
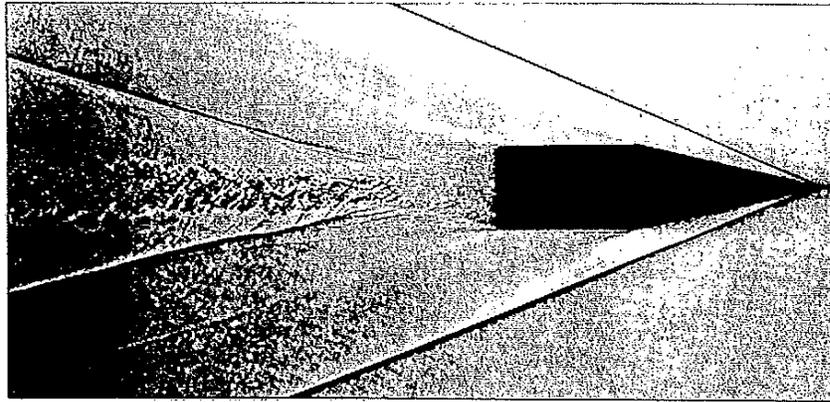digital camera, on-board fuel
supplies and a data-relay antenna
to downlink imagery.

Acoustic Detection Traces Bullet, Shell Trajectories

Faster-than-sound sensors use projectile shock waves to point an electronic finger at snipers.

Acoustic sensors can detect the origin of a passing projectile by discerning the leading-edge shock wave pattern as it fans out from the nose of the object. This shock wave is compared to the weaker recompression shock wave that trails the projectile.

OPTICAL HOLOGRAPHIC FILTER

This is a new approach to using holographic pattern-recognition systems to identify targets. The older systems required a perfect match for target identification.

The new system provides the capability to detect and identify images of target objects and despite distortions in image scale, rotation, or angle of view.

It produces a generalized holographic template that includes all information about a prospective target.

It will identify a target image regardless of the target's position, brightness, or rotation, even if the target is partially obscured by other objects, altered in appearance by reflections or glint, or buried in visual "noise."

It can recognize the shape of a particular aircraft, the plumes of rockets, or other flying objects.

Aerospace objects identified instantly and exactly
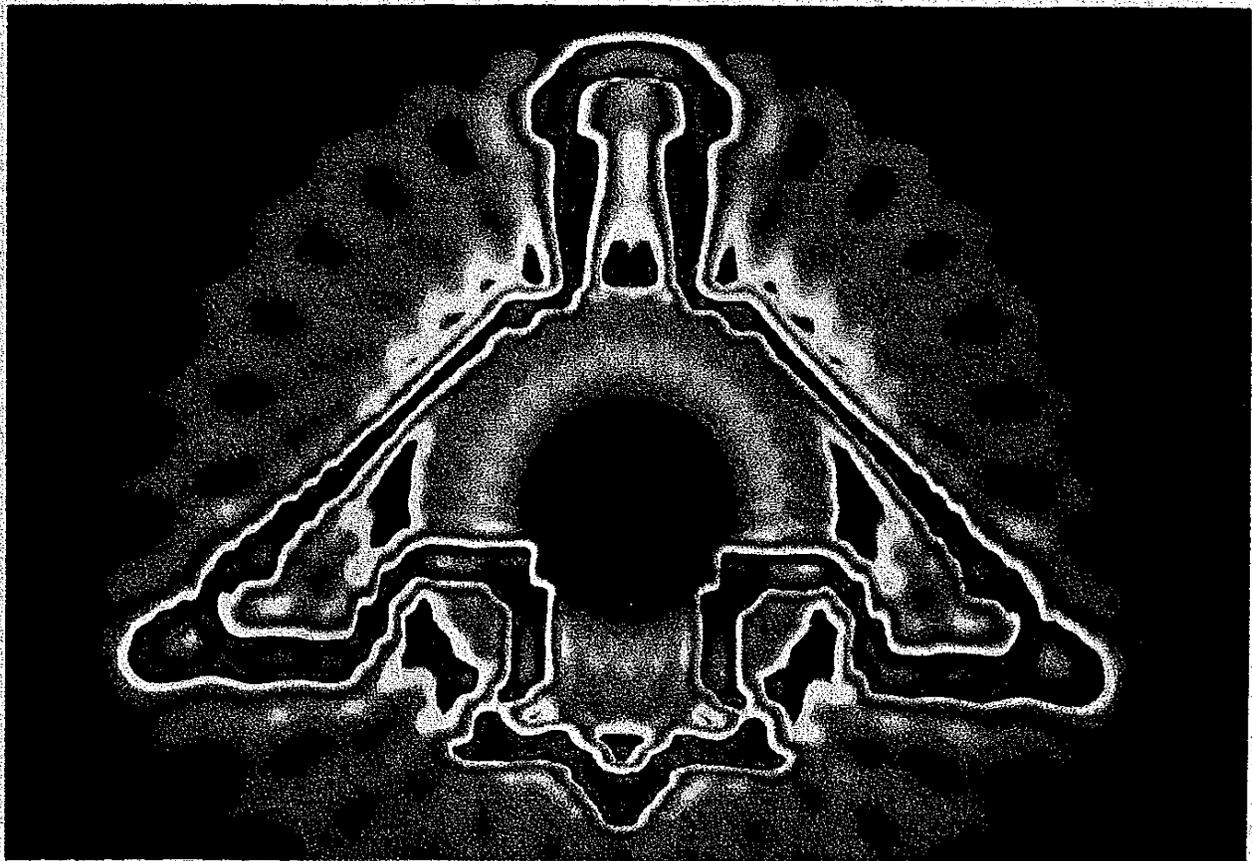
Computer reconstruction of a delta-wing aircraft was made from an incomplete set of image components taken from a drawing of the aircraft. The components, analogous to jigsaw-puzzle pieces, are key elements in a new kind of optical holographic filter.

Laser Radar Imager May Have Many Uses

Engineers at Sandia National Labs, Albuquerque, N.M., have developed a prototype, field-ready scannerless laser radar system that can resolve differences in range accurately enough to use the data to image the size, shape, and contours of the objects it sees, thus providing both image and range information.

The system was developed as part of a program to enable smart conventional weapons to actively seek and identify their targets while discriminating between targets and decoys.

The technology has many other potential applications as well, says project leader John Sackos, including use in robotic vehicles, advanced manufacturing, transportation accident avoidance, and perimeter security.

"It's a technology that a lot of people are interested in," Sackos says.

More info: John Sackos, 505-844-7018.
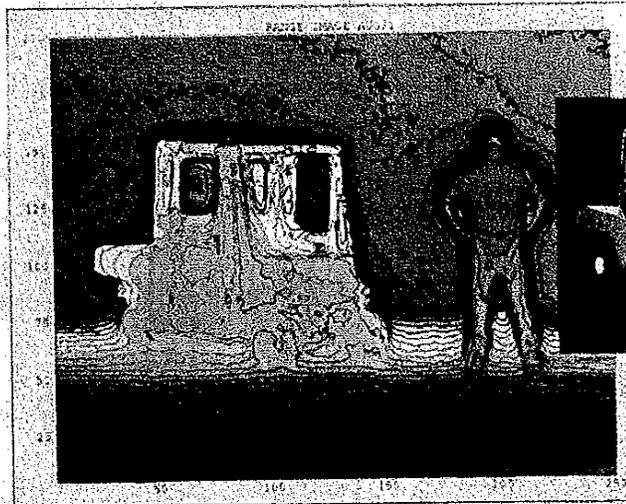
Range image from Sandia's scannerless range imager shows "intruder" John Sackos and cart, while providing accurate, color-coded range information at the same time.

Photonics
TechnologyWorld

New Infrared Focal Plane Array Keeps Its Cool

GOLETA, Calif. — As a first step toward a small, efficient, low-cost, high performance infrared camera, Amber has developed an uncooled infrared focal plane array.

Amber, a Raytheon company, based its new array on microbolometer technology from Honeywell Corp, and integrated a proprietary silicon readout integrated circuit. This, the company says, has produced an uncooled 320 × 240-pixel bolometer focal plane array that generates images comparable to those taken with the company's cooled 256 × 256-pixel InSb-based Radiance 1 camera. The Radiance 1 produces images based on light in the 3- to 5-μm region, while the uncooled array images the 8- to 12-μm wavelength region.

Amber President Art Lockwood said Raytheon funded the year-long development of the array, and company engineers are now working to integrate the new array into high-performance cameras for the military and commercial thermal-imaging markets.

As noted in the March 1995 issue of *Photonics Spectra* ("Thermal Imagers Move From Military to Marketplace," page 103), Honeywell is licensing its bolometer technology to a number of companies rather than trying to manufacture cameras itself. Texas Instruments is already marketing cameras based on a competing uncooled ferroelectric array technology.

Resistive bolometers depend on a change in resistance of material due to a temperature rise when infrared radiation is absorbed. The technology is different from that of photon-sensing detectors such as InSb, but it can theoretically be as sensitive. Amber's manager of industrial products, Arthur Stout, says the company has achieved a thermal sensitivity of approximately 100 mK with the new uncooled array, compared to 20 to 25 mK for current cooled technologies.

Stout said the company's array doesn't require that the scene be "chopped," as does the current ferroelectric technology, such as that available from Texas Instruments. He added that the bolometer's monolithic design may provide some manufacturing advantages over TI's technology that could enable volume cost reductions.

"When we discuss the market ramifications or the driving force, certainly it's the expectation that there will be dramatic growth in the use of thermal imaging in the long-term," Stout said. "We're talking about putting night vision in cars. Cooled imagers will never be inexpensive enough for these high-volume applications."   □

Stephanie A. Weiss
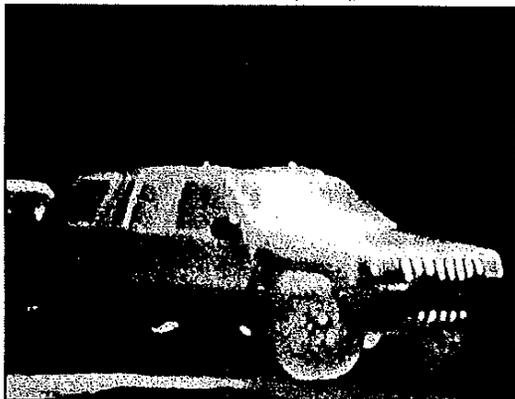
Images of a Jeep Cherokee captured by Amber's InSb Radiance 1 camera (above) and the company's new uncooled bolometer (right).
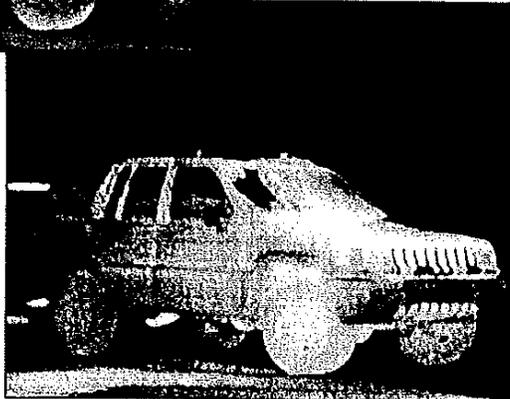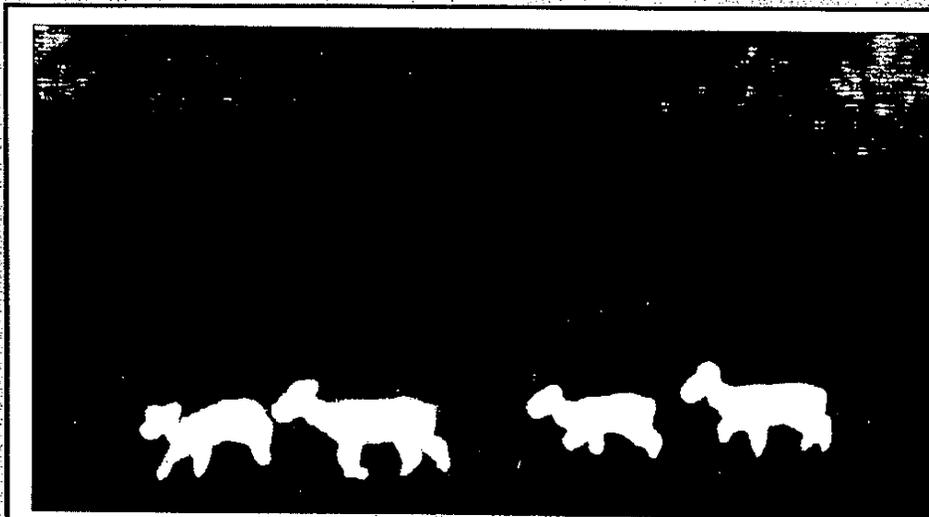
Thermal infrared image of deer observed during a nighttime deer census on Prudence Island, R.I. in a low-resolution frame captured from a high-resolution videotaped image. Mitsubishi's IR-M-500 registers energy in the 3- to 5-μm spectral range on 262,000 PtSi detectors in a focal plane array and converts it to a 512 × 512-pixel image in 256 gray levels.

BusinessWorld Briefs

News & Analysis

Market Watchers Anticipate Growth in IR Imaging

Increased demand for IR imaging focal plane array systems and sensors signal continued steady growth in the IR market, despite growing price and consolidation pressures on companies.

That is the prediction from market watchdog **Frost & Sullivan**, which forecasts an annual growth rate of 29 percent. In 1996, revenues for focal plane array sensors reached $283.7 million; at the integrated system level, revenues reached $1 billion.

The greatest growth will be in emerging microbolometer, ferroelectric and multiple quantum well technologies. The research group also predicts that opportunities will emerge in high-performance IR sensor technologies as new military programs go online.
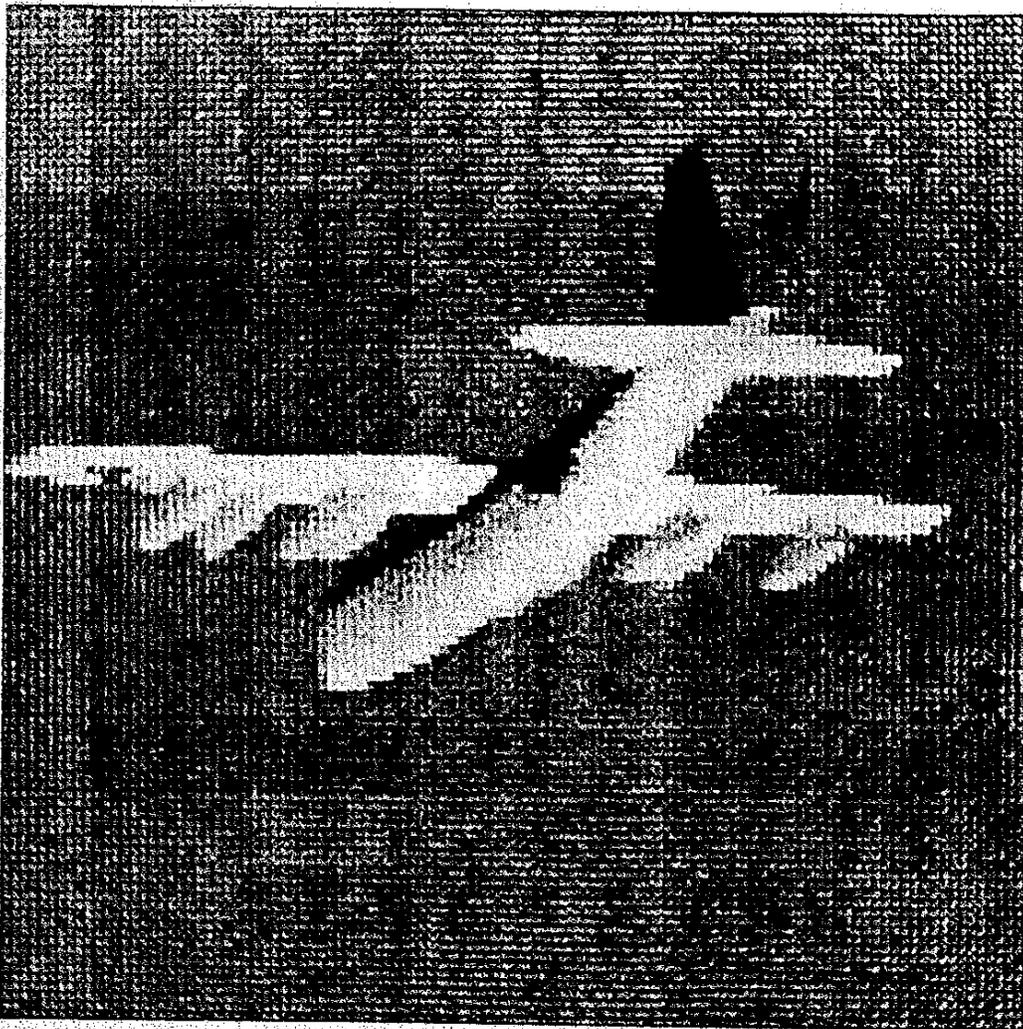
The 3 X 3-meter Infra-Red Image Display of KC-130 tanker is created by 16,384 individual heat elements.

RADAR THAT KNOWS FRIEND FROM FOE

A new radar target-recognition system being developed by university researchers for the Pentagon's Advanced Research Projects Agency could help prevent the accidental downing of non-threatening aircraft.

The major drawback of radar is that it cannot distinguish between different types of planes. That's because radar—which works by bouncing microwave beams off objects—creates only an approximate two-dimensional image of those objects; since planes are asymmetrical, they reflect varying amounts of microwave energy, depending on the angles at which they're traveling. This limitation has led to calamities like the downing of an Iranian airliner in 1988 by a U.S. Navy guided-missile cruiser, whose crew mistook the plane for an attacking fighter.

Electrical engineer Michael Miller and his students at Washington University in St. Louis are adapting a mathematical technique, called pattern theory, to conquer the problem. When their experimental computer program receives a radar image of an unknown plane, it uses equations from pattern theory to calculate how the plane would appear when viewed from other angles. Normally, such calculations would be too complicated for even a supercomputer. However, Miller's technique lessens the computational

quagmire by only determining how key points on the plane differ from one view to the other and estimating other points. Finally, the program compares the various views of the aircraft with images of known planes, contained in a database. As soon as it finds a match, it notifies the operator.

The system is in early development and won't be ready for real-world testing for several years.—*Robert Langreth*
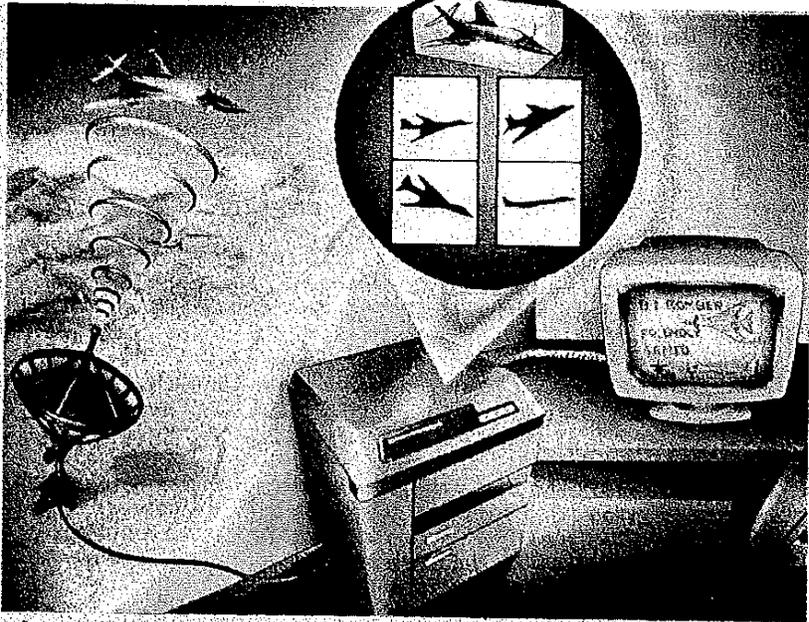
Software is being developed that would use radar images to generate the contours of a plane and then identify the aircraft from images contained in a database.

SATELLITE HYPERSPECTRAL IMAGING

All material things – soil, water, vegetables, structures, metals, paints, & fabrics – generate unique spectral fingerprints. Special algorithms evaluate them to differentiate various natural and man-made materials from one another. "Signature" libraries may be used to identify specific objects by comparing the library's preexisting reference catalog with freshly taken hyperspectral images from space.
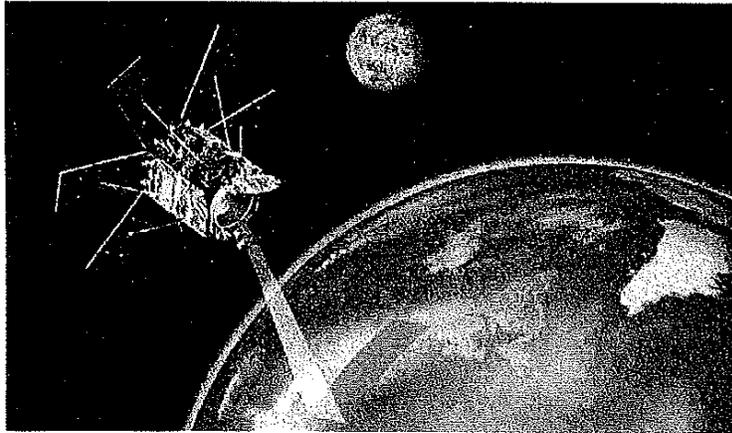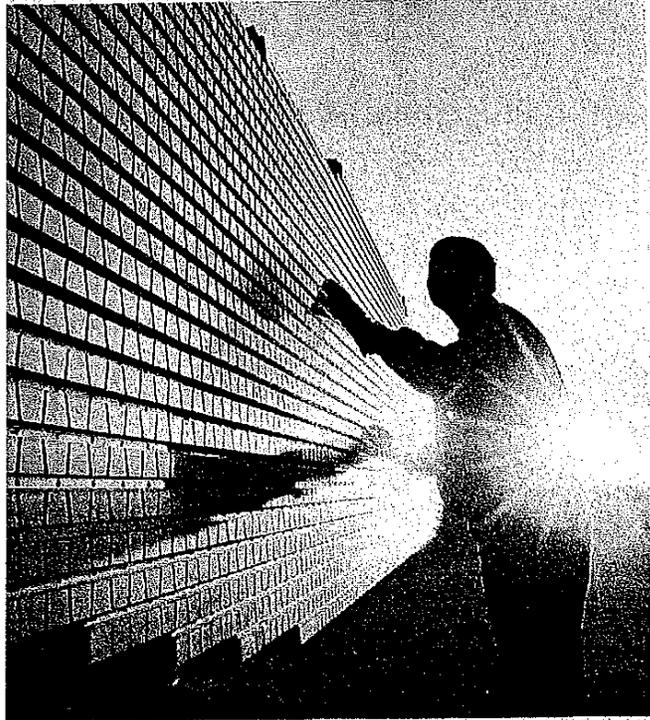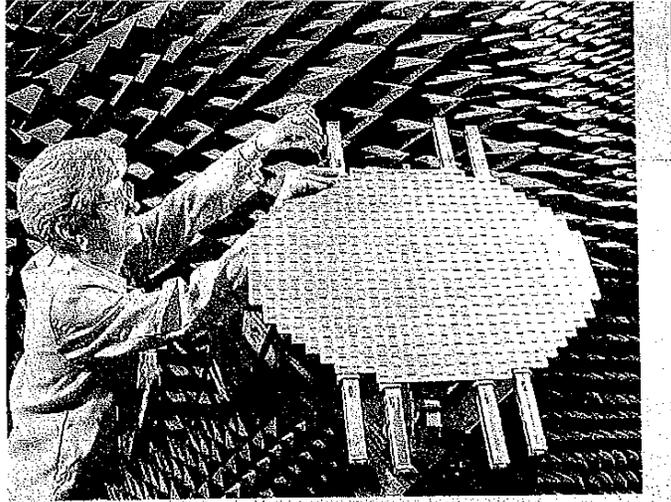
SPACE-BASED INFRARED SYSTEM

Near-Real-Time Sensors find and track anything – moving or stationary. The telescope collects infrared energy and focuses it on the focal plane. The focal plane then produces electrical signals that are transmitted to Earth-based computerized command and control stations that can determine the type of object, its point of origin, and where it is going.

WHERE TO GO FOR INFORMATION?

The options are almost endless. More than 350,000 offices are involved in data and intelligence gathering. Where do we start? Some considerations are as follows:

Uncorrelated Targets are categorized as: Significant UCTs, Non-significant UCTs, Critical UCTs, and False UCTs.

Copies of serious UCT events are sent to the Missions Systems Integration Board, composed of all NORAD and U.S. Space Command Directorates and senior level representatives from Naval Space Command, Army Space Command and Air Force Space Command.

Refer to Space Surveillance Network (SSN) regulation USR 55-12 for policy and guidance for operations.

U.S. Space Command is the Office of Primary Responsibility, but the Command Director and the Air Defense Operations Center of Cheyenne Mountain evaluate Uncorrelated Targets (Unknown Track data). NORAD keeps UTRs for five years.

USAF personnel generate reports using the International Urgency System, PAN or by ground relay of airborne reports or post-landing reports. These are governed by Communication Instructions Reporting Vital Intelligence Sighting (CIRVIS). Reports are maintained at Tyndall AFB, Elmendorf Air Force Base, NORAD's Canadian Headquarters in Canada and elsewhere.

TERMINOLOGY

Acceptable

1. **UTR – UNKNOWN TRACK REPORT:** Either an uncorrelated event or an unknown track.
2. **UCT – UNCORRELATED TARGETS:** For earth-bound unidentified objects.
3. **UER – UNCORRELATED EVENT REPORTS:** For space related events.
4. **UT – UNKNOWN TRACK:** Terminology used for communication exchanges between pilots and radar control personnel.

Unacceptable

1. **UFO – UNIDENTIFIED FLYING OBJECT:** Unidentified flying object – non-military terminology.
2. **UFO – UNCONVENTIONAL FLYING OBJECT:** Unconventional flying object – non-military terminology.
3. **FLYING SAUCER:** Slang.

DOESN'T THE SECURITY CLASSIFICATION SYSTEM MAKE THIS APPROACH IMPOSSIBLE:

Maybe not. It all depends on our approach, the timing, and the politics of the organizations that are involved.

Presidents Foreign Intelligence Advisory Board (PFIAB): Appointed by the President. Comprised of trustworthy, distinguished citizens from outside of government. Makes recommendations concerning the quality, quantity, and adequacy of intelligence collection and analysis, and how things should be run.

Keith Hall, Assistant Secretary of the Air Force (Space) and Director, National Reconaissance Office. NRO activities are highly classified. Some USAF activities are not. There is a relationship between "white and black" space. See http://cryptome.org/nro030800.htm.

U.S. AIR FORCE INFORMATION WARFARE CENTER: A unit of the Air Intelligence Agency, the Air Force Information Warfare Center was created by merging the activities and duties of the Air Force Electronic Warfare Center and Air Force Cryptologic Support Center's Securities Directorate. See http://www.afiwc.aia.af.mil.

National Infrastructure Protection Center: The mission of this organization is to serve as the U.S. government's focal point for threat assessment, warning, investigation and response to threats. It is an interagency center working within the FBI. See http://www.fbi.gov/nipc/index.htm.

SOME ALTERNATIVES TO CLASSIFIED GOVERNMENT-OWNED SYSTEMS

- Colorado fire fighters receive thermal-imaging fire helmets that enable firefighters to "see" through total darkness or smoke-filled rooms. Provided by Aurora-based Colorado EMS Foundation.

Global
Issues

A periodic look at internal regulatory and environmental issues

Legal Battle Heats Up Over Police Use of IR

by Danielle Weaver
Contributing Editor

Breakthroughs in technology often raise legal questions that pit the civil liberties of the accused against the ability of police to enforce a country's laws. More than a decade after it began, the US government's use of thermal imagers in its fight to eradicate illegal marijuana cultivation continues to raise questions regarding defendants' reasonable expectations of privacy.

International law experts predict the same questions will ultimately be raised elsewhere in the world as use of imaging technology spreads. Europe, where the concept of a man's home being his castle originated, is seen as the most likely battleground.

In the US, the controversy stretches back over the last three decades, with federal courts reviewing a series of cases involving the Fourth Amendment to the Constitution, which preserves the people's right "to be secure ... against unreasonable searches and seizures." Those cases have granted police the authority to search open fields, backyards and vehicles; to look through garbage placed at curbside; to have drug-seeking dogs operate at US airports; to plant electronic beepers and bugs; and to obtain telephone numbers dialed from private phones.

State and federal courts have been reviewing the legality of evidence obtained by thermal imagers ever since the US Drug Enforcement Administration (DEA) began using airborne IR imaging in California to pinpoint marijuana farmers. Four separate federal courts have ruled that the imagers' use does not constitute a Fourth Amendment search.

Last October, a three-judge panel of the US Court of Appeals for the Tenth Circuit reviewed the use of a thermal imager, the AG 210 sold by AGEMA Infrared Systems Inc. of Secaucus, N.J. In 1993, police in Wyoming used the imager to obtain evidence for a search warrant to enter a private home. Warrant in hand, police found a large, sophisticated indoor marijuana farm and subsequently arrested Christopher Cusamano and Robert Porco. The two entered a conditional guilty plea so they could challenge the imager's use. If the search were illegal, the so-called exclusionary rule could, under certain circumstances, require the judge to throw out the illegally obtained evidence.

Writing for the court, Senior US Circuit Judge Monroe McKay found that using the imager without a search warrant violated the Fourth Amendment. Nonetheless, he found enough evidence to prosecute the men.

In explaining his decision, McKay said the

Figure 1. A group walking along a dock at night is captured by Inframetrics InfraCAM

Global
Issues

other courts had erred because they characterized the imager as recording waste heat, and then found no reasonable expectation of privacy in that waste heat.

The imager's usefulness depends not on heat loss, but on detecting the presence of distinguishable heat signatures inside a structure, he said. "While there is no explicit societal expectation of privacy inherent in the heat signatures of activity within the home ... it is abundantly clear that the people retain a reasonable expectation of privacy in the undetected, unmonitored performance of those domestic activities that are not knowingly exposed to the public."

Undercover in the bedroom

Imagers, of course, cannot "see" through walls or closed, glass windows, despite what you see in the movies. They can detect tear ducts on a person's face or discern human form through an open, curtained window. McKay said imaging technology continues to improve, and the military can already detect human forms moving through undergrowth. "We do not imagine that it would be considerably more difficult to identify (if, not strictly speaking, to watch) two people making love in the privacy of their darkened bedroom. ... Use of a thermal imager enables the government to discover that which is shielded from the public by the walls of a home," where an individual's expectations of privacy are highest.

The Cusanamo case has been appealed to the full Tenth Circuit; a decision is not expected anytime soon. If the ruling is affirmed, the resulting split in federal opinion would increase the likelihood of review by the Supreme Court of the US, said David Harris, Balk Professor of Law and Values at the University of Toledo College of Law, Toledo, Ohio. Senior District Judge John Kane, who heard the case by designation, invited such scrutiny by suggesting a "fundamental reconsideration of the exclusionary rule."

The legal controversy is not likely to quench police enthusiasm for thermal imagers. The evidence is "very compelling," said Art Stout, manager of industrial products at Amber, a

Raytheon Company in Goleta, Calif. It will not stop Amber's efforts to sell its Sentinel uncooled IR focal plane array imager to the police. Also, because the police use infrared as "just one method of what they call building the wall of evidence," requiring a search warrant prior to use will not be much of an impediment either, he said.

Modern imagers can tell if a person is a person, and they can identify people, whereas before you just saw hot blobs," said Andrew Owen, product manager of ground surveillance systems for Inframetrics in North Billerica, Mass., which

Figure 2. Border patrol agents show up in this IR image from Inframetrics' InfraCAM.

sells the InfraCAM, a handheld imager. Airborne or ground-based imagers are already used in all 50 states, he said. Law enforcement is a "growing market," particularly as imagery improves, reliability increases, ease-of-use goes up and costs fall.

Ron Newport, director of the Academy of Infrared and Thermography in Kamploops, British Columbia, Canada, agreed. Newport has trained the DEA, the US Coast Guard, the US Border Patrol and the Royal Canadian Mounted Police to use imagers and was present during a pot bust involving an imager. Other uses include detecting new paint on hit-and-run vehicles, locating bodies, and finding false panels inside boats, rail cars and residences. Active thermography can detect items concealed in walls, he said. But US and, increasingly, Canadian officers hesitate to discuss the technology for fear their words will be used against them in court.

Enter the ACLU

The privacy issue will not go away, said attorney John Crew, director of the Police Practices Project in the American Civil Liberties Union's (ACLU) Northern California office. Tomorrow, he asserts, the issues will

involve photoradar and will target video cameras, microphones used to locate urban gunfire, or detectors for finding drugs hidden under clothing.

The ACLU, often at odds with those who favor any weapon in the fight against crime, takes a dim view of these new technologies. "The fact that these technologies may not look like the British in their red coats barging in the doors of our forefathers does not mean it's not a Fourth Amendment violation," Crew said.

International law does not address thermal imagers, but the issue could crop up more often as use spreads. The right of privacy is at the heart of most search-and-seizure issues, and a qualified right to privacy exists in human-rights laws under various international treaties, said Jordan Paust, international-law expert at the University of Houston Law Center in Texas.

Trends in the US will influence legal trends abroad, said Paust, who foresees an eventual legal challenge overseas, perhaps in Europe. "The kind of privacy we in the West think relates to the home ... is a fairly uniform expectation" elsewhere. But international efforts to prohibit use of a particular technology "are bypassed rather quickly ... if the technology is generally useful." □

IR Imaging for Autonomous, Pole-Mounted Surveillance

Because most surveillance applications require stand-alone operation, state-of-the-art infrared cameras haven't enjoyed the widespread acceptance in this application that their video counterparts have. The sensors used in today's advanced infrared cameras offer a decided advantage over those used in visible cameras, including immunity to sunlight and darkness. Thus the cameras provide the same high sensitivity and wide dynamic range day or night, with image quality and contrast far exceeding image-intensified video models. But infrared cameras have until now been considered hard to install, operate and maintain, making them less than practical for most surveillance applications.

To overcome these problems, Amber of Goleta, Calif., has developed a new infrared imaging system called Radiance 1 that combines advanced infrared camera performance with the operational ease of video cameras. The camera's electronics are centered around a 32-bit digital signal processor and Flash memory, so that tasks that were once complex, manual IR camera tasks, such as calibration, brightness-setting and contrast enhancement, are now automatic functions. The camera also has additional memory for performing image processing and analysis on its own, so that tasks such as motion detection, autotracking and object recognition can be performed at the camera level.

The cooling system for the 256 × 256 staring InSb array is self-contained, and a wide range of 12- to 35-VDC supplies, including batteries, a car's cigarette lighter or the standard 110/220-VAC adapter, will power the cameras. And, because the Radiance 1 is compact and weighs less than 10 lb, Amber says it adapts well to pole-mounted installations.

Contact Stan Laband, Amber, 5756 Thornwood Drive, Goleta, Calif. 93117; (800) 232-6237; FAX (805) 964-2185.

IR Captures Canine

This infrared image of a prize-winning Rottweiler was recorded by an Amber 128 × 128 indium antimonide staring focal plane array. After it was recorded, the image was photographed from a display generated by Amber's Pro-View imaging system. Photo courtesy of Amber, a Raytheon Co., of Goleta, Calif.

Army Target Identification System: Near-instantaneous target identification is being implemented by the U.S. Army. Refer to the LandWarrior program.

By equipping the soldier with the latest high-technology equipment, the LandWarrior program will transform an individual into a node in a sensor network. Sensor technology will increase in importance as the U.S. Army transformation gains momentum.

- A man-portable sensor capable of detecting objects up to 100 meters away was developed by U.K. based Arkonia Systems Limited is used for surveillance activities.
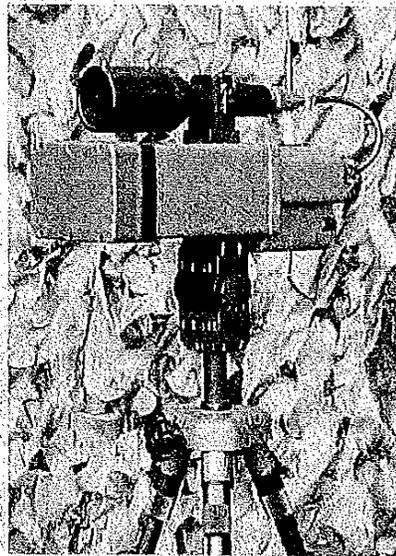
Developed by U.K.-based Arkonia Systems Limited, the Hornet sensor is a portable device consisting of a microwave Doppler radar unit and a passive infrared (PIR) detector. Capable of detecting heat sources from up to 100 meters away, the PIR activates the radar unit to scan the subject. Internal classification software determines the type of target, the direction it is moving, and transmits the information to a pager carried by a sentry.

- **Remote Viewing:** The NIDS SAB has the experts on this technology.
- **University Linking:** Establish a semi-formal linking of university physics and astronomy departments for near-real time study and analysis of UFO sightings via the Internet. This would provide challenging real-world problems for students and staff to work on.
- **Veterinarian Linking:** Similar to the University Linking, this Internet project would provide a link between all veterinarians and NIDS for instant alerting and evaluation of animal mutilation activities.
- **Portal Research:** Many UFO reports contain clues about things coming through portals. Develop a portal sub-team of experts working together via the Internet. Establish protocols, data gathering techniques, site identification methods, and a protocol database. This category could encompass "higher dimension" studies as well.

MESA: A portable multi-energy sensor array for low-frequency electromagnetic field fluctuations

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The study of the relation between electromagnetic fields and various psychological phenomena would be enhanced by the measurement and correlation of time series over multiple energy bands. The paper discusses the design and implementation of a computerized multi-energy sensor array (MESA) that detects and records low-frequency energy fluctuations. The current implementation of MESA focuses on the measurement of magnetic fields, infrared and visible light frequencies, and indices of seismic activity. However, MESA is sufficiently flexible to accommodate the measurement of other variables as well, and it can be configured to suit applications in laboratory and field settings.

Because electromagnetic fields (EMFs) are associated with hazardous biological and behavioral changes, their detection and measurement are an important issue (see, e.g., Kristensen, 1989; Persinger, Ludwig, & Ossenkopp, 1973; Wiedemann & Schultz, 1995). Whereas most research emphasizes man-made sources of EMFs, such as power lines (e.g., Savitz, 1993), the effects of increased geomagnetic activity have received less widespread attention. This is unfortunate, since increases in geomagnetic activity are correlated with medical conditions such as sudden infant death syndrome (R. P. O'Connor & Persinger, 1997) and immunological alterations (Persinger, 1983).

Geomagnetic activity is also associated with more benign effects, such as the onset of hallucinatory episodes and other abnormal behaviors (e.g., Gearhart & Persinger, 1986; Persinger, 1988, 1993; Persinger & Cameron, 1986; Randall & Randall, 1991). It has been hypothesized (Persinger, 1988, 1993) that an increase in geomagnetic activity alters melatonin and serotonin levels in the temporal lobe, leading to microseizures. The accompanying hallucinations and perceptions may involve vestibular alterations, auditory sequences, odd smells, visual forms, acute emotional responses, and disruption from sleep (particularly during REM periods) (Baldwin, 1970; Sterman, Shouse, & Passouant, 1982). It has further been found that these effects closely resemble sensations reported by individuals whose temporal lobe structures are stimulated by focused, extremely low-frequency electric currents (Persinger & Cameron, 1986).

The research cited above characteristically samples only a limited number of electromagnetic frequencies. Savitz (1993), however, has argued that the *interactions* among the various frequencies of the electromagnetic spectrum may be of crucial importance, considering the notably different effects of ionizing radiation, microwaves, and visible light on physiological functioning. Consequently, it seems desirable to study the physiological effects associated with the interactions of multiple frequencies over time.

This paper describes a multi-energy sensor array (MESA), capable of sampling and recording several different frequencies over time so that they can be correlated with standard signal-processing techniques (e.g., Stearns & David, 1988). The current version of MESA was designed to investigate Persinger's hypotheses related to geomagnetic activity. For this reason, the presentation emphasizes the measurement of magnetic fields, infrared (IR) and visible light frequencies, and seismic activity. We want to emphasize, however, that MESA's design is sufficiently flexible to accommodate the measurement of other EMFs as well, and that it can be configured to suit the needs of applications in laboratory and field settings.

MESA
System and Support Specifications

As is shown in Figure 1, the current implementation of MESA can accommodate a maximum of eight sensor inputs that lead into a data acquisition board that is controlled by a portable minicomputer with a moderately sized hard disk drive. Naturally, a phone link can be used between experiments to download the data to a larger computer system with greater secondary storage capacity.

The technical specifications for MESA are listed in Tables 1 and 2 for quick reference. Here we will describe the sensors used in the current implementation of MESA, together with their functional properties.

Sensors

Although MESA can accommodate up to eight sensor channels simultaneously, only five are used currently.

Channels 1 & 2: Tri-Field meters (AlphaLab, Inc.) can detect three fields—magnetic, electric, and radio fre-
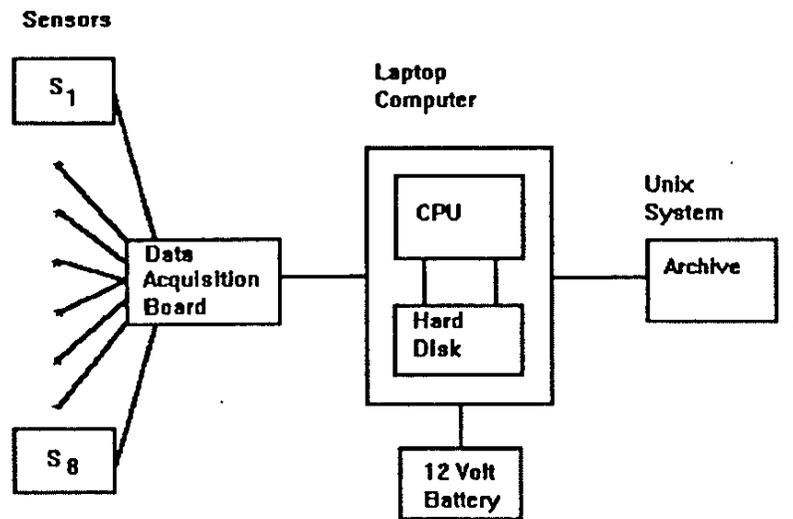
Sensors

Figure 1. An outline of MESA.

quencies. However, the three fields cannot be sampled simultaneously. The meters have two ranges for magnetic fields, 0–3 mG and 0–100 mG. These meters measure the RMS value of sinusoidal magnetic fields. This is a limitation of the device, which is designed to measure ac magnetic fields from 0.2 to 100 mG at 60-Hz frequency. The output voltage for the meter ranges from 0.89 V for a "zero" indication, to approximately 2.55 V for a full-scale indication. Calibration tests have shown that this output voltage remains proportional to the external field strength even past the meter's ability to visually indicate the field strength (i.e., the meter was "pegged").

Channel 3: A CdS photoresistor (Radio Shack, No. 276-1657) operates in the variable resistance mode and is sensitive to visible light wavelengths. The frequency/sensitivity curve for CdS is very close to that of the human eye. Its time domain response characteristic is variable; that is, its output depends on how quickly the intensity of a light source is changing. Minor variations appear to be tracked precisely. For instance, the 60-Hz flicker of a fluorescent light is easily seen on the output of this detector. However, large changes can require up to 2 sec to be accurately reflected in this sensor. The sensor is such that a high voltage results from low ambient light conditions, and a low voltage results from high ambient light conditions. A pull-up resistor is selected which nets the desired sensitivity.

Channel 4: The infrared photoresistor (Radio Shack, No. 276-145) consists of a single transistor whose base region is sensitive to IR wavelengths. Connections to the base and emitter terminals of the transistor make it possible to use it as a variable-resistance device, similar to the CdS photoresistor mentioned above. The IR transistor's characteristics with regard to light levels are very similar to those of the CdS device, with two exceptions: (1) The IR sensor is most sensitive in the infrared (long-

wavelength light) regions, and (2) the response of the IR sensor is much faster, in the nanosecond range. Calibration tests revealed that a 60-Hz flicker source is very easily seen on the IR's output, and response to light changes is virtually instantaneous.

Channel 5: The Vibration/relative seismic activity sensor (Radio Shack, No. 273-091) is a large piezoelectric transducer, which is sold as a speaker element. By mechanically coupling the device to a suitable structure, such as a door frame or floor, it functions as a vibration sensor. Voltages as high as +11 V were measured from the device with moderate levels of compression. High levels of compression presented a problem for the A/D equipment, because overloading of a +5-V A/D input resulted in "splatter" across adjacent channels. However,

Table 1
Technical Specifications for MESA

Number of channels	8
Sampling resolution	8 bits (256 discrete values) per channel
Sampling frequency	Variable: 1–40, 60, and 1,440 samples/sec
Input voltage	0.0–5.0 V (each channel)
Input impedance	>20 MΩ (each channel)
Voltage supply requirement	−12 V dc
Current supply requirement	700 mA (computer), 10 mA (A/D unit)
Power requirement	9 W
Sensor types supported	Variable voltage (chs. 1–8), Variable resistance (chs. 1–4)
Input connector type	50 Ω BNC
Time base	Supplied from host computer: 100-Hz interrupt-driven clock
Computer interface	Bidirectional Centronics–compatible parallel port (TTL)
Digital I/O (computer view)	A0–A2 (output): channel select
	Data (input): serial data from A/D converter
	Clock (output): sample start signal and data clock

Table 2
MESA Data Storage Format: Variable-Length Packets

Byte	Contents
[7] = 1	Packet contains timestamp
[7] = 0	Packet does not contain timestamp
[6:4]	Reserved
[3:0]	No. of one-byte samples to follow
(time-stamped packet)	
2-5	Four-byte time stamp: long integer. Intel byte ordering—seconds elapsed since 00:00:00 GMT, January 1, 1970
6-n	channel data, lowest numbered channel first
(non-time-stamped packet)	
2-n	channel data, lowest numbered channel first

this problem was solved by placing a 5-V Zener diode across the piezo's terminals so that any output voltages higher than the Zener would shunt to ground.

Support Parts and Sources

All pull-up switches (RS1–RS4) used in MESA are composed of 6PDT rotary switches from Radio Shack (No. 275-1386) and multivalued resistors pulling up the sensor inputs to +5 V. All resistors are a 0.25-W, 5% tolerance, carbon film type (JDR Microdevices, RA30). The project box (i.e., instrumentation case) is a JDR, GPB-862. In addition, 50-Ω BNC chassis connectors (JDR BNC-F), a 7805 +5-V regulator (JDR, 7805T), and a parallel port connector (to computer) (JDR, DB25S) are used. MESA currently uses coaxial cables (RD58U), approximately 25 ft in length, for connection of the sensors to the A/D converter.

Placement of the Sensors

Figure 2 illustrates the placement of the aforementioned sensors for our research purposes. Optionally, a 2 × 2 ft Plexiglas sheet may be used to affix the sensors (i.e., the two Tri-Fields and the two light sensors) in a fixed position by means of Velcro or electrical tape. This arrangement facilitates their mobility, since all secured sensors may now be moved simultaneously. However, the

piezoelectric transducer is bonded to the floor, ground, or other stable surface.

Data Acquisition Board

MESA's data acquisition board comprises an eight-channel analog multiplexer (JDR, 4051) and a serial A/D converter (JDR, ADC0831) with 8-bit resolution (±0.5 LSB) and maximum 32-μsec conversion time. The first four inputs to the analog multiplexer are wired to 6PDT rotary switches, with the first five switch positions causing the multiplexer inputs to be connected to resistive pullups to the +5-V rail: 1K, 4.75K, 10K, 100K, and 1 MΩ. The sixth (rightmost) position of the rotary switch provides no pull-up voltage. The remaining four inputs to the analog multiplexer (channels 5–8) are wired directly to the multiplexer's inputs, for use with variable-voltage sensors only.

The computer A/D unit interface is via the computer's parallel port, utilizing TTL voltages (0 and +5 V). Three pins are outputs (A0–A2) and select which of the eight of the analog mulitplexer's inputs are to be connected to the ADC's input. One pin is the clock output, which signals the start of a sample to the ADC and also clocks data out of the ADC. The data input supplies serial data from the ADC to the computer, clocked out one bit at a time, by the clock output, as mentioned above.

Although the eight channels are sampled sequentially, this occurs so quickly that the process appears simultaneous. In particular, the skew between the channels can hardly be detected for rates up to 40 samples/sec. The exact sample rate may vary somewhat over a session, because the computer's operating system Linux features multiprocessing, which may occasionally cause the CPU to be diverted from the task of sampling. It was found, however, that the variations in the sampling rate were insignificant when no contention for processor resources existed.

Unconnected analog inputs were pulled up by a 1-MΩ resistor to +5 V, to minimize channel crosstalk. The analog multiplexer (and wires leading to its inputs) exhibit some capacitive effects, which causes signal levels from
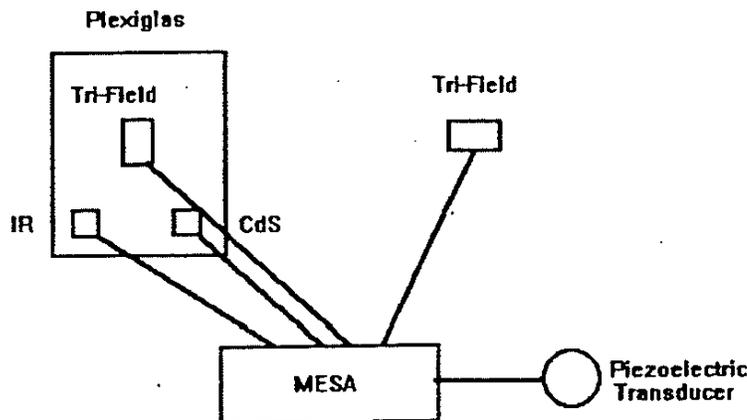

Figure 2. Sensor arrangement in current implementation of MESA.

previous channels to be held if not actively driven by a signal source or resistive pull-up. This prevents the appearance of "shadowing" effects or signal changes in adjacent channels following signal changes in an active channel. With sufficient strength pull-up (or the presence of another active signal source), the effects of shadowing can be completely nullified. Note that shadowing occurs only in completely unconnected channels.

The Computer System

MESA runs on a sub-notebook computer featuring an Intel 80486 SLC 33-MHz processor with 4 MB of RAM and an 85-MB hard drive, using the Linux operating system. All software is written in Gnu C compiler and SVGAlib—a package of display primitives for the VGA display most commonly found on IBM-PC–compatible systems. The supplied software utilizes the $640 \times 480 \times 1$ bit plane mode to display sampled data in "real-time" (i.e., while the experiment is in progress) as well as in "playback" mode (i.e., after the data have been gathered). At an acquisition speed of 40 samples/sec, MESA's storage requirement is 464 bytes/sec, or approximately 1.3 MB/h. Other features, such as variable playback speed and magnification of the displays, are also implemented. Most importantly, variable alarm levels can be specified for any one of the eight possible sensor channels. For example, MESA currently uses a reading of ≥ 7 mG on both of the Tri-Field meters over a 3-sec interval as a threshold to trip the computerized alarm.

Power

MESA is self-contained, including the power supply. Therefore, the various components (i.e., acquisition board, computer, and most of the sensors) are powered by a 10-lb, 12-V deep-discharge marine battery of 34-AH capacity. The battery is connected to a positive voltage regulator (JDR, 7805T) which produces exactly 5 V, provided that the battery voltage remains at or above +5 V. The calibration tests on all of MESA's components and sensors indicated that the apparatus can be run for over 12 h continuously on this battery before recharging is required.

Archive

Upon the completion of an experiment, the observational data can be transferred from the laptop computer for analysis by two methods. The first is the use of a pocket Ethernet adapter to transfer the data using file transfer protocol (ftp) or other protocol utilizing a TCP/IP networking infrastructure. In the prototype, a TCP/IP stack for Workgroups 3.11 was installed on another computer, along with an Ethernet card, and supplied Telnet and ftp clients on the machine running Windows for Workgroups were used to transfer recorded data. The second method is to log on to the laptop computer via its serial port and download data using a transfer protocol such as Zmodem.

DISCUSSION

This paper showed that it is feasible to construct a multi-energy sensor array that is portable and relatively inexpensive (the current implementation costs approximately $3,000) and that can be operated by a single researcher. Thus, it becomes practical to obtain simultaneous time series over multiple EMF bands not only in the laboratory (see, e.g., Green, Parks, Guyer, Fahrion, & Coyne, 1992; Radin & Rebman, 1996) but also in natural settings. This approach may be especially pertinent to studying the role of EMFs in instigating hallucinations and other psychophysiological effects, since various series of frequency interactions may elicit notably different behavioral responses. The authors are currently using MESA in field studies to extend the research correlating EMFs with these hallucinations and abnormal behaviors. However, research in this area might also provide insights into the role EMFs have in such diverse areas as dream recall (Sandyk, 1995), correction of regulatory dysfunctions (Vasilevskii, Sidorov, & Suvorov, 1993), rearing behavior in rats (Rudolph, Krauchi, Wirz, & Feer, 1985), and physical and psychological therapies (M. E. O'Connor, 1993).

Although it would certainly be possible to construct a superior system by using more advanced components, calibration tests indicated that MESA achieved the reliability and precision required for our research. In addition, the option to substitute different sensors makes MESA sufficiently flexible for use in a variety of settings.

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VARIABLES	WEB SITE
Day Length - Sun and Moon Data US Navy Observatory Astro Appl.	**http://aa.usno.navy.mil/AA/data/docs/RS_OneDay.html** SUN twilight, sunrise, sun transit, sunset, end twilight MOON: moonset, moon rise, moon transit, percent of disk visible, waxing waning, etc.
Geomagnetic Activity Astronomical Institute Prague	**http://www.hamradio.cz/progno/Dxc/index.asp** recent and forecast geomagnetic activity, short term data base
Seismic Activity National Earthquake Info Center	**http://wwwneic.cr.usgs.gov/neis/epic/epic_circ.html** current earthquake activity, earthquake data base earthquake lists, earthquake sites
Sidereal Time US Navy Observatory	**http://aa.usno.navy.mil/AA/data/docs/WebMICA_2.html** calculate sidereal time, universal time, rises and sets, many other applications
Sidereal Time	**http://aslan.wheatonma.edu/~glen/sidereal/** sidereal time program for palm calculator, world wide, extensive database
Solar Flare Data Base NASA-BATSE	**http://umbra.nascom.nasa.gov/batse/batse_years.html** catalog and data on line; noninteractive 10-y data bases, listing event number, start, end, and peak, direct links to interactive and dynamic data bases
Solar Radiation Data National Renewable Energy Lab Solar Radiation Research Dept.	**http://srrl.nrel.gov/bms/bms.html** solar calendars and windroses, multi-year data base, updated every 60 secs
Solar Systems Objects US Navy Observatory	**http://mach.usno.navy.mil/cgi-bin/aa_micaform2?calc=40&ZZZ=END** topocentric configuration of planets and other major solar system objects, worldwide approximately 2-Y data bases
Space Weather Now NOAA	**http://www.sec.noaa.gov/SWN/** geomagnetic storms, solar radiation, radio blackouts, solar wind, aurora borealis

limited data base usually going back only a few weeks

Weather Data
NOAA - Global Surace Summary

http://www.ncdc.noaa.gov/cgi-bin/res40.pl?page=gsod.html
click "agree to terms" to get to actual data page
temperatures, wind, barometric pressure, precipitation world-wide multiyear data base

Weather Date
NOAA - National Climate Data Serv

http://www.crh.noaa.gov/ind/world_wx.htm
detailed US weather data, mutlyear data base