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SAND93-2623
Unlimited Release
Printed August 1994

Distribution
Category UC-706

AN EVALUATION OF SOLID STATE VIDEO FRAME RECORDERS

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ABSTRACT

The Department of Energy (DOE) has tasked Sandia with conducting a market survey to identify and evaluate pertinent solid state recorders. This report identifies the chosen recorders and explains why they were selected. It details test procedures and provides the results of the evaluation.

Our main focus in this evaluation was to determine whether the frame grabber altered signal quality. To determine the effect on the signal, we evaluated specific parameters: sensitivity, resolution, signal-to-noise ratio, and intrascene dynamic range. These factors were evaluated at the input and output of the frame grabber.

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1.0 Introduction

Video recording devices play a key role in the assessment security systems used by the Department of Energy (DOE). When an alarm occurs the scene associated with the alarm is recorded. This allows an operator to play back the recording and determine what caused the alarm.

The original video frame was a video disc recorder and was very difficult to set up properly and maintain. In fact, almost all of the repairs and adjustments were difficult, or at least very tedious. The problems existed for several reasons:

- Extreme precautions were needed to ensure that the heads and the platter were not damaged.
- Much work was required on the video heads (aligning, realigning, replacing, and keeping free of dust).
- Maintenance on the disc recorder required a technician that was extremely knowledgeable in both the mechanics and electronic circuitry of the recorder.
- Keeping the disc recorder operating was very time consuming.

In addition, by using the video recorder 24 hours/day, the mean time between failures usually ranged between 25 to 40 days.

The original system was eventually replaced by a solid state frame store developed by Hill Electronics, Inc. The new version proved quite reliable and required no maintenance. Unfortunately, it was functionally limited and expensive to operate (i.e., 128 frames/256 fields of memory cost approximately \$63,000).

Currently, video technology continues to evolve at a rapid pace because of the desire to improve existing and future security systems in the most cost-effective manner. In light of this, DOE has tasked Sandia National Laboratories (SNL) with identifying and evaluating commercially available, cost-reducing solid state video frame stores.

This report documents the results of SNL's video frame store tests. These tests were conducted using traditional parameters of resolution, sensitivity, signal-to-noise (S/N) ratio, and intrascene dynamic range. We examined a frame store currently used at one of the sites, as well as three commercially available frame grabber systems chosen for this evaluation. The results of this evaluation should prove helpful in determining the usefulness of these video frame store units in current or future assessment systems.

2.0 Overview of Current Video Assessment Subsystem

DOE is currently using, among others, the HEI 921, a solid state frame grabber produced by Hill Electronics, Inc. The HEI's mode of operation is a simple one (Figure 1). Through RS-232 communication lines, a host computer receives alarm information from sensors in the field. The computer then transmits commands to a video controller that relays the commands to a solid state video recorder (SSVR) controller. The SSVR controller issues commands to the switcher to record a field of video and switch the output to the HEI. The information is then displayed on a 525/60Hz video monitor. The whole process is complete within seconds after an alarm occurs (as mandated by DOE must happen fast enough to capture an intrusion).

Figure 1. Simple Block Diagram of Video Subsystem

To more fully understand how the HEI system operates, several factors should be considered: how it records (real-time, frame, or field mode), its configuration, the amount of available memory, the cost of the system, and other equipment needed to run the system.

2.1 Types of Recording

Real-time video recording occurs when one field of video is recorded every 1/60th of a second. Two fields of video interleaved make a frame of video. Therefore, a frame of video in real time occurs every 2/60th or 1/30th of a second. Recording with the HEI occurs every other frame and requires master sync (i.e., the master pulse that triggers the system's timing). It is limited to this rate because the switcher is not capable of switching in real time.

2.2 Configuration

The HEI can be configured to record a maximum of 256 fields of video. The current system records 128 and receives a maximum of eight simultaneous alarms. When eight alarms occur, each of the eight cameras associated with the alarm scenes are switched, one at a time (every 1/15th of a second or every other frame), to the HEI. In this way, the HEI records one field of video. A multiplexing algorithm allows for two fields of video to be recorded from each camera every 1 second for 8 seconds of recording time.

2.3 Memory and Cost

Within the HEI, video images are stored in random access memory (RAM) modules with a maximum of 128 frames/256 fields. Each module can store 8 frames/16 fields and costs approximately \$3,000. A unit with full recording capability costs about \$63,000. The one at the site we looked at contains 64 frames/128 fields and costs around \$51,000. Both of these frame grabbers come with a video subtraction module that allows one image to be subtracted from another. This subtraction capability could allow an operator to observe the slightest movement from an intruder positioned close to the scene's background.

2.4 Other Necessary Equipment

Other equipment that make up the HEI video system include the following (may vary with site):

- eight character generators used for annotation
- two video cassette recorders (one for archiving and the other to play back archived information)

- a master sync generator
- a video switcher.

3.0 Video Recorder Selection

We examined each manufacturer's specifications by looking at several key factors. One major selection factor in choosing the recorders was whether they were solid state in nature. Solid state devices are expected to require less maintenance and have a longer life expectancy than mechanical versions. High resolution and bandwidth were also key selection factors. It is important to select a video frame store, when possible, that matches or exceeds the minimum bandwidth of other system components. Therefore, selection was based on published resolution specifications or manufacturer's agreeing to meet the criterion early in the test phase. Normally, the component that limits the bandwidth is the camera and cameras we recommend for perimeter systems provide approximately 550 horizontal television lines. Selection was based also on anticipated ease of integration into current systems, the recorder's unique features that might enhance system performance, and any future expected requirements.

From these factors, we chose three systems to evaluate: the MARK X produced by Nuclear Security Services Corporation (NSSC), the PRESEARCH Image Capture System (PICS) by PRESEARCH, Inc., and the VMF 80 distributed by Vision Security, Inc. (Please note that not all of the systems' features are discussed but only those we considered prevalent.)

4.0 The MARK X and PICS Systems

Both the MARK X and PICS incorporate a feature called pre-alarm that allows an operator to view what occurred prior to the sensor triggering an alarm. The pre-alarm feature involves each camera being dedicated to its own input and continually recording frames of video. The frame storing rate is selectable (the fastest being every 1/2 second apart). The number of frames recorded before and after an alarm is also configurable. Master sync is not required with these systems.

Unlike the HEI, The MARK X and PICS are complete assessment systems, not merely frame grabbers. They can work as stand alone systems requiring only video and alarm information or they can be easily integrated into existing systems. Also, they do not require the additional equipment needed with the HEI.

Both systems can receive alarm information through RS-232 communication. The MARK X can also receive information through its APARS alarm interface. This feature detects alarms by monitoring the output voltages of field sensors. As a result, the communication delay (characterized by RS-232 serial communication) is lessened considerably.

Both systems allow an operator to adjust the contrast of a displayed image. Also, they allow an operator to archive image data to a hard disc, store data to a floppy disc, and print a hard copy of a recorded scene.

The MARK X contains a feature called negative imaging that can help identify an intruder camouflaged to blend into the background of a scene.

Neither the MARK X or the PICS met the resolution requirement when the market survey was conducted. Both produced approximately 275 horizontal television lines (TVL) compared to the published resolution standards of 550 lines. However, representatives from both companies indicated they could meet our suggested resolution criterion. NSSC increased the resolution of the MARK X system to 400 TVL. PRESEARCH, on the other hand, did not provide Sandia with a system with improved resolution.

Listed below are some estimates provided by NSSC for different size systems (price includes system integration). Actual costs will vary depending on specific site requirements.

NSSC's MARK X:

- 1 monitor
- 2 keypad assemblies (CAS and PAC operation)
- 6 operation and technical manuals

Number of Inputs	Price of System
256	\$298,100
128	\$170,300
32	\$ 65,700

PRESEARCH's PICS

PRESEARCH did not respond during a 5-month period to our requests for system cost estimates.

5.0 VMF 80 Frame Grabber

The VMF 80 distributed by Vision Security, Inc., is a frame grabber that does not require master sync. One major advantage is that its ten cameras and ten alarm inputs can be connected directly to field sensors. Also, an operator can use the keypad to enter different record modes, set up annotation, and assess alarms. (The keypad can be replaced by any other RS-232 communication device.)

While this system operates in several recording modes, the 30-field mode most closely matches (at 540 TVL) the evaluation criterion. Because only 30 fields are available, a maximum of four fields are recorded for each camera. These four fields are recorded for the first alarm and then sequentially for the next five, with the last two alarms containing only three images. The formula used for determining the recording time from the first to the last is as follow:

(1) Number of active channels x field storage period (.08 sec.) = minimum storage period.

(2) Number of images - 1 x image storage period = total time.

Example:

(1) 8 active channels x .08 seconds = .64 minimum storage period

(2) 30 images (mode currently used) - 1 x .64 = 18.56 total time.

The problem with the VMF 80 is the time delay between the recording of the first alarm and the recording of the last alarm. An intruder could easily be out of the field-of-view, undetected, long before the last image is stored.

The VMF 80 is an inexpensive frame grabber that costs around \$4,000. Unfortunately, it has very limited recording capacity, especially in the high resolution mode that is usually desirable for exterior perimeter applications. A better application for its use might be in small, interior assessment systems. The tables below describes some of the VMF 80 recording modes.

Table 1. VMF 80 Recording Modes

Number Of Images	Frame or Fields Mode	Approximate Horizontal Resolution In Television Lines	Vertical Resolution
15	Frame	550	488
30	Field	550	244
30	Frame	275	488
60	Field	275	244

6.0 Test Parameters

Our main focus in this evaluation was to determine whether the particular frame grabber altered signal quality. To determine the effect on the signal, we evaluated specific parameters at the input and output of the frame grabber: sensitivity, resolution, signal-to-noise ratio, and intrascene dynamic range.

6.1 Sensitivity

Sensitivity is mainly a function of the camera system. The more sensitive the system, the less artificial light is needed to produce the desired video signal. An increase in lighting translates into an increase in lighting equipment, which increases operating costs.

6.2 Resolution

Resolution is a very important factor because larger zones can be viewed with systems that provide greater resolution. Larger zone coverage can reduce the number of cameras needed to monitor an area. Also, less mounting hardware and cabling is required, thus reducing system costs.

6.3 Signal-to-Noise Ratio

The video signal-to-noise (S/N) ratio directly affects the ability of an operator to distinguish image detail. Although image quality is often subjectively evaluated, metrics can be useful in evaluating this parameter. Basically, video signal quality is a function of the amount of noise present in the signal. Noise content is commonly expressed as an S/N ratio measured in decibels (dB).

6.4 Intrascene Dynamic Range

In a properly engineered system, a full video signal should be produced when an alarm occurs. Without a full video signal, scene information is compressed into fewer shades of gray than actually exists. This results in a low-contrast, washed-out picture where image detail may not be distinguishable from the background. With such poor resolution, an intruder could go undetected (e.g., if an intruder is wearing clothing close to the background color).

7.0 Test Procedures for Evaluating Traditional Test Parameters

To evaluate test parameters, a video measurement system manufactured by Tektronix, Inc., Model 1780R, was used. Unfortunately, the 1780R is compatible only with video signals generated at 60 H and the PICS model displays video signals operating at much higher frequencies. Therefore, certain evaluations (S/N ratio and intrascene dynamic range) were not performed on the PICS.

7.1 Setup

To set up the evaluation, an EIA resolution chart was placed at the end of an optical bench (Figure 2). Front lighting was added using two incandescent light bulbs operating at a color temperature of 3200 K (the historical standard for testing camera sensitivity). The light bulb fixtures were mounted approximately 3 feet away on each side of the chart and positioned on stands equal to the midpoint of the chart. The lights were aimed at 45° angles toward the chart. Dispersion screens were attached to the front of each of the lamp fixtures (to help prevent bright spots). On the top of the optical bench, another camera was mounted and aimed at the chart and aligned with the center axis of the chart. The outer edges of the chart were just inside the camera's field-of-view.

Figure 2. Front-Lighted Chart Test Setup

7.2 Parameters Evaluated at Frame Grabber's Input

To evaluate the parameters at the frame grabber's input, several stages of setup were involved. First, the camera output was attached to the input of the video measurement system. Next, the video output of the measurement system was attached to the input of a video monitor. All recording measurements were then read at the input and output (except the gray scale) for each parameter at 100 IRE units (the desired full video signal) and at 40 IRE units (the minimum usable signal). Finally, the results were tabulated.

7.3 Parameters Evaluated at Frame Grabber's Output

The camera video output was attached to the video input of a frame grabber and the frame grabber output was attached to the video measurement system's input. The video output of the measurement system was then attached to the video input of a video monitor. This allowed for evaluation of the processed signal.

7.4 Intrascene Dynamic Range Test

For the intrascene dynamic range test, the waveform function and the LINE SELECT mode (to display the gray scale) were chosen. The peak white, peak black, and peak-to-peak levels were then read and inserted in columns 3, 4, and 5 (respectively) of row 2 in Table 2. Also read were the video levels for each of the 10 gray scale steps. These were inserted in columns 6 through 15, row 2, Table 2. (For conciseness, P-P represents the difference between peak white and peak black levels measured in IRE units and representing the maximum intrascene dynamic range. NM refers to a parameter that was not measured.)

Table 2. Gray Scale Response at 100 IRE

Manufacturer	Model	White	Black	P-P	1	2	3	4	5	6	7	8	9	10
Condition at Frame Grabbers input.		100	20	80	20	26	42	52	58	60	68	76	86	100
Hill Electronics Inc.	HEI 921	100	20	80	20	26	43	53	58	60	68	76	86	100
Vision Security Inc.	VMF 80	100	20	80	20	26	42	52	58	62	68	76	86	100
NSSC	MARK X	100	20	80	22	24	44	54	58	62	70	78	84	100
Presearch	PICS	NM												

7.5 Horizontal Resolution Measurement

The horizontal resolution measurements were achieved by viewing the resolution chart projected on the monitor. The point where the vertical lines were no longer discernible represented the camera's horizontal resolution limit.

In Table 3 the conditions at the frame store input are shown (column 3, row 3) where the video level is at 100 IRE. The conditions at 40 IRE are indicated in Table 4, column 3, row 3.

7.6 Signal-to-Noise Ratio

The signal-to-noise evaluation examined the noise measurement function of the measurement system. Table 3, column 4, row 3 indicates the conditions at video level 100 IRE. Table 4, column 4, row 3 indicates the conditions at 40 IRE.

Detailed procedures for sensitivity measurements are not described. The degree that the video signal level changed from the frame store input to its output reflects sensitivity variation. For example, in Table 2, column 5, rows 2, 3 and 4 the data indicates no sensitivity change.

Table 3. Resolution and Signal-to-Noise Measurements at 100 IRE

Manufacturer	Model	Horizontal Resolution	Signal-To Noise Ratio
Condition at Frame Grabbers input.			
		565	42
	Hill Electronic Inc.	500	42
	Vision Security Inc.	*540	42
	NSSC	400	42
PRESEARCH	PICS	320	NM

*This high resolution occurs only in 30 field mode.

Table 4. Resolution and Signal-To-Noise Measurements at 40 IRE

Manufacturer	Model	Horizontal Resolution	Signal-To Noise Ratio
Condition at Frame Grabber Input.		565	42
Hill Electronics Inc.	HEI 921	500	42
Adpro	VMF 80	540	42
NSSC	MARK X	400	40
PRESEARCH	PICS	275	NM

8.0 Summary

The purpose of conducting this evaluation was to identify commercially available solid state frame grabbers that could improve the performance of existing and future video assessment systems.

Frame grabbers were selected using certain criteria: they were solid state in nature, contained high resolution, they could be easily integrated into existing systems, and met expected future requirements. (Selection was based on published resolution specifications or on manufacturers agreeing to meet this requirement early in the testing phase.)

To compare system performances, we evaluated an existing video assessment system that incorporates a frame grabber, the HEI 921, as well as three other frame grabber systems: the MARK X, the PICS, and the VMF 80. In our evaluation, we tested some of the operational methods and prevalent features of each system.

The MARK X and PICS, unlike the HEI and VMF 80, are complete assessment systems (not merely frame grabbers). They can operate as stand-alone systems requiring only video and alarm information or they can be easily integrated into existing systems. The MARK X probably would be easier to integrate with most existing systems because its video output is formatted to the more commonly used RS-170 standard. The PICS system, on the other hand, outputs video at much higher frequencies (more common with computers). While both systems can receive alarm information through RS-232 communication, the MARK X can receive information through its APARS alarm interface. This interface provides fast alarm reporting because it detects alarms by monitoring field sensors' output voltages.

The HEI 921 and the VMF 80 more closely match the resolution desired for video frame recorders. The VMF 80 provided the highest resolution at 540 horizontal television lines compared to 500 for the HEI, 460 for the MARK X, and 275 for the PICS. However, the VMF 80 has very limited recording capacity, especially in the high resolution mode (only 30 fields) compared to 256 fields for the HEI. For the other two systems, recording capacity can be added, up to some reasonable limit, upon request.

Another problem with the VMF 80 is the method used to record multiple alarms. In the 30-field mode, the recording time delay is 18 seconds between the first field and the last. Yet, it should be considered for two reasons. First, its cost is relatively low (\$4,000 a unit, depending on the system requirements). Secondly, it can be used in different modes that change the recording rate (refer to the VMF 80 User Manual). This point

is especially important for small assessment systems and interior applications where recording time is less critical.

The HEI can record real time if a capable switcher exists and master sync is provided. The MARK X and PICS record a frame of video simultaneously and continuously for all the connected cameras, providing a pre-alarm capability. Recording in this fashion allows an operator to view frames of video prior to an alarm. The fastest recording rate for both systems is 1/2 second.

Image quality was also addressed in this evaluation. Tests were conducted for intrascene dynamic range, signal-to-noise ratio, and sensitivity. The purpose was to determine whether these parameters degraded after the video signal was processed by the different systems. The tests concluded that for the MARK X, HEI, and VMF 80, no significant changes occurred. The tests were not performed for the PICS because its video output was incompatible with the standard test equipment that was used. It should be noted, however, that no visible degradation was noticed.

The MARK X and the PICS systems both provide a contrast adjustment feature, allow an operator to archive image data to a hard disc or store data to a floppy disc, and allow an operator to print hard copies. The MARK X also contains a negative imaging feature that can help identify a camouflaged intruder blending into the background of a scene.

Finally, this report highlights the main features of the frame grabbers and assessment systems chosen for this evaluation. Actual site requirements should lead to proficient and efficient system design. These designs will dictate the type of equipment to incorporate since many variables (zone width, type of sensor, etc.) determine how fast a system will respond. DOE mandates that the input must be transmitted, recorded, and played back fast enough to capture an intrusion. We recommend, therefore, that designers of these video recording systems become familiar with pertinent DOE orders.

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