# Real-Time High Resolution Digital Video for Range and Training Applications


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## ABSTRACT

The operator interface to a modern radar, sonar or weapons system trainer (WST) is typically one or more high-resolution video displays driven by PC's or other workstations. The training system used to instruct and qualify operators for this type of mission critical application should be capable of recording RGB video data to a fine level of detail. Similarly, ground stations for Research, Development, Test and Evaluation (RDT&E) and Operational Test & Evaluation (OT&E) applications often utilize high-resolution workstation screens to display critical test data. And often, these workstation screens are located in mobile vans, on aircraft, or are otherwise remote from test conductors who need access to the same screen data.

This paper presents a solution for the efficient digitization, storage, replay, and transmission of the data displayed on the high-resolution workstation screens commonly found in these types of training system applications.



## KEY WORDS
High Resolution Digital Video, Range Training Systems, Operational Test & Evaluation (OT&E), Research, Development, Test, and Evaluation (RDT&E)

# INTRODUCTION

The high-resolution workstation screens commonly found today in weapons systems trainers and RDT&E/OT&E ground station applications are often key elements in the training of operators and/or the evaluation of modern weapons systems.

A typical application for a WST might be a high-resolution workstation screen displaying detailed map imagery with overlaid symbols, while a typical application in RDT&E might be a complex screen of critical test parameter data superimposed on an animated mimic diagram of a unit-under-test. Two example applications are described in the following section.

# EXAMPLE APPLICATIONS AND TYPICAL REQUIREMENTS

Figure 1 is an example of a weapon system training (WST) application. The system operators undergoing training sit at high-resolution workstation screens and take part in the training exercise. A trainer or test conductor in a separate “van” records the RGB video output of three hi-resolution consoles and records the actions of the weapons systems operators using NTSC cameras. The monitors in front of the test conductor are optional and support remote monitoring of the RGB and NTSC video during recording as well as playback of previously recorded test data.

Figure 2 is an OT&E example where there are multiple weapons systems or “players” under test out on the range and the “telemetry ground station” mobile van is the focal point for collecting data from the remote “players”. The data collected is typically some combination of video and instrumentation data transmitted via PCM telemetry from the players plus communications and other data sources (TADIL-J, 1553 etc). The senior “test conductor” is typically located in the range control/data center. In this scenario, the remote telemetry, video, and workstation screen data can all be collected relatively close to the test and then transmitted to the range control center using standard ATM network technology. At they control center, standard workstations and PCs can archive and replay the data - data that previously would have only been available in the mobile van out on the range.

An ideal solution for these types of workstation screen acquisition applications may require some or all of the following features:

- Non-intrusive to the operator and system being operated
- Support capture and recording of high-resolution video displays, outputs from NTSC video cameras, audio and other associated data sources
- Support real-time monitoring and display of the above data sources during the test
- Support playback of the above data sources after the test
- Support playback of historical test data while recording continues
- Support synchronization between multiple sources of data
- Support remote access to video data using standard communications networks

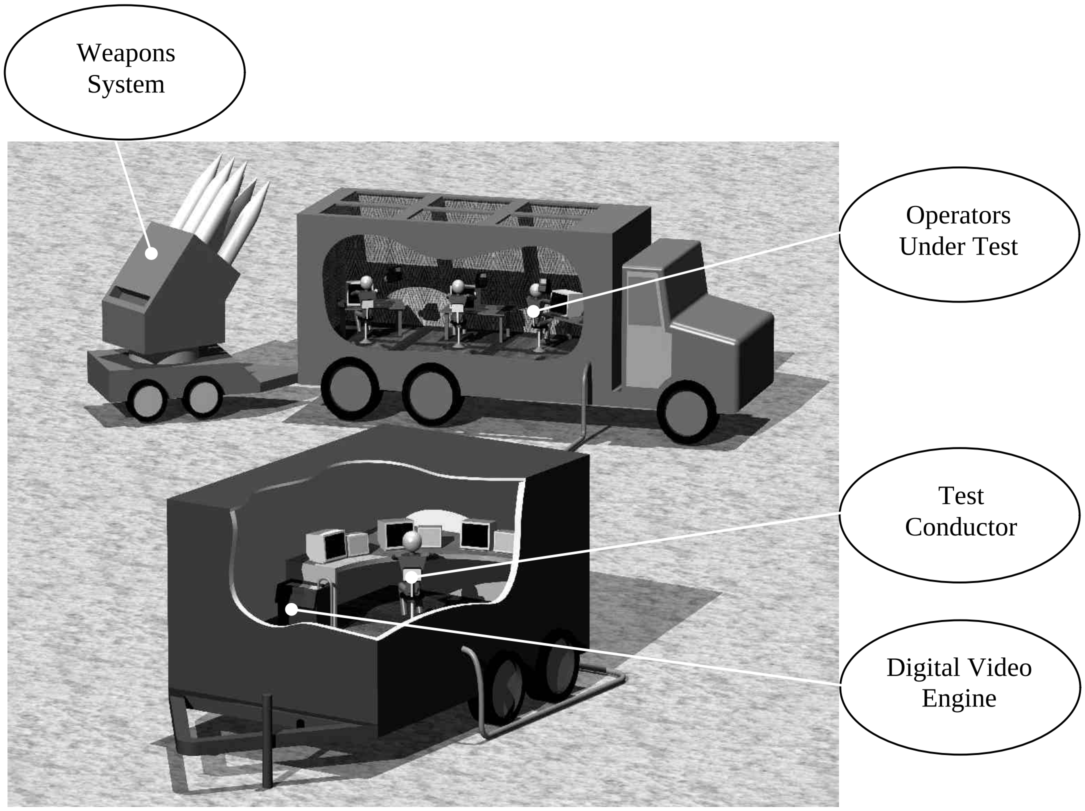


**Figure 1 – Example WST System**

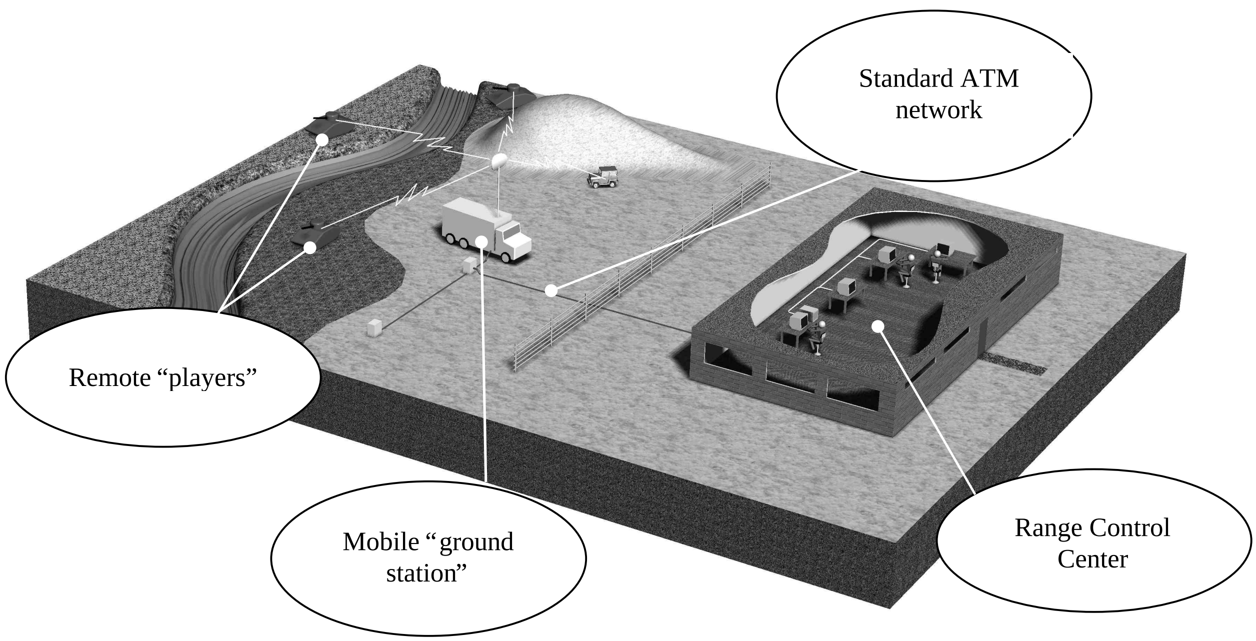


**Figure 2 – Example RDT&E/OT&E System**

# EXISTING SOLUTIONS

The workstation screen acquisition requirement has been met in the past using several approaches, none of them ideal.

For example, one method currently in use – especially in operator training applications - is the incorporation of custom "data dump" software into system under test (SUT). This method is intrusive in that the operational software of the SUT is modified to archive specific data of interest. This can adversely impact SUT performance as well as being a potential software maintenance headache. If the operational software is upgraded, it may also be necessary to modify the "data dump" software in parallel. Another drawback of this method is that custom post-processing software is likely to be required in order to implement playback or data analysis after the test. In summary, the "data dump" method relies on intrusive data logging to characterize operator actions at the SUT consoles.

An alternate approach now commonly in use at many range training sites employs some combination of video recorders to collect images from both NTSC cameras and the RGB workstations themselves (the latter method is often referred to as "scan conversion"). The use of NTSC cameras is most suitable to the monitoring of an operator's physical actions during a test and his interaction with other operators. These cameras (which generally support resolutions of 640 x 480 pixels) are usually used with a standard VHS or more sophisticated video recorder. In some cases, they are also used to record images from the operator console itself, simply by pointing the camera at the screen. The resolution of these "over-the-shoulder" video screen captures is usually very coarse and is not satisfactory for most cases.

To achieve some degree of basic fidelity in recording the RGB video from the operator's console, a video scan converter can be used. This is a commercially available device, which samples the analog video output from the console, and converts it to lower resolution NTSC video for recording on VHS tape. Since the resolution of the recorded video is only 640 x 480, much of the fine detail of the original RGB image is lost. Although scan converters that support HDTV formats have recently become available, they only support a few fixed image sizes up to 1920 x 1080. This restriction can result in a loss of video resolution or distortions in image aspect ratio. Both the NTSC camera and scan converter methods of collecting data have the added limitation of recording a single video stream to each tape. This can present major problems in post-test data reduction and data analysis.

In summary, the existing solutions have problems in the area of RGB video resolution, handling of multiple video streams and intrusiveness. A COTS solution that addresses these concerns is presented in the following section.

## A COTS SOLUTION

The AP Labs DVE-201 High-Resolution “Digital Video Engine” is designed to satisfy the requirement for efficient acquisition, compression, and decompression of workstation screen video.

While high-performance defense-related applications sometimes require custom solutions, the approach taken with the DVE-201 has been to minimize the custom content. Therefore, the DVE-201 utilizes standard, main stream chip-level products designed for high volume data acquisition (for signal acquisition), DSP (for system management), VME interface (for communication with the rest of the system), and image processing (for compression and decompression of the high-resolution images). This reduces cost and development schedule while increasing the possibility for future enhancement as commercial chip performance increases over time. The card set consists of a common VME motherboard which contains the video compression/decompression module, plus the audio acquisition interfaces. A plug-in daughter card provides either high-resolution RGB or NTSC/PAL/SECAM capture and playback.

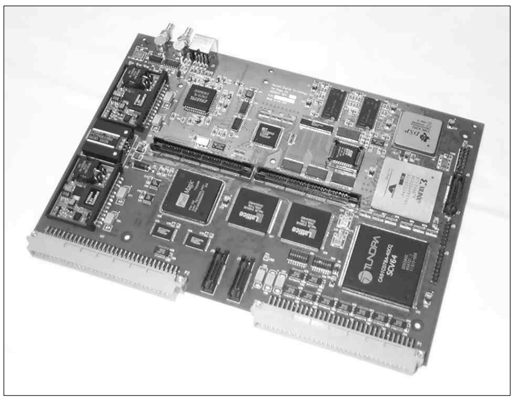

**Figure 3 – AP Labs DVE-201 High Resolution “Digital Video Engine”**

The DVE-201 video card (and the open-architecture systems integrated with the DVE-201 as the core element) provide the following key features:

- Acquisition, recording and playback of RGB images up to 2048 x 2048 pixels
- Per channel configuration of any resolution up to maximum 2048 x 2048 pixels
- Re-configurable to support multiple numbers of RGB, NTSC and other video formats
- Based on open architecture approach, which allows integration of other data sources such as MIL-STD-1553, tactical data links, A/D, serial, digital I/O etc.
- All video and other real-time data is acquired and synchronized using IRIG or GPS time
- Turnkey system available in rugged, portable or rack-mount packaging
- Controlled by VCR-like GUI which runs on any JAVA enabled platform
- Supports fully autonomous and remote control (serial) operation
- Digitized video data can be distributed over standard network (e.g. Ethernet, ATM) for real-time recreation of video displays at remote site

## SYSTEM-LEVEL ARCHITECTURE

The system design is based on modular, open architecture building blocks and common, industry standard technologies such as VME64, Ultra SCSI, Fast Ethernet and the VxWorks real-time operating system. The use of non-proprietary COTS building blocks guarantees the end-user maximum flexibility whether he chooses to integrate video cards into his own system or add capability to a turnkey data system.

The block diagram (Figure 4) below shows the basic components of the system. The Real-Time Video Data Server is the common "building block" for systems such as the examples described above. The Video Data Server contains the video acquisition cards, CPU card and storage devices necessary to record and playback multiple video data streams, as well as the network interfaces necessary to distribute the data across standard networks. Many other standard interfaces can be included (PCM Telemetry, 1553 etc) but are not shown here simply for clarity.

In this example, the "System Under Test" consists of three operator stations. At each station, the sources to be recorded are hi-resolution RGB, NTSC camera and audio.

The System Control Client provides a graphical user interface that can be used to setup, configure, start and stop the real-time system over Ethernet or serial link. Any general purpose PC or workstation can run this GUI software, which is based on the JAVA programming language.

The Display Clients can act as either "quick-look" monitors of video data during recording, or can be used as post-processing stations for off-line analyst review of previously recorded video data. This software can be run on any general purpose PC or workstation since it is written in the JAVA programming language.

Synchronization between all data sources is maintained using IRIG or GPS time stamp of each individual data buffer.

On the software side, the VxWorks real-time O/S guarantees deterministic real-time performance (which prevents loss of data), strong network support libraries and user-friendly development environment. Also, the software architecture for the video record and playback application is based on a client/server model. The software has been developed using a modular approach with clearly defined Application Programmer's Interfaces (API's). The result is that new software modules can be cleanly developed and easily integrated with the baseline code. Examples of included API's are:

- Client/server API – allows integration of new clients for command/control or data distribution/display
- Real-Time I/O API – new types of I/O can be recorded along with the video and audio data (e.g. 1553, NTDS, ARINC-429, tactical data links)
- Real-Time device driver API – VxWorks device driver allows integration of video cards into customer furnished data system

In keeping with current trends toward open architecture software solutions, source code is available, should the end user wish to implement customizations to the baseline

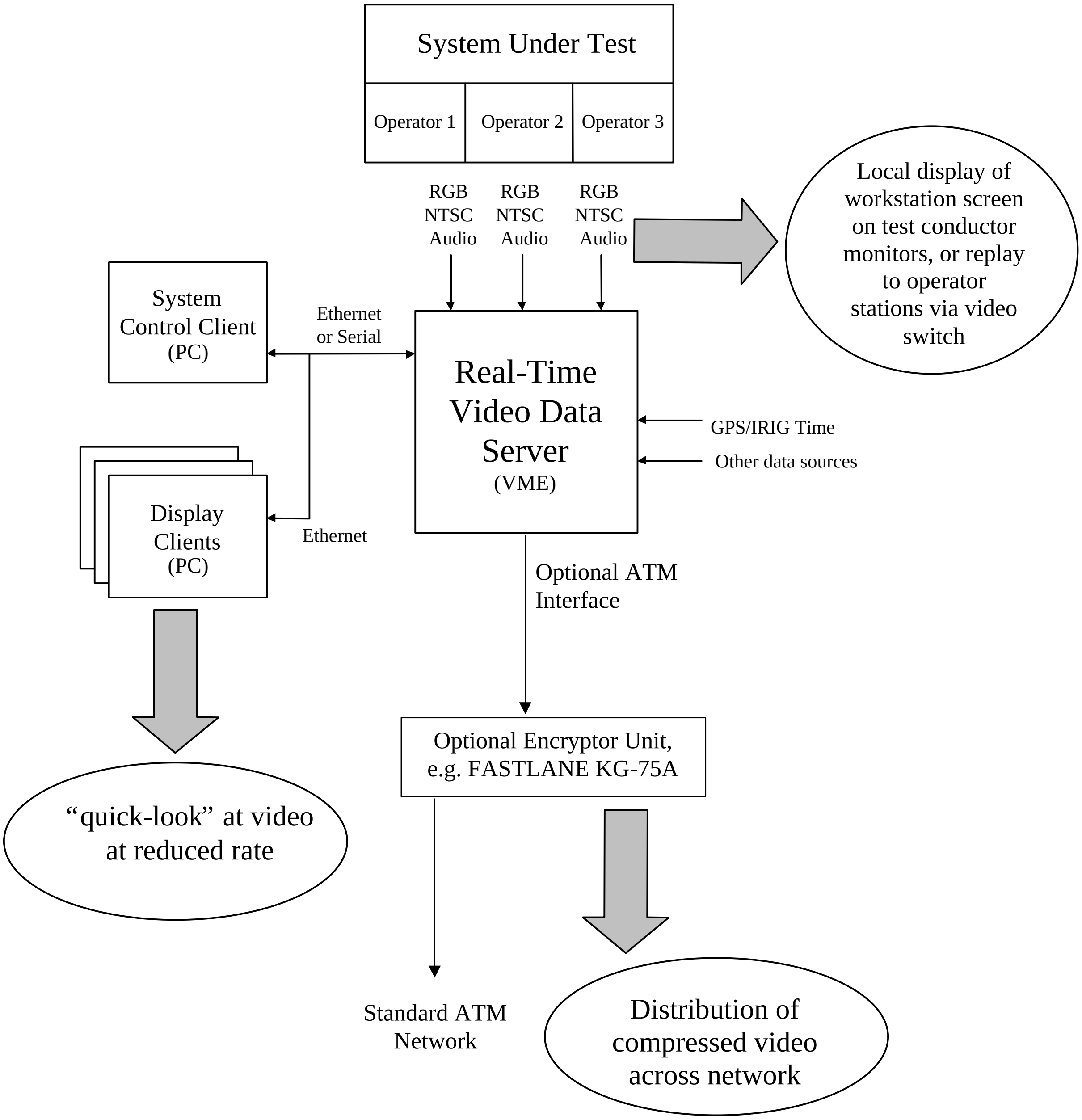


**Figure 4 - High Resolution Digital Video System Architecture**

# VIDEO DATA SERVER OPERATION

The Real-Time Video Data Server supports both record and playback modes for all video and audio channels. While in record mode, each active video channel is sampled by an A/D converter on the RGB or NTSC daughtercard. The resulting digital video data stream is compressed to JPEG format on the VME baseboard. The compressed digital video data is copied across the VMEbus to the PowerPC CPU card, where it is archived to disk, tape or RAID.

During playback, the process is reversed. The compressed digital video buffers are retrieved by the CPU card from the SCSI storage media, then copied over the VMEbus to the designated video baseboard. The digital data is decompressed, then streamed to the RGB or NTSC daughtercard, where it is converted to analog video output.

The user configures the video channel setup prior to recording. For NTSC recording, the frame rate and compression ratio are specified for each active NTSC channel. Default NTSC settings are 30 frames/sec and 30:1 compression ratio. Other settings can be programmed.

For RGB recording, the video format, the frame rate and compression ratio are specified by the user for each channel. Default frame rate for RGB is 10 frames/sec and 20:1 compression ratio. The following RGB video formats are user selectable on a channel-by-channel basis:

- Sun (1600 x 1280) @ 76 Hz
- UXGA (1600 x 1200) @ 75 Hz
- Sun SXGA (1280 x 1024) @ 76 Hz
- SGI SXGA (1280 x 1024) @ 76 Hz
- XGA (1024 x 768), SVGA (800 x 600), and VGA (640 x 480) @ 75 Hz

In addition to these common RGB video formats, the user can define his own custom RGB format by specifying the parameters that characterize the video hardware in the SUT. As an example, the hi-resolution Sun format listed first above was defined with the following parameters.

Number of active pixels per line = 1600
Number of horizontal blanking pixels = 520
Number of active lines = 1280
Number of vertical blanking lines = 60
Vertical Refresh Rate = 76 Hz
Sync type = Composite

The RGB video card has been designed to accommodate all video resolutions currently in use, plus those anticipated to be in use over the next few years. The maximum image size that the RGB video card can record is 2048 x 2048 pixels, which is significantly larger than any existing video formats (or any anticipated video formats).

Since the RGB video card operates at a clock rate of 220 MHz, the digital video data stream is limited to a maximum pixel rate of 220 Mpixels/sec. To calculate the pixel rate for a given RGB video configuration, multiply the total number of pixels in the image (including blanking) by the vertical refresh rate. For the Sun hi-resolution format above,

PIXEL_RATE = Pixels_per_line * Num_vertical_lines * Refresh_rate
= (1600+520) * (1280 + 60) * 76
= 215.9 Mpixels/sec

After a channel has been recorded to the local storage device (hard disk, hi-speed tape or RAID), the playback is performed with the same frame rate, compression ratio and (in the case of RGB) video format.

## SYSTEM SCALABILITY

The system can be scaled to support many channels of video by simply adding cards to the VME backplane – no software recompilation is necessary. The maximum number of video channels that can be supported on a single VME backplane is dependent on the mixture of RGB and NTSC channels (hi-resolution RGB requires more system resources than NTSC).

The following table presents the "worst-case" mixture of RGB and NTSC video cards that can be handled on one VME backplane. These numbers are based on the assumption that all RGB channels are recording at the maximum rate (10 frames/sec, 1600 x 1280 @ 76 Hz) and all NTSC channels are recording at the maximum rate (30 frames/sec, 640 x 480). If it is known that the resolutions and/or frame rates are lower than "worst-case", then more video cards can be handled in a single backplane.

| RGB | NTSC |
|---|---|
| 0 | 20 |
| 5 | 5 |
| 6 | 0 |

**Table 1 – RGB and NTSC Maximum Channel Capability, Per VME Backplane**

For larger applications, multiple Real-Time Video Data Servers can be linked together and controlled from a single System Control Client station. The commands to setup, start and stop the video server are sent over Ethernet or serial links depending on the specific physical configuration.

## SYSTEM MODES OF OPERATION

One or more Real-Time Video Data Servers can be controlled by the System Control Client software which can run on any JAVA enabled workstation, such as a PC, Sun or SGI. In most cases, the communication link between the client workstation and the video server is via Ethernet, although serial is also an option. The client software provides for setup of the individual video and audio channels, start/stop and record/playback control. Status is displayed indicating video sync status for each channel, video frame counters for each channel and status of the disk or tape storage.

Autonomous operation is also supported, which allows the user to download a pre-defined video channel setup into non-volatile memory, then run the Real-Time Video Data Server in stand-alone mode. This configuration may be useful in situations where it is not convenient or physically possible to connect a System Control Client workstation to the video server.

## PACKAGING OPTIONS

A wide variety of VME chassis are available to package the boards and peripherals required for the digital video system. For portability, the FS-4006 flight case enclosure is recommended. This has space for 8 VME slots, front removable power supply, two removable SCSI hard drives and two hi-speed tape drives. For fixed mount applications where shock and vibration protection is required, the FS-7275 or FS-7276 ATR enclosures offer from 7 up to 12 VME slots and space for multiple peripherals. For benign lab environments, the industrial grade FS-1220 or FS-1112/21 offers 12 to 21 slots with a variety of dual backplane configurations. Some examples are shown below.

FS-4006 Transportable FS-7275 1 Long ATR FS-1112 Lab Grade

**Figure 5 - Digital Video System Example Packaging Options**

## CONCLUSIONS

This paper has presented a solution for the requirement to digitize, archive, replay, and distribute the screen data commonly found today on high-resolution workstation screens in WST, RDT&E, and OT&E applications. With current state-of-the-art commercial products, 10 frames per second update rates at 1600 x 1200 resolution is achievable. Future plans include increasing the update rate while reducing the bandwidth requirements for transmission of image data across the Internet.

Although the need for this type of RGB workstation screen recording has primarily been found in defense applications such as those described in this paper, other potential commercial applications include medical image processing and Air Traffic Control. Applications in these additional areas are under investigation.