LA-UR-96-2613

Title: NETWORK ADAPTABLE INFORMATION SYSTEMS FOR SAFEGUARDS APPLICATIONS

CONF-960767--63

Author(s): Cheryl Rodriguez, Len Burczyk, Peter Chare, and Hans Wagner

Submitted to: 37th Annual Meeting of the Institute of Nuclear Materials Management, July 28-31, 1996, Naples, Florida

Los Alamos
NATIONAL LABORATORY

Network Adaptable Information Systems for Safeguard Applications*

Cheryl Rodriguez and Len Burczyk,
Los Alamos National Laboratory
Los Alamos, New Mexico USA

Peter Chare and Hans Wagner
EURATOM Safeguards Directorate
Luxembourg

Abstract

While containment and surveillance systems designed for nuclear safeguards have greatly improved through advances in computer, sensor, and microprocessor technologies, we recognize the need to continue the advancement of these systems to provide more standardized solutions for safeguards applications of the future. The benefits to be gained from the use of standardized technologies are becoming evident as safeguard activities are increasing world-wide while funding of these activities is becoming more limited. The EURATOM Safeguards Directorate and Los Alamos National Laboratory are developing and testing advanced monitoring technologies coupled with the most efficient solutions for the safeguards applications of the future.

1. Introduction

The EURATOM Safeguards Directorate and the Nonproliferation and International Security (NIS) Division at Los Alamos National Laboratory have been pursuing developments in advanced imaging technologies and system architectures for safeguards and nonproliferation applications. Within the Los Alamos NIS Division, the Safeguards Systems Group (NIS-7) has developed video-based safeguards applications designed to protect nuclear materials in storage and process from theft or diversion. A second group in the Division, Space Data Systems (NIS-3), has specifically refined a data systems development methodology based on commercially available de facto-standard hardware and software building blocks.

The goal of the cooperative effort between these three organizations is to develop safeguards applications that provide cost effective technical solutions for international safeguards problems using commercially available hardware and commercially available software development environments. The use of industry-standard hardware, software, and communication protocols allows systems to be *configured* for a specific application rather than developed as a custom implementation.

2. Functional Overview

Network and small satellite technologies have become the foundation for a new generation of data systems based on a commercial, real-time, multi-tasking, distributed system architecture that can provide multiple, remote data acquisition units integrated with widely distributed data review stations. The Network Adaptable Information Systems (NAIS) concept employs these advanced technologies with systems-level development solutions to provide an integrated data environment suitable for the remote collection, automated distribution, processing, and analysis of safeguards data. For nuclear safeguards applications, Network Adaptable Video System (nTV) and Network Adaptable Nondestructive Analysis (nNDA) units can be integrated providing the "eyes" and "nose" for an intelligent, remote monitoring system for nuclear safeguards applications.

3. System Implementation

Using industry standard hardware and software components, a networked-based, image acquisition device (nTV) provides a remote real-time digital video system capable of image capture, analysis, event-detection, filtering, authentication, and compression. Filtered and compressed image data is distributed by the remote nTV unit and stored on a Network File System (NFS) file server. The safeguards video data is made available over a wide geographical area via established

This work supported by the US Department of Energy, Office of Nonproliferation and Arms Control.

satellite/ethernet channels such as the Internet. Networked, intelligent digital camera front-ends are distributed throughout a material storage facility using a simple 50-ohm shielded coax or fiber optic pair. The intelligent, distributed nTV camera consists of a single-board SPARC computer (Themis 5/64) running the Solaris Operating System and a Motorola MVME-162 cpu running the real-time operating system, VxWorks. In addition, each nTV unit provides an Echelon LON interface to permit a direct connection to radiation instrumentation. (Fig. 1)

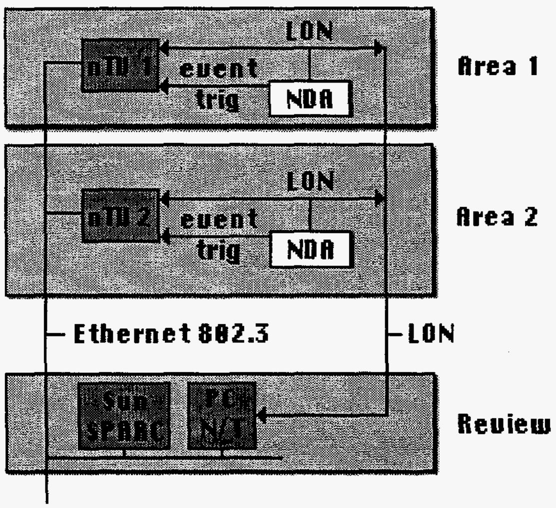

Fig. 1.Typical materials facility implementation of the nTV system.

4. Hardware

Each nTV unit consists of two single-board computers, a Themis SPARC 5/64 running Version 2.5 of the Solaris Operating System and a Motorola MVME-162 running Version 5.1 of the real-time operating system VxWorks. The SPARC 5/64 board (shown below on the left) is an image data server, providing image data via a SunVideo S-Bus frame grabber to a remote Sun Ultra SPARC workstation client. The SPARC 5/64 and the remote UltraSPARC workstation are connected by a standard TCP/IP 802.3 Ethernet connection. Normal data storage is located on the remote SPARC workstation. A 1-GB hard disk connected to the SPARC 5/64 board provides local data storage in the event of network failure. The second single-board computer, the MVME-162 (shown in Fig. 2 on the right), provides a real-time connection to local radiation instrumentation. An external event trigger and Echelon LON interface are implemented using commercial IPbus mezzanine modules. (Fig. 2)

\Two spare IP module locations provide additional I/O capability for functions such as state-of-health. The MVME-162 and SPARC 5/64 communicate over the VMEbus backplane when moving data or over the Ethernet connection when exchanging commands. Image and radiation data are collected, correlated, time-stamped, compressed, and stored in real-time each time an image or radiation event occurs. A major advantage of this design is the application of the existing IVS (Inventory Verification System) software to a distributed architecture with real-time components.

The Themis 5/64 SPARC single-board computer provides a complete SPARC workstation on a single VMEbus board form factor. The three functional component blocks highlighted below are key features necessary to implement a distributed IVS system: the S-Bus SunVideo module, the 100-Mb Ethernet S-bus module, and the SCSI-2 interface for local disk storage (Fig. 3). This board has been successfully applied in other NIS projects, such as the RULLI low-light imaging and CALIOPE Lidar projects, and has been established as an effective building block for our distributed system architecture.

SunVideo is a real-time video capture and compression subsystem that consists of an SBus card and a XIL library to support the card's functionality. SunVideo is a digital video card; it buffers digital video in its data buffer so that the digital data can be downloaded and processed by the host CPU at rates of up to 30 fps. The video capture subsystem accepts standard video in either NTSC or PAL format and performs video signal processing that is required to separate luminance and chrominance information. (Fig. 4)

The subsystem digitizes the analog input and passes the digital byte stream to the compression engine. The compression engine is a programmable video-rate processor implemented with a C-Cube CL-4000 chip. The CL-4000 compresses the digital data, using CellB (Sun Microsystems) JPEG, or MPEG-1. The compressor software provided with the SunVideo subsystem is downloaded to the compression engine under control of an XIL application.

5. IPBus Brief

The IP (Industry Pack) bus is a mezzanine I/O module standard created in 1990 by GreenSpring Computer. A number of other manufacturers, both U.S. and European, also manufacture IP modules. The standard is in wide use at most U.S. National Laboratories as well

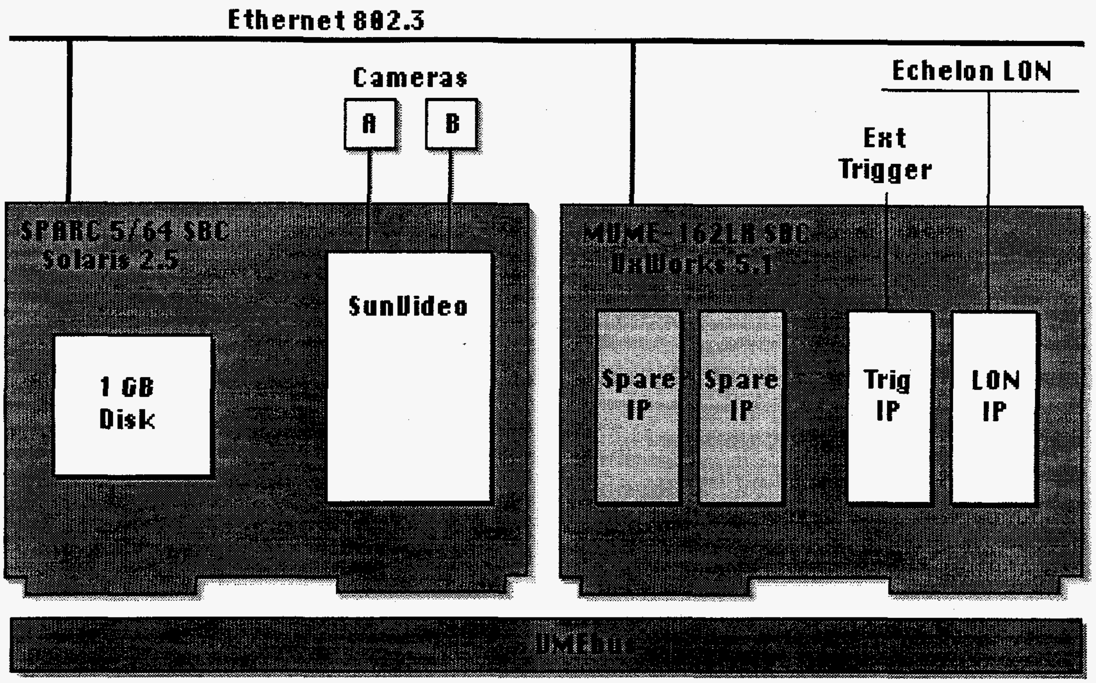

Fig. 2. Block diagram of nTV system .

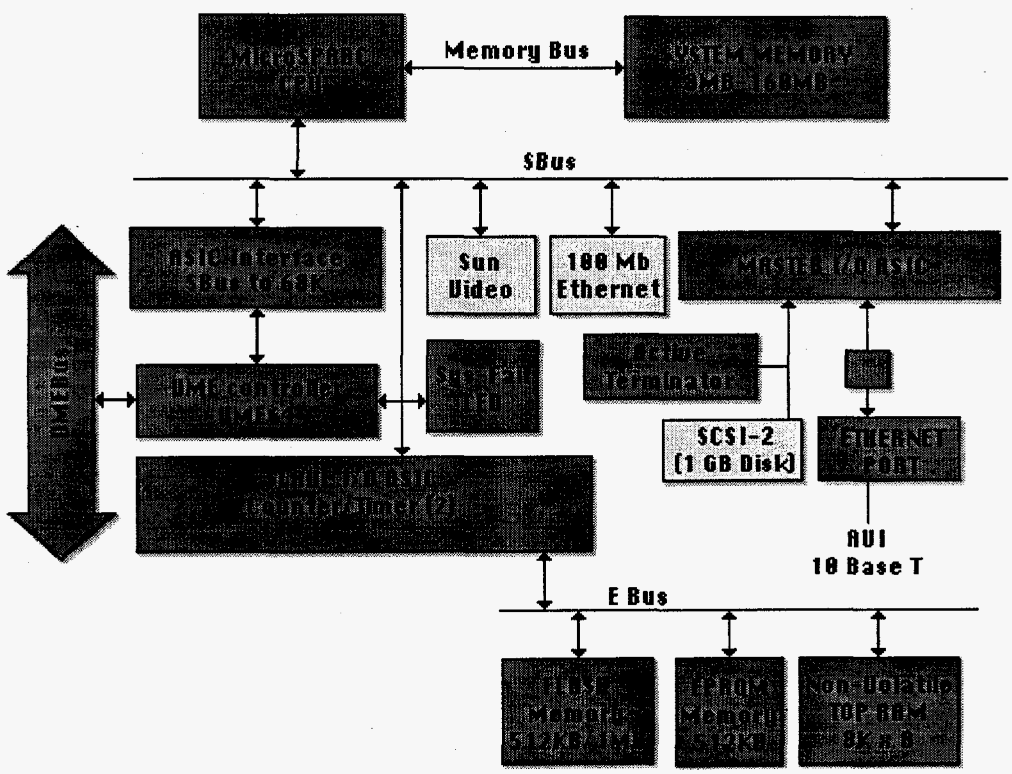

Fig. 3. Themis VMEbus single board SPARC 5/64 computer.

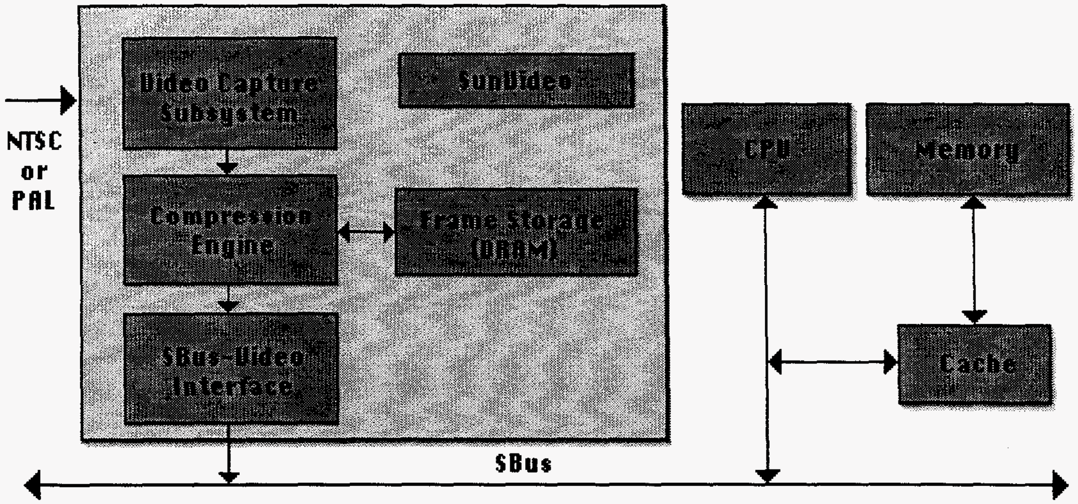

Fig. 4. SunVideo S-Bus module.

as European facilities such as CERN. Motorola has recently endorsed the standard and is now offering single board computers (MVME-162) that accept 4 IP modules for I/O. Several hundred commercial IP modules are available to date. (Fig. 5)

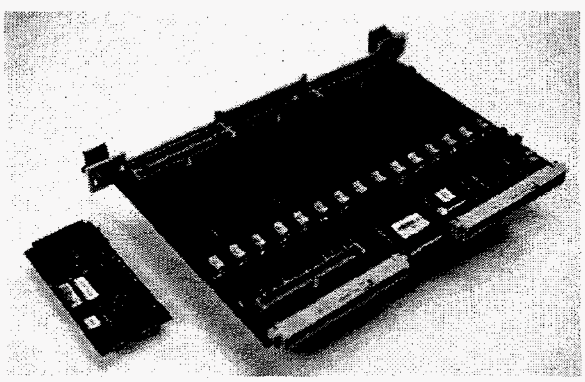

Fig. 5. IPBus mezzanine module (left) shown with VMEbus carrier (right).

The modules are relatively small, about 2 in. × 4 in. and are "bus-independent," i.e., the modules are used with a bus-specific IP carrier. Examples of carriers are VME, PCI, ISA, and NuBus. The Systran VMEbus SC-5 carrier is shown above with a typical IP module on the left.

NIS Division has used the technology since 1990 and has found it to be a very useful mechanism for rapid prototyping of circuits required for custom I/O channels. Used together with FPGA (Field Programmable Gate Array) technology, the IP modules allow I/O circuits to be developed and modified quickly without the need to develop entire VME or PCI modules.

Software for IP modules is often supplied in the form of C source code from the vendor along with the hardware. Custom IP modules developed at LANL usually require a small C device driver; typically this requires 1 or 2 pages of code, including the interrupt-handling routine.

6. The nTV LON Interface

The TIP813 is a single wide IP-compatible module from the German company TEWS DATENTECNIK. The TIP813 provides a complete LON interface using the Motorola 3150 Neuron Chip. Communication is executed via a 4kByte Dual-Port-Ram. A 32kByte EPROM is used to store the protocol firmware for the Neuron Chip and the application program. Three kinds of physical interfaces are available: standard RS-485, transformer-coupled 1.25 Mbit, and transformer coupled 78kbit. A commercial, third-party C language VxWorks-compatible driver is used in NIS-3. (Fig. 6)

Using state notation for nTV procedural descriptions: a short primer.

State notation is a graphical tool to completely describe a real-time procedure. The objective is to define all known states that can exist in a real-time procedure as well as eliminate the occurrence of unknown states. Some number of "states" and "state transition vectors" defines a "state set" or procedure. A "state" is a step or place within a procedure that is active until a prespecified "state transition" occurs. Three things (and logical

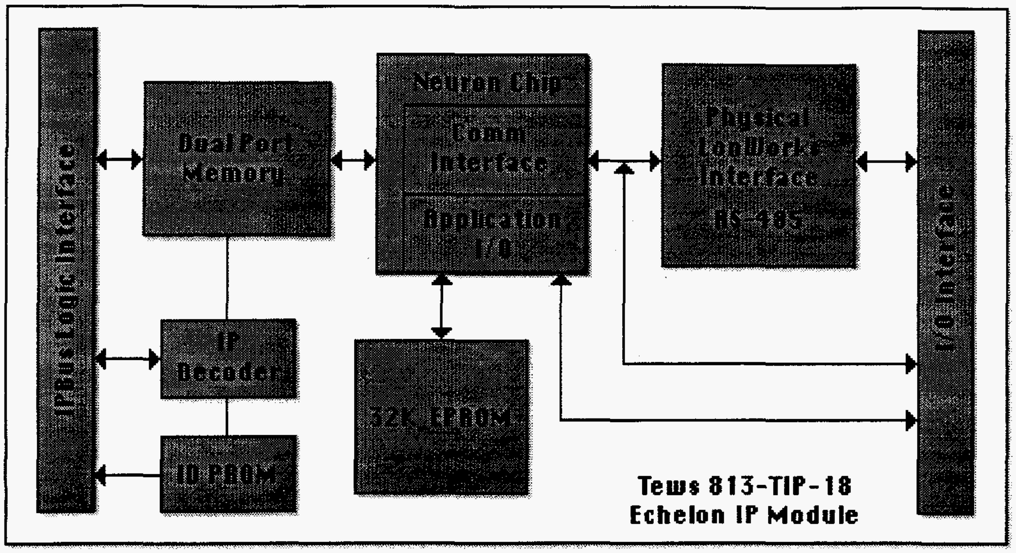

Fig. 6. Tews Datentecnik LON interface IP module.

combinations of these three things) can cause a state transition: the passage of time, an event, or a semaphore. A semaphore can be thought of as a type of "soft" event that is issued from another procedure to facilitate sychronization across multiple procedures. State notation is also widely used to specify the operation of large-scale integrated circuits in the semiconductor industry. (Fig. 7)

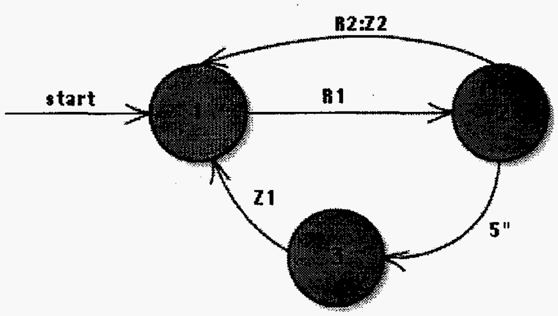

Fig. 7. A basic state diagram example.

start that event or action (typically under program or manual control) that "spawns" or starts the procedure.

R1 an event (usually from hardware) e.g., a switch closure, an external timing or event trigger, an analog threshold.

5" an elapsed time of 5 seconds.

R2:Z2 an event (R2) that also causes a semaphore (Z2) to be issued from this point in the procedure.

Z1 a semaphore that is sent from some other state set; if it arrives when state 3 is active in this procedure it causes a transition to state 1.

The nTV video event detection procedure is shown in Fig. 8 using generalized state notation. When the procedure begins at the "start" transition, a reference video image is snapped in state "1." Once the image is acquired, an immediate transition occurs to state "2." In state "2" a second image is snapped as the image to compare to the first. In state "3" the grey scale subtraction (GSS) operation is performed. If the GSS is equal to zero, an immediate transition is made to state "4." In state "4," two transitions are possible; if one second (1") of time elapses before a Z2 pulse (semaphore) arrives, a transition is made back to state "2" and the process repeats itself. If, while the 1-second timer is timing out, a Z2 pulse (semaphore) is issued from another procedure (for example, a radiation data collection procedure) indicating a significant radiation event, a transition is made to state "5" instead.

Entry into state "5" indicates an "alarm" or "event" condition; in state "5" the video image just acquired is time-stamped and placed in a large circular ring buffer in memory. Transition is made into state "6" where the alarm flag ("A") is checked to see if it is still true. If it is, i.e., A = 1, a transition is made to state 7. State "7" is used to time a 100-mS delay, after which another video frame is snapped. (The 100-mS delay provides an effective 10 frames per second video rate during the "alarm" condition).

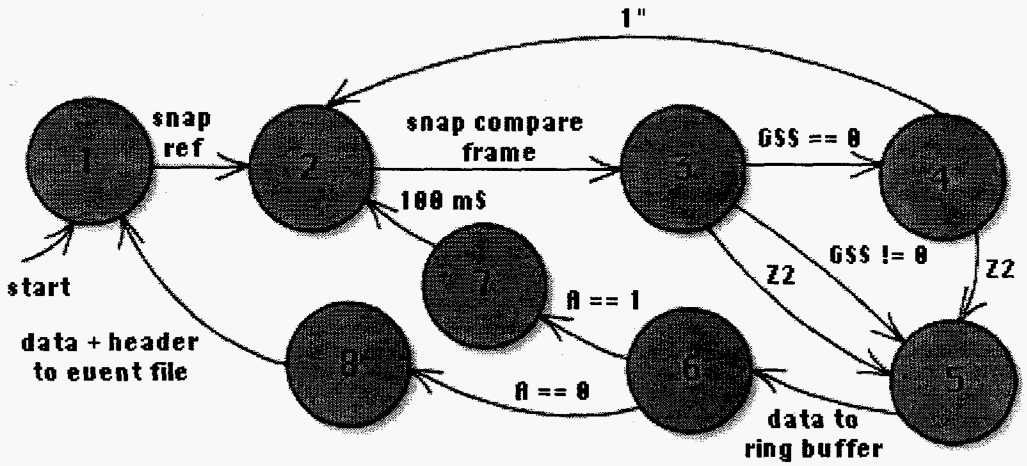

Fig. 8. nTV state diagram.

As frames are being taken at the higher rate the GSS value determines if motion exists in the camera field. When motion exists, i.e., the frames are subtracted and yield a GSS value not equal to zero (GSS != 0), the frames are different and activity is detected. After the frames are subtracted in state "3," the GSS value can cause a transition to state "4" when no difference exists (GSS = 0); or a transition to state "5" when a difference does exist (GSS = 0). When a difference does exist, video frames are buffered in state "5." Next, in state "6" the alarm flag ("A") is again checked, and when equal to "1," the procedure continues to acquire and store frames at the higher rate.

Once the alarm condition expires, the transition from state "6" is made to state "8." In state "8" the complete video event file is written with the compressed video data and the predefined header information. At this point, entry is made back into state "1" where the event monitoring procedure restarts by acquiring the reference frame.

Current software for the nTV units performs real-time, front-end event detection with the capability for regions of interest, data authentication, and high-ratio data compression using wavelet transform image coding. The nTV units each analyze video input at a one frame per second rate for the occurrence of an event, while concurrently monitoring input from radiation monitoring equipment. On detection of a video event, the event can optionally be logged, produce a silent or visible alarm, or be digitally recorded at up to 10 frames per second. (Fig. 9)

A signal from a radiation monitor transmitted over the Echelon LON can also initiate digital video recording. The nTV unit will continue to record until the event has terminated and the view area is again quiet. The nTV unit stores video data on a local high-capacity disk drive, or transmits the information via Ethernet to the collect/review master computer. In addition to video data, the nTV unit can provide gross scene-change information, for example, to show the exact location of an item that has been removed from the area. In Fig. 10, computerized image data shows how the computer detects an event: the lower-left image shows the actual scene under surveillance; upper-left through middle images show the result of computer image analysis as the nTV software detects the vault door opening (1 & 2) and a person entering the area (3); the middle-right image shows the location of the removed item as it is detected by computer image analysis (4).

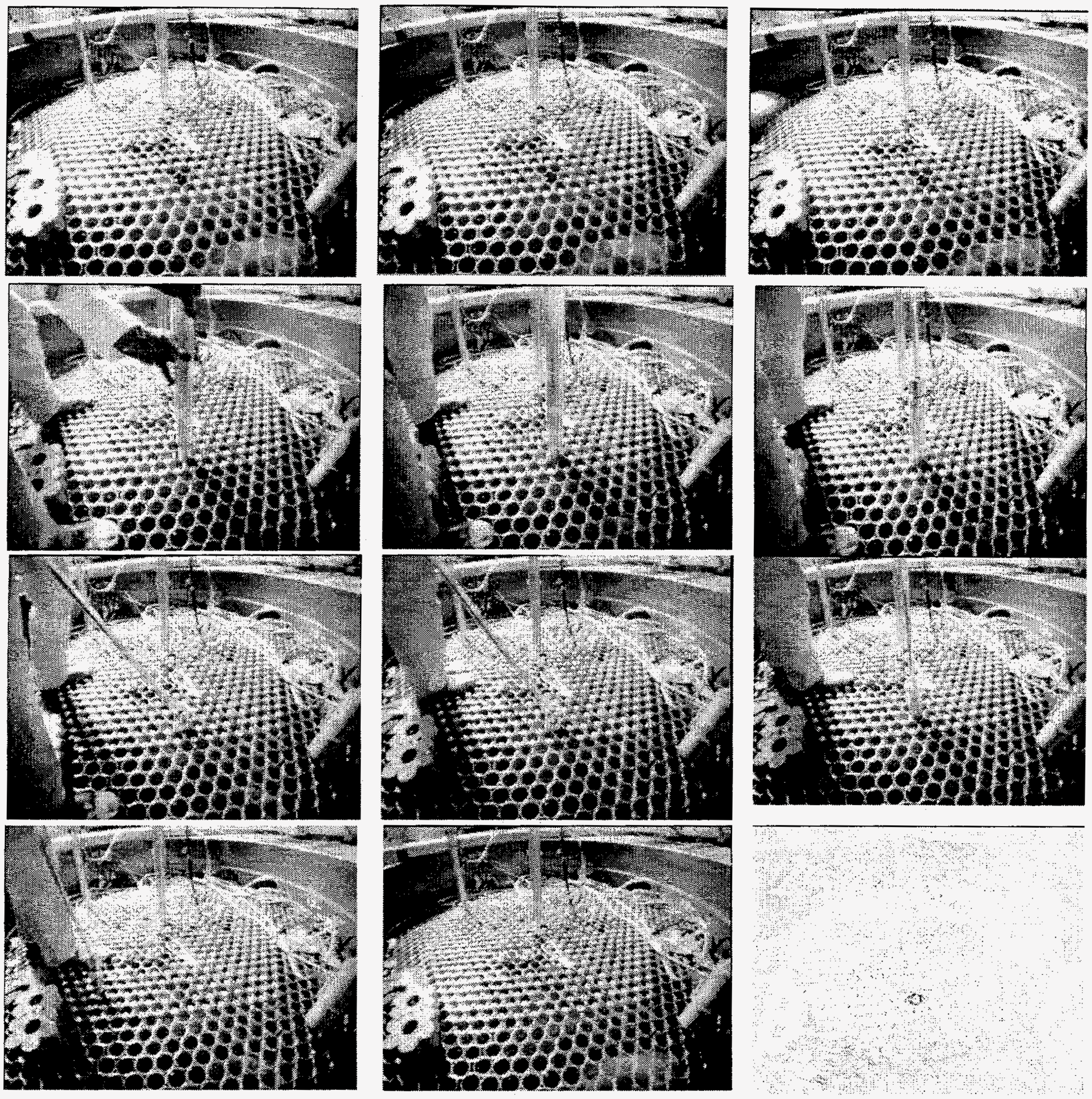

Fig. 9. Successive nTV video frames, upper left through lower middle, recorded upon automatic event detection, stored at a 38:1 compression ratio and reconstructed for display; lower right shows the detection of the removed fuel rod.

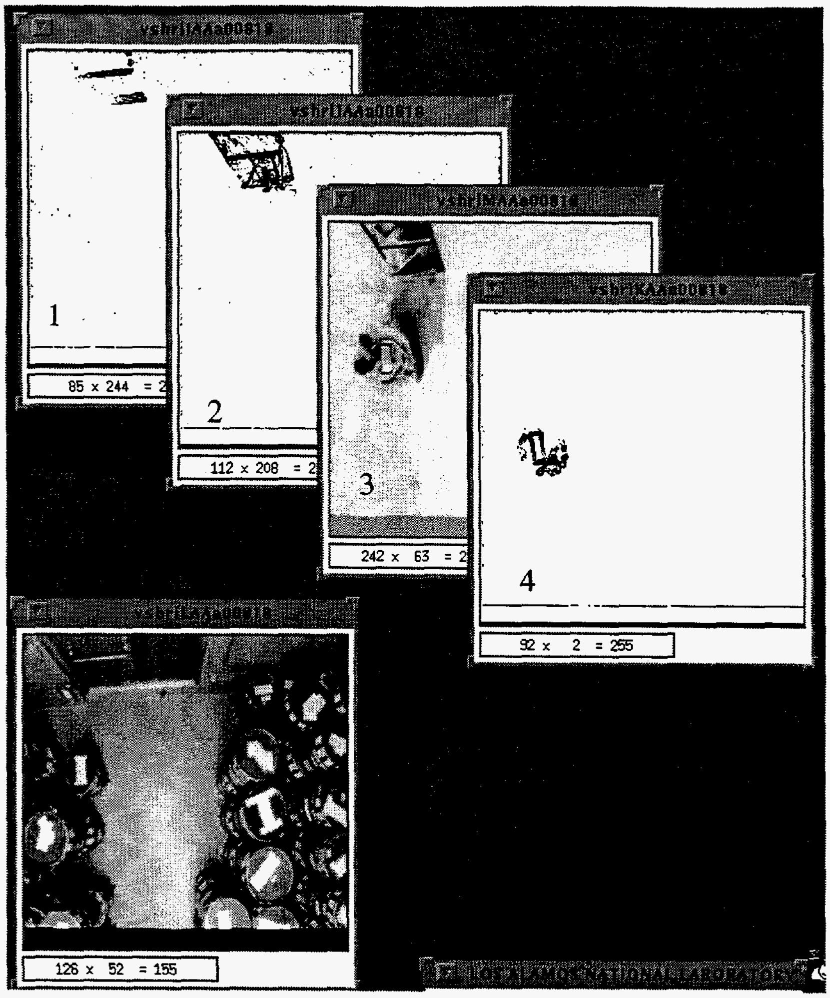

Fig. 10. Detection of a removed item.