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Macro And Micro Remote Viewing Of Objects In Sealed Gloveboxes.

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Abstract -. *Macro and Micro systems that cover a range of 2X to 400X magnifications with a robust system compatible with the harsh glovebox environment were installed. Remote video inspection systems were developed and deployed in Savannah River Site glovebox facilities that provide high quality or mega-pixel quality remote views, for remote inspections*

I. BACKGROUND

The Savannah River Site (SRS) is a nuclear materials production facility operated by the Westinghouse Savannah River Company (WSRC) for the United States Department Of Energy (DOE) and was established in the early 1950's to produce nuclear materials for defense purposes. The 777 sq. km (300 sq. mi.) complex is located in South Carolina and is composed of many separate plant related operations.

The Savannah River Technology Center (SRTC) is also operated by WSRC, and it's purpose is to provide technical research and support for site operations. The Remote and Specialty Equipment (RSE) group is part of SRTC, and its mission is to develop, apply, and support robotics, remote technology, and remote video/viewing to improve safety, reduce personnel radiation exposure, and reduce manpower costs.

The particular field of remote video/viewing is used extensively to extend the data gathering capabilities and control by personnel, into environments not suitable for entry. The provision for viewing remote locations from a safe distance has allowed inspection, documentation, and verification of pipes, tanks, vessels, ducts, rooms, and pits.

The specialized video systems that are the subject of this report exhibited specialized field application of remote video/viewing techniques by expanding remote viewing to high and very high quality viewing in gloveboxes. This technological enhancement will allow the gathering of precision information that is otherwise not available.

II. INTRODUCTION

The Savannah River Site uses sophisticated glovebox facilities to process and analyze material that is radiologically contaminated or that must be protected from contamination by atmospheric gases. The analysis can be visual, non destructive measurement, or destructive measurement, and allows for the gathering of information that would otherwise not be obtainable.

The specific area covered by this report are the high and very high quality visual examinations at either a "Macro" (2X to 20X) or "Micro" (20X to 400X) scale utilizing equipment suitable for the robust environment of a glovebox. For the purpose of this work a 100mm x 150mm size reference picture was considered the output size relative to the magnification X's given.

A typical glovebox, see Figure 1, is an environmentally sealed system for a wide variety of processing requirements and operator interfaces. The operator accesses the interior of a glovebox through permanently attached gloves that provide atmospheric and contamination sealing. The gloves are heavy duty and prevent the potential for transfer of radiological material to personnel. The gloves are, by their very nature, limiting as to reach (i.e. limited fixed locations), and dexterity.

Viewing access is available through special sealed windows. Samples of interest are introduced thorough air locks or similar. The internal atmosphere is highly controlled (i.e. moisture and gas composition) and maintained at a slight negative pressure.

Fig. 1 – Typical Glovebox Facility

The nature of gloveboxes inherently limits the application of optics, microscopes, and viewing systems. The technological needs of SRS are such that they would benefit from all of the above. This report addresses the application of remote viewing technology to this challenge.

III. OPERATIONAL REQUIREMENTS

The application required a method of remotely viewing and documenting the view of samples in a way that was compatible to the environment. It was necessary that the images be transported through the glovebox sealed boundary, through vacuum quality leak tight fittings, to image gathering hardware in the "clean" environment, with a very simple operator interface.

The glovebox boundary requirements, especially the quality of sealing of the wiring bulkhead seal, made a low wire count interface (e.g. "firewire", or USB) considerably more advantageous than a parallel type of interface (e.g. camera link, SCSI, or similar). It was desirable that the imaging Macro or Micro cameras be interchangeable with the optics assemblies in case the future needs changed.

The optics needed to have a large "stand-off" distance (i.e. the space between the sample and the nearest optics) from the samples at all magnifications, especially at the higher levels. This is necessary to prevent the very common problem of accidentally driving the optics into the sample while focusing. This is normally a concern at higher magnifications, but in a glovebox environment, this becomes a more serious concern. The operator's viewing could not reasonably rely on direct "looking through the eye pieces" typical of a microscope due to the intervening glass boundary.

The goal of this work was to eliminate direct physical contact with the optics systems after the samples were placed, due to the limitations of using heavy duty attached gloves for adjustments. All optical adjustment (i.e. focus, zoom, and iris) and all positional adjustments (i.e. X, or Y movement) should be provided electrically, for this purpose. The glovebox boundary electrical penetration requirements, and the operator having his/hers hands already in the gloves configuration made it desirable for the above controls to be completely inside of the glovebox.

All image capture and storage needed to be on a common computer for data control purposes and simplicity. The operator burden for operating diverse systems on a single computer needed to minimized.

As work progressed it became evident that the operator operation of the remote optic system would benefit significantly from having a medium size (e.g. 10") flat screen video monitor in front of him on the outside face of the glovebox. Also, it would simplify operations if ALL images were consistently on this screen, regardless of whether the Macro system (with traditional video) or the Micro system (with mega pixel quality) was in use. The latter would dictate a computer monitor image conversion for the Micro system down to NTSC video quality. This would only reduce the image used for focusing, for which it is adequate, and not reduce the saved image quality.

IV. GLOVEBOX ENVIRONMENT

The typical sealed glovebox is a permanently closed system utilizing double pass-thru doors for sample ingress and egress, that are only breached for non-routine maintenance. The interior is congested, with a tendency for equipment to be handled roughly, with items being pushed around when others are moved, or piled on top of each other. The services (i.e. electrical, instrument, fluids, etc.) that transverse the box wall must be carefully sealed. In the case of the gloveboxes that are the subject of this report, all electrical and instrument penetrations have to use vacuum bulkhead seals that would pass a rigorous leak test. Any type of system interface used would have to be converted to a "potted pins" type of interface. None of the commonly used high speed data interfaces are conducive to this type of connection.

The heavy glove nature of ALL operator manipulations in a glovebox, see Figure 1, require that all systems inside the glovebox that require adjustment or setup be compatible with large hands in thick gloves (e.g. large robust knobs). The difficulty of moving equipment into a glovebox and the near impossibility of moving equipment out of a contaminated glovebox for repair, requires that all equipment be robust, simple, and possible to repair by module replacement.

The glovebox windows are thick and limit the operator usage of certain types of visual analysis equipment once it is placed in a glovebox. Microscope eyepieces are nearly impossible to access directly and stereo microscope eyepieces are basically useless in a stereo mode.

V. IMAGE REQUIREMENTS

The image output of each system needed to be the highest reasonable quality consistent with other requirements and expectations. In the case of the Macro images, the highest quality NTSC (US broadcast video standard) images were adequate to the needs, and considerably more cost effective than other techniques.

S-video was considered to be the most desirable wiring method for the above, due to its inherently better signal quality. Composite video (i.e. analog video signals over a single coaxial cable) is limited by the method used to combine the image details (gray scale) and the color data (red, green, blue) into a single combined signal. This limitation is approximately 320 lines of horizontal resolution. All forms of multi-coaxial cable video transmission (i.e. analog S-Video, VGA, etc.) are not limited in this way, since the image details and color data are not combined. These signals are only limited by the source, camera, and can be 500+ horizontal lines for a typical high quality camera.

All digital video transmission methods are only limited by the data handling method chosen or speed of the electronics. Most, by not all, digital video transmission methods rely on image compression to reduce the burden on the transmission and storage electronics. The various forms of DV video use a 5X compression. For the applications discussed here, no compression was used to maximize the data quality, reduce latency, and maintain all observed anomalies and defects. This increased the burden on the transmission and storage equipment proportionately.

The Micro image required a much higher image quality than was possible with traditional NTSC video but a continuous image output (i.e. "video-like" image) was required, to simplify setup and adjustments. The original work began with 1 mega pixel video cameras but has been expanded to 3.3 mega pixel units. This type of "video" is entirely incompatible with NTSC video systems and interfaces directly to a computer.

High quality NTSC video images, higher quality mega pixel video images, and the images "grabbed" off of both, can take up large amounts of computer memory or archival storage space. Provisions needed to be made for a reasonable data approach. Also, separately acquired images of related observations needed to be linked together and exported on transportable media. The large size of still images, at these resolutions, and very large size of video, dictate that large capacity, inexpensive, media be used, such as CD-R. As the image requirements increase to the 3.3 mega pixel or higher range, it is anticipated that even CD sizes may become undesirable and DVD-R may become more likely.

VI. OPERATOR CONTROLS/VIEWING

The controls for both systems are identical and support the unique glovebox requirements. Figure 2 shows the Micro (right) and Macro (left) systems completely assembled in a laboratory environment. The dual joystick module to the right of each, is typical of all systems, and is used to position the sample and adjust the optics. All linkage between the joystick controls and manipulated components is electronic to eliminate any need for direct contact of the gloved hands and the sample. Precision measurements and high magnification is difficult with "hands on" contact with the sample. Accomplishing this while wearing heavy gloves that are permanently attached to a wall at the shoulder is extremely difficult.

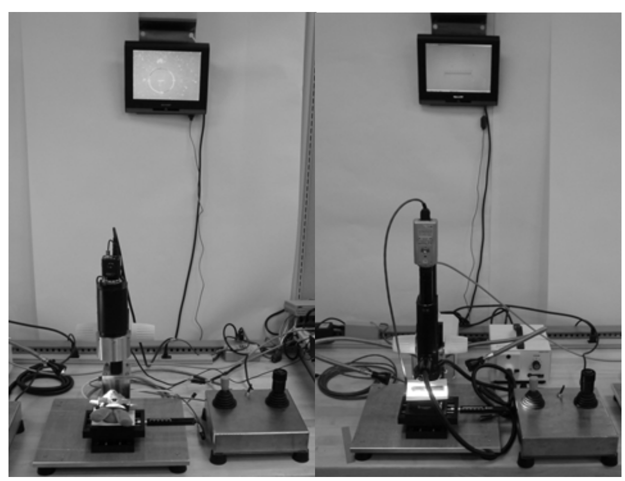

Fig. 2 – Micro and Macro Systems Shown Prior To Glovebox Installat**ion.**

Once the sample is placed under the optics and a rough Z axis position adjustment is made with the optics stand, all adjustments are made with the joysticks. The left joystick is a two axis joystick that adjusts the X and Y position of the sample using motorized position actuators. The right joystick is a three axis joystick that adjusts the image zoom (in and out motion), the focus (right to left motion), and iris (rotation of joystick knob).

The electrical outputs of the joysticks are converted to the voltage and current requirements of the various motors using SRTC designed electronics. The electronics, along with power supplies etc, are mounted in the base of the units. The only other controls are the on-off switch (out of view on the back), and the zoom on-off switch seen in the picture. The latter is an important feature as it allows the disabling of the zoom after a size calibration has been established, since it would be very easy to accidentally contact the zoom joystick with gloved hand during routine glovebox operations.

A glovebox exterior face mounted video monitor has been provided at each work station, hanging from the top edge of the box. Figure 2 shows them in the back of the figures. They hang in front of, and slightly to one side, of the operator. The close proximity of these displays and the fact they are in the logical position (in front of the operator) simplifies the in-box adjustments.

Larger displays of higher resolution are used for common viewing and capture purposes, but they require the operator to "look over his/her shoulder" when they are used. The displays are high resolution NTSC displays and can not directly display the very high mega-pixel images. Therefore, the images are down converted to the NTSC resolution, so that a common, simple, display can be used for all signals. This has been seen as a very good compromise, since the operator displays are used for set-up (i.e. alignment and focusing), and the common displays are still used for image capture.

The common console contains a computer, larger monitor, and various interfaces to view, capture, and archive the desired images. To simplify the operator functions, the desired Macro or Micro view are selected and appear on all glovebox monitors simultaneously. All the monitor stations could have been independently selected but that would have exceeded the customers wishes for simplicity. All images are routed to one of two separate computer programs for the NTSC and mega-pixel images, which are saved in common folders. CD-R is used for transfer and archival outputs as needed.

VII. MACRO VIDEO SYSTEM

The Macro viewing system was designed to cover the viewing range of 2X to 20X magnification, relative to a 100mm x 150mm size reference picture. The actual output size will vary depending on the imaging requirements. Figure 3 shows details of the macro system, and Figure 4 shows the range of magnification possible with that system.

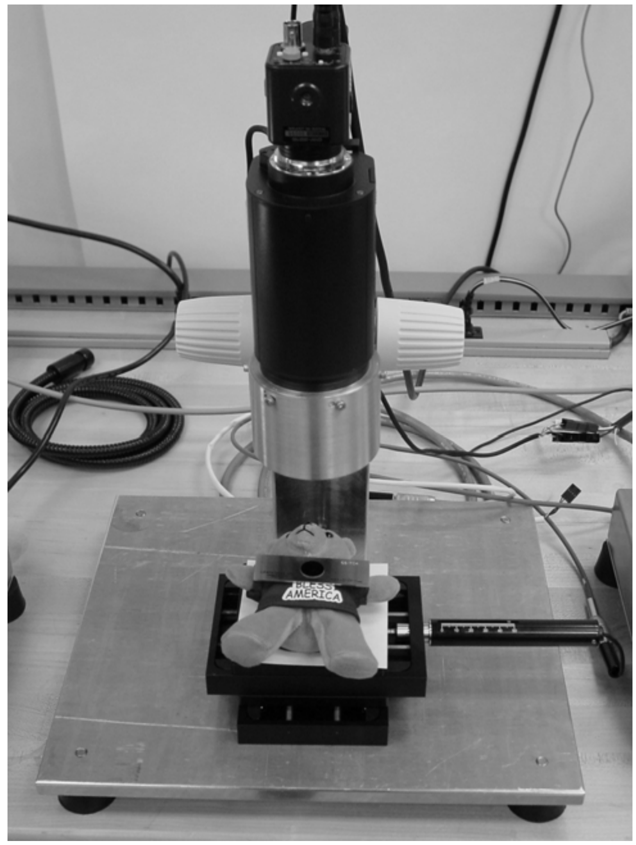

Fig. 3 – Macro System Showing Details

The optics maintain a 75mm standoff and provides the 10 X zoom. A high quality industrial grade zoom lens was selected for robustness and modified for close operation, by mounting a pair of Acromat (i.e. color corrected, low aberration) lens elements to the front of the zoom lens. This combination provides for "stay-in-focus" zooming operation while operating at close range. Industrial zoom lens are usually designed for focusing from infinity to 2m operation. Modifying the lens as described converts this to, nominally, 100mm to 10mm, without effecting the operation of the lens focus or iris.

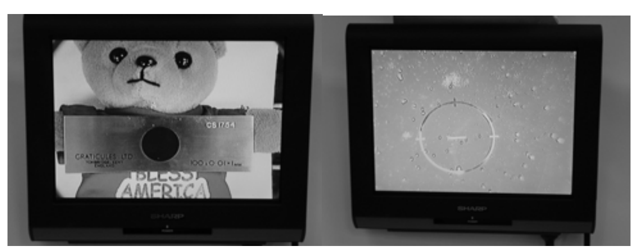
Fig. 4 – Macro System Showing Range of Magnification

A NTSC color video camera of 400+ horizontal lines of resolution with S-video output has been fitted to the system. The S-video requires two paired coaxial cables back to the computer but maintains the maximum possible resolution. For this portion of the work, this image quality is adequate and this type of camera is much less expensive and requires simpler interfaces. An industrial grade "Genwac" brand camera was used. It derives it power source (12 vdc) from the joystick control box, to simplify in-box equipment.

VIII. MICRO VIDEO SYSTEM

The Micro viewing system was designed to cover the viewing range of 20X to 400X magnification, relative to a 100mm x 150mm size reference print. Additionally, the Micro system required the highest reasonable level of image quality consistent with a continuous, video like, image. This will greatly facilitate image alignment and focusing.   Figure 5 shows details of the macro system, and Figure 6 shows the range of magnification possible with that system.

Figure 5 – Micro System Showing Details

The optics maintains a 35mm standoff distance at the provided 10X zoom. Initially a 1 mega-pixel color camera was chosen for this application. This was subsequently upgraded to a 3.3 mega pixel color camera. In both cases, the output is a continuously updated (typically 5+ times per second) image to a computer screen for both display and capture. The cameras used exceed the resolution of NTSC video by 4X, for the 1 mega pixel, or 12X, for the 3.3 mega pixel, and therefore require a computer type display.

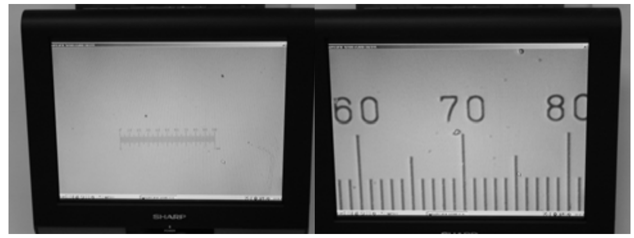

Fig. 6 – Micro System Showing Range of Magnification

The images are transferred to the computer as non-compressed images to preserve the maximum quality and captured at full resolution. The 3.3 mega pixel camera allows set and focusing at a lower resolution, with capture at full resolution, to speed up operation. All images are 24 bit color images to maximize the color fidelity.

IX. BOUNDARY WIRING CONSIDERATIONS

Both of the mega pixel cameras interface to the computer through a IEEE 1394, commonly called "firewire", interface. This interface, or one similar, was considered a necessary attribute to the system since signal transmissions were a major design parameter to a glovebox system.

The alternate high speed image transfer systems (i.e. "CameraLink", LVDS, SCSI., etc.) were problematic due the high number of wires required. IEEE 1394 is a six wire connection while the others are typically 30+ wires. The requirement to get the signal through the glovebox boundary while maintaining the needed signal quality, compelled a simpler interface.

A glovebox boundary transition required a thru connector that would pass a vacuum leak test, to assure a good quality seal. A technology was developed that would pass a IEEE 1394 interface through a commercial vacuum bulkhead seal, see Figure 7. The vacuum bulkhead seal was used to simultaneously pass a number of video coaxial cables. These were used in pairs to pass S-video signals for the NTSC camera, or, if needed, traditional composite video. To date only S-video is being used.

Fig. 7 – Vacuum Tight Bulkhead Seal For Firewire & S-Video

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XI. SUMMARY

Remote video systems have been developed and deployed in the field that provide both Macro and Micro video technologies using either high quality NTSC video, or mega pixel video, into sealed glovebox environments. The systems incorporate the remote viewing technologies with robust remote control of sample positioning and optics adjustments compatible with the heavy glove environment. All images are viewed on operator friendly displays, while common facilities are used to analyze, capture, and combine the images of both systems.