VIDEO BORESCOPE INSPECTION SYSTEM (VBIS) TECHNOLOGY ADVANCES TO SUPPORT EXTENDED RANGE GUIDED MUNITIONS (ERGM) PROGRAM

The Authors

Christopher Ange

In 1983, Chris Ange completed a Bachelor of Science in Mechanical Engineering at Old Dominion University, Norfolk, Virginia. The same year he began a career with the Naval Sea Systems Command in gun testing, acquisition, and development.

His assignments have covered a wide variety of gun systems from 16 inch to 5 inch and included work with small caliber weapons. Chris is an active member of the Association of Scientists and Engineers (ASE) and was recently published in the "Surface Warfare" magazine. His article covered development of the 5 inch MK45 gun in meeting requirements of the Naval Surface Fire Support organization.

In 1997, Chris was chosen by his Command for the AEGIS Excellence Award. Today, he continues his engineering and project management career guiding development of the ERGM projectile.

Thomas Ellert

In 1981, Tom Ellert began his career with the Naval Warfare Assessment Station (NWAS) precision measurement laboratory in Pomona, California. His assignments at NWAS have included precision measurement and certification of Navy Special Interface Gages used on missile components, ammunition, and gun barrels. He helped introduce advanced technology such as the Leitz Coordinate Measuring Machine, the computer-driven Moore Measuring Machine, and video comparitor (Smart Scope) to the laboratory.

In 1995, Tom was asked to lead a design and fabrication project team developing a video system to examine the inside surfaces of gun barrels. Less than 18 months later, the team put a successful working prototype in the field for testing.

Tom has moved from the Pomona laboratory to NWAS engineering offices in Corona and continues to test and improve VBIS. He now serves as the NWAS representative to the team organized to advance VBIS technology in response to ERGM requirements.

Abstract

For more than 40 years, the optically based M3 Borescope had served as the standard device for gun bore examination. Today's technology far surpasses its limited capabilities. The M3 has become difficult to supply with spare parts 40 years after the design was conceived. It relies heavily on operator expertise and can not easily record inspection findings. This paper describes how VBIS was developed to offer remedies for M3 shortcomings and, in addition, meet ERGM requirements.

This paper explains the need for enhanced gun barrel inspection and reporting driven particularly by concerns raised by the ERGM program. It was uncertain what damage the ERGM round and propelling change would inflict on 5"/62 caliber barrel surfaces.

In response to these concerns, the PMS429-NSWC-NWAS team was formed to expand and refine the early VBIS prototype. The probe and control console were to be hardened to withstand the unusual temperature variations, possible shipping damage, and contaminants likely to be encountered. Camera lighting and image definition were to be improved to assure the most discerning examination possible. The ability to show barrel defect dimensions and placement relative to datum points was to be improved. The CRT display had to be more visible in daylight conditions. Once the system in the field records the entire barrel examination, video clips and digital images of defects had to be provided. Finally, a summary inspection report (clips, images, and text) had to be published in hard copy and electronic formats.

This paper describes the progress the team has made in achieving those goals. Also, it discusses how the synergy of this team has produced unanticipated benefits for ERGM and other possible future uses of the system.

Introduction

A gun barrel must be regarded as a pressure vessel. The integrity of any pressure vessel, where personnel safety is a concern, makes periodic inspection a normal requirement. Also, the integrity of the interior surface configuration has a critical affect on projectile accuracy and range. The repeated abuse of high pressures and temperatures, abrasion from projectiles, and corrosive products of combustion, increases the probability of failure and degradation of interior surfaces. For these reasons, the M3 Optical Borescope was developed and put into regular use by the fleet over 40 years ago. It survives today as the standard device for gun barrel examination.

Three years ago, in response to M3 limitations, engineers at NWAS went to work on the problem. The result was a prototype VBIS unit deployed for field testing 18 months later.

This feasibility study, prototype probe contained compact side-looking and forward-looking video cameras each with lighting arrays to illuminate interior barrel surfaces. The video probe was linked to a monitor so the entire examination could be witnessed in real time. The control console also included a compact Video Camera Recorder to preserve the barrel inspection.

At this point, the Naval Sea Systems Command (PMS429) and engineers at Naval Surface Warfare Center (NSWC) Dahlgren took particular interest in the system and its potential. With certain refinements, they envisioned this equipment performing the kind of discerning barrel inspection urgently needed for the Naval Surface Fire Support (NSFS) program. In early 1998, NAVSEA (Chris Ange), Dahlgren (R.D. Cooper and Ray Bowen), and NWAS (Tom Ellert) formed a team. VBIS would be upgraded to evaluate barrels for the NSFS program. Team objectives were outlined:

I. **Hardening the System** The probe and control console must withstand shipping, handling, and test range conditions.

II. **Viewing the Display In Daylight** Enhance the CRT display for clarity in bright daylight.

III. **Capturing Video Clips and Still Images** Enhance video editing capabilities.

IV. **Locating and Dimensioning Defects** Show defect dimensions and positions.

V. **Publishing a Report** Publish a summary inspection report in electronic and hard copy formats.

VI. **Archiving Inspection Records** Establish an inspection record archive system.

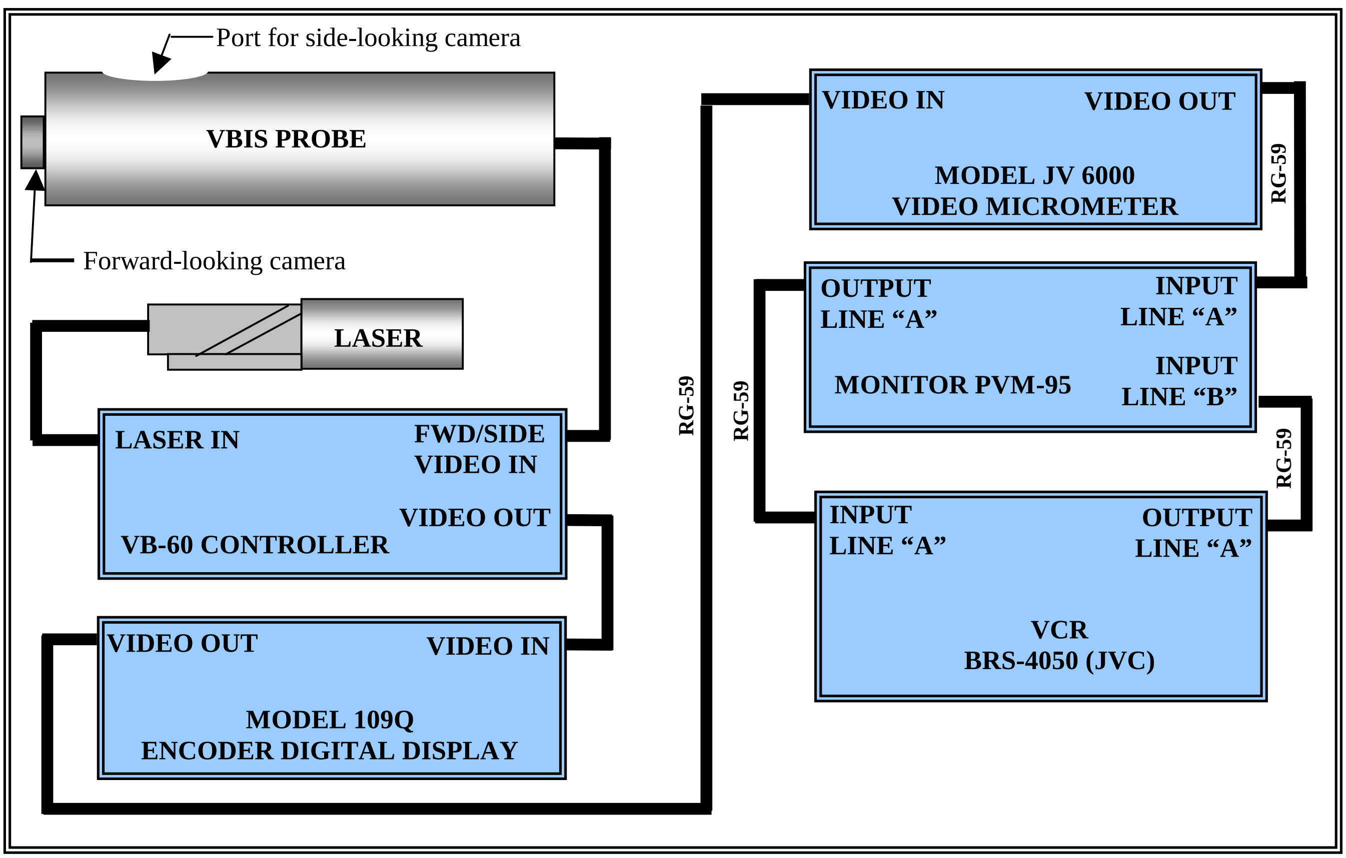
The team realized other unanticipated benefits arising from these advances. Summary inspection reports could also be posted to a network server and made accessible to other activities concerned with the data. Replacement of the outdated mechanical STAR gage, long used for gun barrel diameter measurement, was investigated. A laser scanner in place of the STAR gage could more efficiently collect diameter measurement data. Further, a statistical data base could be established that might enable analysts to better predict barrel longevity and replacement cycles.

I. Hardening the System

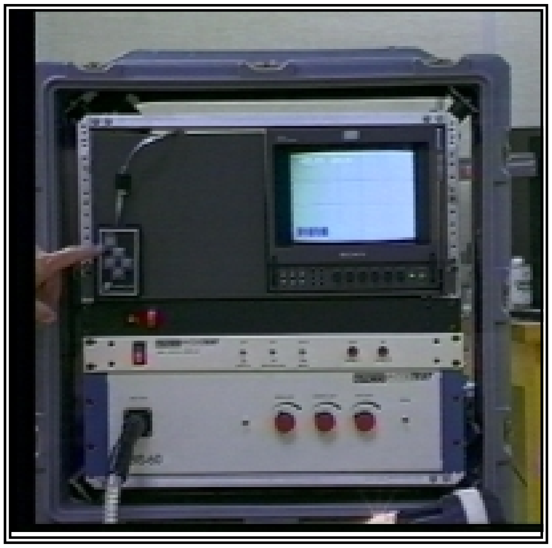
The team anticipated a number of VBIS survivability problems. They could predict that eventually system components would experience shock from inadvertent dropping, surprise rain showers, intense summer heat, corrosive humidity, and infiltration of dust particles.

With this in mind, off-the-shelf components were evaluated for their weight, compactness, shock resistance, ability to seal out contaminants, and temperature tolerance. The few components slated for custom design and fabrication were reviewed and judged by the same criteria.

Control system components (video display, VCR, controller module, display generator,



VBIS Schematic



VBIS Control Components

and video micrometer) were aligned in a durable fiberglass-shipping container. The probe and related loose components were nested in shock absorbent foam and housed in a separate rugged, reusable shipping container.

II. Viewing the Display In Daylight

The team realized that the system would normally be used in full daylight and would require a video monitor bright enough to be visible in these conditions. Industry long ago recognized the problem of daylight use but has not yet totally resolved the problem.

There is intensive competitive effort in the field of flat panel technology. Several manufacturers tout increased viewing angles, greater speed, and sufficient back light intensity for daylight viewing. Manufacturers forecast further technical improvements on the horizon and price reductions as competition heightens and production levels rise.

Team inquiries revealed that "daylight" displays appear to achieve that rating by simply over-exciting fluorescent back lighting tubes. Also, prices remain high and honest estimates of longevity for overcharged back lighting are not optimistic.

In the final analysis, the CRT is still the display to beat. CRTs continue to improve, with higher resolution, better contrast, higher luminance, flatter face plates, and shorter tubes. In view of this, the team elected to stay with a high quality (SONY) display.

III. Capturing Video Clips and Still Images

After recording a complete barrel inspection on video-tape, the team faced editing tasks that required powerful computer hardware and software. They choose a Targa 1000 Pro NLE Workstation with two 9.1 gigabyte hard drives, 256 megabyte RAM, and dual 400 Megahertz processor units. Editing the tape required software that could convert the entire 45 minute tape to digital format (MPEG) and store it on the hard drive. The editor then needed software to capture selected video clips and still images from the digital version on the hard drive. Video clips often required dubbing a narrative and insertion of titles as well. Still images required an overlay of dimensioning data and color or clarity enhancement. AVID MCXpress was selected for this task.

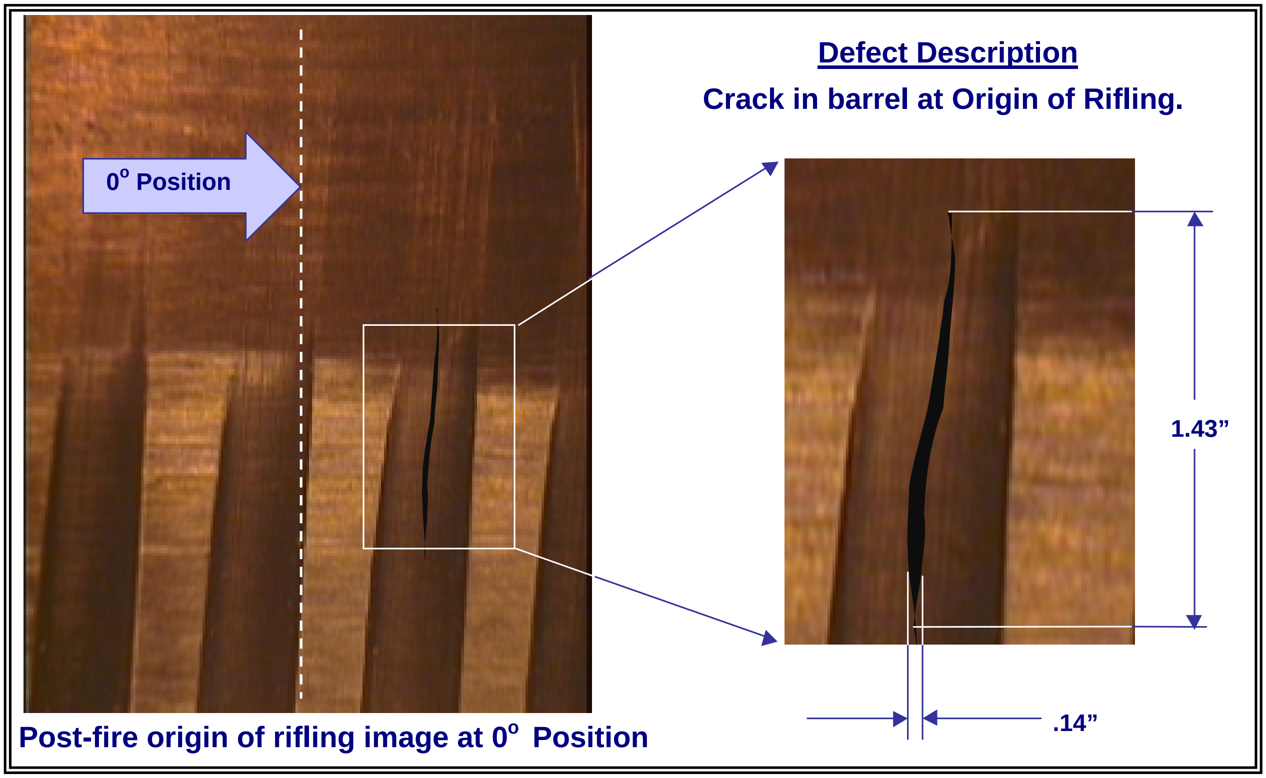
.IV. Locating and Dimensioning Defects

In the field, defect size is measured by the JAVELIN JV-6000 Video Mircometer. Before using this feature of the system, the operator must bring the dual x and y lines shown on the display over a calibration artifact of known size which is placed inside the barrel. Then, if a defect is seen, the x-y lines can be positioned over the area and the defect size determined. These preliminary measurements are displayed for use in the field but not permanently recorded on video-tape. This field defect measurement feature gives test engineers an early understanding of barrel conditions, allows for a preliminary evaluation, and may affect further testing plans.

Defect position within the barrel is determined by two features of the system. A pendulum device within the probe feeds a continual display to the CRT showing clocking position relative to top-dead-center of the barrel. In addition, a laser scanner, normally positioned at the breech, reflects off the forward end of the video probe and feeds continual data on probe position during barrel examination. Both clocking position and probe location data are permanently recorded on the videotape for later reference.

Back in the lab, digital images of a barrel defect are captured by the video editor. Defect length, width, clocking position, and position relative to the examination start point are determined. This information is then applied to the image. At this point the editor relies on VisionGauge™ software to size the image, overlay annotations, enhance quality (where contrast and definition are inadequate), zoom-in on areas of particular interest, perform high-precision measurements, and collect data for later analysis.

In preparation for defect measurement, VisionGauge, is easily calibrated by using an artifact (scale) placed in the barrel area. With VisionGuage the editor clicks on the zero and one-inch mark, for example. When a defect is seen, simply clicking at the extreme size limits of the targeted defect automatically records dimensions on the image. This data can also be compiled in a default or customized report format.



Defect Dimensioning

V. Publishing A Report

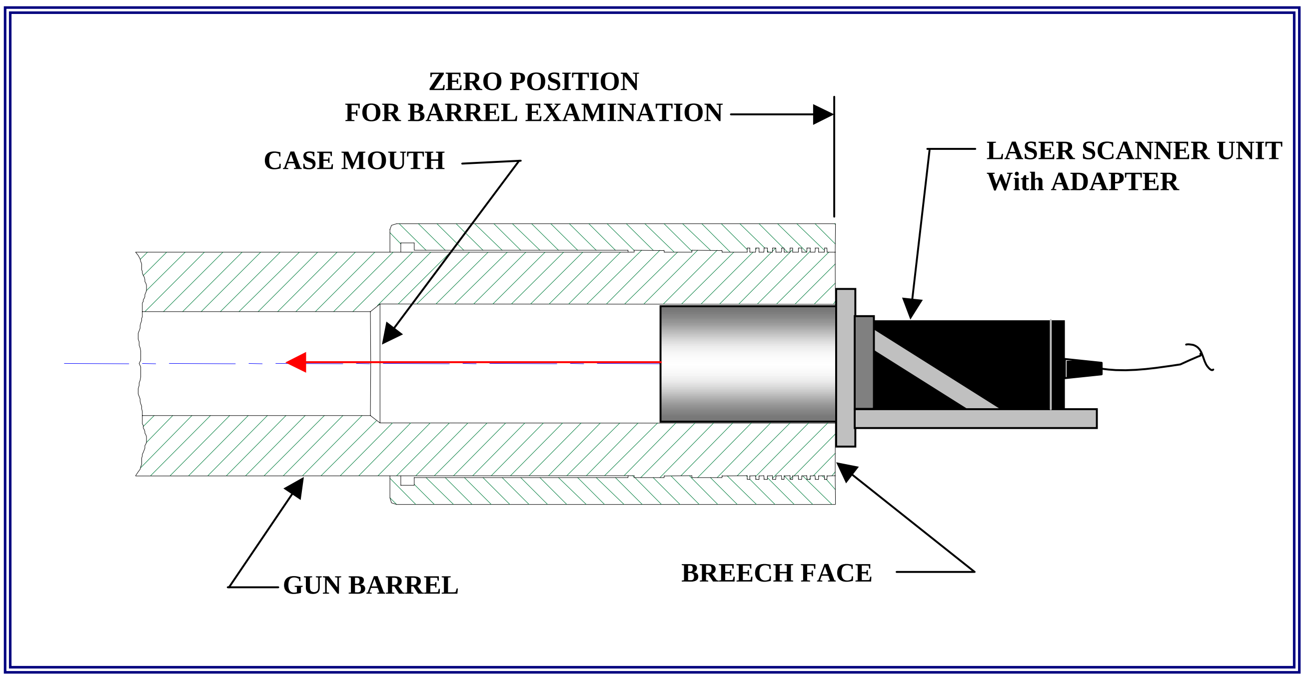
Reviewing a typical 45-minute barrel examination captured on videotape would be time consuming for the busy engineer or manager. Defects and critical areas might also be difficult to isolate. For that reason, selected digital images and brief video clips (clips viewable only on the electronic report format version) are captured from the master tape and a summary inspection report is published that compiles these significant findings.

To further expedite the review of inspection results, the report includes a management summary for those only interested in an overview. For a more in-depth look at the barrel, a detailed section follows that portrays each defect and critical area with a video clip or still image showing defect dimensioning and positioning data.

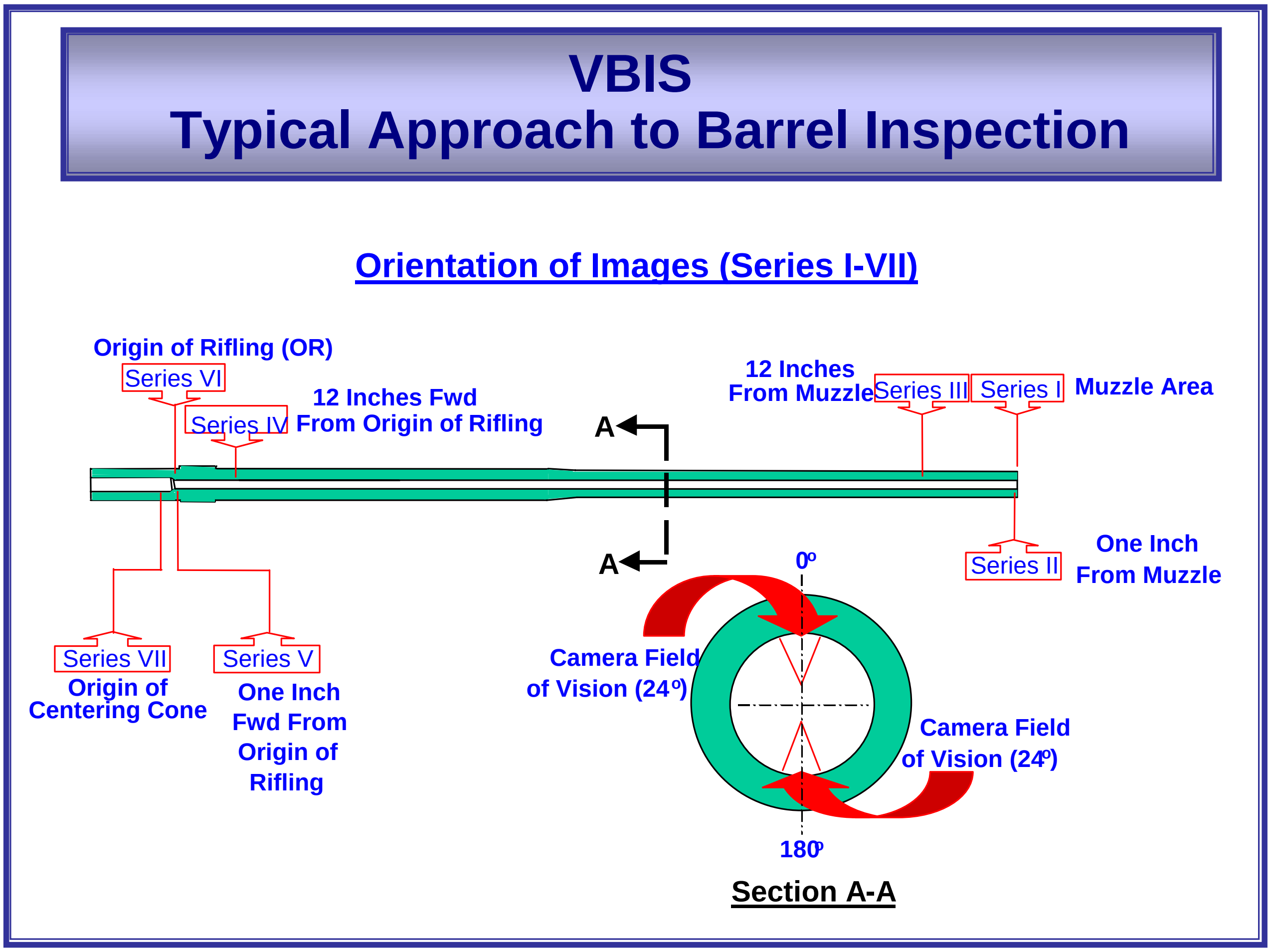
Further, the report offers a schematic showing the points on the barrel surface where images and clips were taken.

The intent of the report is to present enough information to enable the engineer to make a well-informed evaluation. The report avoids assuming the role of analyst, draws no conclusions, and avoids recommendations. However, as a database is acquired on a particular type of barrel or projectile, future inspection reports may include statistical charts and tables dealing with Fatigue, Failure, Risk, and Erosion Life Estimates as possibilities.

While an inspection report is produced highlighting defects and areas of particular interest designated by engineers at the time of barrel field examination, the report is not the final judgment. The team encourages those interested to review entire video tapes and make independent assessments.



LASER SCANNER DETERMINES DEFECT POSITION RELATIVE TO BREECH FACE



Typical Orientation of Images and Clips
Taken From Videotape

VI. Archiving Inspection Records

The archive system simply retains the original master tape to preserve the highest degree of image quality. A secondary master is produced and available on request to team members. A third, working copy, is available for routine use at the NWAS laboratory. Finally, a library of inspection reports in hard copy and on compact disk is available at NWAS.

Team Synergy

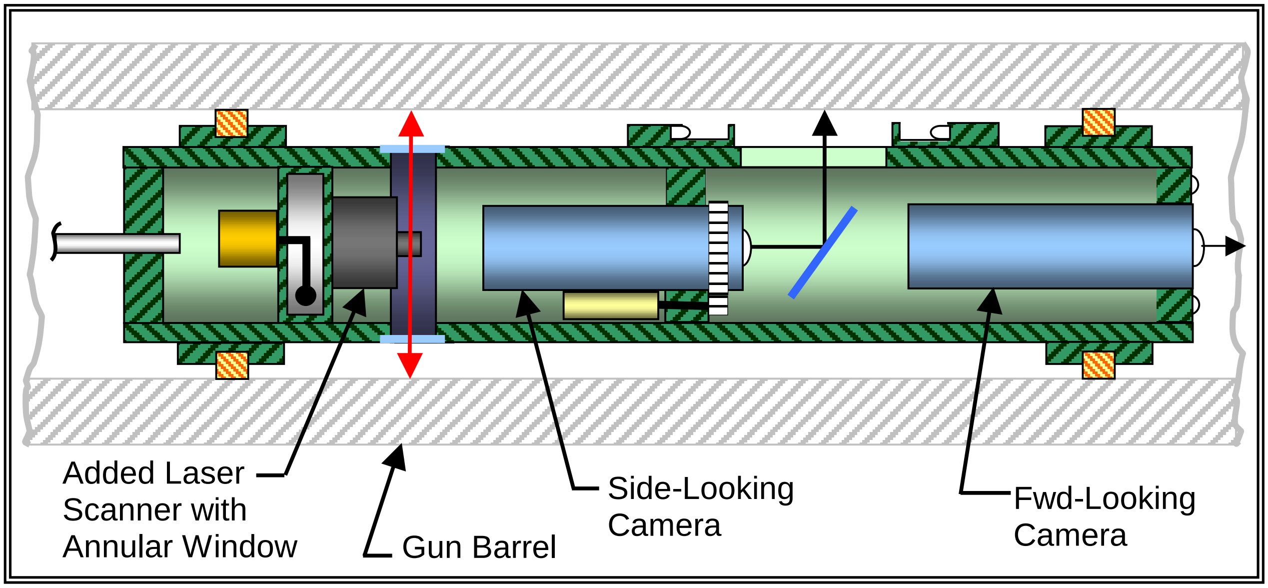
Several examples of team synergy are worth noting. Not long into the project the team found that inspection reports, already produced in electronic format, could be posted to a network server at NSWC Dahlgren and efficiently disseminated to other Navy activities. For example, inspection data is needed by those activities retained by NSFS to consult on barrel wear and longevity analysis. This method efficiently put the information in the hands of analysts and will probably preclude any hard copy or compact disk mailings.

In the course of test firings, the team found that charred barrel lubricant remaining in the rifling was a serious detriment to effective video examination. Conventional barrel cleaning by “stovepipe” brush techniques was slow and lacked thoroughness. Test firing schedules often demanded that the test barrel be cleaned, examined, and returned to test engineers within a brief window. The team brainstormed alternative, more efficient cleaning methods and agreed on a concept that took a new approach. This innovative cleaning method, now in design at NWAS, may in time become standard equipment in the gun community.

Deploying the upgraded VBIS for ERGM test firings at Dahlgren has provided a proving ground for the durability of VBIS. Cross-country shipment of VBIS equipment, test range environments, repeated startup and shutdown, and image capture and editing have put system components to the test. System evaluations by the team identified some shortcomings and concluded that further upgrades were necessary. For example, the control unit should be reviewed again for possible weight and size reduction. The zero reference point for probe travel in the barrel has been changed to equal the position of the projectile seating surface. Image capture and editing computer capacity (hard drive, RAM and operating power) was significantly increased and a powerful image capture/editing software was researched and selected. Inspection reports on the network, splinter projects such as barrel cleaning, and other system upgrades based on experience in the field are results of team synergy.

Future of VBIS

One pressing need surfaced during the team's first year of operation. It involved the mechanical STAR gage that was designed and built over 25 years ago to measure gun barrel inside diameter. STAR gages are a cumbersome device to handle, particularly vulnerable to damage, highly dependent on operator expertise, and now difficult to support with spare parts. In the 25 years since STAR gage inception, laser measurement technology has surpassed mechanical approaches in reliability and accuracy. This year, the VBIS team will evaluate methods to incorporate gun barrel inside diameter measurement by laser scanner. The scanner may be incorporated as part of the VBIS probe or built as a separate accessory item. Either way, dimensional data will be collected with greater accuracy and speed than with the STAR gage. Laser generated diameter data would be included with video examination data in the summary inspection report. Labor and equipment cost savings to the user will be substantial. Hopefully, additional procurement of replacement STAR gages, at approximately $80,000 each, can be avoided.



VBIS Probe In Cross Section with Possible Future Laser Scanner

As VBIS is refined and becomes better known, the system may attract other users. Potential fleet users will appreciate, among other features, reducing VBIS size and weight so it will transport easily through narrow passageways aboard ship. VBIS may eventually replace the optical M3 Borescope and the "Serviceability of Naval Gun Barrels" manual that supports its use.

In addition, Army and USMC test engineers at Yuma Proving Grounds are using a VBIS unit on a full time basis to inspect tank and self-propelled guns. Where gun bore condition is a concern, VBIS may be the better method of inspection.

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