Advanced E-O Test Capability for U.S. Army Next-Generation Automatic Test System

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ABSTRACT

The Future E-O (FEO) program was established to develop a flexible, modular, automated test capability as part of the Next Generation Automatic Test System (NGATS) program to support the test and diagnostic needs of currently fielded U.S. Army electro-optical (E-O) devices, as well as being expandable to address the requirements of future Navy, Marine Corps and Air Force E-O systems. Santa Barbara infrared (SBIR) has designed, fabricated, and delivered three (3) prototype FEO for engineering and logistics evaluation prior to anticipated full-scale production beginning in 2016.

In addition to presenting a detailed overview of the FEO system hardware design, features and testing capabilities, the integration of SBIR's EO-IR sensor and laser test software package, IRWindows 4™, into FEO to automate the test execution, data collection and analysis, archiving and reporting of results is also described.

Keywords: Automatic Test Systems, Calibration, E-O test, Infrared, Laser, Sensor characterization, Test Measurement and Diagnostic Equipment, Visible

1. INTRODUCTION

Reinforced by academic research, practical analysis, and wartime experience, the Army's vision of the support structure needed to ensure system readiness has evolved in recent years. The Army is moving away from the system-centric approach that required special purpose Test Measurement and Diagnostic Equipment (TMDE) for each system, and is moving towards a more flexible, multi-system capability. There is increasing evidence that moving to an adaptable maintenance system that supports multiple systems can improve readiness and availability, resulting in significant cost savings.

NGATS is the latest addition to the Integrated Family of Test Equipment (IFTE), developed and managed by the Product Director Test, Measurement and Diagnostic Equipment (PD TMDE). NGATS is a reconfigurable, general-purpose, mobile, deployable ATS designed to provide off-platform sustainment support to all Army weapon systems, while also providing a pathway for support of other tri-service systems. This flexible testing platform will provide diagnostic maintenance of both Current and Future Force electronic and opto-electronic systems, and will standardize the Army's Automatic Test Equipment (ATE) capability to test Line Replaceable Units (LRU) and Shop Replaceable Units (SRU) and isolate failures to the component level.

SBIR's FEO system takes advantage of SBIR and other commercial off-the-shelf (COTS) hardware, in conjunction with open-system software architecture, to provide improvements in capability, availability/uptime, reliability, and reduced logistic costs. Leveraging SBIR and commercial software development tools both shortens Test Program Set (TPS) development and commissioning times, and reduces costs for new or expanded system diagnostic or characterization support.

The FEO system consists of an integrated rack assembly that contains multi-functional hardware designed to facilitate automated EO-IR-Laser system test, characterization, and maintenance of sensor/system "health" records. The system, shown in Figure 1, is designed for installation into standard, portable containers, depots, or government test facilities. The use of individually-calibrated and easily-replaced modules enables the FEO system

Infrared Imaging Systems: Design, Analysis, Modeling, and Testing XXVI, edited by
Gerald C. Holst, Keith A. Krapels, Proc. of SPIE Vol. 9452, 945205 · © 2015
SPIE · CCC code: 0277-786X/15/$18 · doi: 10.1117/12.2177454

to be maintained in a state of maximum readiness, and its highly-flexible intuitive User Interface (UI) based upon SBIR's IRWindows 4™ software, permits rapid assessment of sensor/system health.

Figure 1 – Future E-O (FEO) TMDE System. Standard operating configuration (left) and target projector access configuration (right) shown.

2. SUPPORTED SYSTEMS

The Future E-O system provides a common test platform capable of performing comprehensive diagnostic and performance testing of the Army's identified inventory of E-O hardware devices, including:

- Ground Vehicle Systems
  - Avenger Air Defense System
  - Commander's Independent Thermal Viewer (CITV)
  - Common Remotely Operated Weapon System (CROWS)
  - Improved Target Acquisition System (ITAS)
  - Improved Bradley Acquisition Subsystem (IBAS)
  - Remote Weapon Station (RWS)
  - Stryker Mobile Gun Station (MGS)
- Airborne Systems
  - Target Acquisition & Designation Sight (TADS)
  - Pilot Night Vision Sensor (PNVS)
  - Mast-Mounted Sight (MMS)
  - MH-60 AN/AAS-44 Multispectral Targeting System (MTS)
- Man-portable/Light-Vehicle Sensors
  - Lightweight Laser Designator Rangefinder (LLDR)
  - Ground Laser Target Designator (GLTD)
  - Long-Range Advanced Scout Surveillance System (LRAS3)
  - Javelin Missile
  - TOW Missile

In addition to the above identified systems, the FEO test system has also been designed to be upgradeable to support other current and future systems with minimum effort and cost. Advanced sensors that provide 'fused' imagery from multiple spectral bands (e.g. VIS/IR, I*2/IR, SWIR/IR), as well as simultaneous two-color IR imagers, hyper-spectral imagers and LIDAR, may all someday form part of the Army's future inventory. The modular architecture approach SBIR has implemented into the FEO permits these future devices to be supported via appropriate hardware and software upgrades.

3. SYSTEM DESIGN

3.1 Test Capabilities – Military E-O devices can be segregated into two broad categories: those that sense or detect radiation, and those that emit radiation. Any E-O imager/camera, the TOW xenon beacon tracker, and laser range finder receivers are examples of devices that fall into the first category, while laser range finders and laser designators fall into the latter group. Table 1 provides lists of primary tests for five E-O device types supported by the FEO system.

3.2 System Hardware – A high-performance, F/5.6 multispectral collimator (nominal EFL=72 inches) forms the core of the FEO system hardware. The large aperture (14 inches) and long focal length permit this optical system to accommodate the full range of Army E-O systems: from handheld IR imagers and tripod-mounted missile launch/track sensors to large armored vehicle day/night targeting systems and multi-sensor weapons or surveillance pods for airborne platforms.

The FEO front plate provides a flexible mounting interface for attaching system-specific fixturing to optically-couple the unit-under-test (UUT) to the FEO collimator. Computer-controlled actuators enable the entire collimator line-of-sight to be precisely steered, permitting it to be accurately aligned to the center of the UUT field-of-view (FOV) for boresight testing, or input target stimuli to be positioned at various locations within the sensor's FOV.

A variety of target sources and patterns can be automatically positioned at the focal plane of the FEO collimator, in accordance with the characteristics and capabilities of the sensor/system UUT, using removable source and target wheel modules contained within the target projector. The source module contains Infinity series high-performance infrared blackbody and visible/SWIR sources, a laser energy detector, and a simulated xenon beacon source (e.g. to permit key testing of systems that include a Xenon Beacon Tracker (XBT) for TOW missile guidance) along with optical relays for laser range simulation. The 16 position Target Wheel includes a number of precision aperture and multi-bar pattern targets designed to support the full range of FOVs and performance levels of the sensor systems listed above in Section 2 and appropriate tests listed in Table 1. A depiction of the FEO system rack (with the covers removed to reveal some of the key modules and components) is shown in Figure 2. The FEO system also incorporates an external large-area IR Flood Source to support specific IR performance tests such as Uniformity.

As described in the next section, pre-defined suites of tests will be developed for each supported system, and the appropriate sources and targets automatically positioned for each test as dictated by the test program set for that particular UUT.

TEST	VIS/SWIR	I*2	IR	Laser	XBT
Boresight Alignment	√	√	√	√	√
Multi-Boresight Alignment	√	√	√	√	
Line of Sight	√	√	√		
Magnification	√	√	√		
FOV	√	√	√		
FOV Coincidence	√	√	√		
Zoom Range	√		√		
Image Tracking	√		√	√	
Focus Range	√	√	√		
MTF	√	√	√		
Gain, Offset, Bad Pixel	√		√		
MRTD Manual			√		
MRTD Automatic			√		
MDTD			√		
MRC	√	√			
Brightness Gain		√			
Resolution	√	√	√		
Responsivity	√				
SiTF			√		
NEI Spatial and Temporal	√	√			√
Receiver ANSD					√
NETD Spatial and Temporal			√		
Non-uniformity Correction	√		√		
Uniformity	√	√	√		
3-D Noise	√	√	√		
Channel Integrity			√		
Laser Presence				√	
Beam Width and Divergence				√	
Simulated Ranges				√	
Multiple Range Returns				√	
Pulse Width				√	
Pulse Repetition Frequency				√	
Pulse Energy				√	
Pulse Coding				√	
Receiver Alignment				√	
Receiver Sensitivity				√	
Nutation Frequency					√

Table 1 – FEO Primary Supported Sensor/System Tests

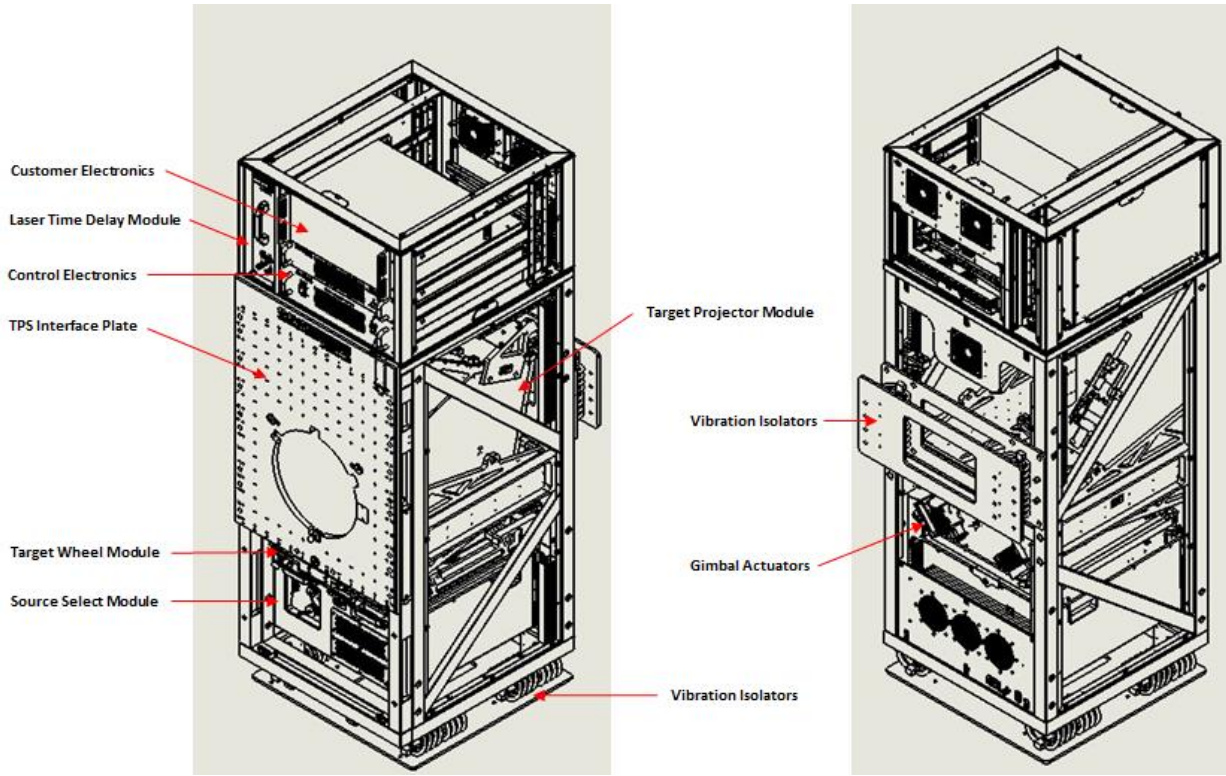

Figure 2 – FEO system rack (covers off) showing several key modules and components

In addition to its extensive infrared and visible/low-light-level sensor test capabilities, the FEO system also includes provisions for testing a wide range of key performance characteristics for systems incorporating laser rangefinders and/or designators operating within the 0.9 – 1.57 um spectral range. These include: laser pulse energy/power, pulse width, pulse repetition frequency (PRF), beam divergence, ranging accuracy, and receiver sensitivity.

4. TEST PROGRAM SET (TPS) DEVELOPMENT

The current programming language used for developing many government TPS's is ATLAS, a language approaching 40 years old. TPSs created with ATLAS are expensive and time consuming to develop. Inefficiencies of ATLAS cause longer than necessary run times for TPSs run on the legacy test equipment. In response, SBIR has implemented IRWindows 4™ as the primary TPS development tool within FEO. Advantages and features of TPS development for EO-IR systems in the IRWindows™ environment when compared to legacy TPS development environments have been previously described in detail and have been expanded upon within FEO.[1]

4.1 IRWindows™ - the IRWindows™ environment decreases TPS development cost and run times by addressing issues with legacy languages:

- Designed for use by E-O engineers and technicians – no programming knowledge required
- Simulation mode available for development without hardware
- TPS changes can be tested instantly without recompiling
- Shorter execution times
- Customized for E-O data types (regions of interest, image data cubes, etc.)

Salient features of IRWindows™, such as faster developer learning curves and TPS development times, an intuitive Graphical User Interface (GUI), virtual asset control interfaces for emulation, open software architecture, and a run-time compiler, all allow for rapid commissioning of TPS releases and responsiveness to new test requirements resulting in significant cost savings to the User. The FEO main GUI panel is shown in Figure 3.

FEO is preloaded with a large selection of previously-developed EO-IR-Laser and FEO system hardware Test Procedures ready for use. Test Procedures developed by SBIR use C# scripts; copies may be made and edited or customized when in a specific User access mode. A test editor is embedded in the IRWindows™ application so that certain user levels can create new tests as required in the field.

The FEO software contains remote interfaces (socket, RESTful, DLL wrappers), which ensures broad level integration support; e.g. programming languages (C#, C, C++, etc. and executives: NI TestStand, ATLAS, etc.).

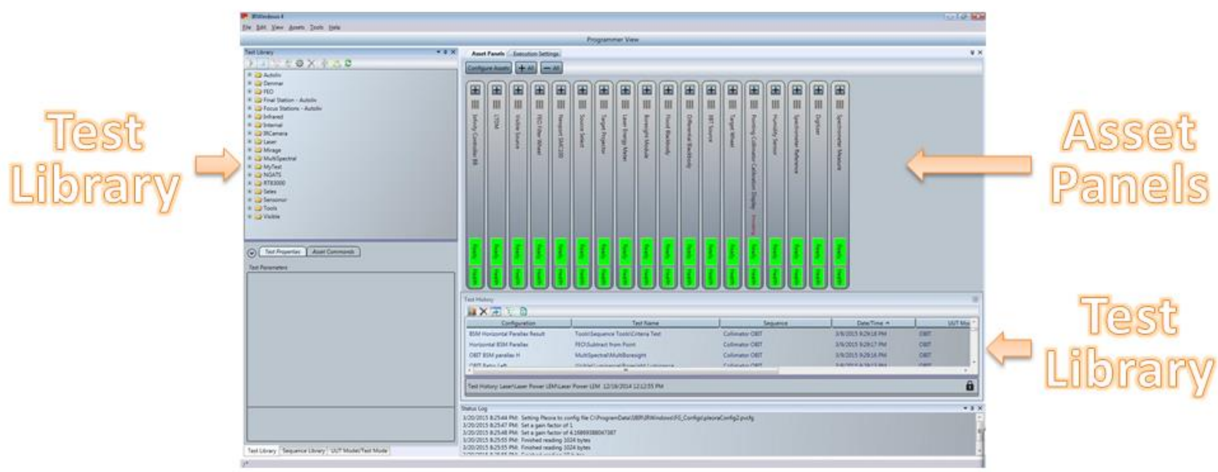

Figure 3 – IRWindows™ Main UI Panel for FEO

IRWindows™ provides a flexible and powerful graphical Test Sequence Builder that allows the User to easily and quickly construct Test Sequences for TPS Development. Test Sequences are composed of Test Procedure Instructions (TPI) and Test Configurations (TC) of valid Test Procedures (TP). TPI pages are instructional constructs that can contain text, images, and video and are used to assist and instruct the User in performing certain tasks in the sequence and to customize the TPS for the end User. This may include informational content, warnings, procedures, etc. (Figure 4).

Test Results (e.g. text, values, images, etc.) for all TP's run are stored in a Test History Structured Query Language (SQL) based database. This allows for powerful data mining and report generation using common database tools and expertise.

Error handling performed by IRWindows™ provides visual indicators within the Main UI Panel of asset health, state, and error identification as well as auto-logging (Figure 5).

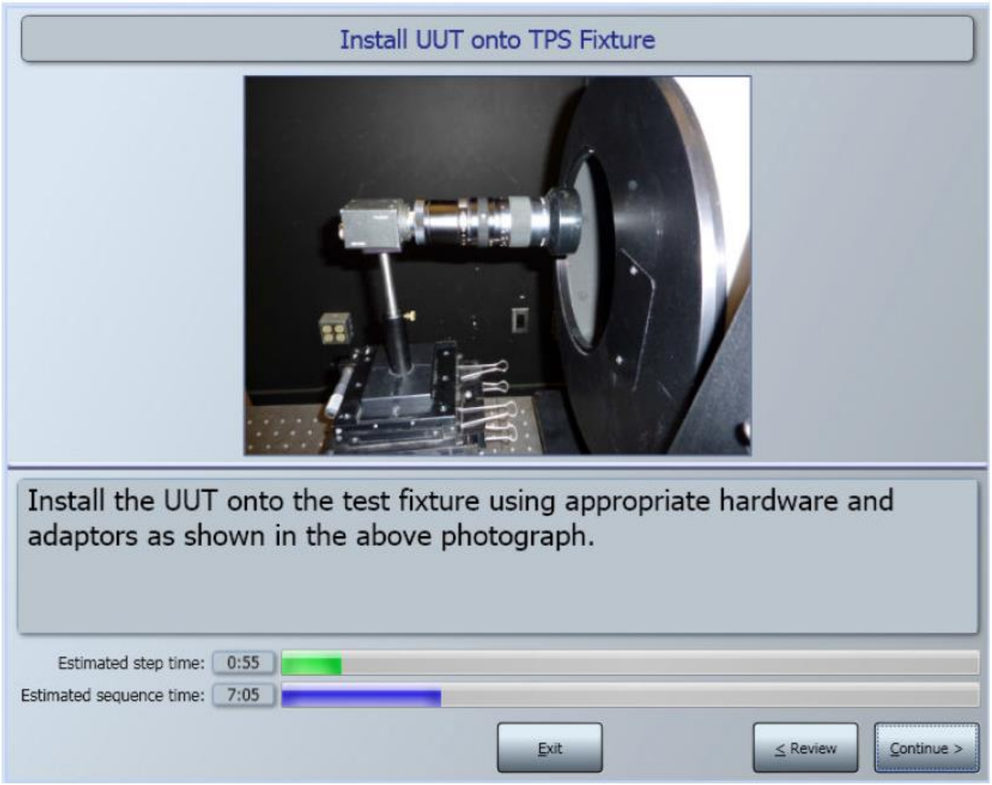

Figure 4 – Example Test Sequence TPI Panel

Current Calibrations

Asset Name	Valid	Component	Part Number	Serial Number	Calibration Date	In-Service Date	Due Date
Differential Blackbody	✓	Blackbody Source Probe	310-000-202	142389 F	2/6/2015		7/30/2016
Differential Blackbody	✓	TLDC	310-002-154	143204 NC	8/7/2014		1/29/2016
Differential Blackbody	✓	Target Wheel Probe	310-001-872	143156 NC	2/6/2015		7/30/2016
Differential Blackbody	✓	Collimator Probe	310-000-202	143155 F	2/6/2015		7/30/2016
Flood Blackbody	✓	Flood Source Probe	310-000-202	141467 F	2/6/2015		7/30/2016
Visible Source	✓	Visible Detector	310-002-126	143104 B	9/16/2014		3/9/2016
Visible Source	✓	Visible Attenuator	310-002-124	142348 B	9/16/2014		3/9/2016
Visible Source	✓	TLDC	310-002-154	143203 NC	8/12/2014		2/3/2016
XBT Source	✓	Laser	310-002-715	6436701 NC	10/2/2014		3/25/2016
Laser Energy Meter	✓	Energy Meter	310-XXX-XXX	123456	1/22/2015		1/22/2016
Digitizer	✓	Vendor Calibration	310-XXX-XXX	987543	3/22/2015		9/22/2016

Figure 5 – IRWindows™ Error Handling

5. MAINTENANCE

Maintenance of the FEO system is facilitated by removable/replaceable hardware modules (Table 2), and integrated Built in Test hardware health monitoring via IRWindows™.

Source Select Assembly • Differential IR blackbody • Visible Source Module • XBT Source Module • Laser Energy Module • Laser Collection Module • iProbe	Laser Delivery Module
Target Wheel • iProbe	Laser Time Delay Module
Range Target Assembly	Power & Motion Control Module
Boresight Module	Source Electronics Module
Collimator Module • iProbe	IR flood source • iProbe
Video Processor	Optical BIT Module
Laser Temporal Module	Path Select Module

Table 2 – FEO Replaceable Modules

Health records are maintained for all FEO system modules, and information about required assets is made available to the User. Health records contain:

- Serial number
- Calibration date, calibration interval, and due date
- Runtime (e.g. visible lamp)
- Operational status

5.1 BIT – The FEO system features an extensive Built in Test (BIT) capability arranged into the following functional groups:

- Electro-mechanical
  - IR source, visible source, target and source selection wheel, digital electronics, source drive electronics, gimbal drive
- Software / System Health
  - Watchdog timers, temperature, humidity, dew point, regression tests, module presence, calibration due date check

FEO BIT functionality is executed via IRWindows™, and has been implemented within a framework comprised of three BIT modes: Background, Commanded, and Power-up.

Power-up BIT (PBIT) is initiated when communications is established with the test station by IRWindows™. The application requests error status, module presence, and calibration data from the test station.

Background (Continuous) BIT (CBIT) ensures asset/function is working correctly during operation with built in closed loop control algorithms at the hardware/embedded level. It checks for timeouts, communication errors, invalid commands and closed loop control issues (e.g. blackbody set-point failures).

Commanded (Initiated) BIT (IBIT) is used to diagnose failure down to replaceable module and is generally used after a Background BIT failure to isolate the issue. Embedded asset drivers provide for complex BIT sequences and for future expandability and upgradeability of BIT sequences.

5.2 Optical Bit (OBIT) – OBIT is unique and was created for FEO in order to diagnose failure down to replaceable module or to baseline a state of health measurement via optical testing methods. It is implemented as an OBIT IRWindows 4™ sequence, and executed when initiated by the User.

Central to OBIT is the use and assessment of the collimator optics. OBIT is implemented through two primary hardware sub-systems: the Optical Reflectance Monitoring System and the OBIT Module.

OBIT assesses the following system characteristics:

- Spectral transmission of collimator
- Focus/alignment of Boresight Module camera
- Focus/alignment of collimator
- LOS pointing accuracy

OBIT is executed by first mounting the OBIT to the FEO front plate at the collimator aperture via three kinematic mounts, and then invoking the OBIT sequence within IRWindows™. Figure 6 shows block diagrams of the above four optical BIT tests and the OBIT module with its key internal components.

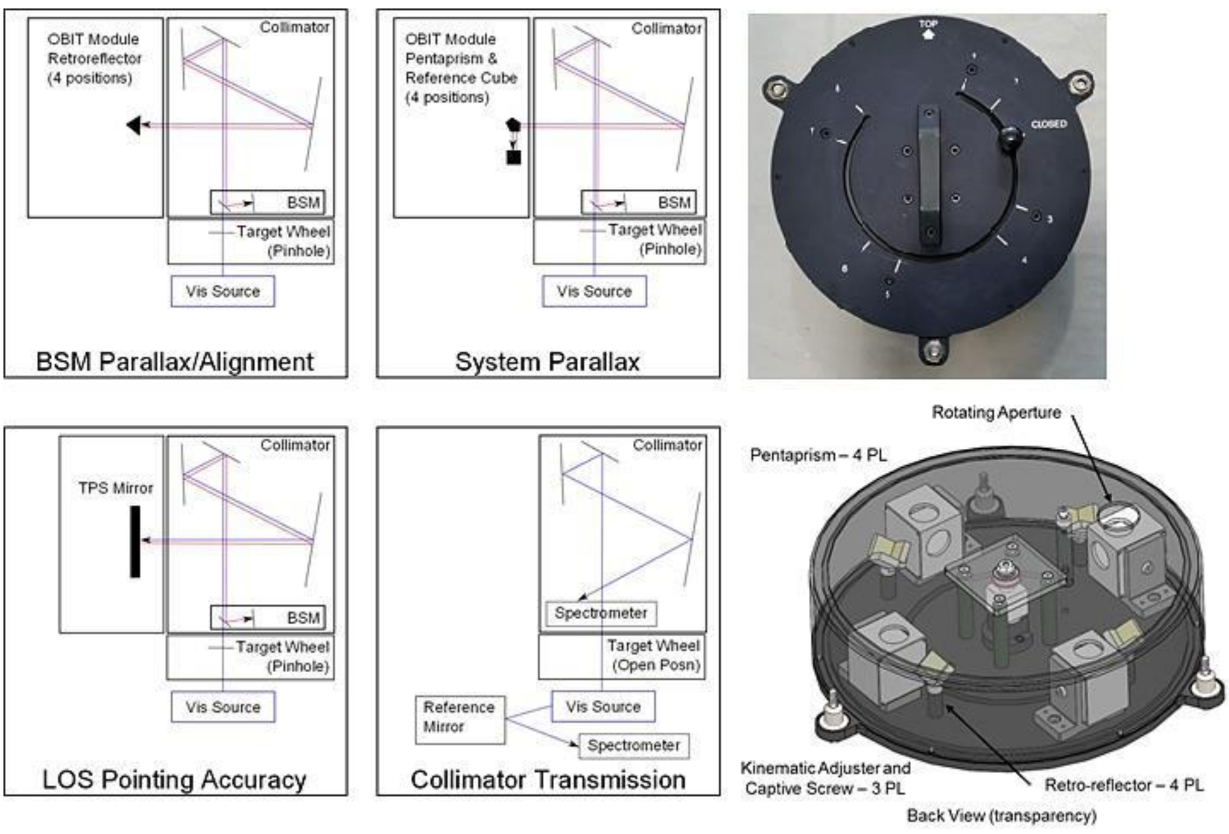

Figure 6 – OBIT Module

6. SYSTEM CALIBRATION

Calibration of system hardware is both simple and fast due to the use of: 1) field-replaceable calibrated sub-modules, and 2) software-based calibration due date and report status tracking/reporting.

A "smart module" philosophy has been implemented whereby all calibrated replaceable modules embed calibration information internally via an electronic memory storage device. Calibration-specific information can be read via IRWindows™ and reported to the User upon command, or upon reaching defined calibration due dates. Module-specific calibration information enables out-of-calibration modules to be quickly swapped with spares to minimize system downtime. Modules start their calibration period when installed in the system.

Calibration Test Sequences can be run to access read-only calibration data, to provide instructions for replacement, and also to store the in-service date within the module. Modules that are out of calibration will be flagged to the User and noted in the health database (Figure 7), but remain operational. "Smart module" incorporation into critical test hardware provides for significant reduction in the cost of periodic calibration and ease of maintenance.

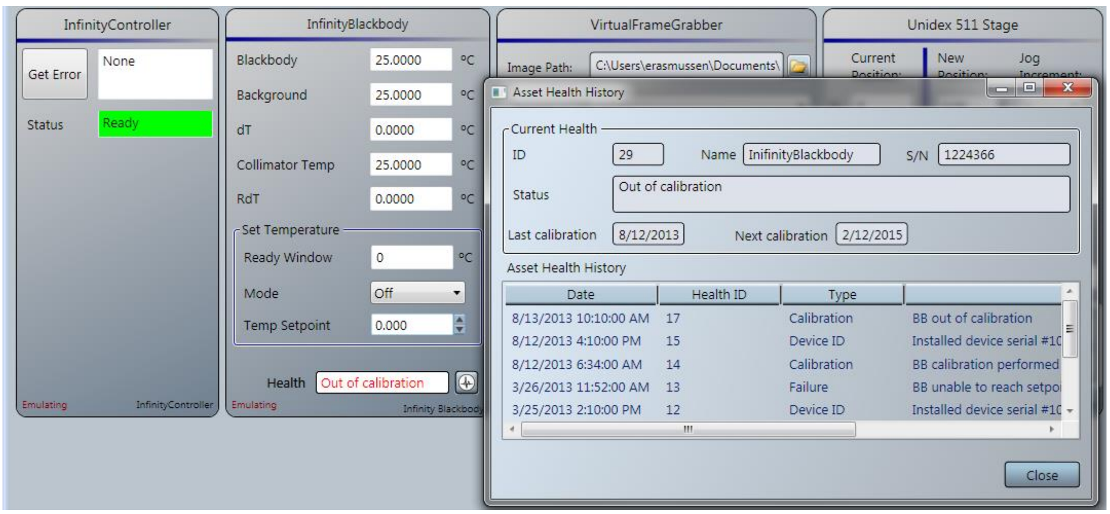

Figure 7 – Asset Calibration Record and Health History Panel

7. SUMMARY

SBIR has produced the highly-advanced and modular Future E-O Automated Test System as part of the US Army's Next Generation Automatic Test System for fielded and future E-O systems. FEO provides the US Army with a wide range of automated EO-IR-Laser test capabilities using leading-technology SBIR products, fully integrated into a single test-ready system and controlled with proven IRWindows™ software.

As E-O systems become increasingly crucial to the warfighter's effectiveness, the readiness state of these devices and systems must be rapidly and accurately determined and communicated to the User. FEO represents a leap forward in capability for integrated E-O test systems with advanced logistics support features.

ACKNOWLEDGMENTS

The authors wish to acknowledge US Army PD TMDE, Huntsville and US Army ARDEC ATSD, Picatinny for design performance input and EO-IR-Laser test and calibration support of this system.

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