Integrated, user reconfigurable testing of electro-optical systems of today and tomorrow (EIRT)

Dario Cabib*, R.A. Buckwald, Moshe Lavi, Oded Neria, Efraim Tzafrir, Shimon Nirkin, Moshe Blau, Jacob Dolev
CI Systems (Israel) Ltd., Ramat Gavriel, Migdal Haemek 10551, Israel

ABSTRACT

Day and night target detection and identification, target ranging, missile threat detection and weapon guidance are all done on an aircraft by a suite of instruments, operating together as an advanced electro-optical system. Basically, these instruments are all specially designed sources and sensors, working in the spectral range from visible to IR, and are becoming ever faster and more accurate. Furthermore, the rapid advance of technology is increasing the level of interdependence of these instruments among each other, so that the well functioning of each of them is more dependent on the well functioning of the others. Therefore, it is a challenge to provide a more complex and accurate system testing while still ensuring the highest operational readiness within a limited budget. CI Systems has taken up this challenge by devising a breakthrough "one-stop, user reconfigurable" testing concept (Electro-optical Integrated Reconfigurable Testing, or EIRT). The EIRT is a family of electro-optical test systems, providing a complete suite of tests in a single hardware, and a unique, reconfigurable software package that controls both the Unit Under Test (UUT) parameters and the test system. The user himself can easily reconfigure the test routine according to his changing needs, to test the weapon systems of the future. This saves testing time and manpower in development, production and field deployment.

Keywords: FLIR testing, CCD testing, Laser Range Finders tests, Laser Designators testing

1. INTRODUCTION

In the last decade, and especially after September 11, 2001, and the ensuing surge of awareness for the need of defense against terror and other potential security threats, the use of electro-optics technology on military vehicles and even civilian aircraft has increased considerably. This trend is continuing and for the time being, is giving no sign of abating. Maybe one of the most remarkable signs of such trend is that even commercial aircraft are being equipped with warning and countermeasures systems against certain types of missiles, which would have been unthinkable just a few years ago.

Many other technological advances, such as the ever decreasing size of computers, the development of uncooled infrared imagers, advances in sensor fusion technology etc., are also contributing to the continuing proliferation of electro-optical instrumentation for defense use. Threat detection speed and identification have benefited from advances in sensor spatial resolution, frame rates and sensitivity. Lasers for ranging and weapon guidance have increased their functional range and accuracy. As a result, the number, complexity and accuracy of electro-optical systems for defense uses are steadily increasing. The increased deployment and performance of the electro-optical instrumentation naturally increases the amount and complexity of testing to be carried out by the manufacturers and the users, while making it more difficult for the user to maintain a high confidence level of full operational readiness at all times.

CI Systems has been a world leader in providing electro-optical test systems to the defense community since the mid eighties. In the beginning, these systems were designed only for testing of FLIRs (Forward Looking Infrared) sensors, providing all the conventional FLIR tests such as MRTD (Minimum Resolvable Temperature Difference), MTF (Modulation Transfer Function), SiTF (Signal Transfer Function) and NETD (Noise Equivalent Temperature Difference), among others. During the nineties, however, responding to users' demands, the Company has been gradually adding features and redeveloping the appropriate hardware and software to keep up with the evolving electro-optical instrumentation mentioned above. In the process, CI Systems has built a substantial portfolio of electro-optical systems testing configurations (both hardware and software), which have been growing in size, variety and complexity, to fulfill the requirements of those users.

* Tel.: 972-4-6448811, Fax: 972-4-6441052, e-mail: dario.cabib@ci-systems.com

Finally, realizing that the technological trend is still one of continuous system improvement worldwide, CI has just developed a unique test system concept (the EIRT), to test the electro-optical weapon instrumentation of both today and tomorrow, which is more easily adaptable and flexible than earlier concepts. This new concept results in lower costs, due to less time and manpower dedicated to testing. This is achieved by a specially designed user friendly software package that not only controls all the tests through the control of the hardware and of the UUT's, but also allows the operator to easily modify the testing methods, the procedures and the order in which tests are done, add new tests for future devices, remove tests, reconfigure the user interface, and obtain reports, all according to need. In addition, even the level of automatization of the whole testing routine can be decided by the user, from being all manually controlled to completely automatic.

2. SYSTEM DESIGN, MAIN FEATURES AND ADVANTAGES

Figure 1 shows an example of military electro-optical system being tested by an EIRT system.

Figure 1: An example of electro-optical system mounted in a pod (green container) being tested by an EIRT test system. On the right are the control panels and computer.

2.1. Hardware

Figure 2 shows a schematic diagram of the hardware of an EIRT system. The system is composed of an off-axis Newtonian projector (all reflective collimating optics) suitable for both, the visible and infrared wavelength regions (0.4 to 15 μ) and a number of sources (high performance extended area blackbody and visible source for sensors testing), filters and sensors positioned near the focal plane of the projector, for laser testing. The system also includes:

i) Up to two target wheels to sequentially select the test targets to be imaged,
ii) A motorized stage to select the relevant source or sensor for a specific test,
iii) A range simulator made of a delay device for laser range testing,
iv) All the electronic control units of the sources and sensors,
v) A PC with frame grabber to capture images from the UUT, and images and signals from the system sensors.

The PC is equipped with powerful software to control the parameters of the UUT and of the sources and sensors of the EIRT system, and to acquire their signals. This is done through communication links and appropriate protocols. This software also analyzes the images and signals from the UUT and the EIRT sensors, through proprietary algorithms and provides the test results. All of the system operation is done by the user through the EIRT user interface, some features of which are described below.

The sources and sensors of the EIRT are specific and interchangeable to suit each test. Figure 2 shows the components of the system. Some of the components (for example the collimator, the blackbody, or others) may be selected among a set of standard models, in order to suit the specific system to be tested and the specific customer requirements. On the other hand, the general layout and some of the components remain unchanged. As an example, the collimator can be selected among different ones whose apertures are between 8 to 16" diameter, to fit the aperture size of the UUT. The focal length can be selected too, between 30 and 120".

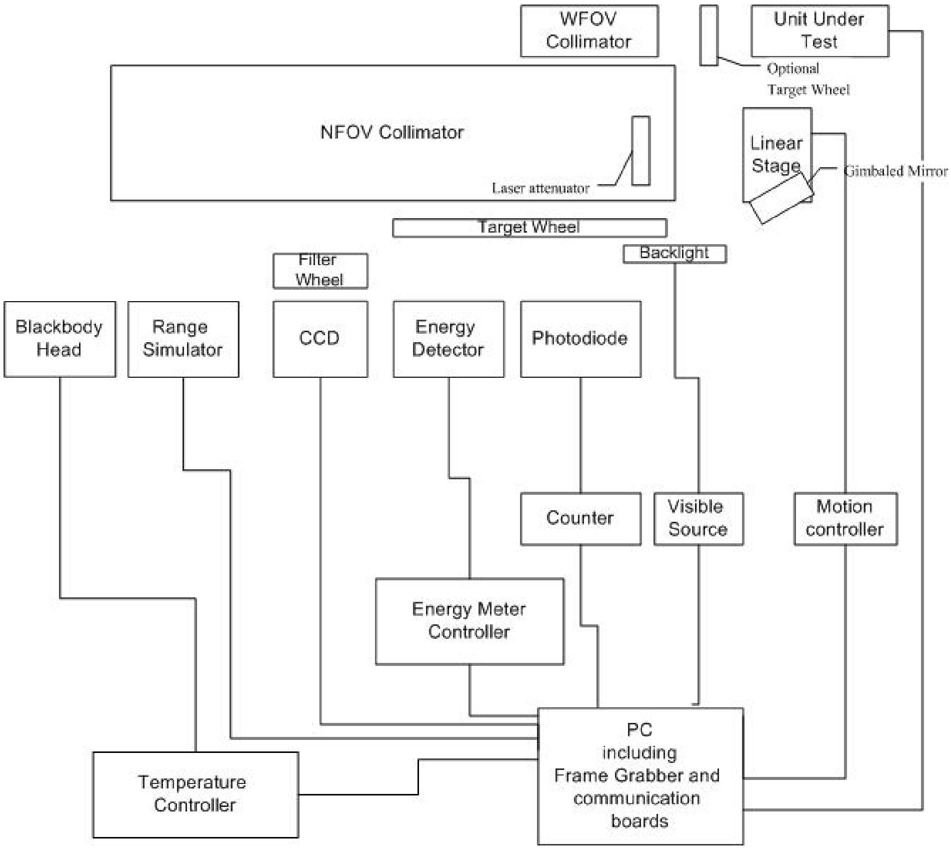

Figure 2: Schematic diagram showing the hardware organization of an EIRT.

The following table summarizes the most important components present in the system, in relation to the tests they are used for.

EIRT Components/Tests	**FLIR tests**	**CCD Camera tests**	**Laser Range Finder tests**	**Laser Designator tests**
4-bar targets+extended area differential blackbody	MRTD			
Half moon target+extended area differential blackbody	MTF			
Other targets+ extended area differential blackbody	Noise Equivalent Temperature Difference (NETD), Signal Transfer Function (SiTF), Field of View (FOV)			
Resolution targets		Spatial resolution		

+visible source				
Resolution targets +backlight+ visible source		Minimum Resolvable Contrast (MRC)		
Other targets+ visible source		FOV, SiTF, MTF, Distortion		
Laser energy detector			Laser pulse energy, average pulse energy and pulse to pulse variation	Laser pulse energy, average pulse energy and pulse to pulse variation
Photodiode			Pulse time characteristics	Pulse time characteristics
CCD			Beam divergence	Beam divergence
Time delay range simulator source			Laser receiver sensitivity, maximum range	
Thermal Target	Laser-FLIR boresight		Laser-FLIR boresight	Laser-FLIR boresight
Boresight target		Laser-CCD boresight	Laser-CCD boresight	Laser-CCD boresight

Table 1: Summary of the most important system components, and related tests.

2.2. Important hardware features and options

Other important features and options are:

- Visible to IR coverage, with glass collimator mirrors, and special mirror coatings ($\lambda/6$ and $\lambda/10$ surface accuracy).
- Light weight aluminum construction with a passive temperature compensation mechanism against optical misalignments, due to room temperature drifts.
- Interferometric procedure for most accurate target wheel alignment on the focal plane.
- Sliding temperature sensor on the target wheel for accurate 4-bar target temperature monitoring.
- Single controller for target wheel and blackbody, and up to three additional motorized devices.
- High temperature resolution and stability extended area blackbody.
- Alignment laser to visualize the collimator line of sight.
- 8-level high brightness source (10000 foot Lambert, 3200K color temperature) and backlight source (1000 foot Lambert) for the CCD camera tests.
- Additional wide field of view collimator (3 to 5 or 8 to 12μ) for wide field of view sensors testing (FLIR or CCD).
- Many targets and target shapes: cross, square, slits, bars, hairline, step, and pinhole. The targets are painted with high emissivity paint on the side of the collimator, and they are highly reflecting on the side of the blackbody.
- UUT stages for tests at different angles.
- Optical table.
- Tracking test simulator.

Figure 3 shows a typical focal plane assembly with the most popular sources and sensors used for electro-optical system testing. Figure 4 shows a typical target wheel with a collection of targets, used for FLIR testing. It is possible to see many 4-bar, a half-moon and square targets for MTF, MRTD, NEDT and FOV testing. The 4-bar targets are of different sizes, to cover a whole range of spatial frequencies.

2.3. Computer and software

The system works with a PC as the central control and analysis unit, on a Windows Operating System. The computer controls the various system modules (sources, sensors, target wheels, stage, etc.) through a GPIB (IEEE-488) or RS232 communication link, and may control the UUT parameters themselves through the appropriate communication protocols. All the controls and test routines are carried out through the EIRT software.

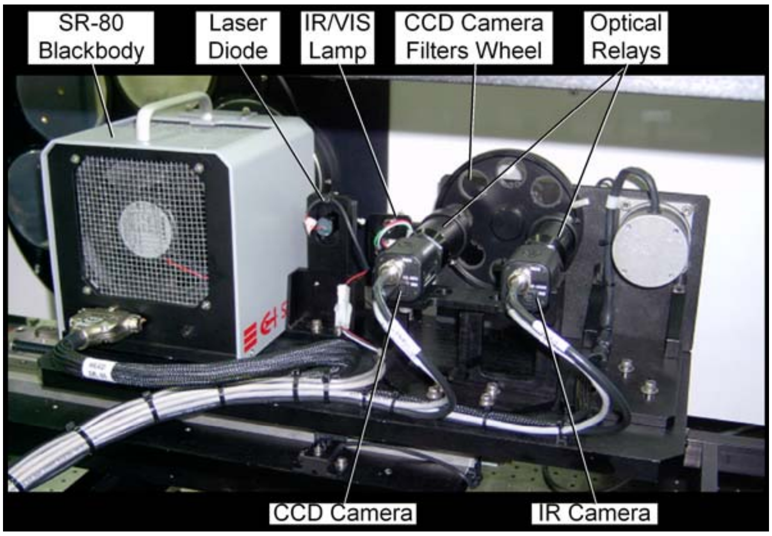

Figure 3: Typical EIRT collection of sources/sensors on the collimator focal plane.

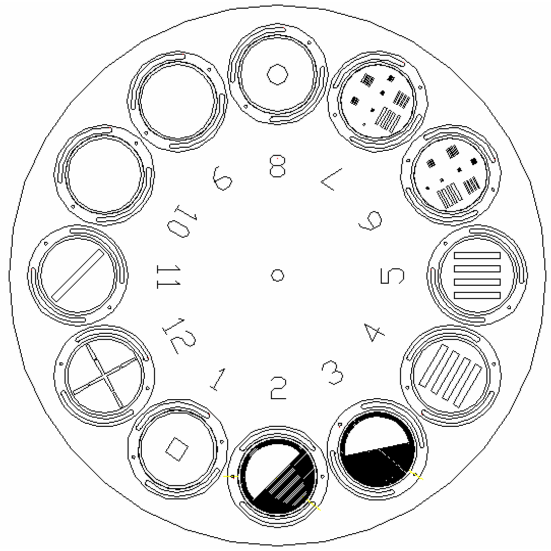

Figure 4: Example of target wheel and targets for FLIR testing.

In addition, the test routine may be configured by the customer to be as automatic as desired. This means that in principle, the software can be configured to perform all the tests, one after the other, including the final report, without the intervention of a human operator. In practice, some intervention is usually required; for example in the MRTD test of a FLIR, the decision of which is the threshold temperature for a specific 4-bar target to give a non-zero contrast on the screen is usually by a human. However, it is possible that new algorithms of image analysis will be developed in the future to replace the human element in this decision: when this will happen, they will be easily incorporated in this software package.

If the UUT is an imager (FLIR or CCD camera) the images of the different targets (presented sequentially on the focal plane of the collimator by the software control) at different blackbody temperatures are captured by the frame grabber in the PC through the UUT video output. Then the software extracts the relevant sections of the images as required for each test, displays them, gets the inputs from the operator, carries out the relevant algorithms, and prepares the test reports, all according to the initial set-up. If the UUT is a laser, its image from the EIRT CCD is used to measure the laser beam size and from this, to calculate the beam divergence; the signals from the photodiode and energy meter are used to calculate the relevant laser parameters (time and energy behavior). They are then displayed by the software on the PC. Figure 5 is a block diagram of the EIRT software.

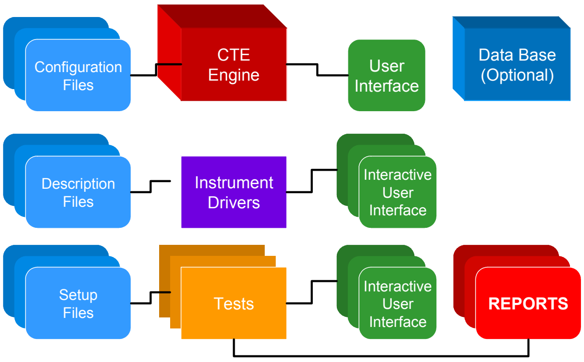

Figure 5: Block diagram of the EIRT software.

Figure 6 is the main screen of the software, through which all parameters and test configurations are set.

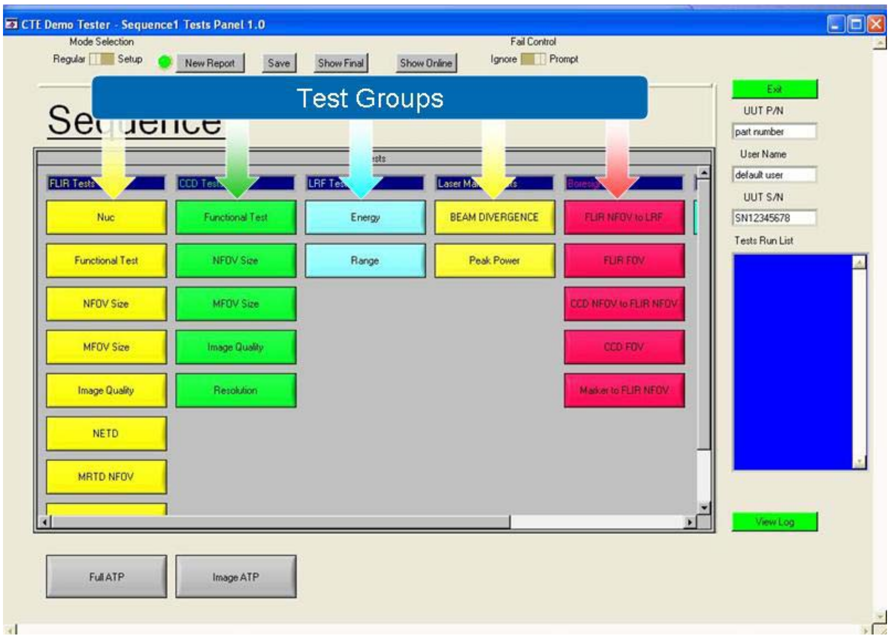

Figure 6: Main screen of the EIRT software.

In the main screen area each instrument to be tested appears as a column of function buttons of different colors. Each button corresponds to a test. The EIRT system is supplied with the required list of tests, but the user can in time add, remove or change the test list and the order of the tests at will, to satisfy new needs.

The reconfiguration and sequence of the tests is easily prepared through an external file (*.ini). The test instruments parameters and status (blackbody, energy meter, etc. and the communication protocols) are configured through a different external file (*.ini, *.csv) or through a Configuration Wizard: this defines the instruments set-up and whether they are enabled, disabled, or simulated. The user interface is then automatically configured by the protocol Excel (*.csv) files every time they are created or changed.

3. CONCLUSION

CI Systems has recently devised a breakthrough "integrated, user reconfigurable" testing concept (Electro-optical Integrated Reconfigurable Testing, or EIRT) of complex, modern electro-optical systems mounted on aircraft and other platforms. The EIRT is a family of integrated electro-optical test systems, providing a complete suite of tests in a single hardware, and a unique, reconfigurable software package that controls both the Unit Under Test (UUT) parameters and the test system. The user himself can easily reconfigure the test routine according to his changing needs, to test the weapon systems of the future. This saves testing time and manpower in development, production and field deployment.