Advanced, manpower and time saving testing concept for development, production and maintenance of electro-optical systems

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ABSTRACT

In all stages of an electro-optics system's life, development, production, and periodic maintenance, a large amount of manpower and time is devoted to testing. Each subsystem separately as well as the system as a whole are tested by a PC controlled test system, which consists of hardware for creation of the appropriate stimuli, and software for tests management and control. A very considerable portion of this manpower and time is devoted by the system manufacturer to configure the test routines, to manually input certain parameter values of the Unit Under Test (UUT) at predefined test nodes, and to reconfigure these routines from time to time, as the needs change during the system's life time.

CI has developed the CTE (CI Test Executive), a software package which is a breakthrough in saving manpower and time devoted to electro-optics system testing. The new concept is based on:

1. The CTE can communicate directly with any UUT able to communicate with the outside world through a known protocol, to automatically set the UUT parameters before testing,
2. The user can more easily reconfigure the communication with the UUT through a provided special Excel file, without the help of the test system manufacturer,
3. The interface screen is automatically reconfigured every time the Excel file is changed to build the new test routine,
4. The CTE can simulate the test system stimuli with error injection capability, and simultaneously monitor communication and other hardware functions,
5. Test "verification" signals are provided on-line for the convenience and time saving of the test operator.

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

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Infrared Imaging Systems: Design, Analysis, Modeling, and Testing XVII, edited by Gerald C. Holst,
Proc. of SPIE Vol. 6207, 62070R, (2006) · 0277-786X/06/$15 · doi: 10.1117/12.665410

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.

Finally, realizing that the technological trend is still one of continuous system improvement worldwide, CI has just developed a unique test system concept, 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 a CTE based system.

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

2.1. Hardware

Figure 2 shows a schematic diagram of the hardware of a CI test 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 software to control the parameters of the UUT and of the sources and sensors of the test 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 test system sensors, through proprietary algorithms and provides the test results. All of the system operation is done by the user through the test system user interface, some features of which are described below.

The sources and sensors of the test system 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".

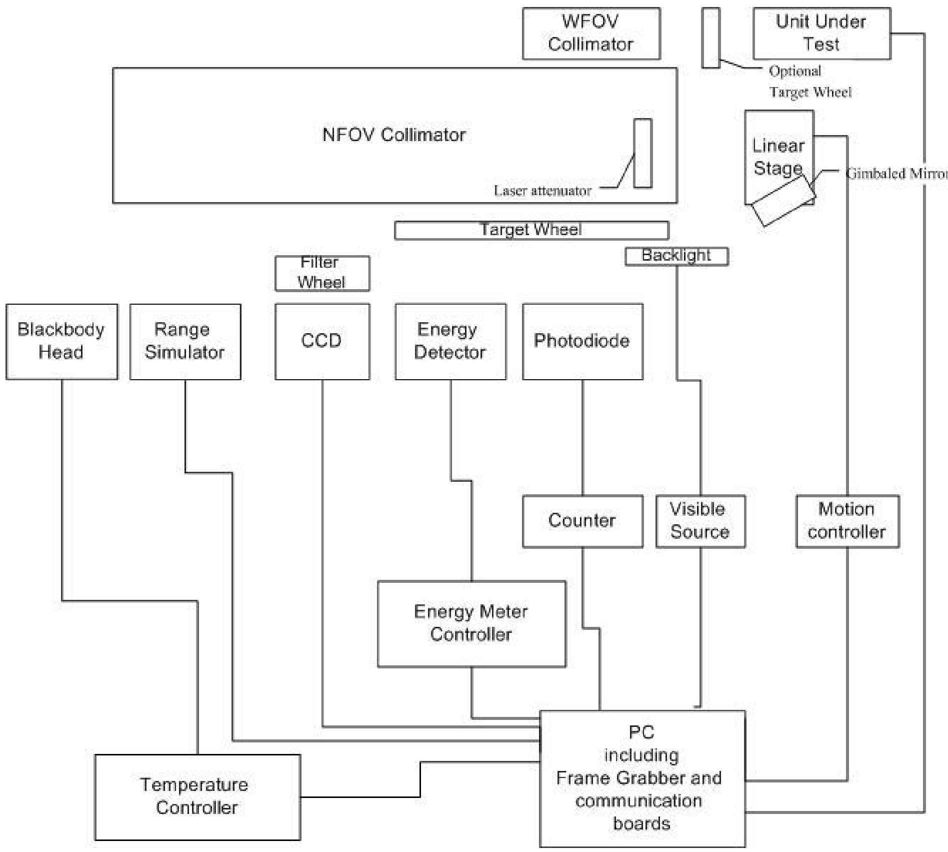


Figure 2: Schematic diagram showing the hardware organization of a CI test system.

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

Test system 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	Noise Equivalent Temperature			

differential blackbody	Difference (NETD), Signal Transfer Function (SiTF), Field of View (FOV)			
Resolution targets +visible source		Spatial resolution		
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.

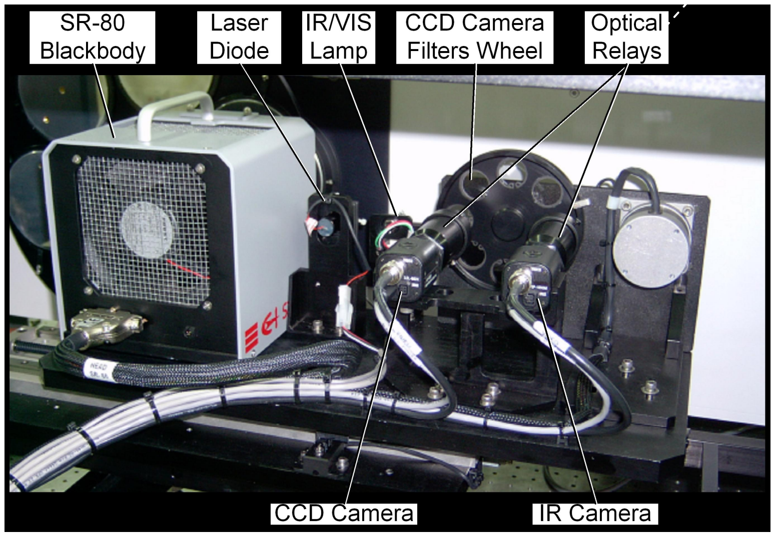


Figure 3: Typical EIRT collection of sources/sensors on the collimator focal plane.

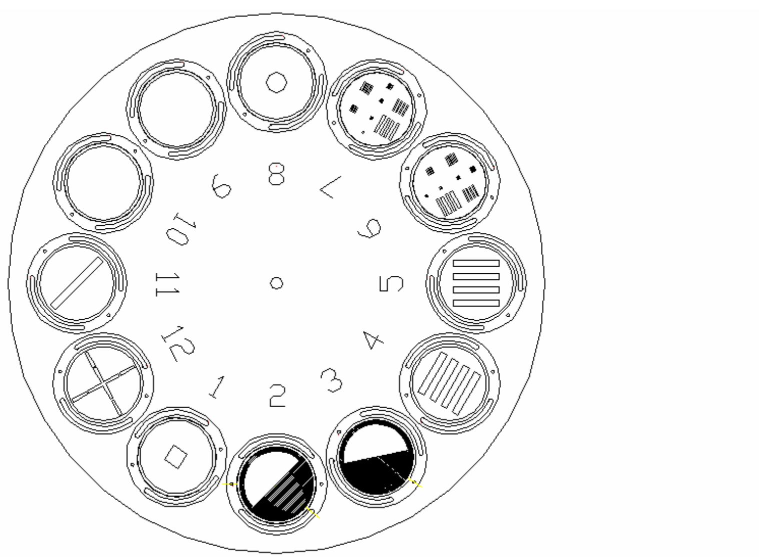


Figure 4: Example of target wheel and targets for FLIR testing.

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 test system 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 system software.

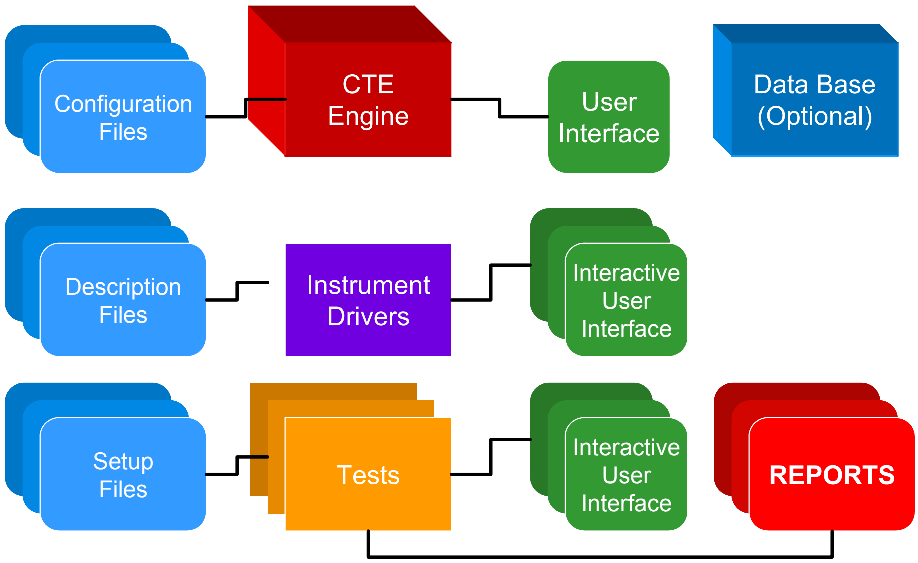


Figure 5: Block diagram of the test system software.

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

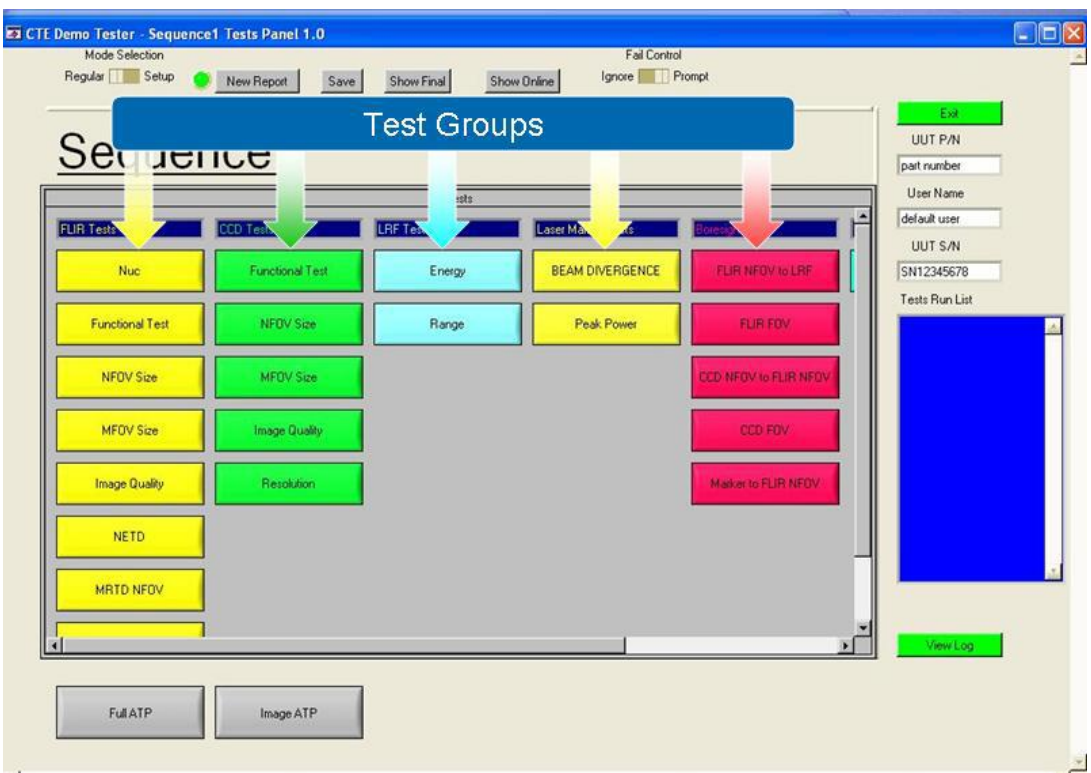


Figure 6: Main screen of the test software.

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 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.

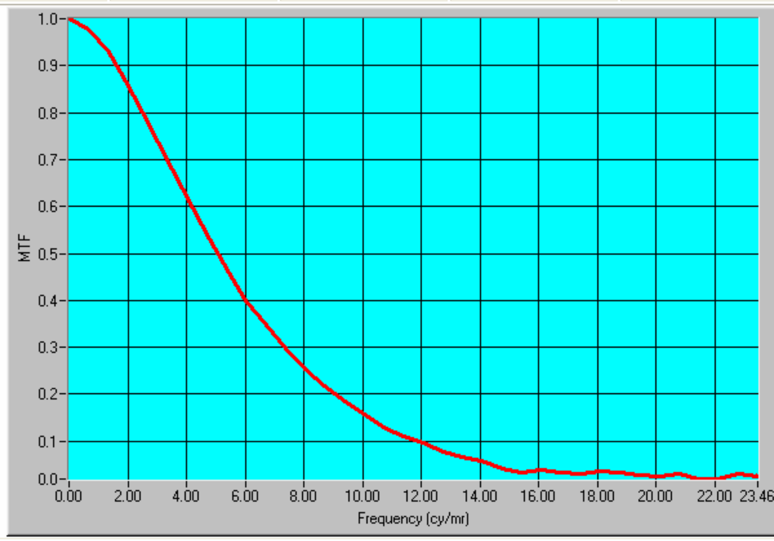
The reconfiguration and sequence of the tests is easily prepared through an external file (*.ini). The test instruments parameters and status (blackbody, energy meter, etc. and the communication protocols) are configured through a different external file (*.ini, *.csv) or through a Configuration Wizard: 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. EXAMPLES OF RESULTS

Here we show a few examples of result screens for different measured parameters.

Figure 7 shows the screen of an imager MTF measurement result. The screen shows the graph of MTF versus spatial frequency, the MTF values for two specific and predetermined frequencies, their tolerance and Pass/Fail result.

MTF



Name	Low	High	Value	Units	Status
MTF NFOV Frequency 16.500000 cy/mr	0.300	1.000	0.038	Pass/Fail	Failed
MTF NFOV Frequency 2.800000 cy/mr	0.400	1.000	0.779	Pass/Fail	Passed

Figure 7: Result of a CCD with lens MTF measurement, with some data summary and "pass-fail" information.

The CTE software in this case accepts as input the frequencies at which the measurement is done and the respective target positions on the target wheel. It then automatically sends the target wheel to the relevant positions, it captures a number of imager frames, it calculates the MTF values at the corresponding frequencies, and at the end it displays the final curve as in figure 7.

Figures 8 and 9 show two typical screens for Noise Equivalent Temperature Difference (NETD) testing of a FLIR. Figure 8 is the image of the rectangular NETD target used for the measurement where the Region of interest (ROI) is shown by a green rectangle, and figure 9 is the NETD graph of each horizontal row of the FLIR within the ROI as function of row number. In this case, the CTE accepts as input the ROI defined on the screen by the operator, and then it automatically calculates the NETD values of each row on the basis of the intensity values as sensed by each pixel within the ROI.

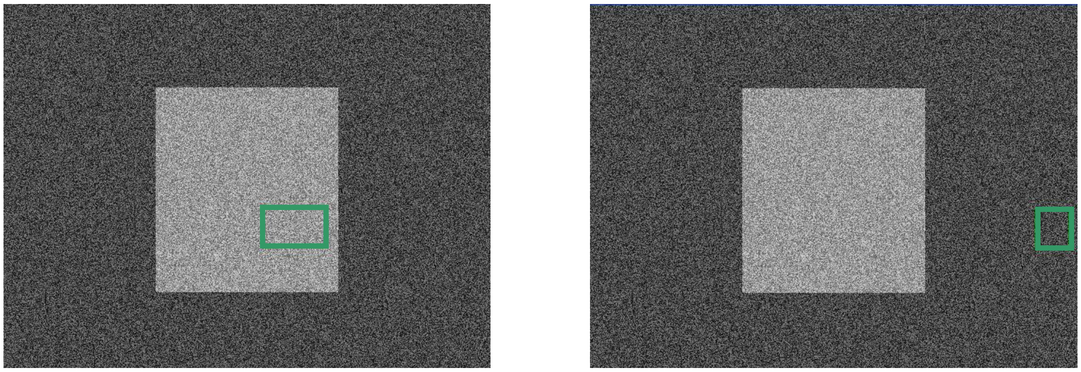


Figure 8: Two input screens for the measurement of NETD of a FLIR. The Regions of Interest for signal and noise measurements are defined by the operator and shown in the green rectangles.

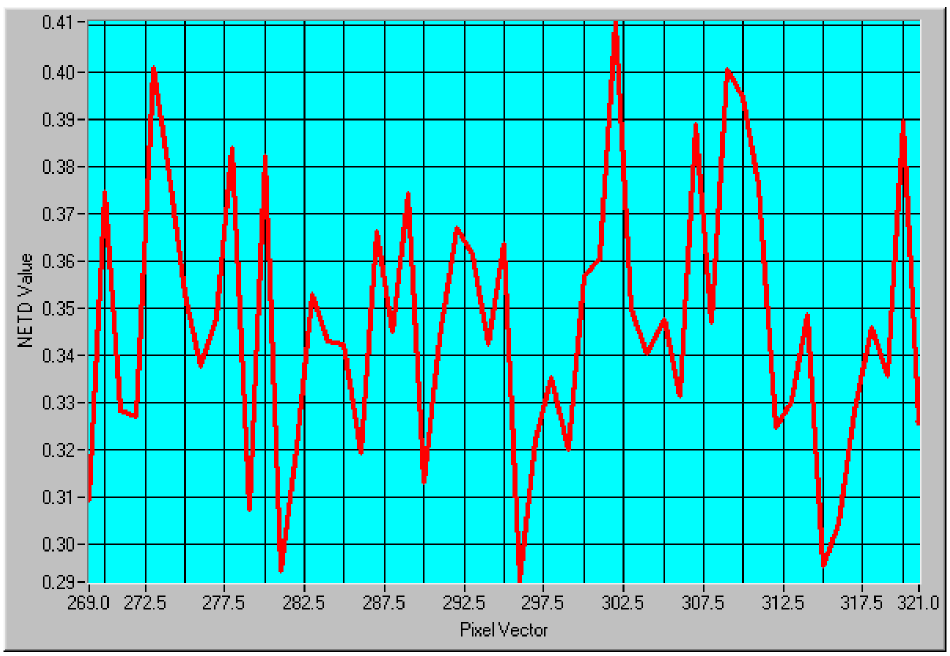


Figure 9: FLIR Noise Equivalent Temperature Difference (NETD) as function of row number within the ROI defined in figure 8.

4. CONCLUSION

CI Systems has recently devised a breakthrough "integrated, user reconfigurable" testing concept of complex, modern electro-optical systems mounted on aircraft and other platforms. The CTE is 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.