DT systems

Testers of thermal imagers

Fig. 1. Photo of exemplary two DT test systems (no PC set)

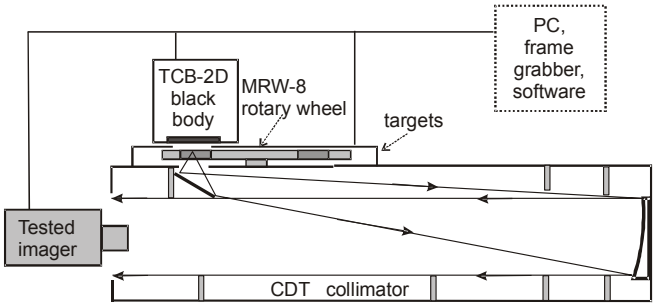

Fig. 2. Block diagram of the DT series test system (basic version)

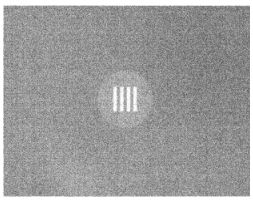

Fig. 3. Image of a 4-bar target (projected by DT 150 system and generated a by thermal imager)

BASIC INFORMATION:

The DT series systems are specialized test systems optimized for task of extensive testing of surveillance thermal imagers at laboratory/depot conditions. The DT systems can be also optionally used for testing TV/LLLTV cameras, and boresighting of thermal imagers to TV/LLLTV cameras. *Attention: MS systems are recommended if more sensors (laser systems, SWIR imagers) are to be tested and aligned.*

The DT series system is a variable target projector that uses a series of different targets to project their images to a tested thermal imager (TV/LLLTV camera). The tested imager generates distorted copies of the projected images. Quality of the images generated by the imager is evaluated directly by humans or by software and its important characteristics of tested imager are measured.

DT test systems enable extensive testing of virtually all surveillance thermal imagers or surveillance TV/LLLTV cameras available on the market including thermal imagers/TV cameras designed for ultra long distance surveillance or for space applications.

DT systems are modular test systems can can be easily optimized for different applications: from basic testing short range thermal imagers to extensive testing big airborne surveillance systems. The DT test systems are characterized by the highest performance to price ratio among test systems available on world market.

DT systems are one of most matured Inframet products that have been verified by a long series of customers all over the world.

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1 DT system structure

DT test system is a modular system built in most advanced version using a long series of modules

1. CDT off axis reflective collimator (collimators of different aperture, focal length and optical quality are available for different applications)
2. TCB differential blackbody (can be delivered in different versions: typical/improved temporal stability; optimization yes/no for cooperation with light source.
3. MRW-8 motorized rotary wheel (optimized for cooperation with a set of IR targets and visible targets)
4. Set of IR targets (targets to be used for testing thermal imagers - different configurations are possible)
5. Standard analog video frame grabber (for capturing images of resolution/frame rate not higher than typical TV signal
6. Optional CameraLink/ or GigE/ or LVDS frame grabber (for capturing images of high resolution/frame rate)
7. PC - typical PC working under Windows 7 operating system (laptop or desktop PC are delivered depending on version)
8. TCB Control - computer program used for control of TCB blackbody and MRW wheel and for support of measurement of MRTD and MDTD characteristics of thermal imagers.
9. TAS-T - computer program used for semi-automatic measurement of a series of objective parameters of thermal imagers: MTF, SiTF, NETD, FPN, non uniformity, distortion, FOV, AutoMRTD, PVF, SRF, ATF, NPSD, 3D noise. Program is delivered in form of different versions of different test capabilities.
10. SUB-T program - computer program that offers software support during measurement of subjective parameters like MRTD, MDTD (and TOD - option)
11. Light source: several different light sources are available of different performance: a)SEM light source - computerized LED light source integrated with blackbody, b)HAL light source - halogen light source integrated with blackbody, c) DAL light source - separate halogen/LED light source.
12. Set of visible/NIR targets (targets to be used for testing TV/LLLTV cameras - different configurations are possible)
13. Light Control program (different versions: SEM Control, HAL Control, DAL Control)
14. TAS-V program : computer program used for semi-automatic measurement of a series of parameters of TV cameras
15. BOR computer program (enables calculation of aligning errors of thermal imagers and TV cameras)
16. ROB computerized focusing platform. The platform enables regulation of focusing of CDT collimator and in this way regulation of distance simulated by projection system based on this collimator
17. Virtual imager software: set of two computer programs that enable computer simulation of tested imagers/TV cameras and can speed up and increase accuracy of measurement of subjective parameters like MRTD, MRC
18. Performance evaluation software: a series of computer programs (Simterm, Mosot, Movis) that enable evaluation of performance of tested thermal imager/ TV camera of known parameters.

2 Test concept

- Testing thermal imagers -> MWIR/LWIR image projector combined with computerized system for analysis of images generated by tested thermal imager. CDT off axis reflective collimator, TCB differential blackbody, and set of IR targets are used for such projection.
- Testing TV cameras -> visible/NIR image projector combined with computerized system for analysis of images generated by tested TV camera. CDT off axis reflective collimator, visible/NIR light sources, and set of visible/NIR targets are used for such projections.
- Boresight of thermal imagers and TV cameras -> computerized test system carries out analysis of images generated by both thermal imagers and TV cameras and calculates angle between a)optical axis of thermal imager at several FOVs, b)optical axis of TV camera at different magnification of zoom objective, c) optical axis of thermal imager relative to optical axis of TV camera.
- Testing imagers of different electronic image formats -> analog video frame grabber is used when testing imagers of resolution lower or equal to 720x576 at 25 FPS. Optional digital frame grabbers (CameraLink, or GigE, or LVDS, etc) can be used for testing imagers of high image resolution or high frame rate.

3 Versions of DT test system

DT test systems are modular test systems that can be delivered in form of different versions of different configurations, test capabilities and price. The latter parameter can vary several times depending on version.
The basic division of DT series system is based on output aperture of the collimator (Table 1).

Table 1. Division of DT series systems based on the collimator aperture

System aperture code	Collimator output aperture
DT 100	100 mm
DT 150	150 mm
DT 200	200 mm
DT 250	250 mm
DT 300	300 mm
DT X	>300mm (optional custom designed)

The rule of thumb for choosing proper aperture is following:

- Acceptable situation: the collimator aperture must be bigger than aperture of optics of tested imager
- Recommended situation: the collimator aperture must be bigger by at least 10% than aperture of tested imager (it is easier to align tested imager).

Possible application areas of the DT series test systems are listed below:

- DT 100 – testing short range imagers of aperture up to 100mm (optimal for testing miniature thermal imagers).
- DT 150 - testing short/medium/long range thermal imagers of optical apertures below 150 mm (most universal test system as at least 95% of all thermal imagers fits to this category)
- DT 200 - medium/long range thermal imagers of optical apertures below 200 mm
- DT 250 - testing long range thermal imagers of large optical apertures up to 250 mm
- DT 300 - testing long range thermal imagers of very large optical apertures up to 300 mm

Collimator aperture is only one of a series of technical parameters that should be determined to optimize DT system for required applications. We need also to determine:

1. Hardware version of IR image projector (versions of collimator and blackbody),
2. Frame grabbers (acceptable electronic image formats of tested imagers)
3. Test range of thermal imagers (number of parameters to be measured)
4. Type of light source (several light sources are offered)
5. Light simulation conditions
6. Test range of TV cameras
7. Virtual imager test support
8. Boresighting capabilities
9. Simulated distance
10. Performance evaluation software

Therefore collimator aperture code and additional code composed from ten letters are use to describe precisely parameters of DT series systems. Definitions of 10 letter code are shown in Tab.2. The columns 1-10 present what letters are to be chosen to define precisely required version of DT test system.

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Table 2. Definitions of the ten letter code used to describe versions of DT test system

	1	2	3	4	5
Code	**Image projector**	**Frame grabbers**	**Test range of thermal imagers**	**Light source**	**Light level**
A	Standard	No frame grabber	Basic: MRTD	No	No
B	Extra	Standard analog video (PAL/NTSC)	Typical: MRTD, MTF, SiTF, NETD, FPN, non-uniformity, FOV	SEM-V computerized white LED light source (to be integrated with DCB blackbody)	Day: from 0.2 to 2000cd/m^2 DAL – up to 10kcd/m^2
C		Additional software accepting USB 2.0/3.0	Typical Extra: MRTD, MTF, SiTF, NETD, FPN, non-uniformity, FOV, distortion, magnification	SEM-VI computerized broadband LED light source (to be integrated with DCB blackbody)	Night: from 0.00001 to 10 cd/m^2
D		Additional frame grabber: CL, GigE, LVDS, CVBS, YpbPr, CoaXPress, HD-SDI, HD-CVI, HD-TVI, AHD, DVI, HDMI, Fire Wire	Advanced: as in 3c but also: Response function, 3DNoise, NPSD, Bad pixels, PVF, SRF, ATF, SNR, MDTD, Auto-MRTD	HAL - computerized halogen light source (to be integrated with TCB blackbody)	Day/Night 0.00001 to 2000cd/m^2 DAL – up to 10kcd/m^2
E			Additional optional parameters: TOD, NER, NEI, NEFD, NEP, D*	DAL - computerized halogen/LED light source (to be used as a separate module)	

	6	7	8	9	10
Code	**Test range of TV cameras**	**Virtual test system**	**Boresight**	**Simulated distance**	**Evaluation software**
A	No	No	No	Fixed distance: optical infinity	No
B	Basic: measurement of resolution at regulated illuminance conditions	Yes - for thermal imagers	Yes	Manual step regulation distance at least from 100xfocal length of the collimator to optical infinity	Simterm
C	Typical: resolution, MTF, Sensitivity, NEI (noise equivalent illuminance), SiTF, FOV	Yes - for VIS-NIR cameras		Computerized ultra precision regulation of simulated distance from 100xfocal length of the collimator to optical infinity	Mosot
D	Expanded: as in 6c but additionally MRC	Yes - for both thermal imagers and VIS-NIR cameras			Mosot, Movis
E	Optional parameters: 3D Noise, Uniformity, magnification, NPSD, Bad pixels, Distortion, SNR, Responsivity function, TOD tests, TRM3 tests				Simterm. Mosot. Movis

Detail description of available options presented in table above is presented below.

1. Image projector

Performance of tested thermal imagers vary very significantly and therefore there are different requirements on collimator, blackbody of test systems. In general resolution of the collimator should be at least five times (ideal case - ten times) better than Nyquist frequency (resolution) of tested thermal imager. Next, temporal stability of the blackbody should be at least ten times better than level of measured noise parameters like NETD, FPN, non uniformity. Nyquist frequency (resolution) of tested thermal imagers vary significantly: from about 0.5 lp/mrad (imagers of wide FOV) to over 20 lp/mrad (imagers of big optics for long distance surveillance). NETD can vary from about 10 mK to 120 mK. Therefore the image projector module (collimator, blackbody, rotary wheel) is offered in two versions: Standard and Extra.

Table 3. Versions of image projector

Parameter	Standard version	Extra version
Collimator resolution	>50 lp/mrad	> 100 lp/mrad
Blackbody temporal stability	3 mK	1 mK
Recommendation for use	for testing thermal imagers/VIS-NIR cameras of resolution not higher than about 7.5 lp/mrad (acceptable situation) or lower than 5 lp/mrad (ideal situation); NETD not lower than 30 mK - at least 95% thermal imagers on the market	testing virtually any thermal imager available on market

DT system using built Standard image projector is slightly cheaper than in case of Extra version due to higher costs of ultra performance mirrors and aligning precision needed to design the collimator and some changes in electronics of the blackbody needed to improve its temporal stability.

2. Frame grabbers

Great majority of thermal imagers and VIS/NIR cameras used in surveillance applications generate video using two standard analog video formats: PAL or NTSC. Therefore analog video frame grabber that enables acquisition of video signals in PAL/NTSC format is a standard module of DT test system.

There are nowadays on market cameras that generate images in higher resolution or at higher speed than mentioned above analog video formats (PAL: 720x576 at 25 FPS) or of the same resolution/speed but using digital transfer. A long series of video formats is used: USB 2.0/3.0, analog HD/SD TV (CVBS, RGB, YpbPr), LVDS or RS-422, Camera Link, CoaXPress, GigE, IEEE 1394 (Fire Wire), SDI, DVI, HDMI. Therefore Inframet offers also additional frame grabbers to enable acquisition of video from any camera available on market.

Detail description of codes used in column no 2 is presented below:

2a - no frame grabber is delivered. This option is optimal for situation when tested imager is equipped with its internal display and only MRTD is to be measured. This option is not acceptable when more extensive testing of thermal imagers/VIS-Nir cameras is to be done.

2b - Frame grabber accepting images in standard analog video format (PAL/NTSC) is delivered.

2c - TAS software is modified to accept cideo in USB 2.0/3.0 format. Attention: Camera should be compatible with MS DirectX.

2d - Second frame grabber is delivered: Customer can choose from a long series of frame grabbers: analog HD/SD TV (CVBS, RGB, YpbPr), LVDS or RS-422, Camera Link, CoaXPress, GigE, IEEE 1394 (Fire Wire), SDI, DVI, HDMI.

It is expected that customers know parameters of tested camera needed to configure earlier mentioned frame grabbers.

Attention: More frame grabbers can be optionally delivered. Please contact Inframet with your specific requirements.

3. Test range of thermal imagers

Test range of thermal imagers is described by a number of parameters that are to be measured.

Test range of thermal imagers is determined by two factors:

1)number of IR targets to be delivered,

2)number of test modules in TAS-T computer program, SUB-T program.
Options A-E presents lists of parameters that can be measured.

4. Light source

Light source is needed for testing VIS-NIR cameras. This module can be delivered in several versions characterized by different design, test capabilities and different price:
4a - No light source module. This version recommended when only thermal imagers are to be tested.
4b – SEM-V computerized white LED light source is delivered. SEM-V source is to be integrated with TCB differential blackbody.
SEM-V light source is a small light module that use white LED as light emitter. Light intensity is electronically controlled from PC. The SEM-V module is attached to a modified TCB differential blackbody. After modification typical TCB blackbody becomes DCB blackbody (dual color blackbody). This DCB blackbody is black in MWIR/LWIR range but is also white in VIS/NIR range. The integration of light source to differential blackbody enables testing both thermal imagers and VIS-NIR cameras at the same time. No movement of mechanical modules is needed.
This option is recommended for testing color VIS cameras for day application of spectrum limited to visible band. .
4c – The same situation like in 4a but SEM-VI ligtht source is offered. It is a special LED light source that offers quasi uniform spectrum up to about 800 nm (option up to 1000nm). This option is recommended for testing monochromatic VIS-NIR cameras.
4d) HAL - computerized halogen light source. HAL source to be integrated with DCB blackbody. This light source emits broadband light of color temperature 2856K.
4d - DAL computerized halogen/LED light source module is delivered. The DAL light source is a multi-channel calibrated light source developed for realistic simulation of light conditions from dark, moonless nights to ultra bright days at different geographical regions. Design of this source is optimized for use in systems for testing VIS-NIR cameras (color/monochrome CCD/CMOS/ICCD/EBCCD cameras) used for long/medium range surveillance applications. DAL light source offers extremely high dynamic range, continuous regulation of light intensity (ability to simulate both ultra bright days and ultra nights), fully computerized design. User can regulate spectrum of emitted light in order to simulate conditions at different surveillance scenarios caused by different spectrum of light that illuminate scenery of interest and different spectral reflectance of such scenery. Resistibility of tested VIS-NIR camera against UV light reflected from the scenery of interest can be checked, too. The DAL source can work in four different modes: 1)halogen bulb of 2856K color temperature spectrum, 2) white broadband LED of color temperature over 5000K spectrum in visible range, 3)mixed mode when both halogen and white broadband LED are active at regulated ratio of halogen/LED light intensity, 4)high intensity UV LED light mixed with halogen light or white LED light. Switching of modes or work in mixed mode enables significant variations of spectrum of emitted light.

5. Light level

All the light sources (SEM, HAL and DAL) can be delivered in different versions capable to simulate
5b)day conditions,
5c) night conditions
5d) both day conditions and night conditions.
It should be noted that all light sources offer very high dynamic of regulation of light intensity (100 000 000 times in case of day/night version.

6. Test range of VIS-NIR cameras

Test range of TV cameras is described by a number of parameters that are to be measured. Test range can vary from a measurement of only resolution parameter (tests by final users) to measurement of a long series of parameters (resolution, MTF, Distortion, FOV, Sensitivity, SNR, NEI, FPN, Non Uniformity, Resposivity function, MRC, 3D Noise, Number of bad pixels and bad pixel localisation) by design teams developing new TV camera.
Test range of TV cameras is determined by two factors:
1)number of VIS/NIR targets to be delivered,
2)number of test modules in TAS-V computer program.

7. **Virtual test system**

There several drawbacks of classical methods to measure subjective parameters like MRTD in case of thermal imagers or MRC in case of TV cameras:
1) time consuming measurement,
2) a long series of resolution patterns in needed to measure accurately these functions in wide spatial frequency range,
3) there are phasing problems when testing under-sampled imagers (typical case in moder FPA imagers).
There have been proposed several methods to overcome these drawbacks in case of MRTD: AutoMRTD method, dynamic MRTD, TOD method, MTDP, etc. However none of these method was accepted by international community due to a series of reasons.

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Recently Inframet proposed concepts of Virtual MRTD or Virtual MRC. These parameters are measured using the following procedure:
1. Objective parameters of tested thermal imagers like MTF, 3D Noise, SiTF are measured.
2. A computer simulator of tested imager is created.
3. MRTD is measured but not using real system but using the computer simulator.
The proposed method was verified experimentally. It was found that proposed Virtual MRTD method generated measurement results with good agreement with results from classical MRTD method.
The main advantage of virtual test system is shortened measurement time. It is also possible to measure MRTD (or MRC) over Nyquist frequency.
Detail description of codes used in 2 column no 7 is presented below:
7a - no software to enable testing thermal imagers or TV cameras using computer simulators of such imagers
7 b - Dubterm program is delivered. This program enables to carry out measurement of Virtual MRTD.
7 c - Dubvis program is delivered. This program enables to carry out measurement of Virtual MRC.
7d - both Dubterm and Dubvis are delivered.

8. Boresight

Boresight of thermal imagers and VIS-NIR cameras is done using additional targets and BOR computer program that carries out analysis of images generated by both thermal imagers and VIS_NIR cameras. The program calculates angle between a)optical axis of thermal imager at several FOV, b)optical axis of VIS-NIR camera at different magnification of zoom objective, c) optical axis of thermal imager relative to optical axis of VIS-NIR camera.
8a - no BOR computer program
8b - one additional IR aligning target is delivered and BOR computer program is delivered.

9. **Simulated distance**

Measurement of parameters of tested imagers is typically done when test system simulate optical Infinity distance. However it is useful to check imager ability to generate sharp Images of targets located at shorter distances but within imager focus range. Therefore Inframet offers three versions of DT system
9 a - Simulated distance: fixed: optical infinity.
9b - Manual step regulation distance at least from 100xfocal length of the collimator to optical infinity.User can specify up to 5 simulated distances within earlier mentioned range. Special VDT variable distance targer is delivered
9c - Computerized ultra precision regulation of simulated distance from 100xfocal length of the collimator to optical infinity. Special FOC motorized platform is delivered. Precision regulation of simulated distance (distance resolution below 1m at low distance range).

10. Evaluation software

The main task of DT test system is to enable measurement of parameters of thermal imagers, optionally of TV cameras. However, parameters of thermal imagers or of VIS-NIR cameras are not easy for interpretation. Therefore even specialists can have problems with interpretation of test results. In order to make interpretation of test results easy task three computer simulation programs are offered:

1. Simterm - the program generates images that resemble images generated by real thermal imagers. We can insert parameters of tested thermal imager and check how would look images of different real targets at different field conditions generated by tested imager.
2. Mosot - the program calculates detection, recognition and identification ranges of several targets using a thermal imager of known MRTD
3. Movis - the program calculates detection, recognition and identification ranges of several targets using a VIS-NIR camera of known MRC.

Detail description of codes used in 2 column no 10 is presented below:
10a - no evaluation software
10b - Simterm program is delivered.
10c - Mosot are delivered.
10d Mosot and Movis are delivered
10e - Simterm, Mosot, Movis program are delivered.

4 Summary

1. DT systems are one of most matured Inframet products that have been verified by a long series of customers all over the world. The system has been improved over the last decade and is an unique test system due to its powerful test capabilities.

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2. Software is an important block of DT test system that increase significantly system test capabilities.
3. DT test system can be easily configured by potential user to suit for his applications by adding/removing modules as shown in Table 1 and in Table 2.
4. If you have problems to choose proper versions of DT test system please **describe your application** in words and Inframet staff shall propose an optimal version.
5. This data sheet present a list of typical versions of DT test system. Inframet can deliver customized versions not listed in Table 2.
6. Please contact Inframet in order to get a detail proposal for chosen version of DT test system.

Version 5.3

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