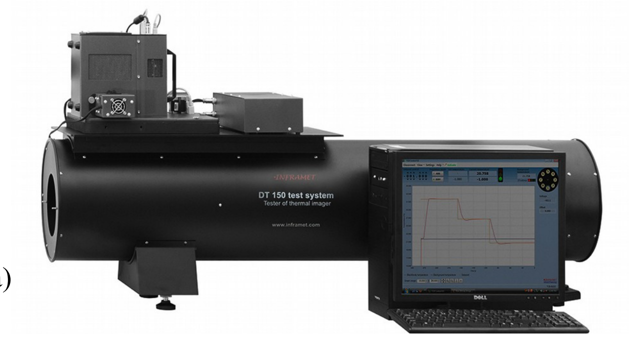
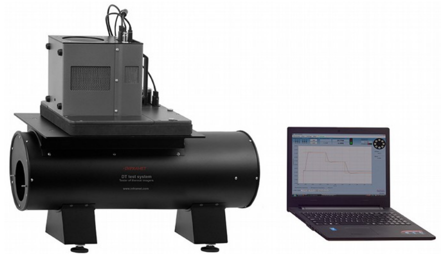
DT

Testers of thermal imagers

a) 

b) 

c)

Fig.1. Photos of two exemplary DT systems: a)most popular DT150 system for testing medium/long range imagers, b)DT100 for testing short range imagers, c) DT400 system for testing ultra long range imagers

1 BASIC INFORMATION

The DT series systems are specialized test systems optimized for task of extensive testing of surveillance thermal imagers (option: camera cores) at laboratory/depot conditions. The DT systems can be also optionally used for standard testing VIS-NIR cameras, and boresighting of thermal imagers to VIS-NIR cameras. However, specialized TVT system is recommended for expanded testing VIS-NIR cameras http://www.inframet.com/tv_cameras.htm.

DT test systems enable extensive testing of virtually all surveillance thermal imagers cameras available on the market. Imagers having optics of any size and resolution, generating output image in any electronic format, manufactured in any form can be tested. DT systems are the most popular Inframet products used in hundreds of laboratories worldwide including top world manufacturers – see reference list on Inframet website (http://inframet.com/references.htm).

2 TEST CONCEPT

DT series system is a variable target projector projects optical images of different reference targets into direction of a tested thermal imager (or VIS-NIR camera) that generates electronic copy of perceived optical images. Quality of the electronic images generated by the tested imager is evaluated directly by humans or by software and important characteristics of tested imager are measured.

TCB area blackbody emitting radiation in MWIR/LWIR range is a typical radiation source in DT system and is used when testing thermal imagers. Optional light sources are used when testing VIS-NIR cameras.

Boresight of thermal imagers and VIS-NIR cameras is done using a computerized test system that carries out analysis of images generated by thermal imagers and VIS-NIR cameras.

Ability of testing imagers generating output image in different electronic image formats is achieved using a series of frame grabbers and advanced acquisition/image processing software.

3 DT system structure

DT test system is a modular system built in most advanced version using a long series of blocks. Some of these blocks can be later delivered in different versions. The list of main blocks of DT system is as below:

1. CDT off axis reflective collimator (collimators of different aperture, focal length and optical quality are offered for different versions of DT system). Details at http://www.inframet.com/Data%20sheets/CDT.pdf
2. TCB-2D differential blackbody (can be optionally delivered as special DCB color blackbody for co-operation with a light source when VIS-NIR cameras are to be tested). Details as in http://www.inframet.com/color_blackbodies.htm
3. MRW-8 motorized rotary wheel (optimized for cooperation with a set of IR targets and visible targets). Details as in http://www.inframet.com/rotary_wheels.htm
4. Set of IR targets (targets to be used for testing thermal imagers - different configurations are possible). Details as in http://www.inframet.com/targets.htm
5. PAB passive area blackbody (used during noise/sensitivity tests of thermal imagers)
6. Analog video frame grabber for capturing analog video image (http://www.inframet.com/computing_system.htm).
7. Digital frame grabber (grabbers) for capturing video digital images in different standards: Camera Link, GigE , LVDS, HD-SDI/DVI/HDMI, AHD/HD-TVI/HD-CVI, CoaXPress, USB2.0, USB3.0, Ethernet (http://www.inframet.com/computing_system.htm).
8. PC set - typical PC/laptop working under Windows 7/10 operating system (with installed frame grabbers and tested by Inframet to check compatibility with the grabbers and Inframet software). Details as in http://www.inframet.com/computing_system.htm
9. High performance monitor for subjective image quality tests of tested imagers
10. Light source: different light sources are available: a)SEM - LED light source offered in two versions of different spectral bands), b)HAL - halogen light source. The light source is to be integrated with a special DCB color blackbody. Details as in http://www.inframet.com/color_blackbodies.htm. Light sources can simulate
11. Set of visible/NIR targets (targets to be used for testing VIS-NIR cameras - different configurations are possible). Details as in http://www.inframet.com/targets.htm
12. Set of OSIM systems that simulate optics of specified F-number and transmission when measuring noise/ sensitivity parameters of thermal camera cores or VIS-NIR camera cores
13. RP rotation platform for positioning of tested imager
14. BOREX boresight stage – special mechanical stage with autocollimation capabilities where the tested imager is attached that is used during boresight tests to a reference mechanical axis (plane)
15. Tools to regulate simulated distance: manual VDT variable distance target or FOC motorized focusing platform
16. 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
17. 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.
18. SUB-T program - computer program that offers software support during measurement of subjective parameters like MRTD, MDTD (and TOD - option)
19. Light Control program (different versions: SEM Control, HAL Control)
20. MOT Control program (control of FOC focusing stage)
21. TAS-V program: computer program used for semi-automatic measurement of a series of parameters of VIS-NIR cameras. Program is delivered in form of different versions of different test capabilities.
22. Virtual imager software: set of two computer programs that enable computer simulation of tested thermal imagers/VIS-NIR cameras and can speed up and increase accuracy of measurement of subjective parameters like MRTD and MRC
23. BOR computer program (enables calculation of aligning errors of thermal imagers and VIS-NIR cameras)
24. Performance evaluation software: a series of computer programs (Simterm, Mosot, Movis) that enable evaluation of performance of tested thermal imager/ VIS-NIR camera of measured parameters

4 SPECIAL FEATURES

DT systems use basically a classical test concept known from 1980s. Test range of thermal imagers is similar to competitor test systems. However DT systems are characterized by a series of special features:

1. Blackbody head integrated with electronic controller. This means that the blackbody is a single module in situation when competitors offers blackbodies in form of two modules. The cables between controller and blackbody head are eliminated (improved reliability). Distance between temperate sensors and electronics is very short (higher resistance to EMI). This solution significantly increase blackbody reliability and extend life time.
2. Vertical design configuration. It means that MRW8 rotary wheel is located on CDT collimator and later TCB blackbody is located on MRW8 wheel. This solution makes DT system compact (smaller optical table needed) and more resistible to vibrations because all block are fixed to the CDT collimator. Next, this configuration improves also temperature uniformity of blackbody emitter (crucial when testing cooled thermal imagers of very low NETD - see http://www.if.pwr.wroc.pl/~optappl/article.php?lp=834).
3. Optional dual color blackbody. It is a special version of classical differential area blackbody combined with a light source that emits radiation in both MWIR/LWIR range and VIS-NIR range. It is a patent pending technical solution extremely useful when testing dual imaging systems (thermal imager combined with VIS-NIR camera). Both imaging systems can see a test target at the same time. No mechanical exchange of blackbody for a light source is needed. There are on market similar fused blackbodies but of much lower performance properties (emissivity and temperature range of the blackbody emitter, spectral range and regulation dynamic of light source).
4. Image acquisition from any imager. There are on market imagers generating video image using a long series of electronic interfaces like analog video, CL, GigE, LVDS, CVBS, YpbPr, CoaXPress, HD-SDI, HD-CVI, HD-VIS-NIR I, AHD, DVI, HDMI, Fire Wire. Images can be generated in dynamic that varies from 8-bit to 16 bit. Some manufactures use non standard technical solutions. Inframet test systems can capture and do image analysis of video images from any imaging system preset on market.
5. Blackbody of ultra high emissivity. Inframet is the only manufacture of systems for testing thermal imagers that offer in standard version blackbody of ultra hight emissivity 0.98±0.01 when typical values are below 0.97.
6. Variable contrast USAF1951 targets. VIS-NIR cameras are typically tested using low cost USAF 1951 targets of 100% contrast. However, these typical targets of 100% contrast poorly simulate low contrast targets commonly met in real life conditions. Inframet offers a set of USAF 1951 targets of contrast from 2% to 100%. It makes possible to measure Minimal Resolvable Contract (MRC) function of tested VIS-NIR camera and calculate detection/recognition/identification ranges according to rules of NATO standards.
7. Long recalibration intervals. Manufactures of typical test systems recommends recalibration of blackbody once per year or once per two years. Inframet can optionally deliver special blackbody of ultra small temporal drifts and then recalibration interval can be extended to once per four years or even longer period.
8. Variable distance simulation. Typical DT test system like similar systems offered on market simulates test target located at so called optical infinity. However optional DT system can enable continuous or step regulation of simulated distance.
9. Evaluation software. In order to make easier interpretation of test results a set of three computer simulation programs is offered: 1) Simterm - the program generates images that resemble images generated by real thermal imagers. User can insert parameters of tested thermal imager and see 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.
10. Educational support. Inframet is the only manufacturer of equipment for testing thermal imagers that offers free book on testing thermal imagers http://www.inframet.pl/Literature/Testing%20thermal%20imagers.pdf.

5 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 basic division of DT series system is based on output aperture of the collimator (Table 1). Higher collimator aperture means larger collimator.

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

System aperture code	Collimator output aperture [mm]	Collimator focal lenth [mm]	Collimator code
DT60	60	600	CDT660
DT 80	80	600	CDT860
DT100	100	800	CDT1080
DT 110	110	1000	CDT1100
DT125	125	1000	CDT12100
DT 150	150	1500 or 1200	CDT15120 or CDT15150
DT 200	200	2000 or 1600	CDT20160 or CDT20200
DT 250	250	2000 or 2500	CDT25200 or CDT15120
DT 300	300	2000 or 3000	CDT30200 or CDT30300
DT 350	350	2000 or 3500	CDT35200 or CDT35350
DT400	400	2400 or 4000	CDT40240 or CDT40400
DT450	450	5000	CDT45500
DT500	500	5000	CDT50500
DT600	600	6000	CDT60600

The basic rules for choosing proper collimator are following:

- Collimator aperture should be bigger than aperture of optics of tested imagers to allow easy aligning and proper work of test system. Minimal difference between collimator aperture and image aperture is about 4 mm, recommended value is about 15-25mm.
- Collimator focal length should not to be too long or too short. Too long/too short focal length creates situation when number of available 4-bar targets (see https://www.inframet.com/targets.htm) that can be resolved by tested imager is too small to measure propery MRTD. It is recommended that spatial frequency of aviailable 4-bar targets should cover at least the range from 0.2 to 1.2 of Nyquest frequency of tested imager (or at least from 0.4 to 1 of Nyquest frequency).
- A common error of choosing big collimators (large aperture and long focal length) for testing small wide FOV thermal imagers should be avoided. Even largest 4-targets can be barely resolved in such a case and system test capabilties are limited.
- For details on collimators used to built DT systems please look at http://www.inframet.com/Data%20sheets/CDT.pdf

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. Collimator resolution,
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 intensity range
6. Test range of VIS-NIR cameras
7. Tests of camera cores
8. Boresighting capabilities
9. Simulated distance
10. Performance evaluation software

Therefore collimator aperture code and additional ten letter code are use to describe precisely parameters of DT series systems. For example DT150 BBBAA-AAAAA is a DT system having collimator of 150mm aperture and design and test capabilities as described in Tab.2.

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

	1	2	3	4	5	6	7	8	9	10
Code	Collimator	Frame grabbers	Test range of thermal imagers	Light source	Light intensity range	Test range of VIS-NIR cameras	Tests of camera cores	Bore-sight	Simulated distance	Evaluation software
A	Standard resolution	No frame grabber	Basic: MRTD	No light source	No	No	No	No	Fixed distance: optical infinity	No
B	High resolution	Analog video (PAL/NTSC) grabber	Typical: MRTD, MTF, SiTF, NETD, FPN, non-uniformity, FOV	SEM0 – not regulated white LED of typical spectrum	about 70 cd/m^2	Basic: measurement of resolution at regulated illuminance conditions	Yes – for thermal imagers	Reference optical axis	Manual step regulation distance	Simterm
C	Ultra high resolution	Additional one digital video grabber (type chosen by customer)	Typical Extra: MRTD, MTF, SiTF, NETD, FPN, non-uniformity, FOV, distortion, magnification	SEM1- improved white LED light source of spectral band 450-700nm.	Day: 0.2 to 2000cd/m^2	Typical: resolution, MTF, Sensitivity, NEI (noise equivalent illuminance), SiTF, FOV	Yes – for VIS-NIR cameras	Both reference optical and mechanical axis (plane)	Computerized ultra precision regulation of simulated distance	Mosot
D		As in B but two additional digital video grabbers	Advanced: as in 3C but also: Response function, 3DNoise, NPSD, Bad pixels, PVF, SRF, ATF, SNR, MDTD, AutoMRTD	SEM2- broadband LED light source of quasi uniform spectrum in 400-850 nm band	Night: 0.0001 to 10 cd/m^2	Typical Extra: MRC, resolution, MTF, Sensitivity, NEI (noise equivalent illuminance), SiTF, FOV	Yes – for both thermal imagers and VIS-NIR cameras			Mosot, Movis
E		Custom set of frame grabbers	Additional optional parameters: TOD, NER, NEI, NEFD, NEP, D*	HAL – broadband halogen light source having 2856K color temperature spectrum at 400-1000nm band.	Day/Night 0.0001 to 2000cd/m^2	Additional parameters: 3D Noise, Uniformity, magnification, NPSD, Bad pixels, Distortion, SNR, Responsivity function				Simterm, Mosot, Movis

Detail description of available options presented in Table 2 is presented in next sections.

DT

Testers of thermal imagers

1. Collimator

Image resolution of tested thermal imagers vary significantly. Therefore there are different requirements on resolution of the off axis reflective collimator used in the test system.
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 (https://www.degruyter.com/downloadpdf/j/oere.2007.15.issue-2/s11772-007-0005-9/s11772-007-0005-9.pdf).
Therefore the collimators used as blocks of DT systems are offered in three versions: Standard Resolution, High Resolution, Ultra Resolution.
Manufacturing accuracy of collimating mirror and collimator resolution are two crucial parameters that determine version of the collimator.

Table 3. Versions of off axis reflective collimators

Parameter	SR standard resolution	HR high resolution	UR ultra high resolution
Manufacturing accuracy of collimating mirror (P-V at $\lambda = 630$ nm)	not worse than $\lambda/2$	not worse than $\lambda/6$	not worse than $\lambda/10$ (option $\lambda/12$)
Collimator resolution (precision values at http://www.inframet.com/Data%20sheets/CDT.pdf)	20-55 lp/mrad depends on collimator aperture and focal length	60-180 lp/mrad depends on collimator aperture and focal length	90-500 lp/mrad depends on collimator aperture and focal length
Application recommendations	Testing short range imagers of resolution not higher than about 5 lp/mrad	Testing virtually all thermal imagers available on market Recommended for universal test systems.	Recommended for testing space class imagers of ultra high Nyquist frequency.

Detail description of codes used in column no 1 is presented below:
1A- DT system built using SR standard resolution collimator
1B- DT system built using HR high resolution collimator
1C- DT system built using UR ultra high resolution collimator
DT system built using HR high resolution collimator is the most popular choice. DT systems built using SR standard resolution collimators are chosen by customers who want to reduce price and need a system only for testing small short range imagers. UR ultra resolution version is recommended for most demanding applicaions.
Details of collimators used in DT system are at http://www.inframet.com/Data%20sheets/CDT.pdf.

2. Frame grabbers

Frame grabber is an electronic device needed to be installed in PC to enable to capture video image generated by tested imager. Inframet offers a series of frame grabbers that makes possible to capture images from virtually all types of electronic imagers offered on market.
Detail description of codes used in column no 2 is presented below:
2A - no frame grabber is delivered. Output video image cannot be captured and digitized but can be displayed on internal or external displays without use of PC set. This option is optimal for situation when only subjective parameters like MRTD or MRC is required.
2B – Analog frame grabber to capture video images in standard analog video formats (PAL/NTSC) is delivered. Output video image from such imagers cant be captured and digitized.
2C – One additional digital frame grabber is delivered. Customer can choose one of digital image standards used by tested imagers: Camera Link, GigE , LVDS, HD-SDI/DVI/HDMI, HD-TVI/HD-CVI, CoaXPress, USB2.0, USB3.0, Ethernet. Attention: virtual frame grabber is delivered for USB2.0, USB3.0, Ethernet standards. It is expected that software driver of tested imager must be compatible with MS DirectX or MS MediaFoundation.
2D – Two additional digital frame grabber are delivered. Frame grabber as specified above.
2E. More frame grabbers or non standard frame grabbers are 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. Letter from A to E represents list of parameters that can be measured. Higher letter means more parameters can be measured. Increased number of measurable parameters is achieved by adding more IR targets and more modules in test software.

4. Light source

Light source is needed for testing VIS-NIR cameras. This module can be delivered in several versions characterized by different design, performance parameters and different price:
4A - No light source. This version recommended when only thermal imagers are to be tested.
4B – SEM1 white LED light source is delivered. It emits light having spectrum of roughly 5000K temperature in spectral band: 450-630nm. The light source can be treated as improved typical white LED. This option is recommended for testing color VIS cameras for day application of spectrum limited to visible band.
4C – SEM2 broadband LED light source is delivered. It emits light having spectrum of 5000K temperature in wide spectral band: 400-850nm. This option is recommended for testing both color and monochromatic VIS-NIR cameras.
4D) HAL - broadband halogen light source. It emits light having spectrum of 2850K color temperature in wide spectral band: 400-1000nm. This option is recommended for tests when type A illumination is needed.
Light intensity of all light sources is controlled from PC. The light source is to be integrated with a blackbody to form so called color blackbody that at the same time emits thermal radiation in MWIR/LWIR range and light in VIS-NIR range.
Attention: more advanced DAL light source characterized by variable spectrum and ultra high light intensity range can be optionally delivered for ultra expanded tests of VIS-NIR cameras.

5. Light intensity range

All the light sources can be delivered in different versions of different light intensity ranges:
5B)Day : 0.2 to 2000cd/m
5C) Night: 0.0001 to 10 cd/m
5D) Day/Night: 0.0001 to 2000cd/m^2

6. Test range of VIS-NIR cameras

Test range of VIS-NIR cameras is described by a number of parameters that are to be measured. Letter from A to E represents lists of parameters that can be measured. Higher letter means more parameters to be measured.

7. Tests of camera cores

Camera core is basically an electronic imager (thermal imager, VIS-NIR camera) without optics but capable to generate output electronic image. DT system can be used to measure noise/sensitivity parameters of camera cores:
thermal camera core: NETD, FPN, non uniformity, SiTF
VIS-NIR camera core: NEI, non uniformity, SiTF.
Measurement is done using special devices that simulate optics of specified F-number and transmission and modified TAS computer program.
Detail description of codes:
7A - no ability to test thermal camera cores or VIS-NIR camera cores
7B - ability to test thermal camera cores
7C – ability to test VIS-NIR camera cores
7D - ability to test thermal camera cores or VIS-NIR camera cores.

8. Boresight

8A - no boresight capabilities
8B – measurement of boresight errors of tested thermal imager/VIS-NIR camera to a reference optical axis.
Angles between optical axis of thermal imager (or VIS-NIR camera) at different FOV or between optical axis of thermal imager and optical axis of VIS-NIR camera are measured.
8C – as in 8B but additionally measurement of boresight errors of tested thermal imager/VIS-NIR camera to a reference mechanical axis (plane). Useful option if tested imager should be always kept at the same angular position relative to optical axis of the CDT collimator.

9. Simulated distance

Tests of imagers are typically done using test systems simulate reference targets at optical infinity. Operational distance of typical surveillance imagers can be roughly considered as optical infinity. However, some users of DT system want to to check imager ability to generate sharp images of targets located at shorter distances within imager focus range. Therefore Inframet offers three versions of DT system

9A - Simulated distance: optical infinity.

9B - Manual step regulation (five steps) of simulate distance in range from at least 100xfocal length of the collimator to optical infinity. Special VDT variable distance target is delivered.

9C - Computerized ultra precision regulation of simulated distance in range from at least 100xfocal length of the collimator to optical infinity. Special FOC motorized focusing platform is delivered.

10. Evaluation software

In order to make easier interpretation of test results three computer simulation programs are offered:

1. Simterm - the program simulates thermal imagers of known design parameters. It generates images that resemble images generated by real thermal imagers. Details at http://www.inframet.com/computer_simulators.htm
2. Mosot - the program calculates detection, recognition and identification ranges of thermal imagers of known MRTD
3. Movis - the program calculates detection, recognition and identification ranges of 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.

Exemplary coding

DT150 DCB AA-AAAAA -popular version for typical testing thermal imagers. The code means:

Digital code: Collimator aperture 150mm

Letter code:

1. Collimator type: High resolution
2. Number and type of frame grabbers: analog video frame grabber and addtional digital frame grabber
3. Test range of thermal imagers: Typical: MRTD, MTF, SiTF, NETD, FPN, non-uniformity, FOV
4. Light source: No
5. Light level: No
6. Test range of VIS-NIR cameras No
7. Tests of camera cores: No
8. Boresight: No
9. Simulated distance: Infinity
10. Evaluation software: No

6 Additional options

Inframet can deliver as additional options:

- Optical tables to be used as stationary, anti-vibration platforms for DT system and tested imager
- Mobile tables to be used as mobile anti-vibration platforms large, heavy tested imagers
- Positioning stages to be used for precision linear and angular positioning of tested imagers.
- Ultra advanced multi-channel DAL light source (http://www.inframet.com/light_sources.htm) for testing VIS-NIR cameras instead of typical SEM or HAL light sources.

7 Summary

1. DT systems are one of most matured Inframet products used in hundreds of laboratories worldwide including top world manufacturers/scientific institutes.
2. DT test system can be easily configured by potential user to suit for his applications by adding/removing features as shown in Table 1 and in Table 2.
3. If you have problems to choose proper version of DT test system please describe your application in words (type of imager is to be tested, what test conditions, output electronic standard preferably in form of data sheet of tested imager) and Inframet staff shall propose an optimal version.
4. This data sheet present a list of typical versions of DT test system. Inframet can deliver customized versions not listed in Table 2, too.
5. Please contact Inframet in order to get a detail proposal for chosen version of DT test system.

Version 9.5

CONTACT: Tel: +48 226668780 Fax: +48 22 3987244 Email: info@inframet.com