DT

Systems for testing thermal imaging systems



a) b) c)

Fig. 1. Photos of three exemplary DT systems: a) most popular DT15150 system for testing medium range thermal imagers, b) DT660 for testing short range imagers, c) DT40400 system for testing long range thermal imagers

1 Introduction

The DT series systems are specialized test systems optimized for task of extensive testing/boresight of thermal imagers and thermal camera cores at laboratory/depot conditions.

DT test systems are modular test systems that can be configured into myriad of versions of different design, test/boresight capabilities and different price. DT systems enable extensive testing of virtually all thermal imagers available on the market. The only exception from this rule are imagers of very small distance range (very wide FOV).

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 What thermal imager can be tested?

DT series systems can enable extensive testing and boresighting of almost all thermal imagers offered on market. in detail, DT systems have been designed for testing/boresight of three main groups of thermal imagers:

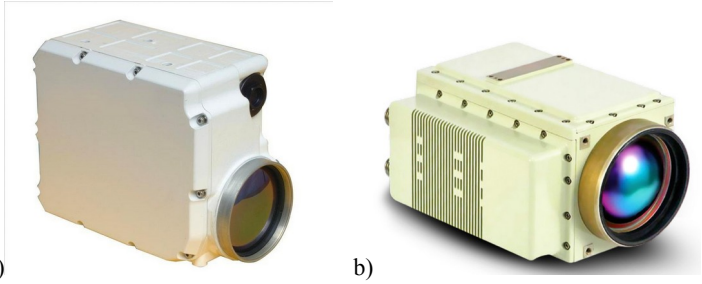
1. Optical output short/medium thermal range imagers: a) thermal monocular: b) thermal binoculars, c) thermal sight, d) thermal clip ons (Fig. 2)
2. Electronic output medium/long range thermal sights for vechicles (Fig. 3)
3. Ectronic output long/ ultra long range thermal imagers (Fig. 4).

It should be also noted that DT systems are not optimal for testing very short range (wide FOV) imagers. Different test systems (DTR, TCAR, SAFT, TWAP) are recommended.



a) b) c) d)

Fig. 2. Four optical output short/medium thermal range imagers: a) thermal monocular: b) thermal binoculars, c) thermal scope, d) thermal clip ons.



a) b)

Fig. 3. Two electronic output medium/long range thermal sights for vehicles



Fig. 4. Two electronic output long/ ultra long range thermal imagers

3 Test capabilities

DT systems in expanded versions can enable measurement of a long list of parameters of thermal imagers. These parameters are listed below using criterion of their popularity:

1. MRTD (Mimimal Resolvable Temperature Difference)
2. NETD (Noise Equivalent Temperature Difference)
3. MTF (Modulation Transfer Function)
4. FOV (Field of View)
5. SiTF (Signal Transfer Function)
6. Distortion
7. FPN (Fix Pattern Noise)
8. 3D-Noise
9. Bad pixels
10. Magnification
11. Response function
12. MDTD (Minimal Detectable Temperature Difference)
13. MTDP (Minimal Temperature Difference Perceived)
14. AutoMRTD Automatic Minimal Resolvable Temperature Difference)
15. VirtMRTD (Virtual MRTD)
16. NPSD (Noise Power Spectral Density)
17. PVF (Point Visibility Factor)
18. SRF (Slit Response Function)
19. SNR (Signal To Noise Ratio)
20. NER (Noise Equivalent Radiance)
21. NEI (Noise Equivalent Irradiance)
22. NEP (Noise Equivalent Power)
23. D* (Normalized Detectivity)

Following boresight tests can be carried out using DT systems:

1. Zoom-through boresight: angular shift of target marked by imager line of sight (indicated by aiming mark) when zooming,
2. Focus-through boresight: angular shift of target marked by imager line of sight (indicated by aiming mark) when focusing (at different range of focusing depending on version)
3. Deflection angle: angular shift of target marked by line of sight of telescopic sight (indicated by aiming mark) at two modes: 1) clip on not used, 2) clip-on is fixed to weapon.
4. Boresight to reference mechanical axis: angle between imager optical axis (line of sight) and reference mechanical axis (Picatinny/dovetail rail).
5. Boresight to reference mechanical plane: angle between imager optical axis (line of sight) and axis perpendicular to reference mechanical plane (typically front wall of medium/long distance thermal sights.
6. Boresight of UUT to collimator: checking if tested UUT is properly positioned relative to collimator output of test system.

4 How DT systems are built?

DT test system is a modular system built in most expaned version using over twenty blocks:

1. CDT off axis reflective collimator (collimators of different aperture, focal length and optical quality are available for different applications),
2. MRW motorized rotary wheel (version of rotary wheel is determined by version of collimator, its FOV and number of targets) or FRW focusing rotary wheel (optional replacement of MRW wheel),
3. TCB precision differential blackbody –versions of different size – and optional visible illuminator
4. Set of IR targets (different configurations are possible),
5. PAB passive area blackbody (used during noise/sensitivity tests of thermal imagers),
6. Set of frame grabber cards to capture video image from electronic output thermal imagers,
7. PC – typical PC working under Windows operating system (laptop or desktop PC are delivered),
8. High performance monitor for subjective image quality tests of tested analog video imagers,
9. Set of control programs: Collimator Control, Blackbody Control,Target Control,
10. Set of measurement support programs: SUB-T, TAS-T, BOR,
11. IL illuminator to help to position of UUT relative to collimator,
12. HEC1 camera of wide FOV to capture image from total display of tested optical output thermal imagers,
13. HEC2 camera of narrow FOV to capture image from center of display of tested thermal imagers,
14. DPM66 diopter power meter to measure range of regulation of diopter power of ocular of thermal sights,
15. XOR optical rail – as platform for movable XAIM stage,
16. XAIM stage – as angular platform to fix position both tested sight/clip ons and the HEC/DPM66 cameras (stage equipped with Picatinny rail and other mechanical adapters for UUT and HEC cameras),
17. BOFOC boresight focuser block that enables to regulate position of pinhole IR source along collimator optical axix (regulation of distance to simulated pinhole target),
18. BREC boresight reference camera to support boresight to a reference mechanica axis,
19. BORIM set to support boresight to reference mechanical plane,
20. Set of OIM imitators that simulate optics of specified F-number and perfect transmission when measuring noise/sensitivity parameters of thermal camera cores,
21. MTB-2D blackbody.

The first five blocks (collimator, rotary wheel, blackbody, set of targets, passive blackbody) form a system that can be called variable target projector. It projects optical images of different reference targets into direction of a tested thermal imager.
The sixt block (set of frame grabbers) enables capturing video image generated by typical electronic output thermal imager in a long series of video standards.
The block 7–10 (PC, monitor, software) form a system that can be called computing/display that control blackbody/wheel, carries image acquisition, image analysis and calculates measured parameters of tested imager.
The blocks 1–10 form a system that can be considered as basic DT system used for basic testing typical electronic output thermal imagers. Higher number blocks expand test capabilities of DT system.
Block no 11 (IL illuminator) enables easy positioning of UUT relative to output of collimator of test system,
Blocks 12–16 (HEC cameras, DPM66 diopter power meter, XAIM stage, XOR rail) enables capturing and analysis of image generated by portable optical output thermal imagers.
Block 17 (BOFOC focuser) is needed for expanded boresight of thermal imagers to reference optical axis (focus through boresight in expanded distance simulated range).
Blocks 18–19 (BREC, BORIM) enables boresight to reference mechanical axis/plane.
Block 20 (set of OIM imitators) enable (combined with others blocks) testing thermal camera cores.
Block 21 (MTB blackbody) enables (combined with others blocks) expanded testing measurement thermal imagers (capable to measure temperature).
Attention: It is assumed that customer is to deliver mechanical platform/angular stages for tested UUT. Inframet can offer some optional platforms/stages. However, they are not on list of basic modules because customers often use need customized platforms/angular stages for regulation of position of their imagers.

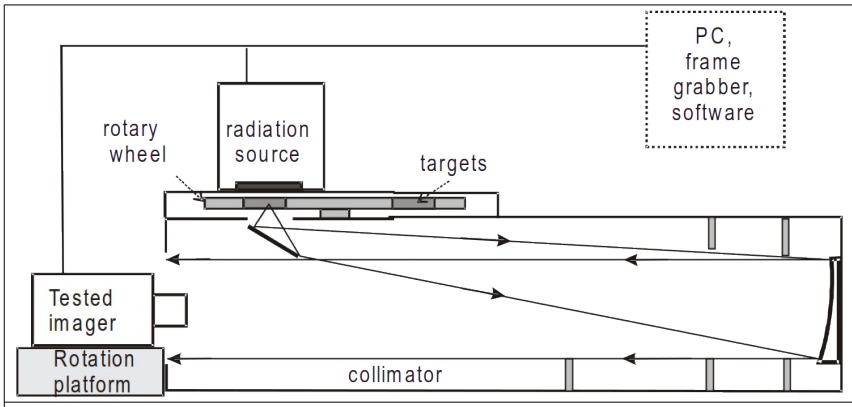


Fig. 5. Block diagram of the DT series test system (basic version)

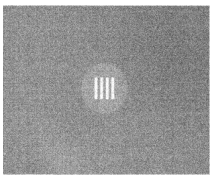


Fig. 6. Image of a 4-bar target generated a by thermal imager

5 Configuration of test system

Inframet typically manufactures its systems for testing thermal imagers in so called vertical configuration. Collimator focal plane is over collimator mirrors. The rotary wheel is put on the collimator (in collimator focal plane). Next, the blackbody is located over the rotary wheel with targets.

This type of collimators enables design of compact test systems (only small narrow table is needed). There is also a more important advantage of collimators in vertical configuration. System for testing thermal imagers built using vertical configuration collimators offer better blackbody temperature uniformity than systems built from the same modules but in horizontal configuration. The reason is that due to laws of physics temperature uniformity of blackbody emitter in horizontal position shall be always better uniformity of the same blackbody emitter in vertical position. Therefore Inframet test systems are perfect solution for testing cooled imagers of ultra low temperature resolution (NETD < 10mK).

More details in the paper: K. Chrzanowski, Li Xian-min, Configuration of systems for testing thermal imagers, Optica Applicata, Vol. 40, 4, 2010).

6 Versions of DT systems

DT test systems are a modular system that can be configured into a long series of versions of different test capabilities and price optimized for testing slightly different groups of thermal imagers.
Choosing proper version of DT system is not an easy task. It can be done in two ways.

1. **Filling questionnaire document** on thermal imagers to be tested and sending it to Inframet. Inframet shall choose optimal test system.
2. Careful reading this section and determination code of DT system. This section talks about this way of determination of version of DT system.

Concept of code that could precisely describe design / test capabilities of DT system is based on idea to use two part code:

Part 1: describe basic design parameters of collimator used by DT system (collimator code),
Part 2: describe test capabilities of DT system (system code).

6.1 Collimator code

Collimator code (example CDT30200-44-8) is determined by choosing one of collimators from list in Table 1. While combining full DT system then collimator letters “CDT” are exchanged by system letters “DT” to get system code DT30200-44-8.

Table 1. List of models of collimators that can be used to build DT systems

CDT collimator model	Aperture [cm]	Focal length [cm]	Max target size [mm]	Number of targets	FOV [°]	Collimator F-number	Minimal frequency 4–bar target [lp/mrad]
660-44-8	6	600	44	8	4.19	10	0.08
1050-35-8	10	500	35	8	4.00	5	0.075
1080-44-8	10	800	44	8	3.15	8	0.10
11100-44-8	11	100	44	8	2.47	9.09	0.14
12100-44-8	12	100	44	8	2.47	8.33	0.14
15120-44-8	15	120	44	8	2.06	8	0.17
15150-44-8	15	150	44	8	1.65	10	0.22
20160-44-8	20	160	44	8	1.54	8	0.23
20200-75-8	20	200	75	8	2.11	10	0.17
25200-44-12	25	200	44	12	1.24	8	0.29
25200-75-8	25	200	75	8	2.11	8	0.17
30200-44-12	30	200	44	12	1.24	6.67	0.29
30200-75-8	30	200	75	8	2.11	6.67	0.17
30300-44-12	30	300	44	12	0.82	10	0.43
30300-75-8	30	300	75	8	1.40	10	0.25
35200-44-12	35	200	44	12	1.24	5.71	0.29
35200-75-8	35	200	75	8	2.11	5.71	0.17
35350-75-8	35	350	75	12	1.20	10	0.30
40240-75-8	40	240	75	8	1.76	6	0.20
40240-44-12	40	240	44	12	1.03	6	0.35
40400-75-12	40	400	75	12	1.05	10	0.34
45500-107-8	45	500	107	8	1.20	11.11	0.30
50300-75-12	50	300	75	12	1.40	6	0.25
50500-75-12	50	500	75	12	0.84	10	0.42
50500-107-8	50	500	107	8	1.20	10	0.30
60600-107-12	60	600	107	12	1.00	10	0.36

Collimator code delivers information about a series of useful parameters:

1. Collimator aperture,
2. Collimator focal length,
3. Target diameter,
4. Number of targets,
5. Effective FOV,
6. Minimal frequency of 4–bar target (testing thermal imagers).

Collimator aperture gives information on maximal diameter of optics of tested imager (collimator apeture overlaps optics of the imager).

Information on **focal length** is needed to calculate angular size/spatial frequency of targets located at collimator focal plane. It gives also information on approximate length of the collimator.

Target diameter delivers information how big can be test targets to be projected by the collimator into direction of tested EO system.

Number of targets delivers information on maximal number of target plates that can be inserted into rotary wheel. Higher number of targets enables to carry out in shorter time expanded test that need many targets. Please remember that in case of small patterns multi-pattern targets can be used to increase number of patterns. See details in targets data sheet https://www.inframet.com/Data_sheets/Targets_IR.pdf

Real collimator FOV is angular size of maximal hypothetical target located at collimator focal plane that can be projected by the collimator. It depends mainly on diameter of the secondary flat mirror. This parameter is rarely published because from user point of view more important is effective collimator FOV. It is angular size of target plane that can be inserted to rotary wheel located at collimator focal plane. This parameter determined also indirectly size of radiation sources (blackbody, light source) that must be sufficiently big to fill collimator FOV.

Collimator F-number gives information of relative uniformity of image quality within collimator FOV. All off axis parabolic reflective collimators can project near perfect image of target located in center of collimator FOV (focus point). However, quality of projected image always deteriorate for non–center targets. The level of this deterioration is much higher for collimators of low F–number. Therefore if non center resolution patterns are to be used then collimators high F–number (over about 8) are preferable.

Frequency of minimal 4–bar target that can be projected is calculated as minimal frequency (biggest bars) of 4–bar target that can be inserted into angular circle equal to collimator FOV. It delivers direct information what is minimal frequency of 4–bar target that can be used during tests of thermal imagers.

However, it is commonly accepted that Nyquist frequency of tested imager should be at least two times higher than frequency of the biggest bar target. Therefore frequency of maximal 4–bar target determines also minimal Nyquist frequency of the tested imagers. The latter Nyquist frequency is simply two times higher comparing to frequency of maximal 4–bar target.

Attention:

1. If two collimator models of the same aperture and different FOV listed in Table 1. can be used for testing imagers of lowest Nyquist frequency then then collimator of lower FOV shall be chosen because such collimator is equipped with rotary wheel with higher number of targets.
2. If none of interesting collimators (proper aperture) cannot fulfill condition then Inframet can deliver customized collimators of bigger FOV (low F-number). However, quality of image of projected target in total FOV is poor. Therefore if high quality of projected image is required in total FOV then FOV of collimator must be small (below about 2 degree).

6.2 System code

System design/test capabilities are described using ten digit code that delivers precision information on ten following criterion:

A Maximal Nyquist frequency of imager to be tested (collimator grade),
B Number of supported video interfaces,
C Tests of electronic output thermal imagers,
D Testing optical output thermal imagers,
E Optical boresight/focus tests,
F Boresight to mechanical axis/plane,
G Distance to simulated targets,
H Additional targets
I Testing thermal camera cores,
J Two point NUC tests.

Precision definitions of ten digit code are shown in Table 2. The columns A–J show what digits are to be chosen to define precisely required version of DT test system.

Table 2. Ten digit code of basic versions of DT systems

	A	B	C	D	E
No	**Maximal Nyquist frequency of tested imagers [lp/mrad]**	**Supported video interfaces**	**Tests of electronic output thermal imagers**	**Test/boresight of optical output imagers**	**Boresight to reference optical axis**
1	5	No video output	Infinity focus, resolution	No	No
2	25	One video interface	+ MRTD	imaging parameters chosen in C column	Zoom through boresight
3	100	Two video interfaces	+ MTF, NETD, FPN, non-uniformity, FOV	+ defection angle, magnification, zero diopter setting	+ Focus throught boresight
4	400	Three video interfaces	+ 3D noise model, distortion, bad pixels	+ diopter power range	
5		Four video interfaces	Customized tests		

	F	G	H	I	J
No	**Boresight to mechanical axis/plane**	**Simulated distance**	**Additional targets**	**Testing thermal camera cores**	**Two point NUC tests**
1	No	Fixed Infinity	No	No	Simplified 2NUC (aperture <100mm)
2	Boresight to reference mechanical axis (mechanical rail)	Continuous regulation	Additional set of eight 4-bar targets	NETD	Advanced 2NUC (aperture <100mm)
3	Boresight to reference plane		IR USAF1951A target	+ FPN, 3D Noise	Advanced 2NUC (aperture <150mm)
4	Both types of boresight		IR USAF1951B target		Advanced 2NUC (aperture <200mm)
5			Custom set of targets		Advanced 2NUC (aperture <300mm)

The ten digit coding looks complicated and difficult to be used. However, the code is necessary to show precisely what configuration of DT is truly needed. Next, details of design of test system are not needed to determine the code. The user is expected mostly to present basic requirements on system test capabilities (what thermal imager to be tested, Nyquist frequencies of tested imagers, and number of parameters/boresight errors to be measured.

A Maximal Nyquist frequency

Requirements on quality of image projected by collimator (collimator grade) are determined by maximal Nyquist spatial frequency of tested imagers.

In detail, Nyquist spatial frequency determines maximal spatial frequency (smallest sinusoidal bar patterns) that imager can reproduce perfectly. Nyquist spatial frequency of tested imagers can be easily calculated in two ways: 1) ratio of imager focal length to (in mm) to dimension of pair pixels of image sensor used by the imager (in μm), 2) half of ratio of pixel number (unitless) of image sensor to imager FOV (in mrad unit).

Maximal Nyquist spatial frequency of tested imagers is a near perfect criterion to estimate real requirements on quality of image projected by the collimator. Nyquist spatial frequency of imagers tested using DT systems often vary a lot: from about 0.5lp/mrad (short range imagers) up to about 100lp/mrad (space imagers). Therefore the conclusion is that requirements image projected by the collimator vary a lot and there is little sense to deliver perfectly aligned collimator built using perfectly manufactured mirrors for testing short/medium range imagers (low Nyquist spatial frequency). Therefore Inframet offers three grades of off axis collimators depending on mirror manufacturing accuracy:

A1. SR (standard resolution) - manufacturing accuracy P-V not worse than about $\lambda/2$ at $\lambda = 630$ nm;
A2. HR (high resolution) - manufacturing accuracy P-V not worse than about $\lambda/4$ at $\lambda = 630$ nm;
A3. UR (ultra high resolution) - manufacturing accuracy P-V not worse than $\lambda/8$ at $\lambda = 630$ nm;
A4. XR (extreme resolution) - manufacturing accuracy P-V not worse than $\lambda/12$ at $\lambda = 630$ nm.

SR mirrors are of lowest quality and are used to built collimators only for testing short range imagers. HR mirrors are used in collimators for testing medium/long range imagers. UR class mirrors are used in collimators for testing ultra long range imagers of ultra narrow FOV. XR collimators are used for special space imagers o big aperture and long focal lenght.

Mirrors of higher manufacturing accuracy can potentially generate high quality images only if used in properly aligned collimators. Therefore SR/HR/UR/XR symbols determine not only mirror manufacturing accuracy but also class of aligning of the collimator. Recommendations on collimator grade depending on maximal Nyquist spatial frequency of tested imager is presented in table 3. The user is expected to calculate maximal Nyquist spatial frequency of imagers to be tested and later to choose proper grade of the collimator.

Table 3. Recommended collimator grade depending on maximal Nyquist spatial frequency of tested imagers

Column a (row number)	1	2	3	4
Nyquist frequency of tested imagers [lp/mrad]	<5	<25	<100	<400
Recommended collimator grade	SR	HR	UR	XR

Attention:
Nyquist frequency in Table is imager frequency in lp/mrad (line pair per mrad unit). It is not image sensor Nyquist frequency in lp/mm unit.

B Supported video interfaces

Tested multi-sensor imaging systems typically generate output image to be analyzed by humans or by software in electronic forms using different video interfaces. This video image must be captured and analyzed to measure parameters of thermal imagers.

Long series of video interfaces can be used: analog video, Camera Link, GigE, LVDS, HD-SDI, DVI, HDMI, CoaXPress, USB2.0/3.0, Ethernet and so on. Capturing video image is carried out using specialized frame grabber cards inserted to PC and image acquisition software optimized for specific video interface. Inframet can deliver frame grabbers/software that support approximately up to four video interfaces. If more interfaces are needed then additional PC with frame grabbers is delivered.

C Thermal imagers tests

This column describes list of measurable parameters of typical electronic output thermal imagers. As can be seen in Table 2 Test range of thermal imagers vary at levels C1 to C5. Below are presented blocks that are delivered or modified to change test capability:

C1. One 4–bar target of specified frequency. No software support.
C2. Set of eight 4–bar targets. Software modules: Blackbody Control program and SUB-T program to support MRTD test.
C3. Additional targets: edge target, dot-cross target. Additional computer program TAS-T program (four modules: MTF, SiTF, noise parameters, FOV, FPN modules);
C4. Expanded version of TAS-T program: new software modules 3D noise model, distortion, bad pixel modules;
C5. Customized solutions.

D Testing optical output imagers

This column describes list of measurable parameters/boresight errors of optical output thermal imagers (imagers having internal diplays where image is generated).
Measurement of imaging parameters (MRTD, MTF, FOV) of optical output thermal imagers is achieved using a concept of cameras capable to capture image generated by tested imager on its internal display.
Deflection angle (boresight error of clip ons) is measured as angular shift of target marked by line of sight of telescopic sight (indicated by aiming mark) at two modes: 1) clip on not used, 2) clip-on is fixed to weapon.
Magnification is measured as ratio of size of image captured by the camera at imager display to size of image captured by the camera of the reference target seen directly.
Diopter power range is measured using special computerized meter capable to analyse incoming beam of rays.

Below are presented blocks that are delivered or modified to change test capability of DT system:

D1. No optical output imagers tests.
D2. Two HEC cameras, XOR rail, XAIM stage, TOPO program.
D3. Additionally special TCB-SEM0 blackbody with internal illuminator, an additional MAG module in TOPO computer program.
D4. As in D3, additionally DPM dioptric power meter, an additional Dioptric range module in TOPO computer program.

E Boresight to reference optical axis

This column describes ability to measure two boresight errors:

1. Zoom-through boresight: angular shift of target marked by imager line of sight (indicated by aiming mark) when zooming,
2. Focus-through boresight: angular shift of target marked by imager line of sight (indicated by aiming mark) when focusing (at different range of focusing depending on version).

The errors can be measured using both electronic output or optical output (if optical output imager is tested). However, they are typically measured using electronic output signal.
Below are presented blocks that are delivered or modified to change test capability of DT system:

E1. No boresight to reference optical axis
E2. BOR software,
E3. Additional BOFOC boresigth focuser.
Attention: Minimal distance that can be simulated by BOFOC can be estimated as 20x FL² (where FL is focal lenght in meters).

F Boresight to mechanical axis/plane

This column describes ability to measure two boresight errors:

1. Boresight to reference mechanical axis: angle between imager optical axis (line of sight) and reference mechanical axis (Picatinny/dovetail rail).
2. Boresight to reference mechanical plane: angle between imager optical axis (line of sight) and axis perpendicular to reference mechanical plane (typically front wall of medium/long distance thermal sights.

The first boresight error is measured in case of portable short/medium range optical output thermal sights/clips ons. The second boresight error is measured in case of medium/long range electronic output thermal sights having reference front wall (example Catherine thermal sight from Thales).
Below are presented blocks that are delivered or modified to change test capability of DT system:

F1. No boresight tools to mechanical axis/plane
F2. BREC boresight set. BREC is a special reference camera having optical axis parallel to its mechanical axis.
F3. BORIM boresight set. This set converts CDT collimator into autocollimator capable to measure angular position of reference mechanical plane of tested imager.
F4. BREC and BORIM boresight sets

G Simulated distance

Thermal imagers are typically tested at lab conditions using test systems that project images of target located at optical infinity. It means that rotary wheel with targets is located at focal plane of the collimator. Such situation is typically totally acceptable because typical work distance to targets of interest is at least several hundreds of times higher that focal lenght of optics of the imager. Such distance can be considered as near infinity because image quality of target generated by imager does not changes when distance is changed from work distance to infinity. Therefore there is typically no need for tests exactly at work distance. However, there are two exception from this rules.
First, faulty mechanical focusing mechanism can generate noticeable image shift even for minor focusing. Second, precision simulation of targets located at variable work distance becomes important for long range imagers built using optics of very long focal lenght (say over 1m). Sometimes customers need also simulation of non infinity distance for other reasons (correction of non vacuum condition, correction of different ambient temperature) .
Due to the first reason Inframet offers BOFOC focuser capable to regulate distance to simulated pinhole target (see column E3).
Due to the second reason Inframet special version of DT system where after collimator modification typical MWR rotary wheel is replaced by FRW focusing-rotary wheel (movement range about 20mm). This version enables continuous regulation of distance to simulated target. In contrast to BOFOC focuser this case enables regulation of distance not to a sigble pinhole target but to all targets in total FOV of the collimator.
Minimal simulated distance depends on focal length of the collimator and is presented in Table 4 .

Table 4. Minimal simulated distance for collimators of different focal lengths

Collimator focal length [cm]	100	120	150	160	200	240	300	350	400	500	600
Minimal distance [m]	50	75	100	125	200	300	400	600	800	1200	1800

Below are presented blocks that are delivered or modified to enable regulation to simulated targets:

I1. Fixed: Optical infinity
I2. Continuous regulation: CDT collimator is modified and typical MRW rotary wheel is replaced by FRM focusing-rotary wheel

H Additional targets

On basis of required test capabilities (see column C) Inframet deliveres set of IR targets needed to measure chosen parameters of thermal imagers. This set of targets typically includes: set of eight 4-bar targets (MRTD tests), slanted edge target (MTF tests) and dot cross target (FOV, distortion tests). This set of IR targets can be too little for two scenarios. First, a series of different thermal imagers is to be tested and more 4-bar targets is needed. Second, customer is ready to sacrifice accuracy of MRTD tests and want to speed up procedure by using multi pattern IR USAF1951 targets.
For this reason Inframet offers additional set of 4-barget targets and/or IR USAF1951 targets.
DT test system can be delivered with set of additional targets.

I1. No additional targets
I2. Set of eight 4-bar targets
I3. IR USAF1951A target (spatial frequency range from 1 lp/mm to 10.08 lp/mm)
I4. IR USAF1951B target (spatial frequency range from 4 lp/mm to 28.5 lp/mm).
I5. Custom set of targets.

I Testing thermal camera cores

This column describes ability to test thermal camera cores. They are basically thermal imagers without optics, but capable to generate output electronic image.
Inframet typically offers specialized set DTCORE for testing thermal camera cores https://www.inframet.com/Data_sheets/DTCORE.pdf. The DTCORE is a modular set built from six following modules: TCB blackbody, PC set, analog video frame grabber, Blackbody Control program, set of two OIM optics imitators, TAS-N computer program Set of OIM optics imitators is the crucial part of DTCORE. From design point of view OIM imitators are mechanical devices that precisely limit the cone where sensor of camera core gets irradiation from a large blackbody of variable temperature to value determined by F-number of simulated IR objective.
The first four blocks are parts of typical DT systems. Therefore by adding set of OIM imitatators and modification of TAS-T computer program to version TAS-N it is possible to convert typical DT system to DTCORE set configuration capable to test thermal camera cores.
Below are presented blocks that are delivered or modified to change test capability of DT system:

1. No thermal camera cores tests,
2. Set of two OIM imitators and TAS-N1 program are delivered. NETD can be measured.
3. TAS-N2 computer program for data analysis is delivered. Additionally FPN and 3D Noise can be measured.

This column presents a low cost solutions for testing thermal camera cores: most of needed modules are blocks of typical DT system. The drawback is that in order to do tests of camera cores it is necessary to remove TCB-4D blackbody from collimator, connect OIM optical imitator and prepare set for the tests.
Therefore if tests of camera cores are to be done frequently it is recommended to order a separate DTCORE set.

J Two point NUC tests

Raw image generated by IR FPA sensors used in thermal imagers is typically very noisy, mostly due to high spatial noise generated by significant variation of gain and offset of pixels of this image sensor. Therefore this spatial noise must be corrected by some image processing. Great majority of thermal imagers (both non-cooled and cooled) are factory-calibrated to generate non-uniformity compensation (NUC) coefficients which are applied automatically by the camera in real time to maintain good image quality. These coefficients are determined during so called two point NUC operation. NUC coefficients are typically calculated on basis of images of a large area, uniform blackbody that fully fills FOV of tested imager taken at typically two different blackbody temperatures. Manufacturers use myriad of different mathematical algorithms to correct spatial noise. However, from point of view of test equipment there two point NUC operation is basically capturing image of two large blackbodies filling imager FOV at two different temperature. Single blackbody cannot be used for 2NUC tests due to long time interval needed by the blackbody to change temperature and stabilize.
NUC coefficients vary depending on ambient temperature. Therefore professional manufacturers of thermal imagers carry out 2NUC tests at variable ambient temperature in temperature chambers.

Inframet offers professional BNUC set for two point NUC tests that can be offered in dozen of versions (https://www.inframet.com/Data_sheets/BNUC.pdf). This column presents possibilities to expand of DT system and enable professional two point NU tests (two blackbodies located at temperature chamber, tested imager moved by a motorized stage).

J1. Two point NUC tests of imagers of aperture below 100mm. In this option Inframet delivers two TCB-4D-TC blackbodies (aperture 100x100mm) TC capable to work at temperature chamber. One of them is used both for typical DT tests and for two point NUC tests. The second only for NUC tests.
J2. Two point NUC tests of imagers of aperture below 150mm. In this option Inframet delivers two TCB-6D-TC blackbodies (aperture 150x150mm) TC capable to work at temperature chamber. Motorized linear stage YLS is delivered, too.
J3. Two point NUC tests of imagers of aperture below 200mm. In this option Inframet delivers two TCB-8D-TC blackbodies (aperture 200x200mm) TC capable to work at temperature chamber. Motorized linear stage YLS is delivered, too.
J4. Two point NUC tests of imagers of aperture below 300mm. In this option Inframet delivers two TCB-12D-TC blackbodies (aperture 300x300mm) TC capable to work at temperature chamber. Motorized linear stage YLS is delivered, too.

It should be noted that:

1. Two point NUC tests are needed for manufacturers of thermal imagers or for advanced users of thermal imagers that have proper software to communicate with imager and modify NUC coefficients. These tests are almost useless for majority of users of thermal imagers that are not allowed by manufacturers to many modifications of imager NUC coefficients.
2. This column presents tools for two point NUC tests as expanding option of DT system. However, practically these tools (two blackbodies and linear stage) form an independent system.
3. This column presents sets for two point NUC testes in most advanced version: two active blackbodies and linear stage working at temperature chamber. However, specialized BNUC system can be delivered in simpler and cheaper versions, too.

7 Exemplary versions

DT can be configured into myriads of versions. Here three popular versions:

1. DT660-44-8-V12-21-11-11-11 – version for basic testing short range thermal imagers;
2. DT12100-44-8-V22-34-32-11-11 – version for testing portable thermal sights/clip ons
3. DT15120-44-8-V23-31-33-11-11 – version for testing medium range thermal sights with electronic output
4. DT40400-75-8-V33-41-31-11-11 – version for testing long range thermal imagers

8 Optional solutions

Inframet can deliver also a series of optional support blocks that can significantly increase test capabilities of DT systems;

1. AT optical table as plaform for test system and UUT,
2. Angular stages for tested UUT,
3. YVAP variable angle projector,
4. VirtMRTD.

8.1 AT optical table

AT optical table is used as a platform for both tested system and test system. It can be delivered in many versions depending on its size and anti-vibration properties (rubber attenuators, air pressure attenuators, QZS attenuators). It should be emphasized that optical table is of crucial importance when testing imager of high Nyquist frequency (over about 50lp/mrad). Details about at tables: https://www.inframet.com/optical_tables.htm

8.2 Angular stages

Customers typicall use customized angular stages for regulation of angular position of their imagers. However, Inframet can optionally deliver both manual and motorized rotary wheels as listed in website to support this task. https://www.inframet.com/positioning_stages.htm

8.3 YAVAP variable angle projector

DT system measures typically FOV of tested imagers using software that compares maximal size of output image with size of image of a reference target of known angular size. The methods works perfectly for imagers of FOV comparable to collimator FOV (typically below 3º). This method enables also relatively accurarate measurement of imager FOV in cases when imager FOV is several times higher over collimator FOV. Practically it means that software of DT system enables relatively accurate measurement of FOV for imagers of FOV up to about 12º–15º.

This range is sufficient in majority of applications of DT system. In addition, Inframet can deliver optional YAVAP variable angle projector that enables accurate FOV measurement up to at least 30º.
YAVAP is a computerized module that mounted at collimator output project image of a pinhole target at regulated angle comparing to collimator axis. Analysis of location of pinhole target at image generated by tested imager enables accurate measurement of imager FOV.

8.4 VirtMRTD

Inframet can optionally deliver Dubterm software that enables to measure MRTD using VirtMRT method. This method is based on a three steps measurement concept using semi-automatic objective measurements and computer simulation. First, objective parameters of the tested thermal imager are measured. Second, software simulates this tested thermal imager and generates the image of 4-bar target of specified spatial frequency (size) and contrast (temperature difference). Third, a human observer analyses the images of the 4-bar target generated by the software on the screen of PC set and measures MRTD of the simulated thermal imager at specified set of spatial frequencies. The proposed method offers higher measurement speed, lower cost and typically better accuracy in comparison with the typical MRTD measurement method. Details as in https://www.inframet.com/Literature/VirtualMRTD.pdf

9 Special test conditions

Typical DT systems are optimized to work at typical laboratory conditions: ambient temperature in range from about 10C to about 30C, typical air pressure conditions. However, DT systems can be optionally delivered in versions capable to work at:

1. Temperature chamber;
2. Clean room;
3. Vacuum chamber.

Please add following abbreviations to system code: TC, CR, VC. However, please note that these are customized test systems and detail information on work conditions is expected before order is accepted.

10 Comparison to previous coding of DT system

New coding of DT systems presented in previous section has been introduced to be valid since 2025 year to replace previous one used for last decade. New code is more detail and present additional information: collimator focal length; collimator FOV; size of target plates; maximal imager Nyquist frequency (collimator grade). There are also significant changes in form of description of test capabilities, especially boresight errors.

11 Summary

1. DT system is one of most sophisticated Inframet test systems capable to test almost all electro-optical imaging/laser systems present market. It can be configured by potential user to suit for his applications by choosing proper version.
2. If you have problems to choose proper versions of DT test system using proposed code please fill questionnaire and Inframet staff shall propose an optimal version. Problem to choose proper version is natural – the reason is complexity of testing therma imagers.
3. Please contact Inframet if you have any questions.

Version 12.2

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