TVT

System for testing high-end surveillance VIS-NIR cameras

a)

b)

Fig. 1. Two exemplary TVT test system: a) TVT300 for testing space VIS-NIR cameras, b) TVT120 for testing medium range VIS-NIR cameras for naval/ground applications

1 Introduction

TVT is a system offered by Inframet for testing high end surveillance VIS-NIR electronic cameras sensitive in both visible and near infrared spectral band and used for medium/long range surveillance at both day and night conditions. In detail, TVT is a variable intensity image projector that projects images of some standard targets into direction of tested VIS-NIR camera. The tested camera generates copies of the projected images. Quality of the images generated by the camera is evaluated and its important characteristics are measured.

The TVT system enable simulation of both ultra dark nights (moonless clouded nights) and ultra bright days (bright sand desert at noon) and accurate testing performance of surveillance VIS-NIR cameras working at any illumination conditions. Testing surveillance VIS-NIR cameras with TVT test station generate a series of parameters that give vital information about potential camera surveillance capabilities for camera users. The projection is done by a big reflective collimator when testing medium/long range VIS-NIR cameras, or using small refractive collimator when testing small short range CCTV cameras.

2 What E-O systems can be tested?

High-end VIS-NIR cameras sensitive in visible and near infrared range built using large lenses narrow FOV lenses are widely used by military/space/security agencies for medium/long range surveillance applications. Cheaper VIS-NIR cameras built using small wide FOV optics are used in huge numbers in civilian CCTV (close circuit TV) applications.

Majority of VIS-NIR cameras is used for day level applications but an increasing number of these cameras is used to enable surveillance in both night and day conditions. In both cases it is important to verify performance of these cameras under varying illumination conditions from very dark nights to ultra bright days. Important missions can fail due to too low sensitivity of VIS-NIR cameras at night conditions (dark, noisy images) or due to too low dynamic at ultra bright day conditions (saturated, blurred images). In addition, it is important to use VIS-NIR cameras that generate high quality images in order to achieve maximal surveillance ranges.

TVT system is basically universal test system that can be used to test great majority of high end VIS-NIR cameras for medium/long/ultra long range surveillance. However, in detail TVT system is optimized for testing four main groups of such cameras:

1. Space VIS-NIR cameras (satellite optical payloads),
2. Long/ultra long range surveillance VIS-NIR cameras for Earth applications,

3. Blocks for medium/long range multi sensor imaging/laser system,
4. High end CCTV security cameras.

Photos of exemplary VIS-NIR cameras from these groups are presented in Figs.2 –5.

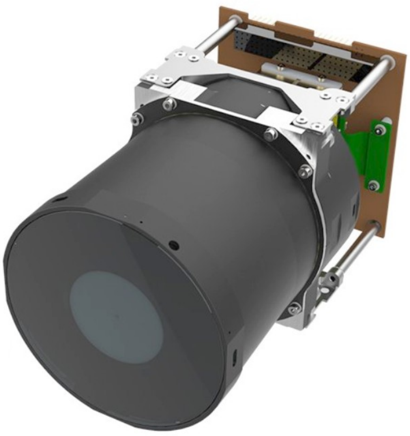

Fig. 2. Simera Sense space VIS-NIR camera

Fig. 3. FUJINON Long Range Multi-Purpose Camera for Earth applications

Fig. 4. Infinity long range VIS-NIR camera block for long range multi sensor system

Fig. 5. FLIR high-performance, 4K Low-Light Modular Camera for high end security applications

3 Test capabilities

TVT system in expanded versions can enable measurement of a long list of parameters of VIS-NIR cameras. These parameters are listed below using criterion of their popularity:

1. Resolution,
2. MTF (Modulation Transfer Function),
3. MRC (Minimal Resolvable Contrast),
4. FOV (Field of View),
5. Noise equivalent input: NEL (Noise Equivalent Luminance), NEI (Noise Equivalent Illuminance), NEIR (Noise Equivalent Irradiance), NER (Noise Equivalent Radiance),
6. FPN (Fixed Pattern Noise),
7. Distortion,
8. 3D Noise,
9. Sensitivity,
10. SNR (Signal to Noise Ratio),
11. Resposivity function (Responsivity, Linearity, Dynamic, Light Range),
12. Bad pixels,
13. GRD (Ground Resolved Distance),
14. EMVA1288 tests – option for testing camera cores,

Following boresight tests can be carried out using TVT system :

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. Boresight of UUT to collimator: checking if tested UUT is properly positioned relative to collimator output of test system

4 How TVT systems are built?

TVT test system is a modular system built in most expanded 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. Device to exchange active target (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) – alternative of MRW wheel,
3. Computerized LS-DAL light source,
4. Set of VIS targets,
5. Set of frame grabber cards to capture electronic video image,
6. PC – typical PC working under Windows operating system (laptop or desktop PC are delivered),
7. Set of control programs: Light source control, Target control,
8. Set of measurement support program: SUB-V, TAS-V, BOR,
9. IL illuminator to help to position of UUT relative to collimator,
10. BOFOC boresight focuser block that enables to regulate position of pinhole of VIS source along collimator optical axis (regulation of distance to simulated pinhole target).

It should be noted that TVT is a system for testing high end VIS-NIR cameras and testing small, cheap cameras of very short range (majority of security cameras) is excluded.

The first four blocks (collimator, rotary wheel, light source, set of targets) form a system that can be called variable target projector. It projects optical images of different reference targets into direction of a tested VIS-NIR camera. The fifth block (set of frame grabbers) enables capturing video image generated by typical electronic output thermal imager in a long series of video standards. The blocks 6–8 (PC, monitor, software) form a system that can be called computing/display center that control light source/wheel, and carries image acquisition, image analysis and calculates measured parameters of tested camera. The blocks 1–8 form a system that can be considered as basic TVT system used for basic testing typical electronic output thermal imagers.

Higher number blocks expand test capabilities of TVT system. Block no 9 (IL illuminator) enables easy positioning of UUT relative to output of collimator of test system. Block no 10 enables expanded boresgith of tested VIS NIR camera. Light source LS-DAL is the heart of TVT system. It is a unique solution on the world market due to a set of features:

1. ability to simulate both day and night illumination conditions (total dynamic of light source equals 10^9),
2. ability to switch its color temperature (broadband spectrum) from typical 2856K to 5000K,
3. ability to limit its spectral band to selected wavelength (monochromatic mode),
4. different ways of calibration: photometric units (cd/m^2, lx), radiometric units (W/m^2), or new unit (silux).

Attention: It is assumed that customer is to deliver mechanical platform/angular stages for tested UUT. Inframet can offer some optional platform /stages. However, they are not on list of basic modules, because customers often need customized platform /angular stages for regulation of position of their imagers.

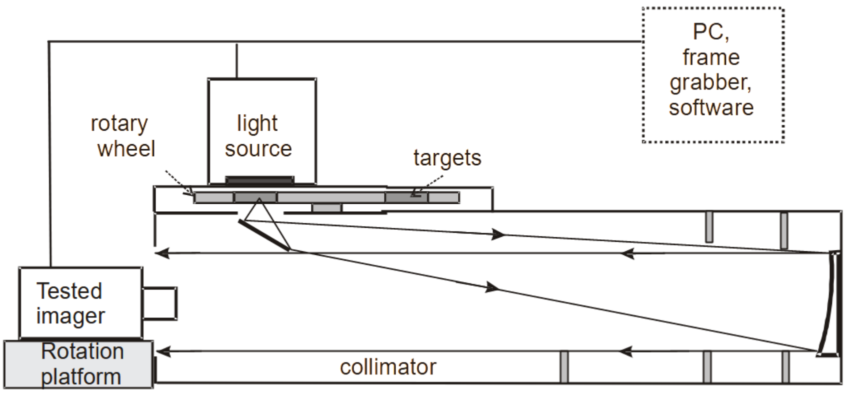

Fig. 6. Block diagram of the TVT series test system (basic version)

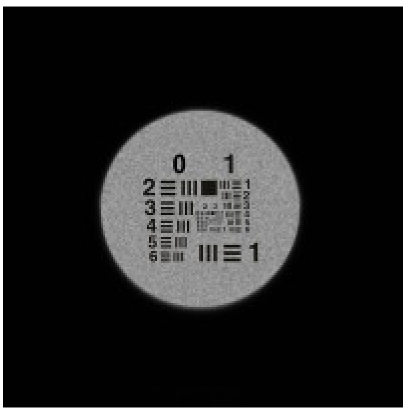

Fig. 7. Image of a USAF target generated the by tested camera.

5 Versions of TVT system

TVT test systems are 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 VIS-NIR cameras.
Choosing proper version of TVT 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 will choose optimal test system.**
2. Careful reading this section and determination code of TVT system.

This section talks about the second way. Concept of code that could precisely describe design / test capabilities of TVT system is based on idea to use two part code:
Part 1: describe basic design parameters of collimator used by TVT system (collimator code),
Part 2: describe test capabilities of TVT system (system code).

5.1 Collimator code

Collimator code (example CDT30200-44-8) is determined by choosing one of collimators from list in Table 1. While combining full TVT system then collimator letters "CDT" are exchanged by system letters "TVT" to get system collimator code TVT 30200-44-8.

Table 1. List of models of collimators that can be used to build TVT system

CDT collimator model	Aperture [cm]	Focal length [cm]	Max target size [mm]	Number of targets	FOV [º]	Collimator F-number	Minimal frequency: USAF1951 [lp/mrad]
660-44-8	6	600	44	8	4.19	10	0.3
11100-44-8	11	100	44	8	2.47	9.09	0.5
15150-44-8	15	150	44	8	1.65	10	0.75
20200-75-8	20	200	75	8	2.11	10	0.50
25200-44-12	25	200	44	12	1.24	8	1.00
30200-44-12	30	200	44	12	1.24	6.67	1.00
30200-75-8	30	200	75	8	2.11	6.67	0.50
30300-44-12	30	300	44	12	0.82	10	1.50
30300-75-8	30	300	75	8	1.40	10	1.50
35350-75-8	35	350	75	12	1.20	10	0.88
40400-75-12	40	400	75	12	1.05	10	1.00
45500-107-8	45	500	107	8	1.20	11.11	1.25
50500-75-12	50	500	75	12	0.84	10	1.25
50500-107-8	50	500	107	8	1.20	10	1.25
60600-107-12	60	600	107	12	1.00	10	1.50

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 USAF 1951 target (testing VIS-NIR cameras).

Collimator aperture

Collimator aperture gives information on diameter of maximal multi imaging/laser system that can be seen by the collimator (diameter of circle that overlaps optics of all imaging/laser sensor of the tested system).

Focal length

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

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

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_VIS.pdf

Collimator FOV

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

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.

Target Frequency

Frequency of minimal USAF1951 target that can be projected is calculated as minimal frequency (biggest bars) USAF1951 target that can be inserted into angular circle equal to collimator FOV. It delivers direct information what is minimal frequency the resolution/MRC tests can be carried out.

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 3-bar pattern in USAF1951 target determines also minimal Nyquist frequency of the tested imagers. The latter Nyquist frequency is simply two times higher comparing to frequency of maximal 3-bar patterns of USAF1951 target.

Attention:

1. If two collimator models of the same aperture and different FOV listed in Table 1 can be used for testing VIS-NIR cameras then collimator with smaller FOV but having more targets is recommended.
2. If none of interesting collimators (proper aperture) cannot fulfill condition then Inframet can deliver optional refractive collimatorts of wider FOV.

5.2 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 Measured parameters of VIS-NIR cameras,
- D Simulated light conditions,
- E Variable broadband spectrum source,
- F Variable wavelength source,
- G Radiometric calibration,
- H Optical boresight,
- I Tests of camera cores,
- J Variable focus colllimator.

Precise 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 TVT test system.

The ten digit coding looks complicated and difficult to be used. However, the code is necessary to show precisely what configuration of TVT 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.

Table 2. Ten digit code of basic versions of TVT system

	A	B	C	D	E
No	**Maximal Nyquist frequency of tested cameras [lp/mrad]**	**Supported video interfaces**	**Measured parameters**	**Simulated light conditions**	**Dual mode light source**
1	25	No video output	Infinity focus, resolution	Day	No. Only halogen 2856K color temperature spectrum
2	100	One (1)	+Typical imaging tests (resolution, MTF, FOV)	Day/Night	Yes. Additional mode: multi LED 5000K color temperature spectrum
3	400	Two (2)	+Noise equivalent parameters, FPN, SNR		
4		Three (3)	+MRC		
5		Four (4)	Customized tests		

	F	G	H	I	J
No	**Monochromatic mode tests**	**Calibration of light source**	**Boresight to reference optical axis**	**Tests of camera cores**	**Variable focus colllimator**
1	Only broadband spectrum	Only photometric units	No	No	Fixed Infinity
2	Up to four manually regulated narrow spectral bands	+Radiometric units	Zoom through boresight	Noise parameters	Continuous regulation
3		+Silux unit	Focus through boresight	EMVA1288 parameters	
4			Both tests		

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 for TVT systems four 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 can be 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 length.

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 above 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 VIS-NIR 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 Measured parameters

This column describes list of measurable parameters of typical VIS-NIR cameras. As can be seen in Table 2 test range of VIS-NIR cameras vary at levels C1 to C4. Below are presented blocks that are delivered or modified to change test capability:

C1. One negative 100% contrast USAF1951 target (groups 0 to 7). No special software.
C2. Slanted edge target, positive 100% contrast USAF1951 target (groups –1 to 7). MTF module of TAS-V program to support MTF measurement.
C3. Additional noise module of TAS-V program to support measurement of noise equivalent parameters, FPN, SNR.
C4. Set of five variable contrast positive USAF1951 target (groups –1 to 7) needed for MRC measurement. SUB-V program to support measurement of MRC.

D Light conditions

VIS-NIR cameras are used at illuminations conditions that vary a lot. Illumination at night at Afghanistan mountain can be below 0. 03 mlx when at bright days at Arabian desert can be up to 30 000lx (dynamic over 10^9). LS-DAL source enable simulation of both extreme light conditions. However, majority of VIS-NIR cameras works only at day conditions and some customers wants only simulation of day conditions. Therefore, TVT stations offers regulation of simulated light conditions:

D1. Only day condition.
D2. Both day and night conditions.

The difference is in design of delivered LS-DAL source.

E Dual mode light source

Calibrated ligh sources used in systems for testing VIS-NIR cameras are typically light sources built using halogen bulb of 2856K color temperature (illuminant A). However there are three main drawbacks of such light sources. First, spectrum of such halogen light source poorly fits to spectrum of typical Sun light at day conditions when VIS-NIR cameras are used. Second, halogen light sources are characterized by relatively short life time of halogen light sources (typically below 1000 hours). In detail, performance deterioration starts several times earlier. Third, mechanically regulated halogen sources are relatively slow to stabilize (up to a minute or more).

In such a situation Inframet LS-DAL light source (models since 2025 year) has been designed to work in two modes: 1) halogen source of 2856K color temperature in spectrum 400 –1000nm, 2) multi-LED source of 5000K color temperature in the same spectral band. This new LS-DAL source eliminates these drawbacks.

Code interpretation:

E1. LS-DAL source is delivered in basic version when can work only in halogen bulb of 2856K color temperature mode.

E2. LS-DAL source is delivered in expanded version when can work in two switchable work modes: 1) halogen bulb of 2856K color temperature mode, 2) multi LED of 5000K color temperature.

F **Variable wavelength tests**

Virtually all VIS-NIR cameras are imagers sensitive in broadband spectral bands: VIS-NIR band or at least VIS band. However, for a series of different reasons it is sometimes useful to carry out tests of VIS-NIR cameras at specified wavelengths (narrow spectral bands). One of such reasons is to verify performance of theoretical optical models.

Typical light sources does not enable work at monochromatic mode or require to use large cumbersome filters.

In such a situation Inframet offers LS-DAL light source in advanced version when it can work in monochromatic mode of wavelength regulated by manual/motorized exchange of monochromatic filters in optical system of this source.

Code interpretation:

F1. LS-DAL source is delivered in basic version that cannot work in monochromatic mode. Only broadband spectrum.

F2. LS-DAL source is delivered in advanced version that can work in monochromatic mode (up to 4 wavelengths). Manual exchange of monochromatic filters.

G **Calibration of light source**

Light intensity of light sources used in systems for testing VIS-NIR cameras is typically characterized by two alternative photometric quantities: 1) luminance in cd/m^2 unit, 2) illuminance in lx unit. However, these photometric quantities describe actually light intensity in visible band when these cameras are typically sensitive in total VIS-NIR band from about 400nm to about 1000nm. Therefore, light intensity of light sources used in systems for testing VIS-NIR cameras can be also characterized by radiometric quantities (exitance/irradiance) measured over total VIS-NIR band in W/m^2 unit.

Another more optimal solution is to characterize light intensity using a concept of so called silux unit. It is a modern solution proposed in recent specialized literature:

Richards, A., and M. Hübner. "Silux: a unit of silicon detector-weighted irradiance." Infrared Imaging Systems: Design, Analysis, Modeling, and Testing XXXIV. Vol. 12533. SPIE, 2023.

Code interpretation:

G1. LS-DAL source is delivered calibrated in photometric quantities:1) luminance in cd/m2 unit, 2) illuminance in lx unit.

G2. In addition to photometric calibration LS-DAL source characterized by broadband exitance/irradiance in total VIS-NIR spectral band.

G3. In addition to previous calibrations LS-DAL source is characterized by silicon exitance/ irradiance in silux unit.

H **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).

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

H1. No boresight to reference optical axis.

H2. BOR software.

H3. Additional BOFOC boresigth focuser.

Attention: Minimal distance that can be simulated by BOFOC can be estimated as 20x FL² (where FL is focal length in meters).

I Tests of camera cores

This column describes ability to test thermal camera cores. They are basically VIS-NIR cameras without optics, but capable to generate output electronic image. Inframet typically offers specialized set system for testing VIS-NIR image sensors/camera cores coded VIT https://www.inframet.com/Data_sheets/VIT.pdf that offers ultra extended characterization of such camera cores (both radiometric, imaging and spectral parameters). Here only a solution for basic tests of VIS-NIR camera cores is proposed. In detail, it is proposed measurement of some radiometric parameters: noise equivalent parameters (detail names depends on source calibration in column G), FPN, 3D Noise, sensitivity. In most expanded version for this column TVT can be also used to measure parameters from EMVA1288 standard. Below are presented blocks that are delivered or modified to change test capability of TVT system:

- I1. No tests of camera cores.
- I2. Basic tests of camera cores (modified design of image projector blocks, special software).
- I3. Expanded tests of camera cores (EMVA1288 tests included - additional software blocks).

J Variable focus colllimator

VIS-NIR cameras 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 length (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 TVT system where after collimator modification typical MRW 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 single 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:

- J1. Fixed: Optical infinity.
- J2. Continuous regulation: CDT collimator is modified and typical MRW rotary wheel is replaced by FRW focusing-rotary wheel.

6 Exemplary versions

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

1. TVT660-44-8-12-11-11-11-11 – version for basic testing medium range VIS-NIR cameras,
2. TVT15150-44-8-22-22-21-34-11 – version for expanded testing long range VIS-NIR cameras,
3. TVT30300-44-8-32-42-22-32-12 – version for testing space cameras.

7 Optional solutions

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

1. AT optical table as platform for test system and UUT,
2. Angular stages for tested UUT,
3. YVAP variable angle projector,
4. Additional refractive collimators,
5. BORIM autocollimator,
6. IL collimator illuminator.

7.1 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

7.2 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

7.3 YAVAP variable angle projector

TVT 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 accurate measurement of imager FOV in cases when imager FOV is several times higher over collimator FOV. Practically it means that software of TVT 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 TVT 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.

7.4 Additional refractive collimators

TVT systems based on reflective collimator are characterized by relatively narrow FOV. Due to this feature they are optimal for testing medium/long range VIS-NIR cameras (max FOV can be estimated at about 15 degrees). It is enough for testing high end cameras but low cost short range security cameras cannot be tested. Therefore Inframet can deliver optional set of two refractive collimators that enable such tests.

7.5 BORIM autocollimator

BORIM boresight autocollimator enables aligning of optical axis (LOS) of imager (thermal imager or VIS-NIR camera) with reference front wall of the imager (axis is perpendicular to the front wall). It is achieved using special ABT target located inside the collimator that emits laser beam to be reflected by small mirror attached to imager reference flat wall. It should be noted that such boresight of LOS of imager to a reference mechanical plane is needed only in case of special thermal sights having such reference wall (example Catherine from Thales).

7.6 IL collimator illuminator

IL collimator illuminator enables to check if tested system is properly positioned relative to collimator of test system. in detail, collimator aperture should overlap optics of all imaging/laser systems. The aim is achieved by emission of visible optical beam by the IL illuminator that that illuminates tested multi-sensor system. It is easy to check if all optics of test system is illuminated to assure that tested system is properly positioned relative to collimator.

8 Special test conditions

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

1. Temperature chamber (TC),
2. Clean room (CR),
3. Vacuum chamber (VC).

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.

9 Comparison to previous coding of TVT system

New coding of TVT 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.

10 Why TVT test system?

There are on market other system for testing VIS-NIR cameras. However, there is a series of reasons to consider TVT station as the best solution for testing long range VIS-NIR cameras.

1. Universal modular test system that enable extended tests of all commercially available surveillance VIS-NIR cameras
2. Ultra expanded measurement capabilities. The system enables measurement of following parameters: Resolution, Minimal Resolvable Contrast, MTF, Distortion, FOV, Sensitivity, SNR, Noise Equivalent Parameters, Input, Fixed Pattern Noise, 3D Noise, Number of bad pixels and bad pixel localization, *Typical test systems offer typically measurement of lower number of parameters.*
3. TVT system offer for testing VIS-NIR cameras (MRC tests) using a set of at least six USAF 1951 targets of contrast from about 3% to 100%. This test is extremely important because most of targets of interest are low contrast targets. It is easy to manufacture high contrast targets but very difficult to manufacture low contrast targets. Inframet mastered technology to produce targets of contrast as low at 3%. *Typical competitor test stations offer usually only one USAF 1951 target of fixed 100% contrast.*
4. Ability to simulate both day conditions and night conditions due to extremely wide range of illumination regulation in range from about 30 µlx to over 30 klx. In other words it can be said that TVT system can simulates both ultra dark nights in Afghanistan mountains and very bright day conditions on Arabia desert. *There is on the market no test system that could simulate illumination condition in so wide range.*
5. Unique light source (two work mode (halogen 2856K color temperature for simulation of night&typical day conditions, white multi LED of 5000K color temperature for simulation of bright day conditions). Typical light sources can work only at halogen mode of 2856K color temperature that is poor fit to simulate day conditions.
6. Optional set of exchangeable refractive collimators enables testing short range VIS-NIR cameras of wide FOV.
7. Advanced software for image capturing and analysis that enable measurement of all important parameters of all types of surveillance VIS-NIR cameras.
8. TVT system offers measurement of aligning errors of zoom/step FOV objective.
9. TVT test system has been experimentally verified by a long series of manufacturers of VIS-NIR imager, space test centers or scientific institutes that do research in field of VIS-NIR imaging who have purchased this test system.

Version 6.2

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