DSTO
AUSTRALIA

TECHNICAL MEMORANDUM
WSRL-TM-55/91

THE DESIGN OF AN INFRARED LABORATORY FOR TESTING SEEKER COMPONENTS

B.W. Smith and R.A. Joyce

SUMMARY (U)

A summary is given of the facilities necessary to adequately test the performance of electro-optic seekers and their components. The basic tests which need to be performed are reviewed, with special emphasis on those for imaging seekers. New developments in seeker technology have required a re-assessment of the standard tests, and some novel methods are proposed.

Author's address:
Guided Weapons Division
Weapons Systems Research Laboratory
PO Box 1700, Salisbury
South Australia

Requests to: Chief, Guided Weapons Division

TABLE OF CONTENTS

LIST OF FIGURES

1. INTRODUCTION

Electro-optic target acquisition and tracking units (E-O seekers) on guided missiles or bombs are constructed from several basic components, each of which require extensive testing in the laboratory. This is necessary to analyse the performance and limitations of present weaponry, as well as support the development of new systems. The latest trend in seekers is to incorporate imaging optics to allow detailed analysis of the target. This places new demands on an infrared (IR) laboratory which need to be carefully considered.

This report outlines the facilities necessary to adequately test seeker components. One requirement is to support the in-house development of an imaging IR seeker. Such seekers comprise three principal sections: the imaging optics (including the scanning mechanism), the photodetector and the image processing algorithms. The infrared laboratory needs to be able to test the optics and detector components, and ensure that the processed image is of realistic resolution and contrast. It also needs to support the testing of non-imaging seekers. The processing algorithms used in imaging seekers for analysing the image and identifying the target are not considered in detail here. However, they must be included in any measure of the resolution of the operational seeker system. The following sections divide the tasks into tests of the optics, the photodetector, and the integrated system. The report concludes with a discussion of equipment selection.

2. MEASUREMENT OF OPTICAL COMPONENTS

The principal function of the optics is to pass the waveband of interest (usually 3 to 5 μm or 8 to 12 μm) and place an image of the target scene onto the photodetector. The optics in non-imaging seekers is often complex due to the need to withstand high temperature gradients without mechanical distortion so that tight focusing tolerances can be maintained. Imaging seekers present even greater design problems. When a single photodetector (or small array) is used, a scanning mechanism is required to sample the complete image of a target scene. This involves the use of moving optics and a driving motor which can lead to degradation of resolution due to vibration or imprecise scanning, particularly with the fast speeds required. The image quality needs to be assessed for the full seeker system, but it is also important to test the optical components during construction to ensure that they are performing adequately. This includes measurements of spectral transmission and reflection, alignment and resolution. The emissivity and reflective properties of the lens mounts and walls are also important.

2.1 Transmission

The total spectral transmission of the optics needs to be matched to the atmospheric transmission windows (either 3 to 5 μm or 8 to 12 μm) and the response of the photodetector. The transmission can be easily measured using a broad-band source (eg a blackbody) coupled to a monochromator, the transmitted signal being measured with a broad-band detector (eg a pyroelectric or thermopile detector). Alternatively, a calibrated photodetector with a limited wavelength response (eg a photoconductive HgCdTe detector) can be used for greater responsivity. The reflection properties of the components and their coatings can be obtained with the same equipment.

2.2 Alignment

The alignment of optical components (usually for a focus with the target positioned effectively at an infinite distance) can be tested by viewing collimated images of pin-holes illuminated by a blackbody source. If the optics contain rotating components, the focus needs to be checked for all orientations. The illuminated pin-hole could be replaced by a low-power 10.6 µm CO_2 or 3.39 µm HeNe laser with beam expansion optics. CO_2 lasers have minimum stable output powers of several watts, which necessitates gross attenuation for use with sensitive detectors. This can be achieved by passing a small portion of a highly expanded beam, or by taking a multiple reflection off a thick ZnSe window placed at an angle to the incident beam.

An imaging pyroelectric detector, which provides a visual display of the IR beam, can be used for initial alignment and focusing. A small photodetector element (of around 30 µm square) on a moving stage can be used for more precise alignment. An additional laboratory aid is a beam selector (a wavelength dependent beamsplitter) to combine 3.39 µm or 10.6 µm laser beams with visible light from a 0.6328 µm HeNe laser (see eg Melles Griot Optics Guide 4, 1988). This simplifies many laboratory measurements on invisible IR radiation.

2.3 Angular resolution

Angular resolution tests for imaging seekers can be performed in several ways. The best measure of angular resolution is given by the modulation transfer function (MTF) which describes the ability of the optical system, as a function of spatial frequency, to transfer object contrast to the image. The MTF gives the ratio of output to input contrast (modulation) for spatial sine waves. As thermal sine wave patterns are not easy to construct, IR resolution testing is done with bar patterns. However, square waves emerge distorted when passed through any optical system and the value of the ratio measured using a bar target needs to be reduced by a factor of around $\pi/4$ to obtain the MTF (Shumaker et al 1988, Wolfe and Zissis 1985).

Measurement of the MTF in this way requires a set of bar targets with differing spatial frequencies (lines per mm). A reflective collimator can be used to image small bar targets placed in front of a blackbody source. Alternatively, large targets (of the order of 1 m) can be illuminated by an IR lamp or diverged beam from a CO_2 laser (for 8 to 12 µm optics). In this case the resolution targets would be placed in a dark tunnel (giving a stable and uniform IR background) at a distance which is calculated to be effectively infinite for the seeker optics (an alternative is to have the targets closer and slightly re-focus the optics onto them).

A more accurate, although more difficult, procedure for calculating the MTF involves measurement of the point spread function (PSF), the MTF being the modulus of the Fourier transform of the PSF. The MTF can only be calculated in a rigorous sense if the optical system is spatially invariant. This is not the case when the system under test contains a scanning element, as the image will contain discrete lines in the cross-scan direction. For this reason linear-scanning systems are commonly tested using the line spread function (LSF) from an illuminated slit instead of the PSF from a pin-hole. The LSF is measured with the slit normal to the high speed scan direction, and the MTF is calculated from the fast Fourier transform (FFT). The FFT needs to be corrected for the finite slit width and the spectra averaged in the power domain to reduce noise effects and FFT errors (Holst 1989). The orientation of the slit will require careful consideration if this technique is to be applied to imaging systems with novel scanning methods.

A more limited measure of the angular resolution can be obtained by the knife-edge test. An imaging detection system (such as an imaging pyroelectric detector) can also be used to test the resolution of the optical components, but it should be noted that the resolution measured can be no better than that of the imaging detection system itself.

2.4 Background radiation

A further problem which must be considered is the radiant emission and reflections from all components in the optical assembly, including the walls of the seeker enclosure. This background radiation has the effect of reducing the sensitivity of the seeker. There is little opportunity to vary the optical components themselves, but the material and coatings for the lens mounts and walls can be carefully chosen. In general these need to be selected so as to give an acceptable balance between low reflection and low radiant emission. Low emissivity is particularly important in the region near the front protective window and the scanning motor where greatest heat is generated. The emissivity can be tested by placing the components in contact with (or coated onto) a heated block of accurately known (and variable) temperature. Calibrated broad-band detectors (eg pyroelectric) can then be used to determine the emissivity. The temperature of the block need not be measured if a reference material of known emissivity is used. The bi-temperature and bi-background methods (Johnson et al 1988) typically yield the emissivity to better than ±0.02.

3. MEASUREMENT OF PHOTODETECTOR CHARACTERISTICS

Photodetector characteristics are critical in determining the overall performance of a seeker. Laboratory measurements are principally necessary to check the manufacturer's specifications and give a direct comparison of photodetectors under various conditions. To this end it is useful to have 'standard' detectors of known performance, against which the detectors under test can be compared. Selection of the optimum photodetector requires measurement of the spectral response, detectivity, speed of response (time constant) and consideration of the ancillary electronic and cooling requirements. Hudson (1969) gives a summary of the techniques involved. As well as the specific items described below, a well-equipped laboratory must contain a detector power supply and preamplifier/bias supplies, as well as a lock-in amplifier for subsequent signal processing.

3.1 Spectral response

The spectral response is measured using a broad-band source coupled to a monochromator, the output having been calibrated using a standard detector. The beam path may be flushed with nitrogen to remove absorption by water vapour or carbon dioxide. If this is not possible it is necessary to link absorptance calculations using LOWTRAN (Kneizys et al 1983) to the analysis routine. A wet and dry bulb hygrometer and a barometer are required to measure the laboratory atmospheric parameters. The atmospheric transmission calculations can be avoided if it is possible to directly compare the detector under test and the standard detector. This requires the same source-detector path length and the same atmospheric conditions.

Seekers normally operate in either the 3 to 5 μm or 8 to 12 μm atmospheric windows. The selection of optimum atmospheric window depends on a complex calculation of photodetector sensitivity, target range and atmospheric transmission in the 'most likely' meteorological conditions (Laflamme 1981, Rice and Findlay 1988). In imaging seekers this calculation is further complicated by the characteristics and requirements of the image-processing software. For example, the primary concern may be the identification of the target from within background clutter during the initial target search phase at a distance of several kilometres, or it may be the correct analysis of 'friend' or 'foe' at much closer range. Since either window may be used, spectral response testing equipment must have capability in both.

3.2 Detectivity

The detectivity is usually referred to an electrical bandwidth of 1 Hz and a photodetector area of 1 cm^2, measured for a particular wavelength and chopping frequency. This results in the quantity D*, a function of the area of the detector (A_d), the electrical frequency bandwidth of the post-detector electronics (Δf), the responsivity (R), and the 'noise' (V_{rms}).

$$D^* = \frac{\sqrt{A_d \Delta f}}{V_{rms}} R$$

The responsivity is the rms signal voltage (output of the preamplifier divided by the preamplifier gain) per watt of incident radiation, and is normally measured using a blackbody source at 500 K. Alternatively, the responsivity can be measured for a range of wavelengths, resulting in a range of D* values. The 'noise' is given by the rms noise voltage measured at the specified chopping frequency. The responsivity and noise can alternatively be measured by current rather than voltage. These measurements are adequate to give the value of D*, and require the use of a blackbody source, a variable-speed chopper with a frequency meter, a calibrated broad-band (thermal) detector, a tunable narrow bandpass electrical filter and an rms voltmeter (or current meter). Laser sources and a monochromator on a broad-band source are useful for obtaining the responsivity at a given wavelength.

3.3 Time constant

For non-imaging seekers, the information on target direction is often encoded by a rotating reticle in front of the photodetector. The response time of the photodetector must be short enough to accurately convert the modulated incident radiation to an output signal. For imaging seekers the requirements are more severe: the response must be fast enough to allow accumulation of data from the full target scene during each scan. Basically, the response time of the detector and electronics must be such to make adjacent 'instantaneous field of view' samples independent; the combination of scan rate and instantaneous field of view defines the required detection and processing bandwidth. As an example, a system which scans at a speed of 4 kHz over a 20° horizontal field-of-view requires a detector with a response of around 1 μs to give a resolution of the order of 2 mrad. Multi-element detection systems may pose different requirements. In the case of a 2-D array in staring mode, the required speed may be defined more by platform or target dynamics.

The speed of response is measured in terms of the time constant, which is normally calculated from a plot of photodetector output versus chopping frequency (using an approximately square pulse shape). However, a time constant of 10 μs would not show a drop of response until around 15 kHz which cannot easily be achieved with a conventional mechanical chopper. One solution would be to use a pulsed light emitting diode as the source, but although some diodes made of ternary alloys give emission in the wavebands of interest they are difficult to obtain commercially. Another solution is to provide the modulated optical input by reflection off a spinning prism (G.G. O'Connor, pers. com.). Pulses of duration much less than 0.1 μs can be obtained, so long as the prism is positioned far enough away from the detector. Examination of the photodetector pulse on an oscilloscope then gives a direct measure of the time constant. A laser is the ideal light source for use with the spinning prism, there being little loss of power over the laser/detector distance. An extended source, such as a blackbody, gives appreciable $1/R^2$ loss of power when both it and the detector are placed far enough from the prism to give a very short pulse. However, longer pulses with a sharp cut-on and cut-off could be generated with an extended source and collimating optics. This would allow independent measurement of rise and fall times.

4. MEASUREMENT OF THE TOTAL SEEKER SYSTEM

The basic requirement for a seeker is to be able to find and adequately track the target. The key aspects of performance for an imaging seeker are the angular resolution, thermal resolution and tracking ability. The first two can be determined by presenting a 'static' target scene to the detector, but the measurement of tracking ability requires an 'active' scene in which the target is moving and increasing in size and aspect as the missile approach is simulated (ie a 'hardware in the loop' simulation). A missile simulation centre to perform this task is presently under construction at DSTO.

4.1 Angular resolution

The angular resolution (for a target of high emittance relative to the background) can be measured using the techniques discussed in Section 2.3. The resolution will be limited by the weakest component in the seeker system. This could be the optics themselves (including the protective window at the face of the seeker), the response time of the detector or associated electronics, or limitations in the subsequent signal processing (eg the software to construct and extract information from the image).

The measurements of image quality can be taken beyond simple resolution tests. The image processing can be tested by presenting more complex images to the seeker. These could be either large targets at a distance, or the collimated images from small target-shaped apertures placed in front of an extended blackbody source. The principal problem with the small aperture approach is that, due to a relatively long focal length, a standard 5 inch collimator at full aperture presents a maximum field-of-view of 9 mrad (whereas, for example, a frigate at 5 km subtends about 20 mrad). Collimators with larger apertures (and similar focal lengths) are available, but at a prohibitive cost. A more economical solution is to view the apertures with a reflective microscope objective. An alternative approach is to use an intermediate scale, with heated models as targets and a low-power collimator (ie supplementary lens) fixed on the seeker axis.

4.2 Thermal resolution

The thermal resolution of the seeker is important because many targets may have an effective temperature of only a few tenths of a degree above background. For example, a seeker designed for targets at near ambient temperature may need to find a ship at an average temperature of 302 K in a sea at 300 K. The 2 K contrast is reduced significantly at the ranges at which initial target detection is required. The seeker sees not just the emission from the ship, but also radiant emission from the intervening atmosphere. The further away from the ship, the greater is the contribution from the atmosphere, as well as the absorption of radiation from the ship. Calculations involving the use of LOWTRAN 6 (Kneizys et al 1983) suggest that a tropical atmosphere at 300 K will cause the 302 K ship to have an effective temperature of about 300.2 K at 10 km (for seekers at either 3 to 5 μm or 8 to 12 μm). Hence for this application it is necessary for the seeker to be able to discriminate target/background temperature differences to better than 0.2 K.

For imaging seekers the ultimate laboratory requirement is to be able to estimate the temperature resolution for a specific target and a particular image processing algorithm. One technique for doing this is discussed later, but for general testing of seeker hardware it is more useful to break the seeker at the image generator/image processor interface and measure specific properties of the image at this interface. These measurements are discussed first.

The thermal resolution of an imager is often defined by the minimum resolvable temperature difference (MRTD), which is the equivalent blackbody temperature difference between a specified target and its background when the target is just resolved visually on a display screen (Lloyd, 1975). The conventional method for measuring the MRTD is to present to the imager a resolution target which is of variable temperature with respect to the background. From the above discussion the temperature differential needs to be accurately controlled and measured to at least 0.1 K, and for comparison of seeker systems an accuracy of 0.01 K would be an advantage. The best approach is to use a differential temperature blackbody source (typically giving temperature differences to 0.01 K), but these items are relatively expensive. Another possibility is to simulate a temperature difference by viewing two coatings painted onto a heated block, the ratio of emissivities being accurately known (and close to one). This technique requires very accurate measurement of the relative radiant emittance from each coating and is unlikely to yield effective temperature differences of less than 0.1 K.

The MRTD should be measured for targets spanning a range of spatial frequencies, yielding a curve which is inversely related to the MTF. The principal disadvantage of the MRTD as a measure of resolution is that it gives only a subjective measure, dependent on a visual interpretation of when targets are just resolved. A number of researchers have attempted to quantify the eye/brain detection process in order to achieve an objective MRTD measurement technique, and a number of measurement routines have been developed (McCracken 1988, de Jong and Bakker 1988, Williams et al 1988, Holst 1989). Most of these techniques equate the MRTD to the noise equivalent temperature difference (NETD) divided by the MTF and multiplied by an 'eye' factor which incorporates a threshold signal to noise ratio and other properties of eye/brain interpretation. For seeker testing the human interface need not be considered as it is not present in the operational system. What is required is a reliable relative measure which can be used to compare different imager systems. The ratio NETD/MTF probably fulfils this requirement (Holst, 1989, found that multiplying this by a factor of 0.7 gave the experimentally derived MRTD for three forward-looking infrared systems). The NETD is a single-valued figure which is a measure of the total in-band noise (see Lloyd, 1985, for a description of the measurement procedure). If the noise deviates substantially from white noise, it is necessary to use the noise power spectrum rather than the NETD.

The above measurements of temperature resolution cannot be directly applied to the image processor section of the seeker. This section can only be tested by specifying a particular target and a given image processing algorithm. The following procedure uses computer generation of images, given some measured system parameters. It has some similarities to the method described by Steinberg and Rivera (1987), who use Monte Carlo simulations to test their processing algorithm.

The image is digitized into a two dimensional array of pixels, each pixel containing a certain signal level (corresponding to photon counts) for one scan. This is the basic input to the image processing algorithm. The presence of a resolvable target in the image will depend upon the magnitude of signal in the target pixels compared with the background pixels, and the way that the image processing software attempts to recognize and classify a target. It is possible to estimate the likelihood of detection (for a given target, target/background temperature difference, scanning rate and processing algorithm) from a measurement of the change with temperature of the quantity 'signal per pixel per scan'. This quantity varies only slowly with temperature (several percent per degree at around 300 K) and can be easily measured by observing a single blackbody source as it heats or cools. Measurement over several degrees allows accurate calculation of the change over much smaller temperature increments (eg allowing calculation of the NETD). If the system response is linear, 'signal per pixel per scan' need only be measured for one temperature.

Once the variation in pixel signal with temperature is known, a computer program can be written to randomly generate scenes. The mean pixel count for positions corresponding to target and background is calculated from their respective temperatures. Poisson statistics and a knowledge of the system noise characteristics provide a random variation of pixel count across the image. When the temperature difference is very small, these variations mask the target. The generated images are used in a Monte Carlo simulation to test the efficiency of the processing algorithm at detecting targets at different temperatures. This method requires an assumption about the system noise, but otherwise is simple to apply. The disadvantage is that it is specific to the individual target and image processing algorithm and it does not incorporate the optical properties of the imaging optics (although these could be built into the model).

From the above discussion it is clear that there are a variety of options for the measurement of thermal resolution and further work is needed to identify an overall procedure which is ideal for seekers. The MRTD gives an adequate measure of image quality before the image processing, but the introduction of a human interface seems unnecessary. The use of the ratio NETD/MTF as a relative resolution measure may be adequate to compare different systems. The real resolution test of an imaging seeker is the ability to correctly classify a target. This can only be tested by scene generation, using either an IR scene generated in a simulation laboratory or one which is computer-generated in the manner described above.

4.3 Environmental considerations

The performance of a seeker system needs to be assessed under various operational conditions. The high temperatures that may be encountered during supersonic flight can be simulated to some extent by heating the seeker in a laboratory oven. The effects of local heating and electronic noise pick-up from scanner electro-mechanical drives can be tested by pulsing them. Driving them at different rates could also provide useful information, although this may alter the system performance due to other factors (eg the detector response time). The degradation of image quality with vibration can also be measured.

It is important to realize that external factors may also influence the angular and thermal resolution attainable. Turbulence during the flight may cause unexpected movement of the target scene during scanning, affecting image reconstruction by the software. During flight the seeker will experience temperature gradients different from those simulated in the laboratory. This could produce de-focussing of the optics and subsequent image-blur. Additionally, the protective window in front of the seeker may contribute undesirable radiation. Apart from reducing the contrast of the target, any non-uniform heating of the window may produce false signals in the target scene. Some of these effects can be estimated (eg Whitney 1976), but a flight trial is necessary to fully determine the combined influence of all factors.

4.4 Tracking ability

Some aspects of seeker tracking ability can be measured without the use of a full missile simulation facility. For example, a single axis spin table can be used to measure the tracking ability as a function of line-of-sight (LOS) rate. Different target scenes can be used to test the performance of both the optical system and the signal processing. A more elaborate approach could involve the use of small radiating resistive components as the target, imaging them onto the seeker with the aid of a reflective microscope objective (O.M. Williams, pers. com.). An array of these components could be controlled so that the target increases in size to simulate missile approach. In developing such a system the IR laboratory must be able to test the resistive components. There are limits to how far the simulation should be refined as this is really the brief of a specialist simulation laboratory.

4.5 Benchmark system

Measurements during the development of experimental seekers have much greater relevance if they can be compared with those from a high quality existing system. The system would also be used for some of the measurements on optical components and ancillary measurements such as investigation of the resistive components described in Section 4.4. Such an imager is also necessary to provide support to the development of image processing algorithms in the seeker. This includes the collection of a library of target (and clutter) images and the validation of models which calculate thermal emission. It would be an advantage to be able to gather images in both the 3 to 5 μm and 8 to 12 μm bands. In addition to standard lenses, it may be necessary to use telephoto optics (either lenses or a Cassegrain reflector) to obtain images of distant objects. For accurate temperature calibration large blackbody sources can be placed in the target scene. An adequate source can be constructed by immersing a black cavity in water which is heated to the desired temperature by an electric element (Oermann 1985). Other reference sources can be constructed from large heated panels (Johnson 1987).

5. EQUIPMENT SELECTION

A summary of the equipment necessary to support seeker analysis and development is illustrated in figures 1 and 2. The list has been derived from the discussion above. Appendix I gives the general specifications for the key items. The selection of most components is clear cut, but some of the sources and detectors need further consideration.

The blackbody source chosen needs to be able to provide adequate power through a small pin-hole for accurate resolution tests. This requires it to be capable of temperatures to around 1000°C. Ideally the blackbody aperture would be several centimetres in diameter, but a 7 mm aperture is acceptable if cost constraints prevail. Even with a chopper system, the pin-hole and target apertures mounted in front of the blackbody may need to be cooled for maximum stability when measuring 8 to 12 μm (Hudson 1969). For monochromator illumination an IR lamp could be used in place of the blackbody source. A monochromator facility with a globar IR source (a rod of bonded silicon carbide), calibrated using a Golay Cell, has been used at DSTO for measuring spectral response from 3 to 15 μm (Oermann and Brunker 1987). A cheaper alternative to a monochromator is a 3 to 14 μm interference filter wheel, on which the film thickness varies with angular position. These give half-bandwidths of less than 2% with transmission >30% . The combination of monochromator and filter wheel would give excellent rejection of unwanted wavelengths, but exacerbates the problem of low monochromator throughput for high resolution.

The choice for broad-band (thermal) detection is principally between pyroelectric or thermopile elements. Thermopile detectors tend to be slower in response (Wolfe and Zissis 1985) and although modern units show good spectral range to beyond 100 μm, the experience in this laboratory is that the black coating which covers the junctions can become degraded with time. Commercial pyroelectric detectors have a similar detectivity but a significantly faster response, making these the preferred instrument. One problem is that the fast response of pyroelectric detectors is achieved through the use of very thin black coatings which are not perfect absorbers at all wavelengths. This can result in 'ripples' in an otherwise flat spectral response. The variable frequency chopper should be external to the detector unit, allowing it to be placed so as to minimize the background contribution.

For many laboratory measurements it is best to use a calibrated photon detector rather than a broad-band thermal detector, as D* is significantly greater. The choice of photodetector depends on the wavelength band to be measured. There are many options in the 3 to 5 μm band, with InSb photovoltaic detectors a popular choice. Ternary alloy detectors such as $Hg_{(1-x)}Cd_xTe$ (MCT) can be tailored to the wavelength response of interest by varying the proportions of each constituent and are suitable for both 3 to 5 μm and 8 to 12 μm bands.

The choice of imager for evaluating the optics and collecting thermal images of targets depends upon the need for flexibility in spectral response. Pyroelectric imaging systems are suitable for all wavelengths (provided appropriate lenses are used) and are invaluable for general laboratory use, but are one to two orders of magnitude less sensitive than systems comprising cooled photon detector elements. An imager such as the Kollmorgen MICRO-FLIR is an obvious, albeit expensive, choice. It has been used in seeker systems and is a standard against which comparisons could be made. Other commercial units are available which use cooled photodetectors with response in either the 3 to 5 μm or 8 to 12 μm bands. The resolution varies widely and needs to be carefully considered before purchase. The ultimate selection is likely to be determined by cost constraints.

Thought should be given to automating some of the measurements. Computer control of sources, motorized positioners and scanners and motorized dual axis mirrors would speed up many of the experiments described above.

There are changing trends in seeker technology which pose new problems for the infrared laboratory. The increasing use of multi-element detectors requires a capability to adequately test these systems. Some of the tests described in this report are not appropriate for multi-elements and some thought needs to be given to the best approach. Additional tests may also be required (eg measurement of cross-talk between elements). Another trend is the use of dual mode seekers (radio frequency and IR). In the future the testing laboratory will need to be able to cope with these as well.

ACKNOWLEDGEMENTS

The requirements for the IR laboratory were compiled during discussions with a number of members of Guided Weapons Division. In particular, Graham O'Connor, Ray Johnson, Owen Williams, Bill Woods and Peter Lozo have contributed many constructive comments.

REFERENCES

Holst, G.C. (1989) Minimum resolvable temperature predictions, test methodology, and data analysis. SPIE, 1157, Infrared Technology XV, 208-218

Hudson, R.D. (1969) Infrared System Engineering. John Wiley and Sons, New York, 642pp

Johnson, R.B., Feng, C. and Fehribach, J.D. (1988) On the validity and techniques of temperature and emissivity measurements. SPIE, 934, Thermosense X, 202-206

Johnson, R.P. (1987) An electrically powered infrared target. Dept of Defence, DSTO Salisbury, Weapons Systems Research Laboratory, Technical Report, WSRL-0498-TR. Confidential report

de Jong, A.N. and Bakker, S.J.M. (1988) Fast and objective MRTD measurement. SPIE, 916, Infrared Systems - Design and Testing, 127-143

Kneizys, F.X., Chetwynd, J.H., Clough, S.A., Shettle, E.P., Abreu, L.W., Fenn, R.W., Gallery, W.O. and Selby, J.E.A. (1983) Atmospheric transmittance/radiance: computer code LOWTRAN 6. Air Force Geophysics Laboratory (OPI), Hanscom AFB, Massachusetts, USA AFGL-TR-83-0187

Laflamme, A. (1981) Detection range probabilities of passive IR systems for the North Atlantic. Defence Research Establishment Valcartier, Canada, DREV R-4233/81

Lloyd, J.M. (1975) Thermal imaging systems. Plenum Press, New York, 456pp

McCracken, W.L. (1988) Objective MRTD as a figure of merit. SPIE, 892, Simulation and Modeling of Optical Systems, 38-45

Oermann, R. (1985) Radiometry using thermal imagers part 1 - the thermal analysis facility. Dept of Defence, DSTO Salisbury, Electronics Research Laboratory, Technical Report, ERL-0305-TR

Oermann, R.J. and Brunker, S.A. (1987) A facility for the measurement of radiometer spectral responses. Dept. of Defence, D.S.T.O. Salisbury, Electronics Research Laboratory, Technical Memorandum, ERL-0420-TM

Rice, B.W. and Findlay, G.A. (1988) Assessment of 3 to 5 μm and 8 to 12 μm thermal images in a tropical environment. Dept. of Defence, D.S.T.O. Salisbury, Surveillance Research Laboratory, Technical Report, SRL-0017-TR. Confidential report

Shumaker, D.L., Wood, J.T. and Thacker, C.R. (1988) FLIR performance handbook. DCS Corporation, Virginia

Steinberg, R.A. and Rivera, J.J. (1987) Infrared ship detection at low signal-to-noise. Fleet Systems Dept, The Johns Hopkins University, Applied Physics Laboratory, FS-87-193

Whitney, T.R. (1976) Aerodynamic window heating and its effect on FLIR imagery. SPIE, 95, Modern Utilization of Infrared Technology II, 116-123

Williams, T.L., Davidson, N.T. and Wocial, S. (1988) Objective Measurement of MRTD. SPIE, 916, Infrared Systems - Design and Testing, 92-98

Wolfe, W.L. and Zissis, G.J. (1985) The Infrared Handbook, revised edition. Environmental Research Institute of Michigan.

APPENDIX I

A summary of the key experimental equipment and a guide to the general specifications required.

Monochromator
Useable wavelength region 1 to 24 μm with interchangeable gratings;
0.01 μm bandpass;
wavelength driver with readout;
matched collection optics for increased collection efficiency (ZnSe optics is preferable to give a flat spectral transmission).

Blackbody source
Emissivity 0.99 ± 0.01;
temperature range 50 to 1000°C;
long term stability 0.1°C;
full aperture of 0.5 inch with an aperture set ranging from 0.0125 inch.
optional: IEEE interface and a fast temperature change capability.

Variable frequency chopper
Frequency range 40 Hz to 4 kHz;
frequency stability ±0.1%;
chopper reference signal output.
optional: computer control.

Collimator
Off axis, reflection optics;
5 inch clear aperture;
precision aperture wheel;
optical resolution 0.2 mrad.

Differential blackbody source
Temperature range 5 to 100°C;
differential temperature range $-20°C < \Delta T < +75°C$;
set point resolution 0.01°C;
aperture 100 mm.

Heated block
Temperature range ambient to 100°C;
imbedded thermocouples.

Large aperture blackbody source
Temperature range ambient to 50°C;
aperture 30 cm.

Laser sources
633 nm HeNe; 0.5 mW with beam expansion optics.
3.39 µm HeNe; 1 to 2 mW with beam expander.
10.6 µm CO_2; 5 to 10 W with beam expander/diverger.

Photodetectors (typical)
Standard detectors:
1 to 5 µm: InSb; 0.25 mm; $D^* = 1 \times 10^{11}$.
8 to 12 µm: MCT; 0.25 mm; $D^* = 4 \times 10^{10}$.
Miniature detectors:
3 to 5 µm: MCT; 0.025 mm; $D^* = 2 \times 10^{9}$.
8 to 12.5 µm: MCT; 0.025 mm; $D^* = 4 \times 10^{10}$.
Two colour detector:
1 to 5.5 µm/8 to 12.5 µm: InSb/MCT; 2 x 2 mm; $D^* = 1 \times 10^{11}/1 \times 10^{10}$.

Broad band detector
Pyroelectric radiometer (spectral response UV to far IR);
measurement range 0.1 to 10^{-8} W;
external chopper.

Imaging detectors
Low sensitivity: Pyroelectric vidicon;
chopped mode;
ZnSe faceplate on vidicon tube for wide band operation (0.6 to 22 µm);
resolution 150 TV lines/ picture height;
sensitivity ≈ 0.5°C;
broad band lens or two lenses of 3 to 5 µm and 8 to 12 µm;
TV compatible, PAL format.

High sensitivity: Cryogenically cooled photodetector imager;
dual photodetectors for 3 to 5 µm and 8 to 12 µm;
broad band lens or two lenses of 3 to 5 µm and 8 to 12 µm;
resolution 2 mrad;
sensitivity 0.1°C;
TV compatible, PAL format.

Lock-in amplifier
Frequency range 5 Hz to 100 kHz;
sensitivity 1 µV to 250 mV rms;
high input impedance.

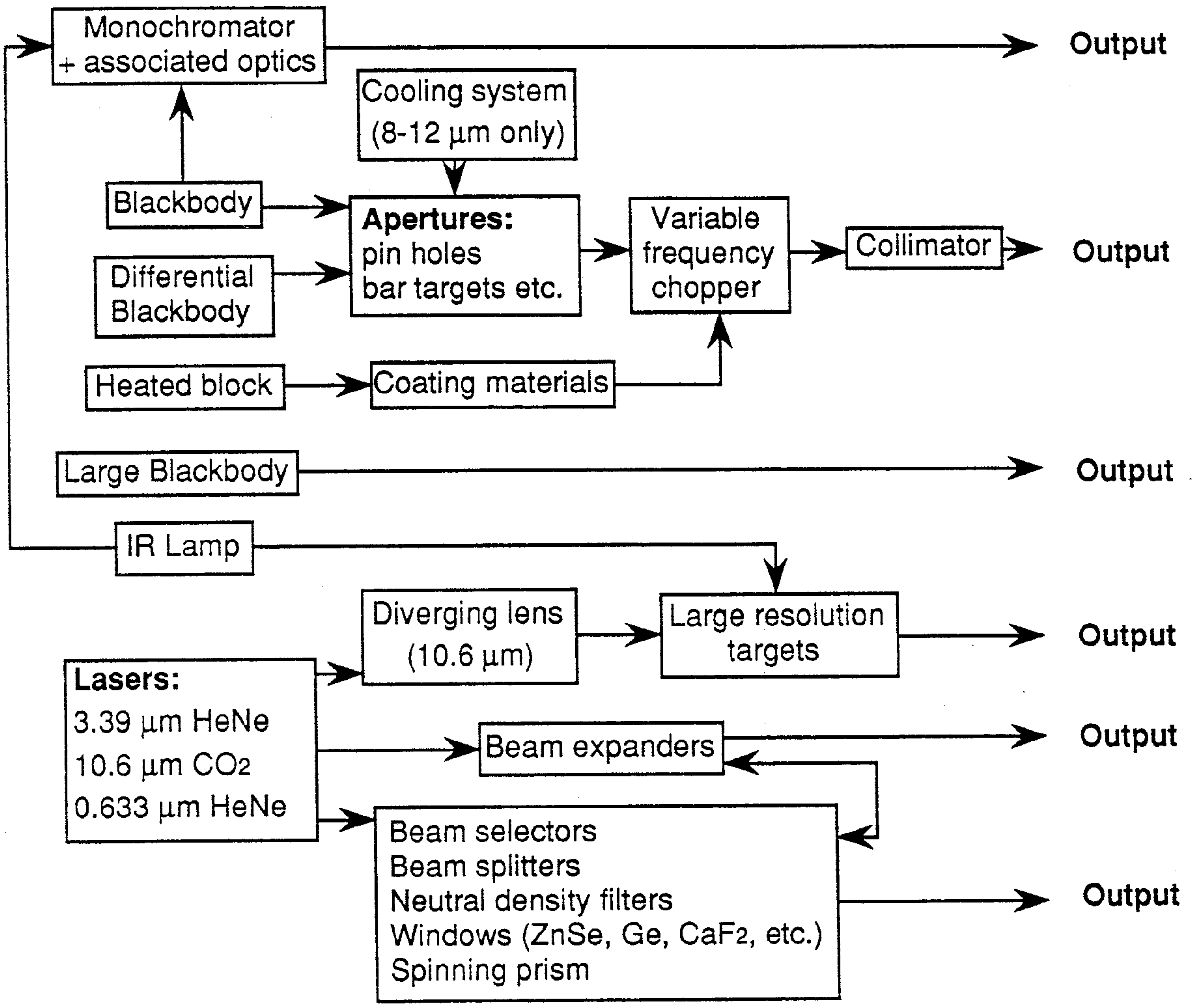

Figure 1. A block diagram showing the sources, optics and targets necessary to test the detection systems of seekers. The arrows indicate the general order in which the components are assembled for the measurements described in the text

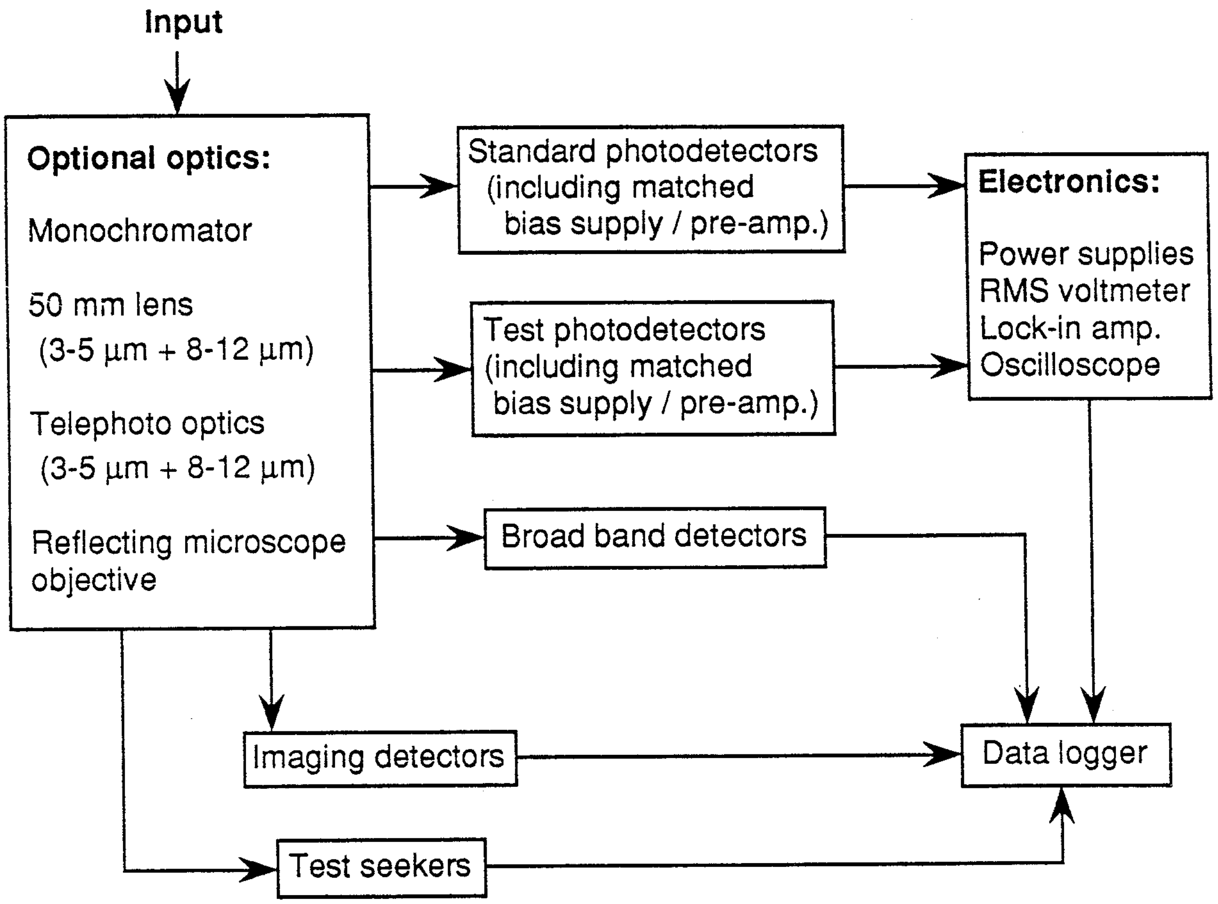

Figure 2. A block diagram showing the detection and electronic components necessary to test seekers, the inputs being supplied by the sources illustrated in figure 1. Again the arrows indicate the order of assembly

DOCUMENT CONTROL DATA SHEET

Security classification of this page : UNCLASSIFIED

1 DOCUMENT NUMBERS

AR Number : AR-006-780

Series Number : WSRL-TM-55/91

Other Numbers :

2 SECURITY CLASSIFICATION

a. Complete Document : Unclassified

b. Title in Isolation : Unclassified

c. Summary in Isolation : Unclassified

3 DOWNGRADING / DELIMITING INSTRUCTIONS

4 TITLE

THE DESIGN OF AN INFRARED LABORATORY FOR TESTING SEEKER COMPONENTS

5 PERSONAL AUTHOR (S)

B.W. Smith and
R.A. Joyce

6 DOCUMENT DATE

August 1991

7

7. 1 TOTAL NUMBER OF PAGES 16

7. 2 NUMBER OF REFERENCES 17

8

8. 1 CORPORATE AUTHOR (S)

Weapons Systems Research Laboratory

8. 2 DOCUMENT SERIES and NUMBER

Technical Memorandum
WSRL-TM-55/91

9 REFERENCE NUMBERS

a. Task : 89/158

b. Sponsoring Agency : DGFD

10 COST CODE

11 IMPRINT (Publishing organisation)

Defence Science and Technology
Organisation

12 COMPUTER PROGRAM (S)
(Title (s) and language (s))

13 RELEASE LIMITATIONS (of the document)

Approved for Public Release.

Security classification of this page : UNCLASSIFIED

14 ANNOUNCEMENT LIMITATIONS (of the information on these pages)

No limitation

15 DESCRIPTORS

a. EJC Thesaurus Terms	Homing devices Infrared tracking Imaging techniques
b. Non - Thesaurus Terms	

16 COSATI CODES

1606,
1707

17 SUMMARY OR ABSTRACT
(if this is security classified, the announcement of this report will be similarly classified)

(U) A summary is given of the facilities necessary to adequately test the performance of electro-optic seekers and their components. The basic tests which need to be performed are reviewed, with special emphasis on those for imaging seekers. New developments in seeker technology have required a re-assessment of the standard tests, and some novel methods are proposed.