April 2021

EXCELITAS TECHNOLOGIES®

High Definition Modular MWIR Cameras

Application Note: High Definition MWIR Camera System Design

Excelitas technologies have created a modular MWIR camera architecture optimised for the latest generation of 10 µm and 8 µm SXGA HOT and cooled sensors.

Operating at lower f-numbers provides increased MTF at higher spatial frequencies and enhanced signal to noise leading to exceptional imaging performance in a ruggedised and compact form factor. The flexible modular architecture enables solutions to be quickly customised to fulfil the customer's specific requirements. These cameras are well suited for numerous applications including counter drone (C-UAS), surveillance, ground based air defense (GBAD) as well as vehicle mounted and maritime targeting applications.

WHITE PAPER

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1. Introduction

Excelitas has a proven pedigree in the design and manufacture of high performance Optronics for all platforms and domains. Our solutions are relied upon globally to deliver outstanding performance in the most demanding of environments on fast-jet, rotary-wing, ground vehicle, dismounted soldier, maritime and space platforms.

In response to customer demand for an affordable, high resolution MWIR continuous zoom camera, we created the CheetIR family of cameras which we launched at SPIE in 2019. The CheetIR design leverages our experience in zoom optics for remote weapon stations where cost effective, ruggedised precision is required. We have delivered in excess of 5,000 RWS optical systems to customers around the globe.

The architecture of the CheetIR camera is modular enabling a range of fields of view to be realised simply by changing the front group of optics. The zoom assembly is common to all variants which simplifies manufacture and facilitates economy of scale. The sensor module is also interchangeable to suit the specific customer application and to facilitate future upgrades. Current sensor options include an HD720, 10 µm and VGA 10 µm with rotary and linear coolers. Further options for SXGA, 8 µm will be available later this year.

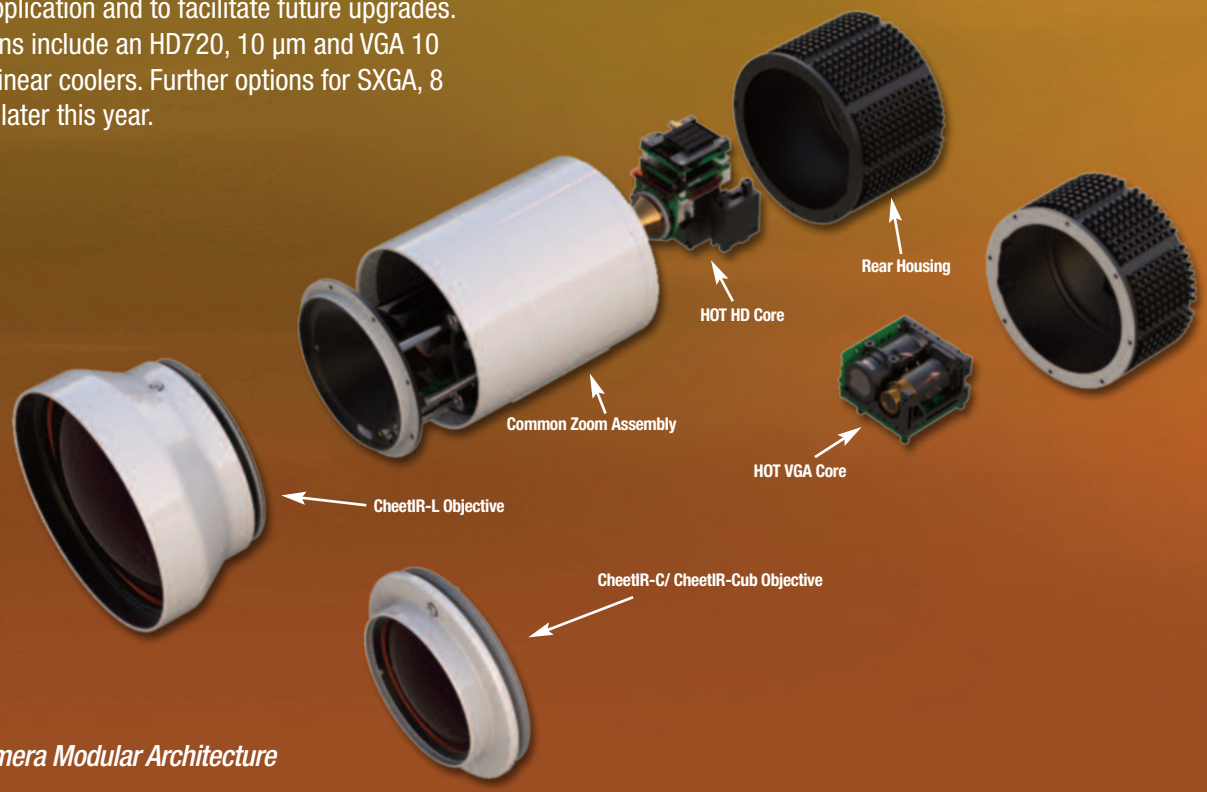

Figure 1 ***CheetIR Camera Modular Architecture***

2. System Performance

The CheetIR cameras operate at F/3 giving good camera system MTF beyond the Nyquist frequency of the detector providing a 2x increase in range performance compared with legacy F/4, 300 mm VGA camera solutions for the same horizontal field of view of 1.8 degrees.

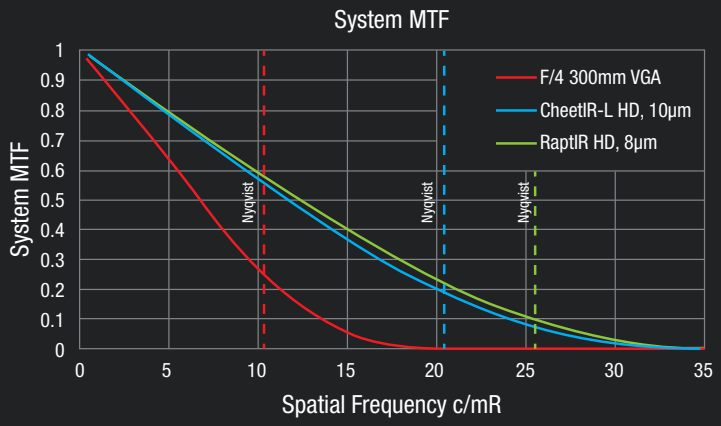

Figure 2 System MTF Comparison of F/4 300 mm VGA with CheetIR-L F/3, 410 mm and RaptIR F/3, 410 mm HD Cameras

The selection of F/3 gives the optimum balance of MTF with size weight and cost for a pixel pitch of 10 µm. If desired, the same lens can also be paired with an 8 µm sensor which we designate as our RaptIR camera series.

Figure 3 compares the key performance parameters of the CheetIR-L and RaptIR cameras with a generic F/4, 300 mm VGA 15 µm, legacy solution. This table illustrates that with CheetIR-L we achieve twice as many pixels on target at a given range which enables a higher level of discrimination in a comparable package to existing systems. This level of performance is particularly attractive for counter unmanned air systems (CUAS) as it enables drones to be detected and immobilized at twice the ranges achieved previously. The low mass and compact form factor of the CheetIR-L camera facilitates easy integration into numerous existing platforms, including pan and tilt heads and gimbals.

Parameter	VGA F/4 300mm Zoom Camera	CheetIR-L HD, F/3, 410 mm	RaptIR HD 8 mm F/3, 410 mm
HFOV	1.8º- 25º	1.8º- 25º	1.4º- 20º
Sensor	640 x 480, 15 µm	1280 x 720, 10 µm	1280x1024, 8 µm
Size (LxWxH, mm)	400 x 120 x 120	345 x 164 x 164	345 x 164 x 164
Weight	6 kg	5 Kg	5 Kg
Ruggedised	No	Yes	Yes
Resolution (Nyquist)	10 c/mR	20.5 c/mR	25.6 c/mR
F#λ/d	1	1.2	1.5
Pixels per metre at 4Km	5	10	12.8
Pixels over a 0.3m Drone at 3Km	2	4	5

Figure 3 Comparison of CheetIR-L performance versus legacy F/4, 300mm zoom cameras

The significance of having more pixels on target for anti-drone applications is clearly illustrated in Figure 5. Here we have taken actual thermal images of a drone and introduced differing levels of pixilation across the 0.3m drone width. The additional level of detail afforded by the increased resolution facilitates drone detection at longer ranges, 24 hours a day than is the case for legacy VGA solutions. These simulations show that there is significantly more detail to discern the drone characteristics as we increase the number of pixels from 2 to 4 and then again to 10 pixels. For the CheetIR-L camera 4 Pixels over a 0.3m drone equates to a range of 3Km.

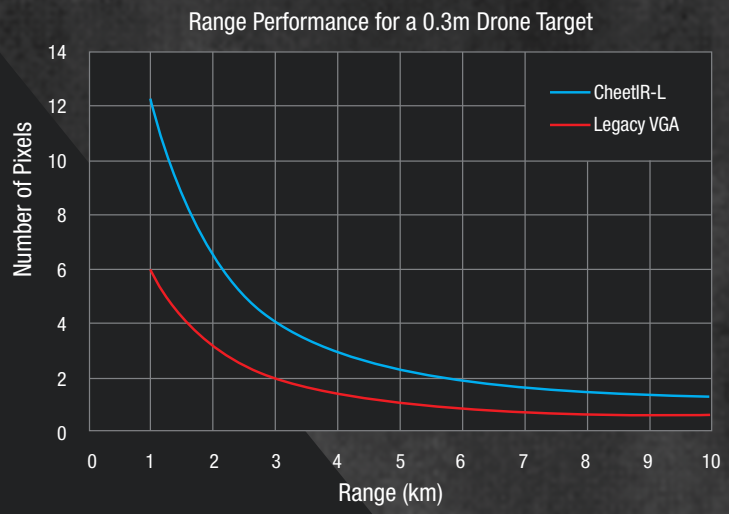

Figure 4 Range performance for a 0.3m Drone Target

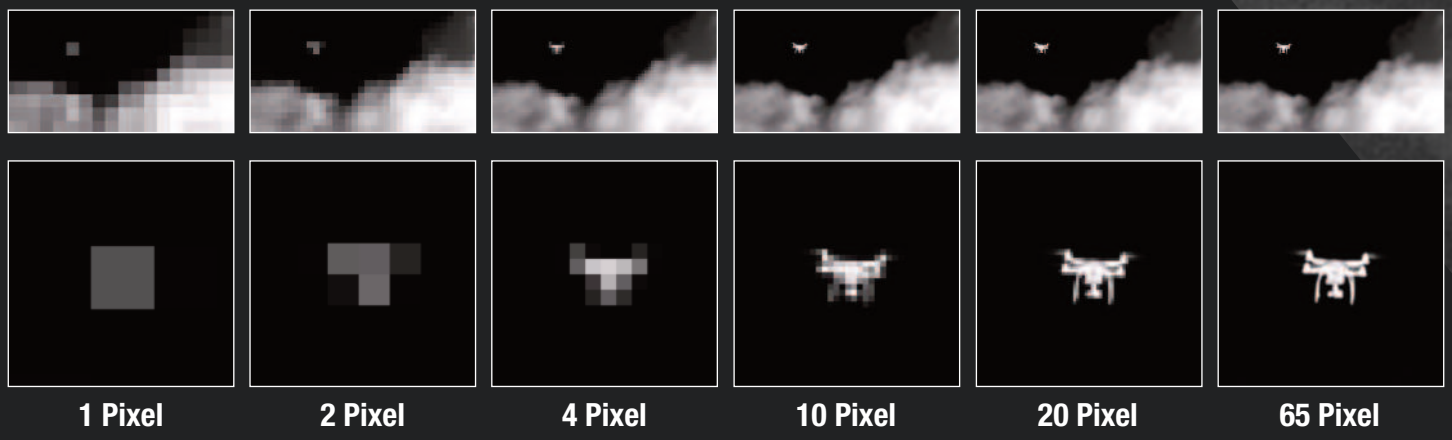

Figure 5 Illustration of drone detection / recognition / identification as a function of pixels over the target

The CheetIR-L camera is currently deployed on numerous C-UAS platforms, one example is the Skytrack system by Openworks Engineering. Figure 6 illustrates Class 1 drone tracking at ranges in excess of 2 Km facilitated by the increased camera resolution.

‘Class 1 Drone Tracking at over 2Km - day and night’

Figure 6 Actual Drone Images Captured using CheetIR-L (Courtesy Openworks Engineering)

2.1 Sensor Enhancements

The ratio of F#λ/d has been proposed[i] as a metric for MWIR camera optimisation where F# is the lens f-number, λ is the wavelength and d is the detector pitch.

For cameras where F#λ/d < 1, the camera range performance is limited by the detector. Conversely, for F#λ/d > 2.0 the range performance is limited by the optics. Optimised cameras have F#λ/d in the range between 1 and 2 with the optimum being approximately 1.5 depending on the actual system parameters. After Driggers et. alii. it is shown that range performance may calculated using the F#λ/d FOM metric, this has been done in Figure 7 for the same drone target described earlier. The CheetIR-L camera is denoted in this figure by red triangles for alternative sensor pitches.

It can be seen in Figure 7 that the CheetIR-L camera can be used with a range of sensor pixels and is well optimised for the next sensor node of 8/7.5 µm. The architecture of the CheetIR camera is intentionally sensor agnostic, future proofing the system and facilitating customisation for specific requirements.

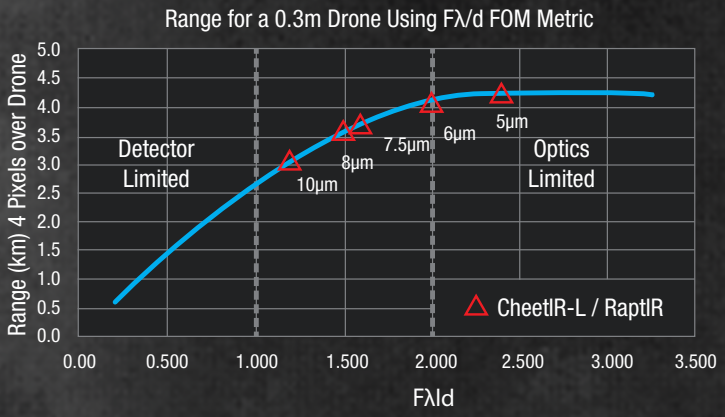

Figure 7 Comparison of Range performance using Fλ/d metric illustrating pixel pitch selection

3. RaptIR and OrcIR

In 2021 we will be launching our RaptIR and OrcIR variants of the CheetIR camera. The OrcIR camera is a derivative of the CheetIR camera using an increased focal length of 500mm.

This is achieved by simply replacing the objective group of the camera, the zoom assembly and sensor are identical to the proven CheetIR-L camera. If desired, OrcIR can be provided with a plano tilted window to facilitate applications that require a wiper, for example naval installations.

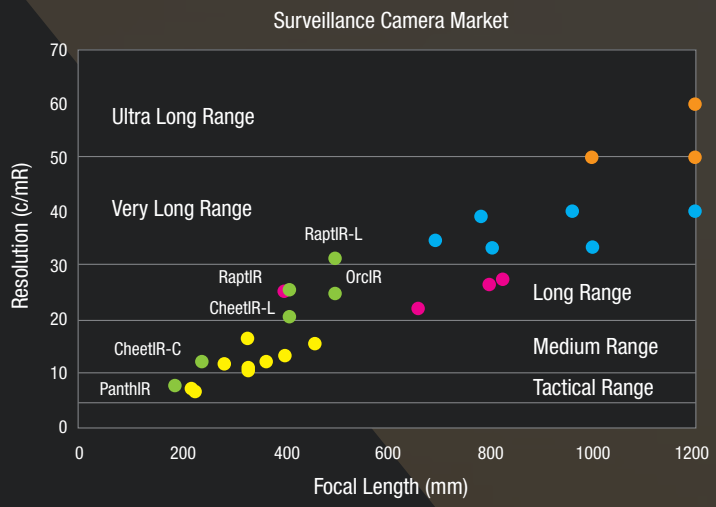

Figure 9 ***Comparison of Camera Focal Length with Resolution***

Figure 8 ***OrcIR Derivative of the CheetIR camera platform***

The RaptIR variants denote the use of CheetIR-L and OrcIR cameras with sub 8 µm focal plane arrays and linear coolers for applications that demand silent operation and increased resolution. These cameras offer a significant advantage for high-end imaging in a significantly smaller form factor than currently fielded systems. The comparative performance with legacy systems is illustrated in Figure 9. Here it can be seen that performance is comparable to systems focal lengths in the range of 800-900 mm. By using the latest small pitch technology, the Excelitas cameras are smaller and lighter reducing the initial cost of acquisition and the payload for pan and tilt heads and gimbals leading to further system level savings.

'Smaller pixels deliver significant size and weight advantage'

4. Summary and Conclusion

Excelitas has developed an exciting new modular family of camera products optimized for the latest generation of High Operating Temperature and cooled small pitch MWIR detectors.

The modular architecture enables a range of fields of view to be created based on a single base design to suit a specific application. The cameras are offered with VGA, HD720 and SXGA 10 µm and 8 µm sensors enabling market leading resolution in a very affordable, compact and rugged form factor.

These cameras are currently being deployed for surveillance, maritime, counter-UAS, and ground vehicle M-Shorad applications. They also offer excellent utility for High Energy Laser (HEL) target acquisition.

Figure 10 ***Excelitas Family of Cameras***

Parameter	CheetIR-L HD F/3, 410 mm	OrcIR HD, F/3, 500 mm	RaptIR HD 8 mm F/3, 410 mm	RaptIR-L HD 8 mm F/3, 500 mm
HFOV	1.8o- 25º	1.5o- 21º	1.4o- 20º	1.2o– 16.4º
Sensor	1280 x 720, 10 µm	1280 x 720, 10 µm	1280x1024, 8 µm	1280x1024, 8 µm
Size (LxWxH, mm)	345x164x164mm	395x195x195mm	345x164x164mm	395x195x195mm
Weight	5 Kg	? Kg	5 Kg	?? Kg
Ruggedised	Yes	Yes	Yes	Yes
Resolution (Nyquist)	20.5 c/mR	25 c/mR	25.6 c/mR	31.3 c/mR
F#λ/d	1.2	1.2	1.5	1.5
Pixels per metre at 4Km	10.3	12.5	12.8	15.6
Pixels over a 0.3m Drone at 3Km	4.1	5.0	5.1	6.3

Figure 11 ***key Parameters for the Excelitas Family of Cameras***

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About Excelitas:

Excelitas are a market leader in Optronics and Photonics serving the Defence and Aerospace, Medical, Semiconductor and Machine vision market segments. Our global manufacturing footprint makes Excelitas the perfect Optronics partner across the world.

[i] *Design Considerations for advanced MWIR target acquisition systems, G Holst, R Driggers, O Furxhi, Applied Optics Vol 59, No. 14 / 10 May 2020*

[ii] *Simple Target Acquisition Model based on Fl/d, R. Driggers, G. Goranson, S. Butrimas, G. Holst and O. Furxhi, Optical Engineering 023104-1, February 2021, Vol. 60(2)*