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Survey of Electro-Optical Infrared Sensor for UAV

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ABSTRACT

The rising demand for the high efficiency and high covertness in UAV motivates the miniature design of the high performing mission sensors, or payloads. One of the promising payload sensors, EO/IR sensor has evolved satisfying its demands and became the main stand-alone mission sensor for 200kg-range UAV. One aspect in development of EO/IR sensor concerns lack of specification criterions to represent its performance. Even though the high demand and competition among each manufacturer caused EO/IR features subject to rapid change collateral to new technology, the datasheets maintained the conventional outdated formats which leave some of the major components in ambiguity. Making comparisons or predicting actual performance with such datasheets is hardly worthwhile; yet, they could be important reference guide for the potential customers what to expect for the upcoming EO/IR. According to UAS Roadmap 2007-2032 published by DoD, one of the main potential customers as well as a main investor of EO/IR technology, EO/IR is expected to play key roll in solving urgent problems, such as see and avoid system. This paper will examine the recent representative EO/IR specialized in UAS missions through datasheets to find out current trend and eventually extrapolate the possible future trend.

Key Words : EO/IR, IR sensor, Daylight CCD camera, Hyper-spectral imaging

1. Introduction

A typical UAS (Unmanned Aircraft System) is composed of UAV (Unmanned aerial vehicle), and the datalink, and GCS (Ground Control System). One of the biggest advantages of the unmanned system is the less vulnerability for the pilot. As reasonable as it sounds, unmanned system has repeatedly replaced 3D (dirty, dangerous, and dull) missions since the introduction of the concept in 1900's. The missions for UAS, with the advantage of having secure LOS (Line of Sight), varies from detecting and locating targets to attacking fighter.

On the other hand, the biggest disadvantage of the UAS is also lack of the pilot on the vehicle. Because the pilot controls from remote location, the perception is very limited. Limited perception may cause the inefficiency or failure of the missions. One of the representative examples of this problem is that UAV is currently banned from public air space because of lack of capability to avoid other aircraft.

In order to improve this problem, high performing sensors are in demand more than ever. Some of the currently adopted payloads, sensors that aid the pilot perception to make decision for the missions, include EO/IR, SAR, SIGINT, and RADAR. Among these sensors, EO/IR is used in the most various types of air-vehicles due to its miniaturization as well as the capability to deliver the details in real time to aid the pilot control.

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In this paper, current trend and capabilities of EO/IR will be evaluated through the missions it has been used and the specifications from the datasheet. Furthermore, the future trend may be extrapolated by speculating where the most advanced technologies are headed.

2. The UAS Missions

Table 1 shows the COCOM (Combatant Commander) and Military Department's UAS needs, prioritized by the aircraft classes. The aircraft has been categorized by its GTOW (Gross takeoff weight) and its various capability-needs as follows : Small (<55 lbs), Tactical (<1320 lbs), Theater (>1320 lbs), Combat (an aircraft designed from inception as a strike platform and larger than 1320 lbs). The criterions of such classes were categorized depending on the UAS missions.(1)

The second priority is target identification and designation. Finding, fixing, and tagging potential target is a clear fit for unmanned systems. The ability to operate in high-threat environments without putting war-fighters at risk is also a significant advantage compared to current manned systems. The characteristics of EO/IR are highly desirable to carry out such missions.

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The JUAS (Joint Unmanned Aircraft System) category in Table 2 demonstrates each division of the mission groups, operational altitude, launch method, etc. The table gives examples of UAVs as well as what type of payload systems are used in each category. EO/IR is equipped in almost all level of UAV missions due to high performance to its weight. Especially, in T2 and T3 classes employ EO/IR as the prime and only payload. Performance of EO/IR as the main payload is getting challenged and reduction of weight is also challenged for the efficiency and for smaller UAVs. The requirement of such EO/IR can be summarized as following : usual mission altitude of about 1.5km, GTOW of about 200kg, and airspeed of about low 100kts, which is the borderline between T2 and T3.

Mission Area	Small	Tactical	Theater	Combat
Reconnaissance	1’	1’	1’	1’
Precision Target Location and Designation	2’	2’	2’	2’
Signals Intelligence	7	3’	3’	4
Battle Management	3’	4	5	6
Communications / Data Relay	8	6	4	7
CBRNE Reconnaissance	5	5	9	8
Combat Search and Rescue	4	7	8	9
Weaponization / Strike	16	8	7	3’
Electronic Warfare	12	11	6	5

Source : DoD UAS Roadmap 2007-2032

Table 1.COCOM and Military Department UAS Needs Prioritized by Aircraft Class

JUAS Categories	Current System Attributes							
	Operational Altitude (ft)	Typical Payload	Launch Method	Weight (lbs)	Airspeed (kts)	Endurance (hrs)	Radius (nm)	Current Systems **(Projected by 2014)**
T1-Tactical 1 Special Operations Forces (SOF) Team Small Unit Company & below	≤ 1,000	Primarily EO/IR or Comm Relay	Hand launched	≤ 20	≤ 60	< 4	< 10	Hornet, BATCAM, Raven, Dragon Eye, FPASS, Pointer, Wasp, BUSTER (rail-launched), MAV
T2-Tactical 2 Battalion/Brigade Regiment SOF Group/Flight	≤ 5,000		Mobile launched	20 – 450	≤ 100	< 24	< 100	Neptune, Tern, Mako, **OAV-II**, Shadow, Silver Fox, ScanEagle, Aerosonde
T3-Tactical 3 Division/Corps MEF/Squadron /Strike Group	≤ 10,000	Above, Plus SAR, SIGINT, Moving Target Indicator (MTI), or WPNS	Conventional or Vertical Take-off and Landing (VTOL)	450 – 5,000	≤ 250	< 36	< 2,000	Maverick, Pioneer, Hunter, Snow Goose, I-Gnat-ER, ER/MP, **Dragonfly, Eagle Eye**, Firescout, BAMS, Hummingbird, Onyx
O-Operational JTF	≤ 40,000		Conventional	≤ 15,000	> 250			Predator, **N-UCAS**, Reaper
S-Strategic National	> 40,000	Above, plus RADAR		> 15,000			Theater wide	Global Hawk

Source : DoD UAS Roadmap 2007-2032

Table 2. JUAS Categories

3. EO/IR

EO/IR sensor is an abbreviation of electro-optical infrared sensor. EO/IR sensor system usually includes two main sensors, daylight CCD camera and IR sensor, and many other sensors as additive options. IR sensor is an infrared-ranged light imaging system which senses and differentiates one object from another by the temperature difference; thus it can be used for both day and night. As people say everything that moves generates heat, IR sensor can be utilized in various missions. Daylight CCD camera is a visible-ranged light imaging system which can only be used in day time. Daylight CCD camera usually carries high magnification and resolution to aid object identification. Beside these sensors, many EO/IR manufacturers offer additional options such as night spotter, day spotter, laser illuminator, laser range finder, and laser pointer, etc. Even though some of these options can greatly increase the overall performance of EO/IR for some missions, they have been separated due to the effort of miniaturization.

Reduction in the size and weight of payload is highly desired in the system integration. As a payload of the flying vehicles, which are critically restrained by weight, minimizing the weight of the payload increase the efficiency, increase covertness, and minimize the structural challenge due to shift in center of gravity. The challenge of this miniaturization comes to optimizing capabilities of EO/IR to the mission. The miniaturization of EO/IR came to the point where it compromises its capabilities with the weight; in other words, decrease in the total weight is achieved through sacrifice of some performance. Depending on what feature each manufacturer value the most, each EO/IR present different physical and capability characteristics due to different degree of compromise in different parts.

One way to evaluate a product is by the datasheet; in other words, each datasheet should represent the product. The EO/IR datasheet, however, does not fully reflect the performance of the product. The performance of EO/IR shows high dependence on the aircraft that it goes onto and the mission environment and the mission environment and mission itself. The quantitative values provided by the datasheet are also subject to change with customizable options. Adding optional devices may enhance the performance ; however, it also adds additional physical restraints beyond what is presented on the datasheet. The specification of such device can't be manifested until the proposal is set and tested. Differentiating and ranking each EO/IR would be very difficult and at the same time it is not the purpose of this paper.

In this paper, the EO/IR weight will be limited to the usual payload capacity of 200kg-range UAVs, which is 50kg. It is the border line specification of T2 and T3 shown in JUAS chart in Table 2. The group was categorized to under and above 25kg. Among many other distinctions, current miniaturization has brought the below 25kg EO/IR to have Daylight CCD camera and IR sensor, two most powerful sensors at short-ranges, as default where as above 25kg EO/IR doesn't necessarily have them as default. This difference comes from the purpose or the missions they are used; in fact 25kg line differentiates light and middle level EO/IR and is subject to change depending on the further miniaturization.

3.1 EO/IR under 25kg.

Among many developers of EO/IR, four representative under-25kg EO/IR were chosen considering the availability of the information.

The Figure 1 lists the four EO/IR ; Wescam's 12DS/TS200, FLIR Systems' MicroSTAR II, IAI/TAMAM's POP200/300, Controp's Quad-1. The full detailed specifications of these four EO/IR sensors can be found in Appendix B.

The datasheet specification values are averages or approximated initial performance values that may be improved or compromised due to the addition of other parts or operating environment.

The specification of EO/IR as imaging system can be represented by detection, recognition, and identification range. Having a long range combines three essential EO/IR specifications, stabilization, resolution, and magnification. Such specifications are also the key factors of the UAV missions, reconnaissance and target location.

Source : Data sheets.

Figure 1. 25kg and Under EO/IR.

There are two specifications related to stabilization in the datasheets. One is the number of gyro axis, in which all four had two-axis gyro stabilization as basic with some options to increase in axis. The other factor is IMU. Each EO/IR contains its own IMU (inertial measurement unit) in order to provide better stability and target-location accuracy. The main reason adding an IMU in EO/IR beside the one in the aviation is to prevent the problems caused by flexure or misalignment that may happen when mounting the gimbal on the aircraft. TS200, POP300, and Quad-1's datasheet indicates IMU stabilization level of about 30~40urad rms/axis where as MicroSTAR II has Fiber-Optic Gyro Stabilization 50. The previous unit represents the measurement of solid-state mechanic IMU. On the other hand, MicroSTAR II presented the measurement of solid-state fiber-optic gyro which was developed to improve the accuracy and to prevent the accuracy deterioration due to abrasion of mechanic IMU in the long-term use. This presents a good example of incommensurability problem between advanced and old technology. While the IMU stabilization comparison remains unresolved, Fiber-Optic Gyro's long lifetime and high reliability over time is highly desirable feature over mechanic IMU.

Resolution involves both detector and display screen. For the IR sensor, with the exception of TS200 with InSb 256 x 256, all company used 320 x 240 InSb Staring Array, or Focal Plain Array, as detector. Higher resolution in detector delivers more details. The InSb sensor has high quantum efficiency of generating current when infrared light is present. However, the nature of InSb sensor generates heat and over time, this heat increases the noise in the detector. For the reason, it requires periodical re-calibrations between cooldowns. Thus, short cool-down time is desirable for the efficiency of the operations. TS200 presented NETD (Noise Equivalent Temperature Difference) as a measure of the sensitivity of a detector of thermal. NETD is the scene temperature difference equal to either the internal noise of the detector or the total electronic noise of a measurement system. Even though NETD is a way to measure the performance of the detector, it has tendency to increase in noise with heat and less practical meaning of representing the overall performance of the detector. Instead, MRTD (Minimum Resolvable Temperature Difference) gives more practical purpose; it is the measure of the minimum temperature difference at which a four bar target can be resolved. Unlike NETD, MRTD represents integrated overall performance of IR detector and able to provide discernible measure, generally known to be about three degree Celsius. Unfortunately none of the example provided MRTD. For the CCD TV camera, CONTROP uniquely equipped with both high resolution detector and display.

Magnification ratio for IR sensor is defined by the ratio between the NFOV (Narrow Field of View) and WFOV (Wide Field of View). There are two methods of magnification, step zoom and continuous zoom. TS200 and POP300 provide four step zoom, which can only be magnified to four specific ratios. Step zoom can jump from one ratio from another by simple quick control. But it can't be zoomed between steps and also possess the danger of losing the target while zooming and in and out. In case of continuous zoom, which Quad-1 adopted, the observer can zoom to any ratio. However, the zooming process takes longer time to zoom in and out, presents complexity in controlling and the internal hardware due to the given degree of freedom. Since one method counteracts each other, MicroSTAR II adopted both methods in one system. The only downside of having both would be higher complexity in controlling and the hardware in IR sensor. The IR sensors have magnification ratio of x11, x10, x13, and x12 accordingly.

	12DS/TS200	Micro STAR II	POP200/300	Quad-1
Stabilization	2 axis Stabilization level < 35 urad rms/axis	2 axis Fiber-optic Gyro Stabilization : 50	2 axis Stabilization level < (30~40) urad rms/axis	2 axis Stabilization level <35 urad rms/axis
Resolution	IR: 256x256 InSb FPA CCD: 480 lines	IR: 320x240 InSb FPA CCD: 270(NTSC) 460(PAL)	IR: 320x240 InSb FPA CCD: N/A	IR: 320x240 InSb FPA CCD: 500 lines
Magnification	IR: 4 FOV (25~2.2) CCD: 20x	IR: 10 Cont. or 3 FOV (21.7~2.2) CCD: 72x	IR: 4 FOV (22~1.7) CCD: 45X	IR: Cont. (27~2.2) CCD: 75x
Human Detection Range	N/A	3.5 km	4 ~ 5 km	5.4km

Source : Data sheets
Table 3. Under 25kg Specification

	12DS/TS200	M.STAR II	POP200/300	Quad-1
Weight(kg)	Turret: 20.87 SIU: 4.08	Turret: 13 ECU: 3.4	Turret: 10.4 PEB: 5.9	Turret: 21.5 PEB: 3.4
Size(cm)	371 x 305	343 x 229	380 x 260	430 x 305
Endurance	Shock, 10g, 11msec -15°C~55°C, 4,572m, 270knot	MIL-STD-810/ DO-160D -20°C~+55°C, 4,572m, 270knot	Shock, 20g, 11msec MIL-STD-810E, Method 509.3, Procedure 1 -30°C~+55°C 4,572m, 300knot	MIL-STD-810F, 514.5, 15g, 11msec -20°C~+50°C 4,572m, 180knot
Option(s)	IRI	LP, SSI, LI	AVT,LP, LRF	AVT,LP,LRF

Source : Data sheets
Table 4. Under 25kg Physical Specification

For the CCD TV camera, there sre optical zoom and electrical zoom. The total zoom can be computed by multiplying both zoom ratios. The total zoom ratios of the examples are x20, x72, x45, and x75 accordingly. The important specifications are summarized in Table 3. Some of the desired features were underlined. From the specifications, one may expect POP300 or Quad-1 will have the longest detection range if those specifications reflect the detection range. In fact, the approximated IR human detection ranges provided by the manufacturers are as following : MicroSTAR II (3.5km), POP300 (4~5km), and Quad-1 (5.4km). TS200 did not provide the estimation, but from the specification, the range is expected to be less than that of MicroSTAR II. The usual mission of GTOW of 200kg UAVs has altitude of about 1.5km and considering mission angle is between 30 to 50degrees, the worst case distance to the object becomes to 2.3km. All detection range satisfies the requirement. However, the challenge will come in a severely affecting weather or in the missions that require recognition or even identification, of which the ranges aren't given by the manufacturers.

Apart from the just specification, one should consider the unique features each manufacturer offered. From the new IMU and zooming method mentioned above, some of the options provided by all manufacturers, like auto-track and stow position, and some of the options provided by only few manufacturers, such as AVT or auto-focusing.

Table 4 shows summary of physical features of the examples. Even though, the payload weight limit of GTOW of 200kg-ranged UAVs is approximately 50kg, the system prefers lightest payload. While all of the examples well satisfy the weight requirement, the economic and overall performance efficiency can be improved by using lighter and smaller payload. MicroSTAR II and POP200/300 are significantly smaller in weight and size than other two; thus they are desirable over the other ones to improve efficiency.

Auto-tracking or AVT are likely to become basic requirements even though they are offered as options. AVT enhances auto-tracking feature by tracking up to six seconds by remembering the object's movement pattern it is very desirable in reducing the workload of the observer.

LI increases the identification capability, and LP and LRF can be used to aim or acquire additional information. Depending on the condition of the mission, such options can be important factor of choice. Such LIDAR features may also become very common because the research on see and avoid system with the features is currently in process.

The endurance of EO/IR is described by the satisfying military requirement, temperature, altitude, and speed limit. One may easily notice that 12DS/TS200 does not satisfy any military requirement; at the same time, POP200/300 has the best fit and Quad-1 has comparably low fit by quantity.

POP 200/300 is one of the smallest, yet with high specification and highest endurance. In addition, the unique advantage of POP series is that it adopted slide style sensor. It is composed of turret and slide style sensor that can be replaced in a few minute by a person. This characteristic enabled it to easily upgrade or to replace broken sensor; it presents very attractive qualities over others. In fact, Shadow 200, currently used by army and marine corps, uses POP 300 EO/IR sensor which relays video in real time via a C-band LOS data link and has the capability for IR illumination (laser pointing). In the future, it is expected to be upgraded to POP 400 with laser designation technology. For the side note, notice that endurance presented the limitation of the worst cases. In other words, satisfying endurance limitations does not guarantee the favorable condition in the missions.

Such requirement may not show on the datasheet representing the specification of the EO/IR itself, but there will be high burden on the mounting UAV. In case of POP 300, it requires higher stabilization when mounting than MicroSTAR II. It is said that depending on the UAV, POP series may require extra stabilizer that adds extra weight and it may or may not perform better than MicroSTAR II in spite of better specification.

Some other factors that need to be considered include mission conditions or weather, observers' familiarity of interface, data type compatibility with existing devices, MTBF (Mean time between failures), price, etc.

CONTROP's Quad-1 represents the tendency of having best specification in the exchange of physical reduction. POP300 was adopted by Shadow200 which is mainly used for the reconnaissance over wide area. On the other hand, Quad-1's high specification may better feat for identification missions that require long range and high covertness than POP 300.

3.2 HD EO/IR.

For the above 25kg ranged EO/IR, two major manufacturers were chosen for the same reason as above four choices. One is FLIR systems and the other is WESCAM.

Source : Data sheets.
Figure 2. 25kg to 50kg HD EO/IR.

FLIR Systems offers Star SAFIRE series and WESCAM has MX-15 series. Figure 2 shows the representative HD level EO/IR for both series and the specification of the two EO/IRs can be found in the Appendix B. LIR Systems' Star SAFIRE series has three kinds : III, HD, and QWIP. All three have the same physical features, same size, weight, and power dissipation. SAFIRE III has the most basic specification and the other two shows more advanced features, even though they have the same physical features; thus the price of the two will be higher. HD and QWIP has almost the same specification; the only difference between HD and QWIP is the wavelength they utilize. SAFIRE HD uses 3~5μm wavelength light where as SAFIRE QWIP uses 8~9μm wavelength light for IR sensor. Because 8~9μm wavelength light shows better transmissivity in the atmosphere, it is a better fit for fog, smoke, dust and many other obscurants in the exchange of some resolution compared to HD. For WESCAM's MX-15 series, MX-15 would be the most basic type of the all four types that are offered. MX-15i, MX-15 True HD, and MX15D also have the similar physical features; the only difference comes from the price and the option pools you can choose from. Each MX-15 series can choose up to six sensors from the option pools, which are different for each model. For example, MX-15 True HD offers a night camera with spotter lens which is not an option for MX-15D. Because of this similarity within each series, only the HD level, the sensors with the highest performance, were chosen from each family for the specification.

	Star SAFIRE HD	MX-15 True HD
Stabilization	6 axis LOS stabilization <5 urad	6 axis LOS stabilization <6 urad
Resolution	IR : 1280 x 720 CCD :1280 x 720 both NTSC/PAL	IR : 640 x 512 (HD)1080 x 720 CCD : 470TV lines
Magnification	IR : 30° ~ 0.25° steps unknown CCD : 120x	IR :26.7° ~ 0.36° 4 Step Zoom CCD : 9.9x

Source : Data sheets.
Table 5. 25kg to 50kg HD EO/IR Specification.

The Table 5 shows the simple specification of each HD level EO/IR. The detection ranges were not given; however, the specification infer that Star SAFIRE HD will have longer human detection range than MX-15 True HD. Some of the desired features were underlined.

	Star SAFIRE HD	MX-15 True HD
Weight(kg)	TFU: 45 CEU: 10.4	Turret: 46.72 MCU: 9.07
Size(cm)	450 x 380	476 x 394
Endurance	MIL-STD-810E & MIL-STD-461F, -40~55°C	MIL-STD-461, MIL-STD-810, RTCA/D0-160

Source : Data sheets.
Table 6. HD EO/IR Physical Specification.

Table 6 presents the physical specification of the two HD level EO/IR. Star SAFIRE and MX-15 series are described as 45kg and 46.7kg accordingly. This may change depending on the options, but over all increase in size and weight shows improved specification, more options, higher degree of freedom in customizing, difference in its role as a payload of UAV, and less available information.

One may find the specifications given in the datasheets from these datasheets do not give as many specifications as the lighter EO/IR datasheets did. Rather, the datasheets presents the specification of more diverse options. As the range and performance of EO/IR increase, it has been employed by the high mission altitude and heavier UAVs among multiple other sensors. In fact, the Star SAFIRE series only offers IR sensor as default sensor and MX-15 series offers no default; all the other available slots can be filled with optional sensors. If the above 25kg EO/IR is considered more of supportive sensors as a predecessor before the miniaturization, the miniaturization not only reduced the weight, but has successfully utilized some of the most powerful short-ranged sensors to establish EO/IR's own color. In other words, the advantage of daylight CCD camera and IR sensor fade as the interference increase, even though the specifications are better than lighter ones.

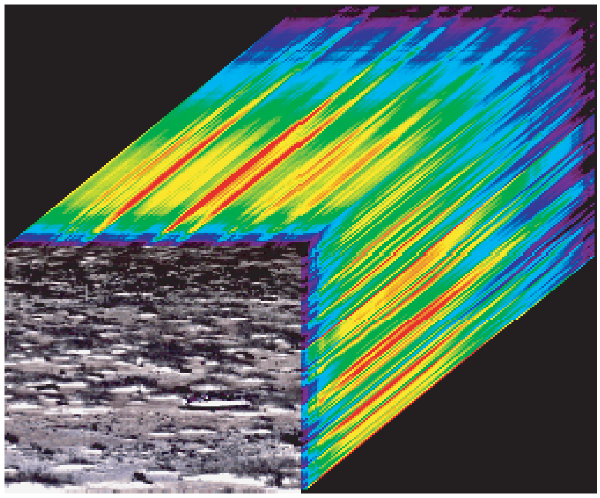
The HD level EO/IR also physically qualify for GTOW of 200kg ranged UAVs with 50kg payload weight. However, the weight is almost saturating the maximum weight limit of the UAV and leaves no room for extra if needed. In addition, considering the usual 200kg UAV's mission height is about 1km above ground, the detection range may be over qualified. Therefore, HD level EO/IR would not fit for 200kg ranged UAV missions.

4. Hereafter Shift

4.1 Hyper-spectral imaging technology

In 2007, BAE Systems announced that they delivered AURORA Generation IV to US forces. AURORA Generation IV is a mid UAV EO/IR sensor which combines day time hyper-spectral imaging technology with an airborne processing system to automatically detect and identify targets.

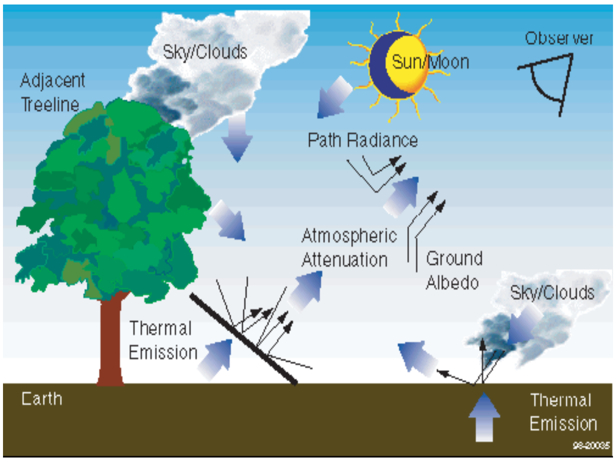
Hyper-spectral imaging, sometimes referred to as spectral imaging, is an electron microscopy technique. In “normal”mapping, an image of the sample was made by the intensity of RGB or a particular emission mapped in an XY raster. Instead in spectral mapping, the entire spectrum at each mapping point is acquired, and a quantitative analysis can be performed by computer post-processing of the data. As shown in Picture 3, each pixel on XY plane of an image contains an array of spectrum which can be quantified and analyzed.



Source : General Dynamics AIS
Figure 3. Spectral Sensor Spectrum.

The 2D system has limitation on identifying the target especially once they lost the target by interference, which delivered a heavy workload to the observer. In the spectral imaging technology, it uses characteristics that different materials has discrete energy gap and respond distinctively to the illuminating light to identify the target. Such technology is accounted for being able to quantify highly accurate characteristics of the target and automatically identify, lock, and track it. BAE’s Aurora Generation IV has shown the possibility of the hyper-spectral imaging technology can be applied to EO/IR sensor to reduce the workload of the observer. On the other hand, it still requires a lot of work. The sensor can only work accurately within the scope of prepared datasheet; for example, the technology was only applied to AURORA's daylight sensors. Also, the systems require fast computers, sensitive detectors, and large data storage capacities. The spectral sensor on EO/IR also has to incorporate atmospheric effects (absorption, scattering and turbulence), radiance/reflectance, background statistics, target signatures, spatial/spectral distortion and focal plane spatial and temporal noise sources. The schematic is shown in Picture 4.

Some of the ongoing research includes data collections, developing efficient algorithm with accommodating optical system, ease to identify targeted signature, and analyzing spectral data in controlled illuminated environment. In a nutshell, we hope to see extension and simplification of the application to various electro-optical uses, adaptation to diverse weather, different multi- color illumination of targets display in the order of priority, and ultimately full automatization of the system.



Source : General Dynamics AIS
Figure 4. Natural Interference.

4.2 See and Avoid.

While the huge investment guarantees the marketability of UAVs, one of the biggest problems with UAV would be increase in air traffic. In order to share the public airspace, NASA, the U.S. military, and the aerospace community are looking for a way to avoid collision by DSA (Detect, Sense, and Avoid), or S&A (See and Avoid). According to a recent AIAA paper, this system is currently in progress in cooperative and noncooperative methods and expect to have synergistic effect to by joining them.(3) The cooperative system utilizes the relative information among the aircrafts to avoid each other, using transponders. The noncooperative system utilizes active (radar) and passive (EO/IR) to pick out smaller, low flying aircraft without transponders.

If the this DSA system succeeds to fulfill the requirement, the EO/IR will become the default sensor of all UAVs that needs to fly in civil airspace. At the same time, current EO/IR had trend of focusing its features on the missions, like tracking or identifying things on the ground. For the expansion of the usage of EO/IR, some of the features will include sensors to detect smaller aircrafts and their relative coordination, and some related laser devices as well.

5. Conclusion

The most important missions of all UAS are reconnaissance and target location regardless of the type or the weight of UAV. Among all the payloads, such as EO/IR, SAR, SIGINT, and RADAR, for the missions, EO/IR can be very light and can efficiently deliver the necessary details to aid human eyes realtime. For the result, EO/IR has been adopted by wide-range of UAVs as a payload and fulfilled the duty of the short-ranged UAV payload. The miniaturization will continue as the new technology develops. When choosing an EO/IR, the best way next to bring each one of them and directly comparing is to look at the datasheets to figure out the ones that satisfy the physical constraints. Then, ask for RFP(Request for Proposal) to increase the reliability of the specification for each manufacturer. Some of the specifications of EO/IR one may pay attention to would be the detection, recognition, and identification range, the requirements or burden for the UAV, endurance, and the UAV or mission application history. Since EO/IR shows high dependency to the mounting UAV, some of the Israeli manufacturers have trend of producing whole UAS, from GCS, UAVs to sensors like EO/IR.

EO/IR still have a lot of problems to solve. Because of its short range usage and the detecting mechanism, the view may often get interrupted by the interferences. Some of the major missions involve on the optional functions, such as auto-tracking or AVT, which often fail to recognize the target after the interruption which resulted in high workload for the observers. BAE's hyper-spectral technology has shown a possible break through by quantifying the spectrum and successfully automatically identify the target. Even though application of this technology is very promising, high specification computer requirement and lack of verification since there has been only one case of commercialized example for such technology. Hyper-spectral technology will need sometime to be verified for commercial use, but it has shown a positive prospect toward automatization.

DSA system must satisfy a high standard to ensure the safety of people from UAVs. If the current DSA system succeeds to pass the requirement, the EO/IR will become the default sensor of all UAVs that needs to fly in civil airspace. As EO/IR will become part of navigating system, further miniaturization will be desirable as well as compacting DSA related features will be necessary.

The best EO/IR is the one that adapts to the environment well and increase the success rate of the given mission duty. This can not be determined only through datasheets. However, for the best of the information given to us, some of the beneficial features like high specification on the datasheet, light weight, small volume are generally the promising features. As daylight CCD camera and IR sensor became the default sensor for the result of miniaturization and missions, it may become smaller and adapt to detect other aviations, as it will be needed for DSA. Also for the full automatization to give less workload to the observer, the efforts to quantify a target so that a computer can identify the target without human interference will continue.

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