

EYES IN THE SKY

- the development of sensors for law enforcement

Records show that police aviation dates from 1914, and that air observation of the period was confined to the capabilities of the human eye. It was not long before the still camera and the movie camera were added as tools for the budding police aviator but both were little more than a means of recording what the eye saw.

Beyond enhancing and recording the capabilities of human observation with the use of cameras there were few advances until television became available to record real time views capable of being transmitted to others.

Following the loss of television broadcasting to the outbreak of war in 1939, the British Broadcasting Corporation [BBC] quickly returned to the further development of the medium in 1946; outside broadcasts were undertaken before the war, but techniques were refined from 1948. In the spring of 1950 the BBC were broadcasting live signals from France to England and in the September they were demonstrating the transmission of live television pictures from a Bristol 170 Freighter in the skies over London and North Weald, Essex. These images, of parts of East London and RAF aircraft in formation beside the camera aircraft were transmitted to a mobile ground station and immediately re-transmitted to viewers across Britain. This was effectively the first public instance of “down-linking”, although use of this term was not common currency for many years. There were other instances of signal transmission trials undertaken by the broadcasting authority, but whilst these included a few “firsts” most were little more than fitting the same large scale equipment into new vehicles. The Marconi Image Orthicon cameras of the time were heavy and bulky items more at home in the studio.

In the mid-1950s, Bristol Aircraft had teamed up with Pye of Cambridge Ltd., television equipment manufacturers, to investigate the range of possibilities in broadcasting television pictures from a Bristol helicopter to a ground station. The Pye/Bristol development programme was primarily designed to miniaturise the equipment and, in the face of helicopters with limited lifting power, reduce the weight that they might have to lift. In 1956 technology remained firmly in the court of the fragile glass radio valve, the transistor was yet to come.

Compared with modern miniaturised television, some elements of the 1956 system were heavy. However taken overall, at 400 lbs. [180kg], the black and white transmission

system displayed a weight not unlike the weight of a 1980s technology colour successor, the Marconi Heli-Tele. As might be expected, by the 1990s weights for vastly more capable twin flir/tv turrets had plummeted downward through the 100 lbs. [45kg] level.

The first trial was to police and military at Filton, Bristol, on January 11, 1956. The limited performance of the Bristol resulted there being little spare lift available obliging it to fly with only the pilot and a single camera operator. The picture was captured upon an movable "Industrial Television Camera", weighing only 8½ lbs.[3kg], monitored on board via a 4½ inch by 3 inch [11 x 7cm] screen. The ground-based monitor was a more substantial 14-inch [36cm] domestic model.

The equipment was bolted in the rear of the cabin area it utilised the existing traverse mounted stretcher points. The aerial for the equipment was literally lashed to the rear boom – thus circumventing a costly certification programme. In his vigorously vibrating eyrie the tv camera operator was responsible for picture selection transmission to the viewing room situated in a part of the airfield flying school. Anyone aware of the unpleasant idiosyncrasies of 1950s television technology will not envy him his task. Although it worked well enough the quality of the air to ground transmissions varied considerably. The Pye airborne system was quietly dropped around the period the company became part of the Dutch Phillips Group.

In the early 1970s Lancashire were allowed an meagre annual budget of around £1,500 for helicopter and fixed wing operations. In 1974 amalgamations caused the removal of the approaches to Aintree races from the responsibility of Lancashire Constabulary, the budget was cut to £800. Fixed wing operations, including coverage of the Open Golf Tournament at Royal Lytham St. Annes in July 1974 were covered using a Piper PA32 Cherokee Six aircraft obtained from a private contractor in Blackpool.

The use of the single engine Piper arose out of the temporary unavailability of the AA aircraft. It provided a stable perch for the two observers, Supt. Mander and Constable Pickles. Pickles was assigned the unenviable task of operating the hand held video camera out of the rear door aperture of the light aircraft. Naturally the officer was securely strapped in, but protection from the slipstream was minimal.

UK v USA. Similar timescale but disimilar methods. The Lancashire ground demonstration leaves some technical details – hats – to be clarified! The Californians led by example. Unfortunately the World was not watching.

Others were working on more sophisticated systems in the same period. The first operational use of a police downlinking system appears to have been undertaken by the

California Highway Patrol [CHP] in 1972. The CHP used their Fairchild-Hiller FH100 helicopters in a traffic observation role, not crime related.

Special television-equipped FH110 helicopters served as eyes for a computer traffic control system. The helicopters were flown at about 400 feet almost daily over a 42-mile section of freeway in Los Angeles during peak periods to give ground based observers in the Los Angeles Area Freeway Surveillance and Control Project control centre a visible appreciation of their own electronics. The road had been implanted with 900 sensors designed to keep a 24-hours a day watch on more than 700,000 motorists but no cameras were included in the system. The sensors were planted every half-a-mile and could detect signs of any slow-down in traffic flow - the result being signalled by a flashing red light on a large map fed directly from the computer. The information that the flow was being interrupted did not give a cause or suggest a remedy.

In suitable weather the helicopters were despatched to investigate the apparent problem – they were able to report the cause within ten minutes, enabling the correct remedial action to be set in place. Little is known about the sophistication of the equipment, whether it was colour or monochrome. The camera itself was reported to be externally mounted under the aircraft.

The original $9.3M project involved a range of other technology trials including changeable message signs, roadside service and tow-away and commercial radio advisories, the helicopter was just part of the whole. It appears that use of the helicopter ended with the original funding in 1973 and there is little evidence that any additional funding was raised.

In 1970 elements of the Army Air Corps were providing air support to the Royal Ulster Constabulary [RUC]. At a time when the Army was only just in receipt of gyro-stabilised binoculars they started to experiment with the means whereby they could capture and transmit live video pictures from military helicopters flying some distance away from the subject of their interest. What they sought was a Trojan Horse system that was relatively small and capable of being placed so far away from the target that no one would suspect its purpose even if they could see the helicopter that carried it. A visible, but covert, information gatherer.

Among the problems they faced was the stabilising of a shake free picture in a vigorously vibrating helicopter. The transmission of the signal to the ground station presented few problems. The trouble was the stand-off requirement that required a high value telephoto lens that effectively magnified the effects of the vibration. They failed first time but further experiments in 1972 led to a working system. The project was eventually taken over by Marconi who came up with the gyro-stabilised Heli-Tele which was shoehorned into the confines of the rear cabin of a standard Westland Scout helicopter. As expected the result was equipment that was an unobtrusive, covert, installation in a helicopter that was already a familiar sight in the skies over Ulster. The full colour system weighed 700lbs [318kg], far more than the monochrome Pye equipment of eighteen years earlier. Development resulted in the overall weight dropping to 380lbs [172kg] but it was always a large system. A superior modern twin sensor system weighs somewhat less than 50lbs [20kg].

One of the original Marconi Heli-Tele units is preserved by the UK Helicopter Museum

For 1975 Heli-Tele performance was breathtaking. The early examples met or exceeded the aims of the requirement, and for many years the secrecy surrounding it was maintained. The success of Heli-Tele was primarily the capability of the camera and lens and the gyro-stabilisation. The Phillips LDK 14D featured a 25:1 zoom facility and a 1.5 times range extender that enabled the camera to zoom from 20° to only 1°. The AAC Scout helicopters were able to stand off the target area virtually unnoticed and take in every detail of the action. It was to be a decade before the true worth of the system was to dawn upon those citizens of Ulster mainly affected by its prying eye.

The development of high quality airborne tv systems was not confined to Britain. An engineer working for Westinghouse in Canada, J Noxon Leavitt lead the design of a new, remote operation, type of camera mount for use on all types of vehicle. The resulting hardware was a relatively large ball which could take either video or cine cameras. This equipment, the subject of a secret US military requirement, was known as the WESSCAM [WEstinghouse Stabilised and Steered CAmera Mount]. At this stage there were no plans for direct transmission of the image to the ground. There were a variety of camera mounts being developed across the world, many remained firmly entrenched in movie technology but even those moving to tv remained largely unsophisticated. The standard means of carrying a camera remained the cameraman strapped into a seat and perched on a movement-damping rig out of a door. There was little equipment available that allowed a full, unobstructed, 360° coverage for the camera. Gradually, all homed in on the ball mount, generally referred to as the gimbal or turret, as the most cost-effective answer to carrying cameras aloft. Once introduced, the sizes shrank and the capabilities grew.

Leavitt bought the rights to the WESSCAM and left Westinghouse in 1974, to set up a new company ISTEC [Inertial Stabilisation Technology] Ltd., based itself in Hamilton, Ontario to develop it. One change was to alter the equipment name to WESCAM.

The first use of an airborne Thermal Imaging [TI] or forward looking infra-red [FLIR] by police in Britain was as part of the security cordon for a visit by Pope John Paul the Roman Catholic church figurehead in the summer of 1982.

In improving the effectiveness of air support over the visit police in the areas affected used a Bolkow Bo105 and an Alouette equipped with the Marconi Heli-Tele, now installed in a large ball turret. In this instance the ball was fitted with alternative loads, the standard daylight camera and a FLIR borrowed from a reluctant military. For police air units largely restricted to operating in daylight, FLIR was to represent a glimpse of an as yet unrealised future of police aviation, the camera that provided an ability to see in the dark.

FLIR was not in itself new. Thermal imaging [TI] techniques had been used for some years in seeking ‘hot spots’ of potential failure in power cables from ground level. The military had investigated the techniques as an alternative to image intensification on the battlefield. Initially they used inflexible mountings but the technology surrounding gimballed ball turrets developed for TV and cinema cameras read across to FLIR/TI and eventually led to the modern turrets with dual sensors. In the case of the supercooled sensor head of the TI, the camera required external mounting to overcome its inherent inability to “see” through glass or Plexiglas.

The military past of the technology has ensured that some elements of the development of thermal imaging have remained veiled. The leading US based supplier of commercial systems, the Portland, Oregon, USA based FLIR Systems Inc [FSI] first developed a commercial TI system as a hand held unit in August 1979. This equipment was used by the California Dept. of Forestry to image forest fires. They soon mounted the hand held unit in a pod on a plane, effectively pre-empting the first Series 1000. First civilian user was shortly afterwards, in 1980; a user on the Pacific Northwest of the USA used the unit on a fixed wing single engine aircraft. Among other things it was used to image the Mount St. Helens volcano eruption. To achieve the necessary coolness to the image sensor they had to pour liquid nitrogen into the system while airborne.

The first FSI system sold to law enforcement was in 1981; the purchaser was the Texas Dept. of Law Enforcement. The first Series 1000 unit, a simple unit offering pan and tilt, was produced in 1981 and entered service with the San Bernardino Sheriff’s Dept in California. The first Series 2000, arguably the most famous of the early flir units, was in production from 1982. The first user was the US Coast Guard.

In Britain the military initiated at least three differing systems in different sections of the electronics industry. Each was to be known as a TICM. Thermal Imaging Common

Module.

TICM I ['tickum one'] was developed by Thorn EMI as a lightweight direct view system. TICM II ['tickum two'], the heavier system for ground vehicle and shipborne use was placed in the hands of Marconi. The TICM II was initiated in the same time-scale as the same company's tv system - 1974-75 - and defined by 1978. TICM III was to have been a separate airborne system, but this was discontinued after it was found that TICM II was of equal use in airborne applications. Models were being produced in the early 1980s and sufficient examples of the B, or airborne, variants were available for the debut of the system in its first shooting war in the Falklands during 1982 – and the Papal security operation. Although marketed as if it were a full system in the 1980s, it was but a part of it. Much improved by advances in the performance of its periphery systems, TICM II systems remained in production and service into the new Millenium, primarily in the military theatre.

Ascribing the first availability of viable thermal systems to a specific country is difficult, particularly as details of developments in the Soviet Bloc are unknown. It would appear that in the mid-1970s the basic science behind the technology was sufficiently advanced for a number of countries to develop domestic operational systems with various levels of sophistication that became generally available for service in the early 1980s.

By way of clarification by 2003, FLIR – or TI – could be found in four main types: -
1) The most common is the TI fitted into a turret with heads down display. This is often coaxial with other sensors including TV, range-finder, image-intensifier etc. The TI acts like a daylight television camera and displays its image on a [cathode ray tube] screen in the cockpit. The crew points the sensor head, and can adjust focus, zoom, contrast and choose whether to show white-hot or black-hot, as well as point the head. This type of imager is used for searching, especially for sea survivors, where the heat picture will display a warm floater or raft at great distances.
In sophisticated modern installations, the FLIR can be pointed 'hands-off' by the aircraft systems prompted by such as the SARBE transmissions of the survivor or the radar.

2) FLIR with head mounted display (HMD) - Here, the flir is tied to a helmet display (a small tv suspended over one or both eyes). On many HMD's the flir is reflected off a mirrored glass, so the pilot can see through the image if the background is bright enough. Often there is a sensor on the pilot's head/helmet reads the angle of the helmet, and directs the flir to point to suit, so the pilot can direct the flir with simple looks ['helmet pointing']. This is most natural, and effective as a flight cue for pilots to fly in zero light circumstances. It is however somewhat expensive.
3) fixed (un-turreted) flir - has no turret, and simply looks where the aircraft points. There is interest in these but these are very poor third choices to the above. When the flir is bolted to the airframe, any motion of the aircraft is displayed to the pilot, so the picture is very unstable. This can be very disorienting especially if one tries to use the display to fly the aircraft.
4) Uncooled imager. Primarily designed for hand held or vehicle rooftop use on the ground. In the airborne arena this has to be hand-held and pointed through open aircraft apertures. It does bring an element of cheapness to airborne operations but it is not a very flexible option. Attempts to design a turret around a similar un-cooled technology camera failed as the end product proved not to be robust enough.

SENSOR SYSTEMS TODAY

Twenty years on there are many company's undertaking work on sensor systems, but with industry consolidation and tight margins those directly involved in the economical "commercial off the shelf" [COTS] sector of the sensor market have reduced to a handful. Many companies choose to remain exclusively in the low production high unit value military market; but some still supply component parts to both market sectors.

Much sensor marketing information gives a clear impression that every unit offered by a given manufacturer is the latest technology and is only available from the single source. That impression is far from the truth. Each supplier is effectively marketing a range of COTS containers for a wide range of generally available sensors from outside suppliers. Although there are exclusive hardware and software marketing agreements, the contents of most sensor pods are drawn from 'centre of excellence' suppliers across the world – be they chips, cameras or lenses. Gimbal contents are subject to negotiation and will ultimately affect the final price of the package to the customer. The ultimate success or failure of the packaged product can often be dependent upon the weight, quality and flexibility of the gimbal, wiring connections and aircraft interface in delivering information to the end user. Even the ergonomics of the hand controller used by the operator can be a major influence on equipment acceptability.

Following its mid-1990s incorporation of the British based BSS in the summer of 1998 FLIR Systems Inc. amalgamated with one of its major rivals AGEMA to inject their excellence in the hand held and uncooled sensor market into the FLIR Systems product line. They also tightened ties with the South African company IRENCO - later Cumulus - for their undoubted expertise in the airborne sector. The following year they took over Inframetrics which effectively condensed the customer choice in 'popular' sector of the market to a straight choice between the US FLIR Systems and the Canadian Wescam.

Wescam also undertook a number of amalgamations and take-overs that have resulted in the company now having manufacturing bases in the USA as well as Canada.

A few independent system manufacturers exist but their market penetration is very small and often localised.

DOWNLINKING

Downlinking has shown itself to be an area of the market in which smaller players can apparently compete on near enough equal terms. and in turn they attract customers seeking to cut costs. It is not always a happy arrangement.

Whilst analogue transmissions remain on something of a technological plateau, day-to-day down linking has improved through miniaturisation and accessibility. By the mid-1990s it was common for receivers to be found on the street in highly portable 'briefcase' sized units. From that point came light-weight hand-held equipment that took the aerial view of the aircraft camera down to providing those on the ground with first hand information. This capability was not exclusively an air support resource, it read across to surveillance cameras on the ground, although significant line-of-sight transmission difficulties were very evident in urban environments.

The latest receiver systems include hand-held units only restricted in ultimate miniaturisation be viewing screen size. The ultimate was perhaps that produced by the Cambridgeshire Police in England. The ‘Skynet’ wristband mounted image receiver incorporated a small 2½ inch [63mm] screen from an off-the-shelf domestic television. The whole was attached to a handy ‘Velcro’ wristband and it worked. It was produced commercially at a very competitive price [£1,000] but failed to sweep the market. In the end the image, whilst fine for viewing a ‘studio’ scene in a domestic scenario, was considered unduly challenged when viewing a typical air to ground scene.

Another means of placing a very small image in a manner that appeared larger to the viewer is the HMD - Here the pilot can see through what appears to be a large image even though it is usually smaller than that offered by such as ‘Skynet’.

All those earliest methods of sending images from the camera employed analogue systems that served the industry well for 50 years. In an aircraft travelling at a reasonable height downlinking, whilst prone to some interference, enjoyed a good line-of-sight transmission capability. The call for an improved system came from the military operating nap-of-the-earth, those using systems for surveillance at ground level and aviators obliged to operate in mountainous areas.

In recent years industry has been promoting digital technology to overcome some of the more obvious deficiencies of analogue. Offsetting a significantly higher first cost it was possible to demonstrate improved signal integrity and an ability to encrypt the signal. The latter is not necessarily important on a day-to-day policing basis, but some special operations do call for it. Another aspect of the change is an opportunity for operators to migrate from one wavelength to another. When a significant number of units have made the transition to 3.4 GHz the momentum to restrict the 237khz facility and eventually hand it back to the military will become more evident.

It was to be a while before industry understood it and years before any police air unit bit the bullet and decided on installing a digital system. As with all technology there were casualties.

The Home Office approved and financed one set of equipment that gained an all-important ‘Framework Agreement.’ One three aircraft fleet was selected to be fitted with it early in

2002. Meanwhile, sidelined from the ‘Framework Agreement’ rival providers were expressing their disquiet.

The SERPASU [Metropolitan Police Service] were chosen to install and operate the joint venture Telemetry Consultants/Rotortech ‘Zenith’ Digital Downlink. Late in 2001 Rotortech installed it on all three AS355N aircraft and live day was predicted to be in the first quarter of 2002. It was times that it would be a first. Meanwhile the trio carried on in service with dual analogue/digital capability. As this article is written in mid 2003 the system has never gone live.

It was still 2002 that a commercial COFDM system was used operationally, but the event took place in North America not Europe. A system produced by Microwave Radio Communications (MRC) was used to provide real-time aerial surveillance video to security forces at the G8 Summit in Kananaskis, Calgary, Alberta, Canada on June 26-27.

MRC's equipment consisted of the STRATA digital COFDM radio; CodeRunner 4 receivers, auto tracking UltraScan Antennas, and Omni-Directional Antennas. Fixed surveillance cameras were housed in strategic areas in and around the city of Calgary and in Kananaskis, the actual Summit Meeting location. Two cameras were housed in airborne units. One of these cameras was installed in the Calgary Police MD520N HAWC-1 helicopter.

On the last night of testing the installation in the police helicopter a range test was undertaken to see how far the MRC STRATA system could transmit from the foothills through the city's tall buildings before signal was lost. The pilot had to turn back to refuel when he was about 35+ miles out (at 1000 feet AGL). They were still receiving infrared pictures of wolves and coyotes in the brush.

The Omni-Directional antenna with its 360-degree transmission pattern allowed the signal to be simultaneously received by all four command centres. Two were fixed locations - Calgary Police Headquarters and an undisclosed location operated by the Calgary Police Service and the Royal Canadian Mounted Police (RCMP); the other pair was mobile units.

Meanwhile many other companies with similar digital technology have been talking to a number of air support and ground units in Europe and demonstrating the undoubted advantages of the digital technology to a range of nationalities.

In Germany CAM [Computer Anwendung fűr Management GmbH] from Gilching managed a range of options. Gareth Davies their technical representative used his bi-lingual sales techniques to good advantage representing both the US Company Broadcast Microwave [BMS] and the local Telesource AG of Burgdorf. In the event the latter system became another casualty, leaving CAM only the BMS option.

It was therefore the BMS option that finally made its operational debut in Europe after sale of COFDM to police air units in Germany in mid-2003. One year earlier the Netherlands National Police accepted the seven sets of digital downlink equipment for its eight new Explorer fleet from ECS the Northamptonshire based electronics supplier.

Unfortunately the aircraft programme itself was two years late and the operational launch of the ECS system suffered. Another casualty – although perhaps only a temporary one.

With the HO Framework system shown wanting new aircraft continue to be delivered with ECS analogue equipment. Not everyone has yet accepted that digital and encryption are the future and no-on appeared to be in a hurry to put out a tender for a non-Framework digital downlink to ensure they have a real choice in which equipment supplier they can use

The COFDM system offers users operating on the ground improved signals to overcome the terrain – be that natural hill and mountains or the ‘canyons’ represented by modern city streets. When applied to aircraft the gains can be quickly eroded simply by flying higher. But height can be a disadvantage – especially if the camera system is of a low specification. Low level COFDM transmissions in a urban landscape can overcome that problem.

The ability of the digital signal to travel around corners [and over hills] led to it being marketed as ‘Bendy Video’. This becomes particularly important if you are in a high rise city and wish to fly low when transmitting or operate in a mountainous region and would prefer that the signals arrived at the receiving station that you cannot see because of the contours in the landscape. If you are with a specialist ground unit there is no reason that you cannot send a signal ‘through’ walls without exposing the aerial. There are ‘Rays through the walls’ after all!

FLIR SYSTEMS

After the series of corporate changes FLIR Systems is now based worldwide. Two sites in the US, Portland and Boston, are complemented by presence’s in Canada, Scandinavia, France Italy and the United Kingdom. The latter is the base for International business and the major service centre. In addition to these factories and service centres there are a number of agents and customers capable of supporting the 500 or so products still in operation.

With a growing grip on the market, FLIR Systems drew on its close association with IRENCO to launch the LEO II into the market. Using an AGEMA sensor the original IRENCO LEO had made deep inroads into the law enforcement market but exhibited a number of engineering drawbacks and its growth potential was size limited. The new gimbal – although offering similar sensors – was effectively a new package with greater potential for expansion.

The LEO II was one of a number of new products being shown for the first time at Farnborough 1998. LEO II built on the success of the IRENCO LEO-400 [at least 80 systems sold in 25 countries] and quickly sold to five UK Police Air Support Units, the Bavarian Police and the South African Air Force.

The primary advance that LEO II brought to the market related to its size. The equipment consists of a flat bolt-on unit that is largely self contained and compatible with existing mountings. A 30% height reduction, partly displaced to an increase in width and partly to miniaturisation, improved integration with the new generation helicopter airframes and reduced the number of additional onboard systems to a single unit. Options including a built in autotracker microwave downlinks, searchlight slaving and a full diagnostic capability by means of a serial link to a standard personal computer and remote diagnostics via modem. The first operational airframe to carry the gimbal was the Central Counties Police Eurocopter EC135T.

In the summer of 2000 the operational capability of the LEO2 package was further enhanced with the incorporation of the European Triple QWIP [Quantum Well Infrared Photodetector] 8-9µm focal plane thermal imager array.

The conquering of QWIP technology was the latest quest of TI manufacturers; many attempted to harness its benefits. At the heart of this is ‘wafer yield rate’. Unless the manufacturer can retrieve a high number of sensor elements [chips] from each wafer the whole process is not financially viable. The Swedish factory [FLIR Systems AB] in concert with another Scandinavian company Acreo SA achieved the standard and patented part of the process.

For many years thermal sensor technology has offered manufacturers two options. One group of sensors offers vision in the 3-5 µm band which performs particularly well in hot, humid and maritime conditions but is a limited performer in penetrating ‘battlefield’ smoke. Sensors in this band allow the military a standoff capability at the cost of being ‘blinded’ in battle. The other group operates in the 8-12 µm band, although they can penetrate smoke the standoff range is lower. The latter tends to operate in temperate conditions. Neither is truly flexible. By using different detector materials QWIP technology sought to close the gap.

In the LEO II and the military StarSapire Q FLIR Systems Inc. have their QWIP ready and available and sold to the first few purchasers. The QWIP offered 30-times more zoom capability than existing technology as well as offering a narrow field of view of less than 1˚. When pressed the company explains that this equates to a wide field of view [WFOV] of 30˚ and a narrow field of view [NFOV] of 0.98˚.

The result is a more detailed image, providing a better information level with less visual ‘noise’ - from a mile [2km] it is possible to clearly see narrow objects including aerials. The sharp image and sub 1˚ NFOV value allows the observer to go in and see if the object the ‘target’ carries is indeed a gun.

The modular design thinking behind the original system allowed the manufacturers of the LEO2 to offer existing customers an immediate upgrade to QWIP without requiring the exchange of other elements of the sensor. It was to be a traumatic period for FSI as the early promise appeared to evaporate. A wholly unexpected problem was that the system required a significant time to cool down and come on-line. With the main market police

units in the UK operating on a reactive basis it was calculated that the average time on station would still leave the system cooling to operational temperature after they arrived. It was initially viewed as a disaster but, although some customers decided they would stick with the earlier system, on balance it was considered that the benefits outweighed the disadvantages. After the trauma the product was renamed 'UltraForce II' and sells well on its merits.

In the period between the introduction of the original LEO2 and the QWIP FSI introduced, or re-branded, a number of other sensors. The Ultra 7000, was an enhancement of the former Inframetrics Mark III Quantum sensor designed to provide 24 hour a day, higher altitude, long-range search and surveillance tool for rotary and fixed wing aircraft. In its new form the sensor includes the addition of three Fibre Optic Gyros'. The compact, hermetically sealed 9-inch [22.8cm] gimbal contains a dual sensor payload that includes a high performance Indium Antimonide (InSb) infrared focal plane array (FPA) detector operating in the 3 to 5 μm range. The 26lb [11.7kg] system features a 10X continuous zoom IR lens with a focal range of 25mm to 250mm, allowing crews to fly higher and see targets with better detail without losing track of a suspect when switching between magnification levels. Housed next to the infrared imager is a colour CCD camera that also features a 10X continuous zoom lens. The CCD camera complements the Ultra 7000's infrared benefits with clear, colour pictures for daytime surveillance. An OCTEC autotracking system reduces cockpit workload by helping the operator maintain target acquisition. With some alterations to the specification this sensor has since been rebranded as the 7500 and 8500.

Focus and zoom switches are located on the back of the hand controller where they rest naturally under the fingertips. This was a feature praised in the original Inframetrics equipment and clearly worthy of retention. An advanced video display gives the operator not only a clear view of the scene, but also provides additional information such as autotracker status, GPS position, gimbal tilt angle and more. The electronic control unit has provisions for optional GPS systems, searchlight slaves and microwave downlinks. Of the other former Inframetrics sensor range only the Mark II remains available to meet specific customer requirements and then only to special order.

The drawback of this class of sensor is its overall ability. Small sensors are fine if you are happy to place your aircraft at a low altitude. In the USA it is acceptable to fly single engine helicopters at 300-500 feet over all types of terrain – including urban – day or night. Although all hope of covert operations is lost the combination meets a primary aim of 'in your face' policing.

In Europe a different attitude prevails. Operational distances there are 500-1,000 ft. and twin engines are a required feature. Although not in the same class as the costly high end military models the type of sensor attracted to this market offers a strong ability of units to 'stand-off' from the target and act covertly where necessarily. These sensors are costly but they perform well. One manufacturer mixed its markets up and, noting the interest raised in the USA offered its cheap low performance sensor into the UK market. It learned its lesson very quickly.

Another offering from FSI was the improved Star SAFIRE II™. offering enhanced features over the original in use with the US military, law enforcement agencies and a host of foreign military and paramilitary organisations. The system is significantly heavier than such as the LEO2 but it is available for installation in larger helicopters and fixed wing

types with a higher air speed limitation. Many of the improvements to this 3 to 5 µm system reflected user comments as well as advances in technology. In the meantime StarSAFIRE II™ has now again been upgraded into a product termed the StarSAFIRE Q offering the QWIP technology.

As with all similar systems users are able to take advantage of up to four different payloads - a CCD broadcast camera, an eye-safe laser range finder, eye-safe laser illuminator and laser designator. Other options include navigation interfaces, autotracker, communication downlinks and video recorders.

Specialised customer requirements have led to FSI developing single sensor broadcast quality camera systems for law enforcement use. The UltraMedia™ series of camera systems were successfully developed to serve the growing needs of the helicopter news gatherers and became the worlds best selling gyro-stabilised aerial broadcast news camera system. Offering good image quality and up to 72:1 magnification in a 5 axis gyro-stabilised gimbal it allows Newscopters to standoff from the action without placing themselves in danger.

Effectively taking the market back to the reasoning behind the 1970s paramilitary security requirements in Ulster, it was this standoff capability that attracted it to law enforcement agencies and led to the development of the specialised UltraMedia™LE system for covert use. Naturally the identities of the specific target end users market are classified. Sufficient to say that this high-class system is in service and notching up significant successes.

Product support falls into two categories – those requiring immediate support and those less demanding. In the US the most demanding customers are the Broadcast Media. Their needs are driven by the competition; they simply cannot afford sensor downtime. Equally demanding are the police in the UK. Operating just one high technology airframe, often on a 24-hour schedule, means that they too demand the highest level of product support. To meet the UK police needs FLIR Systems maintain a seven strong team of engineers to maintain a 16 hours a day 7-day product support telephone helpline at their UK base. In addition they have two licensed engineers they can call upon. This team has a range of loan gimbals to exchange in support of local and international needs. Disregarding transportation and emergencies a scheduled refurbishment can be accomplished in a week. Such work can be expensive, a replacement cooler costs in excess of £20,000 [$30,000]. Because some elements of the equipment require export licenses from the US, acquiring a new unit can take 30-60 days. Failure of these same parts can occasionally stretch an apparently routine refurbishment.

Elsewhere differing operational profiles result in less aggressive customer expectation. Reaction times vary from 24 to 96 hours. A single unit operator located some distance from the UK is going to be more affected by unexpected failures than a daylight only operator with three units in the fleet and in-house engineers trained to work on the gimbals.

By pre-arranging a periodic service for a time that was mutually advantageous the police in Slovenia were able to have their LEO 400 gimbal serviced immediately prior to an important visit by The Pope and have the engineer temporarily retained on site at minimal additional cost. Other operators have unsupportable requirements. Indonesia are the only operators of the large BSS500 gimbal, they do not have the option of a replacement unit. Many customers have now been educated into taking out service contracts. This effort has

generally resulted in improved image quality and serviceability rates across the customer base.

WESCAM

Wescam sensor products are present worldwide, with law enforcement and military operators. The UK police market therefore represents a poor barometer of the world position. Only a single Wescam unit is currently in UK police service. One 16DS gimbal entered service on the North Wales Police AS355F2 in 1994 but this is now out of service leaving a later MX-15 model on a fixed wing aircraft.

Although it is an oversimplification of some very complex issues Wescam's difficulty with the UK law enforcement market surrounded a market preference for the employment of three-chip cameras rather than making use of the greater low light capabilities of the single-chip camera. Simply, the 16DS was available with the preferred three-chip camera option but when it was first offered the 12DS, was not. This product availability situation has now altered because the 12DS has been sidelined in favour of the larger MX-15.

In spite of a significant presence in the UK military market the only other instances where the Wescam has seen regular use in the UK police sector has been when an airship has been leased in to provide coverage for special events.

Wescam has sold its cameras into a number of European countries with examples to be seen in service with the Gendarmerie in Belgium, the Guardia di Finanza and Caribinieri, Italy. At sea the CASA 212 aircraft operated by the Spanish Fisheries and the Australian Customs Bombardier Dash-8 fleet use Wescam turrets but each of these is outnumbered by the large number of Lockheed P-3 Orion aircraft in service. These are typically equipped with such as the Model 20. The latter aircraft serves in a more overt law enforcement role with the US Customs Service on drug enforcement tasks.

After a gap in UK service Wescam returned are to have their MX-15 ball sensor on the BN Group Defender delivered to Greater manchester Police June 2002. The MX-15 offers up to five sensor options including a TI, daylight tv with zoom, daylight camera with long-range spotter, laser range-finder or laser illuminator. The basic 15.5 inch [39.4cm] turret weighs 94 pounds [42.7kg] in dual sensor configuration but the Master Control Unit, hand controller and related cables add at least 28.2 pounds [12.8kg] to this even before the addition of displays and tape recorders. The sensor is designed for use on both fixed-wing and rotary wing vehicles. An important element of this deal is Wescam's placing of a spare sensor ball in the country.

Wescam would dearly love to place their sensor on the highest selling UK helicopter – the Eurocopter EC135. Unfortunately the amount of engineering work required to alter the physical interface was daunting. A number of customers had expressed an interest in moving to Wescam but no formula could be found to defray the costs of the necessary changes. No one customer wished to take the financial burden.

The lead product in the COTS level law enforcement sector is the WESCAM™12DS, a 12 inch dual sensor gimbal designed to fit on existing FLIR 2000 cabling. The marketing sought to 'steal' the large replacement sensor market from their rival.

The 12DS sensor offers 3-5 µm infra-red optics with three fields of view As a compact relatively low cost gimbal, as well as seeking to reduce costs in offering compatibility with elements of the 2000 the system includes the simple Smartlink Interface Unit. Smartlink allows customers with a limited budget to purchase a basic system and yet be able to upgrade it to incorporate a number of additional features.

WESCAM™12DS systems sold to the Gendarmerie in Belgium joined a WESCAM™ 16DS already in service to boost to four the number of systems used. Illustrating the range of types it was suitable for, fixed wing as well as rotary wing, the 12DS subsequently equipped the Cessna 182, MD900 Explorer and MD520N in the Belgian fleet.

The target market – the large numbers of FLIR 2000 operating US law enforcement agencies – willingly embraced the 12DS. An enthusiastic Los Angeles County Sheriff bought a number of the gimbals for use on its MD520N fleet. Recently Dutch and Belgian police used Wescam equipment to assist them with keeping the peace at the Euro2000 football championships. The Wescam 16DS-M camera and SkypodLC transmission systems were on the airship employed at stadiums and cities where championship matches were played. Illustrating the fragile connection between manufacturer and customer, despite that long history with Wescam, in 2003 the Belgian police bought another turret from FSI.

Product support varies with the manufacturing base of the product. The Head Office of the group in Ontario Canada oversees a number of subsidiaries in the Public Safety and Surveillance Division and the Entertainment Division [public broadcasting]. There are currently eighteen licensed Wescam agents across the world capable of undertaking at

least local repair tasks. The level of expertise at each of these varies and each retains the final recourse of returning major problems to the factories.

AERIAL FILMS INC.

Aerial Films, Inc. is primarily a leading manufacturer of gyrostabilised long lens, daylight camera systems used extensively around the world for helicopter, fixed-wing, ground vehicle and marine surveillance applications. They also offer night-vision and thermal systems. Penetration into the overt law enforcement arena is currently small. The GyroCam® family of camera systems is offered for airborne law enforcement, military surveillance and maritime patrol applications with long-lens, day/night-vision technology. Although currently largely restricted to the US law enforcement market, Aerial Films, Inc. located in Morristown, NJ offer turnkey surveillance systems including long lens single sensor gimbals offering high resolution day cameras particularly suited to news gathering aircraft which would equally suit covert surveillance requirements. The alternative dual sensor gimbals with optional dual sensors FLIR are also marketed under the name GyroCam® name. The GyroCam IR provides night-imaging capability and enhanced day operations with the Mil-qualified MicroFLIR. Its use of the long-wave spectrum [8-12 μm] allows penetration of smoke and smog.
The company offers a range of other day and night vision options, microwave packages and briefcase receivers.

ISRAEL AIRCRAFT INDUSTRIES

In 2000 one of the specialist manufacturers, Israel Aircraft Industries Ltd [IAI], Tamam Division Electronics Group, sought to enter the COTS market. The first area of interest is the UK. The keenly priced modular products IAI are promoting to the British are the POP the Plug-In Optronic Payload for airborne, marine and ground applications and the MOSP – Multi-mission Optronic Stabilised Payload.

The IAI duo has already seen service with the Israeli military and police and use in UAV type aircraft. POP is a modular lightweight and compact dual sensor pod offering FLIR and TV sensors at a very competitive price. Uniquely POP has a removable plug-in sensor element that offers the ability to be easily replaced in the field in minutes. Being modular the on aircraft equipment is confined to the turret and the operator controls – IAI state that there are no additional modules [and the weight of its attendant cabling] to be located in the equipment bay.

With a price range that significantly undercuts the opposition there is growing interest in this sensor. Its lower unit price, [£100,000/$140,000] is thought to be at least 50% lower than such as the LEO II [£200,000+]. Although this price might prove attractive the higher priced gimbals offer 4, or even 6, axis stabilisation. The offer of potentially adequate 2 axis stabilisation on the lower priced POP may be attractive, equally it may just too few axis to contemplate! Just like the similar specification Inframetrics/FSI8500 it found little favour for UK police work.

Perhaps the MOSP will serve UK police needs better. With 300 units already produced it still offers a price some 10% lower than the opposition. This is marketed as a family of dual or triple COTS sensors in a lighter modular package package.

With the British known to require a very demanding support organisation for any major product IAI are currently setting up agents and engineering support packages to capitalise on the growing levels of interest in the new market before going forward. Time – and already a great deal of that precious commodity has already passed by – will alone will be the judge.

ECONOMY OPTIONS

All these manufacturers products are highly desirable role accessories for the well-heeled air unit. But there are many other equally deserving potential users of daylight tv cameras and thermal vision aids. Some find it difficult enough to finance the aircraft. Many units cannot afford the significant costs associated with the acquisition, installation and maintenance of new sensor packages at a cost of tens of thousands of any given currency. There are a number of more economical options.

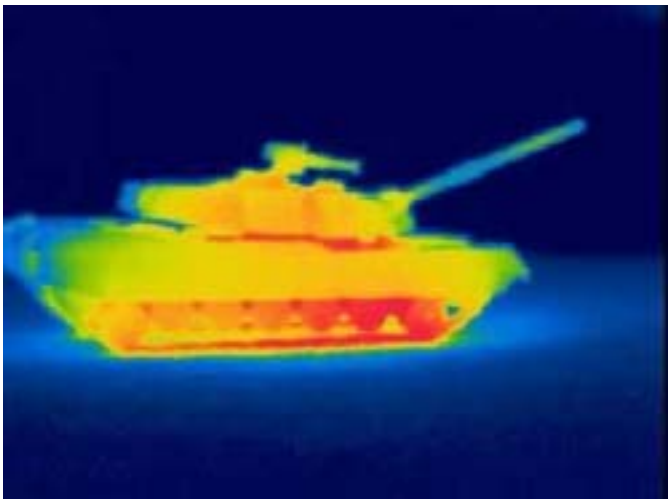
The most likely alternative is to purchase a ‘pre-owned’ gimbal unit from a neighbour upgrading to ‘better things’. Even equipment no longer considered modern is better than none at all, but there may be a price to pay in terms of the reliability of such equipment. Industry sources suggest that the average new FLIR should be written down over just 5 years and that it then has no value. Operators then acquiring such a unit for little or nothing would still be faced with a full reconditioning cost around £50,000 [$70,000]. Although there are exceptions, most units suffer a level of ‘leakage’ that should result in

them requiring attention annually and ‘back street’ repairs are problematical without the infrastructure required to calibrate the result. Underlining the lengths that operators have gone to in order to meet cost saving needs, and their longevity, twenty years on some US air units continue to be equipped with the simple FLIR 1000.

Further down the scale there is the hand held unit potentially incorporating uncooled technology. A new example is often far cheaper to acquire than refurbishing a used gimbal. The airborne user may incur the inconvenience of having to open the aircraft door in flight to use it, but at least when new equipment goes wrong it comes with a reasonable guarantee! Part of the US Drug Enforcement Agency [DEA] drive against the growing of Marijuana is the supply of TI units for issue to ground units. Where aircraft are single manned or only have a crew of two there are difficulties to overcome – including providing an open aperture for the unit to see through and where to stow it when not in use. Not all aircraft provide an in flight opening door and few crew relish a requirement to remove door’s particularly in winter. Clearly the lack of a stabilisation associated with hand-held units restricts their use. They may not be as efficient as ‘the real thing’ but they fill a need at a very economical cost.

The future is impossible to predict. Thirty years ago it may have been possible to predict some of the daylight television advances, but no-one would have predicted the current capabilities of FLIR. The extent of current capabilities would barely have been predicted even ten years ago. Perhaps it will all just become relatively cheaper, perhaps by introducing uncooled technology into TI systems.

Some years ago FLIR Systems introduced an uncooled technology dual sensor turret under the name UltraForce. With an apparent Inframetrics background the four axis gyro stabilised unit only weighed 33 lbs [15kg] and was selling when it became clear it was not going to prove reliable enough to support in the field. Aircraft, particularly helicopters, prove to have airframe vibration that offers a very violent proving ground. The company withdrew it after deliveries had been made and substituted cooled technology units in their place. Neither FLIR Systems or any other manufacturer has overcome the robustness problems sufficiently to try again.



This article first appeared in a 2001 edition of JAES and has been updated to reflect changes in the market.

EXAMPLE FACT SHEET

FSI Ultraforce 2/LEO 2 A5 with QWIP

Outline Specification

Turret: 39kg, slew rate 60deg/sec in az(360deg) and el(+20 to -105deg), fully stabilised.
Internal "black box": 8.5kg
Laptop Controller: 1.5kg

Operating temperature: -20 to +55deg C
Supply Voltage: 22-32 Vdc
Power Consumption: 280Watts nominal, 480Watts peak

Thermal Imager (Triple QWIP)

Camera: Triple QWIP, 3 FOV
Spectral Band: 8 to 9µm
Detector: Focal Plane array, GaAs.
FOV: Wide: 25degx19deg. Mid: 6x4.5. Narrow: .99x.74. Switching time: .5sec.
Zoom: x2 and x4 Electronic Zoom
Polarity: White/Black hot plus multi-coloured
Cooling: Integrated Stirring Cooler, approximately 4-5 minutes to cool down (there is no picture until fully cooled).

TI Performance – manufacturers prediction and user figures:

Detection: Predicted, 15000m. Typical, 17000m
Recognition: Predicted, 7100m. Typical, 7500m
Identification: Predicted, 3600m. typical, 3800m
Focus: Auto/manual
Video Output: NTSC/PAL

Daylight Camera:

Type: Sony Exwave-HAD Interlinr Transfer CCD
SensorFormat: 1/3 inch type 3-CCD [‘three-chip’]
Resolution: 800 TV lines
Active Pixels: 752x582. Total 440000
Minimum Sensitivity: 4 lux
Zoom: x54 (x27 with x2 switchable extender)
Focal Length: 9.5 to 512mm
FOV: min .67x.5 deg. max 35x29 deg
Video Output: NTSC/PAL
S to N Ratio: 58db

Optional Equipment:

Laser Rangefinder: 80-15000m
Spotter TV
Auto Tracker