Defence School of
Aeronautical Engineering

Aerosystems Engineer & Management Training School

Academic Principles Organisation

BOOK 6

Aircraft Reconnaissance Systems

WARNING

These course notes are produced solely for the purpose of training. They are not subject to formal amendment action after issue and they must NOT be used for operating and maintaining the equipment described. Operation and maintenance of equipment is governed by the limitations and procedures laid down in the authorised publications and manuals which must be complied with for these purposes

AIRCRAFT RECONNAISSANCE SYSTEMS

RECONNAISSANCE AIRBORNE POD FOR TORNADO (RAPTOR)

LITENING III TARGETING POD

OBJECTIVES:

T.O.s - 42.4, 42.6, 42.7, 42.8, 43.5, 46.1, 46.2, 46.3, 46.5, 45.4.

E.O. - S93-01 - Outline the function and operation of reconnaissance systems.

KLP Ref – S93-01-03 – Describe the reconnaissance video recording system.

Performance - Describe Aircraft Surveillance Systems.

AIRCRAFT RECONNAISSANCE SYSTEMS

Introduction

1. For as long as the Royal Air Force has been in existence, reconnaissance has played a major part in peacetime and battlefield operations. Today the systems employed to obtain information are classed as ISTAR assets; ISTAR stands for Intelligence, Surveillance, Target Acquisition, and Reconnaissance.

2. Information is collected on an area using a variety of electronic sensors which carry out Surveillance, Target Acquisition and Reconnaissance. This information is then passed to intelligence personnel for analysis, and then to the Commander and his staff for the formulation of battle plans.

3. ISTAR is considered in several sections of Avionics but this section will only consider the function and operational use of current sensors which provide reconnaissance and surveillance, i.e. the Reconnaissance Airborne Pod for Tornado (RAPTOR) and the Litening III Targeting Pod.

Reconnaissance Airborne Pod for Tornado (RAPTOR)

4. RAPTOR was the world's first tactical day and night reconnaissance system capable of obtaining Electro-Optical (visible) and Infra-Red (IR) Long Range Oblique Photography (LOROP) simultaneously along with a facility to collect, record and transmit digital images via Data Link in 'near real time' to a Data Link Ground Station (DGLS).

5. It is capable of imaging pre-planned targets or 'targets of opportunity' and can image over 200 separate points in one sortie. In the past, many reconnaissance pods were designed to operate with the aircraft either over flying or passing very close to the target, however, the RAPTOR was designed from the outset to be used at high altitude and at large 'stand-off' ranges from the area of interest. Figure 1 illustrates RAPTOR fitted to Tornado.

Figure 1 – RAPTOR fitted to Tornado[1]

[1] Image courtesy of Raytheon Systems

Long Range Oblique Photography (LOROP)

6. Long Range Oblique Photography (LOROP) involves the use of using a movable 'telescope' that allow high quality images to be collected digitally at short / long ranges and perpendicular to the aircraft track.

Raytheon DB-110 Digital Sensor

7. To be able to achieve LOROP, the RAPTOR uses the Raytheon DB-110 (Dual Band 110 inch focal length) digital sensor capable of collecting visible and infra-red (IR) imagery day and night using a common telescope and focussing the image onto two focal planes via a beam splitter that separates the visible and mid-IR light. By using a 'pan scanning or swept broom' technique the DB-110 sensor scans the ground scene from horizon to horizon using a roll gimbal. Figure 2 illustrates pan scanning techniques.

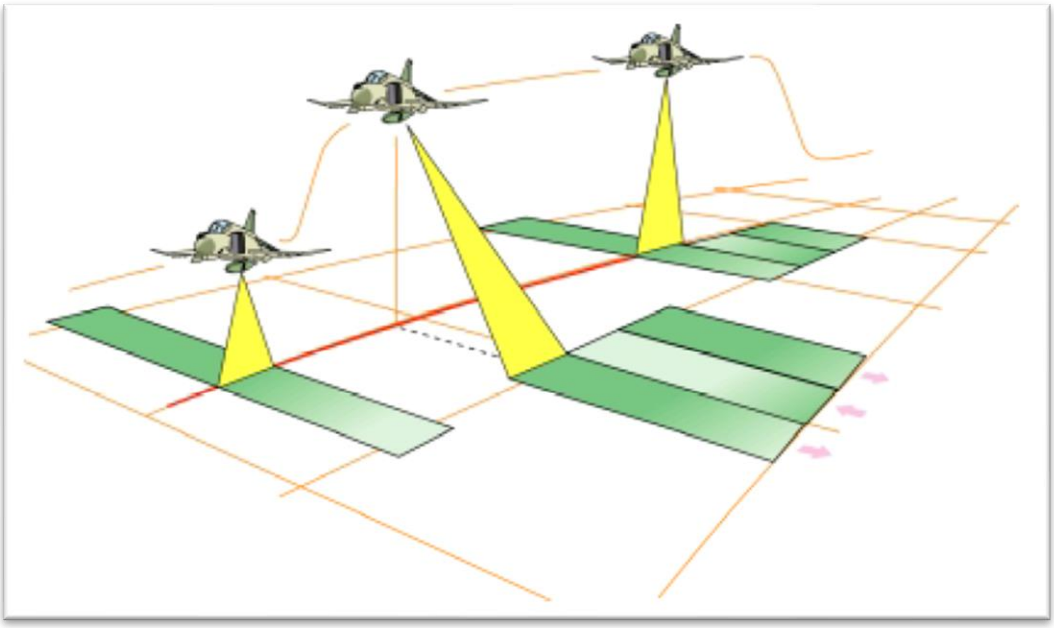

Figure 2 - Pan Scanning techniques[2]

[2] Image courtesy of Raytheon Systems

6. The following images, taken from a Tornado at 24,000 feet and flying at 0.9 Mach, illustrate the capability of the sensor at long / short ranges and in the visible and IR light spectrums.

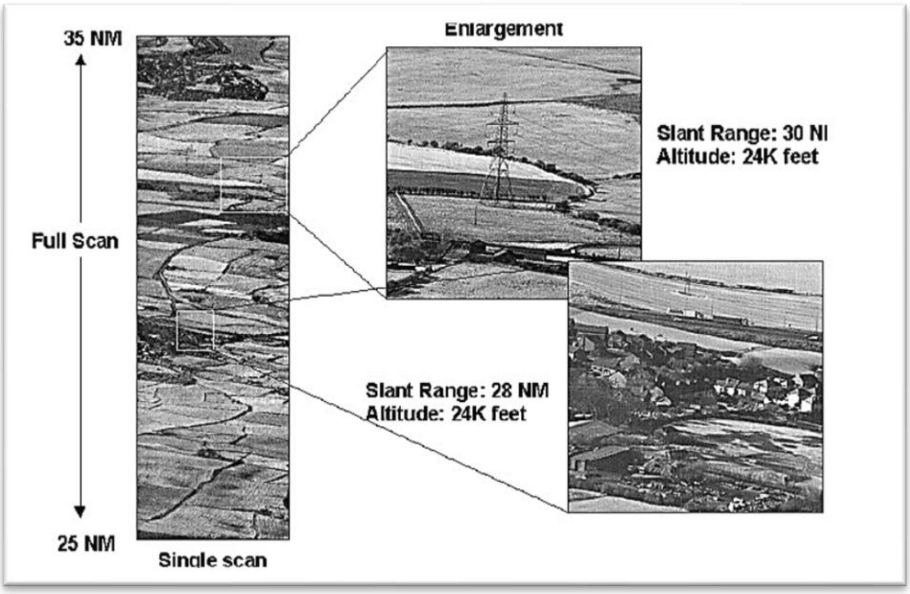

Figure 3 - Daytime Visible - Long-Range Image[3]

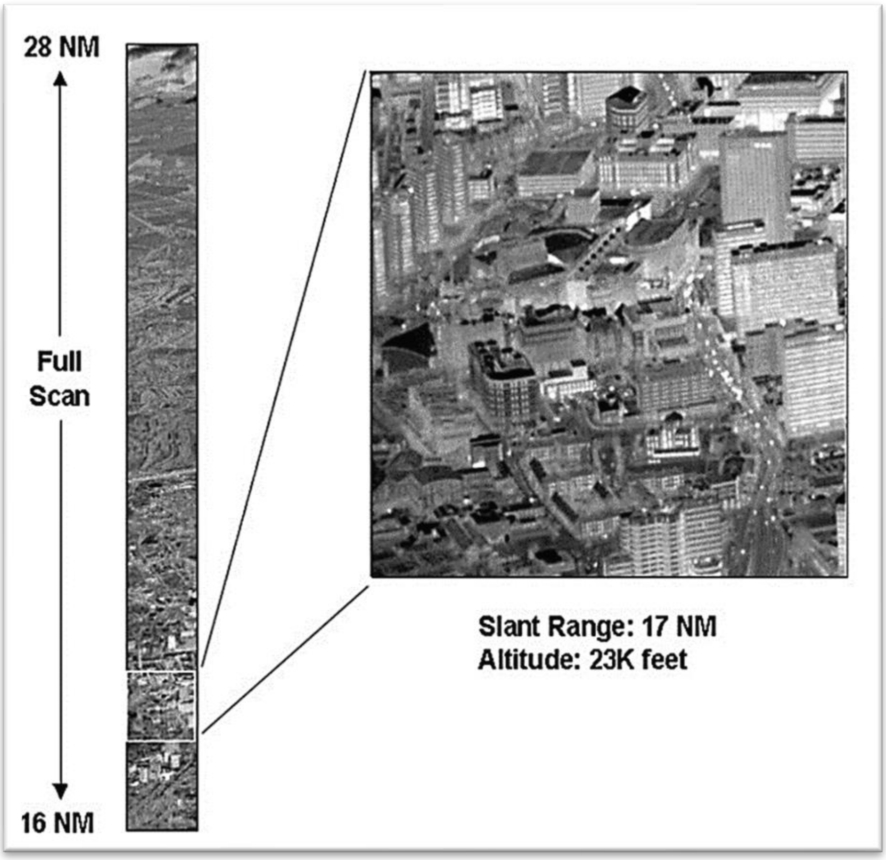

Figure 4 - Night-time IR - Long-Range Image[4]

[3] Image Crown Copyright
[4] Image Crown Copyright

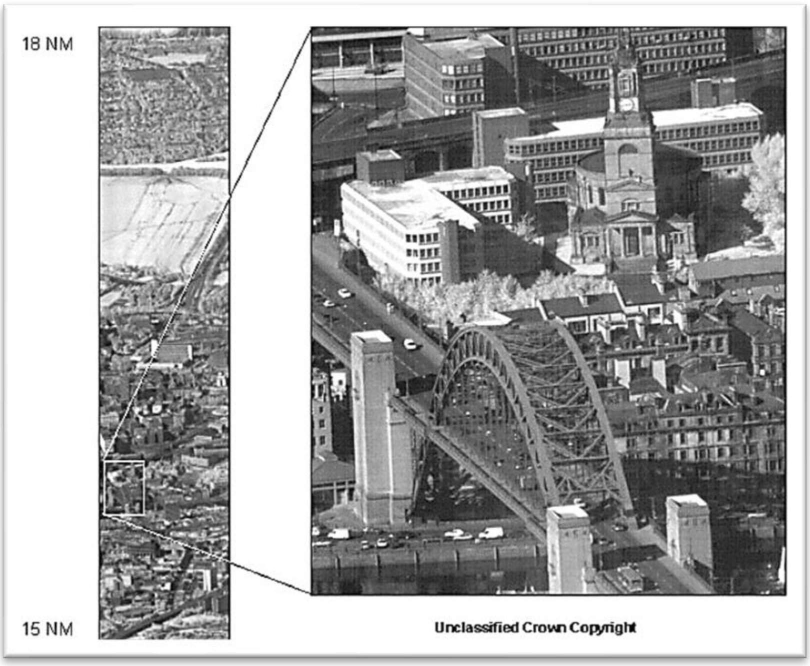

Figure 5 - Daytime Visible - Short-Range Image[5]

Figure 6 - Night-time IR - Short-Range Image[6]

7. Night-time IR imagery has a unique appearance as it is purely a result of emitted thermal energy. From Figure 6, the level of fuel in the POL storage tanks can be seen from their residual thermal signature. The dense fuel oil, which would be heated during the daytime, retains some of that heat throughout the night. The sides of the tanks cool more quickly at night than the fuel and are lighter in appearance in the thermal IR image. The tops of the tanks appear black as they are reflecting the "cold" sky.

[5] Image Crown Copyright
[6] Image Crown Copyright

Pod Sub Systems

8. The sub-systems contained within the pod are as follows:

a. **Sensor System (DB-110)**

Receives the optical and Infra-red radiation from the ground scan via an optical assembly. Mounted on a gimbal assembly, the sensor is stabilised in pitch and roll using the Internal Litton LN-214 Inertial Measurement Unit (IMU).

b. **Sensor Control Unit (SCU)**

Processes control information from the Reconnaissance Management System (RMS) to schedule scanning and slewing operations. The SCU receives information from the Navigation Electronics Unit (NEU) which is used to stabilise and position the sensor.

c. **Reconnaissance Management System (RMS)**

Contains the Reconnaissance Management Unit (RMU) which functions as the Central processor controlling all pod sub systems and 4 types of BIT. The collected imagery is processed within the RMU for display and can also be recorded on a Solid State Recorder (SSR) for subsequent transfer to the DGLS. The RMS also acts as the POD Remote Terminal (RT) on the 1553B avionics databus.

d. **Airborne Data Link Terminal (ADLT)**

Consists of an Airborne Modem Assembly, Radio Frequency Assembly, two 7 inch steerable Antenna Assemblies, one at each end of the pod, and a Waveguide switch which is used to switch Tx/Rx between antennae.

e. **Ground Maintenance Panel (GMP)**

Used by the groundcrew to prepare the pod for flight. It also contains the receptacle for the Data Transfer Module (DTM) where either a Mission PCMCIA card containing the Mission data, or Maintenance PCMCIA card is loaded.

f. **Litton LN-214 Inertial Measurement Unit (IMU)**

The IMU provides navigational information derived from pod navigation and attitude data (Part of Sensor System).

g. **Navigation Electronics Unit (NEU)**

The NEU processes the information from the IMU for use in the SCU.

h. **Environmental Control System (ECS)**

The ECS maintains the sub-assemblies at the correct operating temperature.

i. **Pod Power Distribution Unit (PPDU).**

The PPDU provides switched power to all sub-assemblies. An RS 422 data link between the PPDU and RMU carries status and control signals.

11. Figure 7 shows the position of the various sub-assemblies within the pod.

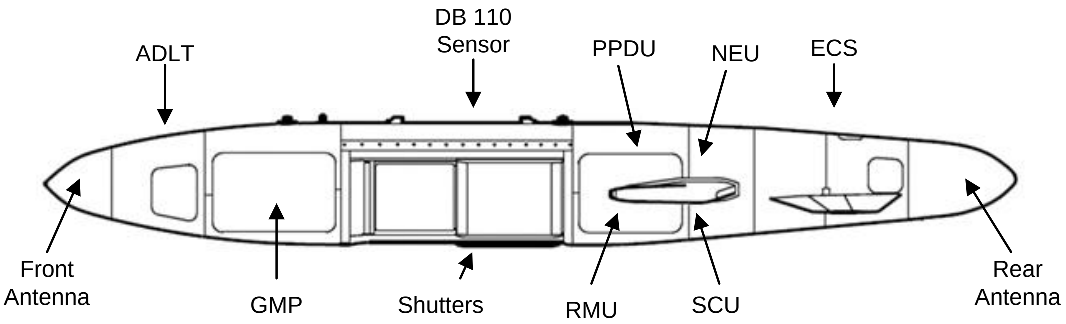

Figure 7 – Sub-Assembly locations[7]

Pod Operation

12. The Pod operates using the DB-110 sensor to acquire digital images of an area of interest either side of the flight path via the three 'shuttered' windows. Areas of interest or targets can be pre-programmed (Automatic mode) which provide commands, calculated by the RMS, to point the sensor towards the desired area based on target's geometric location, aircraft location and attitude provided by the aircraft's Inertial Navigation System (INS) via the 1553B databus. The Pod provides the avionic system with an external synchronisation lock acknowledgement, ID acknowledgement and a 'wrap round' test.

13. The aircraft INS would typically provide Navigation data to the Pod with the following:

a. Aircraft Pitch and Roll attitude.

b. True heading.

c. Aircraft velocities (North, East and Vertical).

d. Terrain height.

e. Aircraft height above mean sea level.

f. Aircraft latitude and longitude.

g. System time.

h. Aircraft Identity.

14. Along with the acquired digital image, the navigation information is stored on a high density Solid State Removable Memory Module located within the SSR for analysis at a later time or in near real time if transmitted to a DGLS.

15. In addition to Automatic mode, Manual mode allows the aircrew to select 'targets of opportunity' via a viewed displayed image through the cockpit interface function.

[7] Image Crown Copyright

Data-Link System

16. The Data-Link system allows the acquired digital imagery to be transmitted to a DGLS via the ADLT using X or Ku band (GHz) ‘point to point’ digital techniques. To be able to communicate effectively with the DGLS, planning is required to take into account the transmitter (Pod) and receiver (DGLS) positions using line of site communication as well as requiring wide bandwidth receivers.

17. For this reason the system uses steerable antennae, Air to Ground and Air to Air relay functions. Air to Ground transmission is limited by earth curvature, terrain and aircraft altitude and therefore an Air to Air relay function is provided. The airborne receiver has limited gain due to a smaller receiver antenna compared with the DGLS antenna and therefore a reduction in data rate is required to retain a practicable range capability.

18. Due to limited bandwidth being constrained by frequency allocation in an already crowded military and civil radio spectrum, typical data link practicable bandwidth would be constrained to around 10 Mbit/sec. This would mean that a 20k x 20k image would take 5.33 minutes to be received.

19. A Data Link (DL) task causes a list of images to be transmitted over the DL which can be divided into Auto (pre-programmed), Manual or Tethered. In Auto, pre-programmed tasks allow images to be collected whilst out of DL range and then once in DL range, transmitted automatically. In Manual, in-flight tasks are selected and transmitted if within DL range. Tethered causes the imagery to be stored on SSR and transmitted simultaneously.

20. In order for the DGLS to receive imagery, Duplex or Simplex transmission is utilised. For Duplex operation a ‘handshake’ is required between the pod and the DGLS. The pod sends an initial transmission (Status Acquire) for the DGLS to interrogate. If the response is accepted to the pod, ‘Locked’ status will be achieved and the imagery is transmitted. In Simplex operation a ‘handshake’ is not required but the pod controls the ‘Locked’ status regardless of the DGLS status.

Pod Safety Precautions

21. One of the dangers imposed is the possibility of transmitting High Energy Radio Frequency (RF) to personnel on the ground. For this reason the RF safety distance is 4 m and mechanical safety interlocks are incorporated to prevent inadvertent operation.

22. Personnel should follow correct written procedures when carrying out maintenance on the pod.

Litening III Advanced Targeting Pod

23. Litening III (LIII ATP) is a third generation Laser Designator Pod (LDP) currently operational with a world wide variety of combat aircraft including the RAF Tornado GR4 and Typhoon.

24. As a third generation pod, the Litening III provides significant improvement in image quality, stabilisation and acquisition range over the second generation Thermal Imaging Airborne Laser Designator (TIALD) pod, previously fitted to Tornado. Additionally, the pod incorporates an RF data link for the in-flight transmission of streamed data, imagery and video to a Rover III ground station. Figure 8 shows the LIII fitted to the Typhoon.

Figure 8 – LIII fitted to Typhoon[8]

24. Although L III is primarily a targeting pod, automatic scanning modes provide the pod with a reconnaissance function. The original function design was intended for Battle Damage Assessment (BDA) but developed into multi-mode recce.

L III Functions

25. The LIII provides the following functions:

a. Day and Night Target Acquisition – Air to Air & Air to Ground.

b. Laser Designation and Range finding.

c. Laser Spot Search and Track.

d. Laser Marking.

e. Datalink

[8] Image Crown Copyright

L III Components

26. L III is divided into 3 major sections containing various components:

a. A forward section containing the sensor package.

b. A rear section containing system electronics.

c. An Environmental Control Unit (ECU) to stabilise the pod temperature.

27. Figure 9 illustrates the major sections of the pod.

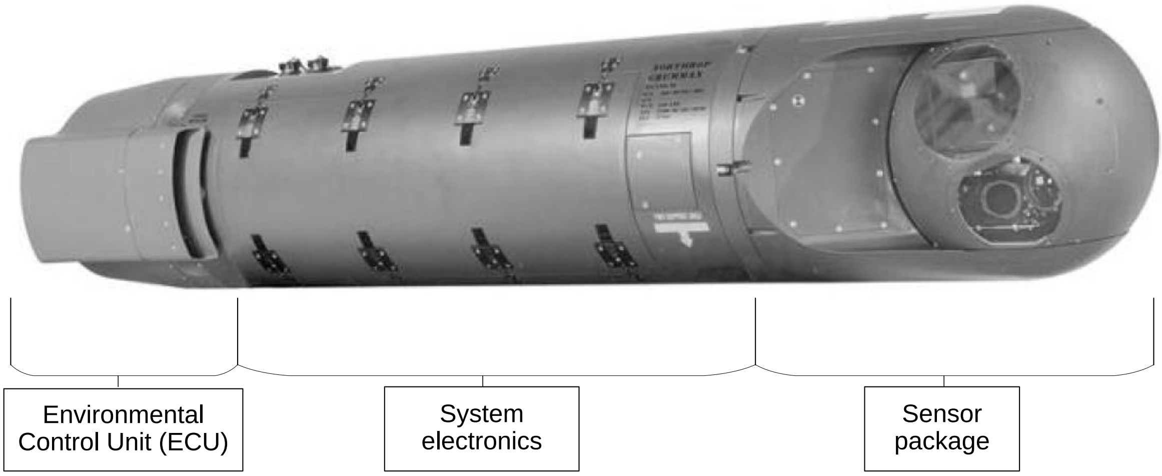

Figure 9 – LIII section locations[9]

Sensor Package

28. The Sensor package consists of a gimballed turret assembly which contains the sensor payload. Sensors include:

a. **Thermal Imaging Sensor (TIS)*.***

The TIS allows the detection and acquisition of targets by day and night and generates video signals from temperature differences radiated from the scene. These differences are detected on a Forward Looking Infra-red (FLIR) Focal Plane Array (FPA) and converted into a suitable format for display.

b. **CCD camera*.***

The Charged Coupled Device (CCD) allows detection of targets by day. Much like a modern digital camera, the CCD detects visible light and processes the image into a suitable format for display. With two identical CCDs, the system processes the image into either a Narrow Field of View (NFOV) or a Wide Field of View (WFOV) image depending on selected mode.

c. **Laser Spot Detector*.***

Using the TIS Sensor FPA, Laser Spot Detection automatically searches, detects and tracks targets designated by another Combat laser. The reflected Laser energy will appear as a 'bright spot' on the FPA and the movement of the spot is tracked by the Systems Electronics Unit (SEU) and used to keep the turret pointing towards the target.

[9] Image Crown Copyright

d. **SDRL Laser Transmitter Unit (SDRL LTU)**.

Switchable Diode and Range Laser (SDRL) performs laser designation and range finding by transmitting a narrow, sequence coded beam towards the target. It offers two wavelengths and associated strengths, where a Combat laser is used for live weaponry whilst the lower strength laser can be used for training purposes to protect the eyesight of troops on the ground.

e. **Laser Marker**

The Laser marker operates on a wavelength which can be detected on night vision goggles (NVGs) and is used to direct troops on the ground to a target location visible from the air.

f. **Inertial Sensor Unit (ISU)**

The Inertial Sensor Unit contains two dual axis gyros and three accelerometers which are used to improve turret stabilisation and eliminates the need for mechanical alignment of the pod.

29. Figure 10 illustrates the sensor payload.

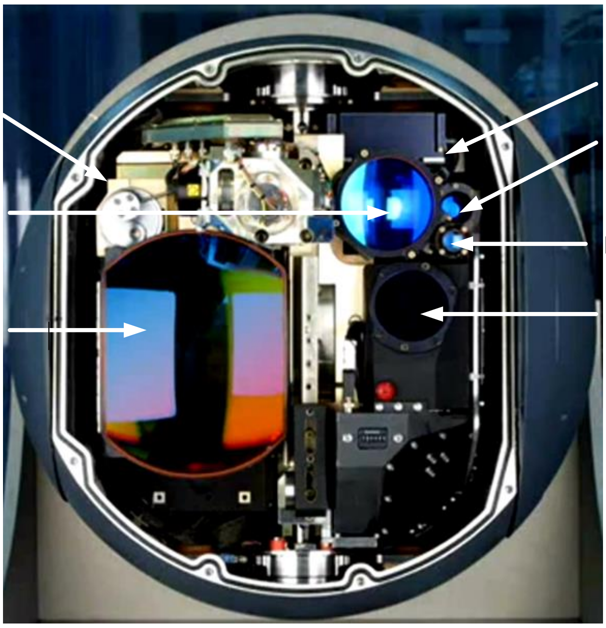

Figure 10 – L III sensor payload[10]

System electronics

30. The pod rear section contains the system electronics. Components include:

a. **Systems Electronics Unit (SEU)**

The SEU is the heart of the LIII and generates all the commands and display symbology. Commands include those required to position the turret and maintain track on a target. For this it uses the inertial parameters of attitude, velocity and position from the ISU to drive the turret motors.

[10] Image Crown Copyright

b. **Video Unit Reconnaissance (VUR)**

Images generated by the IR and CCD sensors are digitally processed by the VUR which includes auto gain, auto contrast adjustment, range compression, filtering and de-rotation (see Figure 13) of the digital video input.

c. **Interface Unit (IU)**

The IU is the link between the aircraft and the pod. Power supplies and data are transferred from the aircraft to the IU via the umbilical connector. It also transfers video output signals to the aircraft.

d. **Power Servo Unit (PSU)**

The PSU acts as an interface between the SEU and the turret servo motors. It contains power amplifiers that convert the signals from the SEU to drive the turret.

e. **Digital Video Recorder (DVR)**

The DVR uses an 18 GB removable Memory Module Cassette (MMC) and records sensor video whenever the pod is operating. The video data is recorded in MPEG 2 format with a recording quality of either High (2 hours) or Low (4 hours). When the MMC is full, the DVR is ‘looped’ back to record over the first images. Ground replay is achieved by connecting the MMC to a Digital Video Debrief Station (DVDS).

f. **Solid State Recorder (SSR)**

The SSR has two 8 GB flash drives which are used to load auto-recce missions and to record still (JPEG) images from both sensors in both manual and auto-recce modes. The SSR can be replayed in flight.

Environmental Control System (ECS)

31. The ECS maintains the Sensor package and System electronics at the correct operating temperature.

32. Figure 11 shows the System electronics component locations within the pod rear section.

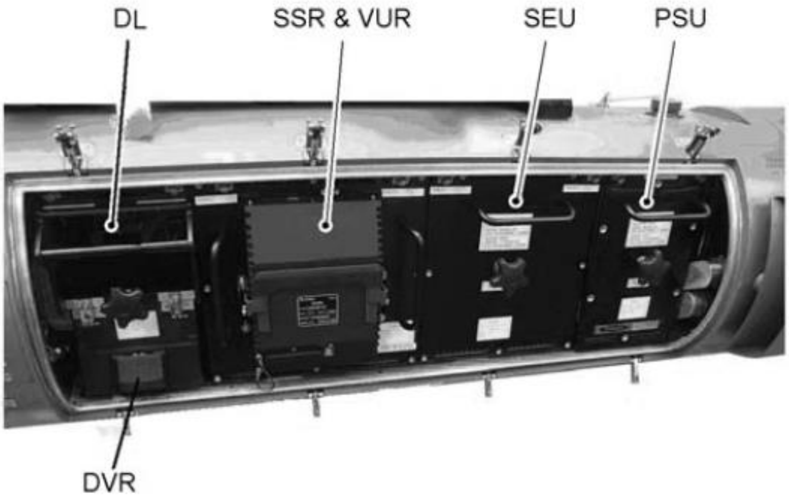

Figure 11 – System electronics component locations[11]

L III Modes of Operation

33. The LIII has several modes of operation:

a. **Standby**

Selected when the pod is fully powered up and available for operational use. In Standby the sensor head is parked to protect the sensor window from damage.

b. **Service**

Service mode is used to present the sensor window for cleaning and is only available from Standby whilst the aircraft is stationary.

c. **Air-Ground (A/G)**

The pod A/G mode is entered by selecting 'Air to Surface (A/S)'. This will slave the pod Line of Sight (LOS) to the weapon system A/S target of interest or the next target waypoint of a pre-programmed route. Once this mode is entered, Laser firing is supported and images are presented on a display along with corresponding symbology.

d. **Air to Air (A/A)**

The A/A Mode is similar to that for the A/G mode except that Laser firing is inhibited.

e. **Navigation**

Navigation uses the pre-stored waypoints to slew the pod LOS along route and provide a visual indication of the waypoint location on the ground.

[11] Image Crown Copyright

L III Tracking

34. Once a target has been acquired the pod tracks it using the processed signals from the SEU to keep the pod LOS on the target.

35. The L III offers three types of tracking:

a. Electro-optical (EO) Tracking.

Designed to track both moving and static targets using combined point and area trackers. The EO tracker operates with both IR and CCD sensors in all Fields of View (FOV).

b. Inertial Tracking

Allows the Inertial Sensor Unit to automatically maintain the target track following the loss of EO tracking. A vehicle entering a tunnel could be an example where EO tracking is lost.

c. Manual Tracking

Manual Track is initiated by the operator slewing the pod LOS.

36. Within each track type, the pod has a number of sub-modes which are available to track targets:

a. A/G Area Track

Uses EO tracking algorithms over the entire Field of View (FOV) to maintain the track of the target.

b. A/G Point Track

Uses EO tracking algorithms but within a reduced window (usually a moving target) around the image centred in the FOV.

37. Figures 12 and 13 illustrate A/G Area and Point Tracking.

Figure 12 – A/G Area Track[12]

Figure 13 – A/G Point Track[13]

[12] Image Crown Copyright
[13] Image Crown Copyright

c. A/G Inertial Track

Automatically adopted when EO tracking cannot be maintained due to an obscured target. Internal pod ISU values are used to ground stabilise the pod Line of Sight (LOS) and maintain track. If EO tracking becomes available, ISU track returns to EO tracking.

d. A/G Manual Track

Initiated by slewing the pod LOS. When slewing ceases, the pod exits Manual Track and enters the previous track mode.

Note: The Laser can be fired in all the above A/G Track modes.

Laser Designation and Range finding

38. Once the target is tracked automatically and is within range, the system will automatically illuminate the target with either the ‘Combat’ or ‘Training’ Laser, updating the weapon system with the target slant range continually. Figure 14 illustrates a target that has been designated using the Combat Laser.

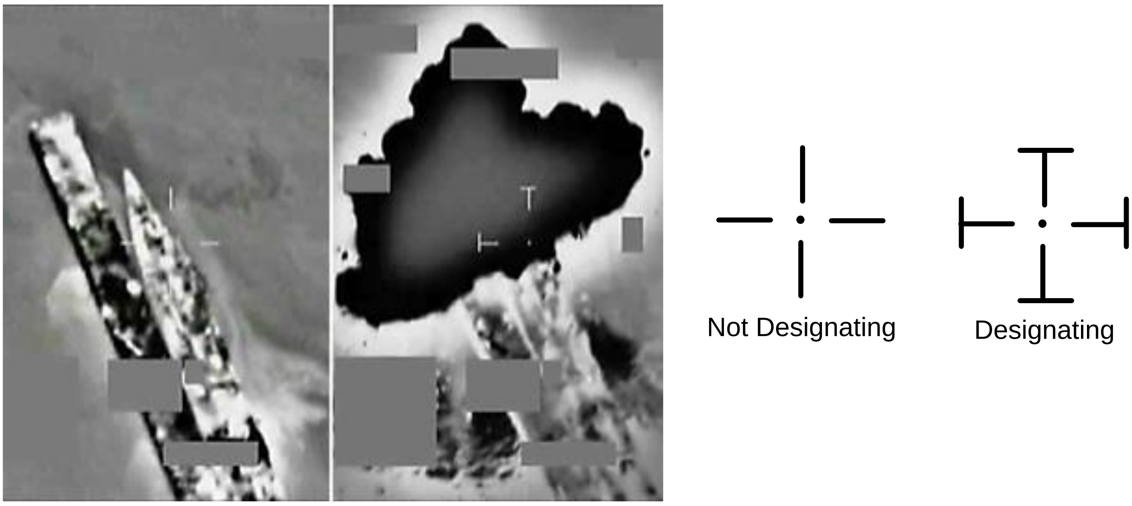

Figure 14 – Target designation using Combat Laser[14]

39. Once the weapon system determines optimum range and using Laser Guided Bombs (LGBs), the weapon is released and self-steer towards the reflected Laser energy.

40. With the operator witnessing the results live on an aircraft display, a battlefield commander may also witness the same result thousands of miles away if the video is transmitted via the Datalink (DL).

[14] Image Crown Copyright

Datalink

41. The Datalink transmits ‘live’ video imagery when fitted with the Multi Band Airborne Data Link (MBADL) to commanders or ground troops equipped with a ROVER III portable ground station. Figure 15 illustrates the ROVER III ground station.

Figure 15 – ROVER III Ground Station[15]

Pod Safety Precautions

42. The following Safety precautions are to be adhered to when working with the Litening III pod:

a. Laser safety

NOTE: CURRENT LASER EYE PROTECTION IS NOT EFFECTIVE AGAINST DIRECT ILLUMINATION BY THE COMBAT LASER OR LASER MARKER. SOME PROTECTION IS AFFORDED AGAINST REFLECTED ILLUMINATION.

WARNING: EYE DAMAGE CAN OCCUR DURING POD LASER FIRING WITHIN THE FOLLOWING DISTANCES:

For the Combat laser – 59.8 km (379 km using binoculars)

For the Training laser – 0 m (320 m using binoculars)

For the Marker laser - 362 m (2.4 km using binoculars)

[15] Image Crown Copyright

b. Mechanical Safety

Due to the movement of the ECS Fans and Turret movement, the safety distance is 5 m whenever power is applied. The System electronics section door can cause injury when opened incorrectly.

c. Electrical Safety

The L III pod requires 115 VAC 3 phase therefore power must be disconnected when removing LRUs.

d. Hazardous Materials

Various hazardous materials are used within the pod, which include:

Americium 241 (Gold coloured coating on screws)

Freon HCFC – 236fa (ECU refrigerant)

ZnSe – Zinc Selenide (FLIR window coating)

Notes