RECENT INTEGRATION OF 2ND GENERATION THERMAL IMAGING ON ARMORED VEHICLES

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ABSTRACT

Raytheon is in the final stages of production of three high performance thermal imaging / fire control systems being integrated on existing USMC and US Army armored vehicles. A goal in the design of these systems was to provide integration into the host vehicle that when viewed by the customer and user provided the enhanced capabilities of today's latest thermal imaging and image processing technology as well as operating in concert with the vehicle as originally designed. This paper will summarize the technical solutions for each of these programs emphasizing the thermal imaging, fire control, image processing and vehicle integration technologies. It will also outline guiding philosophies and lessons learned used to focus the design team in achieving the successful integration. The programs to be reviewed are; USMC 2nd Gen Thermal Imaging System, the USMC LAV-25 Improved Thermal Sight System (ITSS) and the USMC / US Army M1A1 50 Cal Thermal Sight / DayTV System.

PROGRAM SUMMARY

The USMC is in the process of completing the fielding of 3 thermal sight / fire control systems on their armored vehicles. Raytheon's Network Centric Systems – Combat Systems group in McKinney, Texas managed the development and production for all 3 programs.

1. Fire Power Enhancement Program (FEP) - Thermal Imaging System (TIS): The first program conducted under this umbrella effort by the USMC M1A1 upgraded the gunner's Thermal Imaging System (TIS) from 1st Gen thermal imaging technology to 2nd Gen as well as adding a Far Target Location (FTL) capability. The program was conducted out of the MARCORPSYSCOM PM-Tanks office in Quantico, Va. Program competitive development began in 2000 with the first production award in 2004. First of the 530 deliveries occurred in 2006, last delivery is scheduled for 2010.
2. Fire Power Enhancement Program: Another FEP effort was to provide the M1A1 Commander with a thermal sight capability for his weapon station. The 50 Cal Thermal Sight / DayTV System replaced the hard optic periscope with a DayTV and biocular display and added a thermal sight on the weapon cradle. The program was conducted out of the MARCORPSYSCOM PM-Tanks office in Quantico, Va. The US Army procured the same solution for its Tank Urban Survivability Kit (TUSK) Program and all of its M1A1s. Program competitive award was made in 2004 with the first production award in 2006. First of the 1977 deliveries occurred in 2007, last delivery is scheduled for August 2009.
3. LAV-25 Improved Thermal Sight System (ITSS): ITSS provides a complete upgrade to the LAV-25 thermal sight and fire control providing improved Phit and Far Target Location. The program was conducted out of the TACOM PM-LAV office in Warren, Mi. Program competitive development award was made in 2002 with the first production award in 2006. First of the 502 deliveries occurred in 2007. Last delivery is scheduled for August 2009.

PROGRAM DESCRIPTION

FEP Thermal Imaging System

The FEP Thermal Imaging System (TIS), Figure 1, is designed to give the USMC M1A1 Abrams gunner the capability to survey the battlefield and acquire and engage threats day or night in adverse weather conditions with the vehicle stationary or on the move. It provides greater target acquisition ranges than first generation thermal sights, providing dual opto-mechanical fields of view with two levels of electronic magnification for improved situational awareness while retaining or improving current hit probability. It includes a 2nd generation thermal sight based on the same detector (Standard Advanced Dewar Assembly Type II, SADA II) and optics used in the US Army Horizontal Technology Integration B-Kit (HTI B-Kit) program. To accommodate the higher performance imaging

capability a new Biocular Image Control Unit (BICU) is provided. Although the BICU is similar to the unit in the US Army's M1A2SEP vehicles this new BICU was required to be smaller and lighter for the M1A1s. A Far Target Location (FTL) capability is provided based on an inertial north finding module integrated with the FEP TIS, the laser range finder and a GPS receiver.

Army M1A1, M1A2, M2A3 are identical in performance: FOV, image processing, target acquisition range (Detection / Recognition / Identification).

4. Two biocular displays, one for the gunner and commander viewing of thermal imagery. The two biocular displays provide thermal imagery, reticle, FTL Data and symbology when the gunner and/or commander are viewing the thermal image.

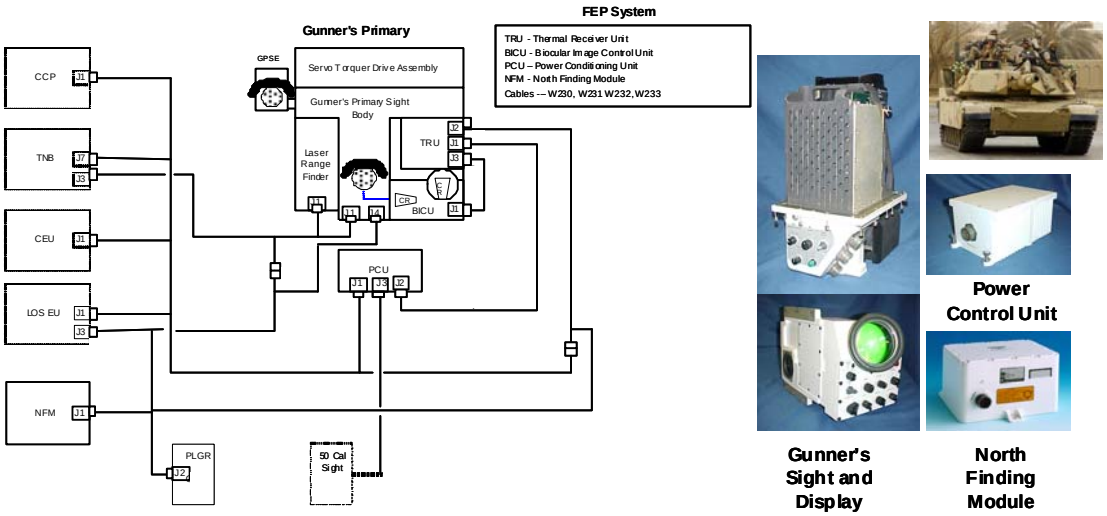


Figure 1. FEP Thermal Imaging System

Improved Thermal Sight System (ITSS)

The LAV-25 (ITSS), Figure 2, upgraded the performance of the LAV-25 day/night sight, the DIM36TH. The mission of the Light Armored Reconnaissance (LAR) Battalion is to conduct reconnaissance, security, and economy of force operations; and within capabilities, conduct limited offensive and delaying operations that exploit the unit's mobility and firepower. The nucleus around which LAR Battalions are organized is the LAV-25. As such the LAV-25 provides a high volume of rapid automatic fire in support of missions assigned to the Battalions. To support this mission the Improved Thermal Sight System (ITSS) provides:

1. The capability for both the gunner and commander to survey the battlefield and acquire and/or engage threats during day/night/adverse weather conditions with the vehicle either stationary or on the move. This is provided with a thermal sight using the same detector, electronics and optics as that used in FEP and HTI B-Kit.
2. Compact packaging configuration to perform its functions. ITSS improved clearance to clear ammo chutes and maintain the 25mm weapon.
3. Dual opto-mechanical fields of view with electronic magnification for improved situational awareness. The gunner's sights for the USMC LAV-25, M1A1 and US
5. Direct View Optics (DVO) allowing gunner viewing of visible imagery through a monocular eyepiece.
6. The gunner with an Eyesafe Laser Rangefinder (ELRF), and the commander with a lasing capability.
7. Far Target Location with an inertial based north finder with self and target positions displayed on the commander and gunner's biocular displays.
8. Full solution ballistic fire control utilizing integrated cant, cross wind and azimuth rate sensors..

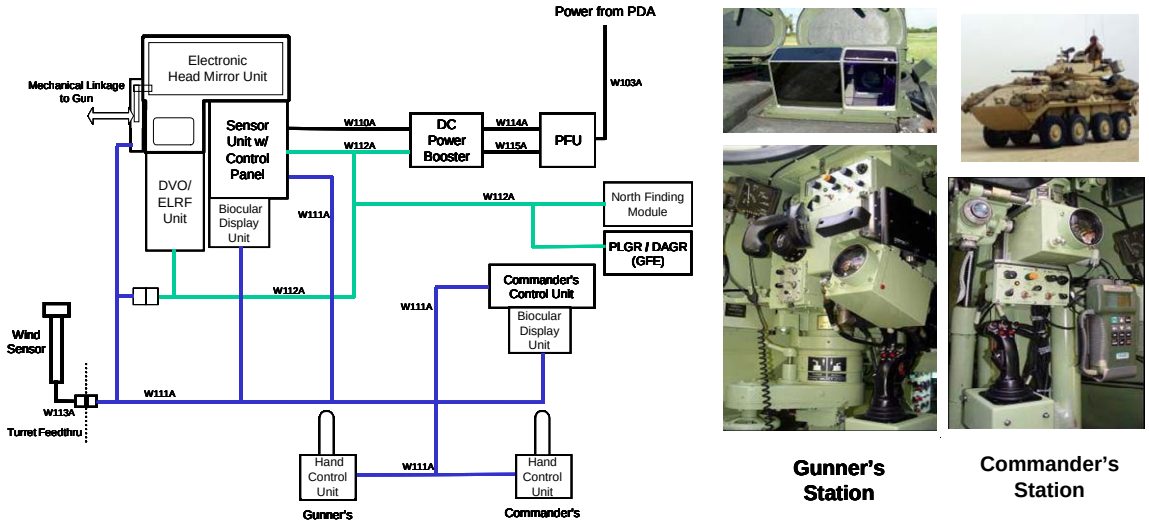


Figure 2. LAV-25 Improved Thermal Sight System

M1A1 50 Cal Thermal Sight / Day TV System

The 50 Cal Sight system, Figure 3, is integrated into the USMC and US Army M1A1 Tank Commander's Weapon Station (CWS). The Thermal Sight Module is mounted on the exterior portion of the CWS on a modified equilibrator bracket. The TSM is uses a Raytheon uncooled microbolometer FPA that is remotely focused. At the commander's position the existing CWS direct view periscope optics are removed, periscope housing with fold mirror and window are retained. The Display/Control Module (DCM) has a biocular viewer and is mounted at the location of the removed CWS periscope eyepiece. A Day TV camera, part of the DCM is mounted to image across the periscope fold mirror. The 50 Cal Sight receives power (+15VDC) from the FEP TIS Power Control Unit (PCU). The gunner's 2nd Gen thermal video is an auxiliary input to the DCM. The commander can select either the 50 Cal thermal, DayTV or the gunner's TIS video to be viewed on his DCM biocular display. Stadiametric reticles for the weapon mounted on the CWS, either M2 or M240, are displayed in the 50 Cal Sight thermal and DayTV imagery. Operator controls are provided to operate, boresight and maintain 50 Cal Sight.

TECHNOLOGY INSERTION

In addition to the latest thermal imaging technology provided to the marine and soldier these programs also provided advanced technologies that lead to improved and new operational capabilities. Three of those technologies will be discussed: Electronic Image Stabilization (EIS), Enhanced - Local Area Processing (E-LAP) and Far Target Location (FTL).

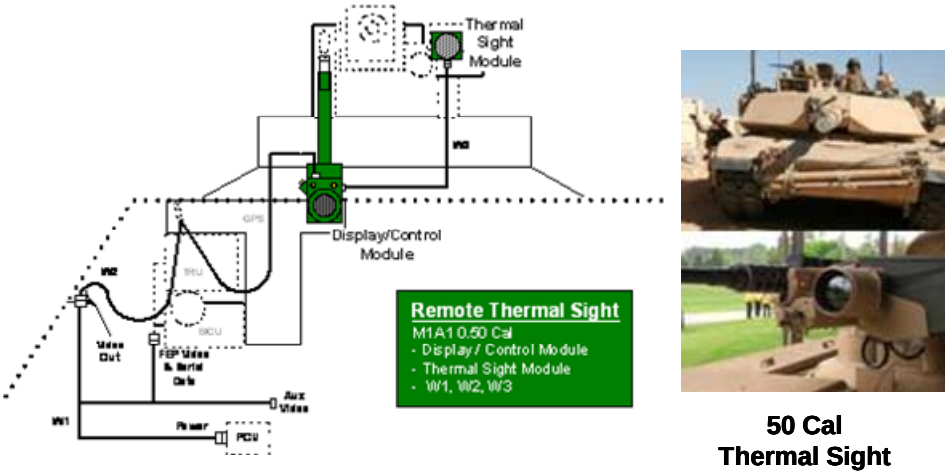


Figure 3. FEP 50 Cal Thermal / Day TV System

Electronic Image Stabilization

FEP provides a second-generation FLIR, but if combined with insufficient LOS stabilization, is not a complete system solution. The Raytheon program approach placed great emphasis on realizing a complete solution. We chose to introduce Raytheon's proven EIS technology which eliminated the need to upgrade the M1A1 with a dual-axis, stabilized Line of Sight (LOS) director such as the one used on the M1A2 Systems Enhancement Program (SEP).

The M1A1 LOS is independently stabilized in elevation with the single axis Servo Torquer Drive Assembly (STDA), azimuth LOS performance is slaved to the stabilized turret. The result is good LOS jitter performance in elevation and relatively poor performance in azimuth. The M1A1 implementation assists the gunner in azimuth by moving the reticle based on the error in the azimuth loop. So even though the LOS is moving the reticle is also moving and in general stays on the target.

For EIS the error in the elevation axis gyro stabilized rate loop is routed to the FEP electronics, for azimuth the same signal used to move the reticle is used. EIS algorithms that actual shift the image need an input in the form of an angle. In elevation the rate error must therefore be integrated and scaled. In azimuth the integration is done in the M1A1 electronics therefore only needs to be scaled to provide the necessary correction.

The FEP thermal sight is a scanned 480x4 system therefore EIS corrections can be applied to portions of the image, rather than just one correction for the whole image. This allows for corrections at frequencies greater than 50Hz. In the case of a staring system running at a 30Hz frame rate corrections can only be made up to 15 Hz.

The FEP EIS field test data showed significant improvement in LOS jitter over various speeds and terrains, Figure 4 and 5. Therefore performance of the 2nd generation thermal sight is not degraded while the vehicle is on the move. Data indicates the USMC M1A1s (and US Army) gunner's LOS jitter performance equals that provided by the dual axis head mirror of the M1A2SEPs.

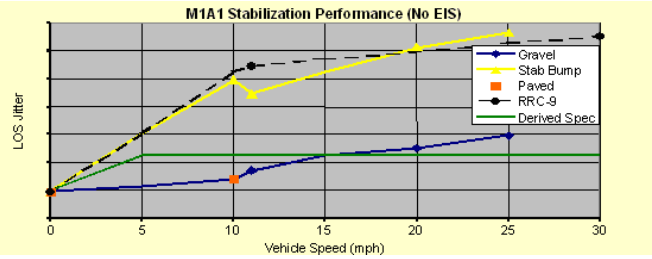


Figure 4. M1A1 LOS Jitter without EIS

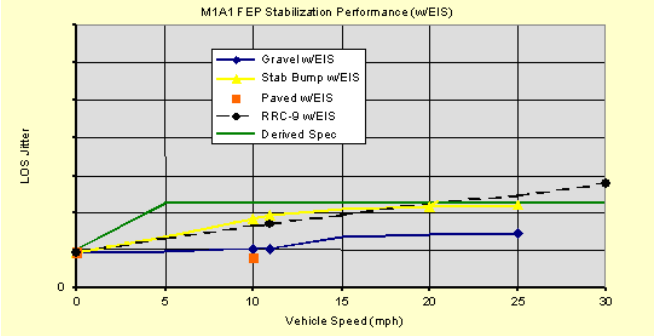
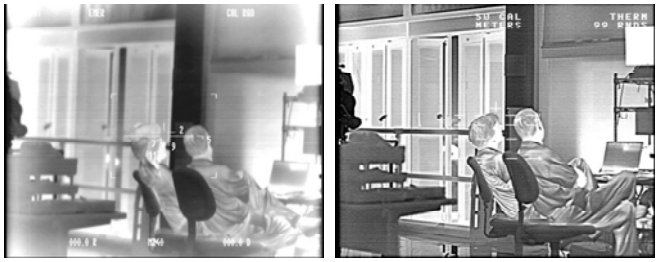


Figure 5. M1A1 LOS Jitter with EIS

Enhanced – Local Area Processing

Enhanced-Local Area Processing algorithms provide scene dynamic image enhancement along with automatic gain and level compensation to the video. This allows hands-off image optimization and significantly reduces user workload. The LAP algorithm enhances image details to provide situational awareness in all scene scenarios. LAP techniques map the wide dynamic range imagery of the sensors to the display's dynamic range.

E-LAP is being delivered on all USMC and Army armored vehicle thermal sights (M2A3 Bradley CIV and IBAS, M1A2 CITV, TIS and 50 Cal, M1A1 TIS and 50 Cal, LAV-25 ITSS). The USMC / USArmy 50 Cal program is the only known thermal sight in the US DoD inventory that does not have manual gain / level controls. User assessments concluded the operator cannot optimize the image better than E-LAP, Figure 6.



Standard Auto Contrast E-LAP Imagery

Figure 6. 50 Cal E-LAP Imagery Comparison

Far Target Location

Far Target Location systems, Figure 7, provide the GPS grid position of the target based on the range to the target, the self position of the host vehicle and the bearing of the LOS of the laser. Range is provided by the Laser Range Finder integral to the sight / fire control system, self position is the GPS location of the host vehicle. Bearing of the LOS of the LRF is based on either a GPS carrier phase measurement (as used on the US Army Long Range Advanced Scout Surveillance System) or an inertial based

north finder. The FEP and ITSS programs use the inertial system. The operator is presented his self-position, bearing to the target and target position every time the LRF is fired.

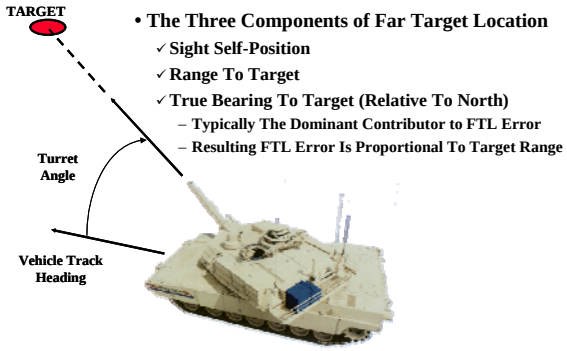


Figure 7. Far Target Location Implementation

INTEGRATION GUIDING PHILOSOPHIES AND LESSONS LEARNED

The three programs discussed involved upgrading existing systems, addition of new capabilities, integration with mechanical, power, stabilization and fire control, all on platforms designed more than 20 years ago. M1A1 documentation was available to the design team, drawings were accurate and current, however specifications and interface control documents (ICDs) were not. In the case of the LAV-25, programmatic issues prevented receipt of any drawings or specifications. To address the development risks associated with lack of documentation and the inherent risks associated with vehicle integration an aggressive effort was undertaken. The following outlines those efforts and the lessons learned.

1. Visit the vehicle often – The 50 Cal development included 9 field integration / evaluation trips during a 13 month period. FEP the design team spent a total of 30 days over a period of 6 months in the field for integration / evaluation.

2. Survey multiple vehicles for those interfaces that are identified as critical, vehicle manufacturing tolerance result in variations in clearance between components. Differences up to 0.25 inches have been measured between turret walls and mounted equipment. This is especially important for vehicles that have been in the field for a significant amount of time. Operators and Contractors often make post-production modifications that are not always adequately documented.

3. Measure all electrical interfaces – Even if detailed ICDs are available time spent verifying that interface is well spent. ICDs only document to the extent necessary to make the original system function. Examples include:

- Great effort was spent on the FEP power interface with the turret, the problems associated with low power and transients were adequately addressed. However, well into the production phase a problem was found with a high voltage condition during vehicle acceleration and gear changes on a small portion of the USMC M1A1 fleet. The FEP system was compliant to Mil-Std-1275 requirement, but this small short duration operational condition was outside the requirement on some vehicles, the 1st Gen TIS was tolerant of this condition.
- A data interface to the M1A1 appeared to be thoroughly defined in the ICD and the design efforts matched the interface defined. However proper operation of the interface was dependent upon unique characteristics of the vintage electronics that were not compatible with today's electronics.

4. Review all documentation available – including that which may not directly pertain to your effort. The '-10' operator's manuals, the '-20' maintenance manuals and the '-24' Repair Parts and Special Tools List were found particularly helpful. Today's technology provides opportunity not only to improve upon existing systems but also provide additional capabilities. Understanding all associated systems assists in this integration.

5. Minimize the number of interfaces to lower the integration risk. The best example of this philosophy is the ITSS integration into the LAV-25.

- Mechanically the sight assembly at the gunner's station fit within the M36 hole in the turret therefore not requiring any drilling or cutting of the turret roof
- The gun linkage and the methods used to perform the sync and plumb alignments were not altered
- Electrically power was the only interface to the existing turret for all operations including fire control. Great emphasis was placed on understanding the characteristics of this interface early in the design. Those efforts resulted in the addition of a power filter unit to manage vehicle transients and a power booster unit. The booster concept has become common in systems with inertial based far target location systems. These systems require up to 5 minutes for the inertial based north finding unit to align, should power be lost (cycling of turret power, engine start) the booster will hold up the power to the inertial unit, preventing the crew from having to wait for an additional 5 minutes.

- The single electrical interface and the fact that there was no interface to the gun/turret drive assisted in resolving Phit testing issues.

6. Honor all existing mechanical interfaces and space claim. Ignoring what has worked for years raises the integration risk. The best examples were derived from the FEP Program.

- The design effort initially had little data other than outline dimensions of the existing 1st generation Thermal Receiving Unit (TRU) and Image Control Unit (ICU). Not knowing the reason for various bumps and cuts and size we established a design philosophy of not to alter the existing form factor. This proved vital in later system integration efforts when it was discovered what appeared to be an insignificant feature was in fact critical to an optical path internal to the gunner's sight assembly.
- Maintaining the size of the BICU to that of the replaced 1st Gen display unit avoided an interference with the opened door of the gunner's control panel.

OPERATIONAL FEEDBACK

The design teams have had the honor on occasion to be out briefed by users. The primary goal of the design team was gather the 'bad' and the 'ugly' issues. Fortunately there were none, but improvement suggestions were offered and included:

- Video recording for the units to get data to review after the missions.
- Provisioning additional spare parts
- Better fault isolation and troubleshooting – have the BIT give better fault isolation.
- The option of using the previous settings of various system functions after a reboot/power cycle.

Finally, it is always assuring to hear the 'good'. The following are paraphrased observations from the marines and soldiers.

50 Cal Thermal Sight

- One of the most liked items from Tank Urban Survivability Kit (TUSK)
- Soldiers loved the added capability it provided them in target acquisition and situational awareness.

FEP – TIS / FTL

- Fantastic piece of gear
- The picture is unbelievable
- We can pull into an OP and leave FEP on for 50/60 hours straight and just swap crews
- The FTL was just as important in the close fight because we needed accurate grid information
- System was easy to use. We read the training material and got into the tank and after 15 minutes felt comfortable with it.
- The little things also matter. Getting rid of the constant clanging noise of the cooler is great! Also it might be just our imagination but the FEP throws off less heat!

ITSS

- Firing on moving targets was very effective.
- Literally amazed that the equipment worked continually in such hot conditions. The missions were often 18 hours.
- Battalion commander said he took 901 Marines over and he brought 901 back.

REFERENCES

None