

INTEGRATED SIGHT BORESIGHTING

March 1998

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ABSTRACT

Development of soldier systems for the 21st century Land Warrior is exemplified by the techniques used on the Integrated Sight (IS) Program to integrate a thermal imager, a CCD camera, a miniature laser rangefinder (LRF), an electronic compass, and an infrared (IR) pointer into an advanced weapon sight and surveillance system. The Integrated Sight is being developed as a technology demonstrator and potential future upgrade to the Land Warrior and Thermal Weapon Sight Programs. A key integration challenge involves initial mechanical boresight alignment of the subsystems as well as boresighting of the thermal sight, CCD camera, LRF, compass, and IR pointer to each other in the IS system, and to the various weapons in the inventory. One aiming procedure requires the soldier to place a reticle on a target and fire the LRF. The IS then computes the ballistic trajectory based on the target range and the selected round, and displaces the reticle to a new aiming point to compensate for the calculated ballistic drop. For this concept to meet requirements, boresight tolerances must be carefully selected and the design of the weapon sight must be robust enough to withstand the rigors of use and the hostile shock and vibration of weapon firing.

The initial mechanical alignment designed into each subsystem precludes requiring mechanical boresight adjustments to compensate for statistical accumulation of mechanical tolerances. This design minimizes field maintenance costs that would be incurred to compensate for subsystem-to-subsystem variations in initial mechanical alignment.

Boresighting can be separated into factory reticle alignment and field boresighting (weapon zeroing). Because the integrated approach requires that the subsystems share the same optical bench, the factory reticle alignment procedure is a one-time only procedure that is performed on a collimator at the factory. This procedure entails aligning the thermal imager reticle with the CCD camera reticle. The LRF transmitter pointing reticle is also positioned to overlay the transmitted beam to complete factory reticle alignment.

The weapon zeroing procedure is simplified through optimized system architecture and engineering the man-machine interface through the selection and location of system controls and the presentation of symbology and reticles in the display. Pull-down menu selections in the system display and simplified step-by-step text instructions prompt the soldier to use a menu switch for adjusting the thermal imager and CCD camera reticles to boresight. The fact that the CCD camera is sensitive to the laser pointer energy allows its video to be observed while adjusting the laser pointer azimuth and elevation adjusters to the weapon zero.

There are fewer boresighting steps for the soldier in field zeroing when all the sensors are integrated into a single housing and factory aligned; only the CCD camera and IR pointer require alignment to the bore for the full system to be aligned. The weapon sight is also designed for boresight retention by minimizing thermal gradients and by providing adequate structural strength to the chassis and baseplate.

REPORT DOCUMENTATION PAGE

Form Approved OMB No.
0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.

1. REPORT DATE (DD-MM-YYYY) 01-03-1998		2. REPORT TYPE Conference Proceedings		3. DATES COVERED (FROM - TO) xx-xx-1998 to xx-xx-1998	
4. TITLE AND SUBTITLE Integrated Sight Boresighting Unclassified			5a. CONTRACT NUMBER		
			5b. GRANT NUMBER		
			5c. PROGRAM ELEMENT NUMBER		
6. AUTHOR(S) Gilstrap, Jeff ; Antesberger, Wayne ;			5d. PROJECT NUMBER		
			5e. TASK NUMBER		
			5f. WORK UNIT NUMBER		
7. PERFORMING ORGANIZATION NAME AND ADDRESS Raytheon TI Systems Plano, TX75023			8. PERFORMING ORGANIZATION REPORT NUMBER		
9. SPONSORING/MONITORING AGENCY NAME AND ADDRESS Director, CECOM RDEC Night Vision and electronic Sensors Directorate, Security Team 10221 Burbeck Road Ft. Belvoir, VA22060-5806			10. SPONSOR/MONITOR'S ACRONYM(S)		
			11. SPONSOR/MONITOR'S REPORT NUMBER(S)		
12. DISTRIBUTION/AVAILABILITY STATEMENT APUBLIC RELEASE					
13. SUPPLEMENTARY NOTES See Also ADM201041, 1998 IRIS Proceedings on CD-ROM.					
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15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:		17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19. NAME OF RESPONSIBLE PERSON	
a. REPORT	b. ABSTRACT	Public Release	10	Fenster, Lynn lfenster@dtic.mil	
Unclassified	Unclassified			19b. TELEPHONE NUMBER International Area Code Area Code Telephone Number 703767-9007 DSN 427-9007	
				Standard Form 298 (Rev. 8-98) Prescribed by ANSI Std Z39.18	

INTRODUCTION

The Integrated Sight is being developed as a technology demonstrator and potential future upgrade to the Land Warrior and Thermal Weapon Sight Programs. It provides a thermal imager, CCD camera, a miniature laser rangefinder (LRF), an electronic compass, and an infrared (IR) aiming light into an advanced weapon sight and surveillance system to benefit the individual soldier through total situational awareness and real-time automated targeting. The resulting system integrates these technologies to provide state-of-the-art imaging, targeting parameters, and weapon aiming to enhance the lethality and survivability of the dismounted soldier in both direct fire and call for fire situations. The size, weight, and power of the Integrated Sight is indicated in *Figure 1* as well as the approximate effective range of each subsystem.

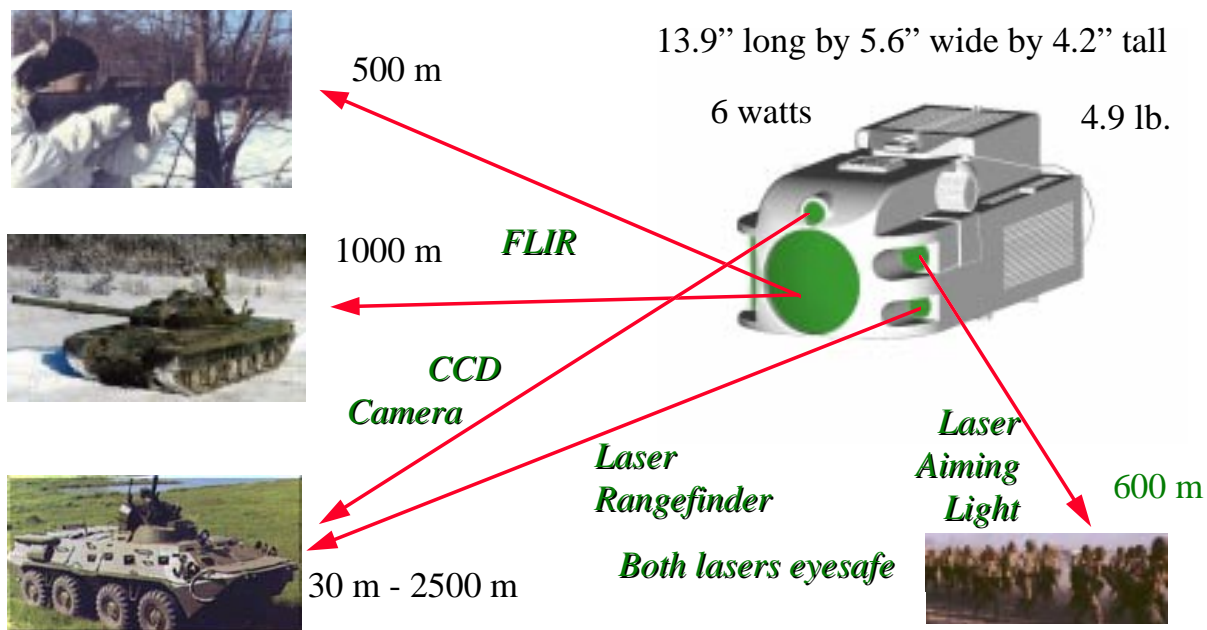


Figure 1. Integrated Sight subsystems

For this system to meet requirements, boresight tolerances must be met and the design of the weapon sight must be robust enough to withstand the rigors of shock and vibration in the field. The initial mechanical alignment designed into each subsystem does not require mechanical adjustments to compensate for statistical tolerance accumulation. Since the integrated approach requires that the subsystems share the same optical bench, the factory reticle alignment procedure is a one-time only procedure that is performed on a collimator. This design minimizes both factory and field maintenance costs that would be incurred to compensate for subsystem-to-subsystem variations in initial mechanical alignment. The weapon zeroing procedure is simplified by an optimized system architecture and by engineering the man-machine interface through the selection and location of system controls and the presentation of symbology and reticles in the display. Pull-down menus in the system display and simplified step-by-step text instructions prompt the soldier to perform weapon zeroing. This Integrated Sight design requires fewer boresighting steps for the soldier to perform in field zeroing, since all the

sensors are integrated into a single housing and factory aligned. *Figure 2* is a functional block diagram which shows the interaction of each of the subsystems of the Integrated Sight.

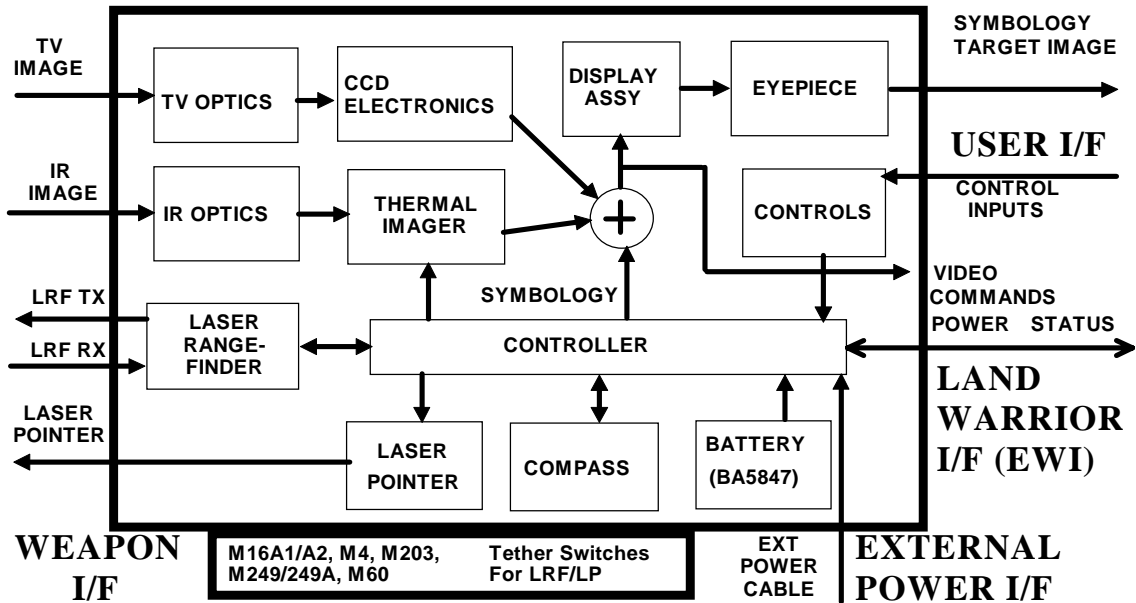


Figure 2. Integrated Sight Functional Block Diagram

The IS provides information to the Soldier by means of graphics overlaid on the display visible through the IS eyepiece or through the Land Warrior integrated helmet assembly displays. A typical soldier's view of the display is shown in *Figure 3*.

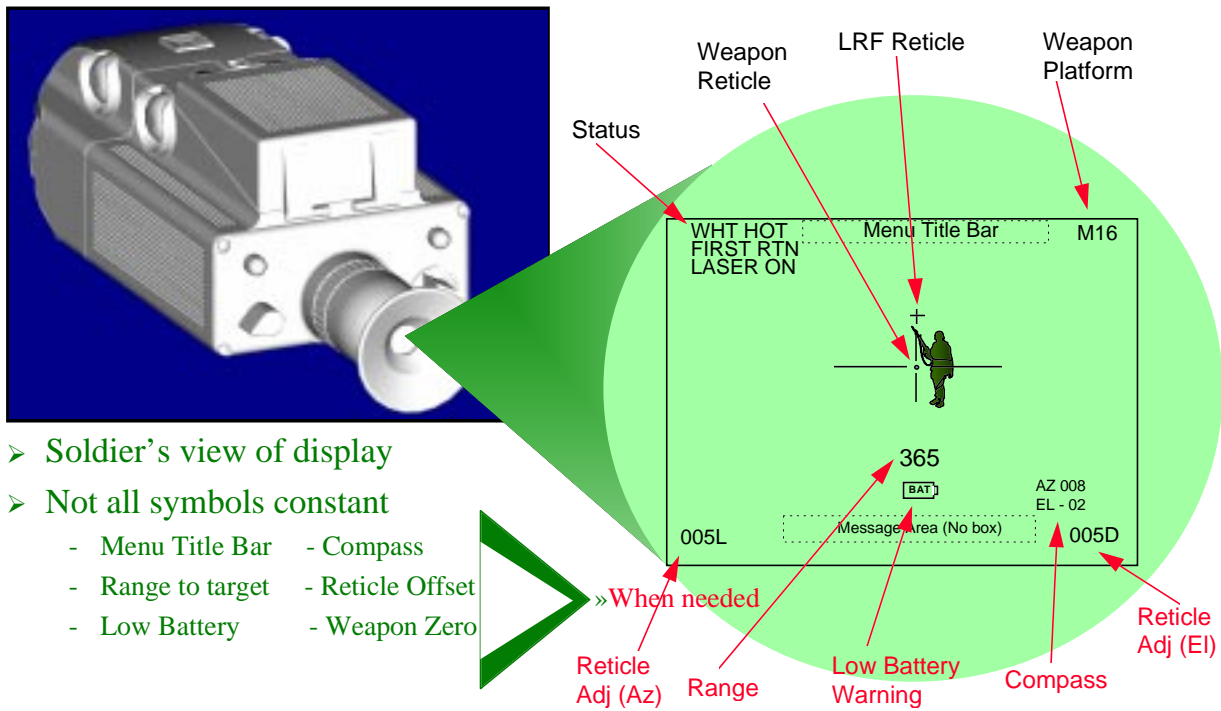


Figure 3. Soldier's View of the Integrated Sight Display

BORESIGHTING AND ALIGNMENT DEFINITION

Alignment typically refers to achieving parallel optical axes of several subsystems mounted on the same optical bench, while boresighting typically refers to the adjustments of the subsystems to a weapon bore at a given range, and may not mandate parallel axes. Boresighting as defined here refers to the adjustment of the sensors and lasers of the Integrated Sight (IS) to each other, the weapon mounting feature, and the weapon bore. The task of boresighting the IS requires the following adjustments:

- 1) IR sight Field-Of-View (FOV) and aiming reticle to the weapon bore.
- 2) Day sight (CCD camera) FOV and aiming reticle to the weapon bore.
- 3) LRF aiming reticle to the transmitter beam.
- 4) LRF receiver to the transmitter beam.
- 5) IR Pointer to the weapon bore.

IR AND DAY SENSOR BORESIGHTING

Boresighting of the IR and Day imaging sensors is accomplished through the use of electronic aiming reticles and precision mounting of the sensor components. Mounting of the optics and detectors of these sensors are controlled so that the center of each sensors FOV is aligned to the mounting feature within 6.1 mrad (a six inch circle at 25 meters). Precision mounting techniques are used that achieve required accuracy without the need for adjustment mechanisms. An adjustable electronic aiming reticle is used for each sensor to zero the sight to the weapon bore. Weapon zeroing can be accomplished using either a barrel-mounted laser for dry-zeroing, or traditional firing range methods.

LRF BORESIGHTING

As with the IR and Day imaging sensors, boresighting of the LRF is accomplished through the use of electronic aiming reticles and precision mounting of the LRF components. All LRF components are factory aligned and do not require field alignments. The LRF transmitter is hard-mounted to the IS chassis, and an electronic aiming reticle is factory aligned to the beam position. This reticle is separate from the weapon aiming reticle and is displayed above it. The LRF transmitter is mounted so that the beam is pointed slightly upward in elevation to displace the LRF aiming reticle above the weapon aiming reticle. This allows the two reticles to be displayed simultaneously while preventing the LRF aiming reticle from obscuring the weapon aiming reticle. Using a separate reticle to aim the LRF prevents the need to field boresight the LRF to the weapon. This feature simplifies field boresighting, reduces the cost and weight of the IS, and eliminates a possible boresight retention error source. Due to the small FOV of the LRF receiver, it is not practical to rely on precision mounting for alignment. Therefore, the LRF receiver is factory aligned to the transmitter.

IR POINTER BORESIGHTING

The IR Pointer is used to designate the strike point of a round. Therefore, the beam itself must be adjustable for field alignment to the weapon bore. The IR Pointer uses mechanical adjusters, or “boresight clickers” to steer the beam in azimuth and elevation for zeroing to the weapon bore. The IR Pointer wavelength is in the near-IR region, and cannot be seen with the unaided eye. However, the CCD

sensor used by the Day Sight is sensitive to near-IR wavelengths and can detect the IR Pointer. To zero the pointer, the soldier merely adjusts the IR Pointer to overlay the Day Sight aiming reticle (after the Day Sight has been zeroed to the weapon).

ELECTRONIC RETICLES

Since the IR and Day cameras of the IS are electronic sensors, their imagery is presented on a electronic (CRT) display as shown in *Figure 4*. Thus the IS is able to exploit the capability of electronic aiming reticles. These reticles are inserted into the video chain between the sensor and the display. Different reticle offsets are available for each sensor, allowing individual compensation of each sensor's pointing error individually. This feature is used by the IS to compensate for ballistic drop at longer ranges. To use this feature, the soldier takes a LRF range on a distant target, and the IS calculates ballistic drop based on target range and round type and then automatically offsets the reticle position on the display an appropriate amount. The soldier then raises the weapon to put the reticle back on target, and fires. Various reticle styles are available for each weapon type and are selectable by the user. Automatic control of electronic reticles is also possible.

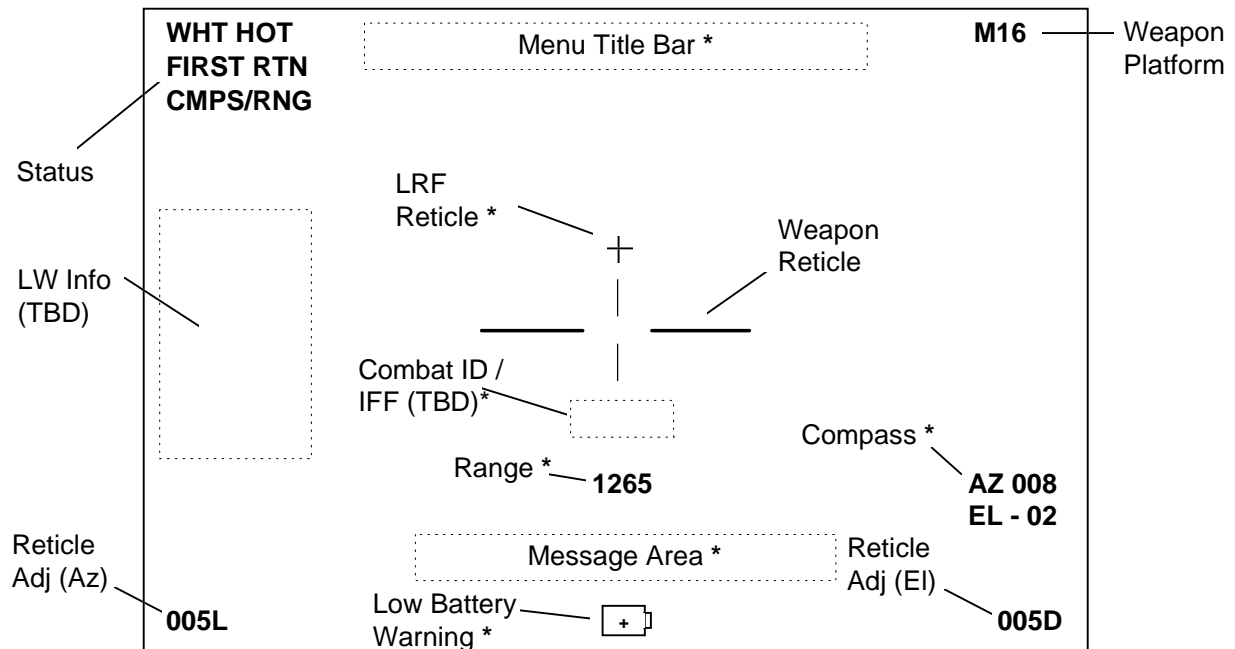


Figure 4. IS Electronic Display

(* All display features shown for illustration - not all features displayed simultaneously)

M203 GRENADE LAUNCHER MODE

The IS exploits its combination of sensors to provide a unique way of launching grenades from the M203 weapon. Most sights mounted to the M203 require a super-elevation bracket to aim the grenade launcher. This is due to the large amount of ballistic drop exhibited by M203 grenades. The weapon must be elevated to extreme angles to compensate for ballistic drop of the grenade, and the sight lowered to keep the target in its FOV. Once this action is performed, the sight is no longer boresighted to the primary weapon. This presents a problem to the soldier in an ambush situation. To alleviate this problem, the IS

uses data from the LRF and the Electronic Compass to present an aiming solution that does not require the sight to be lowered, allowing it to remain boresighted to the primary weapon at all times. Instead, the soldier aims the LRF reticle at the target and takes a range. The IS then calculates the proper elevation angle of the weapon, and displays pointing instructions to the soldier. When the soldier elevates the weapon, the IS senses the elevation angle of the weapon using the Electronic Compass and instructs the soldier where to position the weapon, telling him when the weapon is properly positioned both in elevation and azimuth. If the soldier is ambushed, the grenade launching mode is exited by pressing the LRF switch (located near the trigger), and the aiming reticle returns immediately. This method also precludes the added weight and possible boresight retention problems of a super-elevation bracket.

BORESIGHTING FUNCTIONS

Boresighting the IS is accomplished through three alignment functions:

- 1) Optical and mechanical alignment (Factory)
- 2) Reticle alignment (Factory)
- 3) Weapon zeroing (Field)

OPTICAL AND MECHANICAL ALIGNMENT (FACTORY)

As a general rule, “good” system design practice precludes the use of any adjustments. Adjustable mechanical mechanisms or potentiometers in circuits, for example, are undesirable because of increased costs due to added complexity and additional labor at assembly and test. Adjustable optical mechanisms possess the same negative attributes, but they also have a major negative impact on two of the IS’s most important design parameters: weight and boresight retention. Therefore the IS design minimized the use of optical and mechanical adjustment mechanisms. Instead of using these mechanisms, the Integrated Sight design relies on hard-mounting of precision fabricated components. Sensor and laser components are mounted to a common chassis structure shown in *Figure 5*. The chassis mounting features are produced in one fabrication step to minimize tolerance stack-up. Any small mounting errors encountered are then compensated by the use of electronic aiming reticles, as discussed in the proceeding sections. All of the sensors and laser components in the Integrated Sight employ precision mounting surfaces and alignment pins to meet the requirement for initial alignment. Tolerance stack-ups were minimized, and a statistical tolerance accumulation calculation including Root-Sum-of-Squares (RSS) was performed to insure requirements for initial alignments of the sensors and lasers to the IS mounting feature were met.

The only optical alignment required by the IS is the alignment of the FOV of the LRF receiver to the transmitter output beam. Due to the small FOV of the LRF receiver, it was not practical to try to achieve the required accuracy through controlling mounting tolerances. A mechanical adjustment of the receiver’s detector is required to align the FOV of the LRF receiver to the transmitter output beam. This task is performed during reticle alignment and will be discussed in the next section.

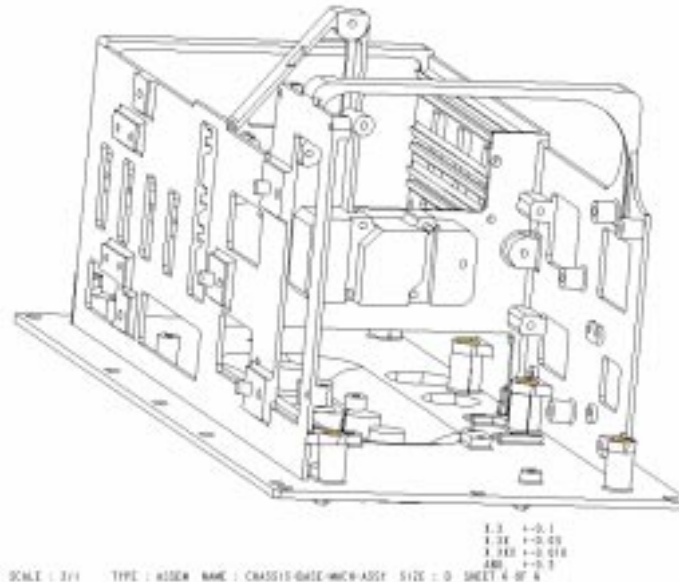


Figure 5. Integrated Sight Chassis

RETICLE ALIGNMENT (FACTORY)

Factory reticle alignment is required to accomplish the following tasks:

- 1) Align the Day Sight and IR Sight aiming reticles to a common target. This supports alignment of the IR Sight using the dry-zero boresighting procedure.
- 2) Align the LRF pointing reticles to the Day Sight and the IR Sight. Alignment of the LRF receiver to the transmitter is also performed at this time. These are factory alignments only and are not performed in the field.

The procedure is performed using a 120 inch reflective collimator. The collimator provides a target source at virtual infinity for alignment of the reticles and LRF. The collimator is reflective, and it is used for both the IR and Day sensors and the LRF. The collimator is equipped with a target plate, a source, and a weapon mounting rail attached to a two-axis tilt stage. The target source used is a gas filled bulb that emits energy in the near IR and long wave IR wavebands, and is therefore visible to the Day Sight, IR sight, and LRF Receiver. A Personal Computer (PC) programmed with appropriate reticle adjustment software and a TV monitor are connected to the IS's Land Warrior interface to control and set the reticle offsets during factory alignment. A phosphorescent card is also used for beam location of the LRF transmitter. The card is sensitive to the frequency of the LRF transmitter and emits radiation which is visible to the eye and the Day Sight sensor. The card contains a cross hair which matches the location of the target plate.

The IS factory alignment procedure consists of the following steps:

1. Verify collimator alignment by auto-collimating from the weapon mounting rail back to the target plate.

2. Mount the IS to the weapon rail and connect the PC to the IS's external interface connector. Switch the IS power to TV and select the TV alignment mode on the PC.
3. Observe the target on the monitor and adjust the Day Sight aiming reticle via the PC controls to overlay the target. When the reticle is satisfactorily aligned to the target, save the position in memory.
4. Switch the IS power to IR and select the IR alignment mode on the PC.
5. Observe the target on the monitor and adjust the IR Sight aiming reticle via the PC controls to overlay the target. When the reticle is satisfactorily aligned to the target, save the position in memory.
6. Switch the IS power to TV and select the LRF-TV alignment mode on the PC.
7. Insert the phosphorescent card in front of the target plate. Adjust the two axis tilt stage down approximately 1/2 degree to compensate for the LRF mounting angle. Pulse the LRF transmitter via the PC and look for the beam spot on the card. Continue to pulse the LRF transmitter and adjust the tilt stage until the spot is seen on the card. Once the spot is found, continue to pulse the LRF transmitter and adjust the tilt stage until the spot falls on the cross hairs of the card. The cross hairs correspond to the location of the target plate.
8. Remove the card and observe the target source with the Day Sight. Adjust the LRF-TV aiming reticle via the PC controls to overlay the target. When the reticle is satisfactorily aligned to the target, save the position in memory.
9. Switch the IS power to IR and select the LRF-IR alignment mode on the PC. Adjust the LRF-TV aiming reticle via the PC controls to overlay the target. When the reticle is satisfactorily aligned to the target, save the position in memory.
10. Attach the adjustment mechanism to the LRF receiver's detector and loosen its mount. Attach an oscilloscope to the amplified output of the detector. Adjust the mechanism until the detector's output is maximized and tighten the mount. Remove the mechanism and the oscilloscope.

WEAPON ZEROING (FIELD)

Weapon zeroing is a procedure used to boresight the IS reticles and IR Pointer to the weapon. The IS is primarily mounted to a weapon via a Picattiny mounting rail (dove-tail type). These types of mounts are commonly used due to their ease of mount/dismount, adjustability of position (front to rear), repeatability of mount/dismount accuracy, and general robustness.

Weapon zeroing is performed using one of the following methods:

1. Dry-Zeroing
2. Traditional firing range methods.

The Dry-Zeroing method uses a device to provide a projected designation of the gun barrel's axis that can be seen with the weapon's sight. This permits zeroing of the sight to the weapon without firing rounds from the weapon. The negative aspect to dry zeroing is that a fired rounds unique trajectory cannot be compensated for completely. However, the IS does provides automatic reticle compensation for ballistic drop.

The IS Dry-Zeroing procedure consists of the following steps:

1. After the IS is attached to the weapon, install the dry-zeroing device onto the weapon. The preferred device is the laser-type, which uses a red or near-IR laser mounted to a mandrel that is inserted into

the weapon bore. The mandrel fits tightly into the bore. The laser mount allows the laser to rotate freely on the mandrel, and employs adjusters to steer the beam for alignment. To align the laser to the bore, activate the laser and rotate it on the mandrel. Observe the designation spot, and note any circular pattern produced by this rotation. Continue to rotate the laser and adjust the beam until the laser produces a stationary spot. The dry-zeroing device is now aligned to the weapon bore, and the laser beam provides an accurate projection of the gun barrel's axis.

2. Set-up a standard 10 or 25 meter zeroing target. Choose a location out of bright sunlight, as the beam spot will be easier to distinguish. Mark the designated strike point on the zeroing target for the appropriate weapon and desired range.
3. Sandbag or brace the weapon. Switch the IS power to TV and activate the laser dry-zeroing device. Aim the weapon at the target and place the beam spot on the designated strike point. Adjust the brightness and contrast knobs on the IS to optimize visibility of the target and beam spot.
4. Press the center button of the five-way menu switch located on top of the IS. Select the weapon zeroing mode and follow the menu instructions presented in the display, as shown in *Figure 6*. Press the up/down and left/right buttons on the menu switch to adjust the reticle to the aiming point of the target. When satisfactorily aligned, press the center button to save the offset. Turn off the dry-zeroing device and remove it from the weapon barrel.
5. Activate the IR Pointer and aim the weapon at the zeroing target. Observe the IS display and rotate the adjusters on the IR Pointer until the beam spot overlays the aiming reticle. This procedure will zero the IR Pointer to the range of the zeroing target (10 or 25 meters). To zero for longer ranges, mark a strike point for the IR pointer on the target (for the appropriate weapon and desired range). Aim the weapon reticle at the target aiming point and rotate the adjusters on the IR Pointer until the beam spot overlays the strike point.

Once the Day Sight is zeroed, the IR Sight is also zeroed. The reticle offsets saved in memory when zeroing the Day Sight are automatically applied to the IR Sight reticle. This technique is made possible by factory aligning the reticles of the Day and IR sights to the same target on the collimator. This technique also requires that the Day Sight and IR Sight FOV's be characterized for differences in magnification, and that the optics of each sight have low distortion in the central area of the FOV's.

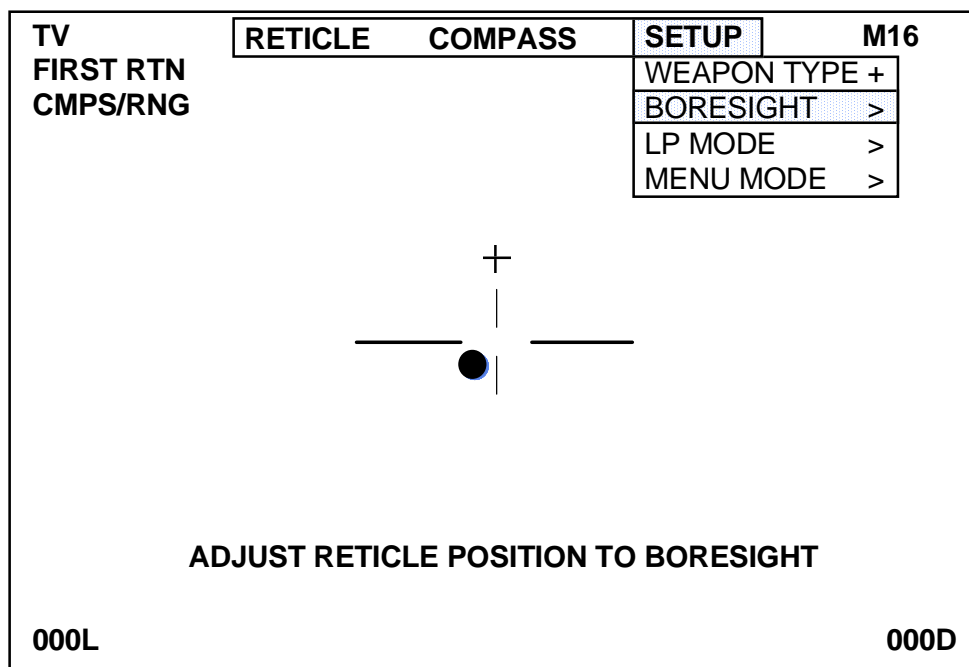


Figure 6. Integrated Sight Display - Boresighting Mode

The other method of zeroing the IS to the weapon uses traditional firing range procedures. Three round groups are fired using 10 and/or 25 meter targets, and the IS aiming reticle is adjusted using the menu switch as detailed in the preceding section. The procedure is repeated until a satisfactory three round group is realized.

SUMMARY

The Integrated Sight provides a thermal imager, a visible CCD camera, a miniature laser rangefinder (LRF), an electronic compass, and an infrared (IR) pointer into an advanced weapon sight and surveillance system to benefit the individual soldier through total situational awareness and real-time automated targeting. The IS boresighting approach minimizes both factory and field maintenance costs through initial mechanical boresight alignment, simplified menu-enhanced factory reticle alignment, and field boresighting (weapon zeroing) procedures.