SPECTRON

SE1420 DASH
DISPLAY MEASUREMENT SYSTEM

OPERATING MANUAL

Spectron Engineering, Inc.
Denver, Colorado

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Caution

Ensure that all cables are properly attached and secured before turning on power.

Do not remove the covers on the Transport, Main Camera or Controller. Removal of these covers will necessitate factory recalibration and may cause damage.

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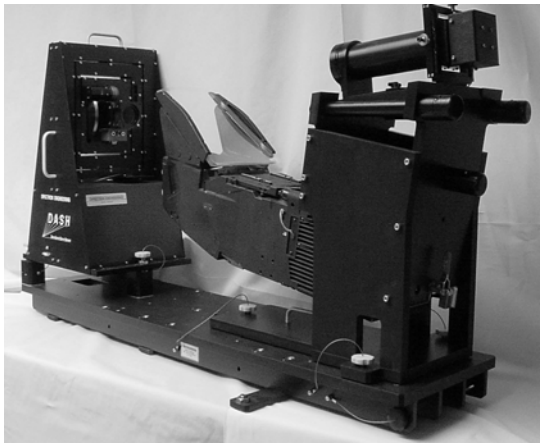
Chapter One

OVERVIEW

SE1420 DASH
DISPLAY MEASUREMENT SYSTEM

Spectron Engineering's high-performance SE1420 DASH Display Measurement System (SE1420 DASH) has been designed to work as a front-end data-gathering device for objectively characterizing HUD or CRT displays. It integrates high resolution optics with precise positioning and sensing devices to measure all aspects of incident photo-optic light waves generated by the image. The design is such that the image can be characterized in real time and the data electronically stored. This enables objective comparison with previous data from the same display, with data from other display images, or with standardized criteria.



SE1420 DASH Transport/Camera with HUD in Test Position

SE1420 DASH Controller - Rack Mount

SE1420 DASH System Modules

CRT/HUD Inspection System EquipmentCRT/HUD Inspection System Equipment
The SE1420 DASH is composed of three interchangeable modules, each of which is calibrated at the factory, and the associated cabling:

- Controller (1) PN: 1420-HC-IS-xx
- Transport (2) PN: 1420-HC-XP-xx
- Camera (3) PN: 1420-HC-CM-xx
- DASH 100 Pin Control (4) PN: OMS-W01
- 9 or 15 Pin Accessory Cable (5) PN: OMS-Wxx
- Power cord (6) PN: WAC4

The three modules, Controller, Transport, Camera, are described briefly below; all components are described in detail in *Chapter Two: Initial Setup and Connections*.

Controller

The Controller, pictured above, is the electronic heart of the SE1420 DASH System. It contains a micro-processor based dedicated controller, firmware, RAM memory, analog and digital sections, power amplifiers, and video and data communications capability. Optionally, the controller may contain a Front Panel monitor or display that reflects the controller video output from the system.

When the Controller is turned on, it will perform a self-test (see. *Chapter 3, Operations*) and download the Camera and Transport calibration information for use in system operation.

Typically, a Controlling Computer will be used to send commands to the Controller through the RS232 or an IEEE488 bus. The test results from the command are passed back to the controlling computer to be stored or processed in accordance with user developed test procedures.

Manual testing can be accomplished with the SE1420 DASH Main Menu software by connecting a dumb terminal (DT) or a personal computer (PC) to the RS232 port. When the system is initially powered up or reset, the Main Menu will be displayed on the DT or PC. Although it is not necessary for operations, the operator will find it convenient to attach a Video Monitor and/or a Video Recorder to the RS170 connection on the Controller Back Panel if extensive manual testing is to be done.

Transport

SE1420 TRANSPORT with MAIN CAMERA

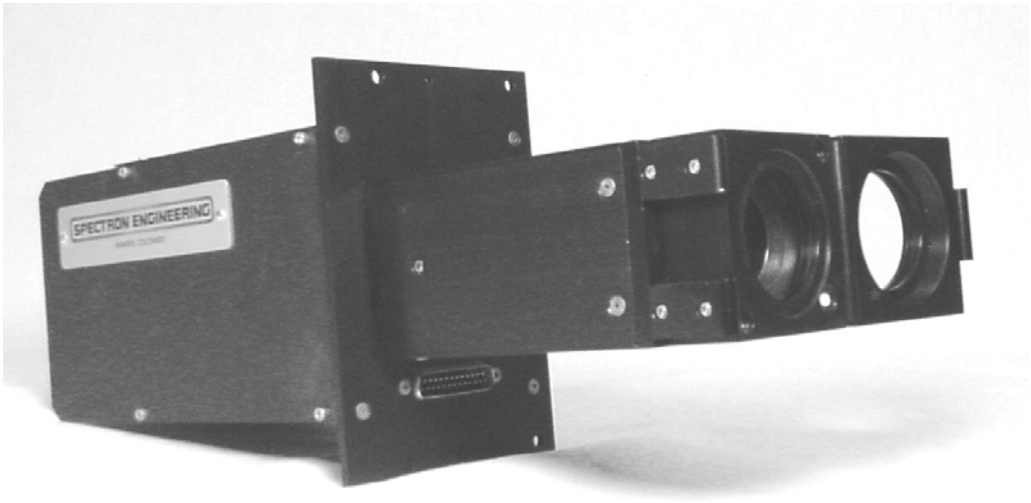
Transport

The Transport is the mechanical heart of the SE1420 DASH system. It secures and precisely moves the Camera (shown above and described below). The calibrated mechanical mechanism of the Transport utilizes two motor/disc assemblies on the horizontal and vertical axes to control the altitudinal and azimuthal angles of the Camera as it is oriented to view, measure and characterize a HUD or CRT image. The motor/disc assemblies in the Transport utilize a friction drive concept that employs a two-motor, anti-backlash, design for precise angular movement. In automatic operation, the mechanism will move the Camera in a pre-programmed test pattern that typically over-samples the display image in all areas of interest. The test equipment is capable of measuring every pixel on the surface of the display more than once.

Camera

Camera and Lens Assembly

The Camera module consists of a high-quality, autofocus photo-diode matrix array camera. It may contain one or more lenses, dependent upon a particular application. Although the Camera is removable for replacement or repair, it is generally left permanently mounted in the Transport.



SE1420 Camera with 2 lens (HUD and Direct View) Configuration

The precise control of the Camera position afforded by the Transport module, along with the factory calibrated and corrected focal plane of the photo-diode matrix array within the Camera, allows the Camera to function as an automated theodolite. In addition, the detector has been tested to have zero defective pixels, tested for photometric linearity, and each pixel of the detector is calibrated and corrected for dark sensitivity errors. The Camera can be considered an "imaging microphotometer" as well as an automated theodolite.

The autofocus feature of the Camera is important because the display image being tested may not actually be at infinite focus. Most image characteristics are best quantified with the Camera automatically focused on the actual image.

The Camera is equipped with 2 neutral density (ND) filters and 3 RBG (red, blue, green) Color filters. Additionally, Spectron optionally supplies apertures that may be utilized to improve the performance of the SE1420 DASH for a given display image or for a particular user required measurement. The ND1 filter passes 10% of the available light to the detector and the ND2 filter passes 1% for use with extremely bright images.

It should be noted that, if used, the location of the apertures is critical to the factory calibration factors stored in the Camera. The utilization of user supplied apertures at a different point along the image axis may adversely affect the optical characteristics of the image.

During factory calibration, information for the precision linear encoder that controls the movement of the Camera focus axis, information for the spectro-radiametrics of the detector, as well as other calibration constants are stored in the Camera and transferred to the Controller upon start-up.

Video Display of Test Result

The SE1420 DASH has the capability to output messages, test results, and other communications via a RS170 video output. Because all tests can be conducted automatically, neither a video monitor nor a VCR is included with the standard system. It is, however, recommended that a video monitor be used during the test development stage. This is accomplished by connecting a monitor to the RS170 port on the Controller. The monitor will enable the user to easily view automatic test results or to conduct interactive, manual tests. This connection is further described in "*Chapter 2: Initial Setup and Connections.*

Automated versus Manual Test Mode

The SE1420 DASH can be programmed, through a controlling computer, to automatically run all tests on a display image. The operator does not have to interact with the system or monitor the video output. However, it is often useful in developing the automatic test procedures and for other reasons, to perform manual tests utilizing the RS170 output and a serial terminal. Manual tests are Menu or Command Line driven, and are described in detail in "*Chapter 3: Operations*."

Factory Calibration of the SE1420 DASH

Factory calibration of the SE1420 DASH is a highly precise and integrated procedure necessary to achieve the specifications set forth in *Appendix A*.

Extremely high quality linear and rotary encoders are used at the factory to determine positional correction factors along all axis of movement within the SE1420 DASH system. All positional movement and luminance calibrations are traceable to NIST standards.

Factory calibration of the Transport module consists primarily of mechanical calibrations of each transport axis with its precision encoder. There is 64K resolution from the rotary encoder and ± .0001" resolution of the linear encoders. When plotted, the position output curve for even the best encoder is generally non-linear. This curve must be linearized to a very high degree in order to obtain the highest resolution possible from the system. Correction factors are defined for each encoder in each axis of movement to make the linearity of that encoder better than it was when received from the manufacturer. This provides great precision for Camera movement and confidence that the Camera is measuring the image at a point where the operator or software has directed. Factory calibration includes analyzing a grid and test data which is fed into a correction table which is stored and used by the system during operation. This corrects and refines the accuracy of each encoder. This calibration cannot be adjusted by the customer. Every Transport, and every Camera, stores its specific factory calibration information in EEPROMs.

Camera factory calibration is of importance for both positional and luminance accuracy. The Camera detector has been tested at the factory to have zero defective pixels. It is tested for photometric linearity, and each pixel of the detector is calibrated and corrected for dark sensitivity errors. The focus transport mechanism of the Camera is calibrated similar to the Transport axes above. Correction factors are stored and utilized during SE1420 DASH operations to maximize the accuracy of auto-focus measurements and for improvement of luminosity measurements both for no filter operation, and for ND or Color filter operations.

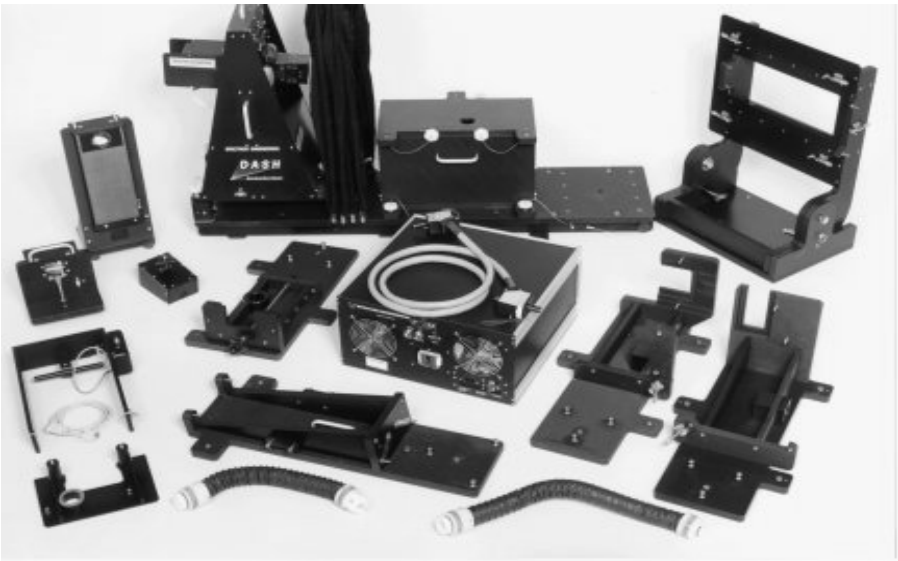
Because the SE1420 DASH is calibrated at the factory as an interdependent system, no attempt to open or repair any of the modules should be made in the field as the validity of the calibration data will be compromised. This includes replacement of circuit boards within the Controller. Instead, return the System to Spectron Engineering in Colorado for service or arrange for factory calibration on-site by Spectron (see, *Chapter 4, Maintenance and Repair).*

On-Site Alignment

Some on-site alignment procedure is required when the system is initially set up. On-site alignment will ensure that the SE1420 DASH is measuring relative to a known reference point. Spectron supplies alignment tools to be used with the SE1420 DASH on an optional basis. If user supplied alignment tools are used to check alignment or to develop a coordinate system of measurement, it should be noted that, unless the principal reference point is traceable to NIST standards, the positional measurement performance of the SE1420 DASH may be degraded from factory specifications.

Ancillary Equipment

As shown directly below, the SE1420 DASH is usually combined with specific fixturing equipment. The Transport and Camera are mounted at a precise location on an Optical Breadboard, with additional fixtures designed specifically to hold the unit under test (UUT) in a known and exact relationship to the Camera. Spectron Engineering designs specific fixtures and fixture combinations to hold the UUT in an optimal position for measurement. Accurate and repeatable fixturing is essential to efficient testing of display devices.



SE1420 DASH Display Measurement
Shown with Holding Fixtures to Test all HUD and Direct View F-15 Displays

Under normal conditions, a controlling computer supplied by the user will be used to develop and control all tests. It should be configured to send commands to both the SE1420 DASH and to the UUT. A user defined request for data will be sent to the SE1420 DASH Controller and the SE1420

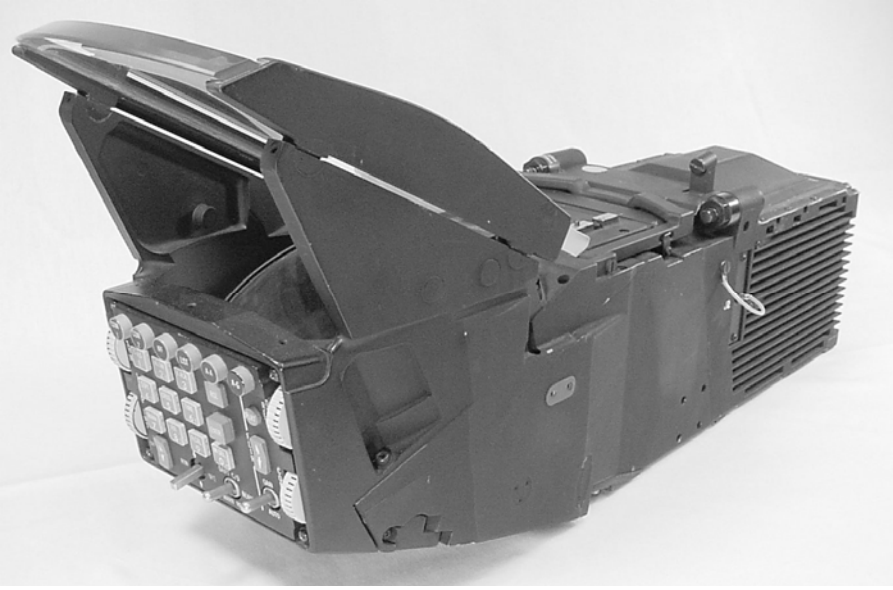
DASH system will return the results of the defined request to the controlling computer.

To perform the test, the SE1420 Controller will typically define the physical position of the Camera, the type of measurement to be performed, collect the data generated, and send the data back to the controlling computer for storage or analysis..

Head-Up Display (HUD)

The SE1420 DASH is designed specifically for applications requiring precise visual display measurements. Unlike some systems, the Spectron system is capable of measuring either flat or holographic images.

HUDs may be designed as holographic (three-dimensional) or flat (two-dimensional) displays, depending on the combiner plate and optics used. Holographic HUDs and other infinity-focus displays cannot be accurately measured with simple x-y test systems, as discussed in more detail below. Most military HUDs utilize a flat combiner plate.



Typical HUD

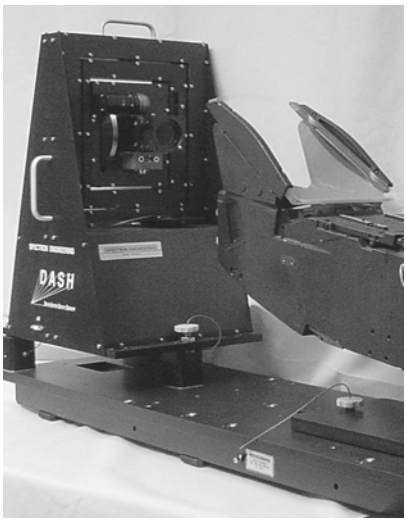
A HUD will project important aircraft instrument data and external simulation data into the field of view of the pilot at a focal point simulating infinity. This allows the pilot to look at the HUD image without changing the focus of his/her eye.

The SE1420 DASH, a particular adaptation of Spectron Engineering's general optical measurement system, measures from the normal pilot eye position in order to test and characterize all image parameters and to test the reliability or integrity of the HUD.

Testing Configurations

The HUD display image originates from a CRT in the cockpit of the aircraft. The CRT image is then collimated with a focusing lens or mirror and projected onto a glass combiner plate. Three optical components, the CRT, collimator lens, and combiner plate, are all part of the HUD unit, as shown above. Because problems can occur with any of these optical components, the SE1420 DASH can help isolate a problem using either one of two high-speed, automated testing configurations:

1) by simulating the eyes of the pilot to test the integrity of the projection image on the combiner plate, or by
2) testing the CRT output image directly.

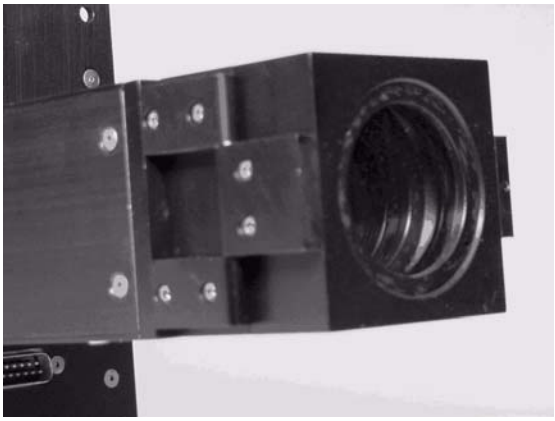


SE1420 DASH Measures HUD from pilot's eye position

The picture directly above illustrates the first test configuration showing how the SE1420 DASH Transport and Camera modules view and measure the projected display image on a combiner plate of a HUD. This is identical to the view a pilot would have in the aircraft. The Camera provides real-time viewing of the image and is capable of automatic and precise movement to look at, measure and characterize all areas of the display image. Focus is automatic.

A HUD display must remain readable to the pilot through a variety of lighting conditions outside of the aircraft; thus, a typical HUD has a luminosity capability ranging from 50 to 12,000 ft.-lamberts. This luminance may be automatically measured by the SE1420 DASH as it gathers other characteristics of the display image.

A second testing configuration involves direct measurement and characterization of a CRT image. This is accomplished with the SE1420 DASH by using appropriate fixturing and placing a CRT unit in place of the HUD. Typically, the Camera Lens configuration is easily changed to measure and characterize direct view displays.



Two lens capability allows easy transition
from HUD to Direct View (CRT) Measurements

About Display Sources

HUDs and direct view displays designed for cockpit use utilize a class of nearly monochromatic high-brightness CRTs, developed specifically for cockpit applications. The light output is high intensity and filtered. Typically these are green phosphor CRTs with a narrow spectral range, peaking at 548 nanometers with only an 18nm bandwidth. The limited range allows the use of sophisticated contrast enhancement filters to handle the various back-light and ambient conditions in an aircraft.

The HUD display may be from either a stroke or raster-type source; the stroke source produces a more intense, higher resolution line than the television-like raster type image. The SE1420 DASH can test either type of source.

Display Testing

Prior to Spectron developed inspection systems, single-point, or x-y, detectors were typically used to measure a HUD image. As the name suggests, that type of detector looks at only one point on the display at a time; thus, some display faults may be missed. These include flickering and slowly moving or out of focus lines. The SE1420 DASH provides the advantage of real-time testing over the entire display image.

The SE1420 DASH also has the capability for high accuracy when testing a display, but in some applications the equipment is restrained because it is testing a visual display across a very narrow wavelength band. For instance, the lines on a CRT output could be oscillating (waving back and forth). The human eye would only detect this type of oscillation when it occurs with a frequency less than one-tenth of a second. The SE 1420 DASH can be programmed to detect visual display problems that will or will not affect the human eye. It utilizes a selectable acquisition time to measure absolute intensity and resolution; that is, the system can increase the integration time in low light to provide a strong signal or decrease the integration time to detect transient conditions.

The combination of a high-quality Camera with precision motion, auto-focus, and a filtering system to handle the wide range of brightness makes the SE1420 DASH unique and powerful. In brief, the system may be considered the equivalent of 100 high-quality cameras looking at the display and measuring brightness levels from 0.2 to 12,000 ft.-lamberts.

What the System Actually Measures

The SE1420 DASH can perform a variety of tests in each configuration, measuring:

- line width and resolution
- line center
- line sharpness (Modulation Transfer Factor—MTF)
- peak brightness
- area brightness
- parallax

These tests are described in more detail below.

Line Width

The Camera can measure line widths from a maximum of ~1.2 degrees to a minimum of ~0.05 degrees. This is limited on the high side by the field of view and on the low side by the pixel pitch of the detector. Lines smaller than 0.05 degrees can be measured, at reduced accuracy, down to the absolute limit of ~0.015 degrees.

The Line Width can be calculated using a single row of pixels across the line or an average of 16 or 64 lines of pixels. Averaging has the advantage of increasing the accuracy of the measurement but can be

misleading if the line is not perpendicular to the detector axes. (See, *Manual, SE1420 DASH Spectron Control Language Commands,* ***LINE*** *Command*, for details.)

Line Center

Line Center measurement is a composite measurement in the SE1420 DASH system. The position of a line in the Camera field of view is mathematically combined with the position of the Altitude and Azimuth transports to get the final angular position of the line. The Line Center can be calculated using a single row of pixels across the line or an average of 16 or 64 lines of pixels. Averaging has the advantage of increasing the accuracy of the measurement but can be misleading if the line is not perpendicular to the detector axes. (See, Manual, *SE 1420 DASH Spectron Control Language Commands,* ***LINE*** *Command,* for details).

Line Sharpness (Modulation Transfer Factor—MTF)

The MTF of a displayed line is based on luminance and is calculated from the formula 100 * (Max-Min)/(Max+Min).

Peak Brightness

The Peak Brightness is a measurement of the luminance intensity of a line. The brightest point in the cross section profile of the line is reported using all of the luminance correction factors. The Peak Brightness can be calculated using a single row of pixels across the line or an average of 16 or 64 lines of pixels. Averaging has the advantage of increasing the accuracy of the measurement but can be misleading if the line is not perpendicular to the detector axes. (See Manual, *SE 1420* DASH *Spectron Control Language Commands,* ***LINE*** *Command* for details).

Area Brightness

The Area Brightness may be a more accurate measurement of display luminance than Peak Brightness because phosphor granularity and other variations can be averaged. However the entire area being sampled must be illuminated for effective measurement. The size of the area being sampled is user selected. (See Manual, *SE 1420 Spectron Control Language Commands,* ***AREA*** *Command* for details).

Parallax

Parallax is a measurement of the angular shift in the position of a line when the viewers eye position is moved laterally. Parallax is an indication of the apparent distance to the image. An image at an infinite distance will exhibit zero parallax. A parallax measurement with the SE1420 DASH is performed by an internal sequence of measurements: a Line Center, a shift in X or Y position, another Line Center and a return to the original X or Y position.

Resolution

This SE1420 DASH provides high quality resolution as it over-samples all areas of the image. It is not possible to take a good quality digital camera, look at a good-quality display, and see the defects in the display without limiting that analysis by the defects that may be present in the camera. The SE1420 DASH Camera combines a high-quality, 100 percent tested and calibrated, photo-diode matrix array with precise angular motion and auto-focus.

Application of System Measurements to Large Scale Testing

Large scale testing with the SE1420 DASH is typically accomplished by an automated and objective procedure that is constructed by combining a series of precision measurements. All of the data returned by the SE1420 DASH is written to a data file in the controlling computer where it may be accessed and used to confirm the display image characteristics. For example, if a line position or line width does not appear correct, upon checking the data it may be discovered that the peak brightness was zero at a particular position. That would indicate that there was no real line in view at that position.

Specifications

For specifications, refer to *Appendix A*.

Chapter Two

INITIAL SETUP and CONNECTIONS

SE1420 DASH DISPLAY MEASUREMENT SYSTEM

The SE1420 DASH is composed of three main modules (Transport, Camera, Controller), and associated cabling. In addition, the Transport module will usually be mounted on an Optical Breadboard, see Ancillary Equipment below. The theory behind the function of each module was discussed in *Chapter One, Overview*. Below we describe how each module is set up and connected for normal operation.

The following Main Modules and associated cables should be located and accounted for. The setup and connection of the Optional Ancillary Equipment is beyond the scope of this manual, however the more common items are listed here as an aid for those users who have purchased one or more of the common options.

System Components

Table 2-1

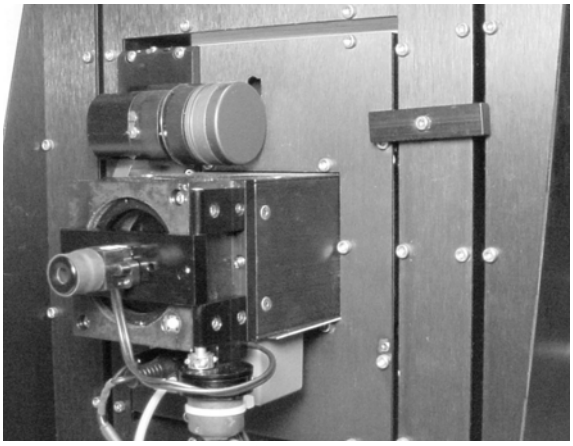
Main Modules	*Part Number*
Controller	1420-HC-IS-xx
Transport	1420-HC-XP-xx
Camera	1420-HC-CM-xx
Associated Cables	*Part Number*
Control cable	OMS-W01
Accessory Cable	OMS-Wxx
Power Cord	WAC4

Optional Ancillary Equipment	*Part Number*
Optical Breadboard	1420-OMS-OBB-xx
Light Shroud	1420-OMS-LS-xx
HUD/CRT Holding Fixtures	varies
HUD/CRT Alignment Tools	varies
HUD Simulator	varies
Luminance Transfer Standard	varies
Ambient Light Source	varies
Stroke/Raster Video Generator	varies
Viewfinder (IFOV, WFOV) Cameras	varies
Joystick Controller/Video Monitor	varies

Setup Procedures

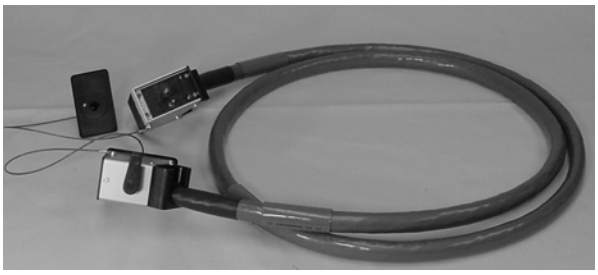
Carefully remove the SE1420 DASH components from their shipping cartons and begin the setup procedures described below. The Transport is shipped with the Camera mounted in position on the Transport, and the two ribbon cables connecting the Camera to the Transport are shipped connected.

IMPORTANT: The shipping lock on the Transport unit is located on the front side of the Transport to the right and below the Camera must remain locked until the unit is securely mounted on the Optical Breadboard or Test Bench and ready for operation.



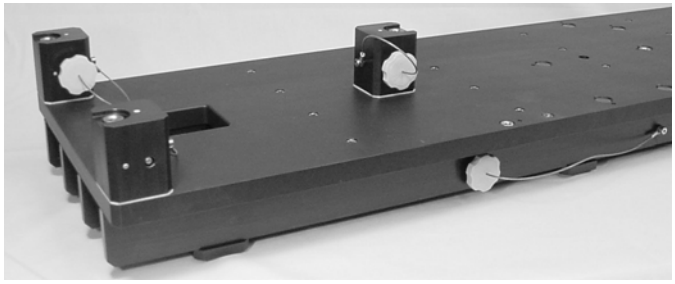
Shipping Lock - Closed Position
Camera shown with optional Viewfinder Camera

The Control Cable will later be used to connect the Controller and the Transport, and the Power cord will connect from the Controller to an electrical outlet. See *Connections*, below.



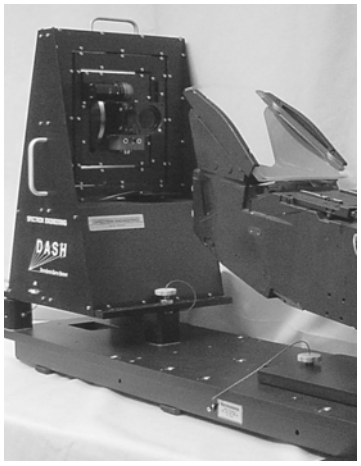
DASH 100 Pin Control Cable

If the Optical Breadboard has been supplied, secure it in its operational position. Typically, it will be bolted to a mobile test cart or to the top of a test bench.



Optical Breadboard showing Transport Mount Points

Mount and secure the Transport/Camera unit on the Optical Breadboard or test bench. If the Optical Breadboard has been supplied, there will be three clamping bolts provided to secure the Transport/Camera unit to the Optical Breadboard.



SE1420 DASH Transport Mounted on Optical Breadboard

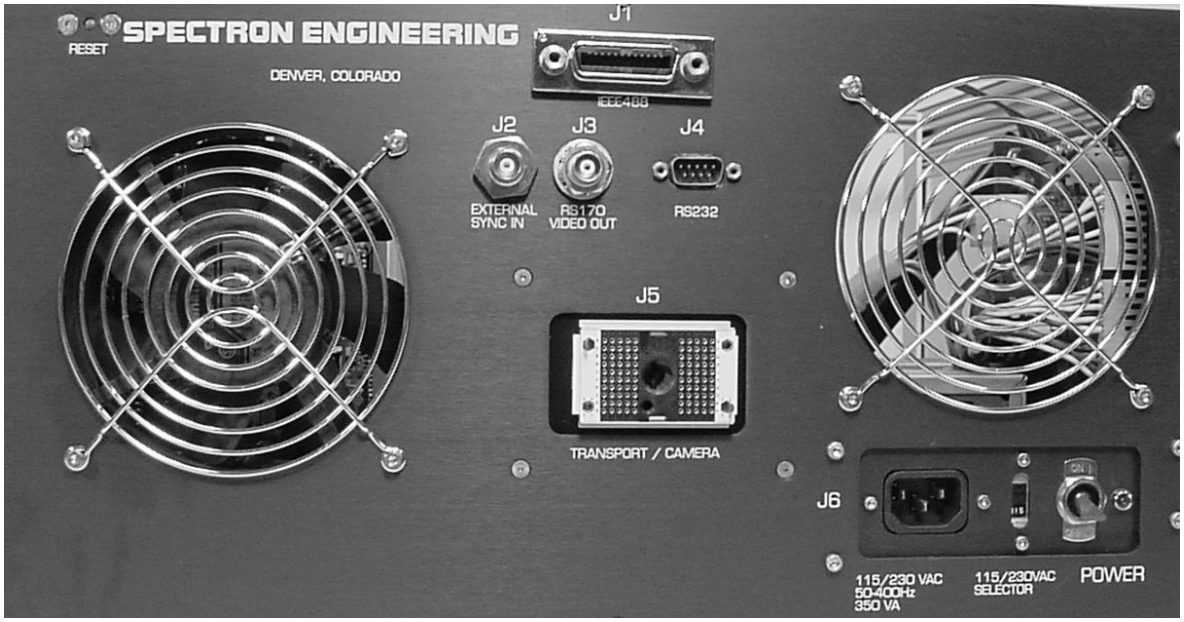
Locate the Controller and position it in a secure position near the Transport/Camera unit. If the Controller is designed to rack mounted either in a mobile test cart or as part of the optical test bench, secure it in its proper operating location near the Transport/Camera unit.

SE1420 DASH Controller - Rack Mount

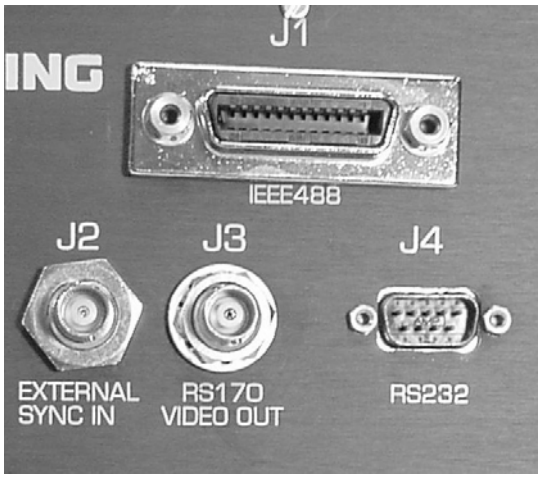
Connections

CONTROLLER

The SE1420 DASH Controller is a micro processor based dedicated controller that may be rack mounted or stand alone. It is normally set in a mobile test cart or an optical test bench convenient to the Transport/Camera modules.



SE1420 Controller - Back Panel



Interface Connectors on SE1420 Controller Back Panel

The Controller includes several interfaces that are not required for automatic testing, but in some cases may make testing easier and allow manual interactive testing. These interfaces are:

- *IEEE488 or GPIB interface (J1 on back panel)*

  This interface connector is located on the back panel of the Controller. This enables the controlling computer to communicate with the SE1420 DASH using Spectron Control Language Commands (Manual, *SE1420 DASH Spectron Control Language Commands*).

- *RS232 Serial Interface (J4 on back panel)*

  This interface, located on the back panel of the Controller, allows two-way serial communication between the SE1420 DASH and a dumb terminal or other RS232 device. This serial interface is also used for factory calibration and checkout.

- *RS170 CRT Output (J3 on back panel)*

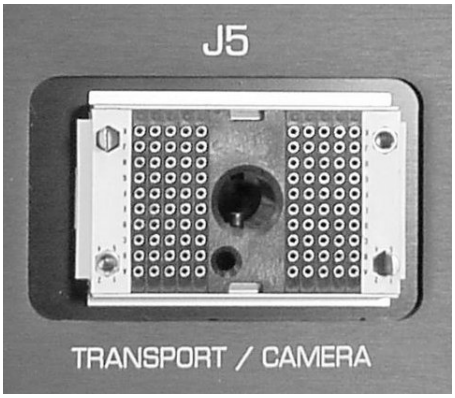
  This connection is a video output used to display test results and command menus on an external monitor.

- *External Sync Input (J2 on back panel)*

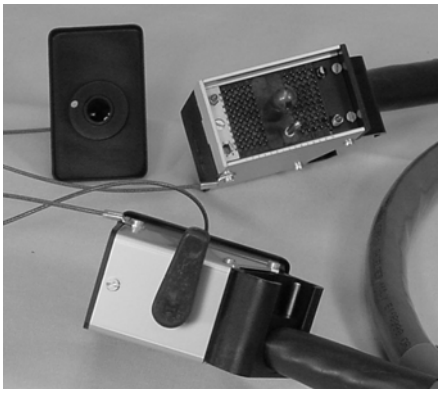
  This interface allows the operator to toggle between external and internal sync. This sync input can be synchronize with a vertical sync pulse from the display system that is undergoing test. Using this external sync function should improve the performance and consistency of analysis functions of external displays.

> ***Note***
>
> The system can function without an external sync, but the system will not work at all if there is no external sync present and the system is in the external sync mode.

Cables to operate the above circuits are not supplied with the SE1420 DASH. Cabling is supplied for the J5 and J6 ports. J5 connects the Controller to the Transport, and J6 is the power cord connection. The back panel of the Controller is shown above.



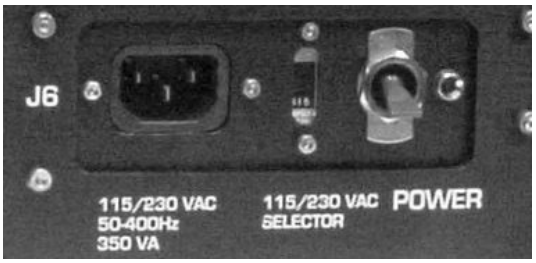
100 Pin J5 Connection - SE1420 Controller



100 Pin Connector - DASH Control Cable

Connect the DASH 100 Pin Control Cable from the Controller (J5) to the back of the Transport. The 100 pin connector is a zero insertion force connection that is keyed to allow insertion only in the proper manner. The cable is symmetrical and either end may be connected to the Controller or Transport.

During operation, the connector must be locked in place with the connector Locking Handle on both the Controller and Transport. Whenever the DASH 100 Pin Control Cable is disconnected, install the tethered protective cover immediately to prevent accidental damage to the connector pins.



Power Section - SE1420 Controller Back Panel

Determine that the power switch/circuit breaker on the back of the Controller is in the OFF (down) position and that the 115/230 VAC selector switch is in the correct position for the power source to be used. Connect the Power cord to the back of the controller (J6) and plug into the power outlet.

The system is powered up by turning on the power switch/circuit breaker on the back of the Controller and operated according to the procedures in *Chapter 3, Operations* of this manual.

Transport

Transport Mechanism

The Transport, illustrated below with the Camera installed, controls the positioning and movement of the Camera in response to commands from the Controller. Installation of the Camera, if necessary, is described in this section below under *Camera.*.

SE1420 Transport with SE1420 Camera

Camera

Camera Assembly

The Camera is shipped installed on the Transport from the factory and is electrically connected to the Transport through two DB25 connectors on the bottom of the Camera (see above photo). **These connectors should never be disconnected in the field unless it becomes necessary to replace the Camera module with another.**

If it should become necessary to remove the Camera, follow these steps:

1. Disengage the screws that secure the DB25 connectors to the bottom of the Camera.
2. Carefully disengage the DB25 connectors from the Camera.
3. Remove the 4 #10-32 screws that connect the flange of the Camera to the rear of the Transport.
4. Carefully slide the Camera to the rear and out of the Transport mounting hole.

To replace a Camera module with another, make certain that the installed Camera is oriented so the Spectron label is on the side, near the top and that the two locating dowel pins are on the top and bottom. The dowel pins are used to line up the Camera with the Transport. Slowly insert the Camera module into the Transport, aligning the dowel pins and the internal connector, prior to securing the camera with the thumbscrews and reattaching the DB25 connectors.

RS232 Connection and Protocol

User supplied and initiated RS232 Communications with the SE1420 DASH system are described in *Chapter 3, Operations*. The following information is supplied as an aid in initiating proper communications through the RS232 port.

The RS232 connector is a DB9 male connector located on the Controller Back Panel (J4). Only five of the nine pins are used, according to the pin out specifications in table 2-1.

Table 2-1

1420 DASH	*Connection*	*Terminal Connection*
Pin 2	RD Receive Data	TRANSMIT
Pin 3	TD Transmit Data	RECEIVE

Pin 5	GND	Ground	GROUND
Pin 7	RTS	Request to Send	CLEAR TO SEND
Pin 8	CTS	Clear to Send	REQUEST TO SEND

Complete instructions for using the RS232 port are contained in *Chapter 3, Operations*.

The RS232 protocol follows an IBM 9-pin "DTE" standard, which is an ASCII system. The serial protocol for this system is:

- 1 start bit
- 1 stop bit
- 8 data bits
- 9600 baud
- Hardware Flow Control

Chapter Three

OPERATIONS

SE1420 DASH
DISPLAY MEASUREMENT SYSTEM

The SE1420 DASH system may be operated in one of three operating modes; 1) automatic mode, with command and data information controlled by user or Spectron Engineering, Inc. created software, 2) menu mode, with command and data information controlled by operator selections from the built in SE1420 DASH Main Menu software, or 3) command mode, with Spectron Control Language Commands directly entered by the operator. The menu mode is only available through the RS232 port as described below. Automatic testing and command mode are available through either the RS232 port or the IEEE488 bus on the Controller.

Whether the tests are performed automatically or manually, if the Controller does not contain the optional Front Panel monitor, it is suggested that an external video monitor be connected to the system through the RS170 connection on the Controller and positioned to allow command and test results to be viewed in real time by the operator. The optional Front Panel monitor or external monitor is the only way to know immediately if the system is working properly, and when used with a personal computer or dumb terminal, provides effective capability for interactive testing.

This chapter will primarily describe the operation and testing procedures for manual operation using the Main Menu system or Spectron Control Language Commands. Automatic testing may be accomplished by software that sends sequential Spectron Control Language Commands, and captures the resulting data as it is generated, according to specific test procedures for the display unit under test (UUT).

Preliminary Check – Before Power Up

Shipping Lock shown in open (normal operating) position

IMPORTANT: The shipping lock on the Transport unit is located on the front side of the Transport to the right and below the Camera. Place the shipping lock in the UNLOCK (vertical) position prior to beginning any power on operation.

At a minimum, the DASH 100 Pin Control Cable must be connected between the Controller and Transport unit, and the Power Cord must be connected to a common 115 volt AC outlet and to the back of the Controller, both as described in *Chapter 2, Initial Setup and Connections*.

Other connections, such as to the controlling computer or to optional ancillary equipment may be made prior to power on, but are beyond the scope of this manual and are not necessary for a successful built in test (BIT) to be completed during power up.

Initial Power Up

Built In Test (BIT)

The power switch/circuit breaker is located on the back panel of the Controller near the AC power cord connector. **After all Setup and Connect procedures described in *Chapter 2, Initial Setup and Connections* have been completed,** the power switch may be turned on This will initiate a system reset and the BIT will occur.

The BIT will be accomplished each time the system is turned on or reset. It tests the electronic circuitry and function of the Controller, Transport, and Main Camera. If all modules are

functioning properly, the items undergoing test will indicate 'pass' and the Main Menu will then be displayed on the external Video Monitor (if installed).

If there is a failure of a component being tested, 'fail' will be indicated in reverse video on that item. If able, the system will continue to function after the 'fail' indication and, in most instances, a short message and error number will be displayed on the Main Menu. The SE1420 DASH system cannot be considered to be operating normally unless the BIT is completed successfully from the beginning (see, *Chapter 4, Maintenance and Repair).*

Upon successful completion of the BIT, the Main Menu will be displayed on the external video monitor, if connected. In manual test mode, the system is menu driven and all of the available functions are listed on the Main Menu.

Warm Up Recommendation

In order to allow all components to reach a consistent operating temperature, the SE1420 DASH system should be turned on approximately 20 minutes prior to use. It is recommend that the operator take a new dark current reading after the initial warm up period by using option "D" on the Main Menu. To ensure continuous good data during normal operations, dark current readings should be taken periodically to compensate for ambient thermal variations.

On-Site Alignment

Azimuth axis, and the Main Camera Focus axis, to a factory calibrated and determined Zero point. If the operator desires to reference a different angular coordinate system, that may be accomplished through appropriate use of an optional Alignment Tool and the ALIGN Command After a successful Power Up, the SE1420 DASH System will move the Transport Altitude and. Either zero point may be offset with the ITR Command (see, Manual, *SE1420 DASH Spectron Control Language Commands*).

Automatic Testing

The SE1420 DASH system is capable of automatically testing a display by responding and replying to all Spectron Control Language Commands (see, Manual, *SE1420 DASH Spectron Control Language Commands*) via the IEEE488 bus or RS232 port. Automatic routines for testing specific displays are not included with the SE1420 DASH system, however, they may be created by the user of the system or separately contracted from Spectron on an optional basis.

Manual Testing

To perform a manual test, connect a dumb terminal (DT) or a personal computer (PC) to the RS232 port on the Controller. Alternatively, a properly configured PC or control console can communicate with the Controller through the IEEE488 bus connection. Use of the IEEE488 bus will effectively override and disable the Main Menu system and the RS232 port. The SE1420 DASH system includes a RS170 output on the Controller which can be attached to a video monitor or recorder. This section will describe the relationship of the video output to what is happening in the system as various test functions are performed.

RS232 Communications Using a Dumb Terminal or Personal Computer

All of the manual testing operations, described below, can be performed via the RS232 port using a dumb terminal (DT) or a dumb terminal emulator on a PC.

When learning to use the system with a DT or PC, it is important to use an external video monitor, and the DT or PC monitor, for comparison of responses. Any ASCII input of a valid character corresponding with one of the Menu functions described later in this chapter will cause the appropriate function to be implemented. Valid ASCII transmission characters are set forth below.

Further description of the RS232 port, wiring information, and protocols are provided in *Chapter 2, Initial Setup and Connections*.

Two-Way RS232 Communications

All transmissions between the SE1420 DASH system and a DT or PC are in ASCII code. Commands that are sent via the RS232 interface return data in their own distinct format. All

transmissions to the DT or PC must be followed by a Carriage Return and a Line Feed.

To begin RS232 communications, reset the system by turning on the power.

Characters Sent by the Dumb Terminal or Personal Computer

The following ASCII codes correspond to the output from the DT or PC keyboard input:

- Characters 0-8 correspond with ASCII characters $30-$38
- Characters A-F correspond with ASCII characters $41-$46

Menu Descriptions

When the SE1420 DASH System is initially powered up, or reset, the system Main Menu will be displayed on the external monitor. The Main Menu, as it appears on the monitor, is illustrated in figure 3-1; the menu functions are summarized in Table 3-1 and are described in detail on the pages that follow. Some test examples will be described.

It is important to note that the Altitude, Azimuth and Focus axis of movement will revert to the factory predetermined settings at power up, or whenever the system is reset Additionally, all Menu functions return to their default settings. Menu default settings, with toggled options, are listed in Table 3-2.

For numerical input and output, the SE1420 DASH system utilizes floating point numerics which provides greater flexibility and accuracy, however, the operator must enter the decimal point whenever one is required. The system allows up to five digits plus a decimal point.

Figure 3-1

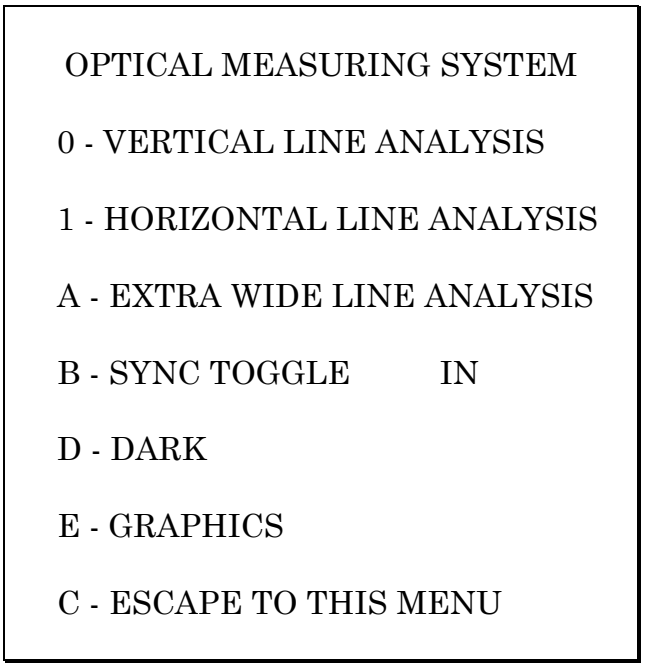


Table 3-1

Summary of Menu Selections and Defaults

Key Name	***Function Description***
Setup Commands:	
C. Escape	Return to Main Menu
E. Graphic Output	Gray scale setting
D. Take Dark	Dark current measurement
B. Sync	Toggle between internal and external synchronization
Data Commands:	
0. Vert Line	Vertical line measurement
1. Horiz Line	Horizontal line measurement
A. EXWIDE	Toggle between narrow, wide or extra wide-line profile analysis

Note
To perform a Hardware Reset, power down the system, then re-start it or Press the recessed Red RESET Button on the Controller Front Panel.

Main Menu Function Descriptions

This section describes in detail how to use each menu function. Menu functions fall into two categories: 1) those used for setting up the system (A-E), and 2) those that return data (0-1).

C. Escape **Return to Main Menu**

Pressing the *C* key at any time will return to the Main Menu, retaining all other system configurations. There may be a delay while the system finishes a current process before returning to the screen

E. Graphic Output **Gray scale setting**

Press the *E* key to display a pictorial representation of the light image being viewed by the Main Camera and displayed on the external monitor. This display will be 96 horizontal by 96 vertical pixels, representing the individual diodes in the matrix array. The operator defines the threshold for the four different gray scales available in an update procedure. Each gray scale range will be 25 percent of the total range, which is determined by the difference between the minimum dark and the maximum light values.

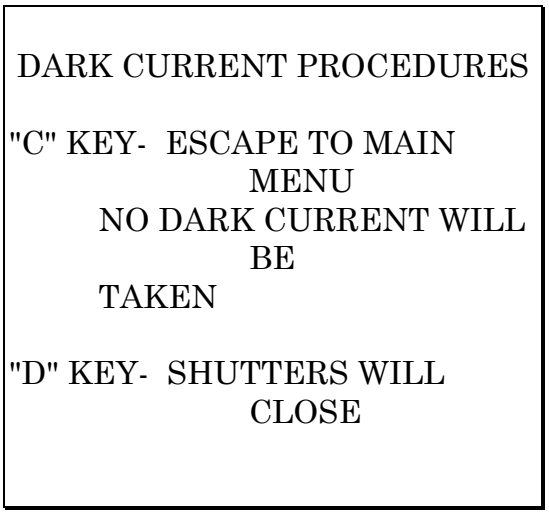
In order to do another update of the gray scale level, press the *E* key again.

D. Take Dark **Dark current measurement**

This function is used to define a baseline current present with the shutters completely

closed. The function subtracts the current flowing through the diode when there is no light present.

The SE1420 DASH system has been set up to implement one dark reading for all functions. This automatic procedure is designed to save time-intensive manual shuttering and mathematical compensation. When the *D* key is pressed, the Dark Current Procedures menu appears on the external video monitor:



D Option — The "D" option is normally used on this menu. If this portion of the Main Menu is called up in error, use the "C" option below and no DARK reading will be taken.

C Option — The "C" option returns to the Main Menu without further operations.

Line Profile Analysis

Table 3-2

Menu Selection	***Default Settings***	***Toggled Settings***
A	EXTRA WIDE line profile	NARROW & WIDE line profile
B	SYNC Internal	SYNC External

Line Profile Analysis

Options A & B of the Main Menu define the parameters of the line being analyzed. Data is received using 0 & 1. The functions are summarized below:

Key	***Function***
B.	Internal or external sync
A.	Narrow, Wide or Extra Wide Line Profile
0, 1.	Vertical and Horizontal line measurements

B. Sync — Toggle Between Internal and External Synchronization

> ***Note***
>
> The system can function without an external sync, but the system will not work at all if there is no external sync present and the system is toggled to the external mode.

A. EXWIDE **Toggle Between Narrow, Wide and Extra Wide Line Profile Analysis**

This function defines whether the line profile analysis, as requested in options 0 or 1 will be narrow, wide or extra wide. The narrow option analyzes both horizontal and vertical lines one single pixel wide and establishes a line profile with this raw data. The wide selection averages over a line 16 pixels wide to establish the line profile, and the extra wide selection provides a 64 pixel line analysis.

0. Vert Line **Vertical line measurement**
1. Horiz Line **Horizontal line measurement**

These two keys analyze the peak brightness, line width, and line center and control the output of corrected line data. Press 0 to measure vertical lines, or press 1 to measure horizontal lines.

COMMAND MODE - RS232 Operations

Press the colon (:) key when using RS232 communications to place the SE1420 DASH system into Command Mode. The following screen will appear on the external monitor:

SPECTRON COMMAND LANGUAGE	
LINE H/V 01/16/64	- LC LW PB
AREA 16/32/64	- LUM
MTF HV 1/16/64	- MTF
POS AZ ALT	- AZ ALT
FOCUS POS/AUTO	- POS

The above screen information is presented as a guide to some of the more commonly used Spectron Control Language commands. IT IS IMPORTANT TO NOTE that when the above screen is in view, only VALID Spectron Command Language Commands, as detailed in Manual, *SE1420 DASH Spectron Control Language Commands,* will be effective. Any other entry, with two exceptions, the "ESC" and "ARROW" keys noted immediately below, will cause the SE1420 DASH system to revert to the Menu Mode.

When a VALID command is entered from the keyboard during RS232 operations, the command will execute. If the command returns data as indicated in Manual, *SE1420 DASH Spectron Control Language Commands,* the data will appear on the DT or PC. The external monitor will display the Main Menu. To enter another command, press ":" and repeat as above described.

COMMAND MODE - IEEE488 Operations

IEEE488 (GPIB) operations are commenced by properly connecting a PC to the Controller and sending any character to the Controller using the GPIB interface software on the PC. Once this has been done, GPIB Mode will be displayed in the lower right corner of the external monitor. Once in GPIB Mode, Main Menu and RS232 Command

functions are disabled and the SE1420 DASH system functions as a "slave" to the GPIB card in the PC until such time as GPIB control is relinquished.

The exact method of controlling SE1420 DASH system operations will vary according to the GPIB interface being used, however, VALID Spectron Control Language commands as described in Manual, *SE1420 DASH Spectron Control Language Commands*, must be sent as string data to the Controller by the GPIB interface software. If a command returns data, the GPIB interface software must capture and display that data for proper interactive operation.

Only those commands that specifically output a display to the external monitor (i.e. GRA, GUP) will be shown on those devices. Other returned data will be fleeting or not shown on the monitors and must be captured and displayed on the PC to be effective.

Chapter Four

MAINTENANCE and REPAIR

SE1420 DASH
DISPLAY MEASUREMENT SYSTEM

The SE1420 DASH is designed to make maintenance and repair as simple as possible. Each time the system is turned on or reset, it performs a self-diagnostic test called a BIT (Built In Test) that checks the electronic circuitry and connections in the Controller, Transport and Camera modules.

The BIT is designed in a tree structure, which means it tests many elements in sequence rather than in isolation. Therefore, it cannot be assumed that the system will work properly after correcting a problem unless another BIT is performed. This is because all circuits and functions may not be tested unless the BIT is completed successfully from the beginning.

Maintenance

No routine maintenance procedures by the operator are required for the SE1420 DASH system between recommended factory calibration service. This includes lubrication of the moving parts of the SE1420 DASH system.

It is recommended that factory calibration be performed every 12 months or 2,000 operating hours, whichever occurs first.

In addition to operating the unit within the specified environmental parameters found in *Appendix A*, the unit should be kept as dust free as possible. The Camera and Viewfinder camera (if installed) lenses may be cleaned using common lens cleaning fluid and tissues suitable for use with coated lenses.

Repair

No repair of the SE1420 DASH system is permitted the user of the system. User initiated repairs will void the factory warranty and invalidate the factory calibration. **In no event should the user attempt to remove factory installed covers and access the internal parts of any SE1420 DASH system Module.** Should it appear that repairs are required, contact Spectron Engineering, Inc. as specified below.

Troubleshooting

If any of the modules fail the BIT, follow these troubleshooting steps **after power is turned off:**

1. Check to ensure that all cables are properly seated and connected. The most common reason for BIT failure is the improper connection of the SE1420 DASH system cables.

2. Turn the power on and carefully monitor the BIT progress on a Video Monitor. Note the exact "fail" mode and contact Spectron Engineering, Inc., as specified below, with that information for further instruction and safe troubleshooting steps for the error condition encountered.

Replaceable Modules

In the SE1420 DASH system, a module is defined as a minimum replaceable component. There are three main modules, two external cables and a power cord that can be replaced. The replaceable components are listed below:

- Transport (PN: 1420-HC-XP-xx)
- Camera (PN: 1420-HC-CM-xx)
- Controller (PN: 1420-HC-IS-xx)
- Control Cable (PN:OMS-W01)
- Accessory Cable (PN:OMS - Wxx)
- Power Cord (PN:WAC4)

Factory Contact

If the user of the SE1420 DASH system encounters problems that cannot be solved by the above procedures, or if any other problems exist, contact Spectron Engineering, Inc. in Colorado at (303) 733-1060, fax (303) 733-2432 or e-mail (se1420support@spectronengineering.com).

APPENDIX A

SPECIFICATIONS

SE1420 DASH
Display Measurement System

RECOMMENDED DASH TEST SPECIFICATIONS
FOR MULTI-FIELD CAPABILITY

Performance Characteristic	Apparent Features from Observer Viewpoint *	Feature as Percentage of 0.50 Radian Reference Field **
Line Center Accuracy: (includes xport position, optical,& analytic errors)	± 0.1 milliradians	± 0.02% field
Symbol Width:		
Range:	0.8 to 2.0 milliradians	0.16 to 0.4% field
Accuracy:	± 0.1 milliradians	± 0.02% field
Parallax Accuracy:	± 0.1 milliradians/ 2.5" displacement	Not Applicable
MTF Resolution:		
Peak to peak modulation:	5% to 95%	5% to 95%
Frequency range:	200 to 2000 TV lines/radian	100 to 1000 TV lines/field
Accuracy	± 5% ***	± 5% ***
Repeatability:	± 1% of full range	± 1% of full range

Luminance:

Peak Brightness:	>12,000 foot Lamberts
Minimum Brightness:	<1 foot Lambert
Accuracy:	± 4% of reading ± 0.5 *fL*
Repeatability:	± 4% of reading ± 0.5 *fL*
Calibration Stability:	<± 1% per year

Note: For Head-Up Display, holographic, or similar systems generating a virtual image for viewing, the angular (apparent feature) specifications should be used directly since the
approximately infinite optical image distance makes conversion to linear dimensions irrelevant and impossible.

NOTES:

*"Apparent Features from Observer Viewpoint" is the angular dimension of features subtended by symbol elements when viewed from the standard viewer eye position.

** Analysis is performed at viewing point where screen width or height has 0.50 radian apparent size. This is the 0.50 radian reference field. Special screen sizes may not fill the field provided for a particular optical configuration.

*** The accuracy specified is maintained only with expected MTF frequency input.

APPENDIX B

THEORY OF OPERATION

SE1420 DASH
Display Measurement System

TRANSPORT MODULE

The Transport module contains precision altitude and azimuth bearing mechanisms and, as such, functions as an automated theodolite. Mechanically, it also contains the automated drive motors , the precision position encoders, and a captive shipping lock mechanism to preclude damage during shipping or on-site relocation. The status of this manual lock can be verified by computer and is tested during the Built In Test (BIT) to verify that the Transport is ready to operate.

Each transport axis uses a pair of motors provided with safety slip clutches that operate in an active anti backlash mode and signals from the Controller to the Main Camera unit are physically fed through the Transport to minimize cable stress during operation.

Nonvolatile EEPROMS in the Transport contain calibration data, including a unique unit code which allows the Controller to identify the specific Transport should future upgrades pose a compatibility problem. This data is downloaded to the Controller on power up, and sufficient loop back hardware exists to allow the Controller to verify all Transport and Main Camera cable connections.

The precision encoders in the Transport are a redundant combination of optical and electro-mechanical encoders, and the agreement between the two types of encoder systems is checked for each axis during power up. The accuracy of these encoders is enhanced, and any mechanism induced errors in the Transport corrected, by using the Transport calibration data collected specifically for each unit at the Spectron factory and stored in the Transport EEPROMS. The dedicated factory calibration system includes:

1. An array of light source targets whose positions have been measured with a theodolite.
2. An extreme precision, 1/10 sec arc resolution rotary encoder.
3. An 8" square glass scale target calibrated with a traveling microscope.
4. An array of collimators whose angular orientation has been measured with a theodolite.

Several thousand test points are measured under the control of factory automated test programs and are used to generate the calibration parameters loaded into the Transport. This procedure serves as a burn in and verifies that the encoder systems produce consistent and repeatable data.

MAIN CAMERA MODULE

The Main Camera unit contains the photodiode detector array and the optics. It also contains a focus transport, motor and encoder. These are used, along with a zonal shutter, to optimize the
focus for direct view and HUD systems. A sensor is provided to verify that the HUD or direct view lens configuration has been correctly set.

Calibration data is stored in an EEPROM and is downloaded to the Controller during power up. Configuration data is included in case later upgrades introduce compatibility limitations. The calibration data is generated from several hundred tests at the Spectron facility to completely characterize each of the optical elements. This includes the detector, the Neutral Density (ND) filters, the color filters, the photopic filter, the focus assembly, and the objective and direct view lenses.

The filters are mounted in two stepper motor driven wheels. A home sensor is provided to establish the reference filter position , and the start up procedure verifies that these locations are found, and that the stepper drive returns to these positions in the proper number of steps.

The shutters, as noted above, provide zonal masking for focus verification as well as light exclusion for dark current monitoring. The system has the ability to measure light signals which are a very small fraction of the dark current - if the dark current is stable. A detector temperature change of less than 1/20 of a degree Centigrade can cause significant error under these conditions. A thermoelectric module is provided to stabilize the detector temperature - heating or cooling as needed to hold a detector temperature near 25°C. This point was selected as a compromise between sensitivity (dark current) and condensation effects, and to assure operation at 50°C to 65°C heat sink temperature.

At high ambient temperature, the cool down to thermal stabilization takes several minutes. The thermoelectric element also causes secondary thermal effects, cooling structures near the detector, and markedly heating those near the heat sink. These secondary processes have longer time constraints and quite a few minutes are needed for maximum stability to be reached under these conditions. These effects - and stabilization delays - are much reduced operating near 25°C. Moreover, the impact of incomplete stabilization is small unless very low light levels are being measured. Thus the internal initialization procedures provide enough delay for the alignment operation to be executed, for example, or other bright pattern tests. Photometric brightness measurement below 1 foot Lambert - on the other hand - should be done only after complete stabilization and, even then, directly preceded by a dark set operation to minimize the effect of residual thermal drift.

The Main Camera also contains an interval optical stimulus. This LED source is used to stimulate the detector during the BIT to verify that the detector and associated electronics respond properly to light.

The Main Camera detector is a zero defect photodiode array. Minor pixel variations are compared in the calibration and dark set data so that each photodiode pixel can be regarded as a calibrated photometer. The semiconductor structure involved tolerates local light overload with little effect on adjacent pixels, is very linear in photometric response, properly integrates the quantum flux in a submicrosecond flash, and continues this integration for many seconds if needed for sensitivity. This allows the electronic integration gain settings to be used with only minor increase in statistical noise.

It is important to understand that when measuring a temporally variant light source - of which the CRT is a fairly extreme example - synchronization of the integration gating and the display refresh is mandatory. The optical quantum flux must be integrated for an exact integral number of refresh cycles. The phase relationship of the synchronization signal is not important as long as it is stable. Unstable or nonexistent synchronization can easily cause photometric errors of 50%.

The synchronization timing must also be stable far beyond the limits of the image sample. The same integration period is used to capture the dark current data, and to establish the rate correction factor. Variation in the external synchronization period as seen by the 1420 DASH internal monitor will be flagged as an " unstable sync " error code.

CONTROLLER MODULE

The Controller contains an analog section and a digital section. The analog section contains 3 motor drive circuit boards and the power amplifiers which drive the Transport and Main Camera motors. In addition, the analog section contains a the regulator board which contains a bank of linear regulators to provide the diverse voltages needed by the various electronic electro-mechanical and electro-optic components. Several of these voltages are locally re-regulated for the highest precision

The power amplifiers contain multiple monitoring and feedback circuits. Motor loading, velocity and acceleration can be monitored, and acceleration and deceleration moves controlled to minimize mechanical hysteresis. The failure of the motors to respond to control input (indicating a jam), or sustained clutch slippage (indicating external interference), activate a Transport power shut down. After clearing the jam or interference, the shut down condition is cleared by a power off - power on reboot of the 1420 Dash System.

Only part of the total position sensing capability, the position control circuitry, is integrated into the motor drive cards. Corrections for this portion of the position encoding circuitry is presently distributed between the CPU firmware and on board circuitry.

The digital section contains 6 circuit boards: 1) CPU board, 2) communication board, 3) video board, 4) horizontal trace board, 5) GIX board, and 6) matrix board.

The CPU card contains system firmware, the details of which, along with the details of the electro-optic and electro-mechanical operations, are proprietary. The following paragraphs will cover only those elements of the system which are common practice in the industry.

PROM circuitry on the CPU card retains the system firmware in the Controller. The CPU RAM memory is used for temporary storage. For example, the Main Camera and Transport correction factors are read into CPU RAM during power up and are combined with the Controller corrections to create the final correction factors used during operation of the 1420 DASH system.

The communication board provides a RS232 and a IEEE488 communications interface to the Controller. The RS232 input provides a valuable second input for diagnostics analysis and debug operations, but otherwise is not characteristically used in most systems.

The video card and the horizontal trace card work together to provide a direct display of analytic results and intermediates which are output RS170. These display elements require a minimum of software support and have little effect on test time. The RS170 results can be easily video taped and analyzed in slow motion to understand why unexpected results are being generated by the automatic program.

The matrix board functions as the Main Camera controller. It generates all the timing signals required to operate the image sensor. It also contains a flash A/D convertor and frame grab memory to capture and analyze the image. Additional memory space is used to capture a dark image or dark current pattern for each of the sensor pixels under the present conditions. These dark corrections, along with other calibration data, are used to correct the low noise input so that each detector element can be treated as a calibrated photometer.

The GIX board contains the latches and data inputs necessary to communicate with the analog section and to monitor the external sync signal. It contains an additional A/D convertor which is multiplexed to monitor the various motor drive diagnostic signals, power supply voltages, and other internal signals.

ALIGNMENT TOOLS

Each of the alignment tools contain two independent calibrated light sources containing a temperature compensated green LED to resemble monochrome CRT displays. These sources are entirely adequate to verify the calibration of the 1420 DASH system, and this verification is performed as part of the " ALIGN " operation.

Each source is equipped with a cross line reticle in a precision adjustable mount. The align operation on either tool will examine the peak brightness, line width, and line position of the horizontal and vertical components of each cross, so that 12 pieces of data are obtained.

These 12 pieces of data are individually examined to verify photometric calibration, proper focus and a credible position before the align operation is allowed to proceed. If all these parameters fall within the expectation windows, then the position components will be used to correct for yaw, pitch and roll errors in the fixture setup.

A limited set of error codes will be generated to prompt corrective action if these tests fail. In most cases the operator action will be to inspect and reset the 1420 DASH fixture and alignment tool set up to correct excessive errors. The use of a second alignment tool can provide an additional diagnostic test. However the independent sources on each tool already provide substantial cross checking.