WSI Operations Manual

DAYLIGHT VISIBLE/NIR
WHOLE SKY IMAGER
(E/O CAMERA SYSTEM 7)

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WSI Operations Manual

Daylight Visible/NIR

WHOLE SKY IMAGER
(E/O Camera System 7)

(July 2000)

This operations manual summarizes the basic support and operational procedures required for the normal operation of the Whole Sky Imager. It is intended as an operational guide for the use of on-site host personnel in operating the WSI and in performing periodic inspection and assessment of the system’s performance.

This Whole Sky Imager was developed by the Atmospheric Group of the Marine Physical Laboratory at the University of California, San Diego. Individuals involved in the design include Janet Shields, Richard Johnson, Monette Karr, Jason Wertz, Justin Baker and Jerry Crum. The system was designed for the Meteorological Observatory Potsdam of the Deutsher Wetterdienst, in collaboration with Dr. Uwe Feister and Dr. Klaus Dehne. We appreciate the support of our sponsors and especially wish to recognize the work of Dr. Feister.

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Daylight Visible/ NIR  
WSI Operations Manual  

Whole Sky Imager  
(E/O Camera System 7)  

July 2000  

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1. Overview

This Operations Manual provides a brief overview of the new Daylight Visible/NIR Whole Sky Imager (WSI), EO System 7 Unit 1, and discusses operation of the instrument. The WSI provides high resolution digital images of the sky in up to 7 pre-selected wavebands through the visible and near infrared. The WSI acquires images of the upper hemisphere and records the resulting imagery with a 12 bit digital CCD camera. The CCD has a 1536x1024 resolution. The optical image is designed to use approximately a 980x980 region of the CCD. A sample image from the WSI is shown in Fig. 1-1. The instrument, with the environmental housing cover removed is shown in Fig. 1-2.

1.1 The Daylight Vis/NIR WSI

The WSI provides digital measurements of the absolute radiance distribution of the sky in each of the optical passbands. In each passband, a radiance distribution over approximately 750,000 directions (taken at 1/6 degree resolution) is determined simultaneously. In addition, the WSI provides an assessment of opaque cloud fraction and cloud position over the sky. It is capable of providing assessments of thin cloud fraction, given appropriate algorithm refinement.

The system is fully automated, and is normally controlled by a PC computer operating under the Windows NT environment. Software is provided for interactive and automated control of the instrument. Processing of the images for cloud fraction and radiance distribution is accomplished off-line with a processing program provided with the WSI.

1.2 Comparative WSI System Characteristics

The instrument is similar in concept to the Day WSI (E/O System 5) and the Day/Night WSI (E/O System 6) developed for other sponsors by our Atmospheric Optics Group at Marine Physical Lab. In comparison with these instruments, this is the first instrument with the higher (essentially 1024 x 1024) spatial resolution. The ability to acquire data beyond 850 nm in the NIR is also new. The instrument is designed for daylight use only, although initial tests indicate it is effective down to sunset and beyond. It has a less sophisticated environmental housing than the System 6 WSI, but like System 6, the housing includes both heating and cooling and is appropriate for a wide range of conditions.

In comparison with the earlier Day WSI, EO System 5, designed and fielded in the 80's, this system has far better optical resolution, due both to the higher chip resolution and the higher quality optical relay. The system also has much lower noise and higher dynamic range, due to advances in solid state sensors, enabling a change to a digital 12 bit CCD camera.
The System 5 Day WSI ran under DOS; the System 6 Day/Night WSI has both DOS and Windows 95 versions; and the new System 7 Daylight Visible/NIR WSI runs under WindowsNT. Several versions of WSI software exist, due to the differences in operating system, differences in sponsor requirements, and differences in the cameras. The current version of the System 7 WSI will have somewhat less sophisticated cloud algorithms initially, but it will have more sophisticated capability for measuring and extracting sky radiance.
Figure 1-1. Sky near sunset acquired through red filter with WSI System 7, 3 Nov. 99 00:15Z, San Diego.
Figure 1-2. WSI in its housing with the housing cover removed.
2. Hardware Overview

2.1 The Optical System

One of the primary challenges with development of multi-spectral WSI systems is the incompatibility between the image size produced by the lens and the size of the CCD chip, combined with the need to allow for the introduction of the 2-wheel filter changer somewhere in the optical path. Our System 6 Day/Night WSIs address these issues by using a tapered coherent fiber optic bundle which minifies the image and transfers the image location. With the System 7 WSI, we have returned to the optical relay concept used with the earlier System 5 Day WSIs. These 1980’s-era instruments used a 5 lens relay to minify the image and extend the back focal length to allow the inclusion of the filter changer. However, we felt that the image quality of the 5-lens relay was not adequate for our present application. A new optical relay was designed, which consists of 10 lenses including one custom lens. This relay has provided outstanding image quality in System 7.

In addition to the lens relay, the System 7 WSI uses a Sigma 8mm f4 fisheye lens as the primary lens. This lens has an approximately 180 degree field of view, so that it images the full upper hemisphere. The optical relay minifies and transfers the image to the CCD chip such that the complete circular image falls within the chip. A 2-wheel filter changer allows the user to place spectral or neutral density filters or polarizers in the light path. The optical relay is designed such that all rays enter the filters at an angle of incidence of less than 5 degrees, in order to minimize spectral shifting.

The image is acquired using a SenSys KAF 1600 12 bit digital low noise camera, with a Scientific Grade 1 1536 x 1024 pixel array. This camera is manufactured by Photometrics (now Roper Scientific). The readout noise is less than 1 count, such that the camera has a full 12 bit dynamic range. The chip is cooled to 10 degrees C. The round image is nearly centered on the array, and the automated WSI code acquires a 980 x 980 subset on the chip.

A photograph of the optical system is shown in Fig. 2-1. At the top of the system is the fisheye lens in its lens shroud. The upper part of the optical relay is below it, and the larger flat surface is part of the filter changer. This is followed by the lower part of the optical relay, and the camera. An optical stack drawing is shown in Fig. 2-2. This stack drawing shows the optics and camera, without the filter changer.

The optical filters selected by the sponsor are listed in Table 2.1. The automated control program, RunWSI, allows the user to select between the spectral options shown in Table 2.2.
2.2 The Equatorial Occultor

The solar occultor is an equatorially driven device that is designed to prevent direct solar illumination from falling upon the camera fisheye lens. This shadowing of the lens prevents undesirable stray light from entering the optical system and biasing the imagery collected by the camera. The equatorial occultor is shown in Fig. 2-3.

The occultor, or more accurately, attenuator, is designed to go to the sun’s position automatically during the 12 hours surrounding local apparent noon (LAN). The axis of the occultor is adjustable, and is set to the latitude of the site. Because it is an equatorial drive, it rotates about this axis, moving 15° per hour, and is directly overhead (90° occultor angle) at LAN. At LAN ±6 hours, the occultor angle is on 180. In the winter, this angle places the flag below the horizon, and in summer it is above the horizon at LAN ±6. If sunset occurs after LAN + 6, the occultor will remain in fixed position, but will still mostly block the sun. (It was designed to work from LAN −6 to LAN +6, but at the sponsor’s request, we have programmed it to run longer.) Following the end of the day, the occultor resets itself to the next morning’s start position.

There is no automatic adjustment to compensate for the systematic drift that naturally occurs in solar declination with the changes in the season. This necessary adjustment is accomplished manually by periodically replacing the occultor support arm. It is changed approximately every 2.5 weeks in spring and fall, and every 2.5 months in summer and winter. A schedule for changing the arm is given in Section 5.

The occultor flag is a 4 log neutral density filter. The sun position can normally be seen through this filter on a clear day, enabling checking of camera alignment to vertical and true north. The flag extends 14.9 degrees from the sun, and covers 4.3% of the $2\pi$ solid angle of the upper hemisphere.

2.3 Accessory Control Panel

The Accessory Control Panel (ACP) provides position readout and control for the filter changer and the solar occultor. It is designed to allow either computer or local control. In the computer mode, the filter changer and occultor are controlled by the computer software written by MPL; in the local mode, they are controlled by the operator using the switches on the front of the ACP. The ACP is shown in Fig. 2-4. The ACP provides position readouts both to the computer and to the front panel. The interior of the ACP is shown in Fig. 2-6. In this illustration, the top third of the housing holds the fisheye lens, upper lens table, and filter changer. The second third holds the lower lens tube and the camera. The lower third allows room for the cable pigtails which convert from standard connectors to environmental connectors.

The “Local Enable” switch shown in the center of the panel in Fig. 2-4 allows interactive access to the ACP. When this switch is set to "Off", the computer will have control of the ACP. With it set to “On”, either the computer or the user will have control,
depending on how the “Computer/Local” switches are set. The occultor can be either driven continuously or pulsed, either forward or reverse, depending on the use of the switches on the front panel. The ACP can drive either filter wheel in either direction, using the switches on the front panel.

2.4 Camera Housing

The camera housing is an o-ring-sealed chamber which houses the camera and optical system. It can be purged with dry nitrogen, and the pressure monitored. In this way, the optics can be kept clean and dry. It is normally pressurized to approximately 5 psi (or 3.4 \(10^4\) pascal). The camera housing is shown in Fig. 2-6. In this illustration, the top third of the housing holds the fisheye lens, upper lens tube, and filter changer. The second third holds the lower lens tube and the camera. The lower third allows room for the cable pigtauls which convert from standard connectors to environmental connectors.

2.5 Environmental Housing

The environmental housing is the external housing which holds the camera housing and the camera’s power supply (sometimes called power brick). The housing is insulated, temperature regulated, and provides protection against rain. It includes a 1500/1800 BTU cooler with a 500 watt heater to keep the camera at approximately fixed temperature, for longer life and stability. This also ensures that the camera chip can be maintained at its 10 degree C set point. The CCD chip is cooled by a thermo-electric cooler, and the hot side of the TE cooler is cooled by conduction to the outside of the camera housing. The environmental housing is maintained near 15 or 21 degrees C at the user’s option. (The cooler is currently set for 21 C, however in cooler climates, the user may wish to lower the thermostat to lower levels.) The environmental housing also includes leveling legs, to enable aligning of the WSI field of view, and tie-down hardware. The environmental housing is shown in Fig. 2-7.

It should perhaps be noted that we normally prefer to use white powder-coat aluminum housings. With this WSI, the sponsor preferred that we budget for a less sophisticated housing. We used UV inhibited ultra-high molecular weight polyethylene as the housing material. While we feel that the resulting housing is adequate, we may find that it has fewer years of longevity. It may be necessary to replace it in the future, either with the same material or with an upgraded housing.

2.6 Computer Control Hardware and Software

The computer is a Dell Optiplex GX1p, operating in a Windows NT environment. The CPU is a Pentium II running at 450 mHZ with 128 MB of RAM. The system includes a CDROM, a floppy drive, and a 3COM Ethernet card. Additional peripherals which have been added are a Digital IO card with 72 IO ports, the Photometrics camera control card, an Adaptec SCSI card for interfacing with external archival devices, and a Hopf GPS card for acquiring accurate time and location. The hardware control system is shown in Fig. 2-8 and data control is illustrated in Fig. 2-9.
Photometrics supplies the V++ image acquisition and processing software system with the SenSys cameras. The automated and interactive WSI control software were designed by MPL. They run within the V++ environment. The MPL code uses scripts to control the camera, and also uses DLLs to bring in C routines such as those required to compute sun angle and control occultor position and control the filter changer. Other MPL-specific routines include the flux control logic for determining the exposure to use, and the logic for applying the radiometric calibrations to the raw data to yield absolute radiance. The software is discussed in Section 4.

### Table 2.1
**Optical Filters in the Filter Changer**

<table>
<thead>
<tr>
<th>Upper Wheel</th>
<th>Name</th>
<th>Nominal Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Open</td>
<td>Open Hole</td>
</tr>
<tr>
<td>2</td>
<td>Red</td>
<td>650 nm peak, with 70 nm passband</td>
</tr>
<tr>
<td>3</td>
<td>Blue</td>
<td>450 nm peak, with 70 nm passband</td>
</tr>
<tr>
<td>4</td>
<td>Pol #1</td>
<td>Polarizer (linear)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lower Wheel</th>
<th>Name</th>
<th>Nominal Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Open</td>
<td>Open Hole</td>
</tr>
<tr>
<td>2</td>
<td>Pol #2</td>
<td>Cross Polarizer (linear)</td>
</tr>
<tr>
<td>3</td>
<td>BG39</td>
<td>Blue-green, 518 nm peak with 278 nm passband</td>
</tr>
<tr>
<td>4</td>
<td>RG850</td>
<td>NIR long-pass filter, approximately 850 – 1070 nm</td>
</tr>
</tbody>
</table>

### Table 2.2
**Filter Wheel Setting Options**

<table>
<thead>
<tr>
<th>Option</th>
<th>Name</th>
<th>Upper Position</th>
<th>Lower Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Open</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>Red</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Blue</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>Pol #1</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>5</td>
<td>Pol #2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>BG39</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>RG850</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>
Figure 2-1. System 7 WSI Optical System. From top to bottom are the fisheye lens, relay optics, filter changer, additional relay optics and camera.
Figure 2-2. Optical Stack Drawing, showing the optics (filter changer is not included in the drawing), camera, and housing.
Figure 2-3 Solar Occultor. This equatorial occultor provides stray light control for the WSI. In the illustration it is shown mounted on the upper half of the camera housing.
Figure 2-4. Accessory Control Panel (ACP). This unit provides readout and control of the filter changer and solar occultor. It is designed to allow either computer or local control.
Figure 2-5. Accessory Control Panel Interior, showing the power supply and printed circuit boards.
Figure 2-6. WSI Camera Housing (with occultor).
Figure 2-7. WSI Environmental Housing.
Figure 2-8. Computer and Monitor used to control the WSI
Figure 2-9 Schematic of the WSI System 7 Data Control
3. Operating the System 7 WSI

The WSI was installed at the Potsdam DWD site by MPL staff. Setup instructions are provided in Technical Memorandum AV00-002t. The setup instructions include an initial power-up sequence to use when the instrument is first deployed or under evaluation. This Operating Manual will only include normal procedures for routine operation of the instrument which may be used subsequent to its initialization period.

The following sections provide the normal power up and power down sequences. Instructions for operating the software are provided in Section 4.

3.1 Power Up Sequence

a) If this is the first time that the WSI has been run in awhile, go on the roof, remove the dome cover, and inspect the WSI and occultor to verify that everything appears normal.

b) We anticipate that the cooler/heater will be left on continuously. If it is not on, or if the user is not certain whether it is on, verify that it is plugged in on the roof.

c) We anticipate that the transformer, which supplies 115 V to the camera and ACP, will be left plugged in continuously. If it is not, plug it in on its 5th floor location.

d) Plug the camera cable and the ACP power cable into the transformer output. The camera is normally left with its on/off switch in the on mode, so plugging in the power should turn the camera on.

e) In the 3rd floor room, verify that the ribbon cables are attached from the ACP to the computer. Turn on the ACP on/off switch at the back right corner of the ACP, as shown in Fig. 2-4. For automated use, verify that the “Local Enable” switch is set to “Off”.

f) We anticipate that the computer and monitor will be left plugged into the power source continuously. If not, plug them in.

g) Turn on the monitor by pushing the square button on the right hand side front of the monitor as shown in Fig. 3-1.

h) Turn on the computer by pushing the Power Button (the upper of the two circular buttons) as shown in Fig. 3-1. The computer will ask you to boot the system by entering the “Ctrl”, “Alt”, and “Del” keys simultaneously. It will then ask for a password, which has currently been left blank. Press “Enter” which will enter a blank password. The computer should bring up V++. At this point, you may use the programs as described in Section 4.
i) If desired, verify GPS operation by clicking on “Hopf GPS” on the task bar at the bottom of the monitor screen using the mouse. This should show the time, date, and GPS status. To exit this screen, click on “V++” on the task bar.

3.2 Power Down Sequence

When you are through running the WSI, the following power-down sequence may be used.

a) If RunWSI is still running, exit the program by pushing either “End” key on the keyboard once, and waiting for it to respond. It may take a minute or more to respond, depending on what part of the sequence the program is in.

b) Exit V++ by clicking on the “X” in the upper right corner of the monitor, as shown in Fig. 3-2.

c) Close down the clock by clicking on “hopf PCI radio clock” and clicking on “exit”.

d) Click on the “Start” button, and then select “Shut Down”, as shown in Fig. 3-3, then confirm shut-down as shown in Fig. 3-4. Wait until the computer indicates that it can be turned off, and turn off the computer by pushing the upper round button on the computer, as shown in Fig. 3-1.

e) Turn off the monitor by pushing the button on the right hand side of the front panel, as shown in Fig. 3-1.

f) Turn off the ACP by pressing the on/off toggle switch on the back right corner, as shown in Fig. 2-4.

g) Go to the 5th floor, and unplug the power cord for the camera and ACP. This will turn the camera off.

h) If the instrument will not be run for a day or more, go to the roof and replace the dome cover. The air conditioner is designed for continuous operation. We recommend that it be left on, as we feel this will provide better protection for the power brick against moisture (by keeping it above dewpoint temperature in the winter time) and temperature changes.
Figure 3-1. Power and Reboot Button on Computer and Monitor.
Press X button to close V++

Figure 3-2. Monitor display in V++ showing the 'X' key to use for exiting the program
Figure 3-3. Monitor Display to request ShutDown, showing the “Start” button and “ShutDown”.
Figure 3-4. Monitor Display to confirm ShutDown, showing the “ShutDown” query.
4. Running the WSI Software

There are three primary modes of operation of the WSI. These are Automated mode, Interactive mode, and V++ mode. The primary features of these modes are shown in Table 4.1. It should be noted that in Automated mode (Secn 4.1 – 4.2), output files are saved to D:\Images. In interactive mode (Secn. 4.3), output files are saved in C:\Images. In V++ mode (Secn 4.4), output files are saved in C:\program Files\Digital Optics\V++\Executable.

4.1 Automated Mode Input File, RunWSI.ini

In the automated mode, the program RunWSI controls the WSI. This program is documented in Tech Memo AV00-033t. The main user inputs are given in the file RunWSI.ini. There are additional input files that are not normally altered by the user. The RunWSI.ini input file is shown in Fig. 4-1. This file is heavily commented; comment lines begin with #. Only entries after the “=” should be altered. Most of the entries are self-explanatory, however a few additional comments may be useful.

The latitude and longitude are set on delivery. After start-up, the latitude and longitude are read from the GPS (Global Position System). The input values are the default if the GPS is not used.

The start and end date and time should be updated, and the continuous variable, which is described in the input file, should be set. If desired, the start date can be set to a date in the past, and the end date set to a date a few weeks in the future, and the start and end times set to 00:00 and 24:00. With these settings, and the instrument will run continuously whenever it is started.

The flux control calculation interval should normally be set to no more than 10 minutes. This interval determines the frequency with which the WSI checks whether its present exposure levels (determined by the flux control algorithm) are appropriate. If the flux control calculation interval is too long, then the images may be overexposed or underexposed due to changes in the optical environment.

There are a total of 7 filter selections, or grab options, as listed in Section 2.1. In the section of the input table starting with “[Grab Option1]”, the user indicates whether or not to acquire each grab option with a 1 or 0. This section on the input file has been left generic, in case the user changes the filters in the filter wheel. To grab all options, set all options to 1; for faster data acquisition, grab only selected filters. The filters corresponding to these grab options at the time of delivery are listed in Table 2.2 in Section 2.

The last section of entries in the input file provides the locations of up to 10 Regions of Interest (ROI). It was originally intended that this be used in the data
processing. Since the data processing is now done by a separate program, these inputs are not used in this program.

To edit the input file, after V++ opens, click on “File”. At the start of V++, V++ is in the default directory C:\program files\digital optics\v++\executable. Verify that this is the directory shown, and then double click on the “RunWSI.ini” file. A window comes up that says "Unknown Format". Select Text format by clicking on the “Text Files (*.txt)” line and then click on “OK”. After editing the text file, save it by double clicking on “Save”. A copy of the original RunWSI input file, as delivered, will be saved in RunWSI/MPL for comparison.

4.2 Running in Automated Mode, Program RunWSI

Once the RunWSI input file is set appropriately, the ACP should be set in computer mode, i.e. with the “Local/Computer” switches in “Computer” and the “Local Enable” switch in “Off” mode.

To verify the camera settings, click on the V++ “Camera” menu option and verify that the settings are as indicated in Table 4.2.

To run in the automated mode, click on “User” within the V++ menu, then click on “RunWSI”. If the current time is less than the start time, the program will initialize the camera, occultor, and filter changer, and then start at the start time. If the current time is after the start time, there will be an initial 5 minute wait to allow the occultor to move as far as it needs to. During the initial period, the program may show the following messages:

Waiting for start date...
Moving occultor to: xxx
Computing initial exposure...
Setting up filter changer... - shown when fc is setup for next image grab
Waiting for start time: xxxx - shown for first grab

Once the initial setup or wait period is over, it will complete the following steps:

Initiating image acquisition...
Image acquisition in progress...
Acquiring dark images...
Preparing images for display...
Archiving images...
Preparing for next grab...
Moving occultor to: xxx
Computing new exposure... -only if flux control is enabled for this grab
Setting up filter changer... - shown when fc is setup for next image grab
Waiting for grab at: xxxx
These steps will be repeated until sunset arrives, the end time arrives, or the user exits by pushing either “End” key on the keyboard. Messages which may be displayed under these occurrences include:

Waiting for midnight...
Finished waiting for midnight
Exiting program

A typical screen display during RunWSI is shown in Fig. 4-2. The RunWSI Program logic is shown in Fig. 4-3.

Although V++ is designed to allow the user to use V++ features during the wait period, we do not recommend doing this. V++ does not appear to be sufficiently robust to handle the multi-tasking. We recommend letting the program run autonomously.

If for some reason a user error causes V++ to fail (or it fails for some other reason), it may fail to save the RunWSI compiled program within V++. That is, when the operator clicks on “User”, “RunWSI may no longer be shown as an option. However, the RunWSI source code is saved as a file. This file can be recompiled and the program reinstalled in V++ using a simple procedure described in Tech Memo AV99-053t.

4.3 The Interactive Program, WSIInteractive

The interactive program, WSIInteractive, was designed to allow the user greater flexibility in operation of the WSI, however it requires that the user be present. This program asks the user to set the desired filter combination on the ACP in “Local”. For this, the ACP “Local Enable” must be set to “On”, and the “Local/Computer” switches must be set to “Local” (See Fig. 2-4). Next, the program asks the user to enter the exposure desired.

Normally, in the red filter, 100 m sec is a good starting point during most of the day. Most of the other filters can use the same exposure as the red filter. The exceptions are the open hole, blue, and BG39, which require exposures of about 0.1, 10, and .25 times the red exposure.

The program then allows the user to move the occultor using the ACP in “Local” mode. Either the “Fwd” or “Rev” switch can be set in “Drive” to move the occultor (but do not put both switches in “Drive” simultaneously). The switch should be returned to the neutral position when the occultor is in the desired position. During this time, the image is continuously updated, so that the user can see when the occultor shades the sun. The user can then enter a new exposure, and the image is grabbed, and saved if desired. The user can also use the V++ features to evaluate the image at the end of the sequence. The overall logic of this program is shown in Fig. 4-4.
4.4 Running under V++

Although both RunWSI and WSInteractive operate within the V++ environment, it is also possible to operate the camera directly with V++ features. First, use the ACP in “Local” mode to set the desired filter combination and occultor setting as described in Section 4.3. To set up the V++ program for image acquisition, click on “Camera”, then set the desired exposure by editing “time” (see Fig. 4-5). Verify that the Exposure type is set to “Normal”. Click on “Properties”, then on “Shutter”, and verify that the shutter is set to “Pre-exposure”. Click on “Apply” and then “Close”. Then click on “Acquire” to acquire the image. Image acquisition size may be controlled also with this dialog box. Click on “List” to see image size options and add image size options, then click on the ROI arrow and select the “Selected ROI” option.

V++ includes many image processing features, such as the examples shown in Fig. 4-6, to allow image zoom, enhancement, windowing, and mathematical image processing functions. For example, “Zoom” may be accessed either by clicking on the “Size” menu, or by clicking on the icon which looks like a magnifying glass. By pressing the shift key on the keyboard, the images may be zoomed smaller.

Also, by clicking on the icon which looks like a box with an arrow, the user may define a ROI. Then, by clicking on “Intensity” and then “Statistics”, one can see statistics such as the average signal within the ROI. Other features include histograms and plots, false color, addition or subtraction of images, and image processing such as application of the Fourier transform.

It should be noted that if you acquire a dark image or bias image, by setting Exposure type to “Dark” or “Bias”, then when you wish to take another normal image, it is necessary to set Exposure type to “Normal” and also reset Shutter to “Pre-exposure”. The shutter does not automatically set itself back to “Pre-exposure” unless you tell it to. RunWSI verifies that “Normal” is used.

Although there is no hard copy document on V++, there is extensive on-line documentation that is somewhat helpful. Also, the beginning section of the PVCAM Reference Manual is somewhat helpful. At MPL, we have gained some experience in the recent months, and are happy to help.

4.5 Additional WSI Programs

Probably the most useful test program for the user is RealTimeGRAB. This program grabs and displays repeated images. It is useful for general testing, for example when testing the filter changer. In this program, there is a delay of approximately 2 seconds between acquisition and display. This delay is due to the chip readout time, and it depends on image size and readout rate selected.

Program DIOTEST is useful for testing the Digital IO card’s ability to sense the filter and occultor position and to change them.
Program ReadHeader can be used to read the embedded header in an image. It will ask for the image name.

Program WSI Post Process processes the data to yield cloud fraction and sky radiance distributions, as well as information for specific Regions of Interest. This program is documented in Tech Memo AV00-032t.

Program RadtoFloat converts radiance images from floating point “tif” format to floating point text format.

Program ReadProcHeader reads the headers on processed images.

Any of these programs may be set up to show in the “User” menu, as discussed in Tech Memo AV99-053t.

<table>
<thead>
<tr>
<th>Table 4.1</th>
<th>Primary Software Modes for WSI Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run WSI</td>
<td>Runs Autonomously (without Operator)</td>
</tr>
<tr>
<td></td>
<td>Continuous Operation</td>
</tr>
<tr>
<td></td>
<td>Controls FC and Occ</td>
</tr>
<tr>
<td></td>
<td>Flux Control Sets Exposure</td>
</tr>
<tr>
<td></td>
<td>Displays Windowed Images</td>
</tr>
<tr>
<td></td>
<td>Saves images automatically with image headers</td>
</tr>
<tr>
<td></td>
<td>Input file used to select options</td>
</tr>
<tr>
<td>WSIInteractive</td>
<td>Run by Operator</td>
</tr>
<tr>
<td></td>
<td>Asks Operator to set FC and Occ, reads back position from ACP</td>
</tr>
<tr>
<td></td>
<td>Shows “live” image during Occ set</td>
</tr>
<tr>
<td></td>
<td>Asks user to select exposure</td>
</tr>
<tr>
<td></td>
<td>Displays windowed images</td>
</tr>
<tr>
<td></td>
<td>Asks User whether to save files, saves with image headers</td>
</tr>
<tr>
<td>V++</td>
<td>Run by Operator</td>
</tr>
<tr>
<td></td>
<td>Program is “unaware” of FC and Occ Position, user must set using ACP</td>
</tr>
<tr>
<td></td>
<td>Exposure must be selected</td>
</tr>
<tr>
<td></td>
<td>Window must be selected</td>
</tr>
<tr>
<td></td>
<td>Full flexibility in grab options</td>
</tr>
<tr>
<td></td>
<td>Images may be saved, but there are no headers</td>
</tr>
</tbody>
</table>
Table 4.2
Normal V++ Camera Settings for Program RunWSI

Exposure Menu:
  Time: (Varies)
  Mode: Timed Mode
  Type: Normal
  Frames: 1

Properties Menu:
  Speed Table:
    Gain Index: 2

Shutter:
  Open Delay: 5 msec
  Close Delay: 10 msec
  Open Mode: Pre-Exposure

CCD Parameters:
  ADC Offset: 6100
  Clear Count: 2
  Clearing Mode: Pre Exposure
  CCD Clocking: Normal
Figure 4-1. RunWSI.ini, the primary input file

# This is the input file for the automated WSI data acquisition
# program RunWSI.
# All lines preceded by a "#" are comment lines.
# Please do not change text located within brackets [].
# Only change data located to the right of the equal sign.
# For all options listed below: 1 = yes, 0 = no

[WSI Location]
# If GPS is present, the GPS lat. and long..
# will override the lat. and long. entered here.
# Use - for West longitude, + for East longitude
WSILat=32.7
WSILon=-117.2

[WSI Start date and time]
# For date use the following format: dd/mm/yyyy,
# where dd is day, mm is month and yyyy is four digit year
# Use GPS time for start time
# For acquisition during full daylight hours,
# use a start time of 00:00, and end time of 24:00.
# Use of Day1Special variable: If Continuous = 1, then first day
# of acquisition will begin at specified start time. The remaining
# acquisition days will begin at sunrise and end at sunset.
# If Continuous = 0, then the specified start and stop times will be
# used for entire acquisition period.
StartDate=11/1/1999
StartTime=14:00
Continuous=1

[WSI End date and time]
# For date use the following format: dd/mm/yyyy,
# where dd is day, mm is month and yyyy is four digit year
# Use GPS time for end time
# For acquisition during full daylight hours,
# use a start time of 00:00, and end time of 24:00
EndDate=11/31/1999
EndTime=3:00

[Time Step in minutes]
# If 0 is used for the time step, images will be grabbed
# as quickly as possible
# Maximum time step is 60 minutes
TimeStep=1
Fig. 4-1 cont.

[Flux control calculation interval in minutes]
# 0 minutes indicates no flux calculation
# Maximum flux control calculation interval is 60 minutes
# Optimal data will be obtained if this is set the same
# as the TimeStep value.

FluxInt=10

[Grab Option1]
# Grab Image with Wheel 1 at Pos 1, Wheel 2 at Pos 1
GrabOption1=1

[Grab Option2]
# Grab Image with Wheel 1 at Pos 2, Wheel 2 at Pos 1
GrabOption2=1

[Grab Option3]
# Grab Image with Wheel 1 at Pos 3, Wheel 2 at Pos 1
GrabOption3=1

[Grab Option4]
# Grab Image with Wheel 1 at Pos 4, Wheel 2 at Pos 1
GrabOption4=1

[Grab Option5]
# Grab Image with Wheel 1 at Pos 1, Wheel 2 at Pos 2
GrabOption5=1

[Grab Option6]
# Grab Image with Wheel 1 at Pos 1, Wheel 2 at Pos 3
GrabOption6=1

[Grab Option7]
# Grab Image with Wheel 1 at Pos 1, Wheel 2 at Pos 4
GrabOption7=1

[Images to display during wait]
# For the RedImage option, if Red image is not grabbed
# it will not be displayed.
DisplayRedImage=1
DisplayAllRawImagesGrabbed=1
DisplayAllProcessedImages=0
DisplayROIResults=0
[Calibration Constants]
# These constants should only be changed by trained personnel
C1=1.3e2
C2=2.3e-2
C3=1.4e3
C4=1.3
C5=32.2
C6=1.02e-4
C7=1.05e-5

[Processing Requirements]
ProcessstoCloud=0
ProcessorforAbsoluteRadiance=0
ApplyLUTtoCloudImages=0

[ROI Definitions]

# Maximum number of ROI definitions is 10
NumberOfROIs=5

# There are 10 ROIs defined below. Only the Number of ROIs
# listed in the "NumberOfROIs" entry above will be used.
[ROI number 1]
Theta=32
Phi=45
HalfAngle=23

[ROI number 2]
Theta=32
Phi=50
HalfAngle=23

[ROI number 3]
Theta=32

Fig. 4-1 cont.

Phi=80
HalfAngle=23

[ROI number 4]
Theta=132
Phi=80
HalfAngle=23
Fig. 4-1 cont.

[ROI number 5]
Theta=232
Phi=80
HalfAngle=23

[ROI number 6]
Theta=34
Phi=80
HalfAngle=23

[ROI number 7]
Theta=32
Phi=80
HalfAngle=53

[ROI number 8]
Theta=32
Phi=90
HalfAngle=23

[ROI number 9]
Theta=32
Phi=80
HalfAngle=25

[ROI number 10]
Theta=132
Phi=10
HalfAngle=23
Figure 4-2. Typical Monitor Display during Program RunWSI.
Read input file for:
  Initial Lat./Long
  Acquisition schedule
    Start date/time
    End date/time
    Grab interval
    Operation mode (Sunrise to Sunset, Continuous or User start
    1st day, User end on last day)
  Flux control interval
  Filter selection schedule (Options 1-7)
    Open
    Red
    Blue
    Pol #1
    Pol #2
    BG39
    RG850
  Images to display during wait
    Display red image only
    All raw images
    All processed images
    ROI results
  Calibration constants
  Processing requirements
    Process to cloud
    Process for absolute radiance
    Apply LUT to Cloud images
  ROI definitions (max. number of ROIs = 10)
    Theta
    Phi
    Half Angle

Setup instrument for initial image acquisition
  Determine start/end, date/time
  Move occultor to proper position
  Determine initial flux control from file
  Set exposure according to flux control
  Position filter changer for first grab

Repeat
  Grab images according to filter selection schedule
  Process images according to processing requirements
  Display user selected images during wait for next grab
  Archive images
Fig. 4-3 cont.

Determine next grab time and if it’s time to wait or stop
If it’s not time to wait or stop then
  Setup instrument for image acquisition
  Move occultor to proper position
  Determine flux control if necessary
  Set exposure according to flux control
  Position filter changer for next grab
If it’s time to Wait
  Wait for midnight then
  Determine next day’s start/end time
  Move occultor to proper position
  Determine initial flux control from file
  Set exposure according to flux control
  Position filter changer for first grab
If it’s time to stop then stop
  If it’s not time to stop then wait until time for next grab
Until End time or User exit
Figure 4-4
WSInteractive Program Logic

The steps of this program are listed below. The entries in italics are commands given to the user.

Repeat -
  * **Setup filter changer.** *Press OK when finished*
  * Read filter changer positions*
  * **Enter Exposure level in milliseconds:***
  * Read Exposure*
  * Set Exposure*
  * *Press OK to begin occultor setup, then when finished press any key.***
  * Do real time grab while occultor position is updated by user. Stop when user presses a key*
  * **Enter Exposure level in milliseconds:***
  * Read Exposure*
  * Set Exposure*
  * Grab image*
  * **Save this image?**
  * if yes:
    * Ask for filename prefix
    * Create header
    * Save image
  * if no:
    * Allow user to manipulate image. Press *<DEL> key when finished*

Until UserExit
Figure 4-5. The Camera Dialog Box in V++. 
Figure 4-6. Additional V++ Feature Selection Buttons.
5. **Routine Maintenance**

This section provides the safety precautions, and the routine maintenance. The routine maintenance consists of the following steps, which are detailed in Section 5.2.

   a) Visually inspect the WSI system and clean the dome on program start-up
   b) Change the occulter arms periodically as discussed in Secn. 5.2.
   c) Open the environmental housing, and inspect the camera housing and camera power brick, and note the camera housing purge pressure and temperature monthly.
   d) Inspect the air conditioner monthly, and change the air conditioner filter as required.
   e) Test the ACP and verify the occulter alignment monthly.
   f) Verify the computer and program operation monthly.

5.1 **Safety Precautions**

The first note below is to protect the operator. The remaining notes are to protect the equipment.

Normally, there is no need to remove the cover of the ACP. If the cover is removed, it should be removed with the power off, due to the live AC inside the chassis.

It is always recommended that the user turn off power to the system before disconnecting or connecting any of the cables.

The camera should not be connected or disconnected from the computer while the camera or computer are powered up. First shut down the computer as instructed in Section 3.2 Steps a – c, and then turn off power to the camera by unplugging the camera power cord on the 5th floor or by turning off the toggle switch on the camera power brick in the environmental housing. Then you may disconnect the camera cable from the computer.

In the event that the user desires to disconnect the ACP from the computer and operate it independently, the ACP and computer must be turned off before the ribbon cables are removed. Then the occulter shorting plug must be installed on the back of the ACP on the occulter ribbon cable jack, as shown in Fig. 5-1, prior to turning on or using the ACP. It should only be used on the occulter output, 7700-01-P5, not on P4.

Do not realign the occulter arm without loosening the four set screws. The location of these set screws is identified in Fig. 5-2.

Before the computer is turned off, all programs and windows should be closed and the computer operating system (Windows NT) should always be shut down before the computer is turned off. These procedures are noted in Section 3.2 Steps a-c. If for
some reason the computer hangs and a clean shut down (or start up) cannot be accomplished, do a soft reboot by pressing the lower round button as shown in Fig. 3-1.

Always keep a backup of the system programs. A backup of the operating system and programs which were provided by the Dell manufacturer were provided with the instrument. A backup of Photometrics' V++ should be created by the user. A backup of the initial versions of the WSI code, written by MPL, was also provided.

5.2 Maintenance Procedures

1. Visually inspect the system and clean the dome on program start-up. The dome may be cleaned with distilled water and a clean cloth. Avoid rubbing the dome hard or pressing hard on it. On visual inspection, note anything that appears abnormal. The dome should be reasonably free of craze marks. The dome should be covered with the dome cover when not in use for periods of a day or more. The occultor arm should be free of debris and not flopping around. The air conditioner/heater should sound normal. If the WSI is run continuously for periods of days, it is helpful to clean the dome daily.

2. Change the occultor arms periodically. There are 7 arms of different length. The arm should be removed, the Occultor flag (ND filter and frame) placed on the new arm, and the arm replaced. This may be done during the evening on the dates indicated in the occultor arm schedule illustrated in Fig. 5-3 and listed in Table 5.1. The arm may be changed following the instructions listed in Table 5.2a.

3. Open the environmental housing, and inspect the camera housing and camera power brick, and note the camera housing purge pressure and temperature monthly. We also recommend doing this initially after the first storm. To inspect the camera housing, remove the environmental housing front cover. Inspect the environmental housing and camera housing for abnormalities. Verify that the camera power brick is clean and reasonably dry. Remove the cap from the pressure valve on the camera housing, and check the camera pressure. It may need to be refilled with dry nitrogen or dry air approximately monthly. If dew begins to form on the inside of the camera housing dome, it is necessary to remove the lower portion of the camera housing, which is called the cable housing, and remove and replace the packets of desiccant. The use of pressurized dry nitrogen or dry air is not strictly necessary; it is used as an indicator that the camera housing seal is reasonably good, and alert the user if there is a problem with the seal. However, optical filters will age more slowly if dry nitrogen is used, and it is important to keep a clean dry environment inside the housing. When inspecting the environmental housing, if you note significant amounts of standing water, it may be necessary to improve the seal of the housing by finding the source of the
leak and sealing with RTV. To check the camera housing inner temperature, use the temperature cable, and measure the resistance across the two leads. The temperature may be determined from Table 5.3.

4. Inspect the air conditioner/heater monthly while the environmental housing cover is off. Verify that the temperature in the housing seems reasonable, and that the heater or cooler come on as the temperature changes. On the outside of the environmental housing, remove the large metal louver, and then remove the plastic louver inside by sliding it up. Inspect the air conditioner filter, and replace it if necessary.

5. Test the ACP and verify the occultor alignment monthly. To test the ACP, end the program by pressing the “End” key on the keyboard and waiting until the program ends. Turn the “Local Enable” knob shown in Fig. 2-4 from “Off” to “On”, and set both “Local/Computer” switches to “Local”. Push the “Step” button to exercise the filter changer, using the “Up/Down” switch to select direction and the “Select” switch to select filter wheel. If desired, you can observe the images by running the “RealTimeGRAB” program, as indicated in Section 4.5. Next, exercise the occultor by pushing up either the fwd drive switch or the reverse drive switch (but not both simultaneously). The occultor moves very slowly, moving approximately 35 degrees per minute. Using forward or reverse, move the occultor to 90 degrees readout on the ACP. Verify that the arm is centered in the image, or go on the roof and verify that the arm is centered overhead. If it is not, adjust as described in Table 5.2b. Please do not adjust the occultor arm without loosening the set screws shown in Fig. 2-3. Return both “Local/Computer” switches to “Computer”, and return the “Local Enable” knob to “Off”. Restart the program by clicking on “User” and then “RunWST”.

6. Verify computer and program operation monthly. Verify that the image on the screen appears normal. Verify that the program appears to be going through all of its steps, as documented in Section 4.2, and there are no error messages. At present, these repeated steps are:

Waiting for grab at: xxxx
*Initiating image acquisition...
  Image acquisition in progress...
  Acquiring dark images...
  Preparing images for display...
  Creating image headers...
  Archiving images...
*Preparing for next grab...
  Moving occultor to: xxx
  Computing new exposure... -only if flux control is enabled for this grab
*Setting up filter changer... - shown when fc is setup for next image grab

* These messages may appear briefly or not at all.
TABLE 5.1  
Occultor Arm Replacement Dates

<table>
<thead>
<tr>
<th>Date</th>
<th>Remove Arm No.</th>
<th>Install Arm No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>9 Nov</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2 Feb</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>22 Feb</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>12 Mar</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>29 Mar</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>16 Apr</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>7 May</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>6 Aug</td>
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<td>6</td>
</tr>
<tr>
<td>27 Aug</td>
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<td>14 Sep</td>
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<td>4</td>
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<td>1 Oct</td>
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<td>3</td>
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<td>19 Oct</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>9 Nov</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

TABLE 5.2  
Occultor Arm Replacement and Alignment Steps

5.2a Occultor Arm Replacement

1. Insert 3/32" allen wrench (UCSD/MPL provided) into each of two 10-32 X 3/8" attenuator arm retaining set screws, and loosen each about one turn.

2. Lift arm from slotted drive disc.

3. Remove square attenuator frame from arm by loosening two 4-40 attachment screws.

4. Attach square attenuator frame to newly selected attenuator arm. Assure that arm and frame mate flat-to-flat. Tighten 4-40 screws securely.

5. Insert newly selected attenuator arm into slotted drive disc, and tighten both 10-32 allen retaining set screws.

6. Inspect installation for secure attachment of Frame-to-Arm, and Arm-to-Disc.
5.2b Occultor Adjustment

1. End the RunWSI program and put the ACP in local mode (see Section 5.2, step 5).

2. Using the ACP, move the arm until the ACP readout is 90° (as described in O.M. Section 5.2, step 5).

3. Loosen all 4 8-32 x1/4” allen retaining set screws using a 5/64” allen wrench (UCSD/MPL provided). These 4 set screws are accessed from the outside circumference of the drive disk.

4. Gently rotate the arm to the 90° position, i.e. directly vertical.

5. Verify that the ACP is still at 90°, and then tighten the 4 set screws with the arm at 90°, with the disk near the end of its axis.

6. If desired, return the ACP to computer mode and restart RunWSI as documented in Section 5.2, step 5.

Table 5.3
Temperature vs Resistance of Camera Housing Thermistor

<table>
<thead>
<tr>
<th>T (°C)</th>
<th>R (kΩ)</th>
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<tbody>
<tr>
<td>0</td>
<td>29.49</td>
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<tr>
<td>5</td>
<td>23.46</td>
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<td>45</td>
<td>4.65</td>
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<tr>
<td>50</td>
<td>3.89</td>
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</table>
Figure 5-1. Back of the ACP showing where the Occultor Shorting Plug should be placed. The shorting plug should be used when the ACP is not connected to the computer. It should only be used on the occultor output, i.e. 7700-01-P5, not P4.
Figure 5-2. Location of Occultor Retainer set screws and Alignment set screws. Loosen both retainer set screws before removing the arm. Loosen the four alignment set screws before aligning the arm.
Figure 5-3
Occultor Arm Replacement Schedule
6. Instrument Products

The data products created by the data acquisition program RunWSI program consist of dark-corrected images. The program acquires raw images and dark images. The dark-corrected image is the raw minus dark image. To save archival space, the sponsor requested that we save only the dark-corrected image. These files are stored in 16 bit TIF format, and are saved in the Images subdirectory of the D: drive.

The filename convention for the saved raw images is yyddhhmmssffnnn.tif, where yy is the year, ddd is julian day, hhmmss is time, fff is wavelength specified as OPN for open, RED for red, BLU for blue, PL1 for pol1, PL2 for pol2, BG3 for BG39, and RG8 for RG850, nnn is “raw” for raw images and “drk” for dark images, and “cor” for dark-corrected images.

In order to look at the images, the user may click on File, and then click on the file name, after finding the appropriate directory. Files saved by RunWSI and WSInteractive are stored in D:\Images. Any of the V++ features, such as “Statistics”, may be used to evaluate the image. The image may also be exported to another system for further analysis on other image processing programs.

Program WSIPostProcess is designed to process the files. Because the sponsor desired to acquire large amounts of files (running with short time intervals between grabs and acquiring all or most filters), it was decided that it was most practical to place this processing program on a second computer. The processing yields radiances and opaque cloud cover. For each radiance file processed, there is a calibrated radiances file and text file. The image file is a floating point TIF file, with the calibrated radiances. The calibration text file includes a table of ROI results for each image processed. The opaque cloud cover is shown in the cloud decision image file, the output of the cloud decision algorithm. Each pixel is identified as opaque cloud or clear/thin. The cloud text file lists cloud fraction, including results for the selected ROIs. At the present time, we are funded to provide the simpler opaque cloud algorithm, with the thin cloud algorithm as a possibility for the future.

The filename convention for the radiances and cloud files is yyddhhmmssffnnn.ttt, where nnn is “RAD” for the processed calibrated radiances and nnn is “CLD” for the processed cloud decision results. The tt entry is “tif” for both the radiances and cloud image, and “txt” for both the radiances and cloud text files. For the radiances files, the fff section of the file name shows the filter selected, using the same filter name conventions discussed above. For the cloud files, the fff section is “000”, since there is no single filter associated with the cloud files.
7. Acknowledgements

This Whole Sky Imager was developed by the Atmospheric Optics Group of the Marine Physical Laboratory at the University of California, San Diego. Individuals involved in the design include Janet Shields, Richard Johnson, Monette Karr, Jason Wertz, Justin Baker and Jerry Crum. The system was designed for the Meteorological Observatory Potsdam of the Deutscher Wetterdienst, in collaboration with Dr. Uwe Feister and Dr. Klaus Dehne. We appreciate the support of our sponsors and especially wish to recognize the work of Dr. Feister.
8. References

8.1. General References


8.2 Technical Memoranda


AV00-001t, “Daylight Vis/NIR WSI Parts List”, J. E. Shields, 19 Jan 00.

AV00-002t mod, “Daylight Vis/NIR WSI Setup Instructions”, J. E. Shields, 19 Jan 00.

AV00-017t, “Flux Control for EO System 7, the Day Vis/NIR WSI”, J. E. Shields, 17 Mar 00.

AV00-019t mod, “Filter Changing Procedure for EO System 7, the Day Vis/NIR WSI”, J. E. Shields, 01 May 00, mod 15 Jul 00.

AV00-020t, “Spectral Curves for EO System 7, the Day Vis/NIR WSI”, J. E. Shields, 03 May 00.

AV00-021t, “Effective Lamp Irradiance Values for EO System 7, the Day Vis/NIR WSI”, J. E. Shields, 03 May 00.

AV00-022t, “Program Documentation: Program AbscalGm6.C”, J. E. Shields, 03 May 00.

AV00-023t, “Summary of Linearity Results for EO System 7 Unit 1”, J. E. Shields, 04 May 00.

AV00-024t, “Discussion of the Handling of the Linearity for EO7 System 1”, J. E. Shields, 09 May 00.
AV00-025t, “Interpretation of Photometrics Linearity Specifications”, J. E. Shields, 09 May 00.

AV00-026t, “Dark and Flat Field Calibration Results for EO System 7, the Day Vis/NIR WSI”, J. E. Shields, 10 May 00.

AV00-027t, “Absolute Calibration Results for EO System 7, the Day Vis/NIR WSI”, J. E. Shields, 12 May 00.

AV00-028t, “Rolloff Calibration Results for EO7 Unit 1, the Day Vis/NIR WSI”, J. E. Shields, 05 June 00.

AV00-029t, “Geometric Calibration Results for EO7 Unit 1”, A. R. Burden and J. E. Shields, 22 May 00.

AV00-030t, “Absolute Calibration Results for EO System 7 Unit 1, the Day Vis/NIR WSI: Summary of the Results of the Calibration, and How to Apply the Calibrations to Field Data”, J. E. Shields, 05 June 00.

AV00-031t, “Evaluation of Sample Calibration Results for EO7 Unit 1”, J. E. Shields, 15 July 00.

AV00-032t, “Program WSIPostProcess Documentation”, J. E. Shields and M. E. Karr, 08 June 00.

AV00-033t, “RunWSI for EO System 7, the Day Visible/NIR WSI”, M. E. Karr, 17 July 00.