MSR

MULTISPECTRAL RADIOMETER

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USER'S MANUAL

CROPSCAN, Inc.

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MSR System Overview
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The Multispectral Radiometer System was initially configured and calibrated at the factory before being shipped to you. There are a few things you should know about the system and its operation before you begin to use it. The MSR User's Manual contains detailed instructions on the setup, calibration, operation, and use of the system. This overview gives a brief high level description of the system and the basic aspects of its operation and use, with reference to the appropriate sections of the MSR User's Manual for further information.

The basic MSR system consists of a Multispectral radiometer (MSR87, MSR5, MSR16 or MSR16R), the Data Logger Controller (DLC), pole, connecting cables, and a few accessories. With the MSR16 radiometer, an MSR 32 Channel Adapter (MSR32CHA) is included. With the MSR16R, an MSR Cable Adapter Box (MSRCAB) is included. They multiplex up to 32 channels of analog signals from the radiometer to the DLC analog inputs.

Basic operations consists of:

- o Connecting the system parts
- o Configuring the software
- o Calibrating
- o Collecting Readings
- o Retrieving recorded data from DLC to PC or Mac
- o Post-processing retrieved data to calculate percent reflectance
- o Subsequent analysis unique to your application

THE MSR.BAS PROGRAM

The DLC is a sophisticated data logger controller. It contains a built-in general purpose data acquisition and control program. The DLC may be thought of as a specialized BASIC language computer with built-in data acquisition circuitry and software. Refer to the DLC User's Manual and Technical Reference if you need information about using the DLC for purposes other than with the Multispectral Radiometer. Like other computers that have BASIC language support, new and different BASIC programs may be entered into the DLC or loaded from the DLC memory card. The program which supports the Multispectral Radiometer System is one such program. It is named MSR.BAS and was preloaded into the DLC's program memory before being shipped to you. Copies of the program are also stored on the memory card if you ordered one with the system, and on PC diskette. Should the DLC become reset or the

MSR.BAS program be accidentally lost from the DLC's program memory, it will be necessary for you to reload the MSR.BAS program either from memory card or by upload from a PC or Mac computer.

MSR.BAS & CONFIGURATION/CALIBRATION BACKUP/RESTORE

When the MSR.BAS program is saved to memory card, all of the MSR system configuration and calibration constants are saved with it as well. It is recommended that whenever you reconfigure or recalibrate your MSR system, that you store a copy of it to the memory card for backup purposes. The MSR.BAS program and configuration/calibration constants can then be quickly reloaded into the DLC, when necessary. The copy of the MSR.BAS program stored on the PC diskette does not contain any configuration or calibration constants information. If necessary, the MSR.BAS program can be uploaded from a PC by use of the UPLDMSR (UPLoaD MSR program). The MSR configuration and calibration constants can be saved separately to a PC file by use of a PC program called SAVECONF. This program can also be used to restore the configuration and calibration constants from the PC file to the MSR.BAS program in the DLC. So, if you do not have a memory card for MSR program and configuration/calibration backup and restore, you can still accomplish backup and restore by use of the UPLDMSR and SAVECONF programs on a PC, it just takes longer and a few more steps are necessary. The initial configuration and calibration performed by ***CROPSCAN, Inc.*** are stored in an MSRnnn.CFG file on the PC diskettes, where nnn is the serial number of your MSR radiometer.

For more information on use of the memory card refer to the HOW TO USE THE MEMORY CARD section of the MSR User's Manual. For more information on use of the UPLDMSR program refer to the HOW TO UPLOAD MSR.BAS TO THE DLC FROM A PC section. The SAVECONF program is briefly described in the PROGRAMS INCLUDED WITH THE SYSTEM section on page 33.

CONFIGURATION

Before the MSR system can be used it must be properly configured and calibrated. An initial configuration and calibration was done at the factory before the system was shipped to you. Before using the system you should verify that the configuration is correct for your use and location. You may wish to recalibrate the system also.

The configurable items of the MSR are as follows:

DATE - Internal Clock Calendar. Must be set for your location's date.

TIME - Internal Clock Calendar. Must be set for your location's time. The DATE and TIME is used for sunangle and cosine correction calculations on the retrieved data in the PC POSTPROC (postprocessing) program.

SUBSAMPLES - subsamples per plot.
If you need to take more than one sample from the plot area then this must configured for the appropriate number of samples per plot. You have the option of recording each individual plot sample or recording the average of the samples each time you start the program. Initially configured at the factory to a value of 1.

REM - A one line text remark that you might use to store a brief description about the experiment sampling you are about to do. This description line gets carried along with the data when it is retrieved from the DLC.

ID - Identifier. An up to three digit number that you might use as an experiment number or anything you like. Initially it is configured to be equal to the MSR radiometer number.

LOCATION - Consists of a three digit alpha or numeric location identifier, latitude, and longitude. Use the three digit location as you like. Initially configured to be an abbreviation of your city or country. Latitude and longitude must be set for the location where radiometer measurements will be taken. Initially configured to estimated values for your location. Latitude and longitude information is used in sunangle and cosine correction calculations on the retrieved data in the PC POSTPROC (post-processing) program.

RECORD - Configure radiometer type, calibration method, and sensor channel items to be recorded. Initially configured to MSR87, MSR5 or MSR16, 2-Pt.Up/Dn calibration method, and recorded items of DATE, TIME, IRR, and channels corresponding to the radiometer and wave length modules you ordered. You can modify items to record. See the section HOW TO SPECIFY ITEMS FOR RECORDING in the manual.

SAMPLES - Number of A/D converter samples made per channel reading. Initially configured to 100, the number by which 60 hertz noise is average filtered from the signal. 120 will filter 50 hertz. You need only be

concerned about the setting for this if you will be using the system near AC power lines.

GMT Difference - The difference in time between Greenwich Mean Time and your time zone. Used in sunangle and cosine correction calculations on the retrieved data in the PC POSTPROC (post-processing) program.

IRR - Identify which wavelength sensor to use as a simulated pyranometer for low light level warnings and possible other post analysis involving solar irradiance.

CALIBRATION - For MSR16R, the waveband serial numbers must be manually entered into the CALIBRATION CONSTANTS table, corresponding to the channel numbers in which the bands are mounted in the radiometer head. This was done for you before the radiometer was shipped from ***CROPSCAN, Inc.*** For the MSR87 and MSR5, their standard center wavelength values are generated automatically. Calibration constants can be viewed or manually changed if necessary. If either of the white standard calibration methods are to be used then the white standard reflectance factors must also be entered in the table for each waveband sensor.

POWER-Off - Amount of time of no operator activity allowed before the system automatically powers-off. Initial default is 255 seconds. Probably not likely that you need to change it.

MODE - Plot numbering mode. Initially configured for AUTO. If MANUAL mode is chosen then plot numbers must be manually entered before each plot is sampled. This is useful if you do not sample plots by sequential plot number. If AUTO mode, then you must specify the beginning and ending plot numbers and the plot numbers will then be automatically incremented. If AUTO mode is selected then scans may be initiated by use of either a manual scan switch (if included in system order) or by pressing the operator terminal space bar or key.

Of the above listed configurable items, those that must be set correctly, for proper operation and subsequent correct data post-processing analysis are the following:

DATE	CALIBRATION
TIME	MODE
SUBSAMPLES	
LOCATION	
RECORD	
GMT Difference	

The other configurable items may be set and used as you see fit.

For more information on reconfiguring these items, refer to the HOW TO RECONFIGURE THE MSR section of the MSR User's Manual.

CALIBRATION

After the system has been properly configured it can be recalibrated. The system supports the following three relative-based calibration methods:

2-Pt.Up/Dn - 2 Point Up/Down which makes use of a diffusing flashed white opal glass to transfer calibrate the up and down MSR sensors. This calibration method is simple to do and can be easily done in the field.

WhiteStd.Dn - White Standard down sensors only. Calibration done relative to a white card of known reflectance. Recalibration must be done periodically and relatively frequently in the field, as samples are taken.

WhiteStd.Up/Dn - Calibration based on use of white card with known reflectance. Calibration constants for up sensors are then calculated based on up and down sensor calibration readings over the white card.

For more information on calibration refer to the CALIBRATION METHODS/ CONSIDERATIONS section. For detailed steps on calibration refer to appropriate HOW TO CALIBRATE section of the MSR User's Manual.

OPERATION

Operation of the system is straight forward after the system has been properly configured. After you have arrived at your sample location, you assemble the system by attaching the radiometer to the pole, level the pole spirit level relative to the radiometer, and connect the cables to the DLC. When the MSR program is started on the DLC you will be prompted for whether you wish to record individual samples or average samples. If auto plot number mode is used then you will be prompted for the beginning and ending plot numbers. At this point you can move from plot to plot pressing the space key on the hand terminal or the space bar on a laptop computer to initiate a plot sample scan. You move from plot to plot until all readings have been made. For detailed steps of operation refer to the OPERATING PROCEDURES IN THE FIELD section of the MSR User's Manual.

Data may be stored on memory card, for later retrieval to a PC using the DLC or a ***CROPSCAN*** Memory Card Reader (MCR) or it may be retrieved directly

from the DLC to a PC or Mac laptop computer in the field or back in the office. A PC RETRIEVE program is supplied to simplify the data retrieval. For more information on retrieving recorded MSR data, refer to the HOW TO DOWNLOAD FROM THE DLC TO A PC section and the PROGRAMS INCLUDED WITH THE SYSTEM section.

The DLC supports seven different recording storage sizes. Refer to the STORAGE CAPACITY section for more information about determining how many plots can be recorded given DLC memory size and MSR configuration.

After the data is retrieved to a PC computer file, the POSTPROC program should be run against the data file. Temperature and sunangle cosine corrections will be made and the percent reflectance calculations will be performed. Refer to the THEORY OF OPERATION section for more information about temperature and cosine correction. The results will be stored in a formatted ASCII text file for subsequent statistical analysis using programs supplied by ***CROPSCAN, Inc***. or of your own choosing.

Refer to the PROGRAMS INCLUDED WITH THE SYSTEM for more information on the other programs supplied by ***CROPSCAN, Inc***. with the system.

This high level system over-view should give you the background necessary to follow the instructions and descriptions covered in the MSR User's Manual.

MULTISPECTRAL RADIOMETER (MSR)
User's Manual

CROPSCAN, Inc.

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Notice

The information in this manual has been carefully checked and is believed to be accurate. ***CROPSCAN, Inc.*** assumes no responsibility for any inaccuracies that may be found. ***CROPSCAN, Inc.*** will not be liable for direct, indirect, special, incidental, or consequential damages resulting from any error in or ommission from this manual.

Contents of this manual and reference are subject to change without notice.

Warranty

All parts of the Data Logger Controller and Multispectral Radiometer are warranted by ***CROPSCAN, Inc.*** against defects in material and workmanship for one year from the shipping date to the original purchaser. If any part of the system manufactured and sold fails to operate properly as specified in the USER'S MANUAL during the applicable warranty period, ***CROPSCAN, Inc.*** will replace the defective part or restore it to its normal operation without charge for parts or labor.

In order to obtain redress under the terms of the warranty, the customer must notify ***CROPSCAN, Inc.*** of the defects before the expiration date of the warranty period and make suitable arrangements for performance of the repair service. Transportation to ***CROPSCAN, Inc.*** and return are a customer expense. Liability is limited to repair or replacement of defective parts. Damage due to abuse, accident, alteration or corrosion are not covered by this warranty. No other warranty is expressed or implied.

Other than the obligation of ***CROPSCAN, Inc.*** expressly set forth herein, ***CROPSCAN, Inc.*** disclaims all warranties of merchantability or fitness for a particular purpose. The foregoing constitutes ***CROPSCAN Inc.*** & Deltek Development's sole obligation and liability with respect to damages resulting from the use or performance of the instruments and in no event shall ***CROPSCAN, Inc.*** & Deltek Development or its representatives be liable for

damages beyond the price paid for the instruments, or for direct, incidental or consequential damages.

Repair policy following warranty expiration: Ship the defective component to ***CROPSCAN, Inc.*** Charges: Labor at $40.00 per hour plus cost of defective parts and return shipping costs (labor rate subject to change without notice).

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Table of Contents

Greeting

Thank you for your purchase of the ***CROPSCAN*** Data Logger Controller (DLC) and MultiSpectral Radiometer (MSR).

With a minimum of maintenance and proper handling, the DLC will serve as a handy companion for your data acquisition or control and remote sensing applications.

Please take a moment to read the warranty terms and conditions, on the opening pages of this manual.

Notation Conventions

The following notation conventions will be used throughout this manual.

Italics	Used for variables and placeholders that represent the type of text to be entered by the user.
<Keys>	Used for specific keys to be pressed on the keyboard or keypad.
[Bracketed items]	Used to identify optional parameters or optional user input.

Introduction

You should find the DLC to be an easy-to-use data logger or controller system. Much attention was given to the ease-of-use concept during the development of this system. The DLC operates from a high level menu driven interface.

For the application of data acquisition from a multispectral radiometer a specialized operations program, MSR.BAS, is provided to meet your needs. This program is loaded into the DLC memory, replacing the normally resident DLC operating program. This program will remain in memory as long as power is supplied to the DLC by either battery pack or by an AC to DC 12 volt converter. The DLC has a memory backup capacitor which will permit power source changes without loss of program or data. If for some reason the MSR operations program is lost, it must be reloaded into DLC memory. To do this follow the directions given in the HOW TO section of this manual.

At this point you are probably anxious to get your DLC hooked-up and running. That is great! The next section, Quick Setup and Checkout, will help you do that.

Extensive instructions on how to perform various procedures with the MSR are provided in the HOW TO sections of this manual.

Specifications of the MSR87, MSR5, MSR16, MSR16R and cable wiring are given in the appendix. For DLC specifications refer to the DLC User's Manual and Technical Reference.

The ***CROPSCAN*** Multispectral Radiometer System was designed for unitless percent reflectance measurements. Calibration of each wavelength in absolute spectral irradiance units is possible, but is not supported by the calibration procedures outlined in this manual.

Aside from the MSR menu interface, the DLC supports direct entry of commands to control and configure many of its' operations. Though the high level menu interface may serve most uses, the command entry method can be quicker in instances where you have learned a particular command syntax. The command mnemonics are also useful if the screen of the terminal, such as the CT100 hand terminal, limits the display to one or two lines by 16 characters. Refer to appendix B for the MSR mnenonic commands.

COMMUNICATIONS PARAMETERS

Parameters for comunications between a PC and the DLC are pre-established in the TERMINAL program included on the MSR Programs diskette. If you wish to use a different communictions program on the PC you must set the communications parameters as follows. (The example is the setup for PROCOMM).

COMMUNICATIONS PARAMETERS

Baud Rate 9600
Parity ..... None
Data Bits 8
Stop Bits 1

ASCII TRANSFER SETUP

ASCII UPLOAD

1) Echo locally ..... No
2) Expand blank lines ..... Yes
3) Pace character ..... 0 (ASCII)
4) Character pacing ..... 100 (1/1000 sec)
5) Line pacing ..... 10 (1/10 sec)
6) CR translation ..... None
7) LF translation ..... None

ASCII DOWNLOAD

8) CR translation ..... None
9) LF translation ..... None

TERMINAL SETUP

---

1) Terminal emulation ..... ANSI-BBS
2) Duplex ..... FULL
3) Flow control ..... XON/XOFF
4) CR translation (in) ..... CR
5) CR translation (out) ..... CR
6) BS translation ..... DEST
7) BS key definition ..... BS
8) Line wrap ..... ON
9) Scroll ..... ON
10) Break length (ms) 350
11) Enquiry (CTRL-E) ..... OFF

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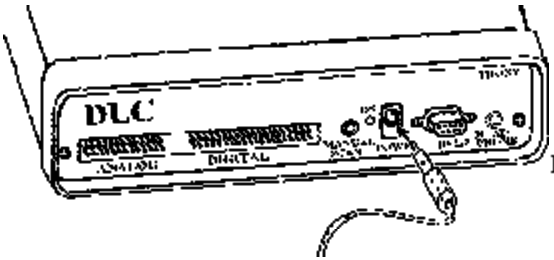
QUICK SETUP AND CHECKOUT

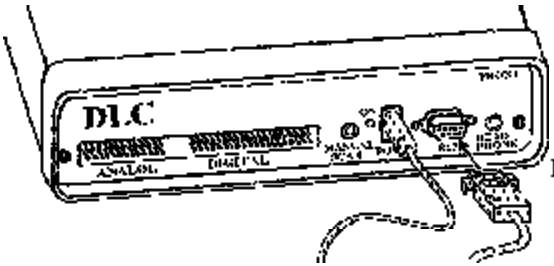
Follow these steps:

1) Connect the DLC to a 12 Volt power source (AC to DC adapter, internal NICAD battery pack, or external battery pack).



Front Panel

2) Connect the DLC to a personal computer or ASCII terminal using the appropriate RS232 cable. (If you are supplying your own cable, refer to appendix for cable wiring information).



Front Panel

3) If you are using a PC with a hard drive, make a directory named MSR and copy the contents of your program diskette to it. Type MSRMENU to display the programs and examples. Position the cursor over TERMINAL and press Enter. Follow the instructions displayed by the TERMINAL program to establish communication with the DLC..

> Most any RS232 serial communications program, such as QMODEM, PROCOMM, or PC-TALK, etc. for the PC compatibles, will work for communications with the DLC.. Many laptop computers have a built-in communication program which may also be used. If your computer or terminal can interface to another computer or terminal, using an RS232 interface, chances are that it can interface it to the DLC also.

The first Enter will wake (power-up) the DLC if it was off (Power LED off), the second Enter will be used by the DLC to automatically adjust to the baud rate you are using, and the third Enter is a verification check that it is the Enter key being pressed.

After waking up, the DLC will only wait for a key for about 5 seconds. If no character is received, after 5 seconds, the DLC will simply go back to sleep.

After pressing Enter the first time the power-on LED will come on. After the third press of Enter the following logo will appear on the screen.

```
DATA LOGGER CONTROLLER (DLC)
Copyright 1992-1994 by CROPSCAN INC.
and DELTEK DEVELOPMENT
```

If your DLC is loaded with the MSR program the following logo will appear on the screen.

```
MULTISPECTRAL RADIOMETER (MSR)
Copyright 1992-1995 by CROPSCAN INC.
```

If the above logo does not appear, the MSR program is not loaded into the DLC memory. The multispectral radiometer program MSR.BAS must be loaded into the DLC memory. If you ordered and received a DLC Memory Card with your system, load the MSR.BAS program from it (Refer to the HOW TO USE THE MEMORY CARD section, menu item 5), otherwise refer to the HOW TO UPLOAD MSR.BAS TO THE DLC (from a PC) section.

The program will then proceed and display the number of wavelengths currently configured for recording. At this point, you can either return to the MSR main menu or proceed with the MSR program.

```
MSR PROGRAM
8 WAVELENGTHS
Enter or M-MenuM
```

Press M to return to the MSR MAIN MENU.

```
          MSR MAIN MENU
1 Config-Status
2 ReConfigure      7 Memory Card
3 Retrieve Data    8 MSR Program
4 Clear Data       9 Exit MENU
5 View            10 BYE
Enter Selection/Command
 *
```

Congratulations! You have successfully connected and brought up your DLC with the MSR operating program on it. If you were unsuccessful, recheck the RS232 cable connections and the parameter selections for communication and try again.

Now proceed to the instructions for checkout of your radiometer on the following pages.

RADIOMETER CHECKOUT FOR THE MSR87, MSR5

Follow these steps:

1) Plug one end of cable MSR87C-9 into the DB25 socket on the radiometer and plug the MSRCA adapter into the other end.

2) Plug the 26 pin female header of the adapter into the 26 pin male header of the DLC. The brown ribbon cable wire must be to the left side.

3) Position the radiometer under a light source such as a desk lamp.

At the MSR MAIN MENU prompt enter RECORD:1-16 for MSR87 to configure channels 1 through 16 for recording. For MSR5 enter RECORD:1-10. Refer to the HOW TO SPECIFY ITEMS FOR RECORDING for more information. From the MSR MAIN MENU choose number 5

```
         MSR MAIN MENU
 1 Config-Status
 2 ReConfigure      7 Memory Card
 3 Retrieve Data    8 MSR Program
 4 Clear Data       9 Exit MENU
 5 View            10 BYE
Enter Selection/Command
*5
```

The following display should appear followed by the millivolt output of each of the channels of the MSR87 radiometer.

```
Press M for mV,
R for %Refl.,
U for Units,
1-9 for # of columns,
Q or Enter to Quit
IRR:   81.3 mV
DATE: 10151993
TIME:    84802
```

Press 2 to display the millivolt outputs in two columns. The odd numbered channels (left column) will display the up-facing sensor readings while the even numbered channels (right column) will display the down-facing sensors readings.

```
IRR:   81.5 mV
DATE: 10151993
TIME:    84811
  1: 25.8725  2: 1.3762
  3: 123.7014  4: 1.9739
  5: 223.1522  6: 1.1139
  7: 482.6625  8: 1.7899
  9: 1101.3515  10: 1.6069
  11: 1266.2639  12: 1.8833
  13: 1363.6155  14: 1.0247
  15: 1279.4700  16: 1.4475
```

The display will be refreshed every few seconds with millivolt output from the radiometer sensors. Turn the radiometer over to display the millivolt output of the normally down-facing sensors (observe right column).

Change in the output of the sensors can be observed when changing the irradiation from the light source. If the output of any of the sensors does not change with changing irradiation or the output of any sensor is near zero when irradiated, contact CROPSCAN, INC.

Press Q to quit the millivolt display and return to the MSR MAIN MENU.

4) Finally, select 10 to put the DLC to sleep. The message

```
Returning to sleep...BYE
```

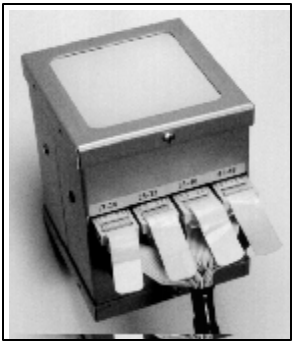
will appear and the power-on LED on the DLC will go out.

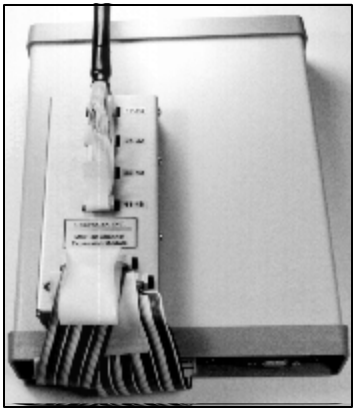
Congratulations! You have successfully connected the MSR87 or MSR5 radiometer and have checked the output of the sensors.

RADIOMETER CHECKOUT OF THE MSR16

Follow these steps:

1) Plug each of the 10 pin female connectors of the cable (MSR16C-9) into the corre - sponding 10 pin male headers on the MSR16 radiometer as pictured at the right.





2) Plug each of the other 10 pin female connectors into the corresponding 10 pin headers of the MSR32 channel adapter as pictured at the left.

3) Connect the MSR32 channel Adapter to the DLC with the two 6 inch ribbon cables.

4) Position the radiometer under a light source such as a desk lamp.

At the MSR MAIN MENU prompt enter RECORD:17-32GAD4 to configure channels 17 through 32 for viewing or recording. GA means gain-automatic. D4 means display to 4 decimal places. If you have a number of MSR16 wavelength modules other than 8 or located in different channel positions then enter the appropriate channel number range. Refer to the HOW TO SPECIFY ITEMS FOR RECORDING for more information.

From the MSR MAIN MENU select number 5.

```
          MSR MAIN MENU
 1 Config-Status
 2 ReConfigure      7 Memory Card
 3 Retrieve Data    8 MSR Program
 4 Clear Data       9 Exit MENU
 5 View            10 BYE
Enter Selection/Command
*5
```

The following display should appear followed by the millivolt output of each of the channels of the MSR16 radiometer.

```
Press M for mV,
R for %Refl.,
U for Units,
1-9 for # of columns,
Q or Enter to Quit
IRR:   81.3 mV
DATE: 10151993
TIME:    84802
```

Press 2 to display the millivolt outputs in two columns. The odd numbered channels (left column) will display the up-facing sensor readings while the even numbered channels (right column) will display the down-facing sensor readings.

```
IRR:   81.5 mV
DATE: 10151993
TIME:    84811
   3: 1292.8   4: 0.1423
  17: 5.8725  18: 1.3762
  19: 23.7014  20: 1.9739
  21: 23.1522  22: 2.1139
  23: 82.6625  24: 1.7899
  25: 101.3515  26: 2.6069
  27: 266.2639  28: 1.8833
  29: 363.6155  30: 2.0247
  31: 279.4700  32: 1.4475
```

The display will be refreshed every few seconds with millivolt output from the radiometer sensors. Turn the radiometer over to display the millivolt output of the normally down-facing sensors.

> Change in the output of the sensors can be observed when changing the irradiation from the light source. If the output of any of the sensors does not change with changing irradiation or the output of any sensor is near zero when irradiated, contact CROPSCAN, INC.

Press Q to quit the millivolt display and return to the MSR MAIN MENU.

4) Finally, select 10 to put the DLC to sleep. The message

```
Returning to sleep...BYE
```

will appear and the power-on LED on the DLC will go out.

Congratulations! You have successfully connected the MSR16 radiometer and have checked the output of the sensors.

USAGE

The ***CROPSCAN*** system of multispectral radiometry has been developed and tested over a period of several years involving experiments on remote sensing of barley foliar diseases. It has also been used to measure reflectance from canopies of wheat, oats, potatoes, alfalfa, soybeans, range grasses, and peanuts. Reports from you regarding other applications are welcome.

The design of the radiometer allows for near simultaneous inputs of voltages representing incident as well as reflected irradiation. This feature permits accurate measurement of reflectance from crop canopies when sun angles or sunlight conditions are less than ideal. Useful readings may even be obtained during cloudy conditions. This is a very useful feature, especially when traveling to a remote research site only to find the sun obscured by clouds.

The system weighs less than 6 Kg. so it is easily hand carried from plot to plot. This allows readings any place, anytime, even in farmers fields where measurement of reflectance with other systems requiring mobile platforms would be restricted.

The use of a high speed A/D converter in the DLC coupled with a portable computer or terminal allows for efficient input and convenient storage of data in DLC RAM. Data collected may be downloaded to memory card or computer. Additional software permits timely analysis of the data.

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APPLICATIONS

Percent reflection of radiation of the various wavelengths is influenced by any condition that influences the normal growth of plants. The radiometer is therefore particularly useful as an objective and efficient means of estimating the effects of any condition that affects plant health on yield or quality of the crop.

Some applications follow:

- o Inputs into models:
  - describing normal plant growth.
  - describing plant canopy color.
  - for estimating vegetation biomass.
  - for estimating crop yield components.
  - for estimating crop quality factors.
  - for estimating leaf area index.
  - for estimating crop yield and quality loss due to
    - disease
    - insect infestation
    - air pollution.
    - nutrient deficiencies.
    - chemical phytoxicity.
- o Objective rating of foliar diseases.
- o Evaluation of plant growth modifiers.
- o Monitoring effects of herbicide activity.
- o Soil amendment and fertility studies.
- o Leaf feeding studies.
- o Irrigation scheduling studies.
- o Effects of drought on plant growth and yield.
- o Characterization of different genotypes.
- o Evaluation of experimental area variability.

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OPTIONAL ADDITIONAL EQUIPMENT

1. CT100 ASCII terminal. This small, light weight CMOS terminal draws its power from the DLC. The LCD screen is 16 characters X 2 lines. The MSR program was designed so this small screen size is adequate for multispectral radiometer data acquisition needs.

2. Tandy Model 100/102 portable computer. This computer can draw its power from internal batteries or from an external battery pack. The built in communications program is ideal for communicating with the DLC. The menus for the MSR are designed to be properly displayed on the Model 100/102 screen.

3. If using the Tandy Model 100/102 portable computer, a Radio Shack CCR-81 cassette tape recorder with connecting cable or the portable 3 1/2 inch disk drive Model 2.

4. Almost any battery powered laptop portable computer with a communications program such as PROCOMM, QMODEM or PC-TALK can be used with the DLC in the field. Mounting of the laptop on the support pole is the users responsibility.

5. A 12 volt battery pack as a source of external power for the DLC as well as the portable computer.

6. Epson memory card. These credit card sized memory cards provide a very fast, efficient method of storing programs or data. See the section on MEMORY CARD for sizes and specifications.

7. Small light weight ear phones to aid in hearing audible beeps generated by the MSR program.

8. A standard cooler chest makes a convenient, dust proof container to transport the equipment to and from the field. It also helps keep the equipment cool on hot sunny days.

9. Manual Scan Switch

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THEORY OF OPERATION

The MSR System operates by converting incoming or reflected irradiance to a millivolt signal for subsequent analog-to-digital (A/D) measurement conversion and storage by the Data Logger Controller (DLC).

Incoming or reflected irradiance is first bandpass filtered with interference type filters. The irradiance that passes through the filter then strikes the surface of a photodiode and is converted into an electrical current. This current is converted into an electrical voltage by integrated electronic amplifiers and is conducted by cable through analog multiplexers to the analog-to-digital converter of the DLC.

Use of the radiometer is based on the assumption that the irradiance flux density incident on the upward facing sensors is equal to the irradiance flux density incident on the target surface. This is a valid assumption when the radiometer is used in sunlight, where the source of light is a long distance from both the radiometer and the target surface.

COSINE RESPONSE AND CORRECTION

An opal glass is used over the upward facing sensors as a cosine transmitting diffuser. A cosine transmitting diffuser is one which transmits irradiance with intensity that varies with the cosine of the angle of incidence of the irradiance on the transmitting diffuser surface.

Clear glass is used over the downward facing sensors. It is assumed that the surface from which reflectance is to be measured exhibits lambertian reflectance properties. A lambertian surface is one for which the reflected radiance is isotropic with the same intensity for all directions regardless of how it is irradiated. The radiant intensity of the reflected irradiance from a lambertian surface varies with the cosine of the angle of incidence of the irradiance.

Use of the glass covers also keep the sensors clear of contamination.

The cosine properties for both upward and downward sensors allow the ***CROPSCAN*** Multispectral Radiometers to inherently correct for varying angles of irradiance. The cosine diffusing property of the opal glass, though not perfect, is quite good in the visible and Near Infra-Red (NIR) (460-1200 nm) regions. Above that, the cosine diffusion property tapers off quite rapidly and corrections must be made in software. There is no known material that provides for good transmitting diffusion for longer wavelength irradiance.

CROPSCAN, Inc. provides cosine response calibration data with each upward facing MSR16 module and includes the cosine correction in the post-processing software (POSTPROC program) provided with the MSR System.

TEMPERATURE CORRECTION

Silicon or germanium photodiodes are used as the irradiance detectors. These devices exhibit excellent linearity with respect to irradiance intensity. Silicon and germanium photodiodes exhibit temperature sensitivity, germanium more so than silicon. Typically, silicon photodiodes are used for 460 to 1000 nm wavelength sensors and germanium photodiodes are used from 1000 nm to 1650 nm.

Both the MSR sensor dark reading (millivolts with no irradiance) and the responsivity (millivolts per watts/m^2 of irradiance) are affected by temperature changes. ***CROPSCAN, Inc.*** provides temperature sensitivity calibration data with each MSR16 sensor and includes temperature correction in the post-processing software (POSTPROC program) provided with the MSR System.

CALIBRATION METHODS/CONSIDERATIONS

There are two methods of measuring reflectance with the CROPSCAN MSR system and three associated methods of calibrations. Reflectance may be measured with either downward facing sensors only or with both upward and downward facing sensors.

USING DOWN ONLY SENSORS

When downward-only facing sensors are used a white standard card with known spectral reflectance must be used as a measurement reference. Reference readings must be taken at intervals sufficiently frequent to compensate for sun movement. The frequency of white standard reference readings will depend on rate of change of the solar irradiance at your location, time of day and your tolerance of solar irradiance change between white standard readings. At some locations, the irradiance change can range from near 1 percent per hour near solar noon to about 47 percent per hour at 60 degree sunangle. If your reference accuracy requirement is 1 percent then you would only need to take white card reference readings about 2 to 3 times per hour near solar noon with increasing frequency per hour up to about once per minute at 60 degree sunangle (early morning & late afternoon). To help you plan your sample times and white standard reference measurement frequencies use the SAMPTIME program.

USING UP AND DOWN SENSORS

Either of two calibration methods may be used when both the up and down MSR sensors are used. The first makes use of an opal glass and is called the two-point (2-Pt.Up/Dn) method. The second makes use of a white standard card and is called the White Standard Up/Dn method (WhiteStd.Up/Dn).

The two-point method uses the opal glass to provide the same irradiance alternately to the up and down sensors positioned at 45 degrees to the sun. It is a convenient method of calibration and can be easily performed in the field. Calibration at 45 degrees to the sun is necessary for accurate sunangle cosine correction by the post processing software.

The white standard up/dn method uses a white card with known reflectance. The radiometer is held perpendicular over the white standard which is positioned at 45 degrees to the sun. The calibration readings from the down

sensors are transferred to the up sensors. As for the two-point method above, calibration at 45 degrees to the sun is necessary for accurate sunangle cosine correction in the post processing software. For wavelengths above 1200 nm, the white card provides a better lambertian source of irradiance than does the opal glass of the two-point method.

OPERATING PROCEDURES IN THE FIELD

1) Mount the radiometer pole bracket on the pole and attach the radiometer.

2) Mount the spirit level attachment to the pole at a convenient viewing position.

3) Lean the support pole and radiometer against a support and adjust it so that the top surface of the radiometer is level.

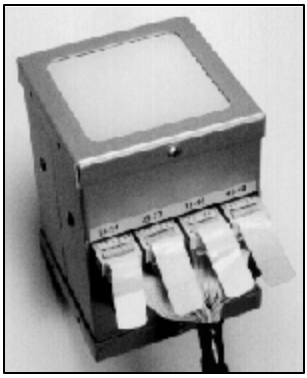
4) Adjust the spirit level to center the bubble. This will insure that the top surface of the radiometer and spirit level are par level.

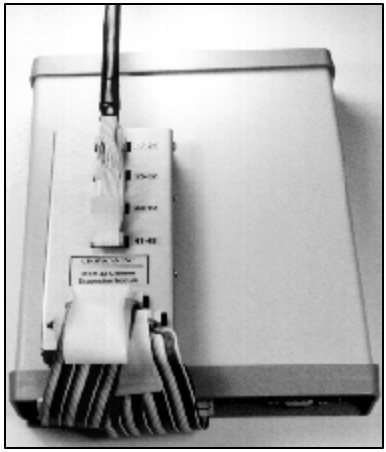
FOR MSR87 OR MSR5:

5) Attach the 9 ft. cable MSR87C-9 with the DB25-male connector to the radiometer and to the ribbon cable adapter MSRCA. Plug the 26 pin female socket of the adapter into the 26 pin male header of the DLC. The brown stripe on the ribbon cable is on the left edge. The DLC may now be placed in the DLC shoulder pack for easy carrying.

FOR MSR16:

5) Attach the 9 ft. cable MSR16C-9 to the radiometer and to the MSR32CHA 32 channel adapter. Connect ribbon cables IOARC-6 and IODRC-6 from the 32 channel adapter to the DLC. The DLC and MSR32CHA may now be placed in the DLC shoulder pack for easy carrying.





6) If you are using the CT100 terminal, mount the pole mounting bracket CT100B on the support pole at a convenient position. (If you are using any other portable computer, attaching it to the pole is your responsibility).

7) If you are using the CT100 terminal, plug the cable CT9M9M-5 into the RS232 connectors of the CT100 and the DLC. Otherwise, use the appropriate cable from your computer to the DLC RS232 connector. Using a small screwdriver, secure the connectors by tightening the connector screws.

8) Adjust the radiometer to a suitable height over the target. The diameter of the field of view is one half the height of the radiometer over the target.

9) Turn the power to the computer on. If you are using a CT100, switch the CT100 power switch to ON.

10) When finished with taking readings of the experimental plots, put the DLC to sleep. (At the MSR MAIN MENU type 10 and press Enter). Switch the CT100 power switch to OFF to prevent battery drain.

TAKING READINGS

If you are using a PC compatible laptop, start the TERMINAL program or load a communicaions program and set the communications parameters for 8 data bits, no parity and 9600 baud.

Press the Enter key 3 times at approximately 1 second intervals. The MSR program will appear on the screen.

```
DATA LOGGER CONTROLLER (DLC)
Copyright 1992-1994 by CROPSCAN INC.
and DELTEK DEVELOPMENT

MULTISPECTRAL RADIOMETER (MSR)
Copyright 1992-1995 by CROPSCAN INC.

MSR PROGRAM
 16 WAVELENGTHS
Enter or M-Menu
```

The number of wavelengths shown depends on which and how many channels are configured for RECORDing. If your radiometer has been adjusted, calibrated, configured for your experiment, and location have been entered, you are ready to proceed with making readings. If it has not been correctly configured for your experiment, press M to return to the MAIN MENU and reconfigure. (See the HOW TO Reconfigure the MSR section of this manual).

Press Enter to proceed with the program.

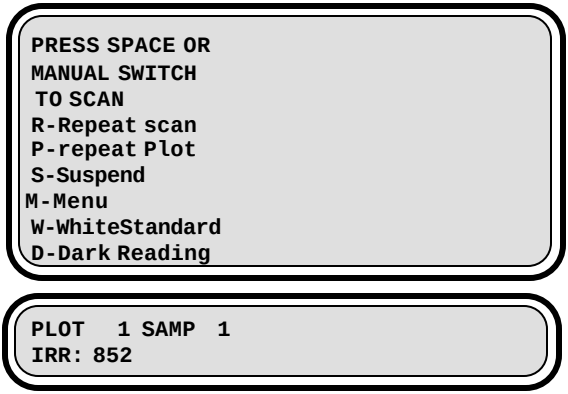
```
RECORD:
1 EVERY SS.
2 AVERAGE SS.1
```

Choose 1 to record every Sub-Sample per plot or choose 2 to record the average of the Sub-Samples.

```
AUTO PLOT #s
BEGIN PLOT#:1
END PLOT#:80
```

If automatic sequential plot numbering is configured. Any plot number may be chosen for the beginning plot number but the ending plot number cannot exceed 99999999. If manual plot numbering is configured, any plot number up to 99999999 may be entered. Spaces are ignored.

After entering the beginning and ending plot numbers, the following information is displayed.



The present plot and sample numbers are then displayed. If the system was configured for 'automatic' plot numbering (Mode:Auto) and 'Space Key' scan initiation then the present plot and sample numbers will be followed by the display of the real time output of the up-facing sensor configured to simulate a pyranometer. The irradiance value is refreshed constantly until a scan is initiated. If the system was configured for 'automatic' plot numbers and scan inititaion by 'Push-Button' then the DLC will automatically go to sleep (power-off) after the present plot and sample numbers are displayed. The computer or hand-terminal may then be disconnected. The MSR system can then be used to obtain readings by use of the manual push-button scan switch. The DLC will wake-up to take the scan readings when the hand-switch push-button is pressed. After the scan has been taken, the sample and plot numbers will be automatically incremented and the DLC will go back to sleep and wait for the next push-button scan initiation. Operation in this manner can extend the number of plots that can be read because the DLC does not consume very much power when 'sleeping' between readings.

In the field, lean the support pole over the plot, point the radiometer towards the sun and center the bubble in the circle of the spirit level. It is important to keep the radiometer pointed towards the sun and level during the scan to insure accurate percent reflectance data.

Initiate a scan by pushing the space key or space bar or by pressing the hand held push-button switch momentarily.

The message ‘scanning...’ will appear on the screen. Simultaneously, an audible beep will be heard. When the scan is complete (about two seconds) two asterisks ‘**’ will be displayed and simultaneously, two beeps will be heard.

At this time you can move to the next plot during which time the data is recorded and the word 'Done' appears. Simultaneously three beeps will be heard. The beeps may be heard more easily if you use ear phones plugged into the ear phone jack on the DLC. The beeps are provided for operation feedback where the MSR system is being used with a hand push-button scan switch and a terminal is not being used. If the space bar is held down too long, another scan will be automatically made. If an extra scan is made inadvertently, you can repeat the scan by pressing the R key. To repeat scans on a plot, Press the P key. In the automatic mode the same plot number will be displayed and the data for that plot will be erased. In the manual mode, the plot number may be re-entered.

To suspend operations after the plot number has been displayed (auto mode), or manually entered (manual mode), press the S key. The DLC will go to sleep and resume operations exactly where you left off upon a restart by pressing the Enter key three times. If you use the CT100 hand terminal, switch the power to OFF to reduce power drain until you are ready to resume operations.

After completing a data collection, the data should be downloaded to a file in the portable computer or stored to a memory card.

It is most efficient to use the automatic sequential plot numbering method of making scans. Taking two samples per plot, records of each plot will take approximately 15 to 20 seconds depending on how far you must walk between plots.

You may return to the MSR MAIN MENU at any time by pressing the M key except if sub-samples are being averaged, the M may be entered after the last sub-sample.

You cannot reconfigure RECORDed items without first clearing the memory. Before the memory is cleared, save the contents of memory, by first downloading it, using the RETRIEVE program, to the computer or by storing it to a memory card.

Readings in the field should be made when the sunangle is less than 60 degrees. Readings taken during cloudy conditions will not be exactly the same as when
the sun is unobscured. Corrections in percent reflectance for each wavelength due to variability in incident irradiation must be determined experimentally. Corrections for sunangle and cloud cover will depend on intensity of incident irradiation as recorded with each scan (IRR), the nature of the crop, its stage of growth and ground cover.

The system is designed to be easily hand carried from plot to plot for data acquisition. The maximum height of the radiometer over the target is approximately 10 feet with the support pole fully extended. To access data over a wider area, the system may be carried on a truck or tractor platform or cherry picker. Remember, the diameter of the field of view is one-half the height over the canopy. The data acquired represents the average reflection from the area sampled. Theoretically, the greater the distance from the canopy, the more valid will be the reflectance data. To acquire data from smaller plots, the radiometer may be lowered so the diameter of the field of view is less. Under these conditions, you may wish to take more samples to maximize the accuracy of the data.

The 0.6Ahr NICAD batteries should operate the system continuously for about 6 hours. If the battery voltage falls below 8.6 volts, a warning BEEP and message appears. The batteries should then be charged for about 12 hours by plugging in the AC-to-DC 12 volt converter.

STORAGE CAPACITY

The number of DataPoints capacity of the DLC for each DLC system RAM size is:

U21	U20	Total	DataPoints
32K	32K	64K	5,461
128K	--	128K	16,384
32K	128K	160K	21,845
128K	32K	160K	21,845
128K	128K	256K	38,229

U20 and U21 refer to memory chip locations inside the DLC.

The RECORD items of the MSR are:

ID,LOC,DATE,TIME,IRR,PLOT#, SS#, BAT,+5V,T,channels

You may choose any of these items to record.

DATE, TIME, IRR, PLOT#, AND SUBSAMPLE# ARE ALWAYS RECORDED.

For the MSR16, channel 3 (radiometer temperature) and channel 4 (ground mV) are also always recorded. For MSR5, channel 15 (radiometer temperature) is always recorded. Each item requires one datapoint of storage per recording scan.

A typical RECORD configuration for an MSR87 might be:

ID,LOC,DATE,TIME,IRR,PLOT#,SS#,1-16

or 23 datapoints per recording scan. For an MSR16 the channel range might be 17-32GAD4 for 8 wavelengths instead of 1-16 and it would require 25 datapoints instead of 23 because channel 3 (radiometer temperature) and channel 4 (ground mV) are also always recorded. For an MSR5 the channel range might be 1-10 for 5 wavelengths, with 18 data points recorded.

Correspondingly, the scan recordings capacity in terms of plots and sub-samples would be:

Typical Storage Capacity with an MSR87 (23 items/scan) or MSR16 (in

RAM Total	DataPoints	#Plots SS.Avg'd	#Plots (each SS recorded) SS=2	#Plots (each SS recorded) SS=4	#Plots (each SS recorded) SS=8
64K	5,461	237 (218) [303]	118 (109) [151]	59 (54) [75]	29 (27) [37]
128K	16,384	712 (655) [910]	356 (327) [455]	178 (163) [227]	89 (81) [113]
160K	21,845	949 (873) [1213]	474 (436) [606]	237 (218) [303]	118 (109) [151]
256K	38,229	1,662 (1,529) [2123]	831 (764) [1061]	415 (382) [530]	207 (191) [265]

parenthesis, 25 items/scan), or MSR5 [in brackets, 18 items/scan]

Other configurations exist so the number of plots storage capacity will vary accordingly.

PROGRAMS INCLUDED WITH THE SYSTEM

CROPSCAN MSR SUPPORT PROGRAMS

These programs and files are provided with the purchase of a CROPSCAN Multispectral Radiometer System for your use with that system. You may use the programs and programming examples for your use of the DLC, but not as part of any programs for commercial sale or resale without the expressed written agreement from CROPSCAN, Inc.

The MSR Programs diskette contains the MSR operating system program, MSR utility programs, analysis programs, MSR data files, examples of output from analysis of MSR data and DLC users manual examples.

Copy these programs and files to your hard disk in a directory named \MSR. You can practice using the programs on the files.

If you are a Microsoft Windows user and wish to be able launch the CROPSCAN Menu program from the Program Manager screen then see the instructions near the end of this section.

MSR.BAS This is an ASCII text file. It contains the MSR operation program. This program may be uploaded to the DLC or MCR replacing the normally resident DLC operation program. This program will take about 8 minutes (on a 25Mhz PC, longer on a slower PC) to upload to the DLC or MCR using a communications program such as PROCOMM or using the UPLDMSR program, described below.

This program DOES NOT include the calibration coefficients for the radiometer. The MSR.BAS program, calibration coefficients and variables may be stored on a memory card and then loaded to the DLC. This is a much more efficient method of loading the program and other variables as it takes only a few seconds. If you are uploading the MSR.BAS program from a PC and you wish to retain your existing MSR configuration and calibration coefficients use the SAVECONF program, described below, before and after the MSR.BAS upload.

The raw data is stored as millivolts in DLC memory. The configuration/status, calibration coefficients and data are downloaded to a PC by using a communications program or the utility program RETRIEVE described below. Raw

data should be saved to filenames with the extension .MV. The program POSTPROC is used to process the raw data and save it to a file with the extension .RFL. The processed data is formatted with text and commas so it may be imported into databases and spreadsheets.

Several programs are supplied to operate on the files created by the POSTPROC program or on ancillary data files if properly formatted. All programs require an asterisk (*) in the line that precedes the first line containing data. Any number of lines of comments may precede this asterisk. When downloading a MSR raw data set from the DLC to a PC using a communications program, always choose ALL to download the configuration/status and calibration constants as well as the data. The program RETRIEVE does this for you automatically.

MSRMENU Cropscan Multispectral System Menu. Executable program designed to run on a PC. To run the program, simply type MSRMENU and choose from the menu the following programs or sub-menus.

FORMAT Selection brings up a menu of the following programs that perform various data formatting.

FACTORID Prepares a file containing experimental factor identifiers and optionally, row and column identifiers for each plot. Usually an experiment is designed so that statistical analysis can be performed on the data. Numbers are assigned to the factors and are entered sequentially by plot number.

EXTRACH Prepares a file containing names and data formatting information for the extra channels configured by the RECORD statement. (For MSR16 only).

PREPROC This program processes data from a stand-alone MSR system running under the DLC.BAS operations program. It combines the data with a calibration file previously retrieved from the MSR.BAS operations program on that same system. A .MV file is produced for input to the POSTPROC program.

TERMINAL A program that enables communication between a PC and the DLC or MCR and provides a direct operator interface to the DLC or MCR.

RETRIEVE Retrieves configuration/status, calibration constants and raw data from the DLC or Memory Card in an MCR and stores it in a PC file.

POSTPROC This program processes data files retrieved from the MSR program in the DLC. The program will access the *.ID file and merge EXPERIMENT FACTOR NAMES after 'PLOT' in the header and row numbers, column numbers and numerical factor identifiers after the PLOT NUMBER in the data records. If extra channels are configured, the program will access the *.EX file and merge extra channel names after 'SS' (subsamples) in the header. In addition, this program will apply sensor sunangle cosine corrections (based on date, time, latitude and longitude) and sensor temperature corrections to the millivolt readings before calculating percent reflection. The data file from the DLC must be saved with the extension .MV. After processing, the new file will be saved with the extension .RFL.

UPLDMSR Uploads the MSR program from the MSR.BAS PC file. Use this if you happen to reset your DLC and do not have a backup copy of the MSR program/configuration on Memory Card. Newer versions of the MSR program, distributed on PC diskettes, may be uploaded to the DLC or MCR using this UPLDMSR program.

SAVECONF Saves/Restores MSR configuration and calibration coefficients to/from PC files. This program allows you to maintain multiple MSR configurations and to quickly reload them to the MSR program. It may be handy for transferring an existing configuration to a newer level of the MSR program, assuming sufficient MSR level-to-level compatibilities. Typically, it would be done as follows:

1) Run SAVECONF to save current configuration and calibration coefficients to a PC file.
2) Run UPLDMSR to upload the new MSR level to the DLC or MCR.
3) Run SAVECONF to restore configuration and calibration coefficients from the PC file.
4) Start MSR program on the DLC and save the Program/ Configuration to Memory Card as a backup copy.

Otherwise, reconfiguring a newly uploaded MSR program

would have to be done by hand and would require either recalibrating the MSR or re-keying the calibration coefficients. Re-keying the calibration coefficients can be time-consuming and error-prone.

SAMPTIME A program that calculates the allowable MSR sample time windows given its location, date, time, and Greenwich Mean Time difference to your time zone. Sample time ranges are output in tabular report form for you to use in planning your sample schedules.

VIEW Allows view of any ASCII file on any disk or directory.

SORTFILE Sorts a formatted MSR file by any column. It is useful for sorting MSR data and ancillary data by plot number for regression analysis.

ANALYSIS Selection brings up a menu of the following analysis programs.

ANOVA A general analysis of variance program which operates on formatted MSR data files. It will handle any number of factors. Use of the correct mean squares to calculate F values will depend on the experimental design.

NTHREG An nth order multiple regression analysis program which operates on formatted MSR data files (X-data) and on matching ancillary data files (Y-data) sorted by plot number. The program will operate on any set of matching independent (X-data) and dependent (Y-data) variables.

You may always exit from a program and return to MSRMENU by pressing Ctrl-Break (Ctrl and Pause keys simultaneously).

LAUNCHING FROM MICROSOFT WINDOWS

For Microsoft Windows users, an icon file and program interface file (PIF) are included to allow you to launch the CROPSCAN Menu program under a DOS session.

The PIF file sets up the MSRMENU DOS session so it will can run in the background and will get 30% of the CPU while in the background.

> For the Cropscan DOS session to be able to run as a background session, Microsoft Windows must be running in the 386 Enhanced mode. If your windows is not running in enhanced mode then you should not switch away from the session during data or configuration transfers.

To install, follow these steps:

1) Copy CROPSCAN.PIF and CROPSCAN.ICO from the MSR Programs diskette to the C:\MSR directory (or wherever you installed the MSR programs), if you have not already done so. Be sure to use the same directory path in the steps below.

2) At the Program Manager screen in Windows, select a Program Group where you would like to have the Cropscan icon located, click on File, then click on NEW, then on Program Item, and then on OK.

3) In the Program Item Properties box complete as follows:

   Description: DLC
   Command Line: cropscan.pif
   Working Directory: c:\msr

   Click on Change Icon. Click OK on next window. Then in the Change Icon window enter File Name: c:\MSR\CROPSCAN.ICO and click on OK. The icon should appear as the current icon. Click OK again and then again on the next window.

The Cropscan icon should be added to the program group. Now double click on the Cropscan (DLC) icon and the MSRMENU session should start.

DOS COMMAND LINE INTERFACE

The menu-driven interface for the CROPSCAN Multispectral System Menu provides a convenient user-interface for operating MSR related programs. Several of the programs have DOS command line interfaces that allow them to be operated byDOS batch processing (see next section). The command line syntax is described below followed by some examples.

The programs with command line support are RETRIEVE, PREPROC, POSTPROC, and VIEW. The command line parameters are those normally prompted for by each program when run from the system menu driver.

The command line parameters for RETRIEVE are:

RETRIEVE *commport savefilename overwrite cleardata*

commport PC serial communications port to use. Allowable values are 1 or 2.

savefilename PC filename of your choosing. If the data file is to be input to the POSTPROC program you must use a file extension of '.MV'. If the data being retrieved is from a stand-alone or remote MSR system an extension other than '.MV' should be used because a remote data file must first be processed by the PREPROC program, which outputs the data to a file with '.MV' extension for subsequent input to the POSTPROC program.

overwrite Indicates whether or not to overwrite the savefile should one with the savefilename already exist. Use Y for yes and N for no.

cleardata Indicates whether or not to CLEAR the data from the DLC memory if the retrieve of the data is successful. Use Y for yes (clear) and N for no clear.

Example: **`RETRIEVE 1 F0118693.MV N Y`**

Retrieve data using serial comm port 1. If F0118693.MV exists it will not be overwritten. Youwill be prompted for a different file name instead. DLC data memory will be cleared when complete.

The command line parameters for PREPROC are:

PREPROC *datafilename calibfilename outmvfilename overwrite*

datafilename The name of the data file retrieved from a stand-alone or remote MSR system.

calibfilename The name of the calibration filename that was retrieved from the MSR program when the stand-alone or remote MSR system was calibrated.

outmvfilename The name of the output file to subsequently be processed by the POSTPROC program. The extension will automatically be made '.MV'.

overwrite Indicates whether or not to overwrite the output file if it already exists. Use Y for yes and N for no.

Example: **PREPROC F0118693.DAT F0118693.CAL F0118693.MV N**

Preprocesses stand-alone data file F0118693.DAT by combining it with the MSR calibration file F0118693.CAL to produce the output file F0118693.MV. If a file with the same name already exist you will be prompted for different filename.

The command line parameter for VIEW is:

VIEW *filename*

filename The name of an ASCII text filename to be viewed.

Example: **VIEW F0118693.RFL**

Start view program to view percent reflectance file F0118693.RFL.

The command line parameters for POSTPROC are:

POSTPROC *mvfilename mergefactorid* [*idfilename*] [*extrach extrachfilename*]

mvfilename	Retrieved mv data filename or filename of mv file from PREPROC program. The output percent reflectance filename will be the same as the input file except the extension will automatically be made '.RFL'
mergefactorid	Indicates whether or not to merge factor id names into the header of the output percent reflectance file. Use Y for yes and N for no.
idfilename	Filename of the factorid file to be merged. Brackets indicate that parameter is only needed if mergefactorid parameter is 'Y'. Do not include brackets when typing line.
extrach	Indicates whether or not to use extra channel names (for channels 5-10, MSR16 system) and data formats in output percent reflectance file. Use Y for yes and N for no. Brackets indicate that this is optional. If not present then No is assumed.
extrachfilename	Filename of the file containing the extra channel names and data formats.

Example: **POSTPROC F0118693.MV Y F0193.ID Y F0193.EX**

Calculate percent reflectance from data in F0118693.MV, merge factor id names from F0193.ID, and use names and data formats from F0193.EX for extra channels.

Example: **POSTPROC F0118693.MV N Y F0193.EX**

Calculate percent reflectance from data in F0118693.MV, and use names and data formats from F0193.EX for extra channels. No merge of factor ids.

Example: **POSTPROC F0118693.MV N**

Calculate percent reflectance from data in F0118693.MV. No merge

of factor ids and no application of extra channel names and formats.

BATCH PROCESSING

The PC DOS command line prompt capability of the RETRIEVE, PREPROC, POSTPROC, and VIEW programs, described in the previous section, establishes the groundwork necessary to develop DOS batch processing files. Nearly total program automation can then be obtained, taking much of the typing work out of data retrieval and postprocessing.

PC batch files can be created to sequence the RETRIEVE, PREPROC, POSTPROC, and VIEW programs. The parameters (filenames mainly) can either be explicitly specified or can be made as batch file substitution variables. Using subsitution variables provides flexibility for managing data file naming. Batch files can be created with most any ASCII text editor or a PC DOS's line editor.

Example:

Automatically retrieve data from a locally (comm port 1) attached DLC, clear DLC, perform percent reflectance calculations on the data, and view the results. Merge factor ids into output file.

The batch file (call it GET%RFL) could be written as:

```
RETRIEVE  1  F0118693.MV  Y  Y
POSTPROC  F0118693.MV  Y  F0193.ID
VIEW  F0118693.RFL
```

At the PC DOS prompt you only need to type GET%RFL and press enter. The data would be retrieved, processed, and the percent reflectance output displayed for your viewing, all without pressing another key.

This always uses the same filenames. To gain control over the filenaming, yet keep the remainder of the batch file automation, substitution variables could be used in the batch file, as in the following example.

Example:

Automatically retrieve data from a locally (comm port 1) attached DLC, clear DLC, perform percent reflectance calculations on the data, and view the results, but specify filename. Merge factor ids into output file.

The batch file (call it GET%RFL) could be written as:

```
RETRIEVE 1 %1.MV Y Y
POSTPROC  %1.MV  Y  F0193.ID
VIEW  %1.RFL
```

The %1 represents a substitution parameter that is obtained from the DOS prompt line following GET%RFL. At the PC DOS prompt you only need to type GET%RFL followed by the desired data filename (without an extension) something like:

```
GET%RFL  F0218793
```

and press enter. The data would be retrieved, processed, and the percent reflectance output displayed for your viewing, all without pressing another key.

Many other variations of batch processing are possible. Refer to a PC DOS user's manual for more information on batch file programming.

The above example could be extended into automatic loading of the percent reflectance file into a spreadsheet or other post processing programs and additional processing done unique to your use of the CROPSCAN Multispectral Radiometer System.

EXAMPLE DATA FILES

Several files which represent typical MSR data are on the disk. You may view these files, by selecting EXAMPLES from the MSR MENU program, and as a tutorial operate on them using the other programs provided. The raw data of F0118693 is a subset of data obtained from an experiment using a Split Plot Design to determine the effect of inoculation of susceptible and partially resistant cultivars of barley with the spot blotch organism.

F0193.ID — A file containing one or more lines of remarks and a header of acronyms representing factors of the experiment and the numerical representation of these factors for each plot of the experiment. This file is automatically generated by the program FACTORID.

F0118693.MV — A raw MSR data set downloaded from the DLC using the communications program. Note the trailing lines after the last line of data. These lines will present no problem.

F0118693.RFL — The data set after inserting the numbers representing experimental design factors corresponding to the plot numbers and calculation of percent reflection using the program POSTPROC.

F01YLD93.ANC — Yield and other ancillary data obtained from experiment F01.

The following are examples of results from analysis using the programs.

F0118693.ANV — Analysis of variance of the 810 nm data from the file F0118693.RFL using the program ANOVA.

F0118693.SP — Analysis of variance of the 810 nm data from the file F0118693.RFL using the program SPLOT.

F0118693.REG — Estimate of yield from percent reflection of all 8 wavelengths from the files F01YLD.ANC and F0118693.RFL using the program NTHREG.

HELP.TXT — Conventions used for naming DLC and MSR files.

In addition, there are example programs for the DLC. Refer to the DLC USER'S MANUAL AND TECHNICAL REFERENCE for a description of these programs.

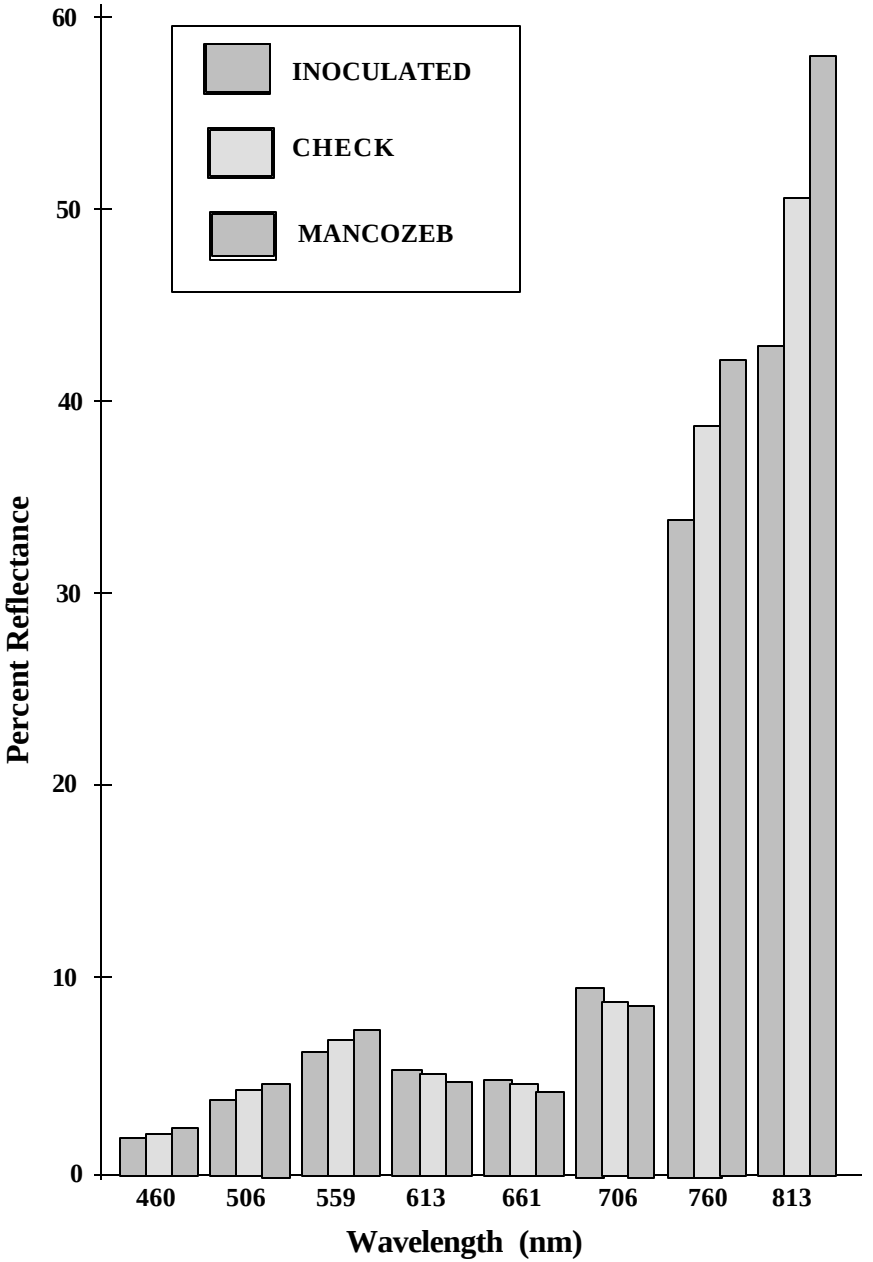


Fig. 1. Percent reflection of 8 wavelengths from plot canopies of Larker barley inoculated with *C. sativus*, not inoculated or treated with mancozeb fungicide.

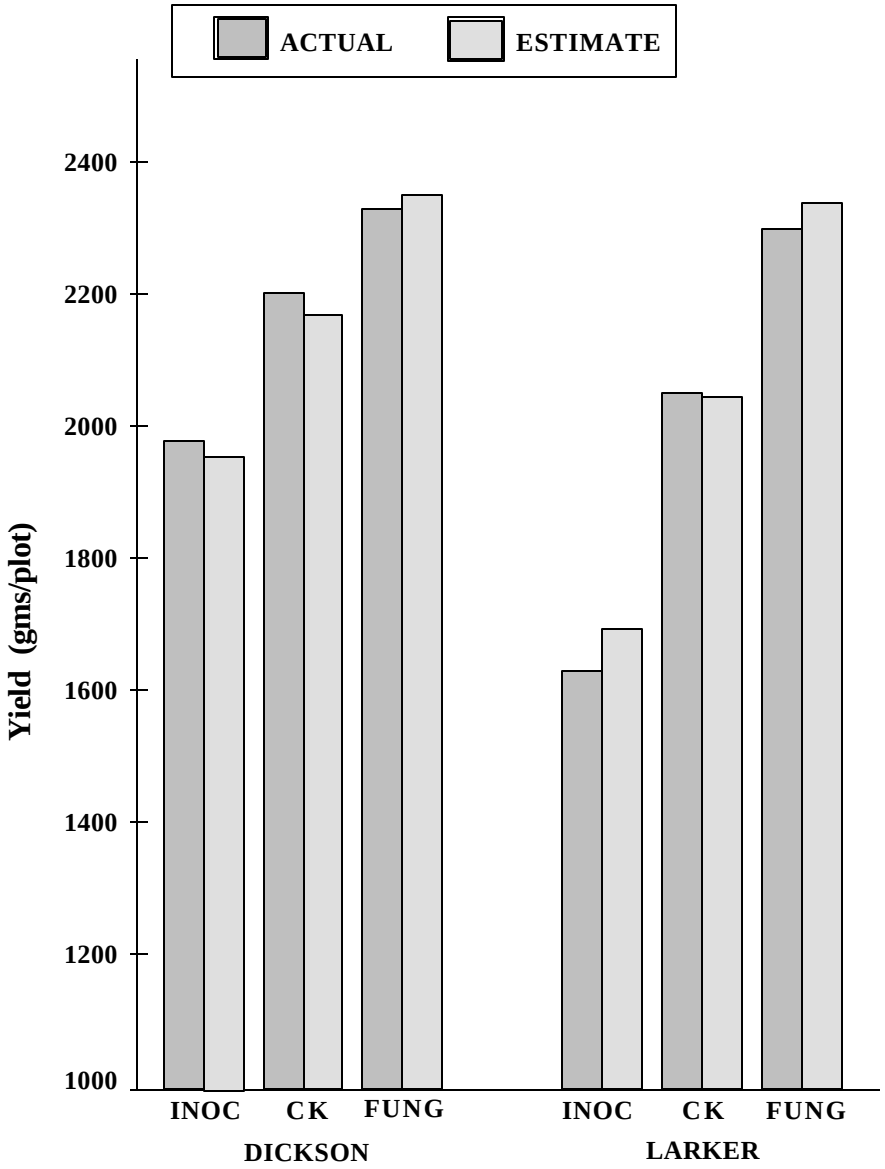


Fig. 2. Actual and estimated yield of Dickson (moderately resistant) and Larker (susceptible) inoculated with *C. sativus,* not inoculated (ck), or treated with mancozeb fungicide. Estimates are based on multiple regression model using percent reflectance of 8 wavelengths from plot canopies.

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HOW TO

RECONFIGURE THE MSR

Bring up the MSR main menu and select #2 'ReConfigure'. The RECONFIGURE MSR menu will be displayed.

```
      RECONFIGURE MSR
1 Date  6 Location 11 Calibrate
2 Time  7 Record   12 Power-Off
3 SS    8 Samples  13 Mode
4 Rem   9 GMT Difference
5 ID   10 IRR       M Main Menu
Enter Selection/Command
*1
```

Now you can select any of the items you wish to reconfigure. Selection of #1 brings up the current date, presents the proper syntax for entering the date and waits for you to enter a corrected date. Pressing Enter leaves the date as configured and redisplays the RECONFIGURE MSR menu.

```
DATE:03/14/1992 (JULIAN = 73 )
 MM/DD/YYYY
DATE:
```

Repeat the above instructions for reconfiguring any of the items.

As examples, each of the items of the RECONFIGURE MSR menu will be displayed in order.

Selection of #2 displays present time.

```
TIME:11:46:44
 HR:MN:SC
TIME:
```

Enter the corrected time or press Enter for no change.

Select #3 to display number of sub-samples per plot.

```
SS:  2
 SS/Plot (1-99)
SS:
```

Any number of sub-samples per plot up to 99 may be entered.

Option #4 allows you to provide a remark which is recorded as part of the configuration/status.

```
REMARK:
 Remark (up to 72 characters)
REMARK: SPOT BLOTCH INOCULATION ON
        LARKER AND DICKSON BARLEY 1993
```

Select #5 to enter a unique number to identify the data set such as experiment number or system serial number.

```
ID:   1
 ID (1-999)
ID:
```

Select #6 to enter a unique experiment location abbreviation

```
LOC:FAR
 Location (3 characters)
LOC:
```

After entering the location, the corresponding latitude and longitude of the location must be entered. This information is required by POSTPROC to correctly calculate sunangle for cosine correction of percent reflectance.

```
LAT: 46  40
 Latitude (d,m format, d=-90 to+90 deg,
           m=0-60 minutes)
LAT:46,40
```

```
LON:   96   4
 Longitude (d,m format, d=0-360 degrees,
            m=0-60 minutes)
LON:96,4
```

Longitude must be entered as a number from 0 to 360 degrees, relative to Greenwich, England and increasing towards the west. For normal map longitudes east of Greenwich, you must subtract from 360 degree before entering at the longitude prompt. The same applies to the SAMPTIME program. For example, the map longitude for a location in Sweden might be 18 degrees. For the MSR or SAMPTIME program, enter 342 degrees (360-18).

SPECIFY ITEMS FOR RECORDING

The following describes how to configure the MSR program for recording radiometer readings using the calibration method and radiometer of choice. The particular calibration method and radiometer that you use will determine the items to be recorded.

To reconfigure the record items and calibration method select option #7 from the RECONFIGURE MSR menu.

The Record Menu will appear. The current calibration method, mV, and radiometer are displayed in the parentheses following RECORD.

```
RECORD (Up & Down. mV MSR16)
 1 Items          Radiometer:
 Calib.Method:     5 MSR87
  2 2-Pt.Up/Dn     6 MSR16
  3 WhiteStd.Dn    7 MSR5
  4 WhiteStd.Up/Dn M Menu
Enter Selection/Command
*1
```

Selecting option 1 (Items) will display the currently configured items to be recorded on each scan of the DLC.

```
RECORD:(WhiteStd.Dn mV MSR16)
IRR,DATE,TIME, 3G1R1D1, 4GAD4, 17GAD4,
18GAD4, 19GAD4, 20GAD4, 21GAD4, 22GAD4,
23GAD4, 24GAD4, 25GAD4, 26GAD4, 27GAD4,
28GAD4, 29GAD4, 30GAD4, 31GAD4, 32GAD4,
 33GAD4

ID,LOC,T,BAT,+5V,c[Rr][Gg][Dd],CLEAR
(c=chanl# or range)

RECORD:
```

The currently configured record items are followed by the list of possible recordable items and the record input prompt, RECORD:. Date, Time, and IRR are always recorded. For the MSR16, channels 3 and 4 are also always recorded. They are the MSR16 temperature and GND millivolt channels, respectively, and their readings are used in the correction calculations of the POSTPROC program. For the MSR5, channel 15 (MSR5 temperature) is also always recorded. Plot, and Sub-Sample though not displayed are always recorded for all radiometers.

T - DLC Temperature (degrees C).

BAT - DLC battery voltage

+5V - DLC +5V source voltage

c[G*g*][R*r*][D*d*] - syntax for specifying which channels to record, the voltage range to use, the gain to use, and the number of digits to display on data retrieval of recorded data, where

c = DLC channel number or range of channel numbers.

For MSR87: Choose from 1-16 depending on wavelengths of interest (odd channel is up sensor, even channel is down sensor). See channel-wavelength assignment list at the end of this section.

For MSR5: Choose from 1-10.

For MSR16: Choose from 17-48 for radiometer sensors depending on the number of MSR16 sensor modules installed and their position in the radiometer (up - odd, down - even). Six additional inputs are provided on the 32 channel adapter(MSR32CHA). They correspond to channels 5-10.

G*g* = gain, where
g=A,1,10,100, or 1000
'A' means Auto-range & gain
(The programmable gain card, PG, must be installed for use of A,10,100, or 1000.)
Default is G1 (gain = 1x).

R*r* = voltage range, where
r=0 means -4095 to +4095 millivolts
r=1 means 0 to +4095 millivolts
Default is R0 (-4095 to +4095 mV).

D*d* = number of decimal point digits to display on data retrieval, where *d*=0,1,2, or 4
Default is D0 (0 decimal digits)

Preceding any item with an X will delete it from the record list.

CLEAR - clears all previously configured items from the record list.

Multiple items, separated by commas, may be entered at the RECORD: prompt. Multiple channels or channel ranges may also be entered. The items may be entered in any order, but the list is processed from left to right.

As an example for the MSR87 with 8 wavelengths, a typical record configuration input might be:

```
RECORD:ID,LOC,DATE,TIME,IRR,1-16D1
```

Suppose that you now wanted to remove channels 3 and 5 from the list and change channel 4 to display 2 decimal digits. You could enter the following:

```
RECORD:X3,X5,4D2
```

The RECORD: prompt allows for the addition, deletion, or changing of items in the currently defined list. This command can be entered at any menu prompt. Just typing RECORD and pressing enter at any menu prompt will display the current list of items to be recorded. For more information on the use of the RECORD command/prompt refer to the DLC User's Manual and Technical Reference.

METHODS of CALIBRATION:

2-Pt.Up/Dn - Two Point Up & Down Sensors (Record Menu option 2)

Both the upward and downward facing sensors are used for radiometer readings. The calibration for this method is based on the use of a flashed opal diffusing glass to alternately provide the same irradiance to the up and down sensors.

WhiteStd.Dn - White Standard Down Sensors Only (Menu option 3)

Only the downward facing sensors are used. Radiometer readings are then made relative to a white reflectance standard. Recalibrations, relative to the white reflectance standard, are necessary every few minutes or so, depending on time of day and sunangle, to compensate for sunangle changes. This method can not be used in cloudy or partly cloudy conditions.

WhiteStd.Up/Dn - White Standard Up & Down Sensors (menu option 4)

Upward and downward facing sensors are used for radiometer readings. The calibration for this method is based on the use of the white standard. The calibration is applied to both up and down sensors. The recalibration is needed perhaps only twice per season. The white standard does not have to be carried in the field as it does for the WhiteStd.Dn only method.

> Before the MSR87, MSR5, or MSR16 can be used with either of the white standard methods, the white standard reference percent reflectance values for each wavelength must be entered into the MSR program. This can be done by selecting option #1 from the CALIBRATION COEFFICIENTS menu. (See HOW TO CALIBRATE THE MSR16 RADIOMETER)

Sensor output readings are always recorded in millivolts (mV).

If the method configured is **2-Pt.Up/Dn or WhiteStd.Up/Dn** then percent reflectance is calculated for each wavelength by the POSTPROC program as follows:

$$\frac{\text{Down Units}}{\text{Up Units}} \times 100$$

If the method configured is **WhiteStd.Dn** then percent reflectance is calculated for each wavelength by the POSTPROC program as follows:

$$\frac{\text{Down Units}}{\text{White Standard Units}} \times \text{White Standard Reflectance} \times 100$$

For the MSR16, GND millivolt offset, temperature, and cosine corrections to the millivolt readings are done in the POSTPROC program prior to the percent reflectance calculation.

RADIOMETER:

MSR87 (Record Menu option 5) or MSR5 (Record Menus option 7)

The MSR87 radiometer contains eight different wavelength sensor pairs (one up-facing and one down-facing) and connects to analog input channels 1-16 of the DLC. The MSR5 contains five wavelength pairs and connects to channels 1-10. Upward facing sensors are input to odd numbered channels and downward facing sensors are input to even numbered channels. The sensor-channel assignment is:

MSR87 CHANNEL ASSIGNMENT			MSR5 CHANNEL ASSIGNMENT		
Sensor Wavelength	DLC Channel Up	Down	Sensor Wavelength	DLC Channel Up	Down
460 nm	1	2	485 nm	1	2
510 nm	3	4	560 nm	3	4
560 nm	5	6	660 nm	5	6
610 nm	7	8	830 nm	7	8
660 nm	9	10	1650 nm	9	10
710 nm	11	12			
760 nm	13	14			
810 nm	15	16			

MSR16 (Record Menu option 6)

The MSR16 radiometer consists of a housing with sockets which accommodate up to 16 up-facing and 16 down-facing single wavelength modules. The socket numbers correspond to the channels with which they are connected. Odd numbered channels from 17 to 47 are for the up-facing sensor modules. Even numbered channels from 18 to 48 are for the down-facing sensor modules. Matching wavelength pairs of up-facing and down-facing sensor modules may be plugged into any successively numbered sockets. This sensor-channel assignments must be defined to the MSR program. (earlier in this section). For example, the sensor- channel assignment for the standard wavelengths might be:

SENSOR CHANNEL ASSIGNMENT			SENSOR CHANNEL ASSIGNMENT		
Sensor Wavelength	DLC Channel Up	Down	Sensor Wavelength	DLC Channel Up	Down
460 nm	17	18	--- nm	33	34
510 nm	19	20	--- nm	35	36
560 nm	21	22	--- nm	37	38
610 nm	23	24	--- nm	39	40
660 nm	25	26	--- nm	41	42
710 nm	27	28	--- nm	43	44
760 nm	29	30	--- nm	45	46
810 nm	31	32	--- nm	47	48

Select #8 to specify the number of samples of analog to digital conversions to average for each of the channel measurements.

```
      RECONFIGURE MSR
1 Date  6 Location 11 Calibrate
2 Time  7 Record   12 Power-Off
3 SS    8 Samples  13 Mode
4 Rem   9 GMT Difference
5 ID   10 IRR       M Main Menu
Enter Selection/Command
*8
```

```
SAMPLES:   47
 Number of samples/reading (1-65535)
 (47 rejects 60Hz, 57 rejects 50Hz)
SAMPLES:
```

The default number of samples/reading is 47. For each scan 47 repetitions of the digitized voltages from each channel will be made and automatically averaged for the sample value. This is done to improve readings where the sensors are in the presence of 60hz powerline noise. 57 samples filters 50hz noise. If you are not near a power line then you may reduce the number of samples to perhaps 5 or 6. Readings should still be accurately made and will take less time.

Select #9 to enter the difference from Greenwich Mean Time to your local time (negative for west and positive for east of Greenwich, England).

```
GMT Diff.(+/-hours, -5 ):
```

One of the wavelengths of the radiometer may be selected for calibration to simulate a pyranometer. The wavelength, channel number and coefficients of a linear equation are all generated when the channel is selected for calibration. (See HOW TO CALIBRATE AS A SIMULATED PYRANOMETER).

Select #10 to display or change the wavelength and channel for a simulated pyranometer and to specify the minimum value of IRR for acceptable readings.

```
Simulated Pyranometer (IRR)
Serial ( 610U000):
Chanl# (    7 ):
DarKmV (  3.321 ):
Sensor Coeff. ( .1767124 ):
Low Warning Value (  300 ):
```

Useful percent reflectance data will be generated even if the incident light is about 1/4 of maximum irradiance. A minimum acceptable level of incident light can be chosen so that if the irradiance falls below that value a warning will appear on the screen accompanied by audible BEEPS. The program will then require that you repeat the scan when the irradiance value is above the low irradiance value specified.

Selection #11 Calibrate is considered in the section HOW TO CALIBRATE THE MSR87 OR MSR5 RADIOMETER and HOW TO CALIBRATE THE MSR16 RADIOMETER.

Selection of #12 displays the current power-off delay setting. The DLC automatically powers down if it has received no input activity during the delay time specified.

```
PO:    255 Sec
 Power-Off delay (30-65535 (sec.) or
 CONTinuous)
PO:
```

Selection of #13 allows you to select whether to enter plot numbers manually by keyboard input or to have the plot numbers automatically incremented sequentially beginning with a selected number.

```
MODE:Manual
 Mode: Manual/Automatic
 MODE:A
Scan Initiation:
 1 Space Key
 2 Push-Button
Enter Selection/Command
*1
```

If the automatic mode is selected, you can initiate scans by pressing the space bar or key or by using the hand held push-button switch. If the push-button

method of scan initiation is selected, the DLC will automatically power-down between scans. If the space key method is selected then it is presumed that a computer or hand-terminal will be used during system use. The push-button can still be used to inititate scans in this case, but the DLC will not automatically power-down between scans. This may be handy where you wish to use a terminal to view plot number sequencing and observe current simulated pyranometer readings, yet use a hand push-button switch for convienence.

Finally, by pressing the M key the MSR MAIN MENU appears. You may then make another selection or select #10 to logoff the DLC.

```
Enter Selection/Command
*M
```

```
          MSR MAIN MENU
 1 Config-Status
 2 ReConfigure    7 Memory Card
 3 Retrieve Data  8 MSR Program
 4 Clear Data     9 Exit MENU
 5 View          10 BYE

Enter Selection/Command
*10
```

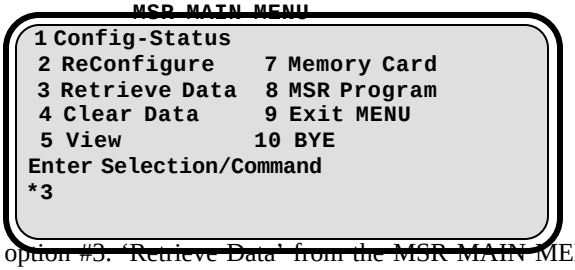
```
Returning to SLEEP... BYE!
```

DOWNLOAD FROM THE DLC TO A PC

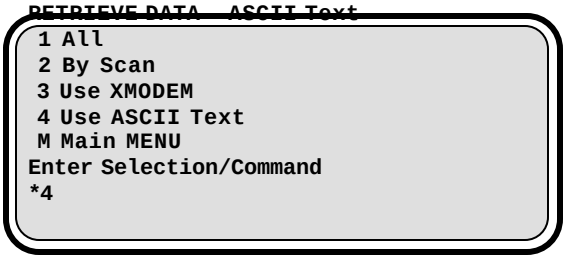
The program RETRIEVE is provided to easily download configuration/status, calibration constants, and data from the DLC to a PC. Start the RETRIEVE program by entering RETRIEVE at the PC DOS command line or by selecting it from the CROPSCAN MULTISPECTRAL SYSTEM MENU program (MSRMENU). The proper communication parameters are built-in to the program. You will be prompted for any necessary information.

You may also use a communications program such as PROCOMM, QMODEM or the Microsoft Accessory TERMINAL program running under Microsoft WINDOWS to download from the DLC to a PC. Be sure that the communication parameters are properly configured (refer to the COMMUNICATIONS PARAMETERS section). The following instructions are for using PROCOMM.

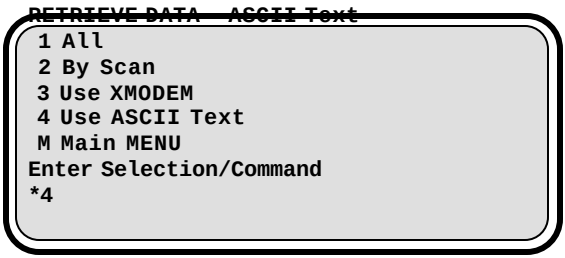
1) Logon to the DLC and go to the MSR MAIN MENU.



2) Select option #3. 'Retrieve Data' from the MSR MAIN MENU.



3) Press #4 'Use ASCII Text'



4) Press #1 ‘All’ to download current configuration/status, calibration constants and data.

5) Press the Page Down key on the PC for download.

6) Choose 'ASCII' from the menu of PROCOMM.

7) Type the directory path and filename. Example: \MSR\F0118793.MV

8) Press Enter. The data will be downloaded to the file using ASCII protocol.

9) After the data is downloaded, press the Enter key.

10) Select M to return to the MSR MAIN MENU

11) Type ‘CLEAR’ to clear the data memory of the DLC.

12) Now you can select #8 to re-enter the MSR program or select #10 to return the DLC to the sleep mode.

UPLOAD MSR.BAS TO THE DLC FROM A PC

The program UPLDMSR is provided to easily upload the MSR.BAS program from the PC to the DLC. Start the UPLDMSR program by entering UPLDMSR at the PC DOS command line or by selecting it from the CROPSCAN MULTISPECTRAL SYSTEM MENU program (MSRMENU). The proper communication parameters are built-in to the program. You will be prompted for any necessary information.

You may also use a communications program such as PROCOMM, QMODEM or the Microsoft Accessory TERMINAL program running under Microsoft WINDOWS to upload the MSR.BAS program from the PC to the DLC. Be sure that the communication parameters are properly configured (refer to the COMMUNICATIONS PARAMETERS section).

1) Load a communications program such as PROCOMM, QMODEM or TERMINAL running under WINDOWS.

2) Logon to the DLC and go to the MSR MAIN MENU.

```
        MSR MAIN MENU
 1 Config-Status
 2 ReConfigure    7 Memory Card
 3 Retrieve Data  8 MSR Program
 4 Clear Data     9 Exit MENU
 5 View          10 BYE
Enter Selection/Command
*
```

3) Press Ctrl and C keys simultaneously to break the DLC out of its current program.

4) Type 'NEW' and press Enter.

5) Press the Page Up key on the PC for upload.

6) Type the directory path and filename of the MSR.BAS file.
   Example: \MSR\MSR.BAS
   (It is on your program disk included with your system). This upload will take approximately 10 minutes.

7) When uploading is completed type 'RUN' to run the MSR operations program. You should reconfigure the MSR operations program at this time. (See the HOW TO Reconfigure the MSR section).

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USE THE MEMORY CARD

A 40 pin Epson Memory card can be used to store programs and configuration or data and program. They are available in three sizes: 64K, 128K and 256K. Power to the memory is maintained by a 3V Lithium battery. (Radio Shack CR2016). The DLC detects and displays the memory card battery voltage. A 'LOW BATTERY' message is displayed if the card is not plugged in or if battery voltage is below 2600 mV. If the memory card is plugged into the DLC the memory card battery can be replaced without losing the memory card contents. The battery should normally last about 2 years. Be sure to replace the battery when the 'LOW BATTERY' message is displayed.

Data or programs are stored on memory cards in either of two formats, data format or program format. In data format, the first 32K bytes of the card will contain a copy of the program and configuration settings from the DLC where the data was copied from. The remainder of the memory card will contain a copy of the data from the DLC. The memory card size must be equal to or greater than that of the DLC from which it is to receive data.

Program formatted cards, on the other hand, only contain copies of DLC programs and configuration settings. Each 32K byte block of a memory card can hold a separate program and its configuration settings. There is no restriction on the size of a memory card relative to the memory size of the DLC for memory cards used as program cards.

The memory cards can be used interchangeably between data or program formats.

Data and programs/configurations may be stored to or retrieved from memory cards. The memory card directory or the memory card battery voltage may be displayed from this menu.

```
      MEMORY CARD OPERATIONS
 1 Display Directory   6 Battery Check
 2 Store Data & Program to Memory Card
 3 Load Data & Program from Memory Card
 4 Store Program/Configuration to Card
 5 Load Program/Config.  M Main MENU
Enter Selection/Command
*
```

Option #1 -Indicates whether the card is a DLC data card or a program card. In addition, the data or program descriptions are displayed.

For data card:

```
DATA CARD:
1 F0118693.MV Spot Blotch Inoculation.
Press Enter.
```

For program card:

```
PROGRAM CARD:
1 MSR Experiment F01
2 MSR Experiment F02
Press Enter.
```

Option #2 -Copies current DLC program and data to the memory card. If the memory card was previously copied to as a program card, then it will be converted to a data card format.

```
PROGRAM CARD:
1 MSR Experiment F01
2 MSR Experiment F02
Move write protect switch to OFF and
Press Enter.
```

Press Enter and the following display appears.

```
Description/comments (or QUIT):
*F0118693.MV Spot Blotch Inoculation.
Storing...
Move write protect switch to ON and
Press Enter.
```

Press Enter and the following display appears.

```
CLEAR DLC DATA (Y/N)?Y
CLEARED!
Press Enter.
```

Option to clear the data in the DLC after having stored it on the memory card.

Option #3 - Copies DLC data and program from memory card into the DLC program and data memory.

```
DATA CARD:
1 F01186.RAW  Spot Blotch Inoculation.
Current data/program will be lost!
Continue (Y/N)?Y
Loading...
```

Option #4 -Copies current DLC program and configuration to the memory card. If the memory card was previously copied to as a data card, then it will be converted to a program card format.

```
PROGRAM CARD:
Program Number:1
Move write protect switch to OFF and
Press Enter.
```

After moving the write protect switch to OFF and pressing Enter, the program allows you to type a description and comments for the program and configuration.

```
Description/comments (or QUIT):
*MSR Experiment F01
Storing...
Move write protect switch to ON and
Press Enter.
```

Option #5 -Copies DLC program and configuration from memory card into the DLC program memory.

```
PROGRAM CARD:
 1 MSR Experiment F01
 2 MSR Experiment F02
Program Number:1
Loading...
```

Select #1 and press Enter. The MSR operation program will load into DLC RAM replacing the current DLC program. This is a very fast and efficient method of loading programs and configurations into the DLC. Two programs and configurations can be stored on one 64K memory card, four on a 128K card, and up to eight on a 256K card.

After the program is loaded (about 3 seconds) it runs from the beginning.

```
MULTISPECTRAL RADIOMETER (MSR)
Copyright 1992 by CROPSCAN INC.
MSR PROGRAM
  8 WAVELENGTHS
Enter or M-MenuM
```

VIEW IN REAL TIME

Logon, go to the MAIN MSR MENU and select 5 'View'.

```
        MSR MAIN MENU
 1 Config-Status
 2 ReConfigure    7 Memory Card
 3 Retrieve Data  8 MSR Program
 4 Clear Data     9 Exit MENU
 5 View          10 BYE
Enter Selection/Command
*5
```

The following message will be displayed.

```
Press M for mV,
R for %Refl.,
U for Units,
1-9 for # of columns,
Q or Enter to Quit
```

The items and channels that were configured for RECORD will be displayed. The default units for the channel values displayed is millivolts in a single column. For multispectral radiometer data, press 2 to display the data in two columns. The first column will display the odd numbered channels with output in millivolts representing the intensity of incident irradiation and the second column will display the even numbered channels with output in millivolts representing the intensity of reflected irradiation. For the MSR16,channels 3 and 4 will always be displayed. Channel 3 is the millivolt output of the temperature sensor inside the MSR16 housing. Channel 4 is the ground millivolt offset. (Example is for the MSR16 with 16 channels configured and with 16 standard wavelength sensors plugged in).

```
IRR: 1535.2 mV
DATE: 7041993
TIME:  130813
 3: 1536.3  4: 0.1724
17: 354.6036 18: 12.8109
19: 783.674  20: 41.9873
21: 449.2828 22: 32.8147
23: 898.5655 24: 43.0767
25: 1225.643 26: 33.2854
27: 2070.112 28: 92.0026
29: 1817.144 30: 425.1376
31: 1072.115 32: 408.3588
```

Press the U key to display the output of each of the channels in units.

```
IRR: 850
DATE: 7041993
TIME:  130813
 3: 27.4  4: 0.1724
17: .9943 18: .0278
19: .9922 20: .0517
21: .9756 22: .0624
23: .9943 24: .0437
25: .9844 26: .0354
27: .9835 28: .0747
29: .9788 30: .3592
31: .9995 32: .4797
```

Units are the product of the millivolt output of each of the channels and the sensor coefficient from the table of CALIBRATION CONSTANTS. When the 2-Pt.Up/Dn or WhiteStd.Up/Dn calibration method is used the units are relative to the solar irradiance at the time of calibration whereby that irradiance level is considered as unity (1.000). If you choose to calibrate the radiometer in absolute terms, using a procedure of your own, and manually enter the corresponding sensor coefficients into the table of CALIBRATION CONTSTANTS then the units displayed in VIEW will be in what ever irradiance units you calibrated to. Units of IRR are Watts/M^2. Remember that while VIEW can display the readings in calibration units, the readings are always recorded in millivolts except for channel 3 (MSR16 temperature) which is always recorded in degrees C.

Press the R key to display percent reflectance in the first column and units in the second column.

```
IRR: 850
DATE: 7041993
TIME:  130813
 3: 27.4  4: 0.1724
17: 2.8124 18: .0278
19: 5.2353 20: .0517
21: 6.4245 22. 0624
23: 4.4542 24: .0437
25: 3.6743 26: .0354
27: 7.6731 28: .0747
29: 36.7334 30: .3592
31: 48.0122 32: .4797
```

Percent reflectance is calculated as follows:

(dn units / up units) x 100

Corrections are not made for temperature, ground millivolts or sunangle in VIEW mode.

To return to the MSR MAIN MENU, press Q any time and select option 10 'BYE' to return the DLC to the sleep mode.

```
      MSR MAIN MENU
 1 Config-Status
 2 ReConfigure    7 Memory Card
 3 Retrieve Data  8 MSR Program
 4 Clear Data     9 Exit MENU
 5 View          10 BYE
Enter Selection/Command
*10

Returning to SLEEP... BYE!
```

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CALIBRATE AS A SIMULATED PYRANOMETER

Any one of the radiometer up sensors may be chosen for use as a simulated pyranometer. The following discussion and example assumes that Channel 7 for the MSR87, Channel 5 for the MSR5, or Channel 23 for the MSR16 is used.

A two point method for calibration is used where the slope of the linear equation is defined by the maximum millivolt output of channel 7 (5 or 23) equivalent to the maximum irradiation (Watts/Meter^2) in sunlight and the minimum millivolt output of channel 7 (5 or 23) in darkness equivalent to minimum irradiation (0 Watts/Meter^2).

The algorithm for calculating the intercept (A) and the slope (B) of the linear equation Y = A + BX is:

$$B = P/(M-D)$$
$$A = -B*D$$

Where: P = W/M^2 from a standard pyranometer in sunlight
M = mV from channel 7 (5 or 23) in light
D = mV from channel 7 (5 or 23) in dark

The MSR program makes it easy for you to calibrate one of the channels of the radiometer to simulate a radiometer.

If a standard pyranometer is unavailable for calibration reference, you can assume the intensity of irradiation in bright sunlight will be about 1000 W/M^2 with the top surface of the radiometer at 0 degrees incident angle.

The procedure for calibration is as follows:

1) Bring up the MSR MAIN MENU.

2) Select #2 to display the RECONFIGURE MSR menu.

```
      RECONFIGURE MSR
 1 Date  6 Location 11 Calibrate
 2 Time  7 Record   12 Power-Off
 3 SS    8 Samples  13 Mode
 4 Rem   9 GMT Difference
 5 ID   10 IRR       M Main Menu
Enter Selection/Command
*11
```

3) Select #11 to display the CALIBRATION COEFFICIENTS menu.

```
      CALIBRATION COEFFICIENTS
 1 Enter Calibration
 2 Display Calibration
 3 Recalibrate
  M Menu
Enter Selection/Command
*3
```

4) Select #3 to display the RECALIBRATION menu.

```
RECALIBRATION
  1 IRR
 2 Two-Point
 3 White-Standard Up & Down
  M Menu
Enter Selection/Command
*1
```

5) Select option #1 to display the instructions for inputs for calibration.

```
  SIMULATED PYR CALIBRATION

Serial ( 613UA03):
```

6) The program waits for you to input an MSR16 module serial number or an MSR87 or MSR5 wavelength+U or D +radiometer serial number for calibration. Press Enter for no change.

```
Chanl# (    7 ):
```

7) Likewise, the program waits for you to input a new channel number or Enter for no change.

```
POSITION WITH TOP FACING BRIGHT SUN
POSITION PYR PAR LEVEL WITH IT
PYR Reading (IRR): 1000
```

8) Instructions are displayed and the program waits for you to input the standard pyranometer reference reading. The millivolt output from channel 7 (5 or 23) is then recorded.

```
PLACE OPAQUE CARD OVER TOP SURFACE
PRESS ENTER WHEN READY
```

9) The dark millivolt output from channel 7 is recorded.

Upon pressing Enter, the previous menu is displayed.

```
RECALIBRATION
 1 IRR
 2 Two-Point
 3 White-Standard Up & Down
 M Menu
Enter Selection/Command
*
```

You may now proceed with the MSR87, MSR5, or MSR16 calibration.

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CALIBRATE THE MSR87 OR MSR5 RADIOMETER

Your radiometer was adjusted and calibrated by the two-point method (2 Pt. Up/Dn) before it was shipped to you, but if you wish to recalibrate it to familiarize yourself with the procedure and to check on the accuracy of calibration under your conditions, follow the procedures described.

Calibration accuracy will be optimum if you calibrate on a perfectly clear day within 2 hours of solar noon. Avoid nearby buildings, trees or your own body that may influence the spectral characteristics of incident or reflected irradiation. You should not need to calibrate more than once a season, but there is no guarantee that the interference filters will not deteriorate in time. The useful life of the interference filters depend on the conditions to which they are subjected. High temperatures and high humidity must be avoided. The radiometer should be stored in the sealed plastic container with a silica gel pack and should not be subjected to high temperatures when not in use.

The first step in the calibration procedure is to configure the RECORD items.

At the MSR MAIN MENU type REC:1-16 (REC:1-10 for MSR5) and Enter.

The second step in the calibration procedure is to check on the adjustment of each of the photodiode amplifier gains.

1) At the MSR MAIN MENU select #5, 'View'

2) The millivolt output of all selected channels will be repeatedly displayed in a single column. Press 2 to display the output in two columns.

3) Position the radiometer with the top surface facing the sun. The left column will now display the odd numbered channels (Up facing sensors). They should each be between 3000 and 3900 millivolts. If they are all within this range then proceed to step #5. If any are outside this range and the radiometer has gain adjustment slot openings go to step #4, otherwise contact CROPSCAN, Inc.

Adjustment of gains for individual up facing channels:

4) While holding the radiometer with the top surface facing the sun, change the gain on a channel by adjusting the appropriate potentiometer. The pots from right to left adjust the gains on the amplifiers for the respective incident light measuring wavelengths.

Continue with the adjustment procedure until you have readjusted all up-facing channels that require readjustment.

Adjustment of gains on individual down facing channels for the 2Pt.Up/Dn method of calibration:

5) Turn the radiometer over and place the opal glass diffuser over the surface. Follow the same procedures for adjustment of the reflected irradiation measuring sensors as for the incident light measuring sensors. The reflected irradiation measuring channels are the even numbered channels. Each of the reflected irradiation sensors should have an output ranging from 2800 to 3500 millivolts. If outside this range then re-adjust the appropriate channel if the radiometer has a gain adjustment slot opening. If outside this range and there is no adjustment slot opening then contact CROPSCAN, Inc. Otherwise, proceed to step #6.

Adjustment of gains on individual down facing channels for the White Standard Up & Down or White Standard Only methods of calibration:

5) Position the white standard at a 45 degree sunangle and mount the radiometer over it. Follow the same procedures for adjustment of the reflected irradiation measuring sensors as for the incident light measuring sensors. The reflected irradiation measuring channels are the even numbered channels. Each of the reflected irradiation sensors should have an output ranging from 2800 to 3500 millivolts. If outside this range then re-adjust the appropriate channel if the radiometer has a gain adjustment slot opening. If outside this range and there is no adjustment slot opening then contact CROPSCAN, Inc. Otherwise, proceed to step #6.

Adjustment of the gains in this manner will insure that none of the voltage inputs to the channels will go over range with maximum irradiation under normal conditions.

6) Select #2, 'ReConfigure' from the MSR MAIN MENU.

```
        MSR MAIN MENU
 1 Config-Status
 2 ReConfigure      7 Memory Card
 3 Retrieve Data    8 MSR Program
 4 Clear Data       9 Exit MENU
 5 View            10 BYE
Enter Selection/Command
*2
```

METHODS OF CALIBRATION

Three methods of calibrating the radiometer are possible. Each has its advantages and disadvantages. See the CALIBRATION METHODS/ CONSIDERATIONS section for a discussion of these methods.

TWO-POINT METHOD OF CALIBRATION

Make sure the system is configured properly for this method and for the MSR87 or the MSR5.

1) On the MSR MAIN MENU select #2 to display the 'RECONFIGURE MSR' menu.

```
       RECONFIGURE MSR
1 Date   6 Location 11 Calibrate
2 Time   7 Record   12 Power-Off
3 SS     8 Samples  13 Mode
4 Rem    9 GMT Difference
5 ID    10 IRR       M Main Menu
Enter Selection/Command
*7
```

2) Select #7 'Record' to display the RECORD menu.

```
RECORD (2-Pt.Up/Dn  mV MSR87)
 1 Items          Radiometer:
 Calib.Method:      5 MSR87
  2 2-Pt.Up/Dn      6 MSR16
  3 WhiteStd.Dn     7 MSR5
  4 WhiteStd.Up/Dn  M Menu
Enter Selection/Command
*2
```

The presently configured Calib. Method and Radiometer is shown in parenthesis after RECORD. Select #2 for 2-Pt.Up/Dn and #5 for MSR87 or #7 for MSR5. Both of these must be configured before proceeding to the next step.

3) Press M to return to the RECONFIGURE menu.

4) Select #11, 'Calibrate' to display the CALIBRATION COEFFICIENTS menu.

```
   CALIBRATION COEFFICIENTS
 1 Enter Calibration
 2 Display Calibration
 3 Recalibrate
 M Menu
Enter Selection/Command
*3
```

5) Finally, select option #3 'Recalibrate' to display the RECALIBRATION menu.

```
RECALIBRATION
 1 IRR
 2 2-Pt.Up/Dn
 3 WhiteStd.Up/Dn
M Menu
Enter Selection/Command
*2
```

Now proceed with the methods for calibrating the MSR87 or MSR5 by the Two - Point method. Position the radiometer on a black opaque card on a platform so the opal glass diffuser is upward with its surface at 45 degrees with respect to the sun's irradiance.

6) Select #2 '2-Pt.Up/Dn'. The following step by step instructions will appear on the screen.

```
   MSR CALIBRATION

POSITION AT 45 DEGREES ON BLACK CARD
PRESS ENTER WHEN READY

PLACE OPAL GLASS OVER TOP SURFACE
PRESS ENTER WHEN READY

TURN RADIOMETER OVER ON BLACK CARD (45
DEGREES)
PLACE OPAL GLASS OVER SURFACE
PRESS ENTER WHEN READY

Calculating...
```

When finished with the last step, the previous menu appears.

```
RECALIBRATION
 1 IRR
 2 2-Pt.Up/Dn
 3 WhiteStd.Up/Dn
 M Menu
Enter Selection/Command
*M
```

This calibration is based on the following assumptions:

1. Both sets of sensors are viewing the same irradiation intensity provided by the sun illuminating the standard opal glass diffuser.

2. Each sensor response is linear over the operating range.

This method of calibration has several advantages. It is convenient. It may be carried out in the field anytime provided sunlight conditions are ideal. Caution: when turning the radiometer over, cover the surface immediately with the opal glass diffuser to avoid overexposing the normally down-facing sensors to the sun.

The calibration coefficients generated for each channel by this method are stored in the CALIBRATION CONSTANTS table. They will remain with the program until they are changed by recalibration or by editing.

WHITE STANDARD UP & DOWN METHOD

The second method of calibration is White standard Up & Down. It requires the use of a white standard for which the spectral reflectance is known. Before using this method of calibration you must enter the reflectance value corresponding to the peak wavelength of each of the MSR87 filters into the CALIBRATION CONSTANTS table in the WhiteStd. column for the down sensors (even channels). This table is displayed on the following page.

Select #2 to display the current CALIBRATION CONSTANTS for your MSR87 or MSR5 radiometer that have been configured by RECORD.

```
- CALIBRATION CONSTANTS -
At Temp.(C):  21.5
 CH nmSerial   DKmV  SensorCoeff  WhiteStd.
 -- -------- ------- ----------- ----------
  1  460U000  -1.997  3.855 E-4   0.000 E+0
  2  460D000  -5.705  1.319 E-4   9.530 E-1
  3  510U000  -0.887  3.864 E-4   0.000 E+0
  4  510D000  -4.200  1.398 E-4   9.060 E-1
  5  560U000  -2.100  3.835 E-4   0.000 E+0
  6  560D000  -5.193  1.402 E-4   8.310 E-1
  7  610U000  -1.574  3.954 E-4   0.000 E+0
  8  610D000  -3.805  1.511 E-4   8.000 E-1
  9  660U000  -1.495  3.836 E-4   0.000 E+0
 10  660D000  -3.655  1.467 E-4   8.170 E-1
 11  710U000  -1.730  3.823 E-4   0.000 E+0
 12  710D000  -3.607  1.486 E-4   8.250 E-1
 13  760U000  -1.649  3.976 E-4   0.000 E+0
 14  760D000  -2.812  1.617 E-4   8.360 E-1
 15  810U000  -4.024  3.813 E-4   0.000 E+0
 16  810D000  -5.128  1.507 E-4   8.280 E-1
```

Wavelengths + U for up-facing sensors or D for down-facing sensors + 000 are automatically generated for the MSR87/MSR5.

Dark millivolt calibration reading from each sensor.

White standard reflectance value. Determined by averaging the spectral reflectance of the white standard over the particular bandwidth of the sensor. This value needs to be entered only if you plan to use the White.Std Up/Dn or White.Std Dn only methods of calibration.

Reserved

Sensor coefficients from Two-Point or White Standard Up/Dn calibrations. Not used for White Standard Down Only method.

The sensor coefficient values are automatically generated when calibrated and are used by the POSTPROC program to calculate percent reflectance and by VIEW to display irradiance or percent reflectance.

After the CALIBRATION CONSTANTS are displayed, press Enter to return to the CALIBRATION COEFFICIENTS menu.

```
       CALIBRATION COEFFICIENTS
 1 Enter Calibration
 2 Display Calibration
 3 Recalibrate
 M Menu
Enter Selection/Command
*1
```

To edit any of the items of the table, select #1, 'Enter Calibration'

```
Which Channel?
*2
  2  660D000  -5.705  1.319 E-4   9.530 E-1
Serial ( 660D000): 660D151
DarkmV (  -5.705 ):
Sensor Coeff. ( 1.3196954 E-4 ):
White Standard Reflectance ( .953 ,
  Press Enter if none):
```

The current wavelength serial number and constants will be displayed successively. Each of the items may be changed. For example, you may wish to change the last three digits of the serial number corresponding to the channel number to correspond to your radiometer serial number. If you intend to use the White Standard Only method of calibration in the field, the correct White Standard Reflectance value must be entered for each of the down facing (even numbered channels). Press Enter for no change for each of the items. After all items have been displayed the CALIBRATION COEFFICIENTS menu re-appears.

```
       CALIBRATION COEFFICIENTS
 1 Enter Calibration
 2 Display Calibration
 3 Recalibrate
 M Menu
Enter Selection/Command
*3
```

Select #3 to display the RECALIBRATION menu.

```
RECALIBRATION
 1 IRR
 2 2-Pt.Up/Dn
 3 WhiteStd.Up/Dn
 M Menu
Enter Selection/Command
*3
```

Select #3 'WhiteStd.Up/Dn'. Position the white standard with it's surface 45 degrees to the sun's irradiance. Mount the radiometer vertically over it so that the opal glass surface is exactly parallel to the surface of the white standard. The following step by step instructions will appear on the screen.

```
   CALIBRATION TO WHITE-STANDARD

POSITION RADIOMETER OVER WHITE CARD
 (45 DEGREES TO SUN)
PRESS ENTER WHEN READY

PLACE OPAQUE CARD OVER TOP SURFACE
PRESS ENTER WHEN READY

PLACE OPAQUE CARD OVER BOTTOM
PRESS ENTER WHEN READY

Calculating...
```

When finished with the last step, the previous menu appears.

```
RECALIBRATION
 1 IRR
 2 Two-Point
 3 White-Standard Up & Down
 M Menu
Enter Selection/Command
*M
```

The calibration coefficients generated for each channel by this method are stored in the CALIBRATION CONSTANTS table. They will remain with the program until they are changed by recalibration or by editing.

WHITE STANDARD DOWN ONLY METHOD

The third method of calibration requires the use of a white standard of known spectral reflectance positioned horizontally in the field at a location so readings of it may be taken periodically and immediately before taking readings of plots. Only the down-facing sensors need to be configured for recording.

Make sure the system is configured properly for this method and for the MSR87 or MSR5.

Position the white standard on a platform with its surface exactly level. Leave the white standard in that position for all subsequent readings.

Before taking readings of any of the plots in the field, position the radiometer vertically over the white standard and follow these rules for the use of the 'D' an 'W' keys for the calibration procedure.

Log on to the DLC and proceed to the prompt for PLOT NUMBER: or BEGIN PLOT#:

In **MANUAL MODE:**

At the PLOT NUMBER: prompt, press the 'D' key.
The following instructions will appear on the screen:

```
PLOT NUMBER:D

PLACE OPAQUE CARD OVER BOTTOM
PRESS ENTER WHEN READY
```

After Enter is pressed the message 'SCANNING...' will appear. The dark mV readings for each of the down facing channels will be recorded with the plot number identifier of -1.

When finished, PLOT NUMBER: prompt will again appear. Remove the opaque card from the bottom of the radiometer and press the 'W' key. The following message will appear:

```
PLOT NUMBER:W

POSITION OVER WHITE STANDARD
PRESS ENTER WHEN READY
```

After Enter is pressed the message 'SCANNING...' will appear. The reflected mV readings from the white standard, for each of the down-facing channels, will be recorded with the plot number identifier of '0'

In **AUTO MODE:**

The beginning plot number will be displayed. Enter the beginning and ending plot numbers.

At the SUBSAMPLE: prompt, press the 'D' key. Cover the bottom of the radiometer with the dark card and press Enter to take the dark mV readings. When scanning is complete, remove the dark card and press the 'W' key for the white standard readings.

This calibration procedure should be repeated periodically. The frequency of repetitions will depend on the rate of change of the sunangle. In general, the greater the sunangle, the greater the error in percent reflectance between the first plot reading and the last plot reading before another set of calibration readings. Use the program 'SAMPTIME' to estimate the frequency of calibration repetitions depending on sunangle.

Percent reflection is calculated by the POSTPROC program. It uses the first set of dark mV and white standard readings to calculate percent reflectance for all readings of plots up to the next set of dark mV and white standard readings. Therefore, this calibration procedure can only be used if sunlight conditions are ideal. Any change in sunlight due to clouds, fluctuating haze or sunangle will cause errors in percent reflectance calculations.

This calibration procedure is most useful if you wish to use down facing sensors only. It is also the most accurate method of calibration because corrections are automatically made for variations in temperature and sunangle. (See the section CALIBRATION METHODS/CONSIDERATIONS for a detailed discussion).

CALIBRATE THE MSR16 RADIOMETER

Your MSR16 modules were calibrated and tested before they were shipped to you. They were individually tested for temperature sensitivity in a special irradiance and temperature control chamber by CROPSCAN, Inc. Separate calibration files, containing the temperature sensitivity calibration values, are provided on a PC diskette. The temperature sensitivity calibration values are used to correct retrieved data during post-processing by the POSTPROC program prior to calculating percent reflectance.

Silicon photodiodes, used in the visible to NIR wavelength modules, are typically negatively temperature sensitive (in the 0 to -0.5 percent per degree C range) while Germanium photodiodes, used in the mid NIR wavelength modules, can have larger temperature sensitivities (as high as 2 or 3 percent per degree C).

The upward-facing MSR16 modules were also individually tested for cosine response by CROPSCAN, Inc. Cosine correction factors were developed and included in the calibration files for these sensors. The POSTPROC program uses these factors to cosine correct upward facing sensor readings based on the location, date, and time.

The deviations of the MSR16 sensors from true cosine sunangle response are due to imperfect irradiance diffusion of the opal glass and small reflectance properties inside the module tube. The uncorrected cosine deviation of sensors in the 460 to 1100 nm range is about +/-3 to +/-5 percent maximum, relative to the calibration angle of 45 degrees sunangle over the operating sunangle range of 0 to 60 degrees. There is no known good irradiance transmitting diffuser material for wavelengths greater than 1100 nm. Opal glass provides some irradiance diffusion beyond 1100 nm, however it tapers off rapidly beyond about 1200 nm. For wavelengths above 1100 nm this uncorrected deviation increases to about +/-10 percent maximum over the operation sunangle range of 28 to 60 degrees. Use of the cosine correction calibration factors in the POSTPROC program typically corrects these deviations to within +/-1 percent maximum for the shorter wavelengths (<1100 nm) and within +/-2 percent maximum for the longer wavelengths (>1100 nm).

There are three different methods of calibration of the individual modules. Two of the methods may be carried out anytime whenever sunlight conditions are ideal. They are the 'Two-Point' and the 'White-Standard Up & Down methods. The third method, 'White-Standard Down Only', is carried out in the field immediately prior to taking readings of plots.

The individual modules were calibrated by the 'Two-Point' method, before they were shipped to you but if you wish to recalibrate to familiarize yourself with the procedure and to check on the accuracy of calibration under your conditions, follow the procedures described.

Calibration accuracy will be optimum if you calibrate on a perfectly clear day within 2 hours of solar noon. Avoid nearby buildings, trees or your own body that may influence the spectral characteristics of incident or reflected irradiation. You should not need to calibrate more than once a season, but there is no guarantee that the interference filters will not deteriorate in time. The useful life of the interference filters depends on the conditions to which they are subjected. High temperatures and high humidity must be avoided. The radiometer should be stored in the sealed plastic container with a silica gel pack and should not be subjected to high temperatures when not in use.

METHODS OF CALIBRATION

Three methods of calibrating the radiometer are possible. Each has its advantages and disadvantages. See the CALIBRATION METHODS/ CONSIDERATIONS section for a discussion of these methods.

TWO-POINT METHOD OF CALIBRATION

Make sure the system is configured properly for this method and for the MSR16.

1) On the MSR MAIN MENU select #2 to display the 'RECONFIGURE MSR' menu.

```
RECONFIGURE MSR
1 Date  6 Location 11 Calibrate
2 Time  7 Record   12 Power-Off
3 SS    8 Samples  13 Mode
4 Rem   9 GMT Difference
5 ID   10 IRR       M Main Menu
Enter Selection/Command
*7
```

2) Select #7 'Record' to display the RECORD menu.

```
RECORD (2-Pt.Up/Dn mV MSR16)
 1 Items          Radiometer:
 Calib.Method:     5 MSR87
  2 2-Pt.Up/Dn     6 MSR16
  3 WhiteStd.Dn    7 MSR5
  4 WhiteStd.Up/Dn M Menu
Enter Selection/Command
*2
```

The presently configured Calib. Method and Radiometer is shown in parenthesis after RECORD. Select #2 for 2-Pt.Up/Dn and #6 for MSR16. Both of these must be configured before proceeding to the next step.

3) Press M to return to the RECONFIGURE menu.

4) Select #11, 'Calibrate' to display the CALIBRATION COEFFICIENTS menu.

```
    CALIBRATION COEFFICIENTS
 1 Enter Calibration
 2 Display Calibration
 3 Recalibrate
 M Menu
Enter Selection/Command
*3
```

5) Finally, select option #3 'Recalibrate' to display the RECALIBRATION menu.

```
RECALIBRATION
 1 IRR
 2 2-Pt.Up/Dn
 3 WhiteStd.Up/Dn
M Menu
Enter Selection/Command
*2
```

Now proceed with the methods for calibrating the MSR16 by the Two-Point method. Position the radiometer on a black opaque card on a platform so the opal glass diffuser is upward at 45 degrees with respect to the sun's irradiance.

6) Select #2 '2-Pt.Up/Dn'. The following step by step instructions will appear on the screen.

```
    MSR CALIBRATION

POSITION AT 45 DEGREES ON BLACK CARD
PRESS ENTER WHEN READY

PLACE OPAL GLASS OVER TOP SURFACE
PRESS ENTER WHEN READY

TURN RADIOMETER OVER ON BLACK CARD (45 DEGREES)
PLACE OPAL GLASS OVER SURFACE
PRESS ENTER WHEN READY

Calculating...
```

When finished with the last step, the previous menu appears.

```
RECALIBRATION
 1 IRR
 2 2-Pt.Up/Dn
 3 WhiteStd.Up/Dn
 M Menu
Enter Selection/Command
*M
```

This calibration is based on the following assumptions:

1. Both sets of sensors are viewing the same irradiation intensity provided by the sun illuminating the standard opal glass diffuser.

2. Each sensor response is linear over the operating range.

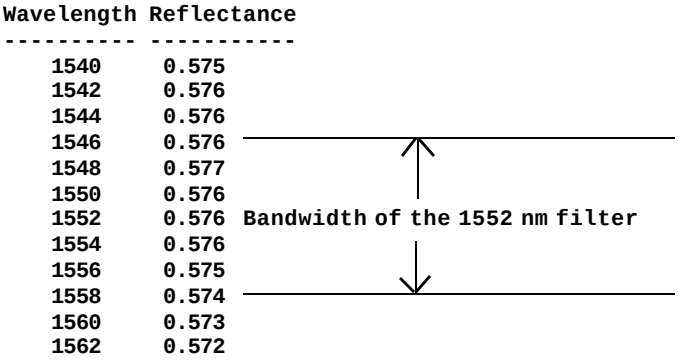
This method of calibration has several advantages. It is convenient. It may be carried out in the field anytime provided sunlight conditions are ideal. Caution: when turning the radiometer over, cover the surface immediately with the opal glass diffuser to avoid overexposing the normally down-facing sensors to the sun.

The calibration coefficients generated for each channel by this method are stored in the CALIBRATION CONSTANTS table. They will remain with the program until they are changed by recalibration or by editing.

WHITE STANDARD UP & DOWN METHOD

The second method of calibration is White standard Up & Down. It requires the use of a white standard for which the spectral reflectance is known. Before using this method of calibration you must enter the reflectance values of the white standard corresponding to the wavelengths of each of the MSR16 filters into the CALIBRATION CONSTANTS table in the WhiteStd. column for the down sensors (even channels). For the white standard obtained from CROPSCAN, enter the reflectance value corresponding to the peak wavelength of each of the standard wavelength filters of 460 to 813 nm. For wavelengths longer than 860 nm, enter the average of the half-peak bandwidth of the filter.

As an example, the following is a portion of the White Standard Spectral Reflectance values which includes the half peak bandwidth range for a 1552 nm filter.



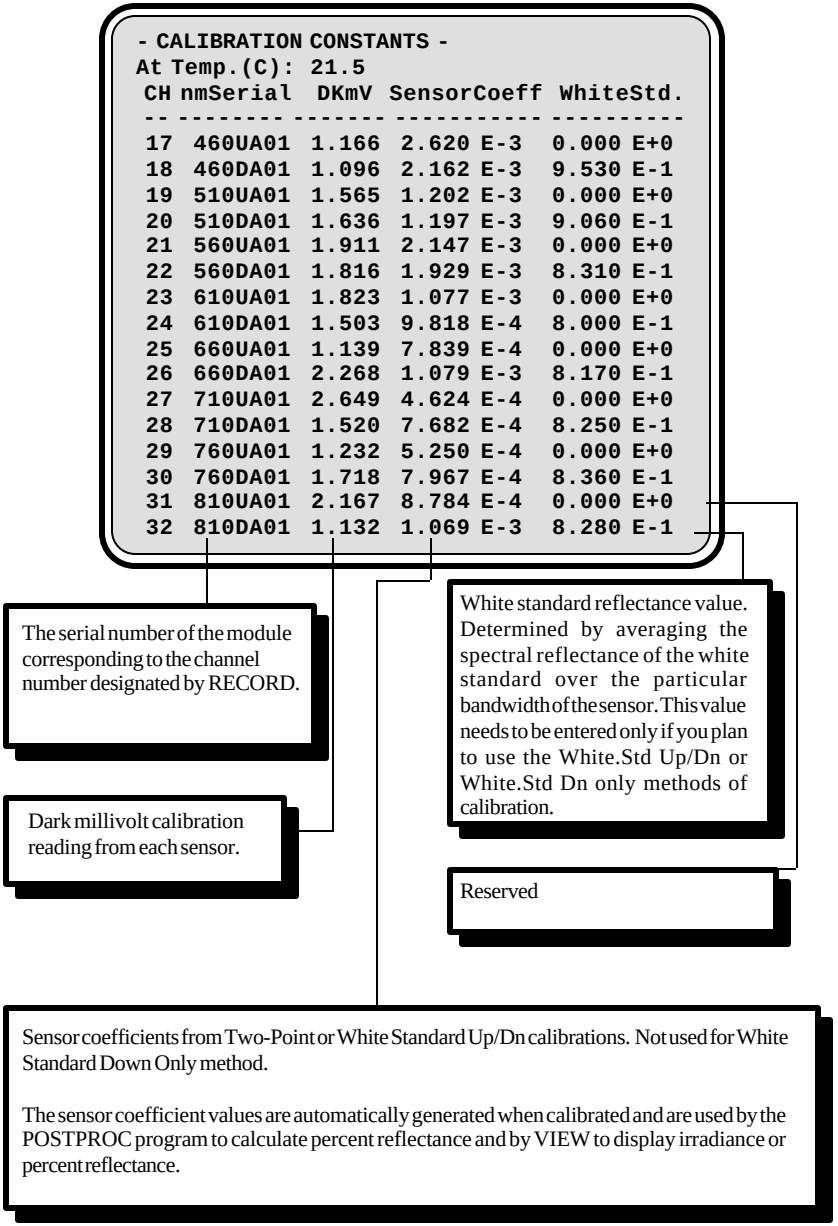
The specifications for the filters can be obtained from the .CAL filter calibration files on the diskette you received with your MSR order.

The white standard reflectance value is determined by averaging the spectral reflectance over the bandwidth of the filter. For the 1552 nm filter, the value is:

(0.0576+0.577+0.576+0.576+0.576+0.575+0.574) / 6 = 0.576

This value is entered into the table of CALIBRATION CONSTANTS as shown on the following page.

Select #2 to display the current CALIBRATION CONSTANTS for your MSR16 radiometer that have been configured by RECORD.



After the CALIBRATION CONSTANTS are displayed, press Enter to return to the CALIBRATION COEFFICIENTS menu.

```
     CALIBRATION COEFFICIENTS
 1 Enter Calibration
 2 Display Calibration
 3 Recalibrate
 M Menu
Enter Selection/Command
*1
```

To edit any of the items of the table, select #1, 'Enter Calibration'

```
Which Channel?
*18
  18  460DA01  1.096  2.162 E-3   9.530 E-1
Serial ( 460DA01): 460DA06
DarKmV (  1.096 ):
Sensor Coeff. ( 2.162 E-3 ):
White Standard Reflectance ( .953 ,
 Press Enter if none):
```

The current wavelength serial number and constants will be displayed successively. Each of the items may be changed. For example, you may wish to change the last three digits of the serial number corresponding to the channel number to correspond to your module serial number. If you intend to use the White Standard Only method of calibration in the field, the correct White Standard Reflectance value must be entered for each of the down facing (even numbered channels). Press Enter for no change for each of the items. After all items have been displayed the CALIBRATION COEFFICIENTS menu re-appears.

```
     CALIBRATION COEFFICIENTS
 1 Enter Calibration
 2 Display Calibration
 3 Recalibrate
 M Menu
Enter Selection/Command
*3
```

Select #3 to display the RECALIBRATION menu.

```
RECALIBRATION
 1 IRR
 2 2-Pt.Up/Dn
 3 WhiteStd.Up/Dn
 M Menu
Enter Selection/Command
*3
```

Select #3 'WhiteStd.Up/Dn'. Position the white standard with its' surface 45 degrees to the sun's irradiance. Mount the radiometer vertically over it so that the opal glass surface is exactly parallel to the surface of the white standard. The following step by step instructions will appear on the screen.

```
  CALIBRATION TO WHITE-STANDARD

POSITION RADIOMETER OVER WHITE CARD
 (45 DEGREES TO SUN)
PRESS ENTER WHEN READY

PLACE OPAQUE CARD OVER TOP SURFACE
PRESS ENTER WHEN READY

PLACE OPAQUE CARD OVER BOTTOM
PRESS ENTER WHEN READY

Calculating...
```

When finished with the last step, the previous menu appears.

```
RECALIBRATION
 1 IRR
 2 Two-Point
 3 White-Standard Up & Down
 M Menu
Enter Selection/Command
*M
```

The calibration coefficients generated for each channel by this method are stored in the CALIBRATION CONSTANTS table. They will remain with the program until they are changed by recalibration or by editing.

WHITE STANDARD DOWN ONLY METHOD

The third method of calibration requires the use of a white standard of known spectral reflectance positioned horizontally in the field at a location so readings of it may be taken periodically immediately before taking readings of plots. Only the down facing sensors are configured for recording.

Make sure the system is configured properly for this method and for the MSR16.

Position the white standard on a platform with its surface exactly level. Leave the white standard in that position for all subsequent readings.

Before taking readings of any of the plots in the field, position the radiometer vertically over the white standard and follow these rules for the use of the 'D' an 'W' keys for the calibration procedure.

Logon to the DLC and proceed to the prompt for PLOT NUMBER: or BEGIN PLOT#:

In **MANUAL MODE:**

At the PLOT NUMBER: prompt, press the 'D' key.
The following instructions will appear on the screen:

```
PLOT NUMBER:D

PLACE OPAQUE CARD OVER BOTTOM
PRESS ENTER WHEN READY
```

After Enter is pressed the message 'SCANNING...' will appear. The dark mV readings for each of the down facing channels will be recorded with the plot number identifier of -1.

When finished, PLOT NUMBER: prompt will again appear. Remove the opaque card from the bottom of the radiometer and press the 'W' key. The following message will appear:

```
PLOT NUMBER:W

POSITION OVER WHITE STANDARD
PRESS ENTER WHEN READY
```

After Enter is pressed the message 'SCANNING...' will appear. The reflected mV readings from the white standard for each of the down facing channels will be recorded with the plot number identifier of '0'

In **AUTO MODE:**

The beginning plot number will be displayed. Enter the beginning and ending plot numbers.

At the SUBSAMPLE: prompt, press the 'D' key. Cover the bottom of the radiometer with the dark card and press Enter to take the dark mV readings. When scanning is complete, remove the dark card and press the 'W' key for the white standard readings.

This calibration procedure should be repeated periodically. The frequency of repetitions will depend on the rate of change of the sunangle. In general, the greater the sunangle, the greater the error in percent reflectance between the first plot reading and the last plot reading before another set of calibration readings. Use the program 'SAMPTIME' to estimate the frequency of calibration repetitions depending on sunangle.

Percent reflection is calculated by the POSTPROC program. It uses the first set of dark mV and white standard readings to calculate percent reflectance for all readings of plots up to the next set of dark mV and white standard readings. Therefore, this calibration procedure can only be used if sunlight conditions are ideal. Any change in sunlight due to clouds, fluctuating haze or sunangle will cause errors in percent reflectance calculations.

This calibration procedure is most useful if you wish to use down facing sensors only. It is also the most accurate method of calibration because corrections are automatically made for variations in temperature and sun angle. (See the section CALIBRATION METHODS/CONSIDERATIONS for a detailed discussion).

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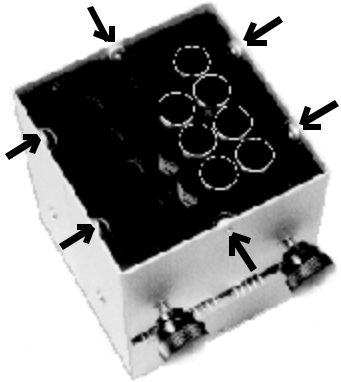
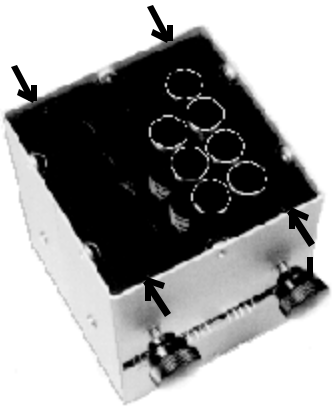
INSERT OR REMOVE MSR16 MODULES

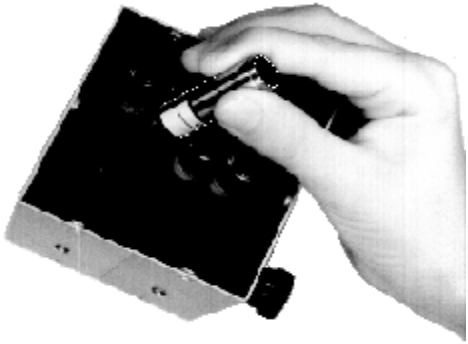
The MSR16 radiometer was designed for easy module insertion or removal. If you ordered MSR16 modules at the same time as you ordered the MSR16 system then the modules were pre-installed for you at the factory. If you ordered modules later then you will have to install them yourself. To install or remove MSR16 modules do the following:

1) Remove the six screws from the top and the six screws from the bottom covers and remove the covers. If you only use the down sensors (WhiteStd.Dn only method) then only remove the bottom cover.



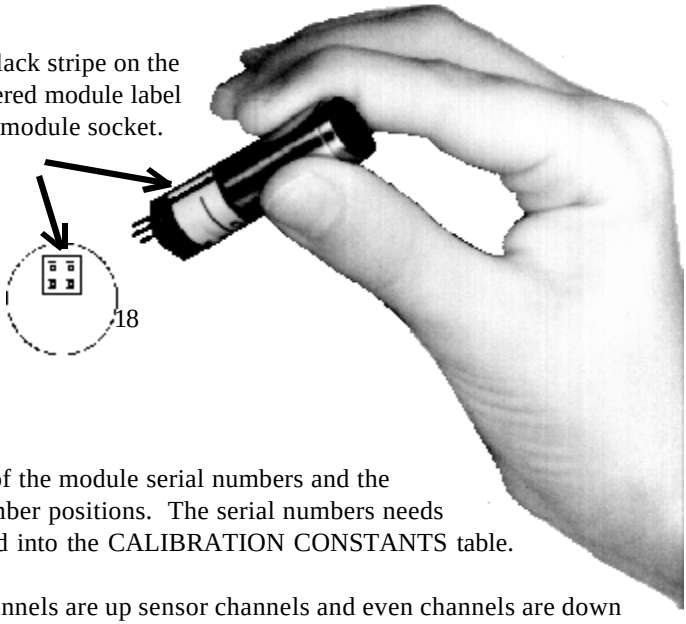


2) Remove the four screws hold ing the black module holding guide and remove the guide.



3) Insert the modules in or remove the modules from the desired positions. The shorter modules are up sensors and are identified by a 'U' in the serial number. The longer modules are down sensors and are identified by a 'D' in the serial number. The modules must be inserted in a certain orientation so the pins mate properly with the module sockets. See the diagram on the following page.

Orient the black stripe on the serial numbered module label towards the module socket.



Make note of the module serial numbers and the channel number positions. The serial numbers needs to be entered into the CALIBRATION CONSTANTS table.

The odd channels are up sensor channels and even channels are down sensor channels. The down channel corresponding to a given up (odd) channel number is the next consecutive even channel. For example, if an up wavelength sensor is to be placed in channel 25 then the corresponding down sensor should be placed in channel 26. The channel numbers are scribed or printed next to the module socket position on the lower-level module guide template on each of the up and down sides.

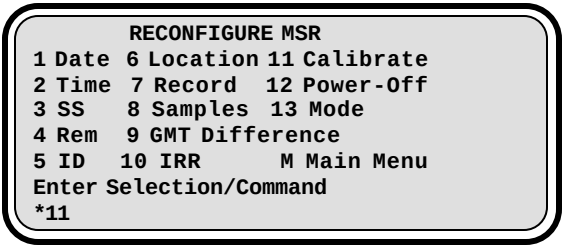
To enter the serial numbers into the CALIBRATION CONSTANTS table do the following:

1) Start the DLC and go to the MSR MAIN MENU

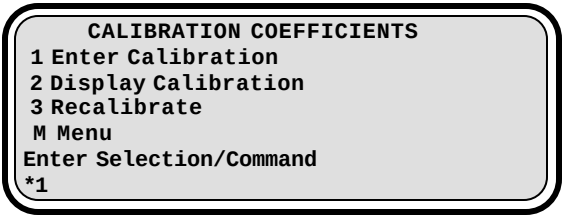
2) Select #2, 'ReConfigure' from the MSR MAIN MENU.

```
        MSR MAIN MENU
 1 Config-Status
 2 ReConfigure    7 Memory Card
 3 Retrieve Data  8 MSR Program
 4 Clear Data     9 Exit MENU
 5 View          10 BYE
Enter Selection/Command
*2
```

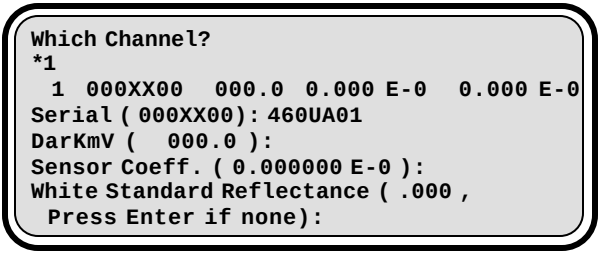
3) Select #11, 'Calibrate' from the Reconfigure MSR Menu.



4) Select #1, 'Enter Calibration' at the Calibration Coefficients Menu.



5) At the 'Which Channel?' prompt enter the channel number for one of the installed MSR16 modules (channel 1, an up module, in this example).



6) At the serial number prompt enter the corresponding MSR16 module serial number.

7) Press Enter at the subsequent DarKmV, Sensor Coeff., and White Standard Reflectance prompts, until you return to the Calibration Coefficients Menu. The DarKmV and Sensor Coefficient values are determined and automatically entered during the calibration procedures. If you will be using a white standard calibration method then you may enter the White Standard Reflectance value, corresponding to each MSR16 waveband, at this time (refer to the White Standard Calibration Method sections of this manual).

8) Repeat steps 4-7 for each channel that contains an MSR16 module installed in the MSR16 radiometer.

9) Proceed to the Reconfiguring and specifying Items to be Recorded sections of this manual to complete the system reconfiguration and to identify which MSR16 sensor channels to record.

STAND-ALONE/REMOTE MSR OPERATION

The MSR System was originally designed for hand-held operations, but it can be used in an unattended stand-alone or remote MSR operation if the equipment is properly housed in weather-proof enclosures. It can take readings automatically at any specified period. The system can be remotely reached for data retrieval or operational changes by use of modems and a telephone line or cellular telephone connection. The MSR16 system has 6 spare analog inputs which may be used with other sensors so it can also monitor other environmental conditions, in addition to reflectance.

Setting up an MSR system for stand-alone operation involves calibrating the radiometer, installing the radiometer in a weather-proof enclosure, installing the remaining equipment in the DLC weather-proof enclosure (DLCENC), and routing the cable from the DLC enclosure to the radiometer enclosure.

The steps to set up an MSR system for stand-alone operation consist of the following:

1) Set-up a mounting structure for the MSR enclosure and DLC enclosure. The MSR pole might be used as a cross-arm on a tripod or firmly attached to a sturdy pole.

2) Mount the DLC enclosure at a convenient location.

Before installing the radiometer and DLC in the enclosures, the radiometer should be calibrated and a calibration file obtained.

3) Using the MSR.BAS program in the DLC,

- Configure for the desired sensor channels, calibration method, and be sure to enter the sensor serial numbers for each channel. If using a white card for calibration, be sure to enter the appropriate white card reflectance for corresponding down (even channel) sensor. Be sure to configure latitude, longitude, and Greenwich Mean Time difference for the location where the MSR system is located. Refer to the HOW TO Configure the MSR and HOW TO Specify Items for Recording sections of this manual.

- Calibrate the Radiometer using the MSR.BAS program. Refer to the appropriate HOW TO Calibrate MSR87, MSR5 or MSR16 Radiometer sections of this manual.

4) Retrieve the calibration data to a PC file (use the RETRIEVE program) and keep in a safe place. This calibration file is needed later by the PREPROC program when preprocessing data from the remote or stand-alone MSR system.

5) Now, install the MSR in the MSR weather-proof enclosure and the DLC in the DLC enclosure. It is recommended that you put a desiccant (silica gel or similar) in the MSR enclosure to keep the moisture level low, to prevent fogging and erroneous reflectance readings, and to extend the life-time of the interference filters in the sensors.

6) Load the DLC.BAS program into the DLC. To do so, bring up the DLC (MSR program), press Ctrl-C, type RESET at the BASIC READY > prompt, and press Enter to Reset the DLC and load the DLC.BAS program from EPROM. If you already have a configured copy of the DLC program on memory card you may load it from the memory card instead.

> The MSR.BAS program does not support stand-alone or remote operations. The built-in DLC can support stand-alone and remote operations.

7) ReConfigure the DLC.BAS program (option 2 from the DLC Main Menu).

- Set the items for RECORD:
  For the MSR87 radiometer:
  Configure RECORD: for DATE and TIME plus the desired radiometer sensor channels (1-16). Use Gain=1, Range=0, and 4 decimal digits. For example,
  RECORD:DATE,TIME,1-16G1R0D4.
  For the MSR5 radiometer:
  Configure RECORD: for DATE, TIME, and channel 15 (MSR5 temperature) plus the desired radiometer sensor channels (1-10). Use Gain=1, Range=0, and 4 decimal digits. For example,
  RECORD:DATE,TIME,1-10G1R0D4,15G1R1D1.
  For the MSR16 radiometer:
  Configure RECORD: for DATE, TIME, 3G1R1D1, and 4GAD4 plus the desired radiometer sensor channels (17-48). Use automatic gain and 4 decimal digits. For example (if 8 wavelengths are used),
  RECORD:DATE,TIME,3G1R1D1,4GAD4,17-32GAD4

> For the MSR16, the radiometer temperature is measured on channel 3 and the GND millivolt offset is measured on channel 4. These are required by the POSTPROC program when percent reflectance calculations are made on the retrieved data from an MSR16 system.

- **o** Configure the scan rate and other configuration parameters as needed (ReConfigure Menu). Refer to the DLC User's Manual for more information on reconfiguring the DLC (page 22).

- **o** If you will be using a modem for remote communications to the DLC you must determine the mode of operation, connect the appropriate hardware, and configure the DLC software accordingly.

  Refer to the REMOTE COMMUNICATIONS INTERFACE-TELEPHONE MODEM section beginning on page 68 of the DLC User's Manual for detailed information on how to do this.

8) Enter conversion equations:

For the MSR87: None required.

For the MSR5:

Enter the following temperature conversion routine by first pressing Ctrl-C, to bring the DLC to the BASIC Ready prompt, and then typing the program lines as shown.

```
10101 X(15)=-273.15+X(15)/10
```

List the lines just entered by entering
LIST 10101-10101
to verify that the lines were entered correctly.

For the MSR16:

Enter the following temperature conversion routine by first pressing Ctrl-C, to bring the DLC to the BASIC Ready prompt, and then typing the program lines as shown.

```
10101 X(3)=X(3)-X(4):R=(V5V/X(3)-1)*34E3:IF R<1 THEN R=1
10102 Q=LOG(R):X(3)=1/(8.2790357E-4+2.0869887E-4*Q+8.0850365E-
                                                  8*Q**3)-273.15
```

List the lines just entered by entering
LIST 10101-10102
to verify that the lines were entered correctly.

You may enter the conversion routines for any extra channel sensors that you may have connected to the MSR32 Channel Adapter at this time. Do so in a fashion similar to that above. Refer to the Mid-Scan Hooks section, starting on page 166, of the DLC User's Manual for more information and examples.

A memory card with the write protect switch in the OFF position may be left inserted in the DLC. Remotely, by modem, you can then save collected data in the DLC memory to the memory card and then CLEAR the DLC data memory. This would allow the DLC to collect more data and double the time between site visits to retrieve the data, if you do not plan to retrieve the data by modem.

If you plan to use a memory card left plugged into the DLC and will remotely control storing data to it, then enter the following:

```
3626 RETURN          (press Enter)
3627                 (press Enter)
```

This modifies the DLC operations program so that it is not required to physically move the memory card write protect switch to the protect position after each remotely controlled storage of DLC data to the memory card. However, you must move this switch on the memory card before removing it from the DLC.

Type RUN and press enter to return to the DLC program.

> After the DLC program is configured, you may save it to a memory card for the convenience of future reloading.

9) Put the DLC into the Auto Scan Mode (MODE:AUTO) to start automatic scanning operations.

Data Retrieval and Processing

After the system has collected data it can be retrieved to a computer by a local RS232 connection, by memory card, or remotely by modem and telephone.

10) Retrieve the data from the remote or stand-alone MSR system to a PC file. When you are sure you have successfully retrieved the data from the DLC be sure to CLEAR the data from the DLC to make memory space available for new data.

    If you retrieve data remotely by modem use a PC communications program like PROCOMM, QMODEM, or any commercial communications program that supports XMODEM transfer protocol. Configure the DLC for XMODEM data retrieval. This will ensure a higher level of data integrity due to the error detection and retransmitting capabilities of the XMODEM protocol.

11) Run PREPROC to combine the MSR calibration file created in step 4 above with the data file from step 10 to create an .MV file for input to the POSTPROC Percent Reflectance calculation program.

    (optional) If you use any extra analog channels (5-10) of the MSR16 32 Channel Expansion/Adapter Module, MSR32CHA, you may run EXTRACH to define the names and formats that the POSTPROC program will use for them. If this program is not used, the output data header will simply contain the appropriate channel number (CH5, CH6, etc.) and the data will be formatted as retrieved from the DLC.

12) Run POSTPROC to calculate percent reflectance from the data collected.

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TROUBLE SHOOTING

DLC will not power up (red LED does not light) after pressing Enter three (or more) times:

Check the power source to the DLC. The DLC must have at least 8.6 volts DC.

Check the cable connections between the computer or terminal and the DLC. Make sure the cable is wired properly. (See appendix A for cable wiring specifications).

The circuitry on the DLC board is protected by a 2AG 1/2 A fuse. Replace if necessary. (A spare fuse is taped to the circuit board).

The DLC will power up (red LED does light) but the logon message does not appear on the computer or terminal screen.

Check your communications program and make sure the parameters are set correctly (See page 4.1 for communications parameters). Check that the correct communications port is being used.

The DLC program may require a reset. Use a pencil tip to press the Soft Reset on the back panel of the DLC. Try logging on again. If this fails, press the Hard Reset on the back panel. After pressing it, wait a few seconds for the red LED light to go out and then press Enter. The LED will light and after a few seconds you will hear an audible beep. Then press Enter twice at about 1 second intervals to logon. The DLC Logon message and option to enter security code will be displayed. Enter 'N' for no security code. Enter 'N' for security. (The security option is not supported by the MSR program). Now you must reload the MSR operations program to replace the DLC operations program. Follow the procedures for doing this in the HOW TO UPLOAD MSR PROGRAM LINES section or in the HOW TO USE THE MEMORY CARD section.

Percent reflection values do not appear normal or as expected for the various wavelengths.

Recheck calibration of the radiometer as outlined in the procedure. Test to determine if there is an output for each of the sensors when irradiated. You can do this under sunlight or artificial light. Select option #5 'View' from the MSR MAIN MENU. The output of each of the up

facing sensors (odd channel numbers) and down facing sensors should all fluctuate in response to varying illumination. If any of the outputs do not fluctuate, make sure the module is installed correctly for the MSR16 radiometer and make sure all cables are properly connected to the radiometers as well as to the DLC..

All interference filters will deteriorate with time depending mostly on moisture penetration. This process is known as hydrodiffusion. One of the symptoms of deterioration of the visible wavelengths may be leakage in the NIR. Another indication is the filter surface showing discoloration near the edges and occasionally non-uniform spotting. You can test for leakage by comparing the output of the visible wavelengths when covered by an opaque card with the output when covered with a Wratten 87C filter. (This filter passes NIR from about 750 nm but blocks all visible wavelengths). If the visible wavelength filters are good, there should be no significant difference in the output of the sensors when covered by the opaque card and the Wratten 87C filter. Wavelength sensor above 750 nm cannot be tested in this manner. They can only be tested with a spectrophotometer. If there is a significant increase in output of any of the visible wavelength sensors when covered by the Wratten filter, that filter must be replaced. Contact CROPSCAN for replacement.

Internal NiCad batteries do not hold a charge like they used to.

NiCad batteries discharge and charge cycles require some attention. A NiCad cell's 'memory' may have been reduced by continual use of the AC adapter without occasional full battery discharge/charge cycles.

Do not leave the AC adapter/charger plugged-in for more than a couple days or do not continuously use the DLC with the AC adapter. NiCad battery discharge and charge capacity can only be kept in shape by proper exercise, much like the human body. NiCad batteries when properly charged and discharged will last about 500 cycles, less than that otherwise.

Refer to the DLC User's Manual section BATTERY OPERATIONS AND CONSIDERATIONS for more information.

RETRIEVE program does not complete successfully when used under Microsoft Windows.

Increase background priority settings (click once on active Cropscan icon, click on settings, then change background priority) or do not switch

away from the Cropscan RETRIEVE session until after the data retrieval completes.

If all else fails, contact CROPSCAN INC to arrange for repair and a possible 'loaner' while repairs are being made. If under warranty there will be no charge except for postage and handling. Otherwise, you will be billed for the cost of repair.

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APPENDIX A: SPECIFICATIONS

MSR87 RADIOMETER:

The housing contains 8 standard wavelength/sensor cells to measure incident irradiation and matched cells to measure reflected irradiation. Signal conditioning for each of the cells is provided by signal conditioning circuitry on printed circuit boards.

Field of view

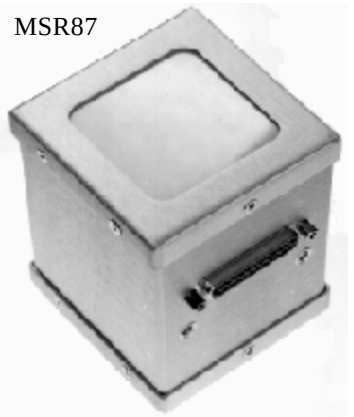
Incident irradiation - 180 degrees (flashed opal glass diffuser).
Reflected irradiation - 28 degrees

Typical spectral passbands of the standard wavelength set (460, 510, 560, 610, 660, 710, 760, & 810nm center-wavelengths) are 25 - 35 nm with 50 percent minimum peack transmittance. Refer to the specifications that you received with your radiometer.

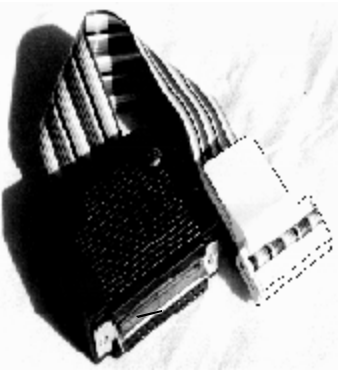
Radiation transducers:	Silicon photodiodes.
Signal conditioner:	Linear operational amplifier
Operating Temperature Range:	0 - 50 degrees C
Operating Humidity Range:	0 - 100 percent, non-condensing
Storage Humidity Range:	< 20 percent

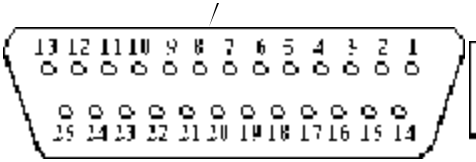
MSR87 RADIOMETER AND MSR87CA CONNECTOR PIN-OUTS:

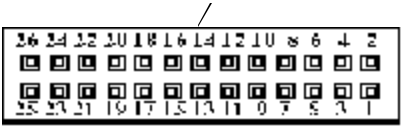
MSR87



MSR87CA







DB25	WAVELENGTH	CHANNEL	26 PIN HEADER	COLOR
13	GND		1	BROWN
13	GND		2	RED
11	460 UP	1	3	ORANGE
10	460 DN	2	4	YELLOW
9	510 UP	3	5	GREEN
8	510 DN	4	6	BLUE
7	560 UP	5	7	VIOLET
6	560 DN	6	8	GREY
5	610 UP	7	9	WHITE
4	610 DN	8	10	BLACK
12	+ 5V		11	BROWN
12	+ 5V		12	RED
			13	ORANGE
			14	YELLOW
15	+ 5V		15	GREEN
15	+ 5V		16	BLUE
3	660 UP	9	17	VIOLET
2	660 DN	10	18	GREY
1	710 UP	11	19	WHITE
25	710 DN	12	20	BLACK
24	760 UP	13	21	BROWN
23	760 DN	14	22	RED
22	810 UP	15	23	ORANGE
21	810 DN	16	24	YELLOW
14	GND		25	GREEN
14	GND		26	BLUE
20	TEMPERATURE	–	NC	
16-19	NC			

MSR5 RADIOMETER:

The housing contains 5 standard wavelength/sensor cells to measure incident irradiation and matched cells to measure reflected irradiation. Signal conditioning for each of the cells is provided by signal conditioning circuitry on printed circuit boards.

Field of view

Incident irradiation - 180 degrees (flashed opal glass diffuser).
Reflected irradiation - 28 degrees

Spectral center wavelengths and passbands are similar to those of the first five bands of the LANDSAT satellite THEMATIC Mapper. Refer to the specifications that you received with your radiometer. Typical spectral bands are:

450 - 520 nm
520 - 600 nm
630 - 690 nm
760 - 900 nm
1550 - 1750 nm

Radiation transducers: Silicon and Germanium photodiodes.

Signal conditioner: Linear operational amplifier

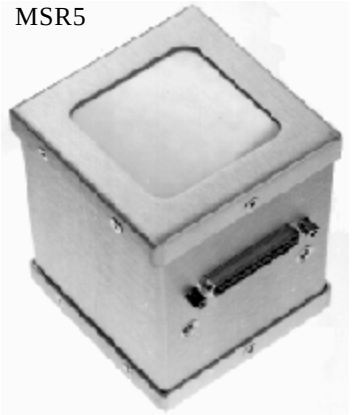
Operating Temperature Range: 0 - 50 degrees C

Operating Humidity Range: 0 - 100 percent, non-condensing

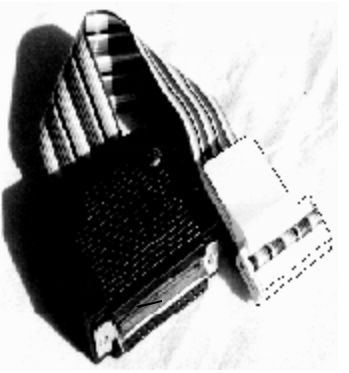
Storage Humidity Range: < 20 percent

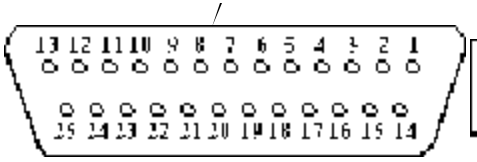
MSR5 RADIOMETER AND MSR87CA CONNECTOR PIN-OUTS
(Note: MSR87CA Cable Adapter used for either MSR87 or MSR5):

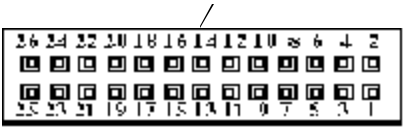
MSR5



MSR87CA







DB25	WAVELENGTH	CHANNEL	26 PIN HEADER	COLOR
13	GND		1	BROWN
13	GND		2	RED
11	485 UP	1	3	ORANGE
10	485 DN	2	4	YELLOW
9	560 UP	3	5	GREEN
8	560 DN	4	6	BLUE
7	660 UP	5	7	VIOLET
6	660 DN	6	8	GREY
5	830 UP	7	9	WHITE
4	830 DN	8	10	BLACK
12	+ 5V		11	BROWN
12	+ 5V		12	RED
			13	ORANGE
			14	YELLOW
15	+ 5V		15	GREEN
15	+ 5V		16	BLUE
3	1650 UP	9	17	VIOLET
2	1650 DN	10	18	GREY
1	NC	11	19	WHITE
25	NC	12	20	BLACK
24	NC	13	21	BROWN
23	NC	14	22	RED
22	TEMPERATURE	15	23	ORANGE
21	NC	16	24	YELLOW
14	GND		25	GREEN
14	GND		26	BLUE
16-20	NC			

MSR16 RADIOMETER:

The brushed aluminum housing contains sockets for up to 16 pairs of modules. Module wavelength and bandwidth can be specified by the customer at the time or order. The modules are user-installable.

Field of view

Incident irradiation - 180 degrees (flashed opal glass diffuser).
Reflected irradiation - 28 degrees (determined by module dimensions).

Spectral passbands of the standard wavelength set, at the time of this writing are the same as for the MSR87.

Radiation transducers (in module): Silicon photodiodes, visible to NIR. Germanium photodiodes, Mid-NIR

Signal conditioner (in module): Linear FET operational amplifier

Temperature sensor (in MSR16 housing): Thermistor (Unicurve type)

Temperature sensitivity calibrations for each module and cosine correction calibrations for each up module are provided in individual files on a PC diskette. Corrections are applied in post data collection processing (POSTPROC program).

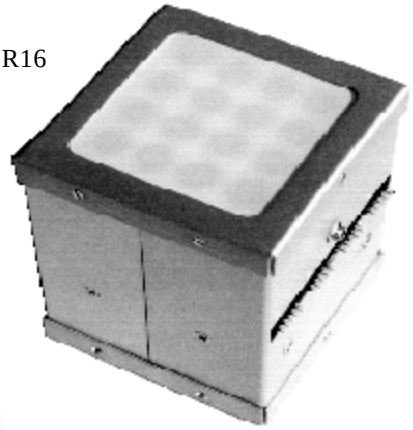
Operating Temperature Range: 0 - 50 degrees C

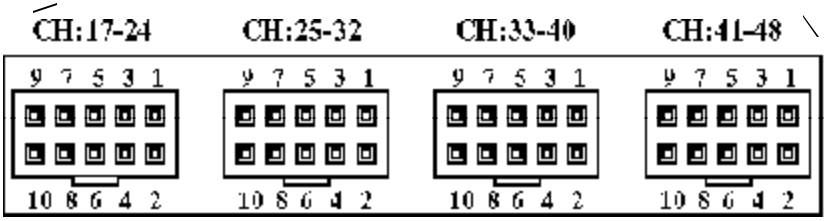
Operating Humidity Range: 0 - 100 percent, non-condensing

Storage Humidity Range: <20 percent

MSR16 RADIOMETER AND MSR32CHA CONNECTOR PIN-OUTS:

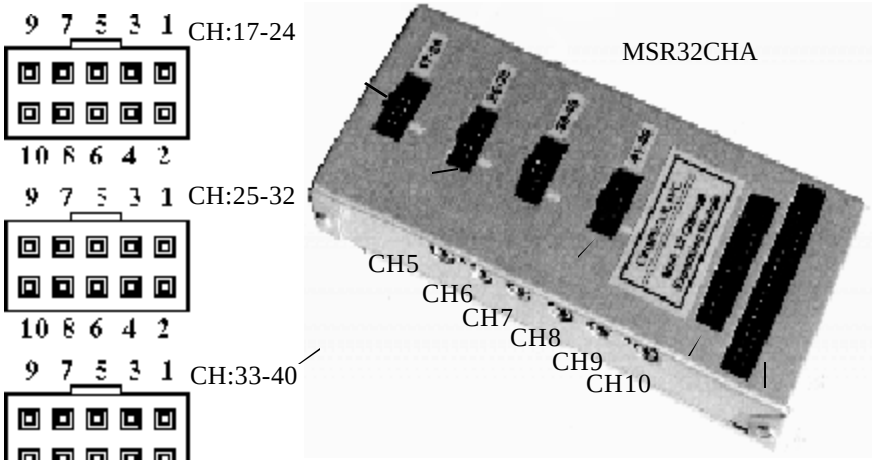
MSR16





CH:17-24		CH:25-32		CH:33-40		CH:41-48	
1	CH21	1	CH29	1	CH37	1	CH45
2	CH17	2	CH25	2	CH33	2	CH41
3	CH22	3	CH30	3	CH38	3	CH46
4	CH18	4	CH26	4	CH34	4	CH42
5	CH23	5	CH31	5	CH39	5	CH47
6	CH19	6	CH27	6	CH35	6	CH43
7	CH24	7	CH32	7	CH40	7	CH48
8	CH20	8	CH28	8	CH36	8	CH44
9	+5V	9	+5V	9	+5V	9	Thermistor
10	GND	10	GND	10	GND	10	GND

This pin definition also applies to the 10 pin connectors on the 32 Channel Expansion Adapter (MSR32CHA), pictured on the following page.



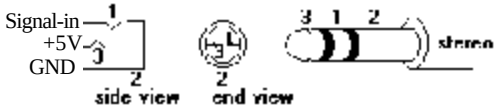
Pins defined on previous page.

Analog Connector to DLC

Digital Connector to DLC

Analog and Digital Connectors to DLC pins are defined in the DLC User's Manual and Technical Reference on pages 274 and 275.

Extra Channels 5-10 Inputs:



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MSR16R RADIOMETER:

The housing contains up to 16 sensor bands to measure incident irradiation and reflected irradiation. Signal conditioning for each of the bands is provided by signal conditioning circuitry on printed circuit boards. The MSR Cable Adapter Box (MSRCAB) is required for use with the ***CROPSCAN, Inc.*** Data Logger Controller (DLC). It contains additional signal multiplexing for the radiometer and six additional inputs for other external sensors.

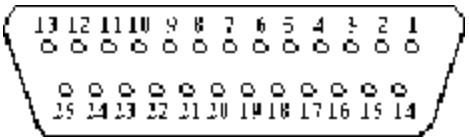
Field of view

Incident irradiation - 180 degrees (flashed opal glass diffuser).
Reflected irradiation - 28 degrees

For specification of the MSR16R sensor bands, refer to those listed in the .cal files included on the MSR Program diskette included with your system.

Radiation transducers:	Silicon photodiodes, visible to NIR. Germanium photodiodes, Mid-NIR
Signal conditioner:	Linear FET operational amplifier
Operating Temperature Range:	0 - 50 degrees C
Operating Humidity Range:	0 - 100 percent, non-condensing
Storage Humidity Range:	< 20 percent

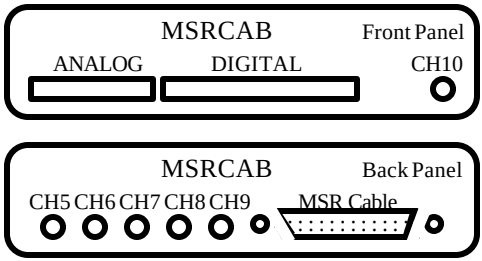
MSR16R RADIOMETER PIN-OUTS:



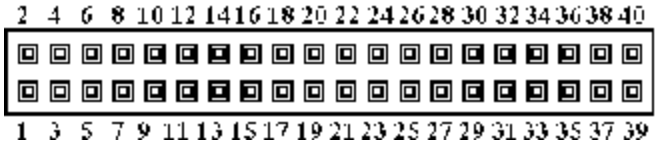
DB25	DESCRIPTION	
1-7	Reserved	
8	Bands 9-12 (multiplexed out)	DLC Channels 33-40
9	Bands 1-4 (multiplexed out)	DLC Channels 17-24
10	Bands 13-16 (multiplexed out)	DLC Channels 41-48
11	Bands 5-8 (multiplexed out)	DLC Channels 25-32
12	+V	(5.5 to 6 volts, 5.7 volts from DLC)
13	GND	
14	GND	
15	+V	(5.5 to 6 volts, 5.7 volts from DLC)
16	MSR16R ID (GND out)	
17	MUX Address 1 (in)	See table below for MUX to MSR16 Channel
18	MUX Address 2 (in)	addressing (0 = Gnd, 1 = +V volts)
19	MUX Address 3 (in)	
20	Temperature out (T = (V/10) - 273.15, degrees C)	
16-19	Reserved	

MUX Address			Sensor Band (Up/Dn) on DB25 pin				Corresponding DLC Channel			
3	2	1	8	9	10	11	8	9	10	11
0	0	0	9U	1U	41	5U	33	17	41	25
0	0	1	9D	1D	42	5D	34	18	42	26
0	1	0	10U	2U	43	6U	35	19	43	27
0	1	1	10D	2D	44	6D	36	20	44	28
1	0	0	11U	3U	45	7U	37	21	45	29
1	0	1	11D	3D	46	7D	38	22	46	30
1	1	0	12U	4U	47	8U	39	23	47	31
1	1	1	12D	4D	48	8D	40	24	48	32

MSR CABLE ADAPTER BOX (MSRCAB) PIN-OUTS:



Analog Connector to DLC



Digital Connector to DLC

Analog and Digital Connectors to DLC pins are defined in the DLC User's Manual and Technical Reference on pages 274 and 275.

Extra Channels 5-10 Inputs:

The extra channel inputs can be used to input other external sensor signals to the DLC. GND and +5V are provided on pins 2 and 3, respectively, of the jack. The sensor signal must be on pin 1 of the plug.

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APPENDIX B: COMMANDS

The following are the operational commands supported by the MSR BASIC program. They may be entered at any command line or menu selection prompt. Command entry may be abbreviated to the capitalized mnemonics shown.

CONFIGURATION COMMANDS

BCV:*v*<CR>	Battery Cut-out Voltage, *v* > 8.6.
BCV<CR>	Display battery cut-out voltage.
CONfiguration<CR>	Display current configuration settings.
DATE:*mm*:*dd*:*yyyy*<CR>	Set present calendar date, *mm*=month (01-12), *dd*=day of month (01-31), *yyyy*=year.
DATE<CR>	Display present date.
IDentification:*nnn*<CR>	Set Radiometer Serial Number or Experiment Number. *nnn* = 001 to 999.
IDentification<CR>	Display Radiometer Serial Number or Experiment Number.
LAtitude:*d*:*m*	Latitude. *d*, degrees=-90 to +90, *m*, minutes=0-60.
LOCation:*lll*<CR>	Identify location (*lll* = up to 3 characters).
LOCation<CR>	Display current location identification.
LONgitude:*d*:*m*	Longitude. *d*, degrees=0-360, *m*, minutes= 0-60.
MENu<CR>	Go to Menu Interface Mode.
MOde:M<CR>	Set plot scan mode to Manual plot identification entry.

MOde:A<CR> Set plot scan mode to Automatic plot number incrementing.

MOde<CR> Display plot scan mode setting.

POwer:*n*<CR> Power-down delay,
n = 30 to 65535 seconds.

POwer:CONT<CR> Continuous power (no power-down)

POwer<CR> Display current power-down timeout value.

SS:*n*<CR> Plot 'SubSample'. The number of sub-samples per plot, *n*= 1 to 99.

SS<CR> Display current number of sub samples setting.

RECord:CLEAR, CLEARs all previously configured record items.

Identify items to be recorded on scans. DATE,TIME, IRR, PLOT, and SUBSAMPLE are always recorded. For MSR16 channel 3 (temperature) and channel 4 (GND mV) are also always recorded. For MSR5 channel 15 (temperature) is always recorded.

ID, Unit or Experiment ID
LOC, Location
BAT, Battery Voltage
+5V, +5V Supply Voltage
T, DLC Temperature (degrees C)
c[R*r*][G*g*][D*d*], Channel, *c*, Voltage
<CR> Letters in brackets are optional functions.
c = channel or channel range, 1-48
R*r* = voltage range,
r=0 for -5 to +5 V
r=1 for 0 to +5 V
G*g* = gain, *g*=A,1,10,100 , or 1000,
A means Auto-range and gain
D*d* = Decimal points, *d*=0,1,2 or 4
Xitem will eXclude item from RECORD, if previously configured.

Note: The record command may be used repeatedly to add or remove items to or from previously identified items for recording.

Example: To instruct the DLC to record location, date, time, channels 1-5 with gain of 1, range of 0 to +5 volts, channels 6-7 with automatic gain and range determination, and data format of 2 decimal places, the following RECORD command could be used.

REC:date,time,1-5G1R1D2,6-7GAD2<CR>

To exclude (remove) channels 3 and 6,

REC:X3,X6

To add digital inputs to items recorded,

REC:DI

RECord<CR> Display a list of the current items to be recorded.

REMark:*remark string*<CR> *Remark string*, up to 72 characters in length

REMark<CR> Display remark

SAmples*n*<CR> Set number of samples to average per analog channel reading, *n* = 1 to 65535.

SAmples<CR> Display current number of samples setting.

TIME:*hh*:*mm*:*ss*<CR> Set present time (military format),
hh=hour of day (00-23),
mm=minutes (00-59),
ss=seconds (00-59).

TIME<CR> Display present time.

REAL TIME COMMANDS

BYE<CR>	Causes the DLC to return to sleep.
CLEAR<CR> => ARE YOU SURE (Y/N)?	Clear Data RAM.
DATA<CR>	Display all data recorded.
DATA:**A**scii<CR>	Configure subsequent Data Retrievals to be done as ASCII Text.
DATA:**S** *s*[-*e*]<CR>	Display Data for Scan or scan range, *s* = starting scan number, *e* = ending scan number.
MEMory<CR>	Display system memory size.
VERsion<CR>	Display MSR (and DLC) software level and assembly date and time.
VIew<CR>	Continuous display (view) of real-time data for items identified previously with RECORD command.