LUNARSCAN

User's Guide Version 1.5

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1 LUNARSCAN USER'S GUIDE

1.0 INTRODUCTION

The ***LunarScan*** software was originally developed in 1999 to process the video imagery associated with meteoroid impacts on the moon that had been collected by Dave Dunham during the Leonid meteor storm of that year. Under sponsorship by the NASA Meteoroid Environment Office, the software was ported from a Macintosh to PC compatible systems as well as a frame-to-frame registration algorithm implemented and tested for more robust flash detection. Version 1.5 upgrades include the ability to read single large AVI files without pre-splitting them.

IMPORTANT NOTE: Please provide impact flash observations that include the date, time, location of observatory, and location of the impact on the moon to NASA's Meteoroid Environment Office at the email address listed under "Contact Us" at the website http://www.nasa.gov/centers/marshall/news/lunar/index.html

1.1 SYSTEM REQUIREMENTS AND INSTALLATION

The ***LunarScan*** software has been written for the IBM compatible PC series of computers to detect meteoroid impact flashes on the moon. Specifically the development and testing has been done on a HP desktop system with Windows XP and Metrowerks Codewarrier release 6 and should be compatible on most PCs available today. Although the basic detection algorithms are not wedded to a particular computer system, the software does operate by reading from an AVI file stored on the computer's hard disk. Thus the computer system must be capable (independently through other third party software) of ingesting video imagery and storing the frame sequence as an AVI file on a hard drive prior to processing by ***LunarScan***. The non-real-time nature of the existing version does not put any processing constraints on the size and speed of the processor.

One needs to have sufficient hard disk space to store the typical size of an AVI video file. Most camcorders record using digital video compression (DV) with a resulting file size of 12 Gbytes per hour of video. Prior to version 1.5, these files needed to be split into less than 1 Gbyte chunks since LunarScan had used the Video for Windows (VFW) interface API. For version 1.5 and beyond, there is no longer a need to break apart large AVIs as the software has been interfaced to an AVI reader which can handle AVI files of any size. Thus for a two hour tape recording of a given night, one must have a minimum of 24 Gbytes of hard disk storage available to digitize the imagery. It is recommended that the disk be defragmented prior to running any software that ingests video to hard disk for optimal throughput.

The software is provided as an executable and thus there is no need for compilation or linking to operate. Simply first create a folder of your own naming convention (e.g. C:\LunarScan) that you will use to run the software from. Next move the executable "LunarScan150.exe", the parameter settings file "LUNAR_SETTINGS.txt", the working list of meteor showers "MeteorShowerTable.txt", the DLLs (libfftw3-3.dll, avcodec-51.dll, avformat-51.dll, avutil-49.dll) into that folder and create subfolders “AVIs” and “Data” and put the test.* files into the Data subfolder. The LUNAR_SETTINGS.txt” file has been preset to read AVI files from the subfolder within this main folder called “AVIs” and output results will be put in the other subfolder called “Data”. You could specify different folder names residing anywhere on the hard disk for input and output by using an absolute directory pathname in the LUNAR_SETTINGS file.

Note that the av* DLLs were created from the ffmpeg support website at http://ffmpeg.arrozcru.com/builds/ based on the files contained within the windows shared build “ffmpeg-SVN-r7215-shared-win32.zip”. The DLLs are subject to the Lesser General Public License (LGPL) and its source code can be obtained from the URL listed above for release 7215. Note that only the LunarScan executable is also governed under the LGPL having linked in the ffmpeg modules.

For optimal viewing, the system’s display monitor can be set to 1024x768 pixels to completely fill the screen with the windows generated by the software. Wider screen formats can be used if desired. The software’s dimensional requirements have been set to accommodate digital video (DV) format imagery. The arrays have all been declared globally with a maximum dimensional image size currently set to 576 rows x 768 columns. Smaller sized video imagery such as NTSC 480 x 640 is thus accommodated.

1.2 INITIAL TEST of INSTALLATION

The ***LunarScan*** software should be tested for proper function when first installed on a PC. Double clicking the ***LunarScan*** executable icon should launch the application and a series of five windows should appear. Ensure the console entry window is highlighted (if necessary, click the mouse in the lower right window). Enter a “5” and the program should go into viewing mode. Type “test” and carriage return for the name of the pre-processed data file and the first detect should be displayed in the upper left and right windows. Press the spacebar to move to the second detection. Press the spacebar again should return to the main menu. Pressing “Q” should exit the software.

1.3 RUN-TIME EXECUTION

The ***LunarScan*** software has been designed to run autonomously by image processing pre-recorded lunar imagery stored on the hard disk of a personal computer. The user interacts during the initialization, processing setup, and post-scanning phases of the operation. The software scans through every frame in the user provided AVI file, searching for impact flash events.

1.3.1 Preparing the AVI file(s) on Hard Disk

Prior to execution start, the user must store a video sequence onto the hard disk of the processing computer. For digital video this is typically done by connecting a DV camcorder to an IEEE 1394 (firewire) port on the PC. Running a third party program such as Windows MovieMaker can then play the videotape in the camcorder and create an AVI format video file on the hard disk. Other software and/or video digitizing hardware/software may be used. It is recommended to store the video data in DV AVI format to avoid compression losses induced by switching from the data's native format (DV) as typically stored on the camcorder. Storing in an uncompressed format is also not recommended as this would use up 60 Gbytes for every hour of video.

Starting with version 1.5, it is no longer necessary to split the AVI into 1 Gbyte chunks. When questioned about whether or not the file is a split AVI, imply enter this is NOT a split AVI and type in the name of the file when requested during execution The software uses an AVI read interface which requires certain DLLs which are distributed at the FFMPEG development website. See section 1.1 on installation above.

1.3.2 Initialization and Execution

Prior to execution start, the desired optimal scan settings can be adjusted in the "LUNAR_SETTINGS.txt" data file which is in ASCII format and should be accessible via any text based editor. The file is updated after each processing step or scan completion so that a quick restart is possible using the most recent set of control parameters. To avoid losing a particular group of settings the user may save this file under another name and recall it later by renaming it back to "LUNAR_SETTINGS.txt". The program always reads the file named "LUNAR_SETTINGS.txt". The following is a sample "LUNAR_SETTINGS.txt" file and should be a good initial set of values.

```
------------------------------------------------------------------------------------------
                                    Version          = 1.500000
THRESHOLD FACTORS:
  k1 -> 4 x Primary sigma factor                     = 10
  k1plus --> extra above k1 for doublet              = 4
  Frame look back for differencing                   = 1
DETECTION PROCESSING PARAMETERS:
  Movie loop 1/2 band width (pixels)                 = 15
  Patch size (odd #pixels with max 33)               = 33
SCAN MODE DEFAULT PARAMETERS:
  Mode: 1-BIT 3-AVI                                  = 3
  Frame Proc: 0-Mean 1-Registered                    = 1
  Cluster: 0-Trips 1+Pixel 2+Doubles                 = 2
  Segment Surf: 0-3 No Manual Auto Grad              = 2
  Save Format 0-No, 1-Frame, 5-Mean                  = 1
PROCESSING REGION PARAMETERS:
  Row for the top of proc. window                    = 0
  Row for the bottom of proc. window                 = 479
  Column for the left of proc. Window                = 0
  Column for the right of proc. window               = 719
MASKING REGION PARAMETERS:
  Row for the top of the mask                        = 20
  Row for the bottom of the mask                     = 40
  Column for the left of the mask                    = 690
  Column for the right of the mask                   = 710
LUNAR SURFACE REGION PARAMETERS:
  Row for the top of the region                      = 160
  Column for the left of the region                  = 340
  Std dev factor for minimum median                  = 3.500000
  Std dev factor for maximum median                  = 15.000000
```

TRACKING FILTER RESPONSE COEFFICIENTS:
  Primary coef, 2 raised to this power   = 4
FILE CONTROL PARAMETERS:
  Digital Input File Directory   = AVIs\
  Output File Directory   = Data\
  Number saved TIFs before and after   = 5
--:

The user can control various scanning control parameters through these settings. For example, if there is a time stamp in the image, a selected rectangle of pixels can be masked from the detection processing if false alarms from the changing time stamp prove to be a nuisance. The filter response coefficient can also be adjusted, although the value shown is fairly optimal for most imagers. The threshold parameter k1 is four times the scale factor times each pixel's standard deviation to declare an exceedance. The k1plus term is used to define a higher level threshold for doublet only processing and should be of order one sigma higher (4 higher for the entry value). The threshold factor k1 is one parameter that may need adjusting based on video characteristics and noise/alignment of the imagery. See section ***1.4.4.3 Window Displays and Threshold Optimization*** later in this chapter. In addition to setting parameters through the LUNAR_SETTINGS.txt file, several parameters such as the threshold can be adjusted interactively via control keys by noting the options listed in the lower left window during runtime.

For initialization preparation, the computer system should be cleared of all programs other than ***LunarScan*** which may require a restart to free up any system memory that was allocated to an application but not released back to the system. The user then executes the ***LunarScan*** program by double clicking the executable icon which initializes various processing and transformation variables. The initialization startup includes several steps:

(1) Graphical window setup and display of sign-on logos
(2) Main menu display and user prompting

1.3.2 Mode Option Selection from Main Menu

The main menu display currently provides the user with several processing options and an exit program capability. These processing options may be executed in any order but the normal order would be 1, 2, 3, 4, 5, ... In the event of a complete system hang on the PC, select simultaneously the keys control-alt-delete to get to the task menu and manually exit the program. Options in the Main Menu include the following modes:

(1) Set the mask region, processing region, and lunar surface region
(2) Generate a dark field correction from a cover closed AVI collect
(3) Scan the video data for impact flash events.
(4) User based confirmation of suspected flash events.
(5) Review impact flash results and generate image files in TIFF format.
(F) Future prediction of impact zones for specific meteor showers.
(P) Playback AVI file on monitor – no image processing

(T) Run timing test
(Q) Quit the MeteorScan program

The current PC implementation does not use interface functions for the menu interface that would give the system a more GUI-like feel. A future upgrade may include the interfaces with radio button selection and standardized window-driven file selection.

1.3.3 Field of View Masking, Processing Region and Lunar Surface Selection

With mode option "1", the imagery AVI file can be fed through the system and a single masking region set interactively on the display rather than through the LUNAR_SETTINGS.txt parameters. The purpose of the mask is to define a rectangular region that gets excluded from detection processing. This is to prevent a time/date stamp with rapidly changing seconds digits from triggering the detection algorithm and producing false alarms. This also is useful to mask other inserted superpositioned subimages (such as camera ID numbers) that would interfere with registration algorithms used in some detection modes since the stamps are tied to the focal plane and not the shifting image. Once the video feed is displayed on the monitor (upper right window) the user can control the height, width, and position of the mask via control keys. The control key definitions are displayed in the lower left window. The mask is represented by four white angled fiducial marks at the four corners of the rectangle. The mask can also be adjusted during the scan mode of operation using the same control keys.

In addition, a region can be defined for the area to be processed to avoid edges that may have noise or other artifacts. Again while the video feed is displayed on the monitor (upper right window) the user can control the height, width, and position of the processing region via NON-control keys. The key definitions are also displayed in the lower left window. The processing region is represented by a black complete rectangle. The processing region can also be adjusted during the scan mode of operation using the same control keys.

Furthermore, a lunar surface region can be defined by the user to define a spot that represents the lunar surface intensity to help the processing algorithm distinguish between the moon and the sky. In the automated lunar surface ID mode, this region is ignored. Once the video feed is displayed on the monitor the user can control only the position of the region. The lunar surface sample region is represented by four short black angled fiducial marks at the four corners of a small rectangle. The region can also be repositioned during the scan mode of operation using the keys indictaed in the lower left window during masking or scanning modes of operation.

1.3.4 Dark Field Correction

With mode option "2", a previously collected dark field AVI file can be used to save an average dark field for subtraction from Lunar videos collected with the same imager. Before processing, the user should collect a short (optimally 10 seconds) video with the CCD covered in a darkened environment. The dark field correction algorithm proceeds by ingesting the user specified dark field AVI file, and averages the available frames up to a maximum of 256 frames. It writes a dark field data file named "darkfield.dat" to the input directory for subsequent use on all future execution runs of LunarScan. The user can rerun option 2 to replace the file with all zeros or another dark field measurement or simply delete or rename the file if no longer used. If no “darkfield.dat” is found during a scan, the program defaults to an all-zero dark field and issues a warning message. It is expected that the dark field is not required to be collected every night of observations since the imager would most likely change slowly over time. It is used to eliminate “hot” pixels in the focal plane that can mimic impact flashes when image shifts occur due to telescope jitter and registration processing imposes a re-alignment of the focal plane. Note that a separate TIF formatted file of the dark field is written to the output directory.

1.3.5 Scanning Mode of Operation

1.3.5.1 Input Parameters

Selection of “scanning” from the main menu generates a secondary menu with choices for scan processing parameters to apply to the video data. The choices are listed below and each can be toggled through cyclically by pressing the associated letter on the keyboard without a carriage return. The choices are not permanently set for the scan until the user hits the return key. Note that the default settings shown on any given run are based on the most recent scan run having been read from the LUNAR_SETTINGS file (which gets updated after any mode operation is completed). The underlined values represent the most likely settings to be used. There are additional parameters that can be set in the LUNAR_SETTINGS file that do not appear in the following list. Those parameters should be adjusted prior to program start by editing the LUNAR_SETTINGS.TXT file.

(A) *Selection of scanning mode:* **Built-in-test (BIT)** or **<u>Digifile AVI</u>.** For BIT, no AVI file is needed to be present and the software runs a simulated lunar impact sequence. For the Digifile AVI mode of operation, the processing will be applied to set of split AVI files with a common basename.

(B) *Selection of differencing algorithm:* **<u>Frame Mean</u>, Registered Mean.** Selects the differencing algorithm to be used for impact flash detection. The “frame mean” option keeps a running mean and standard deviation tied to the focal plane independent of any shifts occurring in the FOV. This is the fastest mode of operation but with higher false alarm rate so should be run with a higher k1 threshold (typically 14). The “registered mean” option registers each frame to align the mean and standard deviation estimate prior to the frame differencing. Currently this mode runs slower but with a lower false alarm rate permitting lower thresholds nearer to k1=10 for fainter detection.

(C) *Selection of clustering algorithm*: **Triplets Only, Trips and Pixel** or **<u>Trips and Doubs</u>**. Sets the clustering algorithms to search for exceedances that are characterized by three horizontal adjacent pixels, or to search for triplets that also have a single pixel two rows above or below, or to search for triplets that have a adjacent pair of exceedance pixels two rows above or below the triplet (recommended to lower false alarms).

(D) *Segment lunar surface*: **No, Manual Region,** or **<u>Auto Histo</u>**. The user can turn off lunar surface segmentation which then searches for flashes over the entire processing region (star scintillation will cause false alarms in this mode). The manual region option uses the lunar surface region defined in the mask mode to identify the lunar surface from the darker sky background. This option requires that the testing region remain superimposed over the lunar surface during the entire processing period. The auto histogram option ignores the surface region and instead uses a full image histogram to separate sky from lunar surface (recommended).

(E) *Saved Sum Format Specification:* **Single**, **Mean**, or **None**. The user can select the type of data to save for each detection. A multi-frame subimage of the raw imagery for each suspected flash event is always saved. In addition, the full image can be saved as: a single frame at the time of peak intensity of the track, the running mean, or no full frames at all.

Once the user is satisfied with the processing configuration, pressing the return key freezes these options for the scan. These values will be saved for the next scan so the user need not re-specify them for a second or subsequent scan. An option is available to exit from the scan menu back to the main menu by hitting the escape key.

Once the return key is hit the software will perform the following functions:

(1) Setting and testing of image processing dimensional limits and processing parameters. If any problems are encountered an error message is displayed and the program exits.

(2) Prompts the user for the input AVI filename. The user is first asked if this is a split AVI file (uses the name.##.AVI filename convention of VirtualDub). Then the user must enter the AVI file name without the .AVI or in the case of a split set of files without the .##.AVI.

(3) Prompts the user to enter an output filename "*basename*" to which an extension is added by the software for the file type to be created:

basename.sus = suspected event file of subimage sequences
basename.sum = suspected event file of single or mean full frames

If for some reason a .sus file exists for the base filename selected, the user will be prompted for another name to avoid overwriting any files with duplicate filenames.

(4) Opens the files for the suspected events output

The user is then prompted to enter an ASCII information header of their own choosing but restricted to a single line of text. This may be used to record lens/camera configuration data, environmental conditions, and/or tape unit used as examples.

Lastly the user is prompted for the date and time of the first frame in the AVI file to be processed. The user should enter the data in the following format

FORMAT: month/day/year(4 digits) hour:minute:seconds.decimal_seconds in UT
Example: 12/14/1997 22:10:03.01

1.3.5.2 Scanning Start and Completion

The software will then automatically begin the image processing functions. The software will continuously update the upper right graphics window with the latest digitized image every 60 frames so the user knows the software is operating during the entire scan. The frame number is displayed in yellow at the top of the window along with the number of exceedances found for that frame. The elapsed time for any detections is based on the AVI file's frame header information and is typically spaced at 29.97 fps for NTSC. All detections will be referenced as elapsed time with respect to the given starting time as well as the absolute UT. The frame number in the file for the detection will also be saved. Upon reaching the end of the AVI file (or last AVI file in a split AVI sequence), the processing halts, files are closed, and the software returns to the main menu.

1.3.5.3 Window Displays and Threshold Optimization

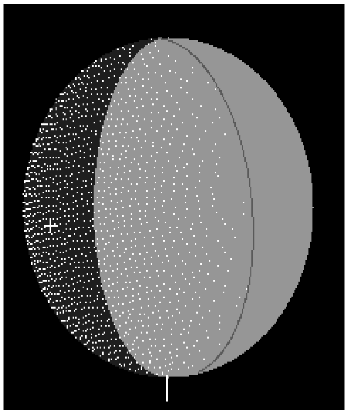
During the scan image processing, several windows are displayed to assess status and display results. The upper right window is used to display a single raw frame of imagery every 60 frames to confirm continued receipt of the AVI data. The TAB key toggles this display to show the threshold tracking filter mean, the threshold crossers from one difference frame operation, or the segmented sky/lunar surface. A diagnostic set of values are superimposed in this window continuously indicating the progress of the processing. The number of frames processed (F) and the number of primary threshold crossers (X). The diagnostic display can be toggled on and off by using the specified key stroke in the lower left window.

Optimization with respect to false alarms can be made by adjusting the primary threshold. It is highly recommended to adjust these parameters via the LUNAR_SETTINGS file prior to starting execution for a given night's data. However options for changing the threshold setting on the fly is provided through control key application. CTRL-Q or CTRL-A will increment or decrement the primary threshold by one respectively. If the threshold is changed on the fly, please note that it will take <u>several hundred frames</u> for the threshold filter to respond to the new setting.

The primary threshold should be set as low as possible. The primary threshold governs the number of faint (just above noise) meteors that are presented to the detection algorithm, so a lower value here is preferable. However, this will raise the false alarm rate, so the user will need to adjust this setting until an acceptable detection to false alarm rate is found for the imaging system in use.

The upper left display shows the peak intensity frame of the last detection with black/white crosshair fiducial highlighting the flash position. The event number, time elapsed, and row/col for the detection is displayed in the console window.

The lower left window shows the <u>potential</u> impact site geometry for the meteor shower closest in time to the processed video collection date and time. The bright sunlit face of the moon is shown in light gray and the shadowed face is shown as dark gray. The dots highlight the lunar surface area for potential impacts. The plus sign (white for near side, black for far side) indicates the sub-radiant point of the meteor shower (radiant overhead on lunar surface). The black line is the horizon line for the meteor shower beyond which no shower associated meteoroids could impact the lunar surface.



Orionid meteor shower for October 21, 2007

Control and non-control key functions are listed below and their defintions are displayed in the lower left window. When one of these selections are made, a line of text reporting the changed parameter will be displayed in the console window.

Processing Controls:

CTRL-P	Halts scan processing when pressed twice
ESCAPE	Disable/Enable detection toggle key
\	Backslash key disables/enables detections

Display Controls:

CTRL-X	Toggles the diagnostic display on/off
CTRL-O	Increases time between display updates by one second
CTRL-L	Decreases time between display updates by one second
TAB	Right image: video feed, threshold, exceedances, surface

Thresholds:

CTRL-Q	Increment the primary threshold by one
CTRL-A	Decrement the primary threshold by one

Masking Region:

CTRL-K	Toggle the mask pixel shifts between 2 and 10
CTRL-R	Increase the width of the masking region
CTRL-F	Decrease the width of the masking region
CTRL-T	Move the masking region left
CTRL-G	Move the masking region right
CTRL-Y	Decrease the height of the masking region
CTRL-H	Increase the height of the masking region
CTRL-E	Move the masking region down
CTRL-D	Move the masking region up

Processing Region:

R	Increase the width of the processing region

F	Decrease the width of the processing region
T	Move the masking processing left
G	Move the masking processing right
Y	Decrease the height of the processing region
H	Increase the height of the processing region
E	Move the processing region down
D	Move the processing region up

Lunar Surface Region:

4	Move the surface region left
6	Move the surface region right
2	Move the surface region down
8	Move the surface region up

Note the backslash (\) key requires a single hand operation that can have serious impact on processing. It is designed to disable detections temporarily (though all other processing continues) to allow the user to prevent false alarms from occurring from rapid slewing of the image scene. To enable detections simply hit the backslash key again. A large red display DETECTION DISABLED will appear in the lower left window if the system is currently disabled for detection.

To refresh the windows if they get obscured from view, mouse/click over to the main LunarScan console window on the screen or select the console window on the MS Windows bar at the bottom of the screen. This will bring focus back to LunarScan. Hitting the spacebar key will then refresh all the LunarScan windows.

1.3.5.4 Files Generated by the Scanning Mode of Operation

The "*basename*.sum" data file contains either no imagery, a <u>single</u> full frame of imagery (peak intensity frame of flash event), or a mean full frame image. The *basename*.sus data file contains elapsed time from the initial reference point, a multi-frame subimage sequence of the area around the flash event, as well as some processing parameters. The user selects the filename to be chosen. The software will not allow duplicate filenames so as to not overwrite previously scanned data.

1.3.6 User Confirmation of Meteor Detection

Selection of "Confirmation…" from the main menu allows the user to view the suspected events file and save only those events that appear to be meteoroid impacts. The user is prompted for the *basename* and the software finds and opens the "*basename*.sus" and "*basename*.sum" suspected flash event files. In addition the output file of flash imagery "*basename*.lun" and a summary text log file of the detected flash parameters and time "*basename*.llg" are created and opened.

The software displays the full frame in the left window and a variety of subimages in the right window. Two movie loops of the raw subimagery and difference frame band imagery are run over a one-half second period centered on the impact flash. The specified keys can be used to increase or decrease the movie image contrast and speed. The full frame data has been median filtered to increase the contrast for faint flashes near the noise limit. Other displays on the right window include 21 snapshots of the subimage region as well as the center 3 blown up to double the size. The single subimage in the upper left is the exceedance plot for the peak intensity subimage.

The user accepts an event as a impact by hitting the return key. Any other key moves on to the next suspected track. The "confirmed" impact flash data is saved to the "*basename*.lun" file in a similar format as the suspected track file as well as the track parameters being written to the "*basename*.llg" file. Reaching the end of the suspect file causes the files to be closed and control returned to the main menu. **Important note**: it is possible to back up one or more tracks in the file by using the delete key and then reevaluating the suspected track.

The log file is a simple ASCII text file that can be printed out on a standard printer. An example follows:

```
Scan processed w/version 1.2

Scan  date & time: Sat Jan 27 12:18:35 2007

 Video information: Test Scan
 Video date & time: 11/16/2006   0:00:00.000  UT
 AVI filename Impact_S_2006Sep16


 Options:                    Scan Settings Used:
------------------         --------------------
Scanning Mode               Digifile  AVI
Frame processing            Frame Mean
Clustering                  Trips + Doubs
Segment Lunar Surface       Auto Histogrm
Save Format                 Single Frame

Primary filter coef        = 2**4
Primary threshold factor   = 10
Primary plus extra thresh  = 4
Number of frames lookback  = 1
==========================================

Flash  Frame        UT           Elapsed     Row    Col
 No.   Number  Hr:Mi:Second  Hr:Mi:Second  pixel  pixel
-----  ------  ------------  ------------  -----  -----
   1     6699  00:03:44.022  00:03:44.022    225    516
   2    16184  00:09:00.502  00:09:00.502    155    607
   3    22727  00:12:38.822  00:12:38.822    443    305
```

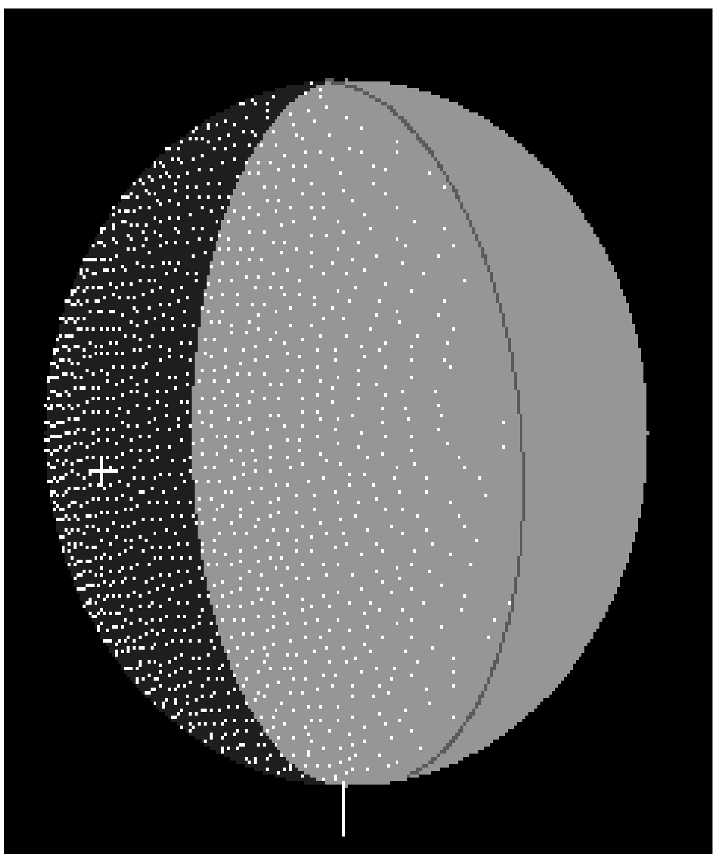
1.3.7 Post-Detection Review and TIFF File Generation

The confirmed impact flash file can also be reviewed in the same manner as in the user confirmation mode by choosing "viewi and extract" from the main menu. Each flash is again displayed in full frame and movie mode with a selection option to store the full frame screen image as a TIFF file. The file naming convention concatenates the *basename* with the flash number and the extension ".TIF". The user can then open the TIF file with a graphics program and print a hardcopy of the image. The keystroke options are nearly the same as in the confirm mode of operation.

1.3.8 Future Predictions

The future predictions mode generates TIF files and displays potential impact regions given the radiants of known meteor showers and the date desired. Either an individual date can be specified where the closest meteor shower in time will be selected or the prediction plots for the entire set of meteor showers in a given year are generated with a summary text file of rise/set times, lunar phase, percent dark face coverage by shower meteoroids.

A sample display for the Orionid meteor shower of October 21, 2007 is shown below (north is up in this diagram):



The bright sunlit face of the moon is shown in light gray and the shadowed face is shown as dark gray. The observations are typically carried out covering the non-illuminated (dark gray) region. The plus sign indicates the radiant sub-point on the moon (meteor shower radiant overhead) and the black line is the horizon line for the meteor shower beyond which no shower associated meteoroids could impact the lunar surface. The white dots delineate the region where shower meteoroids could impact.

1.3.9 Playback of AVI file

The playback mode allows the user to simply play the AVI file without any processing to confirm readability of the AVI by the software. Future versions may allow some shuttle options for rewind, fast forward, goto frame, slow motion, reverse.