NASA Workshop:
Meteor Video Observations and Analysis

Pisgah Astronomical Research Institute, August 4-5, 2011

The advent of low cost, low light level video cameras has resulted in the rapid spread of meteor video systems, from narrow field to all-sky. This explosion of operational instruments has resulted in many challenges to both meteor scientists and amateur meteor observers, especially in the areas of data analysis and information sharing. The primary aim of this workshop is to gather professional and amateur meteor observers together into an open forum where observational techniques, detection software, and data analysis methods can be presented and debated.

Organized by the NASA Meteoroid Environment Office

4-August

0800-0830	Check-in, Coffee	
0830-0840	Workshop Welcome	William Cooke
0840-0850	PARI Welcome/Safety Brief	PARI Staff
	All-sky Networks	
0850-0915	The Southern Ontario Meteor Network: Instrumentation and Data Processing Techniques	Peter Brown
0915-0940	Five Years in the Building of the Saskatchewan Fireball Camera Network	Gordon Sarty
0940-1005	The New Mexico State University All-Sky Camera System	Laura Boucheron
1005-1015	Break	
1015-1040	Status of The NASA Fireball Network	William Cooke
1040-1105	The NASA Fireball Network Database	Danielle Moser
1105-1130	The NASA Fireball Network All-Sky Cameras	Robert Suggs
1130-1230	Lunch	
	Specialized Networks	
1230-1255	CMN – A High Camera Density Amateur Video Meteor Network	Damir Segon
1255-1320	NASA's Cameras for Allsky Meteor Surveillance Network (CAMS)	Peter Jenniskens
1320-1345	Video Meteor Triangulation Using Multiple Low Cost CCD Cameras	Pete Gural
1345-1400	Break	
1400-1425	The Canadian Automated Meteor Observatory: Equipment Overview and Initial Results	Peter Brown
1425-1450	Lunar Impact Detections During the 2010 Geminid Meteor Shower	Ron Suggs
	Visual Observations	
1450-1515	American Meteor Society Fireball Program	Mike Hankey
1515-1600	Discussion	All
1600	Tour of PARI	All
1730	Informal Dinner at PARI	All

5-August

0800-0830	Coffee	
	Detection Software	
0830-0855	Comparison of ASGARD and UFOCapture	Rhiannon Blaauw
0855-0920	From MeteorScan to FTP: A Variety of Meteor Detection Software Packages and Approaches	Pete Gural
0920-0945	A Comparison of the Impact of Jitter and Timing Errors on the Accuracy of Several Popular Video Capture Devices	Chris Peterson
0945-0955	Break	
	Analysis Methods	
0955-1020	A New Meteor Trajectory Estimation Algorithm Employing Multiple Unsynchronized Camera Measurements	Pete Gural
1020-1035	High Accuracy Meteor Orbit Determination	Regina Rudawska
1035-1050	The Parent Body Search	Regina Rudawska
1050-1115	Progress on a Sky Survey Image Database for the Detection of Serendipitous Meteoroid Images	David Clark
1115-1215	Lunch	
1215-1240	Mason Dixon Meteor	Mike Hankey
1240-0200	Discussion	All

The Southern Ontario Meteor Network: Instrumentation and Data Processing Techniques

P. Brown, University of Western Ontario

Abstract unavailable.

Five Years in the Building of the Saskatchewan Fireball Camera Network

Gordon E. Sarty, University of Saskatchewan

The Saskatchewan Fireball Camera Network actually contains two cameras in neighboring Manitoba - in Winnipeg and Dauphin. The remaining four cameras are located in Saskatoon, Lucky Lake, Yorkton and Regina. Three of the cameras are fisheye lens systems while the other three use all-sky convex mirrors. The network is tied together by Rob Weryk's asgard software with images and videos being automatically downloaded every morning from the camera computers to a central correlator computer in Saskatoon. The correlator computer automatically identifies coincidental detections and computes meteor flight paths and orbits. The network is built from parts donated by Richard Spalding from Sandia Labs and from surplus computer equipment donated by the University of Saskatchewan. Network growth has been slow but steady. The Saskatoon camera captured the Buzzard Coulee fall when it was the only camera on the network. More recently, a potential fall in British Columbia was captured by the Lucky Lake camera and all-sky cameras in British Columbia. Small networks may be merged into larger networks, like the one proposed by the New Mexico State University, through the use of video splitters and computers devoted to each network. Alternatively, a cron job on the correlator computer could also forward data from smaller networks to the larger network.

The New Mexico State University All-Sky Camera System

David Voelz (NMSU), Laura Boucheron (NMSU), and Steven Bannister (NMSU)*

The Klipsch School of Electrical and Computer Engineering at New Mexico State University is developing an all-sky camera system intended to monitor, track, and analyze atmospheric meteor events to provide a database for assisting satellite operators in separating natural and man-made events and for instrument calibration tasks. The program objectives include: 1) field a network of uplooking, wide angle view cameras at a number of sites throughout the continental United States, 2) develop the network to access/archive data and make the data available for processing and analysis by interested parties, 3) develop software tools for calibration, removal of detector effects and anomalies, automatic event detection and correlation among stations, and automatic trajectory computation, and 4) develop a companion multi-band detector for the all-sky sensors to improve the diagnostic capability of the camera network. In addition to providing an overview of our system, we will discuss in more detail our recent developments on frame calibration and design of our prototype multi-band radiometer.

Status of The NASA Fireball Network

William J. Cooke, NASA Meteoroid Environment Office

In the summer of 2008, the NASA Meteoroid Environment Office (MEO) began to establish a video fireball network, based on the following objectives: 1. Determine the speed distribution of cm sized meteoroids 2. Determine the major sources of cm sized meteoroids (showers/sporadic sources) 3. Characterize meteor showers (numbers, magnitudes, trajectories, orbits) 4. Determine the size at which showers dominate the meteor flux 5. Discriminate between re-entering space debris and meteors 6. Locate meteorite falls

In order to achieve the above with the limited resources available to the MEO, it was necessary that the network function almost fully autonomously, with very little required from humans in the areas of upkeep or analysis. With this in mind, the camera design and, most importantly, the ASGARD meteor detection software were adopted from the University of Western Ontario's Southern Ontario Meteor Network (SOMN), as NASA has a cooperative agreement with Western's Meteor Physics Group. 15 cameras have been built, and the network now consists of 4 operating cameras, with 2 more slated for deployment later this summer. Expansion has been slow, largely due to NASA bureaucracy, which requires a contractual agreement (Space Act) with each site hosting a camera system. Naturally, this greatly increases the amount of time to bring a site online. The goal is to have 15 systems, distributed in two or more groups east of the Mississippi River, operational sometime in 2013. The cameras will send their data to a central server for storage and automatic analysis; this server also automatically generates a web page containing the particulars of the previous night's events each morning.

During 3 years of operation, over 1,500 multi-station fireballs have been observed, 3 of which potentially dropped meteorites. A database containing data on all these events, including the videos and calibration information, has been developed and is being mined for information.

The NASA Fireball Network Database

Danielle E. Moser, Dynetics/Meteoroid Environment Office

The NASA Meteoroid Environment Office (MEO) has been operating an automated video fireball network since late-2008. Since that time, over 1,700 multi-station fireballs have been observed. A database containing orbital data and trajectory information on all these events has recently been compiled and is currently being mined for information. Preliminary results are presented here.

The NASA Fireball Network All-Sky Cameras

R.M. Suggs, NASA MSFC EV44/Space Environments Team

The construction of small, inexpensive all-sky cameras designed specifically for the NASA Fireball Network is described. The use of off-the-shelf electronics, optics, and plumbing materials results in a robust and easy to duplicate design. Engineering challenges such as weather-proofing and thermal control and their mitigation are described. Field-of-view and gain adjustments to assure uniformity across the network will also be detailed.

CMN - A High Camera Density Amateur Video Meteor Network

Damir Segon, Croatian Meteor Network

The Croatian Meteor Network is an amateur video meteor network established in 2007 with thirty cameras sited across the Republic of Croatia. The imagery collection systems are based on inexpensive 1004X cameras equipped with 4mm f/1.2 lenses that archive night sky frame sets on a PC platform using Mark Vornhusen's freeware SkyPatrol as the capture software. A breakthrough in the post-collection data processing has been accomplished using Pete Gural's MTP_Detector software, which processes CMN's SkyPatrol observations and provides the data necessary for precise meteor analysis and orbit estimation. The operational cameras allow multiple view sky coverage over all of Croatia and part of neighboring countries. Basic network information such as sky coverage, data flow, precision, as well as some of results (including recent meteorite fall observations and recovery) will be presented.

NASA's Cameras for Allsky Meteor Surveillance network (CAMS)

P. Jenniskens (SETI Institute), P. S. Gural (SAIC)

With support from NASA's Planetary Astronomy program, a new network of low-light video cameras was established called the Cameras for Allsky Meteor Surveillance (CAMS). The project website is at: http://cams.seti.org. Goal of the project is to verify the 300+ meteor showers in the IAU Working List of Meteor Showers that remain unestablished.

The project consists of three stations, each equipped with twenty Watec Wat-902H2 Ultimate / Pentax 12 mm f1.2 cameras, which have a small 20 x 30 degree field of view. The stations are located at Fremont Peak Observatory south of San Juan Bautista in California, at Lick Observatory and in Mountain View. The latter station was more recently moved to Lodi.

The video data is compressed in a distortion-free (Four-Frame) format and written to disk during the night. In the morning, all files are examined with MeteorScan to find the meteors. Those files are later collected and re-processed to obtain the astrometry of the metoer tracks and the photometry of the meteor light curves at 60Hz. Once all data are in one place, an interactive coincidence program searches for meteors and calculates the trajectory in the Earth's atmosphere and the orbit in space.

The network has been in operation since October 21, 2010, collecting on average about 100 meteoroid orbits per night. We will introduce the CAMS project and outline the procedures used to get data and report on the verification of minor showers from observations in November of that year and the discovery of a previously unknown meteor shower caused by the dust trail of a long-period comet in February 2011.

Video Meteor Triangulation Using Multiple Low Cost CCD Cameras

Pete Gural, SAIC

With the proliferation of inexpensive CCD video cameras, the availability of extremely low cost frame grabbers, and the successful deployment of the CAMS system that uses COTS hardware and a completed video-

to-orbit software processing suite, a new concept for amateur participation in meteor stream study presents itself. Many meteor amateurs use all-sky low-resolution systems that are restricted in their sensitivity to bright meteors and fireballs. This is useful for broad area coverage and meteorite dropping trajectory analysis. However, for studies of meteoroid stream orbits and dynamical evolution, better resolution and sensitivity is desireable. Taking the CAMS concept of employing multiple narrow-FOV low-cost CCD video cameras at only two sites, and extending it to a regional network of many separated sites with fewer cameras per site, allows a group to monitor a common small volume of atmosphere. Each site could deploy from one to four cameras depending on the available participant budgetary investment. The existing CAMS software would work seamlessly within this distributed deployment architecture which would permit higher quality meteor orbital estimation for either amateur or education based networks.

The Canadian Automated Meteor Observatory: Equipment Overview and Initial Results

P. Brown, University of Western Ontario

Abstract unavailable.

Lunar Impact Detections During the 2010 Geminid Meteor Shower

Ron J. Suggs, NASA MSFC EV44/Space Environments Team

Lunar video observations are routinely conducted at the NASA Marshall Space Flight Center in Huntsville Alabama for the detection of meteoroid impacts. Over 240 impacts have been detected since the start of the observing program initiated approximately 5 years ago. During this time it has been fairly rare that lunar observing conditions and the weather have been favorable during the peak of the major showers. However, observing conditions were marginally favorable during the peak of the 2010 Geminids. On Dec. 14, 2010 approximately 5.5 hours of video were recorded. Even though the lunar phase was just outside the constraints established for optimum lunar impact monitoring, the resulting video was of sufficient quality that 21 lunar impacts were detected yielding an average impact rate of approximately 4 per hour. This compares to 17 lunar impacts detected over 40 nights of observations (approximately 100 hours of lunar video) yielding an average impact rate of 1 per 6 hours for the whole of 2010, excluding Dec. 14. The results of the 2010 Geminid lunar impact detections will be discussed along with previous results from the 2006 Geminid shower that also coincided within the lunar observing window.

American Meteor Society Fireball Program

Mike Hankey, American Meteor Society

Recent improvements and planned additions to the AMS website and fireball reporting tool are described. Site enhancements include the setup of a dynamic database driven reporting, approval and publishing system that results in more rapid response times to events; the introduction of data collection widgets which improve the accuracy of data collected by witnesses; the automatic plotting and visual display of witness reports for events;

the automatic generation of recursive two observer trajectory models; and an open structure and application programming interface (API) for extracting witness reports. Additional explanation of more recent site developments and future plans will also be discussed including a fireball video upload and repository database system (linked to the existing AMS fireball events) and the introduction of the AMS All Sky Camera Program.

Comparison of ASGARD and UFOCapture

Rhiannon C. Blaauw (Dynetics/Meteoroid Environment Office) and Katherine S. Cruse (West Virginia University/NASA MSGR Intern Program)

The Meteoroid Environment Office is undertaking a comparison between UFOCapture/Analyzer and ASGARD (All Sky and Guided Automatic Realtime Detection). To accomplish this, video output from a Watec video camera on a 17 mm Schneider lens (25 degree field of view) was split and input into the two different meteor detection softwares. The purpose of this study is to compare the sensitivity of the two systems, false alarm rates and trajectory information, among other quantities. The important components of each software will be highlighted and comments made about the detection/rejection algorithms and the amount of user-labor required for each system.

From MeteorScan to FTP: A Variety of Meteor Detection Software Packages and Approaches

Pete Gural, SAIC

Detection software and algorithms, specifically aimed towards transient meteor discovery, requires a number of different approaches depending on the collection system characteristics. This presentation will highlight several software packages and their underlying core algorithms that have been optimized to a variety of deployed sensor systems. This includes the MeteorScan package and detection module/library for video frame rate imagery used in real-time and non-real-time modes, the short and long frame integration software for snapshot mode sensors, the AIMIT algorithm for minimal latency response, and the MTP/FTP interface of MeteorScan for temporally compressed video imagery. Alternative streak detection methods developed recently in the image processing community will also be highlighted.

A Comparison of the Impact of Jitter and Timing Errors on the Accuracy of Several Popular Video Capture Devices

Chris Peterson, Denver Museum of Nature and Science

The combination of high sensitivity and low cost makes conventional B&W analog output (PAL/NTSC/RS-170) video cameras popular in allsky meteor monitoring applications. A variety of devices are available which digitize the analog output of these cameras and make the data available for manipulation on a computer. I bench tested three popular frame grabbers (Fusion 878A, Matrox Meteor II, Imaging Source DFG/USB) and a digital camera (modified Logitech QC4000), utilizing reference video signals as well as artificial meteors, and

determined that various timing errors significantly degrade the ability to extract accurate positional information from the digitized video images when compared with the digital camera images. Future improvements in the positional accuracy obtained from allsky video cameras will probably require the adoption of fully digital cameras.

A New Meteor Trajectory Estimation Algorithm Employing Multiple Unsynchronized Camera Measurements

Pete Gural, SAIC

The conventional trajectory estimation methods, that solve for a meteor's path through the atmosphere, typically involve a boot-strapping technique. First the orientation of the track is obtained, followed by a solution for the velocity and deceleration along the track. A new approach is suggested whereby a fully coupled propagation model is iteratively solved for, converging to the most likely four-dimensional trajectory in 3D space plus time. The algorithm is designed to handle multiple cameras from two or more disparate sites as well as additional camera tracks obtained from the same site. The latter could represent separate begin and end portions of the same meteor trail on two different cameras. Since very often video meteor cameras are not well synchronized to GPS time or between each other, the trajectory estimation algorithm finds the timing offsets as part of the motion propagation solution. This is part of a coupled solution to the meteor's begin point position and velocity vectors, and includes options for several deceleration models commonly used in the literature. A downhill simplex-ameoba technique is used for the functional minimization that solves for all free parameters simultaneously. A Monte Carlo component adds empirical error estimation for the key parameters.

High Accuracy Meteor Orbit Determination

P. Atreya, R. Rudawska, S. Bouley, J. Vaubaillon, F. Colas, T. Silbermann*

Meteoroid are small rocky bodies (micron to meter size) travelling through interplanetary space. The main way to study them is to observe their impact on Earth as meteor showers. But these observations mainly done with video camera suffer of a lack of accuracy. Our goal is determination of the parent body of a meteoroid which enables us to study the origin of the Solar System as well as its evolution by linking the small bodies between each other. However, with present accuracy it is impossible to have an accurate view of the streams in the past.

We present here the results of CABERNET camera (CAmera for BEtter Resolution NETwork) using a large CCD chip for a good astrometry and a special acquisition mode which allow acquisition rate up to 1 Khz. These observations will allow us in the future to compute the most precise orbit never calculated of these meteoroids. Additionally, in 2011, we will install 3 other stations in France in order to maximize the detection and accuracy of meteoroid orbits calculation.

The Parent Body Search

R. Rudawska, P. Atreya, S. Bouley, J. Vaubaillon, F. Colas, T. Silbermann*

Meteor Observation Networks, such as the double-station meteor network developed in CABERNET project (PODET-MET), will provide soon a vast amount of meteors' observation data with the aim to calculate each orbit of the meteoroids.

On the 12th and 13th December 2011, we found 100 meteors observed by the double-station CABERNET systems. Data were processed and accurate orbits were computed. In order to retrieve the parent body from such collected data set, we used already existing procedures aiming to determine the origin of meteoroid streams.

In the survey some questions arose, such as, which dissimilarity function to use in aim to find a parent body for observed meteors. When we associate the meteor with a parent body, are we able to find the exact moment of meteoroid ejection from its surface? Presenting our results during the talk we would like to provide insights on those (and other) questions.

Progress on a Sky Survey Image Database for the Detection of Serendipitous Meteoroid Images

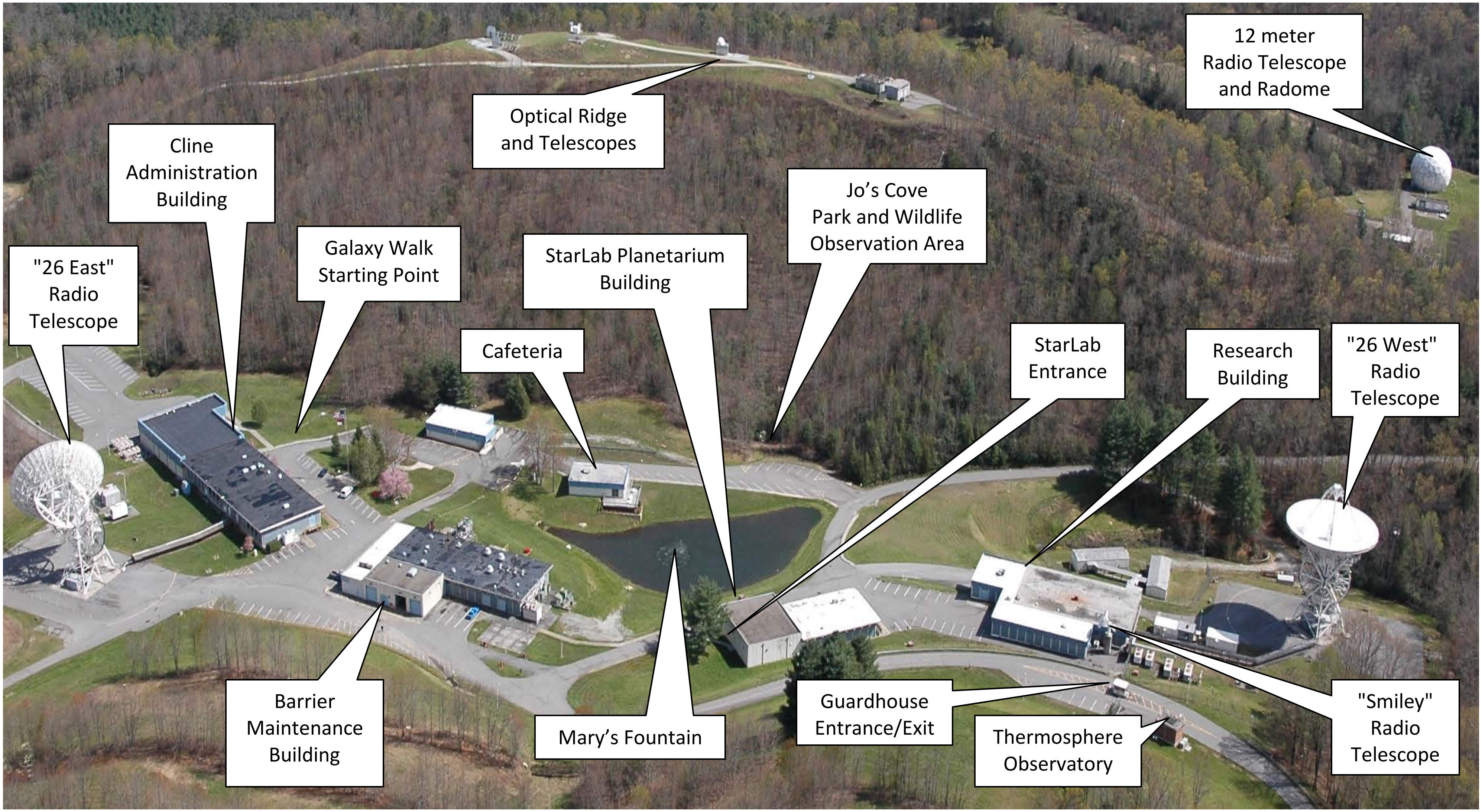
David L. Clark, University of Western Ontario

The Fireball Retrieval on Survey Telescopic Image (FROSTI) project seeks to locate meteoroid image candidates in catalogues of pre-existing sky survey images. Meteoroid trajectories are used to search a database of sky survey image descriptions in order to identify serendipitous observations of an impactor within the minutes or hours prior to entering the atmosphere. Sky survey image descriptions are stored in a survey independent fashion, with particular attention paid to the relevance of observing location when searching for nearby objects such as pre-contact meteoroids. The image description database currently incorporates images from the CFHT, Spacewatch and Catalina surveys, with an interface under development for PanSTARRS. I present the issues and progress on incorporating major sky surveys into the database, and speak to plans for the incorporation of fireball data sources.

The Mason Dixon Meteor

Mike Hankey, American Meteor Society

A summary of events and efforts to track down and find fragments from a large meteor event that occurred over Maryland and Pennsylvania in July 2009. Topics include analyzing and calibrating videos from security cameras, trajectory modeling, multiple dark flight models and other aspects of this ongoing meteorite recovery effort.



PARI Visitor Guide

Cline Administration Building
- Instrument Control Room
- Multi-Media Room
- Main Campus Data Center
- Exhibit Gallery
- Image Gallery
- Library

Galaxy Walk
Scale Model of Solar System starting with the Sun in front of the Cline Administration Building

Research Building
- Astronomical Plate Data Archive (APDA)
- Gamma II Hi-Resolution Scanner
- RF Laboratory
- Aeronomy Laboratory
- Research Building Data Center

The Tunnel
A 943 foot tunnel between the Cline Administration Building and the Research Building provides for cabling and pedestrian access.