Overview:
NASA All Sky Fireball Network & Southern Ontario Meteor Network

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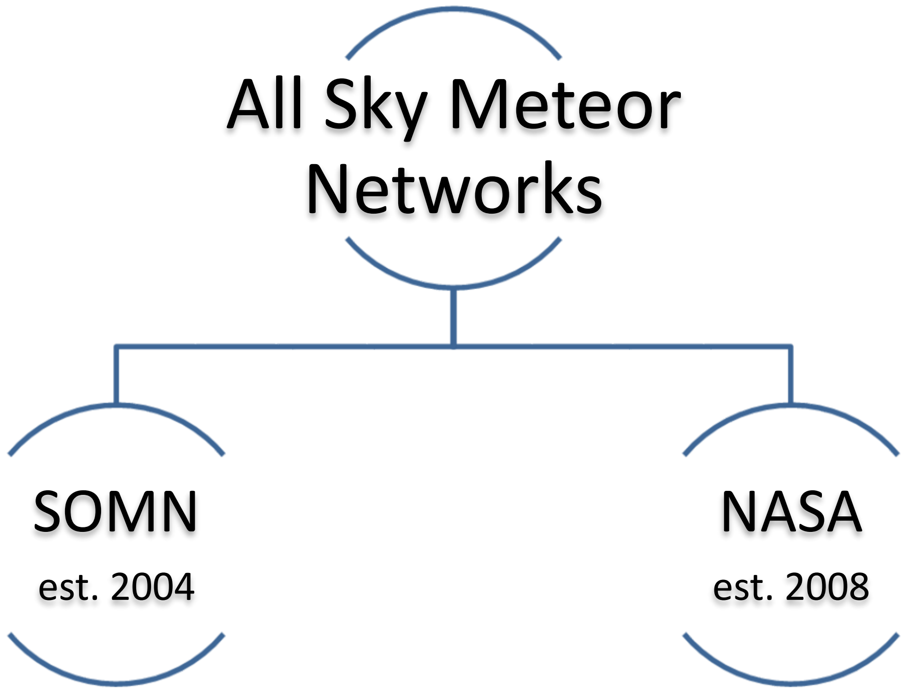
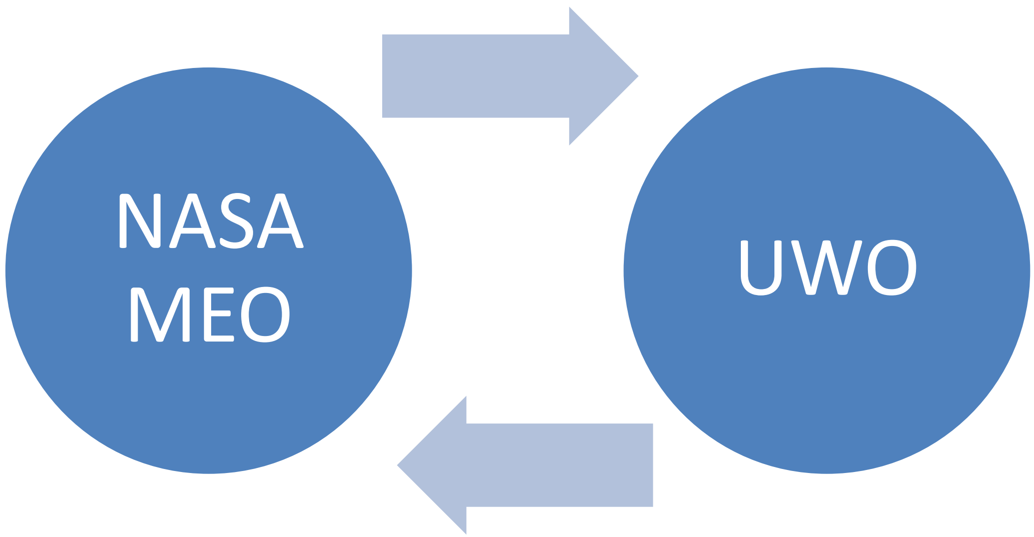
Sister Networks



- Similar cameras
- Identical software
- Automated detection and analysis

NASA-UWO Cooperation

MEO funding support via cooperative agreement to develop hardware & software



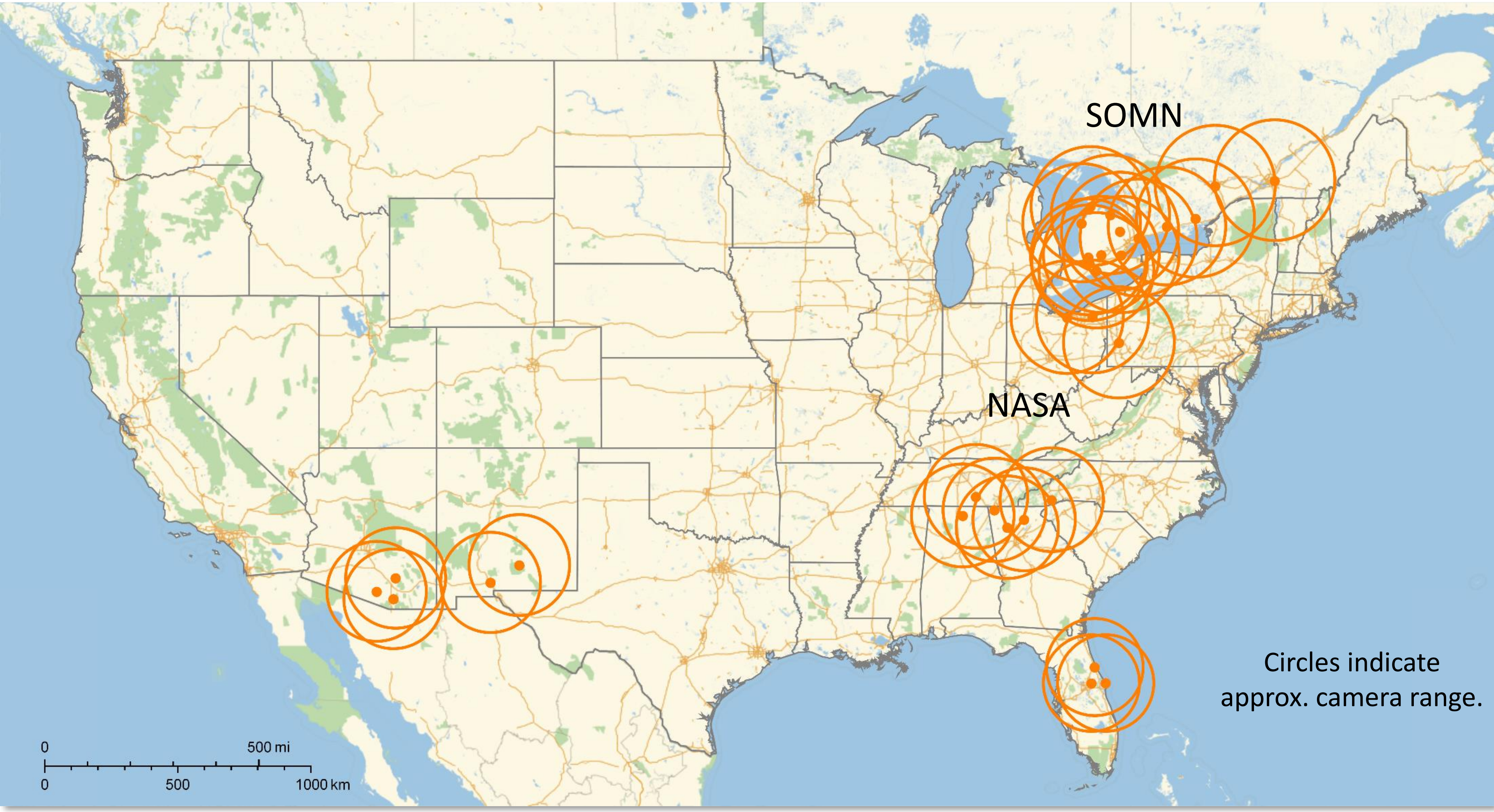
UWO-built hardware & software deployed in NASA Network & SOMN

Network Objectives

Overarching objective: Multi-camera observations of bright fireballs ($M_v \approx -4$) caused by cm-sized meteoroids

- SOMN
  - Multi-sensor calibration of relative meteoroid mass/energy scales: video, radar, infrasonic, seismic
  - Probe of observational biases in meteor observations
  - Detailed ablation modeling as a proxy for physical structure
  - Flux of small NEOs
  - Meteorite fall observations
- NASA
  - Tracking and characterizing meteor events of USG and public interest
  - Characterize meteor showers
  - Determine the speed distribution and major sources of cm-sized meteoroids
  - Meteorite fall observations

Network Map


SOMN
NASA
Circles indicate approx. camera range.
0
500 mi
0
500
1000 km

Deployed Stations

SOMN

Camera #	Location
2	Elginfield, ON
3	Hamilton, ON
4	Tavistock, ON
5	Collingwood, ON
6	Orangeville, ON
7	Kincardine, ON
8	Aylmer, ON
10	Yarker, ON
11	Oliphant, ON
12	Oak Heights, ON
13	Montreal, QB
14	Pittsburgh, PA
16	Oberlin, OH
17	Hiram, OH
18	Ottawa, ON
19	Toronto, ON
20	London, ON

NASA

Camera #	Location
1	Huntsville, AL
2	Chickamauga, GA
3	Tullahoma, TN
4	Cartersville, GA
5	Las Cruces, NM
6	Mayhill, NM
7	Rosman, NC
8	Dahlonega, GA
9	Kitt Peak, AZ
10	Mt Lemmon, AZ
11	Mt. Hopkins, AZ
14	Pittsburgh, PA
16	Oberlin, OH
17	Hiram, OH
18	Daytona Beach, FL
19	Orlando, FL
20	Cape Cannaveral, FL

Station

Camera

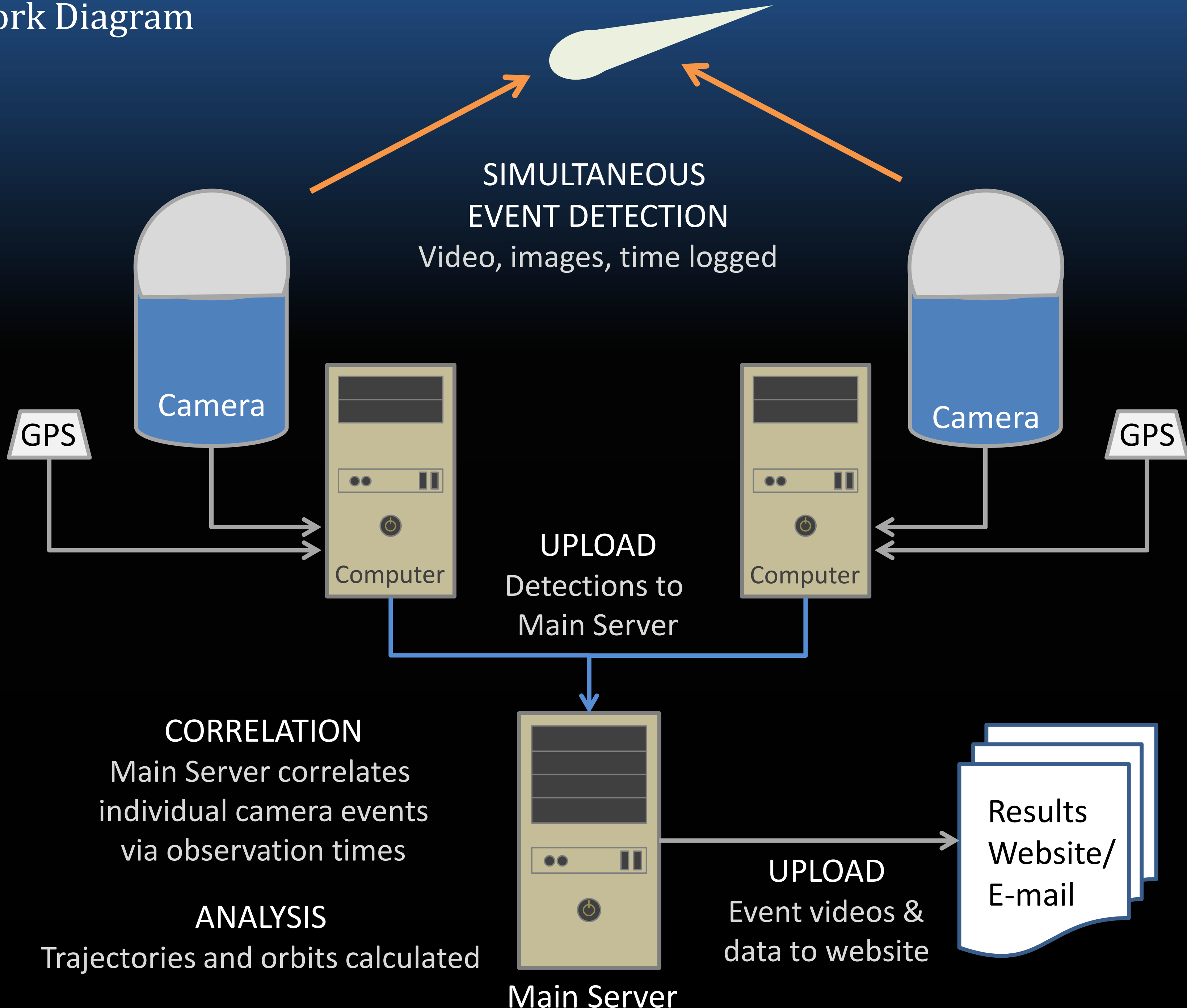
Computer

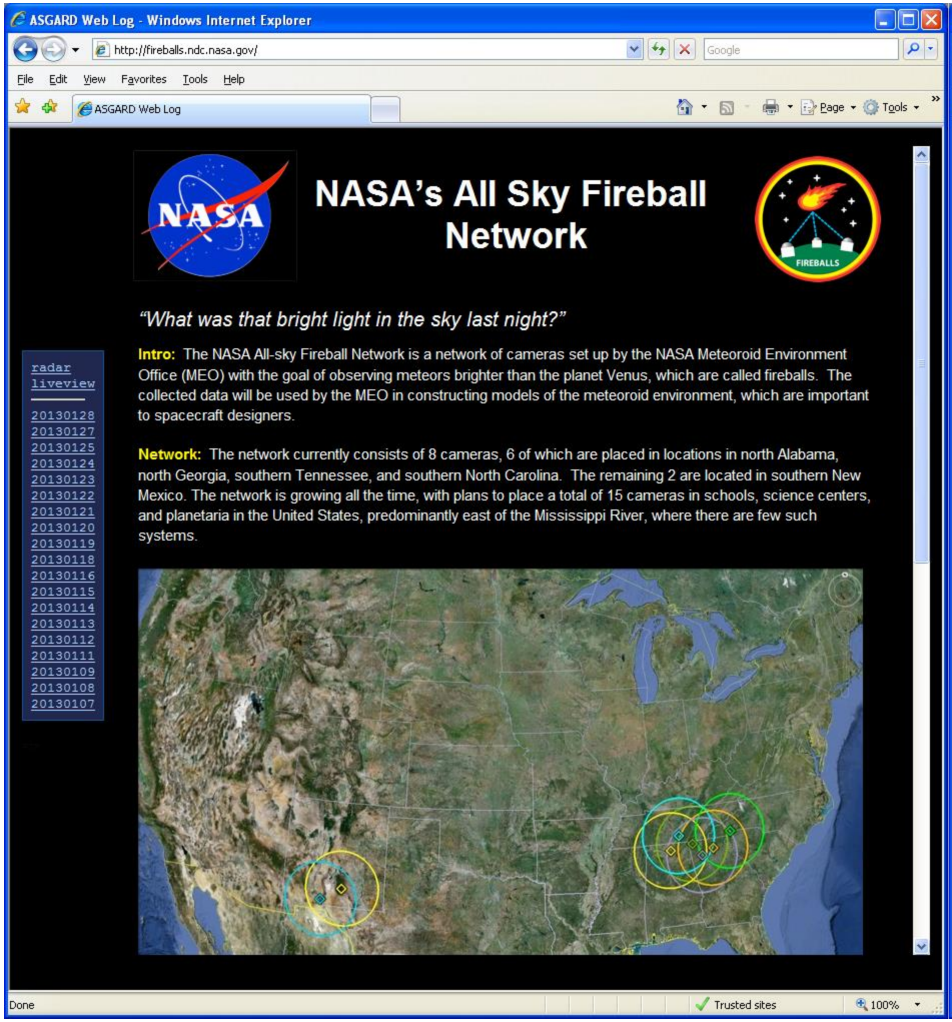
- Watec 902-H2 Ultimate or Sony HiCam HB-710E
  - monochrome 8bit CCD video cameras
  - 1/2” CCD chip, effectively 768x494 px
  - Interleaved 30 fps video
- F1.4, 1.6-3.4mm Rainbow L163VDC4P fisheye lens
- Weatherproof PVC enclosure with twilight sensor, thermostat, heater, fan
- Flat-roof or pole mounted

- Standard desktop computer running Debian Linux
  - Frame-grabber card
  - Large disk storage for streaming video buffer
  - ASGARD software for meteor detection, correlation, analysis, and storage
  - USB GPS for time synchronization
- Network link

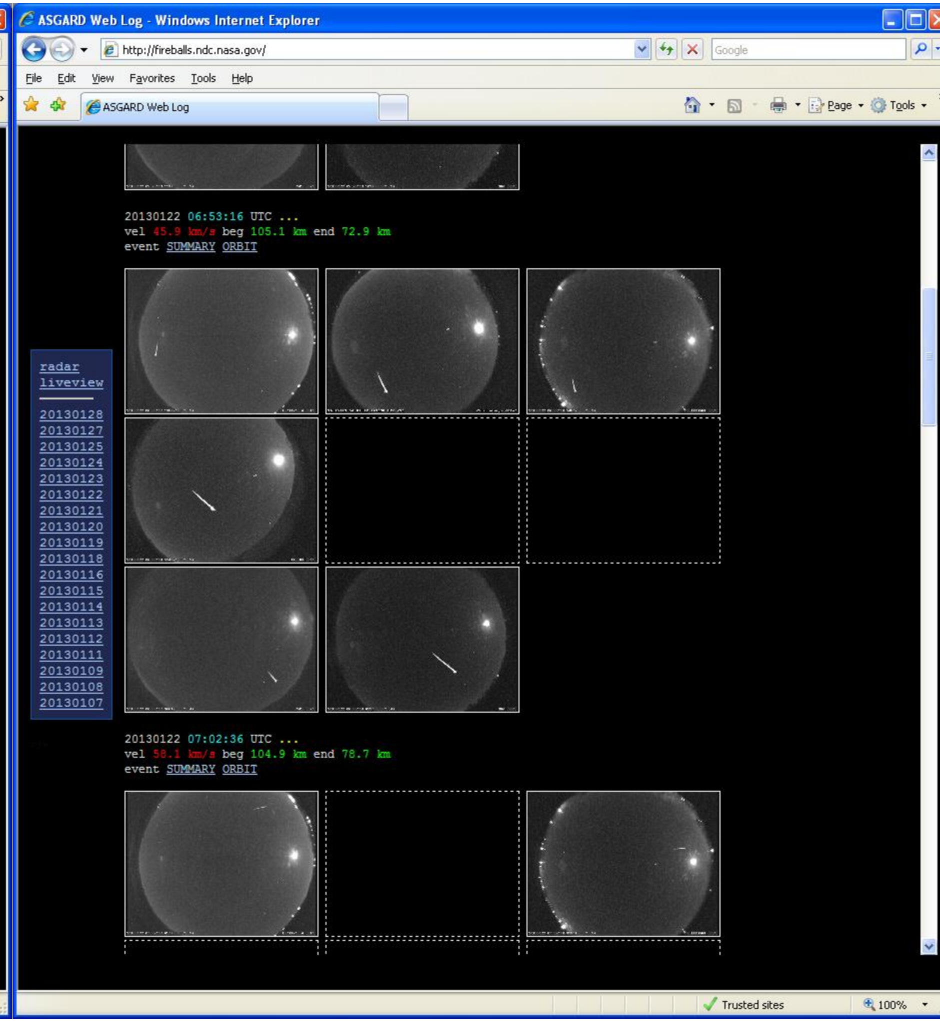
FOV and Detections

Network Diagram





Images, movies sorted by date



Meteor speed, trajectory, orbit, brightness, mass

Daily e-mails


```
  date      time    :                                                     :  vel  mass   beg   end  : src
 -------------------+-----------------------------------------------------+------------------------+----
+ 20141215 06:08:06 : -- -- -- 04 -- -- 07 08 -- -- -- -- -- -- -- -- -- : 35.6 -2.19  90.7  67.1 : GEM
+ 20141215 06:08:42 : -- -- -- -- -- -- -- -- 09 10 -- -- -- -- -- -- -- : 33.9 -3.36  89.2  83.1 : GEM
+ 20141215 06:16:33 : 01 02 -- 04 -- -- -- -- -- -- -- -- -- -- -- -- -- : 35.7 -2.32  90.4  71.0 : GEM
+ 20141215 06:17:38 : -- -- -- -- -- -- -- -- -- 10 11 -- -- -- -- -- -- : 66.3 -2.91 109.3 100.7 : DLM
+ 20141215 06:18:18 : -- 02 -- 04 -- -- -- -- -- -- -- -- -- -- -- -- -- : 36.2 -2.72  87.3  76.9 : GEM
+ 20141215 06:22:14 : -- -- -- -- -- -- -- -- 09 -- 11 -- -- -- -- -- -- : 35.8 -2.68  90.9  80.5 : GEM
+ 20141215 06:23:14 : -- -- -- -- -- -- -- -- 09 10 11 -- -- -- -- -- -- : 34.4 -2.29  91.7  81.4 : GEM
+ 20141215 06:25:46 : -- -- -- -- 05 06 -- -- -- -- -- -- -- -- -- -- -- : 29.6 -2.48  83.8  71.8 : ...
+ 20141215 06:26:56 : -- -- -- 04 -- -- -- 08 -- -- -- -- -- -- -- -- -- : 39.1 -2.84  92.5  80.2 : GEM
+ 20141215 06:31:48 : -- -- -- 04 -- -- 07 08 -- -- -- -- -- -- -- -- -- : 59.9 -2.15 107.0  94.6 : DLM
+ 20141215 06:32:35 : 01 02 03 -- -- -- -- -- -- -- -- -- -- -- -- -- -- : .... ..... ..... ..... : ...
+ 20141215 06:37:09 : -- -- -- -- -- -- -- -- 09 10 11 -- -- -- -- -- -- : 35.6 -1.53  92.9  72.8 : GEM
+ 20141215 06:52:13 : -- -- -- -- 05 06 -- -- -- -- -- -- -- -- -- -- -- : 34.6 -2.74  87.5  78.4 : GEM
+ 20141215 07:05:28 : -- -- -- -- -- -- -- -- 09 -- 11 -- -- -- -- -- -- : 35.5 -2.76  91.5  80.8 : GEM
+ 20141215 07:18:57 : -- -- -- -- -- -- 07 08 -- -- -- -- -- -- -- -- -- : 35.5 -2.61  89.1  79.8 : GEM
+ 20141215 07:33:42 : -- -- -- 04 -- -- -- 08 -- -- -- -- -- -- -- -- -- : 35.9 -2.50  89.0  79.0 : GEM
+ 20141215 07:41:31 : -- -- -- -- -- -- -- -- -- 10 11 -- -- -- -- -- -- : 34.0 -2.49  88.4  76.7 : GEM
+ 20141215 07:47:00 : 01 02 -- 04 -- -- -- -- -- -- -- -- -- -- -- -- -- : 33.4 -2.35  91.3  77.8 : GEM
+ 20141215 07:59:08 : -- -- -- -- 05 06 -- -- -- -- -- -- -- -- -- -- -- : 36.3 -2.42  93.3  72.6 : GEM
+ 20141215 08:13:26 : 01 02 03 -- -- -- -- 08 -- -- -- -- -- -- -- -- -- : 65.7 -1.96 106.1  83.7 : DLM
+ 20141215 08:16:28 : -- -- -- -- -- -- -- -- 09 10 -- -- -- -- -- -- -- : 35.4 -2.23  90.8  77.1 : GEM
+ 20141215 08:20:20 : -- -- -- -- -- -- 07 08 -- -- -- -- -- -- -- -- -- : 41.1 -1.60  93.1  84.9 : MON

    GEM : Geminids
    DLM : December_Leonis_Minorids
    MON : December_Monocerotids
```

- Summary of multi-station detections
- Radiant maps and solution plots for each event
- Useful maintenance information about free disk space, GPS status, calibration data

ASGARD Software

All Sky and Guided Automatic Real-time Detection (Weryk et al. 2008)

- Event capture and detection
  - Video capture
  - Detection
  - Rejection
- Processing and storage
  - Event transmission
  - Multi-station solutions
  - Data retrieval
- Results
  - ASGARD weblog
  - Daily e-mails
  - Event plots and data tables

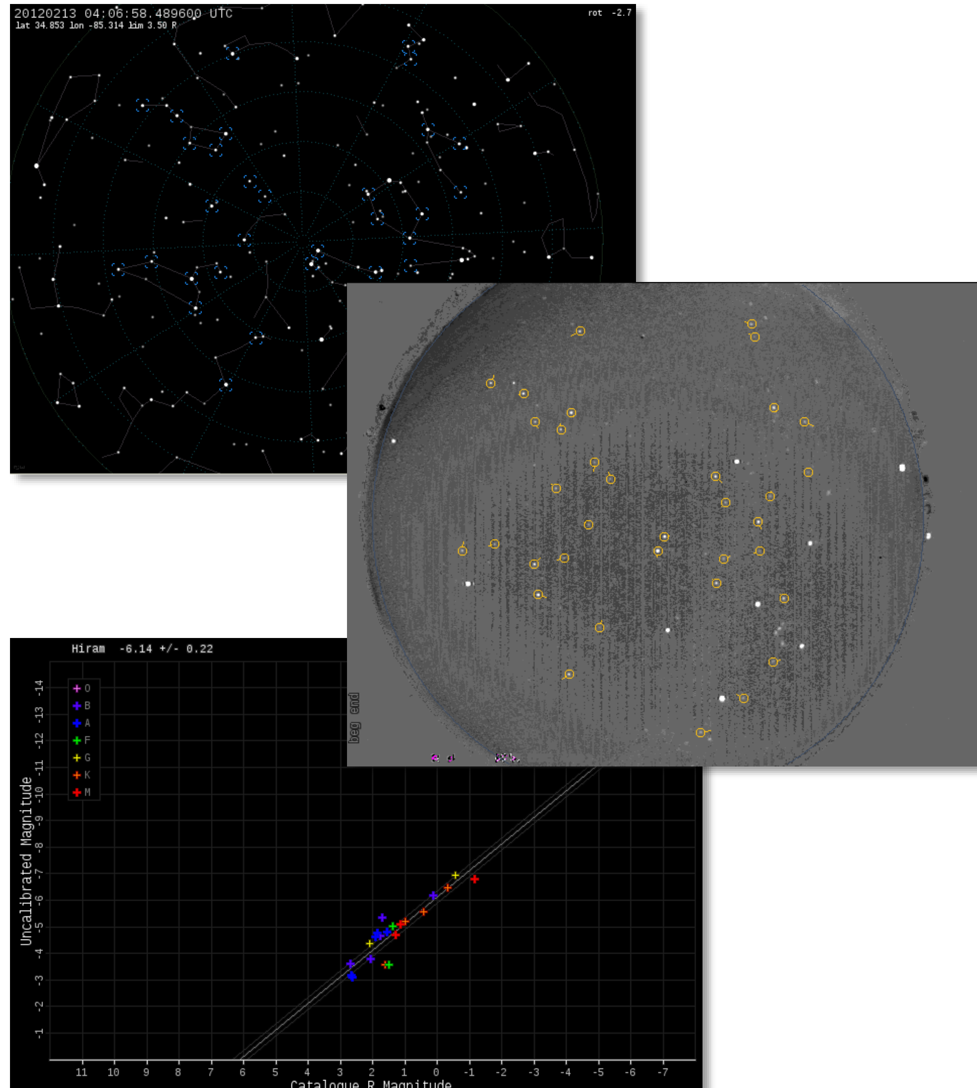
ASGARD Software

All Sky and Guided Automatic Real-time Detection (Weryk et al. 2008)

- Detects events using frame difference thresholding
- Events run through detection and rejection filters to identify meteors and weed out satellites, planes, bugs, etc.
- Consolidates camera detections at central server, correlates and processes multi-station events

Astrometry / Photometry

- Calibrated using stellar point sources
  - Stacked calibration images used to create plates following Borovicka et al. (1995)
  - Instrumental magnitudes compared to cataloged magnitudes
- See talks at this workshop:
  - Aaron Kingery, “MEO All Sky Camera Installation and Calibration”
  - Steven Ehlert, “Meteor Photometry for All-Sky Cameras”

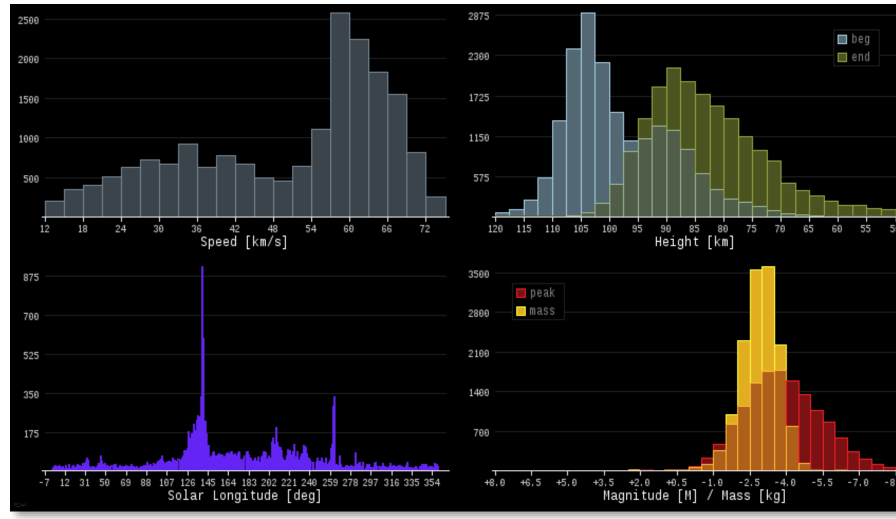


Trajectory / Orbit

- Meteor trajectories can be approximated as simple lines in 3D space
- Trajectory determined following methodology of Borovicka (1990)
- Orbits determined following methodology of Ceplecha (1987)
- See talk at this workshop by Denis Vida, "Comparison of Meteor Trajectory Solvers"

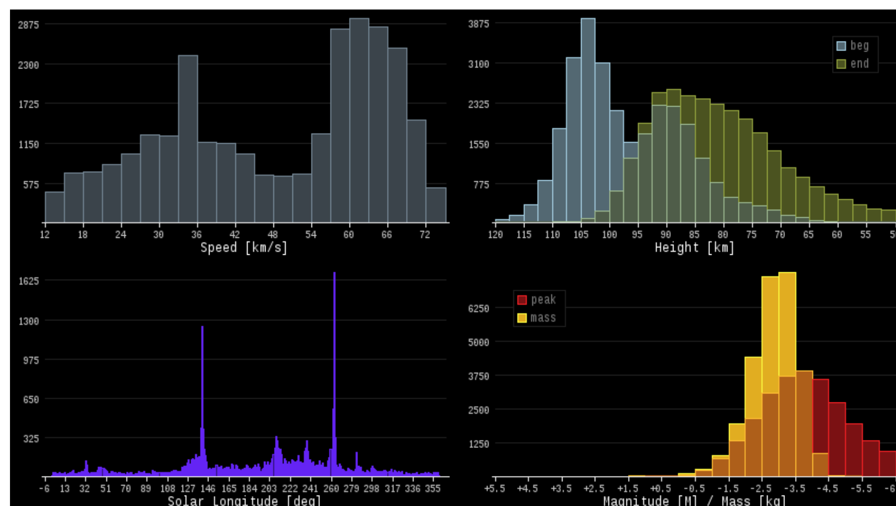
SOMN

Time period: early 2006 to present
meteors: 17,000+ multi-station
Lim meteor mag: -2.0 (Jupiter)
meteorite falls: 7



NASA

Time period: late 2008 to present
meteors: 27,000+ multi-station
Lim meteor mag: -2.0 (Jupiter)
public interest: ~1/week avg
meteorite falls: 2



Grimsby Meteorite Fall

September 26, 2009 01:03 UT

Detected by

- 7 SOMN stations
- infrasound
- CMOR
- large format CCD camera

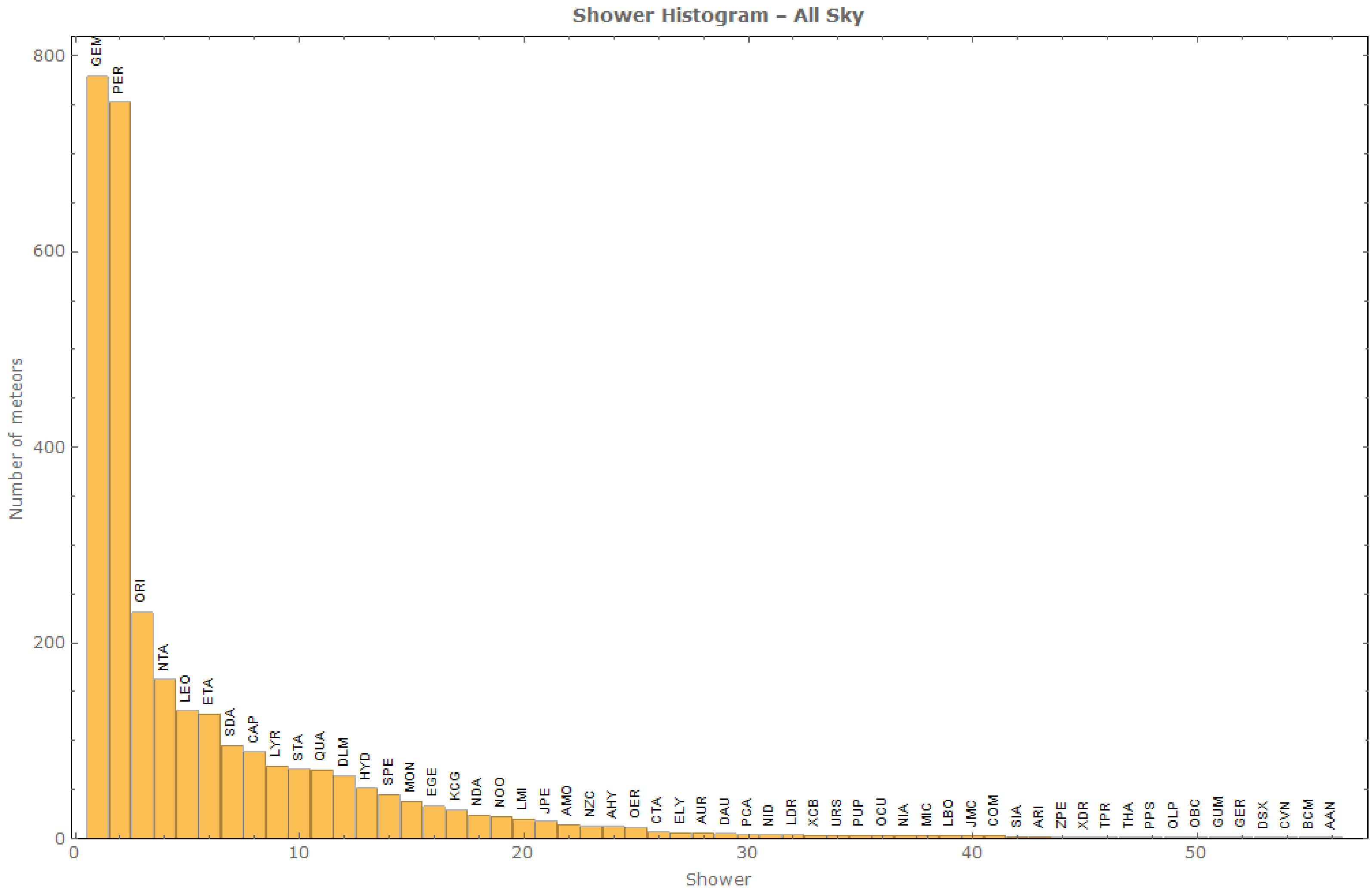
Initial mass: 20-50 kg

Recovered mass: 215 g

Absolute magnitude: -15 (v)

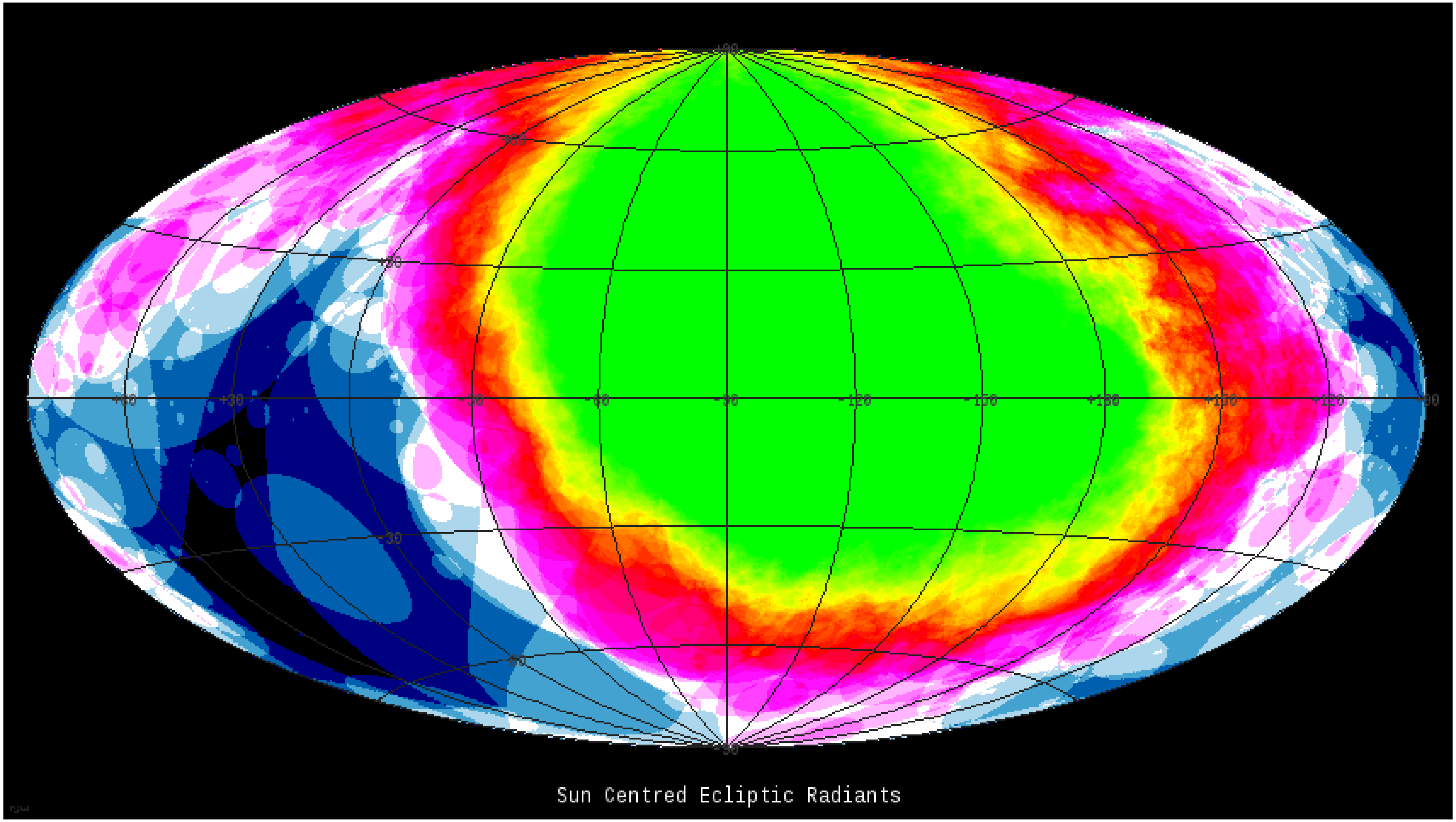
UWO meteorite fall info: http://meteor.uwo.ca/#

Meteor Showers



For 3-letter meteor shower abbreviations, see https://www.ta3.sk/IAUC22DB/MDC2007/

Results to Date



Summary

- The NASA All Sky Fireball Network and SOMN are two "sister" all-sky meteor networks in North America
- Both are automated networks that perform detection, correlation, and analysis yielding meteor trajectories, orbits, and magnitudes
- NASA results posted daily to public website
- NASA characterizes events for the USG and news media
- NASA and UWO actively pursuing research objectives
- UWO working on new hardware and software improvements

References

J. Borovicka. (1990) “The comparison of two methods of determining meteor trajectories from photographs,” *Bull. Astron. Inst. Czech.* 41, 391-396.

J. Borovicka, P. Spurny, and J. Keclikova. (1995) “A new positional astrometric method for all-sky cameras,” *Astron. Astrophys. Suppl. Ser.* 112, 173-178.

Z. Ceplecha. (1987) “Geometric, dynamic, orbital and photometric data on meteoroids from photographic fireball networks," *Bull. Astron. Inst. Czech.* 38, 222-234.

R. J. Weryk, P. G. Brown, A. Domokos, W. N. Edwards, Z. Krzeminski, S. H. Nudds, and D. L. Welch. (2008) “The Southern Ontario All-sky Meteor Camera Network," *Earth Moon and Planets* 102, 241-246.

Acronyms

Acronym	Meaning
ASGARD	All Sky and Guided Automatic Real-time Detection
CCD	Charge Coupled Device
CMOR	Canadian Meteor Orbit Radar
FOV	Field of View
GPS	Global Positioning System
JSEG	Jacobs Space Exploration Group
MEO	Meteoroid Environment Office
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NEO	Near Earth Object
PVC	Polyvinyl Chloride
SOMN	Southern Ontario Meteor Network
USB	Universal Serial Bus
USG	United States Government
UWO	University of Western Ontario