Status of the NASA Allsky Camera Network

William J. Cooke
Lead, NASA Meteoroid Environment Office
william.j.cooke@nasa.gov

In the Beginning...

- There were visual observers (and still are)
- Data limited to radiants and rough estimates of speed and brightness
- Can get very cold during winter nights

FIG. 3-3. Modern visual meteor observing at Springhill Meteor Observatory near Ottawa. Warm air is supplied to the individual compartments.

Photographic Observations

Wide field

Meteorite Observation and Recording Program (MORP)

All sky

Modra Observatory

- All sky systems are nice because only 1 camera is needed per station

Super Schmidt Cameras

- First employed in the 1940's
- Detected bright meteors (magnitudes > +3)
- Large FOV
- Multiple stations and use of rotating shutter enabled location, speed, and orbit determinations

- Much of what we know is based on data taken with these systems

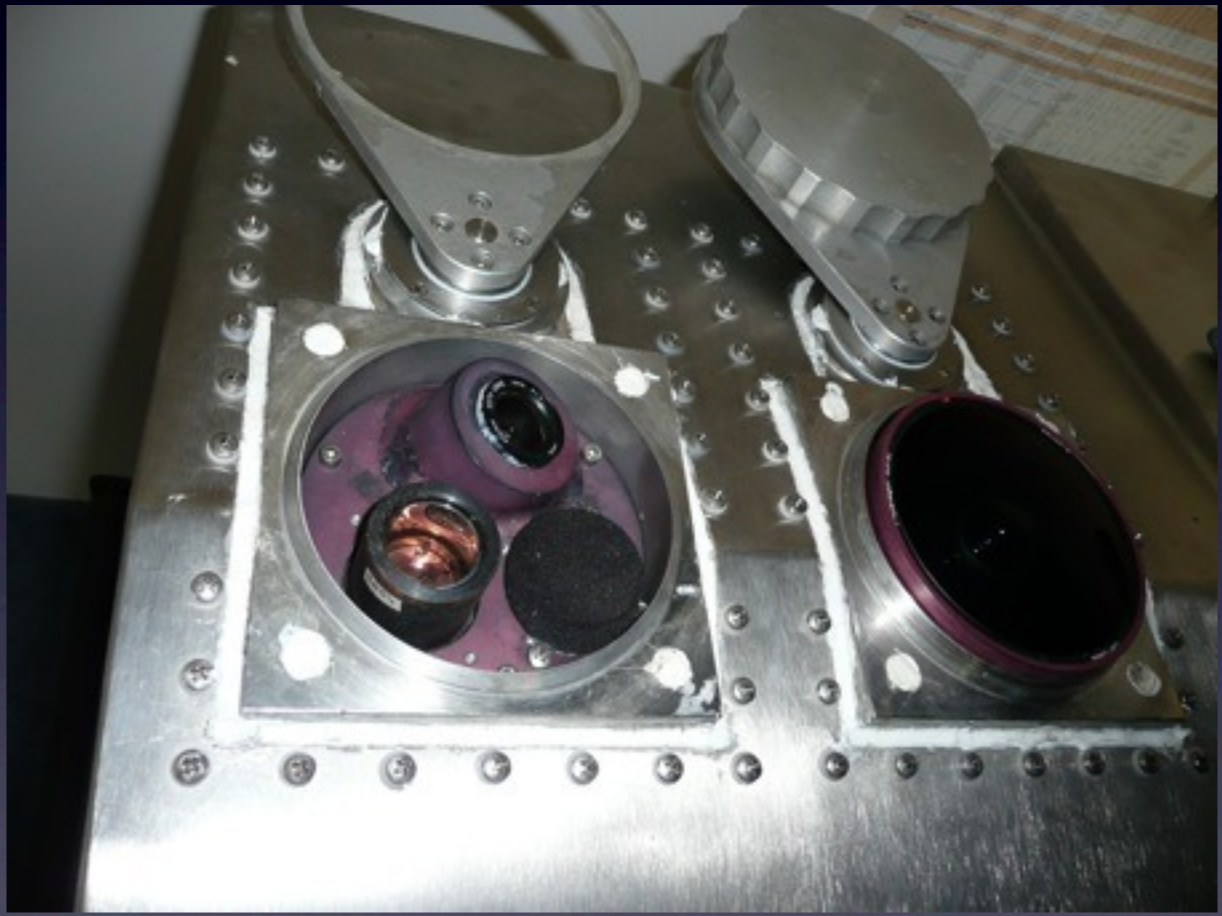
Super Schmidt camera (Haleakala)

- The advent of fast, wide field photographic systems led to the creation of the first meteor networks
- European Fireball Network began in 1958 in Germany and Czechoslovakia
- The Prairie Network began in 1964 in the U.S. Funding was terminated in 1975
- MORP began in Canada in 1968. Its 12 stations used Super-Komura cameras. Funding discontinued in 1985

- Th… s… …es (at least in part)
- Funding discontinued due to lack of scientific interest and disappointing number of finds (1 each for Prairie and MORP)
- Only European network remains operating today

Photographic Advantages

- Large dynamic range
  - Good photometry
- High resolution
  - Precise astrometry
- Can be automated to <u>some</u> degree



Czech system

Video Observations

- Largely pioneered by Clifton and Naumann in the 1960's at MSFC (Meteor Physics Branch)
- Advantages:
  - 100x better sensitivity over Super Schmidt cameras
  - 30 fps rate gives better temporal resolution than rotating shutter
  - Unrivaled temporal accuracy thru GPS time stamps
- Disadvantages:
  - Limited resolution compared to photographic
  - Limited dynamic range (most systems are 8 bit)

The Sandia Sentinel Systems

- Sentinel I (1998) - “look down” system with hardware meteor detection. 6 second buffer, parallel connection to computer (Moooo)
- Sentinel II (2004) - conventional all sky with hardware detection. USB connection to computer
- Sentinel III (2007) - all sky system with software detection

Camera: Hi-Cam HB-710E
Lens: Rainbow L163VDC4 1.6-3.4mm f/1.4 lens

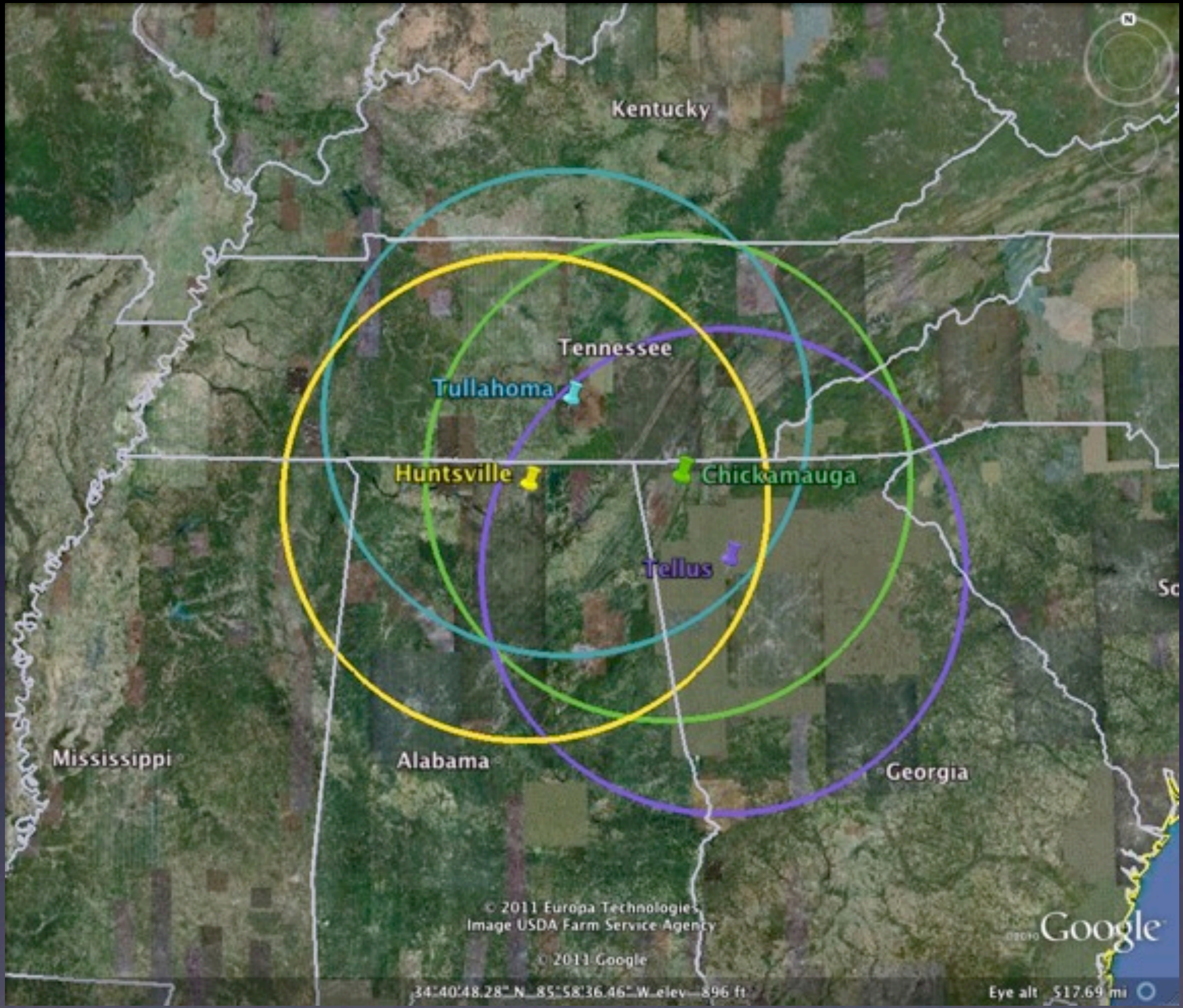
Current Fireball Networks

Name	System Type	Start Year	Reference
European Network	Photographic	1951	Oberst et al (1998)
Japan Fireball Network	Video	1977	Shiba et al (1998)
Sandia All-sky Network	Video	1997	
Spanish Meteor Network	CCD/Video	1997	Trigo-Rodriguez et al (2008)
Denver Museum Fireball Network	Video	2001	Sullivan and Klebe (2004)
Southern Ontario Meteor Network	CCD/Video	2004	Weryk et al (2008)
Desert Fireball Network	Photographic	2004	Spurny and Borovicka (2006)
Polish Fireball Network	Video	2004	Olech et al (2006)

Goals of the NASA Network

- Establish the speed distribution of cm size meteoroids
- Determine which sporadic sources produce large particles
- Determine (low precision) orbits for bright meteors
- Attempt to discover the size at which showers begin to dominate the meteoroid flux
- Monitor the activity of major meteor showers
- Assist in the location of meteorite falls

Station Locations



- 11 more to install!

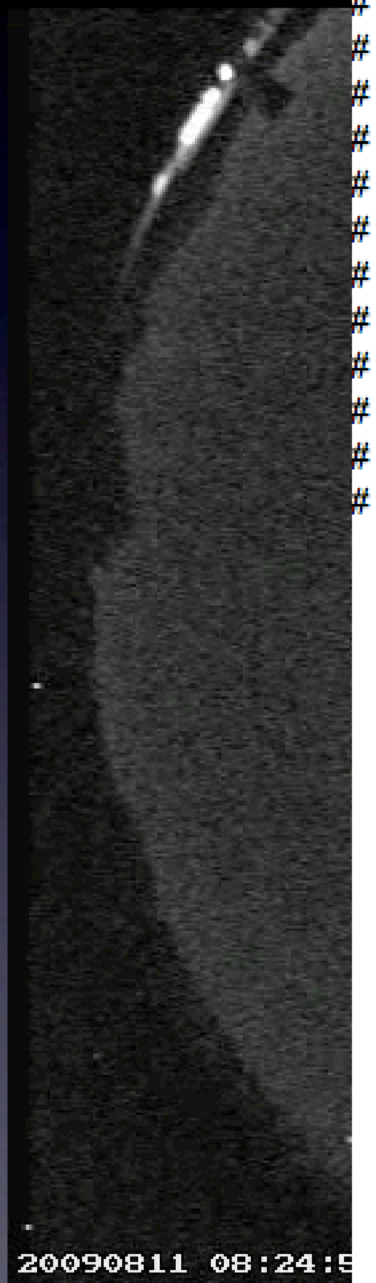
Automated Lunar and Meteor Observatory (ALaMO)

Station Components

- All-sky Camera
  - Low light level video camera
  - All sky (fish eye) lense
  - heater/fan to prevent dewing

- Computer running ASGARD (**A**ll **S**ky and **G**uided **A**utomatic **R**eal-time **D**etection) software
- GPS
- Uninterruptible Power Supply (UPS)
- Internet connection

Detection

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#    num_fr : 20
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#      unix : 1249979091.297046
#       ntp : LOCK 62141 181788 31681
#       seq : 43288344
#       mul : 0 [A]
#      site : 02
#    latlon : 34.8535 -85.3143 246.0
#      text : C3PO
#     label :
#     plate : 20090724-094001-02-aut-calib-ID
#      geom : 640 480
#    reject : 0
#
```

# fr	time	sum	seq	cx	cy	th	phi	lsp	mag	flag
30	-0.500	4499	43288329	300.265	308.405	24.895	-75.082	-7.15	-7.15	0000
31	-0.467	5283	43288330	301.501	310.025	25.186	-76.129	-7.54	-7.54	0000
32	-0.434	4890	43288331	301.857	314.106	26.190	-77.110	-8.12	-8.12	0000
33	-0.400	5619	43288332	303.022	316.712	26.756	-78.211	-8.48	-8.48	0000
34	-0.367	7861	43288333	303.941	320.176	27.574	-79.268	-8.62	-8.62	0000
35	-0.334	7651	43288334	305.163	322.512	28.087	-80.263	-8.82	-8.82	0000
36	-0.300	6796	43288335	306.232	326.347	29.011	-81.338	-8.98	-8.98	0000
37	-0.267	8053	43288336	307.425	328.721	29.554	-82.238	-9.07	-9.07	0000
38	-0.234	9157	43288337	308.517	332.484	30.478	-83.205	-9.12	-9.12	0000
39	-0.200	7418	43288338	310.156	335.234	31.113	-84.283	-9.24	-9.24	0000
40	-0.167	8873	43288339	311.224	338.986	32.056	-85.133	-9.28	-9.28	0000
41	-0.133	7929	43288340	312.432	342.882	33.039	-86.010	-9.33	-9.33	0000
42	-0.100	7909	43288341	313.751	346.717	34.011	-86.882	-9.45	-9.45	0000
43	-0.067	8397	43288342	314.826	349.421	34.697	-87.531	-9.52	-9.52	0000
44	-0.033	13750	43288343	315.998	356.506	36.573	-88.429	-10.22	-10.22	0000
45	0.000	14263	43288344	316.409	358.491	37.099	-88.699	-10.62	-10.62	0000
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47	0.067	12812	43288346	318.587	366.500	39.220	-89.918	-10.87	-10.87	0000
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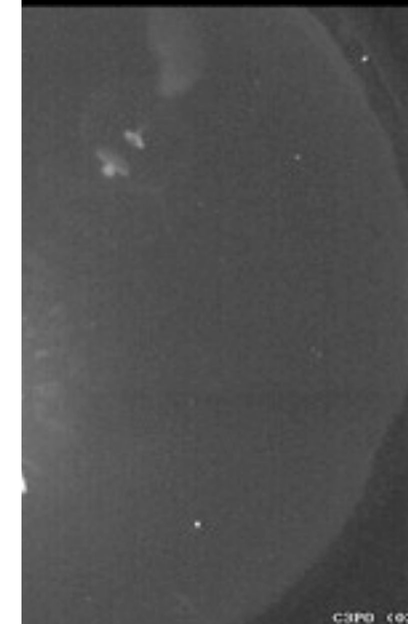

-ID

cy	th	phi	lsp	mag	flag
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.025	25.186	-76.129	-7.54	-7.54	0000
.106	26.190	-77.110	-8.12	-8.12	0000
.712	26.756	-78.211	-8.48	-8.48	0000
.176	27.574	-79.268	-8.62	-8.62	0000
.512	28.087	-80.263	-8.82	-8.82	0000
.347	29.011	-81.338	-8.98	-8.98	0000
.721	29.554	-82.238	-9.07	-9.07	0000
.484	30.478	-83.205	-9.12	-9.12	0000
.234	31.113	-84.283	-9.24	-9.24	0000
.986	32.056	-85.133	-9.28	-9.28	0000
.882	33.039	-86.010	-9.33	-9.33	0000
.717	34.011	-86.882	-9.45	-9.45	0000
.421	34.697	-87.531	-9.52	-9.52	0000
.506	36.573	-88.429	-10.22	-10.22	0000
.491	37.099	-88.699	-10.62	-10.62	0000
.889	37.673	-89.865	-10.24	-10.24	0000
.500	39.220	-89.918	-10.87	-10.87	0000
.218	39.623	-91.050	-10.04	-10.04	0000
.902	40.040	-91.990	-8.52	-8.52	0000

Calibration

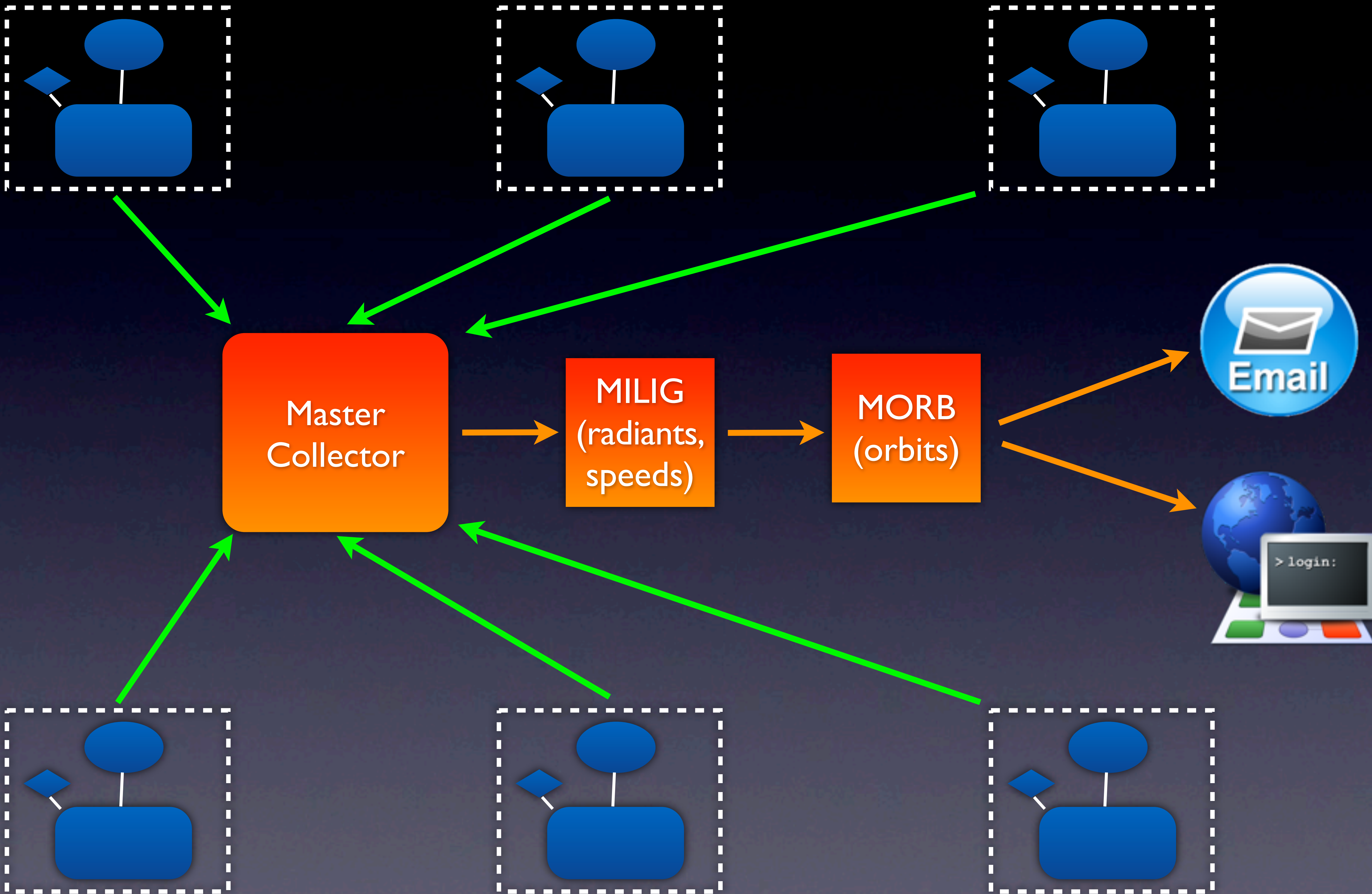
- Need to transform between pixel coordinates to az, el
- Every 30 minutes the camera computer produces a calibration plate (several images stacked together to show lots of stars)
- User runs an IDL script to match stars to image
- A least squares fit is performed to determine plate parameters

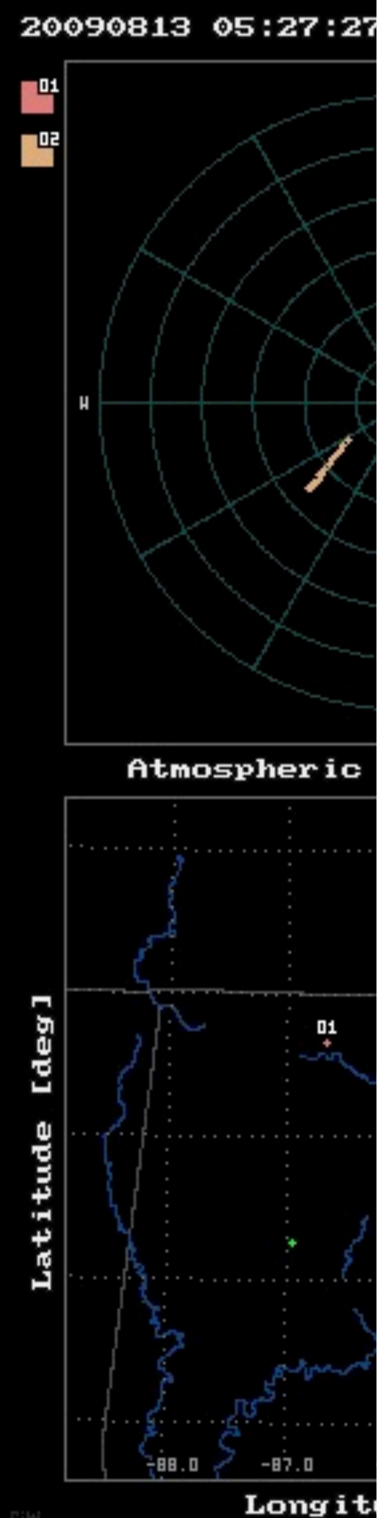
The transformation of the plate coordinates x, y to the celestial coordinates a, z is done by means of five equations. The equation for r can be rewritten as

$$r = C\left[\sqrt{(x-x_0)^2+(y-y_0)^2} + \right. \tag{9}$$
$$\left. + \; A\,(y-y_0)\,\cos(F-a_0) - A\,(x-x_0)\,\sin(F-a_0)\right],$$

where we introduced the global scale factor C (see below). The other four equations are

$$u = Vr + S(\mathrm{e}^{Dr}-1) + P(\mathrm{e}^{Qr^2}-1) \tag{6}$$
$$b = a_0 - E + \arctan\left(\frac{y-y_0}{x-x_0}\right) \tag{4}$$
$$\cos z = \cos u\,\cos\varepsilon - \sin u\,\sin\varepsilon\,\cos b \tag{1}$$
$$\sin(a-E) = \sin b\,\sin u/\sin z \tag{2}$$


Master Collector
MILIG (radiants, speeds)
MORB (orbits)
Email
> login:



From: "asgard (02)"
Date: August 13, 2009 6:03:52 AM CDT
To: "list"
Subject: **allsky 20090813**

Last sync and disk usage :

01 : 20090813 06:00:01 CDT : 280188 / 465365 MB free
02 : 20090813 07:00:02 EDT : 282305 / 465365 MB free

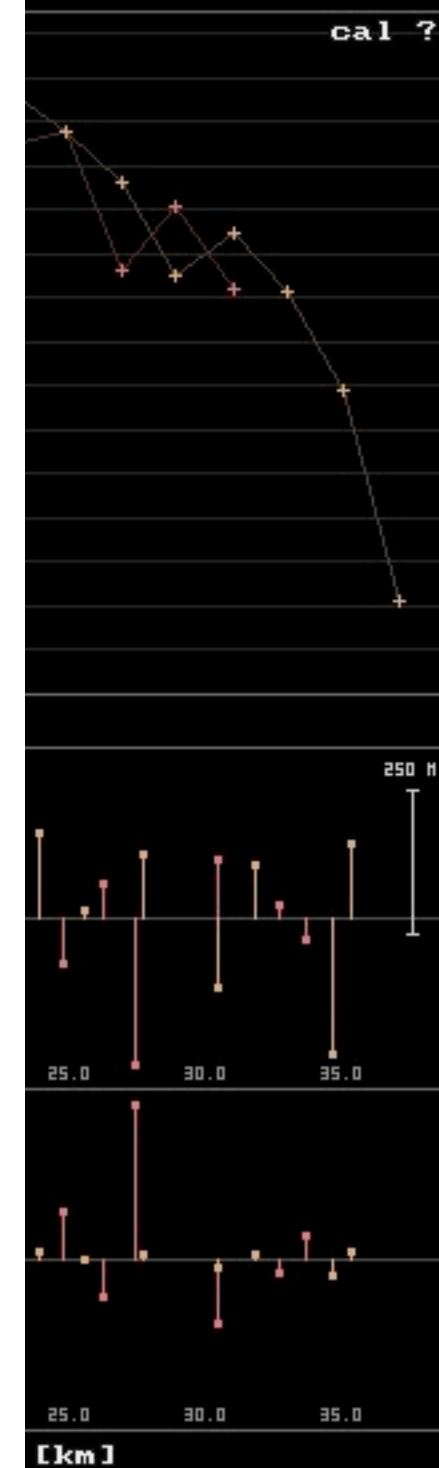
Last recorded event and plate :

01 : 20090813 100436 UTC : 20090724-094001-01-aut-calib-ID
02 : 20090813 102022 UTC : 20090724-094001-02-aut-calib-ID

ASGARD version and NTP status :

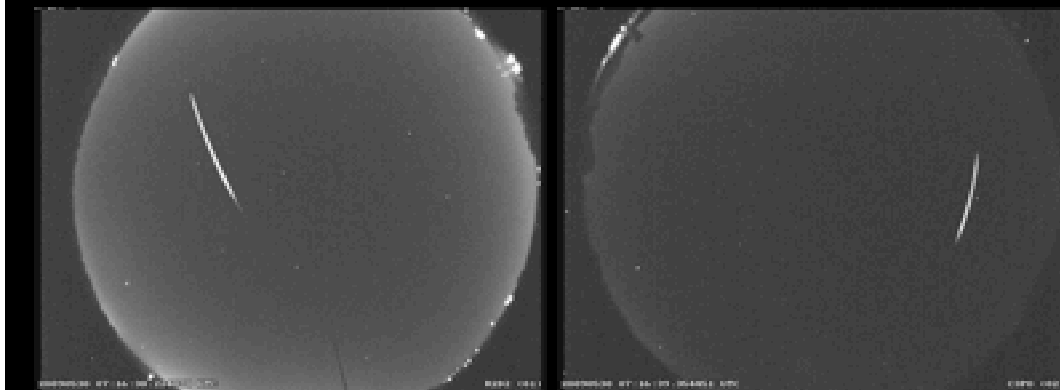
01 : 20090611 : LOCK 18154 64069 4032
02 : 20090611 : LOCK -13559 63498 7150

```
  date     time   :      : vel  beg   end  : src
-------------------+--------+-------------------+-----
+ 20090813 03:16:41 : 01 02 : .... ..... ..... : ...
+ 20090813 04:01:55 : 01 02 : 59.7 109.8  99.5 : PER
+ 20090813 04:05:44 : 01 02 : 58.1 107.5  95.4 : PER
+ 20090813 04:10:46 : 01 02 : 58.0 103.4  93.5 : PER
+ 20090813 04:19:51 : 01 02 : 39.4  98.1  86.8 : ...
+ 20090813 04:25:20 : 01 02 : 60.4 109.8  90.7 : PER
+ 20090813 04:26:40 : 01 02 : 59.8 107.5  97.0 : PER
+ 20090813 04:38:54 : 01 02 : 60.5 109.6  95.5 : PER
+ 20090813 04:46:45 : 01 02 : 63.6 109.1  90.0 : PER
+ 20090813 05:04:44 : 01 02 : 58.8 106.9  89.6 : PER
+ 20090813 05:08:56 : 01 02 : 60.6 111.1  85.8 : PER
+ 20090813 05:09:33 : 01 02 : 60.5 102.5  92.1 : ...
```

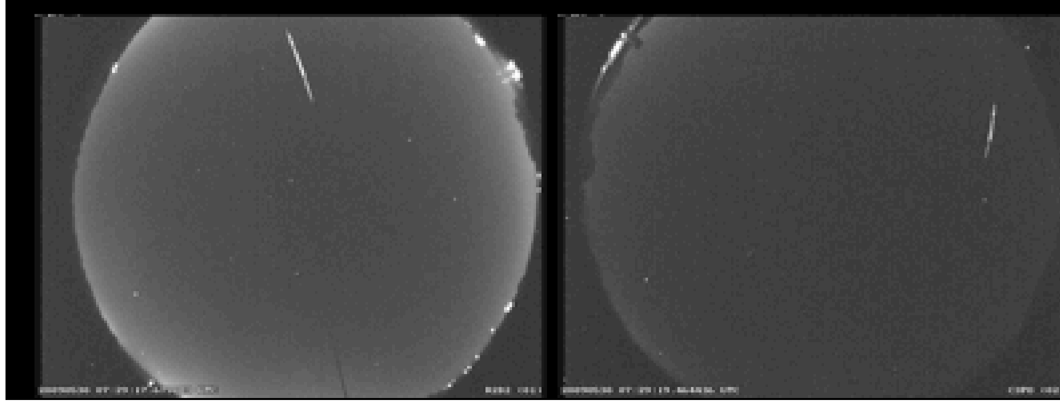


Live View
20090615 E I
20090614 E I
20090613 E I
20090612 E I
20090611 E I
20090610 E I
20090609 E I
20090608 E I
20090607 E I
20090606 E I
20090605 E I
20090604 E I
20090603 E I
20090602 E I
20090601 E I
20090531 E I
20090530 E I
20090529 E I
20090528 E I
20090527 E I
20090526 E I

20090530 07:16:38 UTC ...
vel 24.5 km/s beg 82.3 km end 53.8 km
evcorr TXT PNG milig INPUT ZMILI ORBIT



20090530 07:29:17 UTC ...
vel 26.6 km/s beg 87.4 km end 58.2 km
evcorr TXT PNG milig INPUT ZMILI ORBIT



time 20090530 7.4881 hours
lat 35 26 11.179 = 35.4364 deg
lon 273 28 02.828 = 273.4675 deg
ht 0.000 b 3.61297 -4.69162 -6.88988 -18.76613
alp 253.822 +/- 0.084 deg
del -10.430 +/- 0.171 deg
v_inf 26.645 +/- 0.262 km/s
v_avg 26.645 +/- 0.262 km/s

a 2.292 +/- 0.076 AU
e 0.771 +/- 0.009
incl 8.245 +/- 0.208 deg
omega 276.178 +/- 0.201 deg
asc_node 68.911 +/- 0.000 deg
v_g 24.325 +/- 0.288 km/s
v_h 36.920 +/- 0.173 km/s
alp_geo 251.922 +/- 0.090 deg
del_geo -12.710 +/- 0.186 deg
q_per 0.525 +/- 0.003 AU
q_aph 4.059 +/- 0.154 AU
- 0.090 deg
- 0.186 deg
- 0.186 deg

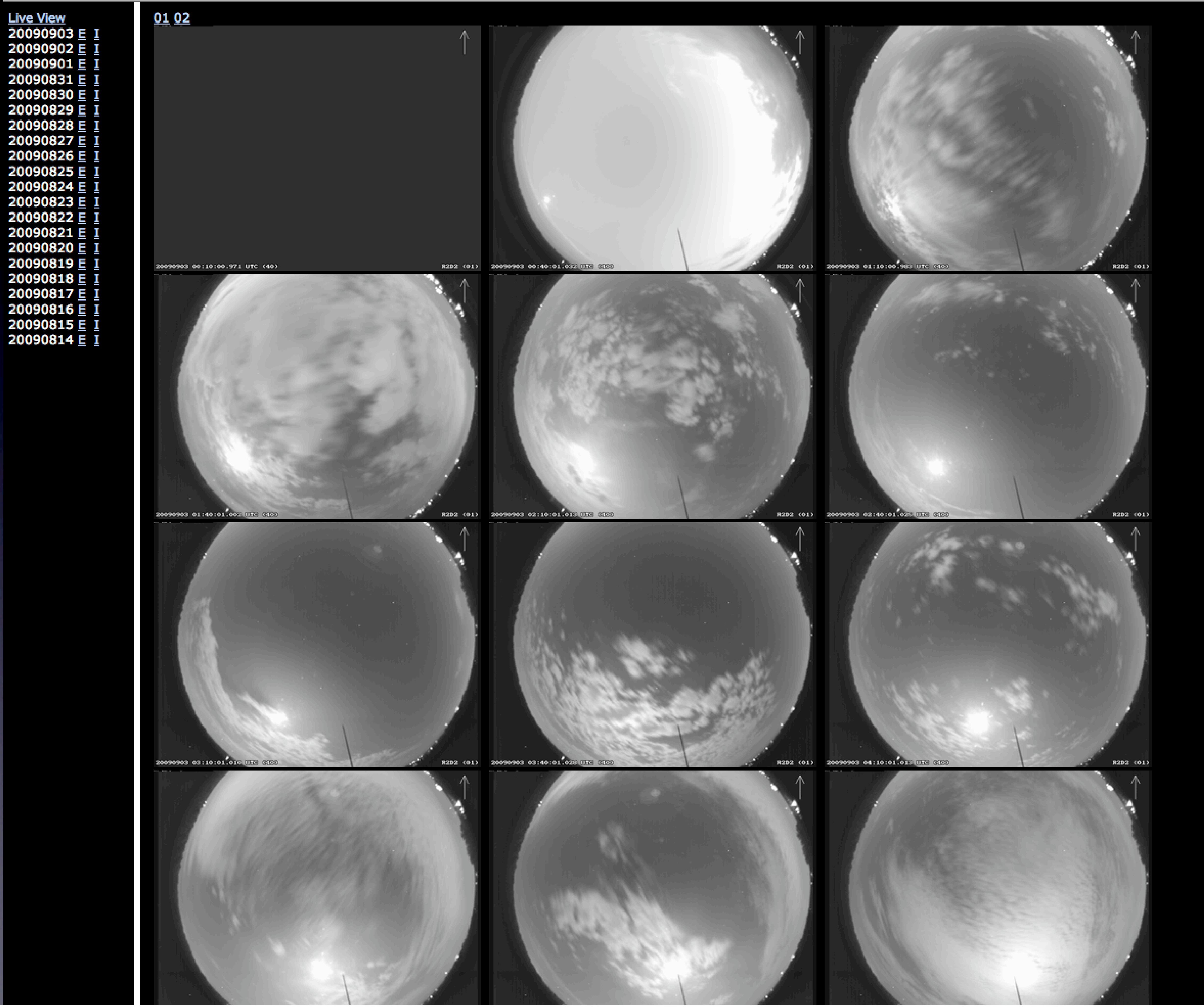
201
eg
deg
g

BEGINNING POINT:
X = 329.933 Y = -5281.118 Z = 3703.070
.059 .011 .068
GEOGRAPHIC LAM = -86.69515 FI = 35.16388 H = 87.381 KM
.00063 .00078 .040

END POINT:
X = 342.215 Y = -5238.779 Z = 3711.185
.052 .010 .058
GEOGRAPHIC LAM = -86.53255 FI = 35.43644 H = 58.225 KM
.00057 .00067 .034

Note: LAMBDA approximate (valid for TIME=0)

FOR THE END POINT: AZIMUTH= 26.107 ZNT. DISTANCE= 49.577
.131 .162


Live View
20090903 E I
20090902 E I
20090901 E I
20090831 E I
20090830 E I
20090829 E I
20090828 E I
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20090825 E I
20090824 E I
20090823 E I
20090822 E I
20090821 E I
20090820 E I
20090819 E I
20090818 E I
20090817 E I
20090816 E I
20090815 E I
20090814 E I
01 02

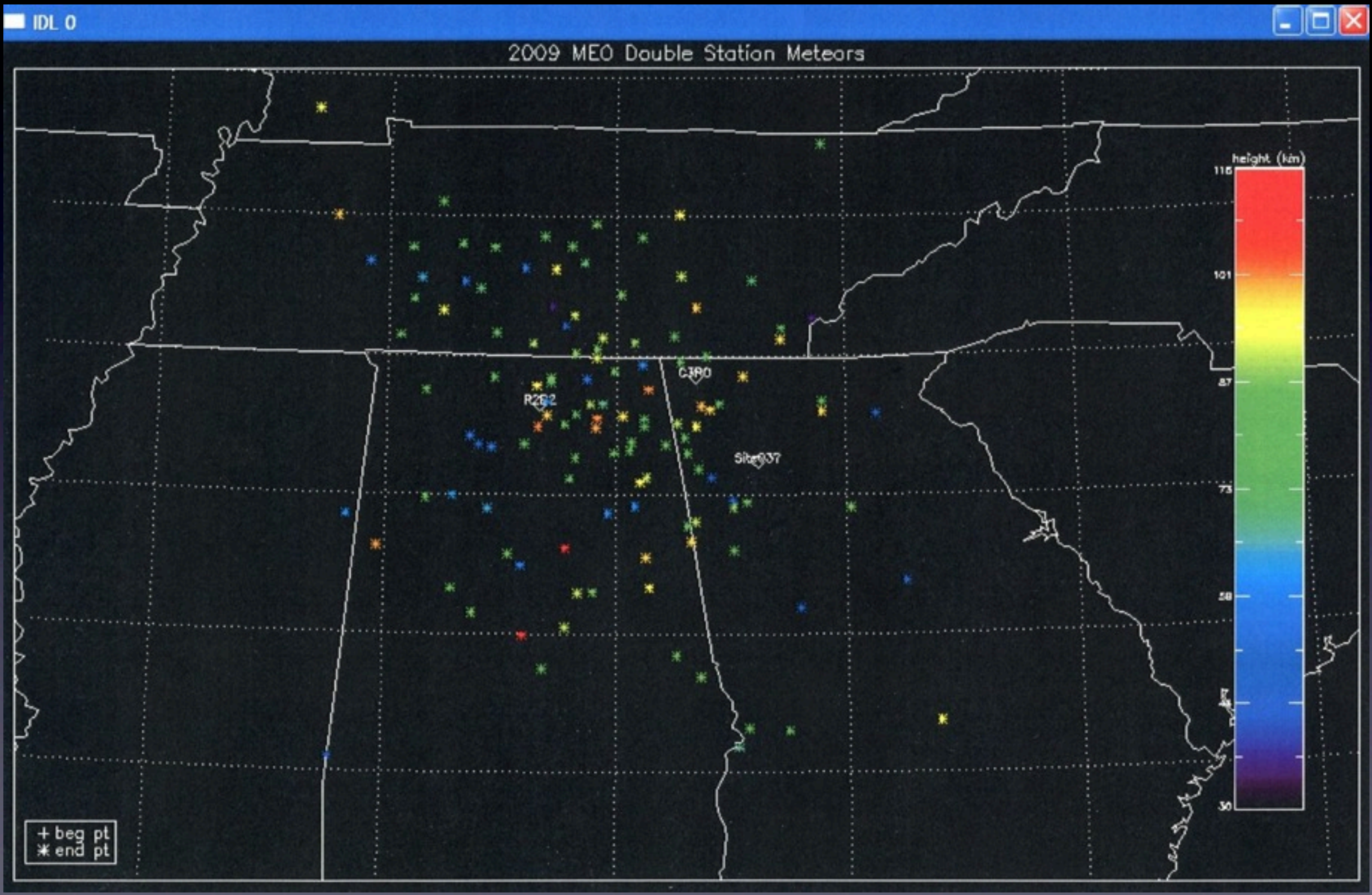
Sensitivity and Response

- Can detect magnitude 0 meteors
- ASGARD software can handle simultaneous events
- Aircraft (flashing lights) made detection algorithm crazy; continual improvements have reduced number of falses

System Requirements

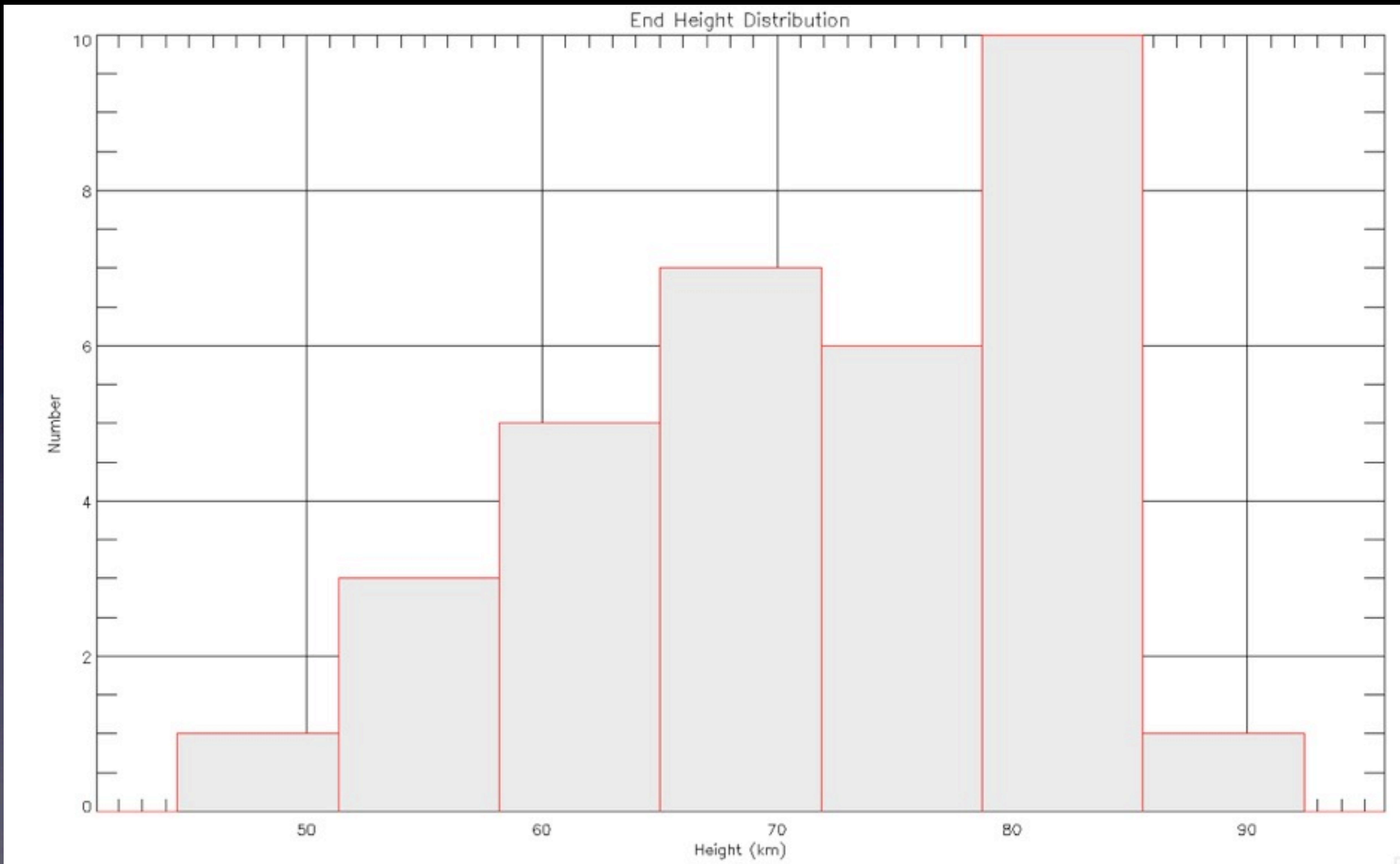
- ✓ Pentium 3, 900MHz, 512Mb RAM
- ✓ at least 40 Gb data space, in 2 partitions (>20 Gb for video buffer, rest to store events)
- ✓ US GlobalSat BU-353 Waterproof USB GPS units (required, available from http://www.gpscentral.ca/products/usglobalsat/bu353.htm)
- ✓ Brooktree 878A framegrabber (Hauppage WinTV card)
- ✓ Debian linux version 5
- ✓ DSL or faster internet connection

Coverage



IDL 0
2009 MEO Double Station Meteors
height (km)
115
101
87
73
58
30
R2D2
C3PO
Site037
+ beg pt
✳ end pt

Preliminary Geminid Results



2009 Perseids