The Status of the NASA All Sky Fireball Network

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Abstract

Established by the NASA Meteoroid Environment Office, the NASA All Sky Fireball Network consists of 6 meteor video cameras in the southern United States, with plans to expand to 15 cameras by 2013. As of mid-2011, the network had detected 1796 multi-station meteors, including meteors from 43 different meteor showers. The current status of the NASA All Sky Fireball Network is described, alongside preliminary results.

1 Introduction

The NASA Meteoroid Environment Office (MEO), located at the Marshall Space Flight Center in Huntsville, Alabama, USA, is the NASA organization responsible for meteoroid environments as they pertain to spacecraft engineering and operations. Understanding the meteoroid environment can help spacecraft designers to better protect critical components on spacecraft or avoid critical operations such as extravehicular activities during periods of higher flux such as meteor showers.

In mid-2008, the MEO established the NASA All Sky Fireball Network, a network of meteor cameras in the southern United States. The objectives of this video network are to 1) establish the speed distribution of cm-sized meteoroids, 2) determine which sporadic sources produce large particles, 3) determine (low precision) orbits for bright meteors, 4) attempt to discover the size at which showers begin to dominate the meteoroid flux, 5) monitor the activity of major meteor showers, and 6) assist in the location of meteorite falls.

2 Instrumentation and Software

In order to achieve the above objectives 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 the ASGARD (All Sky and Guided Automatic Real-time Detection) 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.

To date, 15 cameras have been built with the goal of deploying 15 stations in the United States, distributed in two or more clusters with overlapping fields of view, operational sometime in 2013. Currently the network has 6 cameras operating in the states of Alabama, Georgia, Tennessee, and New Mexico, with plans to expand into North Carolina in 2012. The locations of these stations are shown in Figure 1. Network 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 (Table 1).

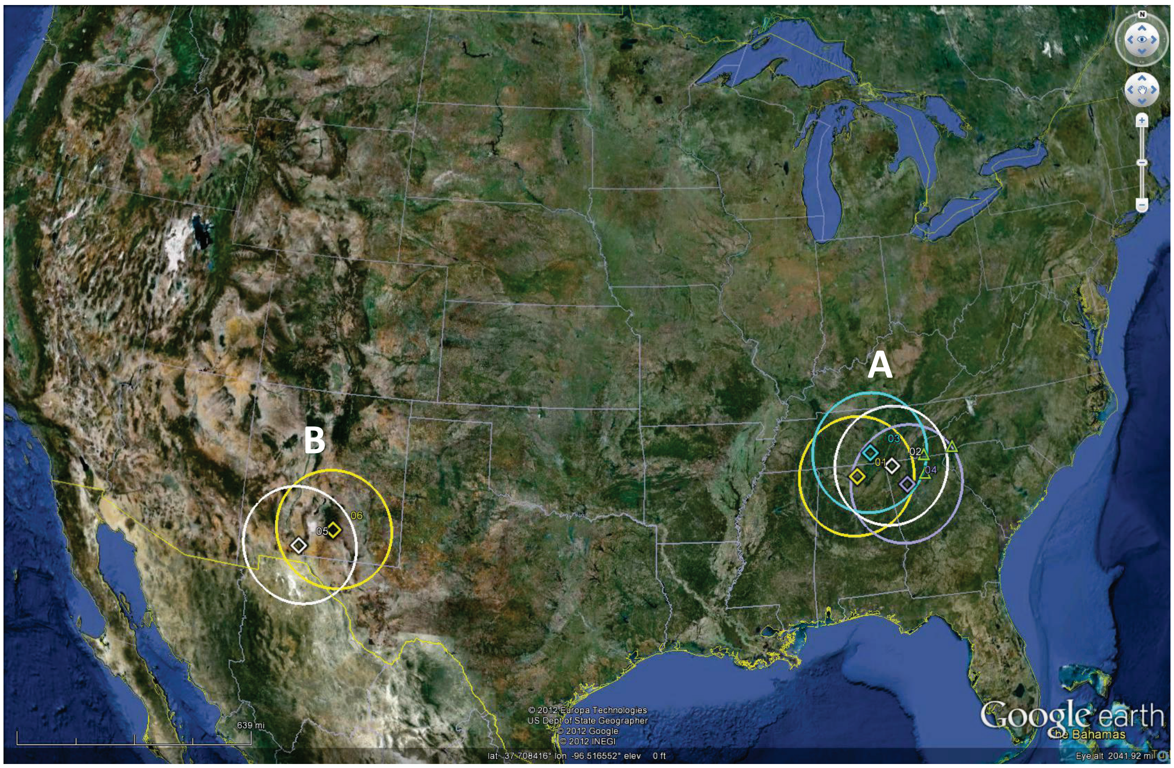


Figure 1: *Location of the 6 stations of the NASA All Sky Fireball Network. Circles indicate approximate sky coverage. 2012 expansion locations are shown as triangles. Letters A and B indicate cluster assignment.*

Table 1: *NASA All Sky Fireball Network station location, establishment date, and cluster assignment.*

Location	**Date established**	**Cluster**
Huntsville, AL	June 2008	A
Chickamauga, GA	October 2008	A
Tullahoma, GA	January 2011	A
Cartersville, GA	March 2011	A
Las Cruces, NM	September 2011	B
Mayhill, NM	September 2011	B

Each station consists of a computer and a black and white, all sky, low light level video camera – a Watec 902H2 Ultimate equipped with a 3.4 mm f/1.4 fisheye lens running at 30 fps. The weatherproof camera housing consists of 5 inch diameter PVC pipe and a clear acrylic dome. Figure 2 shows a picture of a typical camera. Thermal control is accomplished with micro-fans and heaters, while a timer switch turns off all power to the camera between 6 am and 6 pm local time. The system is run by a 12V 2A off-the-shelf power 'brick'. Cabling integrates power and video coaxial cable, and feeds into a Linux machine running the ASGARD software. GPS receivers are used for time keeping and an Uninterruptible Power Supply (UPS) provides emergency power to the system. This design is robust but inexpensive.

Figure 2: *NASA All Sky Fireball Network meteor camera, pictured here undergoing testing and calibration before deployment.*

The ASGARD software is discussed in detail by Weryk et al. (2007) and Brown et al. (2010). Installed at each station, ASGARD detects and records events throughout the night. Each station then sends its data to a central server, where ASGARD correlates the events from each camera in the network based on the time of the observation. (Fast, reliable internet is therefore a requirement for each station.) For each multi-station event, ASGARD runs MILIG (Borovička, 1990) to compute the atmospheric trajectory and MORB (Ceplecha, 1987) to calculate the heliocentric orbit. The central server, where data storage of each event and automated analysis occurs, also automatically generates a web page (http://fireballs.ndc.nasa.gov) each morning containing the particulars of events from the previous night (Figures 3 and 4). It also e-mails the interested parties with a detection summary each day.

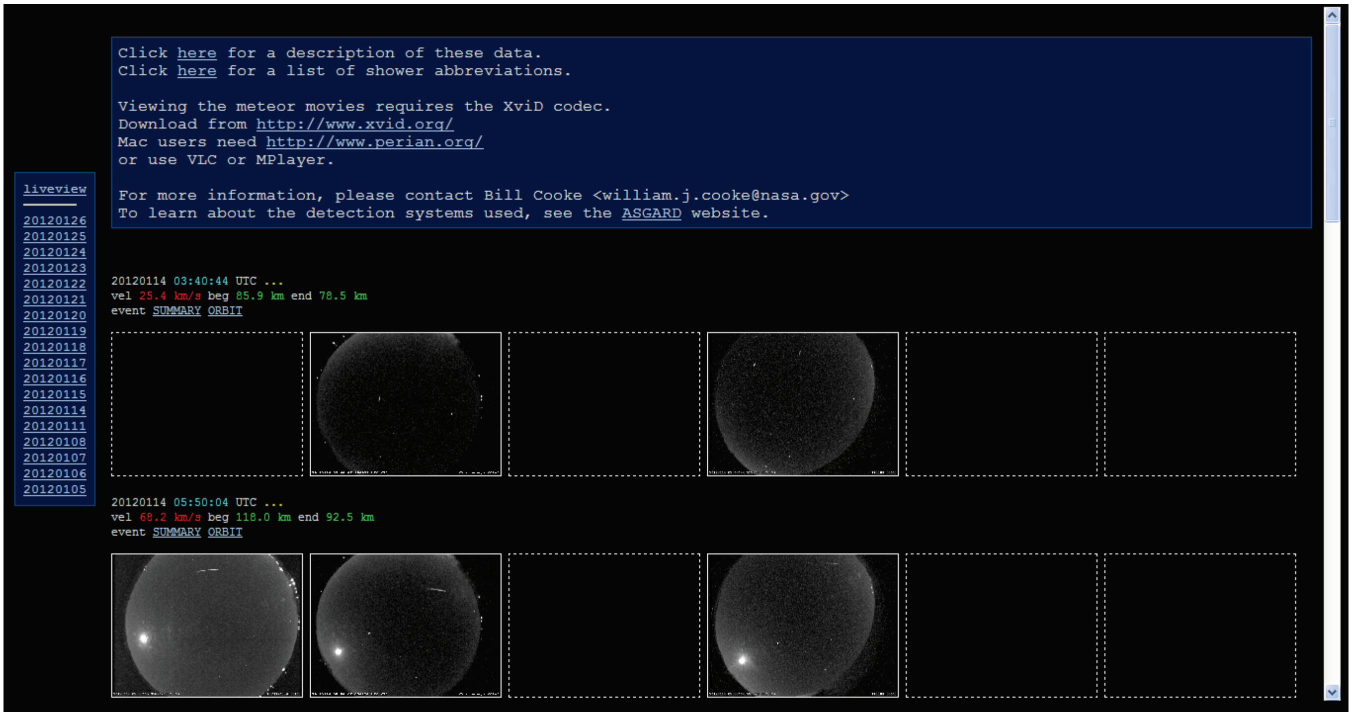
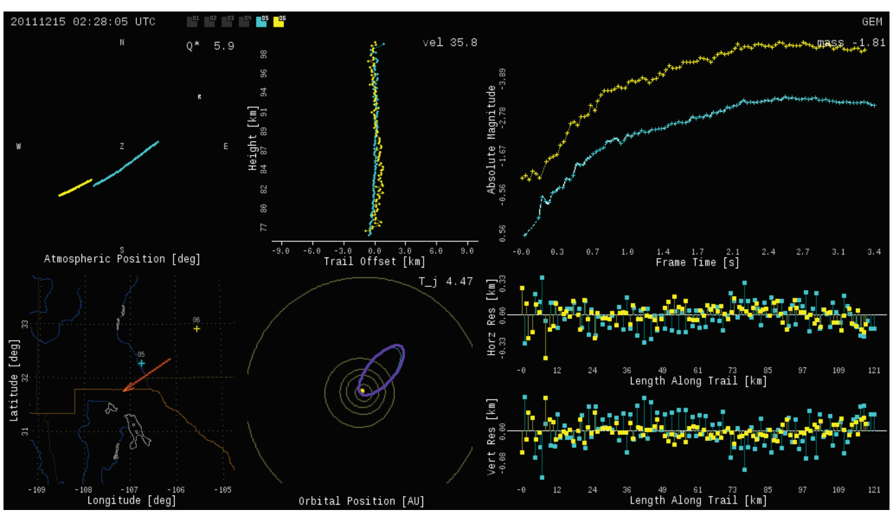


Figure 3: *The webpage generated by ASGARD each morning. The site contains videos and images of events seen the previous night, alongside speed, height, shower identification, and orbital information.*

(a)



(b)

```
 time 20111215 2.4681 hours
  lat  31 46 02.244 =  31.7673 deg
  lon 252 50 08.484 = 252.8357 deg
   ht 76.291 b 15.59815 3.01520
2.33686 20.64929
        alp 112.113 +/-  0.333 deg
        del  33.783 +/-  0.088 deg
      v_inf  35.810 +/-  0.198 km/s
      v_avg  35.810 +/-  0.198 km/s

          a   1.287 +/-  0.024 AU
          e   0.885 +/-  0.003
       incl  24.120 +/-  0.423 deg
      omega 324.014 +/-  0.468 deg
   asc_node 262.576 +/-  0.000 deg
        v_g  33.695 +/-  0.208 km/s
        v_h  33.369 +/-  0.191 km/s
    alp_geo 114.534 +/-  0.345 deg
    del_geo  32.872 +/-  0.092 deg
      q_per   0.148 +/-  0.003 AU
      q_aph   2.426 +/-  0.047 AU
     lambda 110.985 +/-  0.294 deg
       beta  11.191 +/-  0.097 deg
 true anom 215.990 +/-  0.097 deg
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Figure 4: *Other data products generated by ASGARD and placed online include (a) a summary graphic for each multi-station meteor as well as (b) orbital information. From left to right, the six sections of the summary graphic show: the location of the meteor in the camera's field of view, the height of the event as a function of trail offset, the light curve, the geographic location of the meteor overlaid on a US map, the meteor's orbit, and errors in the trajectory determination.*

Calibration plates are created approximately every two weeks using stacked 40 second images produced by ASGARD every 30 minutes. Stacking the images lets a user identify more stars, and in turn, match them to those in the star catalog. This process allows for the transformation from the pixel coordinates of the camera to celestial coordinates (azimuth and elevation), performed using a least squares fit to determine plate parameters as outlined in Ceplecha (1987).

3 Preliminary Results

As of mid-2011, 1796 multi-station meteors had been detected by the network. This count includes meteors from 43 different meteor showers (as listed in the IAU Meteor Data Center), the most active of which have been the Perseids (Figure 5). A radiant map of all meteors, color-coded by speed, highlights the shower radiants in Figure 6. Removing the shower meteors, Figure 7 shows the radiant distribution of the sporadics, again color-coded by speed. There is some shower contamination here that has yet to be removed at this early stage of analysis. The majority of the events are double-station as the network operated only 2 cameras until early 2011.

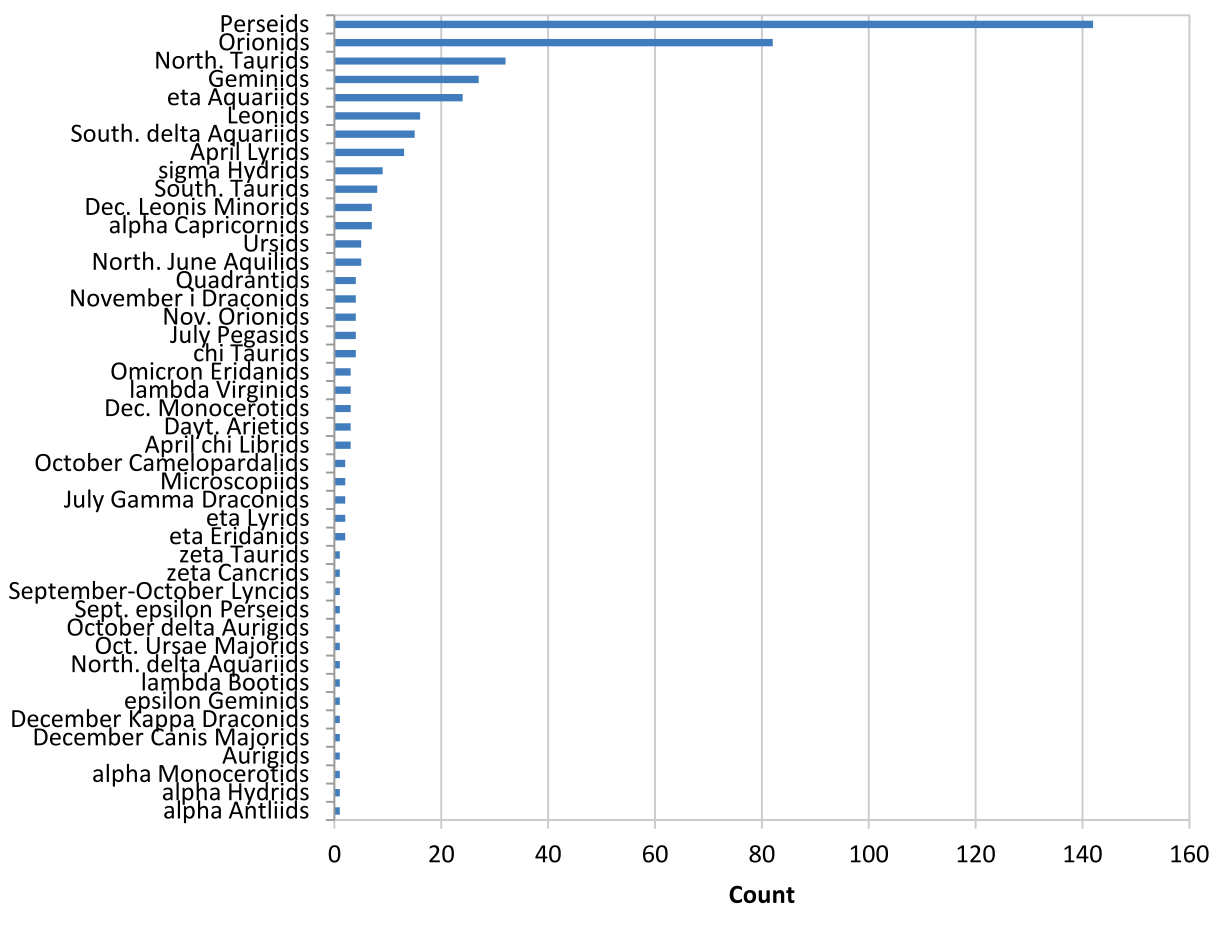

Figure 5: *Shower histogram. As of mid-2011, the Perseids and Orionids made up 31% and 18% of the shower meteors detected by the NASA All Sky Fireball Network, respectively.*

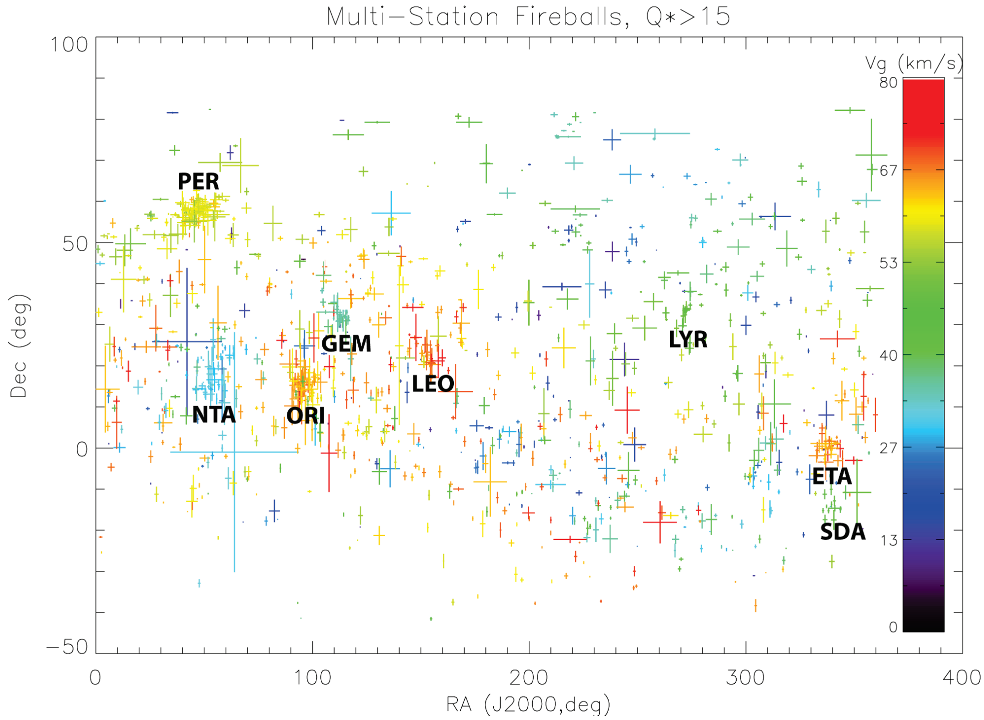

Figure 6: *Radiant map of meteors detected by the NASA All Sky Fireball Network, color-coded by geocentric speed. Only meteors with convergence angles greater than 15° are plotted.*

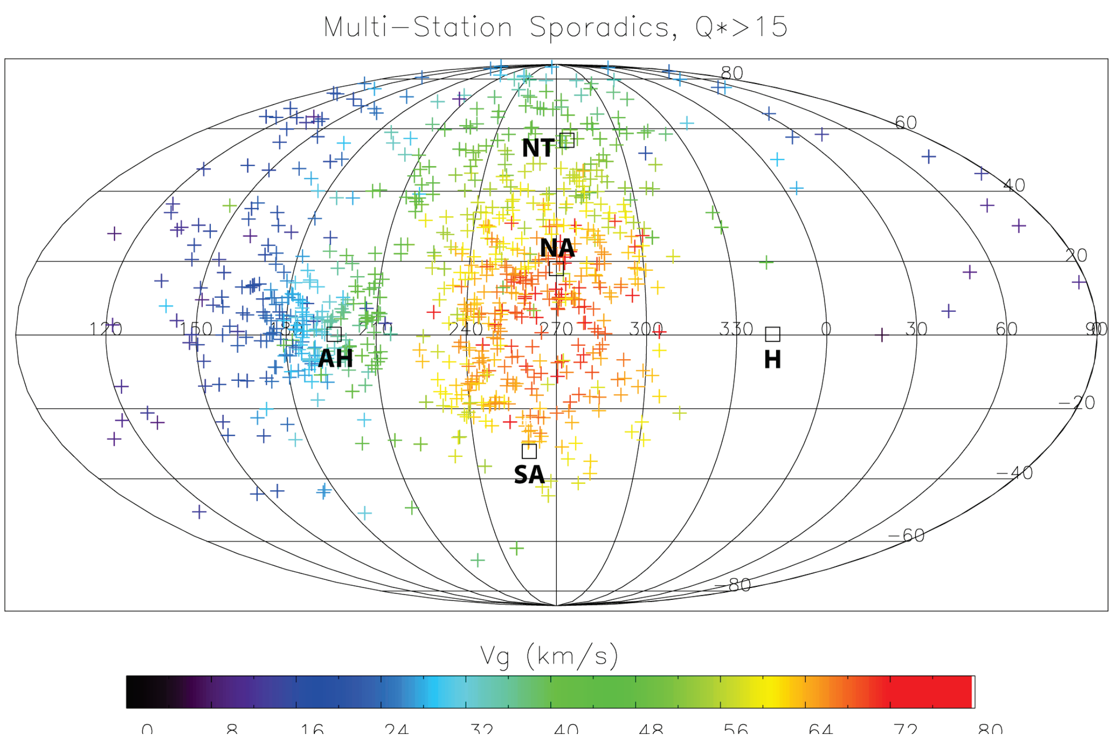

Figure 7: *Radiant distribution of sporadic meteors detected by the NASA All Sky Fireball Network, color-coded by geocentric speed. Only meteors with convergence angles greater than 15° are plotted. The sporadic sources are also given: H=Helion, AH=Anti-Helion, NA=North Apex, SA=South Apex, NT=North Toroidal. There may be some shower contamination in the data at this early analysis stage. Error bars are removed for convenience.*

4 Summary

The NASA All Sky Fireball Network is operational and detecting decent numbers of meteors. Detections are expected to increase as the network grows from 6 cameras to 15 in the next 2 years. Video of all of the meteors, as well as trajectory and orbital information, is posted online every morning by ASGARD at http://fireballs.ndc.nasa.gov.

Acknowledgements

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