Performance of new low-cost 1/3" security cameras for meteor surveillance

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It's been almost 5 years since the CAMS (Cameras for All-sky Meteor Surveillance) system specifications were designed for video meteor surveillance. CAMS has been based on a relatively expensive black-and-white Watec WAT-902H2 Ultimate camera, which uses a 1/2" sensor. In this paper, we investigate the ability of new, lower cost color cameras based on smaller 1/3" sensors to be able to perform adequately for CAMS. We did not expect them to equal or outperform the sensitivity for the same field of view of the Watec 1/2" camera, but the goal was to see if they could perform within the tolerances of the sensitivity requirements for the CAMS project. Their lower cost brings deployment of meteor surveillance cameras within reach of amateur astronomers and makes it possible to deploy many more cameras to increase yield. The lens focal length is matched to the elevation angle of the camera to maintain an image scale and spatial resolution close to that of the standard CAMS camera and lens combination, crucial for obtaining sufficiently accurate orbital elements. An all-sky array based on 16 such cameras, to be operated from a single computer, was built and the performance of individual cameras was tested.

1 Introduction

The Cameras for All-sky Meteor Surveillance project (CAMS) is a NASA sponsored project using video surveillance of the night sky to map the visible meteor showers throughout the year (Jenniskens et al., 2011; Gural 2011). The primary CAMS network in California consists of three 20-camera array boxes positioned at Fremont Peak, Lick Observatory, and Sunnyvale, CA, with data gathered and processed at the SETI Institute. In 2011, software was developed, by Pete Gural, for amateur astronomers to add one or more cameras to this network in a project called **single-CAMS**. Since then, the single-CAMS software has been enhanced to support 2, 4, and 16 cameras from a single computer. Several single-CAMS local networks have been established in Northern California, the Belgium/Netherlands/Luxembourg area (BeNeLux), the Washington DC area, Northern Florida, Croatia, and now also in New Zealand[1].

The de facto standard for video meteor surveillance – and workhorse for this science - has been the Watec 902H2 Ultimate black and white security camera based on its very sensitive 1/2"-inch sensor. This camera is based on the Sony EXview HAD 1/2" architecture. It has several favorable properties: (1) The sensitivity is measured to 0.0001 lux (effectively being able to record stars down to magnitude +5.4 with an f/1.2 12-mm lens); (2) Is a compact camera suitable for flies-eye type all-sky configurations; (3) Uses BNC connectors to achieve a reliable connection to the camera; (4) It is easily configurable. The biggest drawback for amateur astronomers is that the standard camera/lens configuration is expensive. The Watec Wat902H2 Ultimate camera sells for around $US390 (Note that all prices quoted in this paper are internet-derived prices per October 2014 and are prone to changing) and the recommended Pentax 12mm f/1.2 lens (mfr #C61215KP) will typically cost around $US95, plus shipping (internet pricing October, 2014). The expense of the equipment is often a deterrent in setting up new sites or expanding a site to multiple cameras.

In the 5 years since the camera specifications for the CAMS project were made, lower cost color security cameras have come on the market that are based on later model 1/3" sensors. They boast high sensitivity, which we attempt to test in this paper. These new color cameras have a Night Mode. There are several aspects to the Night Mode of these cameras. One major one is that they increase the sensitivity by switching from color mode to black and white mode. The firmware driving the cameras also supports Sens-Up technology. Sens-Up, and the other Night Mode

[1] http://cams.seti.org.

related features degrade the performance for CAMS and they should be disabled.

These new cameras may not be as good as the Watec, but perhaps sensitive enough to perform well enough to be used for the CAMS project. We found a few cameras available for under US$60.00. We also found some f/1.2 near-IR corrected lenses available for US$8.00.

In this paper, we examine whether or not these new cameras might be suitable to expand the data gathering ability of the CAMS project and enable more amateur astronomers to participate in single-CAMS networks. Another question that should be answered is whether these smaller sensors can cover the sky using a 16 camera array?

2 Camera models and properties

Testing was performed from several sites in the Northern California single-CAMS network. The two main test sites were Foresthill, CA and Brentwood, CA. These two sites are 132 km apart. There were several occasions where the pointing of the cameras was adjusted to test the ability to capture low-light meteors at various elevation angles and distances to the camera. For the first few months, the Brentwood station used the standard Watec configuration and the Foresthill site used the 1/3" cameras. Eventually, the Brentwood station switched to using one EXview and one Super HAD II to complete the tests.

There are basically three tiers of elevation angles used to provide all-sky coverage at this distance. All lenses were tested at each elevation tier.

The sensitivity of security cameras is often specified in lux. However, there is no real standard for advertising lux ratings, so you can't really trust the advertised lux sensitivity without testing unless more detail is available, such as the focal ratio and gain. In this paper we try to show the usefulness of these cameras regardless of lux levels.

Sony "Effio-E" System

Before we delve into the different cameras, we need to clear up some confusion regarding the firmware utilized with these cameras.

The word "Effio" translates to "Enhanced Features and Fine Image Processor". You can think of it as the operating system for a camera. The Effio system's signal processor has useful security features like high color reproduction, high S/N ratio, and high resolution. The Effio system also provides the on-screen display menu (OSD). The Effio series cameras also have higher night time sensitivity by changing the camera from color mode to black and white mode. In addition, features, such as Sens-Up and other night mode functions are also part of the Effio system. Many advertisements of Effio series security cameras can boast of lower lux levels due to these Sens-Up and night mode settings. Briefly, Sens-Up switches the camera to 1/15 sec exposure time up to 4 second exposure integrations to attain the increased sensitivity. Some of the other features with the Effio-P, S, and E series cameras are Wide Dynamic Range, Privacy Masking, Motion Detection, Image Stabilization, Exposure control for IR lighting, Adaptive Tone Reproduction (ATR), 2D & 3D NR, and Highlight Compensation (HLC). While all of these features are useful in security cameras, only the privacy masking feature is potentially useful with CAMS. However, this feature has not been tested. One of the features of the EXview OSD was a way of making dark frames so that hot pixels could be masked by the in-camera image processor. This will be a useful feature as the camera ages.

The Effio-E System is the entry level Effio system that has a simple, 2-chip structure consisting of an analog IC and a signal processing IC and supports a wide range of sensors. They are provided in compact chip packages (helps in miniaturization) and they consume 1/2 the power of previous systems. The Effio-S and Effio-P Systems provide additional features that are not used for CAMS.

The New 1/3" Cameras

Several new low-light camera models are now on the market. Here, we will discuss the Sony EXview HAD II 960H 700TVL based cameras and the Sony Super HAD II 960H 700TVL based cameras. Of the 20 cameras used in this test, the camera models tested were: 2 x EQ700; 17 x PSCB-100H; and 1 x LN-300-6H672.

Figure 1 – EverFocus Ultra Series Super Low Light Box Camera" (mfr # EQ700).

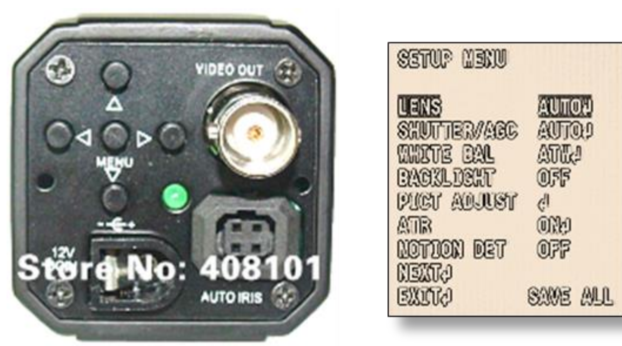

Figure 2 – LN-300-9H672 OSD Menu buttons for configuring the camera settings and PSCB-100H Effio-E OSD Menu.

The sensor types tested have a specified lux rating of 0.003 lux at 30 IRE with a normal shutter and f/1.2 lens and AGC settings (compared to 0.000033 lux for the Watec Wat902H2 Ultimate at high gain setting with an f/0.8 lens –

no IRE provided). The lux for the Watec in AGC was not specified). Contrary to the Watec camera, these new cameras provide all configuration settings with an OSD (On-Screen Display) menu using the OSD buttons on the back of the camera. There are pros and cons to this. Ideally, we'd like to see the ability to control the camera settings via software, but the settings on these cameras are not controlled by software.

Table 1 – Vendor's advertised specs for the EverFocus EQ700.

Sensor	EQ700 1/3" EXview 960H 700TVL
Resolution	700 TVL
Minimum Illumination	0.0001 lux 30 IRE Normal shutter f/1.2/AGC
S/N Ratio	> 50 dB (AGC OFF)
Pixels	976 x 494 NTSC (976 x 582 PAL)

Initially, two EXview HAD II type cameras were purchased by JW, the "EverFocus Ultra Series Super Low Light Box Camera" (mfr # EQ700), from B&H, for about US$120 each in May, 2014 (Figure 1). We tested these two EQ700 cameras for a few months using various lens configurations.

Later, sixteen Effio-E cameras with the Sony Super HAD II 960H 700TVL sensor (the PSCB-100H) were purchased by JW cameras from AliExpress for US$43 on sale (Figure 3). The price at time of writing is US$47. We tested those cameras with various lens configurations and camera settings. Figure 2 shows the OSD menu for this camera.

Figure 3 – PSCB-100H Super HAD II camera.

The specs for the PSCB-100H camera are as follows:

Table 2 – Vendor's advertised specs for the PCSB-100H-960H.

Sensor	1/3" Super HAD II 960H 700TVL High Sensitivity CCD
Resolution	700 TVL
Minimum Illumination	0.003 lux 30 IRE Normal shutter f/1.2/AGC
S/N Ratio	> 50 dB (AGC OFF)
Pixels	976 x 494 NTSC (976 x 582 PAL)
Size	130 (L) x 60 (H) x 50 (D) mm
Weight	450g

The Spectral sensitivity, from the Sony site[2], shows that these cameras share very similar sensitivity, with the EXview having a slightly higher sensitivity in yellow and IR (Figure 4).

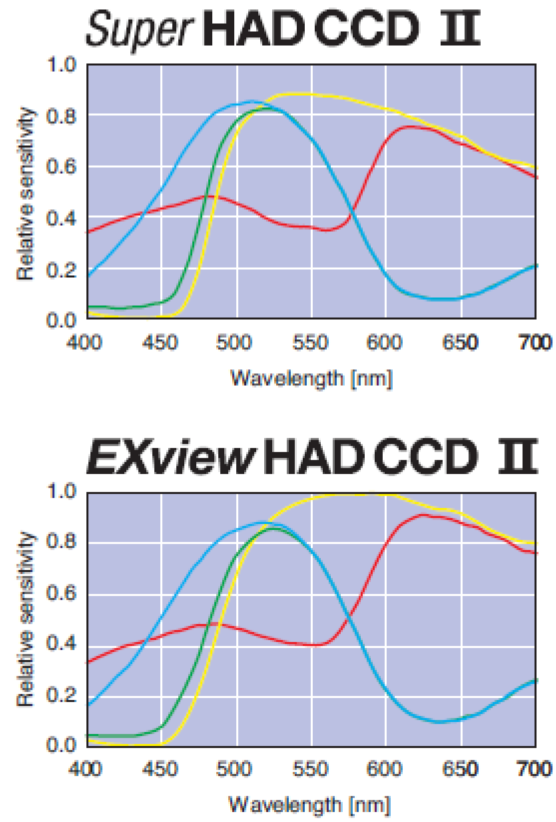

Figure 4 – Spectral Sensitivity Characteristics Comparison between EXview HAD II and Super HAD II. The EXview shows slightly higher response in Yellow and IR.

DS then purchased one Sony LN-300-9H972 for US$56, also of EXview HAD II 960H 700TVL type from AliExpress. The 9H672 is much smaller than the PSCB-100H - closer to the size of the Watec camera (see Figure 5). The manufacturer shipped the 9H672 (NTSC), as opposed to the 9H673 (PAL). The 9H672 camera received was missing an adapter to allow the ability to use CS mount lenses. Another cams group member purchased the 9H672 and the adapter ring was included. Figure 2 shows an example of the OSD menu buttons on the back of the camera.

[2] High-Sensitivity, High-Resolution Camera Systems for Security Cameras based on Diagonal 6.0 mm (Type 1/3" 480K/570K-Effective Pixel Color CCD Image Sensors. (CXD4127GG, CXD4816GG, ICX672ADA/ICX673AKA sensor model numbers) This document is the Sony publication that shows the specifications for the sensors: http://www.sony.net/Products/SC-HP/cx_news/vol61/pdf/cxd4127_4816gg.pdf

Figure 5 – LN-300-6H692 based with the Sony EXview HAD II 960H 700TVL sensor.

Table 3 – Vendor's advertised specs for the LN-300-9H672.

Sensor	1/3" EXview HAD II 960H 700TVL High Sensitivity
Resolution	700 TVL
Minimum Illumination	0.003 lux 30 IRE Normal shutter f/1.2/AGC
S/N Ratio	> 50 dB (AGC OFF)
Pixels	976 x 494 NTSC (976 x 582 PAL)
Size	62 (L) x 43 (W) x 42 (H) mm
Weight	150 g

Removing the IR-cut Filter

Testing yielded similar results for star sensitivity for all the cameras tested, but the Sony LN camera was slightly more sensitive in the near-IR than the PSCB 100H Super HAD II camera. By default, both these cheaper cameras come with a near-IR-cut off filter glued over the sensor's environment window. This reduces the sensitivity of the camera and it should be removed. Be sure to order LN-300-9H672 without the IR cut filter. The EQ700 camera is a higher-end model. It has a tiny motor that moves the IR-cut filter out of the way during night mode.

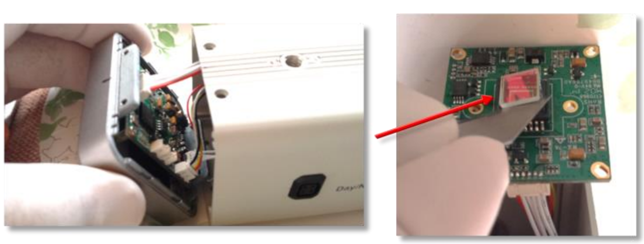

Figure 6 – Experimental removal of IR cut filter from first batch of PSCB-100H cameras by JW improved limiting magnitude by nearly a full magnitude.

The Super HAD II based PSCB 100H cameras had a small IR-Cut filter glued to the sensor. When these were removed (see Figure 6), the cameras gain about a magnitude in light gathering. These cameras only reach the 0.0001 lux with this removed. After JW pointed out the need to remove the IR cut filter for meteor observing, the AliExpress vendor made arrangements with the manufacturer such that if the cameras were ordered with the explicit instructions to ship the cameras without the IR-cut filter installed, they would do that. Because of this, the IR cut filters had not been installed, per request, for both cameras when the Super HAD and the EXview cameras were purchased by DS.

3 Results for meteor observations

To achieve precise orbital elements, CAMS requires a spatial resolution of about 4 arcminutes/pixel or better, and ideally, with a field of view of around 20 x 30 degrees, for each camera.. A good balance between spatial resolution and image scale is achieved by using longer focal lengths and correspondingly smaller field of view for lower elevations (more distant meteors).

Figure 7 – Inexpensive 1/3" CS IR corrected lens set.

We tested various fast lens configurations, including the 8mm f/0.8, 12mm f/0.8, 6mm f/0.8, and 9mm f/0.75. While over 1 magnitude brighter than the f/1.2 lenses used in CAMS, all these fast lenses are difficult to find (However, testing showed that the sensitivity of the 1/3" cameras with these brighter lenses matched the sensitivity of the Watec with its f/1.2 lens). We eventually tested with the US$8 near-IR-corrected CS format 6mm f/1.2, 8mm f/1.2, and 12mm f/1.2 lenses (see Figure 7). These lenses are all readily available and very inexpensive. As they are IR corrected, they performed very well. There is no coma or pincushion and they provided sharp stars out to the edges of the frame - even in the 1/2" camera.

When a single-CAMS user purchases a camera, it might be a good idea to have at least one full set of these three focal lengths.

The spatial resolution of these lenses is shown in the following table. The lower the elevation angle, the longer the distance to the target. This table shows that these lenses are suitable for CAMS.

Table 4 – Spatial Resolution at distance determined by elevation angle and 90 km height.

Elevation Angle (degrees)	Focal length (mm)	Spatial Resolution per pixel	Coverage Area km^2
29	12	100 meters	9098
46	8	100 meters	5362
75	6	110 meters	4015

For the Sun facing cameras, you might consider purchasing a DC auto-iris lens to protect the sensor. These were not tested. In the 1/3" CS format, they are much cheaper than the 1/2" format and they can generally be obtained for under US$70 online.

Sensitivity Tests Results

We first compared the 1/3" Super HAD camera with the more sensitive 1/2" Watec by capturing for a night with both cameras centered on the same part of the sky using the same focal length and focal ratio lenses. Hence, the field of view for the 1/2" sensor is larger (44 versus 34 degrees). The images in Figure 8 show the same meteor observed by the Super HAD type camera and the Watec 902H2 Ultimate type camera. By matching the light gathering (8mm f/1.2 for the 1/2" sensor versus 8mm f/1.2 for the 1/3" sensor), the light gathering ability of the cameras was close, but the field of view of the Watec 902H2 Ultimate is larger.

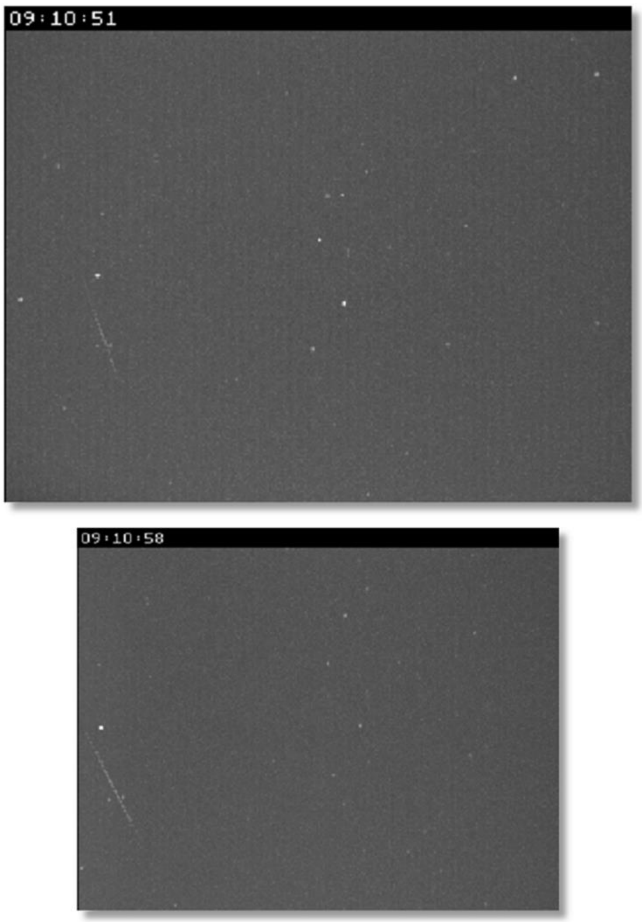

Figure 8 – Same meteor detected (top) by a Watec 902H2 Ultimate with 8mm f/1.2 44 deg FOV(top) and (bottom) by the PSCB-100H 960H camera with 8mm f/1.2 for smaller 34 deg FOV, with MGC set to same levels as AGC. Images are contrast enhanced and brightened to show the differences.

The star limiting magnitude in the Super HAD II 1/3" cameras (8mm /f1.2) is between magnitude +4.0 and +5.0, while the Watec 902H2U camera has about a +5.0 star limiting magnitude with 8mm f/1.2 lens. What's also interesting to note is that the $ 8 lens appeared to perform adequately, compared to the $ 90 Pentax lens.

In the CAMS capture software, average frames are used for astrometry. 256 frames are averaged, amounting to 8.542 seconds NTSC or 10.24 seconds of PAL. In the table above, we used the AutoCAMS auto-calibration routine to show the magnitudes of the dimmest stars detected by setting auto-cal to 140 minimum stars and O-C to a high 2.50 arcmin/pixel. The table lists the faintest star that was matched by the program. Note: Typical auto-calibration results in 0.015 to 0.300 arcmin per pixel for a 12mm lens, around 0.321 for 9mm, and 0.500 for 6mm lenses.

It is difficult to compare one system with another to compare meteor counts unless you have different systems pointing to the target area at the same time with the same focal ratio lens on the camera on the same night. The night we performed this test, there were 14 meteors in the Watec 1/2" camera and 12 in the 1/3" camera. Odd thing was, the 1/3" camera picked up some meteors that were not detected by the 1/2" camera and vice versa. So it's probably safe to say that the 1/3" camera will not detect as many meteors as the Watec, but the percentage of difference is quite low. More testing is needed in this area if this is of concern.

These first few weeks of October, each 1/3" camera was detecting about 20 – 25 meteors per night per camera. The Brentwood and Foresthill stations are only running 2 cameras per station and out of the 40 – 50 meteors per night per site, the average number of orbits calculated has been an about 26 orbits per night. That's 13 orbits per night per camera in October. This is the same average as we've maintained from the Brentwood station for years, while using the Watec. So overall, we could conclude that the number of orbits per camera per night is about the same as with the Watec 902H2 Ultimate.

We didn't capture the measured star limiting magnitudes for all combinations because we later discovered that the camera settings were not ideal. The Foresthill array is currently taking advantage of the set of f/0.8 and f/0.75 lenses available. The 12mm f/0.8 is showing the best-measured star limiting magnitude of +8.00 (256 frame average). The 9mm f/0.75 lens is showing +8.10 on a different night. The 6mm f/1.2 is showing +6.41, while the EXview with the 6mm f/1.2 is showing +6.92.

4 An All-sky Array of Cameras

The regular CAMS network deploys 20 cameras for full sky coverage above 30º elevation, using 5 servers. The newer low-cost cameras now make such an array within reach of amateur astronomers. While less sensitive, a larger number of cameras can increase the yield of relatively bright meteors.

For the purpose of this project, JW designed and built a box housing an array of 18-cameras (His box is using 18 cameras instead of 16 cameras because he had 18. 16 cameras will be run through the dual 8 port Sensoray grabbers while the remaining two will be run from a separate laptop using EZCap grabbers). Inexpensive 1/3-inch PSCB-100H cameras were selected to operate with either a single 16-channel capture card or two 8 channel cards. The lower cost per channel of the Sensoray 8 channel card makes this latter most appropriate for cost savings, which was one of the objectives of the design. The cameras are arranged to point through a minimal sized opening to reduce both scattered light within the enclosure and solar flux if left open during daylight hours. It should be noted that camera and lens manufacturers do not recommend direct exposure of the detector to sunlight and the array has always had a secondary cover to block sunlight from entering the aperture.

Figure 9 – 18-camera amateur array at the Foresthill, CA single-CAM station.

Figure 10 – Inside view of the 18-camera setup, showing cameras, brackets, and 16-port power supply.

Cameras are mounted on fixed elevation brackets attached either to the base (for inner ring cameras) or to elevated blocks attached to the base (for the outer ring cameras). Elevations are color-coded and azimuths number-coded so each camera and its cabling is readily identifiable by their unique color/number assignment.

The color code can be seen on the mounting blocks and the video cables (Figure 10). 500 feet of video cable was purchased, cut into 18 x 27ft lengths, and finished with crimp-on BNC connectors. A 16 channel 12v CCTV power supply was mounted in the lower section of the box with ventilation provided by the cable thru-holes to minimally warm the camera compartment and slow the onset of dewing. Video cables are routed out the bottom of the lower section through an enclosed cable-way to the building interior location for the capture card and computer.

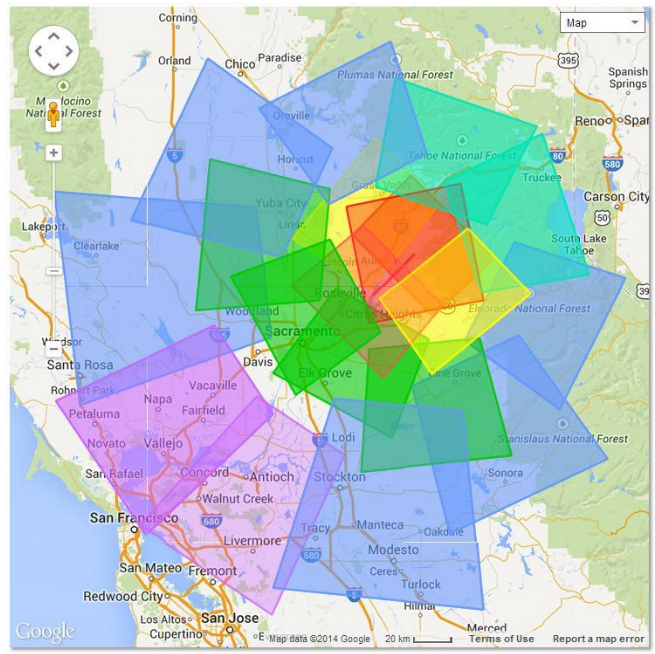

Figure 11 – Eighteen camera laydown in current setup based on measured calibrations against the stars.

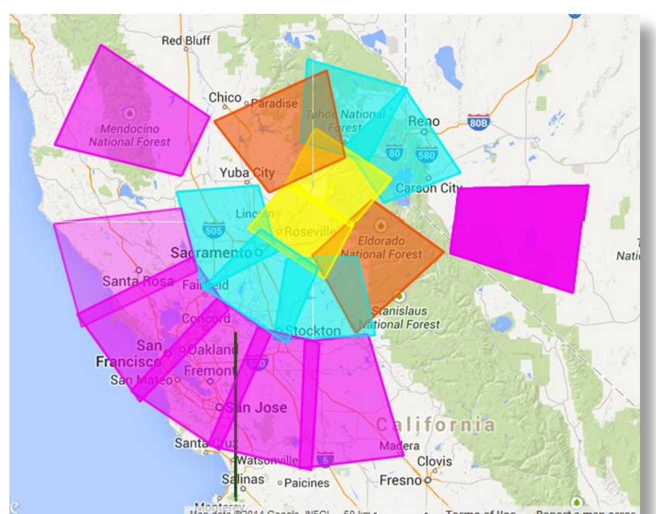

Figure 12 – Sixteen cameras sparsely distributed to reach single-CAMS users.

This 18-camera array provides the same area of coverage as a regular CAMS station (Figure 11). It's good to point out that laydown configurations for maximum coverage area have lower elevation angle coverage areas (Figure 12). However, care must be taken to use the appropriate lens to obtain the appropriate spatial resolution

By varying the focal length of the cameras to match the elevation angle, we achieve the same spatial resolution across the sky (at the 90km target height). We calculated the spatial resolution to be as shown in table 4.

Two 16 camera arrays can be tuned for maximum coverage overlap while aiming toward each other. The idea is that a new local CAMS network could optimize two sites to provide overlap between just those two sites. Single-CAMS stations can be used to provide coverage gaps, if any. Single-CAMS stations can also be used to extend the coverage area.

Based on the lower-cost cameras, a 16 camera site can be established for around US$2600 at current prices, including computer and cabling, so that two 16 camera (32 cameras) sites for triangulation can be established for around US$5200 (approximate prices per October 2014).

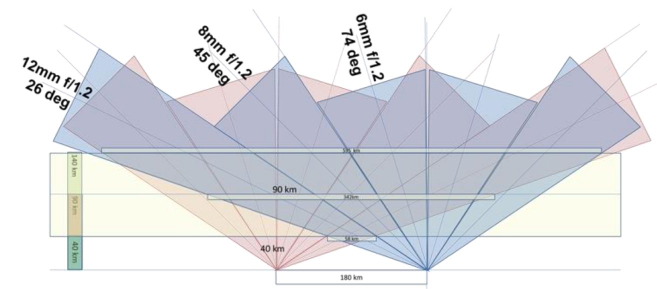

Figure 13 – Elevation angle cross section - Different focal lengths to match the elevation angle. 180 km baseline.

5 Camera Settings

This section shows the camera settings for the EXview camera. The OSD camera settings for the PCSB-100H Effio-E camera will be difficult to record at this time since the camera is mounted inside its enclosure outside.

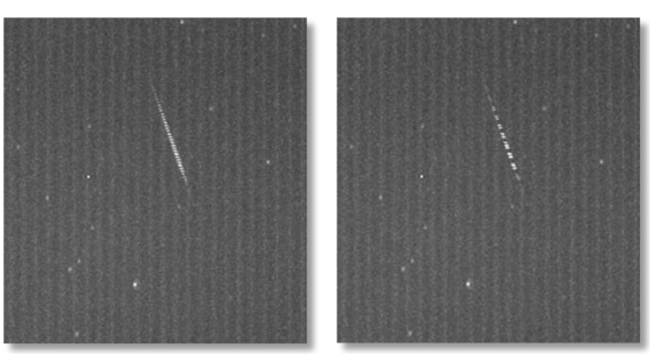

Figure 14 –Watch for strobing caused by various forms of Night Mode.

With the Effio, it is somehow difficult to keep the camera operating at the 1/60 interlaced setting using the EZCap grabbers. It has not been an issue with the Sensoray 2255S grabber.

EXview OSD Menu Settings

Here are the settings being used for the EXview HAD II 960H 700TVL LN-300-9H692 for CAMS.

- EXPOSURE
  - LENS = ELC
    - E.SHUTTER = 1/60
    - BRIGHT = 50
  - HBLC/D-WDR = OFF
  - AGC = MID
  - 2D DNR = OFF
- WB
  - WB MODE = ATW
  - R-Y GAIN = 128
  - B-Y GAIN – 128
- DAY&NIGHT
  - D&N MODE = B&W
  - C-SUP = 050
  - A-SUP = 050
- FUNCTION
  - MIRROR = OFF
  - SHARPNESS = 010
  - LSC = OFF
  - MONITOR = MODE1
  - GAMMA = USER
    - 0.30
- MOTION
  - MOTION = OFF
  - AREA SEL
    - Set all of them to = OFF
  - SENSITIVITY = 1
  - DISPLAY = ICON
  - HOLD TIME = 008
  - ALARM = OFF
- PRIVACY
  - Set all masks = OFF
- SETUP
  - TITLE = OFF
  - MANUAL DPC = MANUAL
  - AUTO DPC = AUTOC
    - DPC LEVEL = 150
  - OLPF = 850 or 650 (I'm not sure)
  - OSD COLOR = GRAY

6 Issues and Workarounds

One issue that we had when using the EZCap video grabber with the software that came with it in conjunction with these cameras is that sometimes the settings would revert to a mode where the camera was imaging at 1/15 or 1/30 sec instead of 1/60. This is very apparent when looking at thumbnails and other samples of the images. These "night-mode" shutter speeds cause a "strobing" effect on meteors (see Figure 14). It is also apparent, during coincidence processing, even if you don't have the images or thumbnails available. In that case, the cameras that are imaging at 1/60 sec will have dots between the dots of the strobing cameras. So be careful with that. With the 4 channel Sensoray grabber, this issue was not apparent once the camera settings were established and saved.

With the EZCap and a 16 or 18 cameras in position in the box, it becomes somewhat cumbersome for JW to fiddle with the OSD menu buttons inside the box and attempt to set all the cameras to their optimal settings. So, if you're going to build such a box, be sure that access to the OSD buttons on the back of the camera are accessible when the cameras are in position and that they can be used without moving the camera.

One issue we found was that the cameras produced different levels brightness and contrast with the same settings. We do not know the source of this inconsistency. Therefore, the cameras were set to mostly their default settings and, using the EZCap grabber, the ULead driver software was used to make adjustments in the gain, brightness, sharpness and contrast for each camera. Since this was something that was accomplished on the screen at the computer, it was much easier to do.

Figure 15 – 18-camera box housing. Ventilation maintains internal temperature close to ambient.

Another issue that is bothersome is when the camera settings are set to a level where there are not enough stars to perform a manual star-field calibration on. We found that when there is more sky fog in the background close to sunrise, the cameras seem to show more calibration stars. However, using the EZCap grabber, the settings needed to be manually adjusted to attain a balance between being able to see enough calibration stars (70 is usually the goal) during manual calibration and too high of gain, producing too bright of an image resulting in added noise and quicker saturation for the rest of the normal night's meteor capture.

AutoCAMS also uses an "autocal" routine, which iterates throughout the night's capture session and finds the best calibration from that collection of thousands of files. With the Watec, we typically see over 200 nStars in the calibration field. With the 1/3" cameras, we're seeing around 180 nStars, depending on the focal length.

Hot pixels become a problem after a while. They appear as fixed white spots in the camera's sensor. They don't move with the stars. They become problems when doing plate-solves and auto-calibration because they are sometimes mistaken for stars. A means of masking these out of calibration will be needed as these cameras encounter more cosmic ray damage as they age. The 1/3" EXview camera has a built-in noise calibration as well as an automatic one (SETUP > MANUAL DPC or AUTO DPC). For one, it takes a dark by the user placing a lens cover and running that routine. The other method is the automated method whereby the camera can somehow tell from the captured frames what compensation for the hot pixels and variations on the sensor are required. DPC means "Dead Pixel Compensation". Dead Pixels are black pixels (the opposite issue as hot pixels), which aren't so much of a problem for CAMS. Since the camera that DPC was tested on is not yet showing hot pixels, we could not verify that the DPC feature will remove the hot pixels during capture.

7 AutoCAMS software

AutoCAMS is an open-source Windows scripting language based system for performing most of the daily functions of a single-CAMS site. It consists of almost 40k lines of script code written by Dave Samuels. In many cases, it acts as a wrapper around the executables written by Peter Gural. In some cases, it provides additional functionality. For example, autonomously launching the daily capture procedure, checking on the available disk space, checking on the start/stop times for any date, archiving the sessions into zip files, uploading the daily capture session summaries to the SETI Institute CAMS server, etc.

AutoCAMS has some very specific goals, namely to never send bad data to the SETI Institute server, consistently and accurately facilitate the capture of meteor data every night, perform these daily functions autonomously, perform validation and verification of the data before submitting it to the SETI Institute server. Essentially to ensure that the network coordinator or the lead scientist never has to ask for reprocessing and/or resubmission of data, and to simplify the daily tasks into easily workable steps.

8 Conclusions

We have demonstrated the feasibility of applying new low cost 1/3 inch format video cameras and lenses for meteor detection within the parameters specified as suitable for use with the SETI CAMS meteor orbit program. An 18 camera array has been constructed and has been placed in service. These low cost systems are suitable for others to replicate as individual cameras, twin cameras or 16 camera arrays.

The 1/3" cameras are averaging about 10 – 15 triangulated orbits per night throughout this period. The accuracy of the calculated orbits falls well within the acceptable tolerances. In fact, the accuracy is the same as with the Watec cameras. The only difference is a slight drop in the count due to the extra sensitivity of the higher priced Watec cameras. This is within about 90% of the rate per camera for the Watec cameras.

The 18-camera array is still waiting for the dual 8 channel Sensoray and a way to work around the changing sensitivity issue.

For camera settings for either Effio or EXview OSD menus, contact dave@davesamuels.com for the settings to start with. For more information about AutoCAMS or to join the single-CAMS user support group, email seticams-subscribe@yahoogroups.com. It's only open to approved members. So include a message regarding who you are and what your interest is in joining.

Acknowledgements

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References

Gural P. S. (2011). "The California All-sky Meteor Surveillance (CAMS) System". In, Asher D. J., Christou A. A., Atreya P., and Barentsen G., editors, *Proceedings of the International Meteor Conference*, Armagh, Northern Ireland, 16–19 Sept. 2010. IMO, pages 28–31.

Jenniskens P., Gural P. S., Dynneson L., Grigsby B. J., Newman K. E., Borden M., Koop M., Holman D. (2011). "CAMS: Cameras for Allsky Meteor Surveillance to establish minor meteor showers." *Icarus*, **216**, 40–61.