CILBO - Lessons learned from a double-station meteor camera setup in the Canary Islands

Detlef Koschny[1], Jonathan Mc Auliffe[2], Esther Drolshagen[3], Felix Bettonvil[4], Javier Licandro[5], Cornelis van der Luijt[1], Theresa Ott[3], Hans Smit[1], Hakan Svedhem[1], Olivier Witasse[1], Joe Zender[1]

[1]**European Space Agency, ESTEC, Noordwijk, The Netherlands**
Detlef.Koschny@esa.int, Cornelis.van.der.Luijt@esa.int, Hans.Smit@esa.int, Hakan.Svedhem@esa.int, Olivier.Witasse@esa.int, Joe.Zender@esa.int

[2]**European Space Agency, ESAC, Villanueva de la Canada, Spain**
Jonathan.McAuliffe@esa.int

[3]**Univ. Oldenburg, Oldenburg, Germany**
Esther.Drolshagen@uni-oldenburg.de, Theresa.Ott@uni-oldenburg.de

[4]**Astronomical Institute Utrecht, Utrecht, The Netherlands**
f.c.m.bettonvil@astro-uu.nl

[5]**Instituto de Astrofisica de Canarias, La Laguna, Tenerife/Spain**
jlicandr@iac.es

We have been operating a double-station meteor camera setup and have collected more than 12 months of simultaneous observations until mid-2014. First science is being produced. In this paper we report on the lessons learned and provide information on what went well and what did not. The intention is to help other teams considering setting up similar systems to avoid the same issues.

1 Introduction

CILBO stands for **C**anary **I**slands **L**ong-**B**aseline **O**bservatory. We use two automated stations hosting an image-intensified video camera observing the same volume in the atmosphere during the night, one located on Tenerife, one on La Palma, in the Canary Islands, Spain. The complete setup is robotic, i.e. the system switches itself on when it is dark and the weather conditions are appropriate. Meteor data is saved automatically and sent via ftp to a central server. From there it is downloaded for data analysis. An additional camera on Tenerife is equipped with an objective grating. It records spectra of the brightest meteors.

The two main scientific goals of the system are:

(a) To study physical and chemical properties of meteoroids, and, taking into account the modifications of the meteoroid properties during their flight in the solar system, to constrain the physical and chemical properties of their parent body.

(b) To study the variability of the background dust flux in the Earth environment during a complete year.

The use of image intensifiers allows the system to record fainter meteors than non-intensified systems, bridging the gap to radar observations.

In this paper, we briefly describe the setup to provide the context. We present some observational statistics to demonstrate the performance of the system. Finally we produced a (most likely not complete) list of points relevant for setting up other similar systems, so-called 'lessons learned'. We strongly encourage everybody who wants to set up a similar system to not only read through our lessons learned, but also apply them.

2 The Setup

This section gives a brief overview of the setup. For a much more detailed description please refer to Koschny et al. (2013).

Figure 1 shows a sketch of the system produced with Google Earth. The cones indicate the field of view of the two cameras. One is located on Tenerife (ICC7) and one on La Palma (ICC9). Note that ICC stands for 'Intensified CCD Camera'. The fields intersect at a point half way between the islands in a height of 100 km. The top cut of the field of views is done at 100 km and shows the overlapping area in this reference height. Table 1 is taken from Koschny et al. (2013) but corrects an inadvertent swap of longitude and latitude in this reference.

The additional camera with the objective grating is called ICC8. It is located on Tenerife and tilted such that it can record spectra of meteors observed by ICC7.

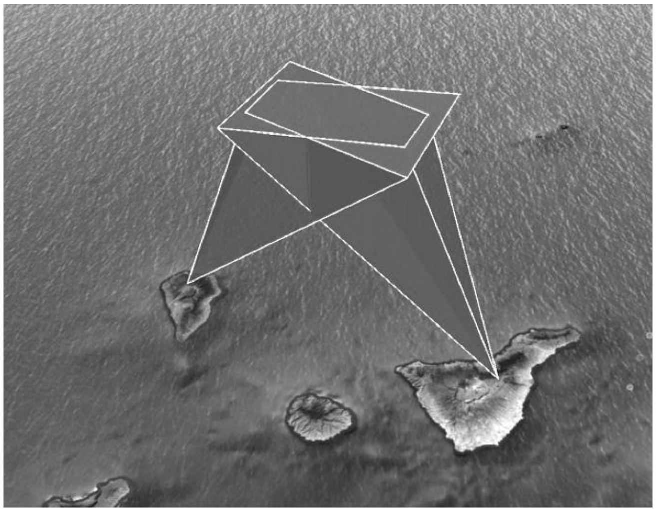

Figure 1 – This view shows Tenerife (right) and the corresponding field of view of ICC7 and La Palma (left) with the field of view of ICC9. The cones for the field of view are cut off at 100 km height.

Table 1 – Geographical positions of the two observing stations and the aim point.

Island	Station code	Latitude	Longitude	Elevation
Tenerife (ICC7/ICC 8)	CILBO-T	28°18'04" N 28.3011° N	16°30'43" W -16.5119°	2395 m
La Palma (ICC9)	CILBO-L	28°45'36" N 28.7600° N	17°52'57" W -17.8824°	2327 m
Aim point		28°32'00" N 28.5333° N	17°10'00" W -17.1667°	100000 m

The complete setup is automated. Commercial motorized roofs house cover a small hut poured from concrete. A steel pier has mounting facilities for up to four commercial tripod heads. The cameras are custom-built video systems using image intensifiers. While they increase the sensitivity of the camera systems to about 7.0 stellar limiting magnitudes, they also mean that the camera can be damaged when the Moon enters the field of view.

The detection of meteors is done with the software MetRec (Molau, 1999). A custom-written scheduling software launches MetRec in the evening and sends the data of the night to a central server in the morning. This scheduling software also checks that the system is only operational when the weather conditions are ok.

The computer for ICC7 on Tenerife is located in the basement of the Optical Ground Station (the building housing ESA's 1-m telescope). The computer for ICC9 on La Palma is located in the nearby building of the Automated Transit Circle. A weatherproof box mounted directly at the housing protects the local control electronics, i.e. the roof controller and a watchdog system.

3 Operations up to now

ICC7/8 have been operational since 13 September 2011, ICC9 since 13 December 2011. Due to an unknown error the Moon went through the field of view of ICC9 in March 2012 and left a visible dark track. We switched off ICC9. Due to travel and weather constraints, we managed to bring ICC9 back online only in January 2013. Since then, both cameras have been operating continuously with only small interruptions.

Table 2 gives some relevant statistical information on operating time and meteor numbers. We consider the time until May 2013 the commissioning period and provide the statistics only for the time frame of one year starting from 1 June 2013. In total, ICC7 has obtained data from more than 45000 meteors so far, ICC9 almost 40000.

Figure 2 shows a histogram plot of the meteor number per night, for the two stations.

Table 2 – Operating nights and hours of ICC7 and ICC9, as well as observed meteor numbers in the time frame 1 June 2013 to 31 May 2014.

	ICC7	ICC9	Simultaneous
Number of meteors	12491	15913	6663
Observing nights	287	299	
Observing hours	2245.0	2106.6	1799.5

4 System availability and reasons for downtimes

Table 2 shows that within one year, both cameras have been operated individually for more than 2100 hours. Assuming an average nighttime availability of 8 hours per night we estimate a maximum possible dark time of 8 h * 365.25 = 2922 h. Then the availability are for ICC7: 76.8 %; for ICC9: 72.1 %; for the complete system with both cameras simultaneously: 61.6 %.

The following items were reasons for the unavailability of the cameras:

(a) The Moon. A large part of the unavailability of the complete system is due to the Moon. The way the system is set up is that when the Moon gets closer to the center of the field of view than 30 degrees, the system shuts off and closes the roof to protect the intensifier from moonlight. ICC7 points northwest and is affected in times before the Moon sets. ICC9 points southeast and is affected in times

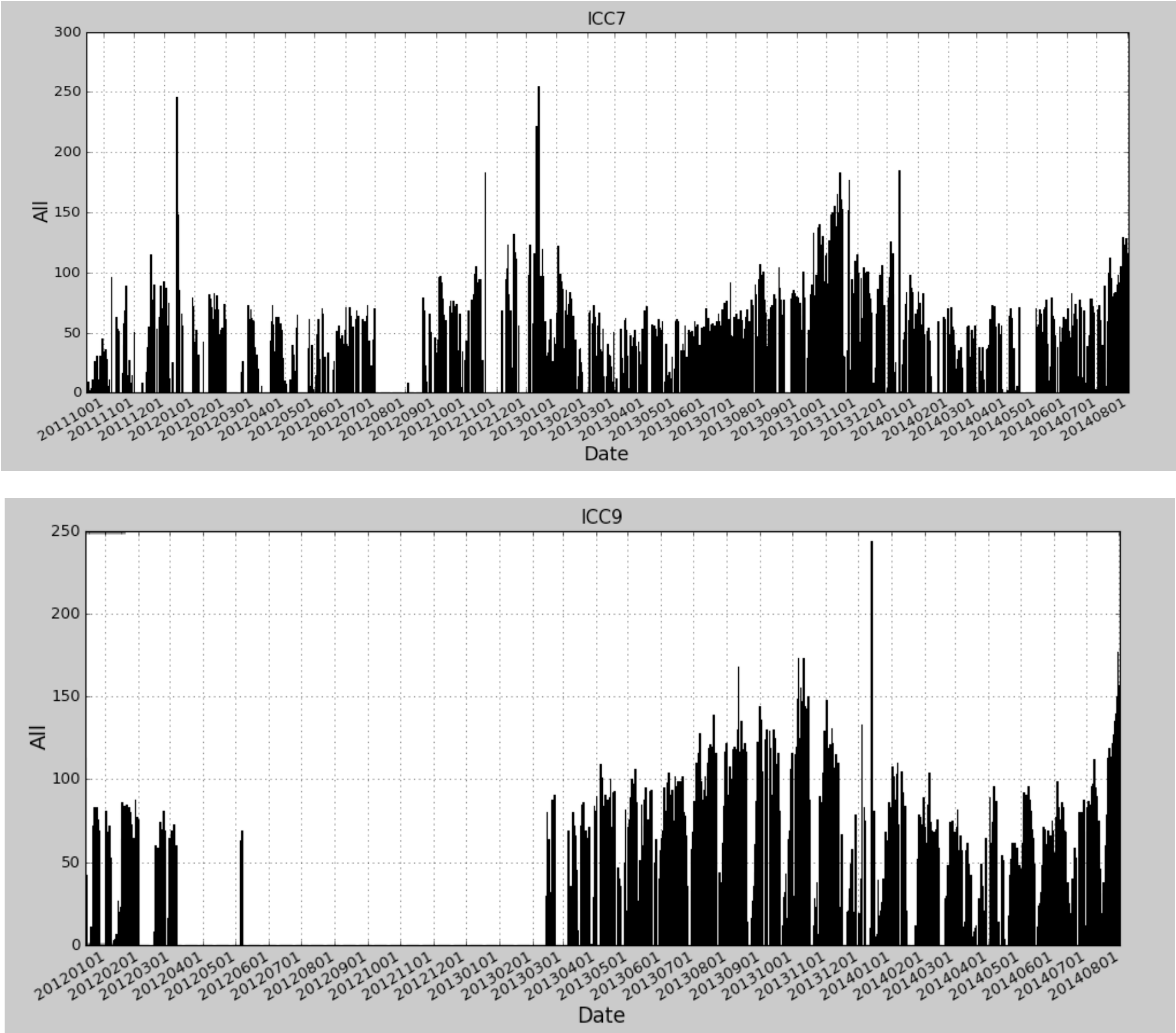

Figure 2 – The number of meteors per night as a function of time. These plots give a top-level overview of the availability of the systems. It also shows a systematic variation of the total meteor numbers per night due to the camera unavailability because of the Moon too close to the field of view. Some streams like the Geminids are apparent, as well as an increase in meteor numbers in spring and summer with respect to fall and winter.

after the Moon rises. Thus in times between quarter and full moon, first ICC9 is switched off, then ICC7.

(b) *Adverse weather conditions*. We use a Boltwood cloud sensor that can detect cloud cover by measuring the temperature of the night sky in the thermal infrared. We have set it such that it closes the roof at a sky temperature of 40 K below ambient temperature. We still have the occasional night (about 3 or 4 per year) where scattered clouds go through the field of view, but all in all we are very satisfied with the operations of the sensor. We also close the roof if the humidity is larger than 70 % or wind speeds larger than 50 km/h.

(c) *Intensifier damage*. The main technical problem which we had was that for an unknown reason ICC9 did not switch off when the Moon went through the field of view on 5 March 2012. An attempt to exchange the camera in spring 2012 failed due to severe weather conditions for a whole week. We then took the camera back to ESA after the visit of our station during the IMC 2012. We shipped the repaired camera to La Palma but our local support staff did not feel qualified to install it. One of us (JL) installed the camera in January 2013. While the camera was then operating, the aperture was set to minimum and we lost a few more nights until the camera was fully back in operation on 14 February 2013.

(d) *Pressed emergency button*. The camera stations are small and the wall height is only about 1 m. In principle it is possible to step into the station when the roof is open. The motor to close the roof is fairly strong. Even though there is a current limiter that senses if the motor meets resistance and then cuts off the motor current, we have added an emergency stop button to the station. We had two occasions on Tenerife where a pressed emergency stop button was the reason that the roof did not open; in one other occasion the roof did not close. We were initially told that there is no need to put a fence around the station, so one can just walk up to it. We suspect passing visitors to have pressed the button 'for fun'. On La Palma, we have not (yet) observed this issue. Note that in the case of the 'stuck open' case we were lucky - the whole mountain was within clouds and local personnel were able to close the roof before the sun could do any damage.

(e) *Power failure*. We have experienced several power failures (3-4 per year) on La Palma. The computer is setup such that it boots upon power up. In principle all software is installed as Windows services and should start running. This normally works well. Occasionally, however, in particular the time synchronization did not start properly. Only one power failure has occurred on Tenerife. Other than the only hour-long failures on La Palma, this one lasted for several days. We had relied on un-interrupted power supply services from the Optical Ground Station. Apparently this had not worked, for reasons beyond our control.

Other issues which are worth mentioning:

(f) *Time synchronization stopped.* So far the time synchronization has stopped working twice for ICC7. We use the freeware program 'timememo.exe' for synchronizing via NTP (Network Time Protocol) our PC time with some timeserver. Timememo.exe is installed as a service on our computer and should in principle always be running. For unknown reasons, however, it stopped working twice since the beginning of operations for ICC7. Every morning, a log file is written into the data directory of the night. We have failed to verify, on a daily basis, the existence of this file.

We have checked at what dates the log file is missing. By comparing the logged difference of the PC time with the correct UTC time upon restart of the software, we know the drift of the PC clock in the non-synchronized time period. It is now straight-forward to correct the recorded times of ICC7 by applying a linear interpolation of the time difference. For ICC9, we have not yet seen any issues.

(g) *Time server issues.* We have found time periods where apparently the timeserver (swisstime.ch) had provided a wrong time. Checking this issue via the Internet, we found notes that this has been done on purpose. Because of an overload of the 'swisstime' timeserver, the service provider had decided to purposely make wrong time information available in short periods of time in the order of seconds. Polling the timeserver every few tens of seconds to minutes, one would not notice this time error. As a result, we have reduced the time interval when we poll the server to 1 min rather than 15 s.

From the list of issues which we have encountered and from the positive experiences of what has actually worked well, we draw a number of 'lessons learned' which we will share in the next section.

5 Lessons learned

(a) *The robotic roof.* We are using an electric roll-off roof from the company Pier-Tech in the US[1]. It comes with its own dedicated controller and includes a 'Boltwood' cloud sensor from the company Cyanogen. ESA lab technicians have added some electronics to this controller. In particular they have added a watchdog that checks the communication between the computer and the roof. If there is no communication for a certain time period, the roof will close automatically independent on the weather conditions. This functionality constitutes a 'hardware override' to all automation implemented in software. It has the advantage that even if the control computer fails, the system will get itself into a safe state. This additional electronics has demonstrated its usefulness a couple of times already and is definitely worth the effort. But, all in all, the existing roof controller has been proven to be quite satisfactory.

(b) *Robotic roof - the emergency shutdown button.* We have added a manual emergency stop button for the roof. The roof motor is quite strong (e.g. to overcome problems of ice blocking the mechanics). If a person were stuck in the roof it could result in injuries. We have therefore added an easily visible emergency stop button. We had three occasions where for unknown reasons this button was pressed and the roof did not move any more. It could be that animals had jumped onto the button, or it could be that by-passers pressed it on purpose. The lesson here is to put a fence around your observatory to avoid unwanted people or animals to get close.

(c) *Boltwood cloud sensor.* We are using the so-called cloud sensor as a general weather sensor. It provides information not only on cloud cover, but also on humidity and rough wind speeds. It has worked extremely well and only failed once on ICC7 when it fell off its mast. We assume that the constant load from the wind has weakened the mechanical connection of the sensor to its mast. The lesson learned is to only use self-locking screws and double-redundant mechanical connections. The environmental conditions at 2800 m altitude can be very severe.

(d) *Our scheduling software – and: testing.* Our self-written scheduling software has worked well so far - but only after it had been beta-tested in a real-sky environment. Even though we have performed many module-level tests, a number of critical issues have only been discovered during a test when the complete setup had been installed in the backyard of the first author for 6 months, see Figure 3. The lesson learned is that testing is very important – a seemingly obvious statement, which is still often ignored.

(e) *Camera hardware.* Here we propose the same concept as in the previous bullet: Test, test, test. We have used camera hardware which, on component level, we had used before for many years. The actual cameras used for the Canary Islands were first operated for a few weeks in the real-sky test environment. The lesson: Only use equipment you are familiar with.

[1] http://www.pier-tech.com

Figure 3 – The CILBO hut is the small hut on the left, next to the first author's private observatory with IAU code B12. CILBO was used in this configuration for a 6-month real-sky system test. The control computer was located in the hut of B12. A simple plastic pipe was used as a cable duct.

(f) *Manpower support.* While we have set up a robotic observatory, it is still useful to have personnel available on-site for emergency maintenance. We had one occasion where the emergency button had been pressed and prevented the roof to close. This could have resulted in the 'roof open' position in damage to the image intensifier if the sun had shone into the system. We were lucky and it was cloudy on that morning. In addition, we managed to send observatory staff to manually close the roof within a few hours. However, we did realize that we did not have all telephone numbers to reach the right people. Our lesson learned is: Always prepare an emergency procedure – know whom you need to call, and have some backup in case the contact person is on leave.

(g) *Time synchronization:* As described in the previous section we had two occasions where the time synchronization had stopped working. While this can be recovered by subsequent processing it is annoying and makes the data analysis less straightforward. This issue could have been avoided, had we checked the existence of the log file from the time synchronization software in a timely manner, i.e. once per day. This can be implemented by a software script, which sends out an email notification if the log file is not there. Lesson learned: Perform timely checks (once per day) of the completeness of your data.

(h) *The Moon.* Our scheduling software computes the apparent distance of the Moon to the center of the camera field of view. If the Moon is closer than a certain value (currently 30 degrees) the camera will be switched off to avoid damage to the intensifier. It turns out that the increase in background brightness will result in a large number of false detections, often several hundreds per night. We have decided to accept these false detections and delete them manually. However, one should be aware of this and take the Moon's influence into account.

(i) *Mounting stability.* In particular for ICC7, we see slight changes in the pointing position of the camera. Sometimes during the course of one night, but also during several nights, the actual position of the stars had moved by up to two pixels (about 2') with respect to the expected position as displayed by the meteor detection software. This shift is observed only in the up-down direction of the camera. We assume that it is linked to a change in the pointing due to the load by cables on the back of the camera, or by thermal effects. ICC7 is mounted to the pier together with ICC8, thus the holder has to hold twice the mass compared to ICC9. MetRec is correcting its internal reference star file during the night. This means that re-computing the meteor coordinates with the reference star file of the night will give better results than using the normal reference star file obtained at just one epoch. Unfortunately MetRec does not automatically use the latest reference star file for computing the positions. Lessons learned: For cameras with pixel scales of 1' or less, the mounting stability can be an issue. In particular if one is interested in the best possible astrometric accuracy, one should use the reference star file generated during the observing night. It is suggested that MetRec should use this file for the computation of the meteor position.

(j) *Timeliness of data checking and log files.* We are generating a number of log files and a graphical overview of the observations of the night, see Figure 4. This overview has proven extremely useful. With just one glance one can get a feeling for the conditions during the night. The system sends an email to some key people every morning after the end of an observing night. We know that if we do not receive an email something went wrong; if we do receive an email, opening the graphical summary gives us a quick idea of what happened during the night.

And, as mentioned before: We have been able to follow and correct the missing time synchronization via the log files of the application 'timememo.exe'. We generate log files for all our applications. These have proven to be essential for error tracking and correcting.

Lesson learned: Log files are important. A graphical overview arriving every morning in the users email inbox is extremely helpful. Do not forget to check these emails. As a result of item (g) we will include some kind of flag to show whether the time synchronisation log file was written or not.

(k) *Person in the loop* - All data is being checked, following the standard IMO visual network procedures, by a human operator. While this is a time-consuming task, it was seen that it is important. False detections may accidentally lead to reasonable trajectory solutions which would not be real.

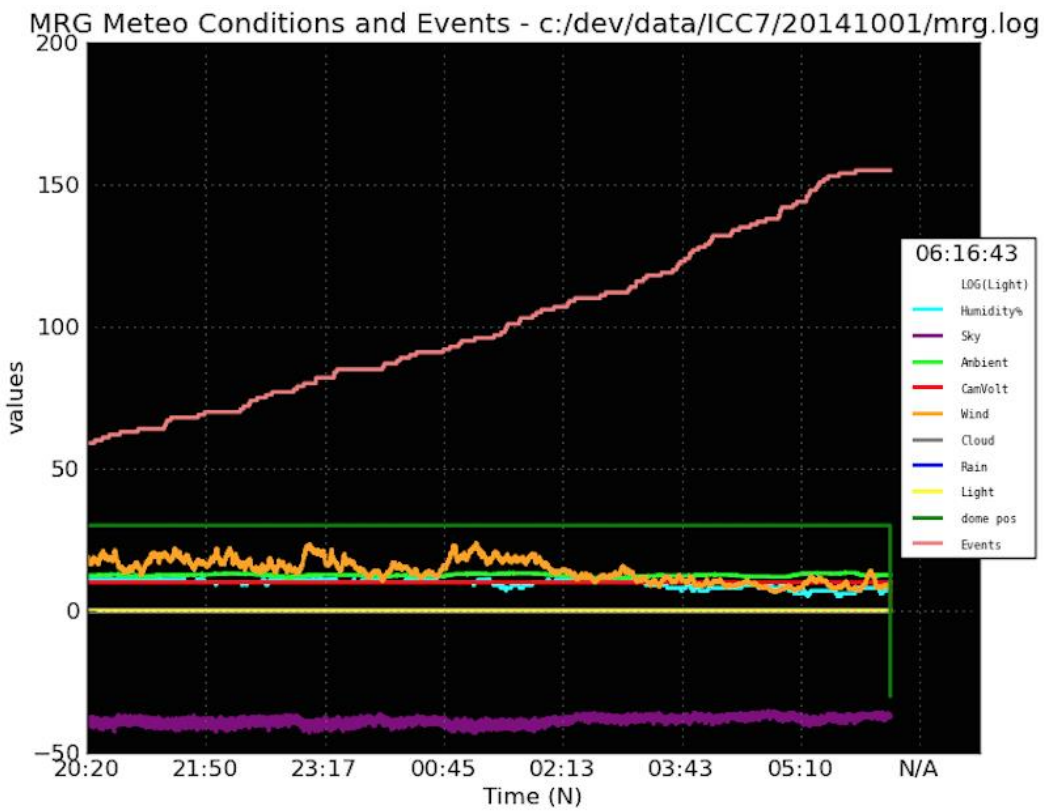

Figure 4 – Screenshot of the log of one night of observation for ICC7. The different lines denote the weather conditions, the position of the roof, and the cumulative number of detections. This graph gives a quick overview of the observation night.

6 Summary

In this paper we present lessons learned from setting up and operating a double-station meteor camera setup in the Canary Islands. Our main lessons learned are: Test, test, test. Keep logfiles, ensure your time synchronization works. Check your data in a timely manner.

We have been operating our setup, after a commissioning phase of 1.5 years, since May 2013. First science is being produced (see Drolshagen et al. and Ott et al., this issue). We showed that the setup works and could be reproduced if necessary.

We have chosen the approach of using a comparatively large hut with a roll-off roof to house our cameras. In principle one could simplify the weather protection by using covers for individual cameras. Our system has the advantage that it is easy to add additional camera systems.

Acknowledgments

We thank the Instituto de Astrofisica de Canarias for providing space for our systems and assisting in the setup and maintenance. We thank the ESA SSO lab facilities and machine shop for providing extensive support in the construction of the equipment. The hardware for the setup was supported by the research budget of ESA's Science Support Office.

References

Drolshagen E., Ott T., Koschny D., Drolshagen G., Poppe B. (2014). "Meteor velocity distribution from CILBO double station video camera data". In Rault J.-L., and Roggemans P., editors, *Proceedings of the International Meteor Conference*, Giron, France, 18–21 September 2014. IMO, pages ???–???.

Koschny D., Bettonvil F., Licandro J., v. d. Luijt C., Mc Auliffe J., Smit H., Svedhem H., de Wit F., Witasse O., Zender J. (2013). "A double-station meteor camera setup in the Canary Islands – CILBO". *Geosci. Instrum. Method. Data Syst*., **2**, 339–348.

Molau S. (1999). "The Meteor Detection Software MetRec". In Arlt R., Knoefel A., editors, *Proceedings of the International Meteor Conference*, Stara Lesna, Slovakia, 20–23 August 1998, IMO, pages 9–16.

Ott T., Drolshagen E., Koschny D., Drolshagen G., Poppe B. (2014) "Meteoroid flux determination using image intensified video camera data from the CILBO double station". In Rault J.-L., and Roggemans P., editors, *Proceedings of the International Meteor Conference*, Giron, France, 18–21 September 2014. IMO, pages ???–???.