

FMI All-Sky Camera Network

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Abstract

Finnish Meteorological Institute (FMI) operates an all-sky camera (ASC) network for ionospheric studies. This publication describes shortly the previous ASCs and then concentrates on the technology of the latest computer controlled cameras.

The ASC station consists of an all-sky imager mounted inside a transparent dome and a station computer which controls the imager. A fish-eye lens is used to capture the whole sky in one image - hence the name all-sky camera. There are currently six stations out of which four are in Finland, one in Sweden and one in Svalbard (Norway).

The FMI ASCs form an integral part of the Magnetometers - Ionospheric Radars - All-sky Cameras Large Experiment (MIRACLE). This multi-instrument array for ionosphere-magnetosphere coupling studies is an international collaboration under the leadership of the Geophysical research of FMI.

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NOTATION AND SYMBOLS

The notations and symbols used in this work are listed here.

ASC	All-sky camera.
CCD	Charge coupled device.
DAT	Digital audio tape.
DDS2	Digital data storage standard for DAT.
FMI	Finnish Meteorological Institute.
FMI/GEO	Finnish Meteorological Institute, Geophysical research.
FOV	Field of view. In general this indicates the solid angle that can be seen. The <i>angular</i> FOV is the top angle of the cone formed by the solid angle.
IGY	International Geophysical Year.
IMAGE	International Monitor for Auroral Geomagnetic Effects.
ISDN	Integrated Service Digital Network.
ITACA	ITalian All-sky Camera for Auroral observations.
IFSI/CNR	Istituto di Fisica dello Spazio Interplanetario of Consiglio Nazionale delle Ricerche, Italy.
NMEA	National Marine Electronics Association (refers to NMEA-0183 interface protocol).
PC/AT compatible	A computer model that is compatible to IBM PC/AT computer.
SGO	Sodankylä Geophysical Observatory is an independent national institute of the University of Oulu.
STARE	Scandinavian Twin Auroral Radar.
Tcl/Tk	Tool command language/toolkit.
UPS	Uninterruptible Power Supply.
UT	Universal Time.
UTC	Coordinated Universal Time.

1 INTRODUCTION

1.1 HISTORICAL OVERVIEW

The Finnish Meteorological Institute (FMI) started auroral imaging during the International Geophysical Year (IGY) in 1957–58. The operation principles of the camera configurations used by FMI are illustrated in Figure 1.1.

The first generation cameras utilised a spherical mirror which reflected the image of the whole sky. A secondary mirror reflected the image through a hole in the spherical mirror to an upward looking camera inside the camera housing [Stoffregen, 1956]. Sensitive black and white film was used. In 1964, a battery-operated mechanical clock was added to the design and the camera was re-positioned to the place of the secondary mirror. In this new configuration, which propagated to second generation cameras, the camera looked downwards and could capture both the image of the sky and the clock display at the same time.

The second generation cameras introduced colour film and digital control electronics [Hyppönen *et al.*, 1974]. The electronics unit provided a time display in the field of view of the camera. Also orientation marks and three radioactive light standards were added. The exposure times could be set between 2–16 seconds and the imaging interval between 20s and 1h. The operator was required to change the film but there was a light sensor that controlled the starting and stopping of imaging. The electronics were mains powered with a battery backup system. These second generation cameras were routinely operated during 1973–1997.

The development of the third generation all-sky cameras began in 1995 [Syrjäsuo, 1996] and — after a prototyping winter 1996–97 — five modern cameras replaced the old cameras. The new cameras utilise an imager with a fish-eye lens with a field of view of 180° , a filter wheel for colour, or spectral line, separation, an image intensifier and an integrating CCD-camera. The operation of the imager is fully controlled by the station computer. These cameras form a camera network that can be remote controlled, although under normal operation the stations acquire images autonomously at nominal 20-second interval. All imaging parameters (exposure time, imaging intervals and filter selections) can be changed via network.

1.2 THE PURPOSE OF THIS REPORT

As with almost any scientific instrumentation, the operation of the all-sky camera network is under continuous development. New research topics may sometimes require changes in either the hardware or in the imaging parameters. This report describes the network after four years' operation, during which the instrumentation configuration has changed considerably from the prototype described in Syrjäsuo [1996]. The emphasis is on hardware, most of which will be the same for several years onwards. The station

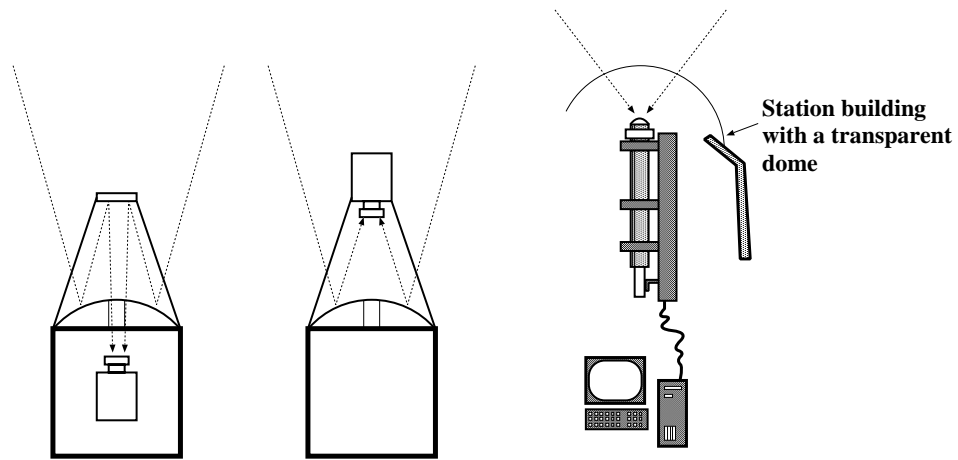


Figure 1.1. The camera configurations: 1957– (left), 1964–(middle) and 1996– (right)

computer will most likely capture images in a similar way as it does currently, but new software features will undoubtedly be added to respond to new ideas in the theory in auroral physics.

In Chapter 2 the optical instrumentation is described; further details can be found in the imager user's manual [*KeoConsultants*, 1996]. In Chapters 3 and 4, the station computer, the software and the all-sky network are described. Chapter 5 summarises the experience in servicing and maintaining the network.

2 NETWORK OPERATION

The *Magnetometers – Ionospheric Radars– Allsky Cameras Large Experiment* (MIRACLE) is a two-dimensional instrument network (see Figure 2.2) constructed for mesoscale studies of auroral electrodynamics, which is maintained and operated as an international collaboration under the leadership of the Finnish Meteorological Institute [Syrjäsuo *et al.*, 1998]. The network covers an area from subauroral to polar cap latitudes over a longitude range of about two hours of local time.

The MIRACLE all-sky cameras comprise all of the FMI all-sky stations, the ASC operated by the Sodankylä Geophysical Observatory (SGO), and the *Italian All-sky Camera for Auroral observations* (ITACA). ITACA is located in Ny Ålesund, Svalbard, and is maintained by the Istituto di Fisica dello Spazio Interplanetario of Consiglio Nazionale delle Ricerche (IFSI/CNR). Both the SGO camera and the ITACA are based on the FMI camera: the actual imagers are identical to FMI ones and the computer software is of FMI origin.

The geographical locations of the currently operational stations are given in Table 2.1. Out of the eight active stations six are operated by FMI. The remaining two are operated by the collaborating institutes.

Table 2.1 Geographical locations of MIRACLE all-sky camera stations.

<i>Station</i>	<i>Abbr.</i>	<i>Lat</i>	<i>Lon</i>
Kevo	KEV	69.76	27.01
Kilpisjärvi	KIL	69.02	20.79
Muonio	MUO	68.02	23.53
Hankasalmi	HAN	62.30	26.65
Abisko (Sweden)	ABK	68.36	18.82
Longyearbyen (Svalbard)	LYR	78.20	15.70
Ny Ålesund (Svalbard, operated by IFSI/CNR)	NAL	78.92	11.95
Sodankylä (operated by SGO)	SOD	67.37	26.63

MIRACLE

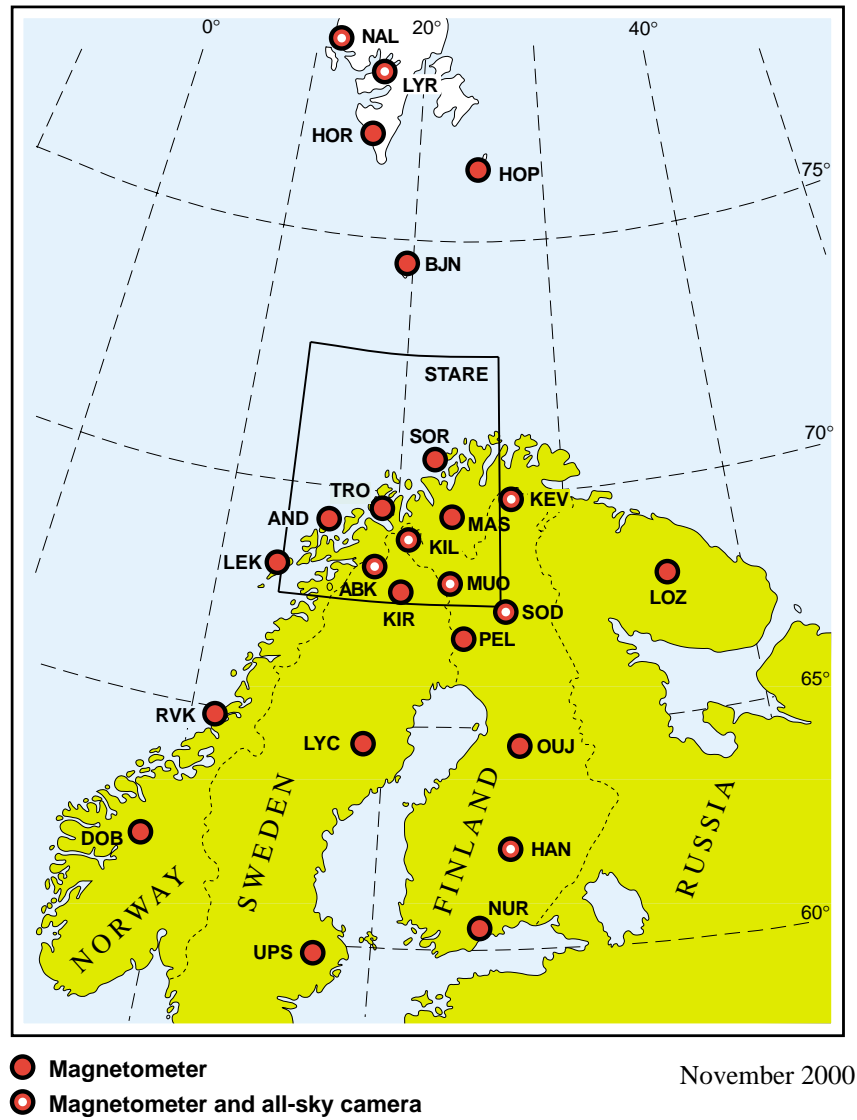


Figure 2.1. MIRACLE network: magnetometers, ionospheric radars and all-sky cameras.

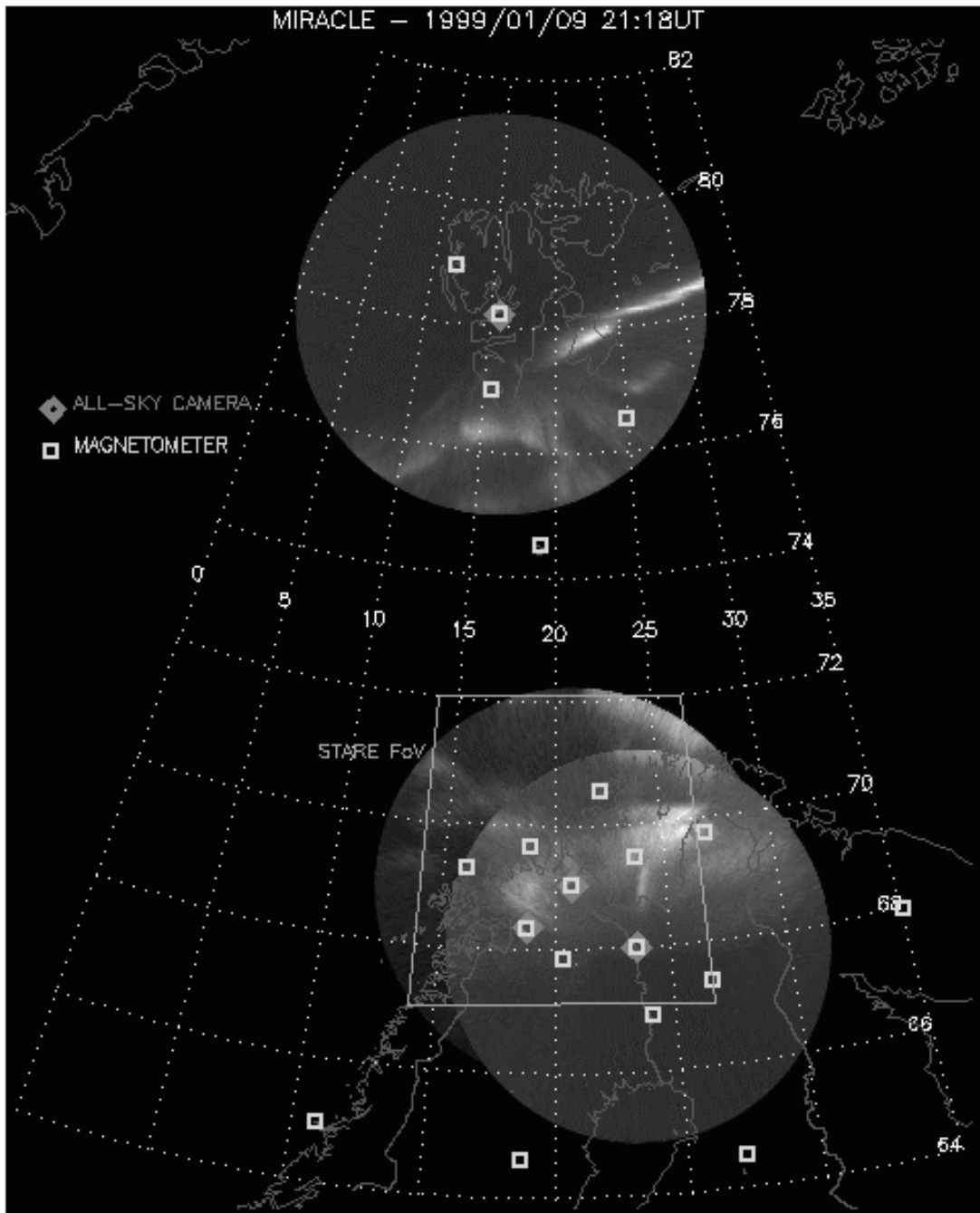


Figure 2.2. Auroras as recorded by the Finnish all-sky camera network: three images projected on a map. The locations of the MIRACLE magnetometers and the field of view (FoV) of STARE auroral radar are marked on the map as well.

3 THE ALL-SKY IMAGER

3.1 OVERVIEW

The all-sky imagers were manufactured by KEO Consultants [*KeoConsultants*, 1996]. The imager consists of the optical system, the CCD camera and the control electronics that controls the image intensifier, the mechanical shutter and the filterwheel. The control electronics is connected to the all-sky station computer via a standard RS-232C serial line interface. A photograph of the imager is shown in Figure 3.1 and an overview of the station in Figure 3.2. The imager component list is given in Table 3.1.

3.2 FRONT LENS AND SHUTTER

The fish-eye lens is a Canon 15mm/F2.8 with a 180° angular field-of-view (FOV). A mechanical shutter is placed immediately after the lens. The purpose of the shutter is not to control the exposure but to completely block the light to allow the capturing of “dark” images required to determine the dark current in the system. The shutter also protects the filters from unnecessary aging due to Sun light.

3.3 FILTERWHEEL

3.3.1 *Filters and telecentric optics*

The imager uses narrow band-pass interference filters. Currently, there are filters for 557.7nm, 630.0nm and 427.8nm with a full-width half-maximum (FWHM) of about 2-3nm. The interference filters are manufactured by coating a glass plate with several thin layers with known refractive indices. Finally, another glass plate is laminated on top of the layers to protect the inside layers. As the light passes through the filter, the differences in the refractive indices affect the propagation and reflection differently at different wavelengths. By choosing the thicknesses and materials properly, the resulting interference cancels all but the wavelengths in the pass band.

The transmission wavelength depends on the incident angle. Thus, it is necessary to use telecentric optic elements between the shutter and the filter wheel to provide the same incident angle at all image points on the filter (Figure 3.3).

3.3.2 *Wheel housing and operation*

The filter wheel has seven positions for two-inch filters. Because the filter centre wavelengths shift with temperature the temperature is controlled by an Athena XT16 temperature controller, which can heat the wheel by using two heater pads mounted inside

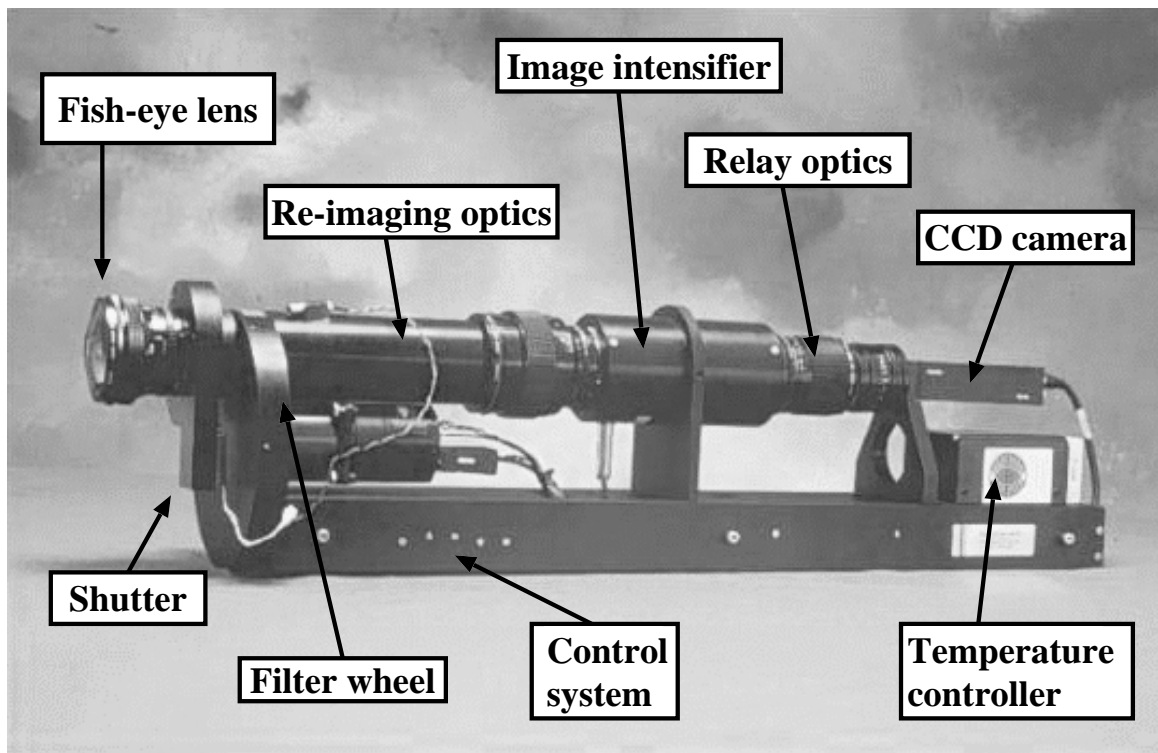


Figure 3.1. The all-sky imager

Table 3.1 Imager components

<i>Item</i>	<i>Description</i>
Fish-eye lens	Canon 15mm/F2.8
Additional optics	Telecentric lens elements
Filter wheel	7-position filter wheel for 2-inch filters
Filters	Narrow passband interference filters (557.7nm, 630.0nm and 427.8nm)
Intensifier lens	Canon 85mm/F1.2
Image intensifier	Varo 25mm MCP Gen II Image Intensifier model 3603
Reimaging optics	Canon 100mm/F2
CCD camera lens	Fujinon 25mm/F0.85
CCD camera	Pulnix 765E, 756(H)x581(V)

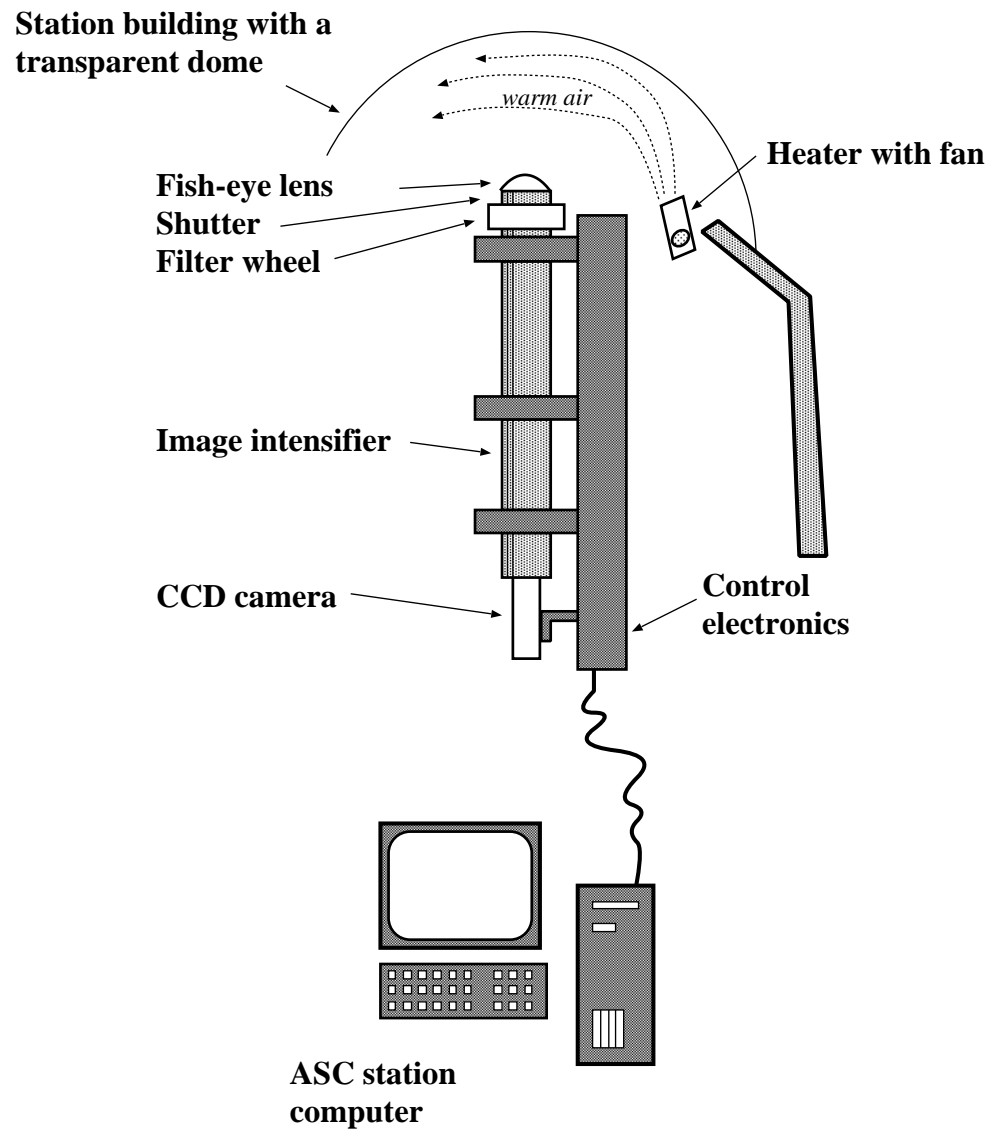


Figure 3.2. An overview of the station: the imager and the station computer.

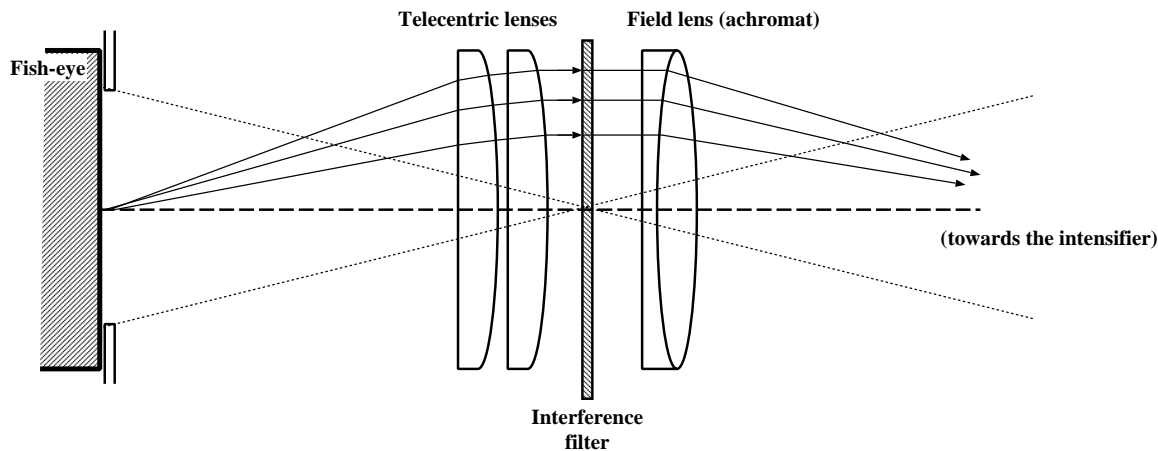


Figure 3.3. The telecentric optics provides the same incident angle on the whole filter area (adopted from *KeoConsultants* [1996])

the housing [*Athena*, 1994]. The temperature is set to the ambient temperature level of the calibration procedure, in which the filter transmission curves were measured.

The wheel itself is rotated by using the Animatics SMARTMOTOR [*Animatics*, 1996]. The SMARTMOTOR system has an embedded microprocessor with built-in memory and it controls the intensifier and the shutter as well.

3.4 IMAGE INTENSIFIER

3.4.1 Optics

The image diameter at filter is approximately 42mm and must be resized to approximately 22mm for the intensifier. This is accomplished in the re-imaging optics (Figure 3.4) consisting of two achromatic lenses, the Canon lens (85mm/F1.2), and a field-curvature corrector lens.

3.4.2 The intensifier

The intensifier is a 25mm Microchannel Inverter Intensifier model 3603 manufactured by VARO (USA). A schematic overview of the intensifier's inner details is shown in Figure 3.5. The low light level image is transmitted to the photo cathode where the photon image is converted into an electronic one. The electrons are accelerated towards the phosphor screen, and the electron amplification is provided by the Microchannel plate. The cathode is thinned tri-alkali for improved blue quantum efficiency, and the output phosphor is P20 for good time response (decay time to the 10% level is ~ 1 -2ms).

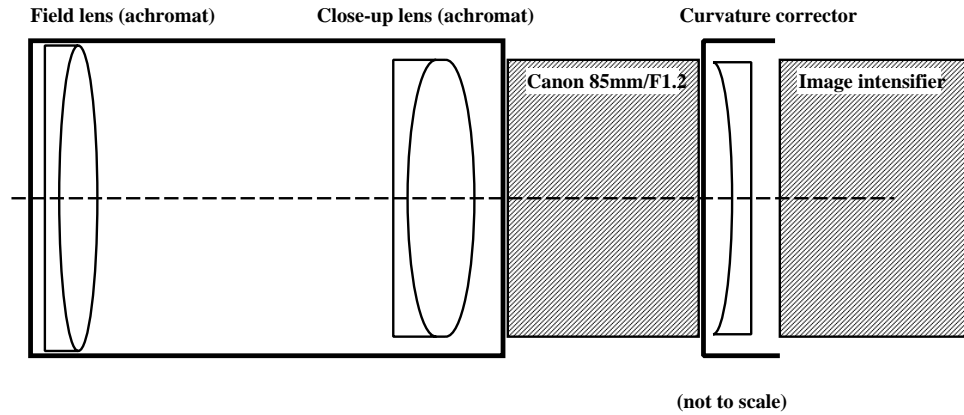


Figure 3.4. Re-imaging optics (adopted from *KeoConsultants* [1996])

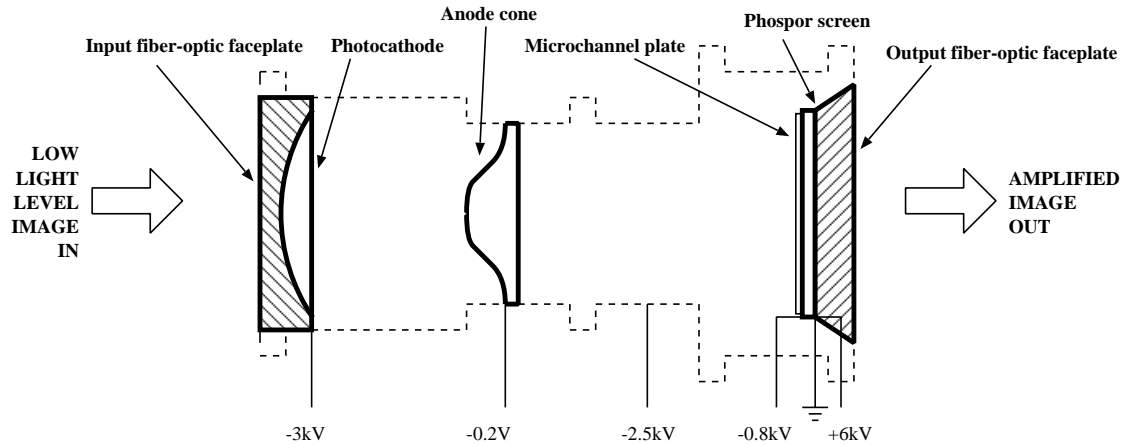


Figure 3.5. The image intensifier

The intensifier power can be switched on and off via the serial line. There are four preset intensification gains that can be selected remotely. The actual gain values can be set by four potentiometers in the control electronics and are normally set to fixed values during camera calibration.

3.4.3 The light sensor

A light sensor acts as a master power switch to the intensifier: if the ambient light level is too high, the intensifier cannot be switched on. Adjustments of this light protection can be performed by using a potentiometer in the control electronics.

3.5 CCD CAMERA

3.5.1 *Relay optics*

The output image of the intensifier is relayed to the CCD camera via a Canon 100mm/F2.0 lens coupled to a Fujinon 25mm/F0.85 lens. Again, the image is resized (22mm to 5.5mm).

3.5.2 *The camera*

The Pulnix TM-765E CCD camera has a spatial resolution of 768×512 pixels. The video output is a standard CCIR (composite black&white, 25 frames/s). The integration feature of the camera is used to capture images with longer than video rate exposures. The frame grabber of the station computer controls the integration and captures the exposed image.

4 THE STATION COMPUTER

4.1 OVERVIEW

The station computer controls all aspects of the imaging. It uses time and location to calculate the Sun elevation, and acquires all-sky images at pre-defined time intervals, exposures and filter selections if the Sun is below the horizon.

At noon, a keogram (see Figure 4.3) is created from the images of the previous night. All captured images are also copied onto tapes. These extra processes do not prevent imaging and in Svalbard images are captured 24 hours a day during the mid-winter.

4.2 COMPUTER HARDWARE

4.2.1 *General*

The computer hardware consists mostly of off-the-shelf components (Table 4.1). On average, about 70MB of harddisk storage is required for one night. However, the captured images on the station harddisk are not removed before the data are copied onto CD-R disks. Nominally the tapes are changed every two weeks and sent to the FMI headquarters in which the copying is performed routinely. Large harddisks allow more tolerance in the timetable and also provide storage for occasional campaigns during which the data rate is usually doubled.

There is a serial port expander card in the computer to provide the required additional ports. Depending on the station, the network is realised by either ISDN-cards (all stations in Finland), Ethernet (Longyearbyen), or a modem (Abisko). Every station has an Uninterruptible Power Supply (UPS) that provides power to the computer and the imager during short power failures.

4.2.2 *Timekeeping*

The computer clock is synchronised to the time signal provided by a Global Positioning System (GPS) receiver. The receiver is connected via a serial line and uses the NMEA-protocol for sending time information. The receiver also generates a digital one-pulse-per-second output with $\pm 1\mu\text{s}$ accuracy. The computer, however, uses only the serial line which provides less than one seconds accuracy, which is of the order of the exposure time. The station time zone is set to (coordinated) universal time (UT or, more accurately, UTC).

Table 4.1 Station computer details

<i>Item</i>	<i>Description</i>
CPU	Pentium (100-200MHz)
Memory	16-64MB
Harddisk	15GB
Tape drive	DDS2-drive (HP1533C)
Frame grabber	MuTech MV-1000 (8-bit grey-scale)
Time synchronisation	Trimble SVeeSix 6-channel GPS-receiver (RS-232C, NMEA)
Network	ISDN (HAN, KEV, KIL, MUO), modem (ABK) and ethernet (LYR)
Operating system	Linux (SuSE 5.3, kernel 2.0.36)

4.2.3 *Frame grabber*

The Mutech MV-1000 frame grabber controls the integration and digitises the analog video signal. The CCIR video is interlaced into odd and even fields containing the respectively numbered horizontal lines of a full frame. There are 50 fields per seconds — resulting in 25 frames per second — and the fields are separated by a vertical synchronisation pulse. The individual lines consist of a horizontal synchronisation pulse followed by the actual data in analog format. The horizontal pixels of each line are sampled at regular intervals in the digitalisation process. The black and white levels define the conversion range which can be adjusted in software. The final captured image is a 512×512 pixel window inside the 768×512 pixel video frame.

For longer than video rate exposures one must use the integration mode: the integration signal is brought low to collect light on the CCD. When the integration signal is returned to high, the next video frame will contain the exposed image and must be captured. The frame grabber software performs this operation automatically. The time synchronisation of video and integration signals are illustrated in Figure 4.1.

4.3 OPERATING SYSTEM AND ADDITIONAL SOFTWARE PACKAGES

The operating system in all station computers is Linux. The distribution is SuSE version 5.3, and the kernel version is 2.0.36. The installation of the operating system is based on a pre-selected configuration that contains all required packages from the distribution and the all-sky camera software on one CDROM.

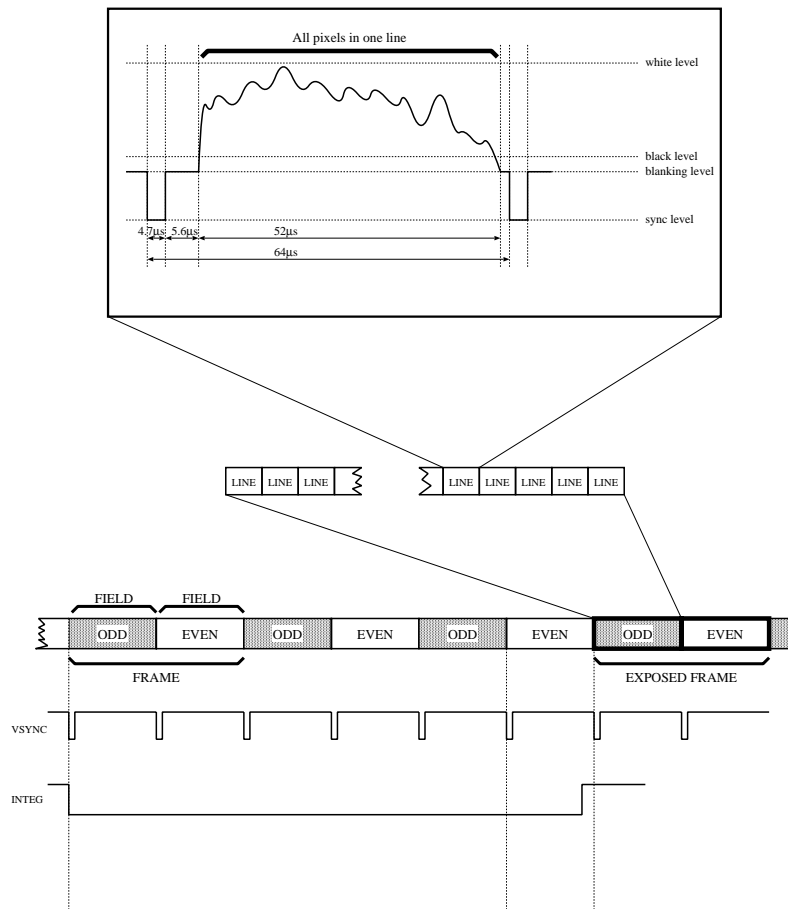


Figure 4.1. The CCIR video signal.

Table 4.2 Software setup

<i>Item</i>	<i>Details</i>
Base system	“Normal” workstation setup
Development software	C and C++ compilers, Tcl/Tk, perl
Graphical user interface	X-windows (XFree86)
Secure networking	Secure Shell (SSH) package
Timekeeping	Network Time Protocol (NTP) package
Frame grabber	MuTech MV-1000 driver
ASC control	All-sky camera software

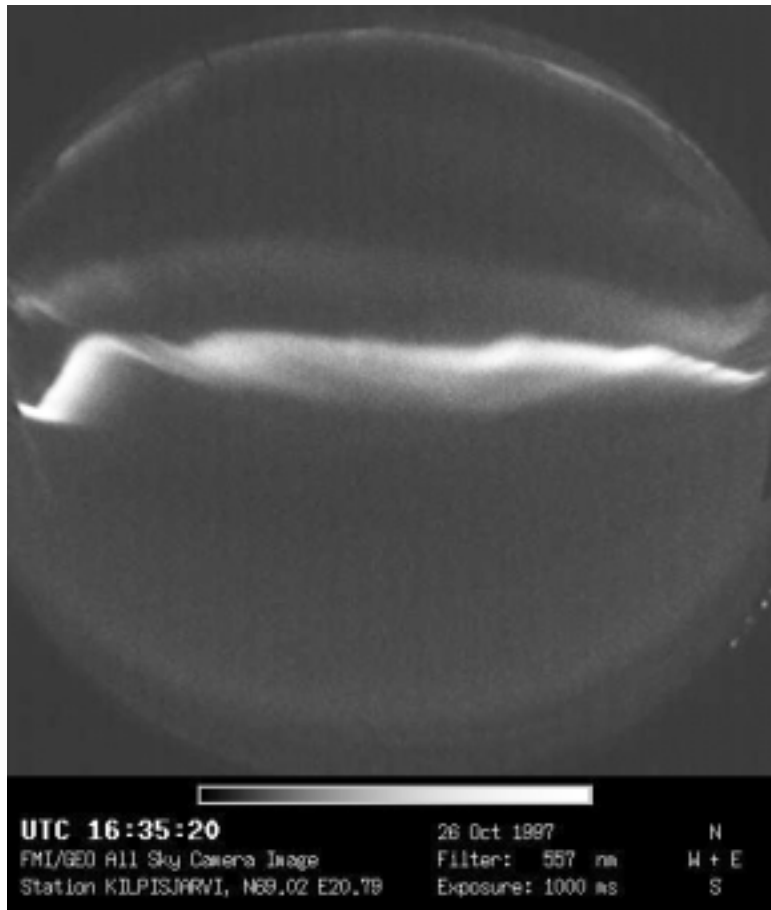


Figure 4.2. Kilpisjärvi all-sky camera image with labels and greyscale bar (1997/10/26, 16:35:20)

4.4 ALL-SKY CAMERA SOFTWARE

4.4.1 *Imager control*

The imager is controlled by an all-sky daemon `ascd` — a process that is active always. The daemon uses time and location information to determine whether the Sun is below the horizon and images can be acquired. After an exposure, simple labels are added to the image (Figure 4.2), which is then compressed and stored to disk.

The images are compressed with lossy JPEG-compression, which introduces small artifacts in the uncompressed images but produces small file sizes on average. The artifacts are most visible if there is little difference in the aurora and the background. The choice of the compression algorithm was based on the popularity and availability of suitable decoders. Typical compressed file sizes are 10 . . . 15kB for dark sky or weak auroral activity and 24 . . . 50kB for active auroras. The uncompressed file size is 310kB giving a compression ratio of about 1:25 for quiet and 1:9 for active aurora.

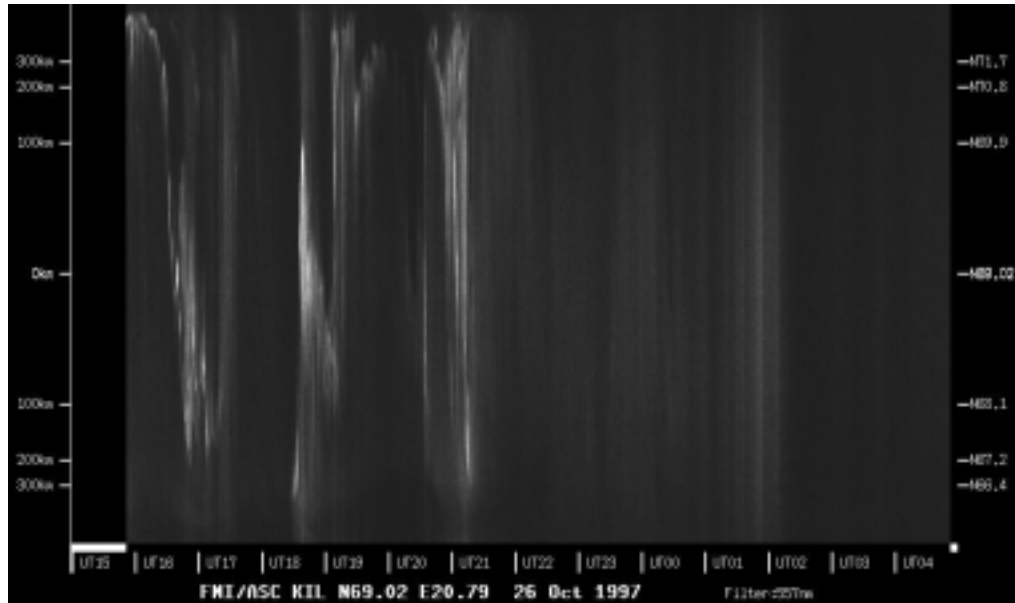


Figure 4.3. Kilpisjärvi all-sky camera image with labels and greyscale bar (1997/10/26, 16:35:20)

The station computer is also a World Wide Web (WWW) server, and it is possible to follow the aurora in real-time within the FMI network. Access from outside is possible to provide real-time data to, for example, rocket sounding experimenters.

4.4.2 Keograms

Keograms are time versus latitude plots: one north-south aligned pixel column is extracted from individual images to form a summary plot. Because one keogram contains information covering the whole night, they serve as quicklook data. In Figure 4.3, we can immediately observe that there was auroral activity, for example, between 1600-1730 UT during that night. Furthermore, there was little activity between 1730-1830 UT.

The vertical step size in plots is a constant zenith angle step. This results in varying latitudinal step size, and several latitude labels are marked assuming an auroral altitude of 100km.

Keograms are produced automatically at every station around noon (1215 UT), after which they are transferred to the FMI WWW-server. The keograms form an important part of publicly available MIRACLE quicklook data.

5 SOFTWARE CONFIGURATION

5.1 OVERVIEW

The auroral imaging is a completely automatic process initiated by the all-sky camera daemon `ascd` (see Chapter 5.5.3). Currently the imaging schedule is as follows:

- 557.7nm-images every 20 seconds; this actually consists of *two* captures with a 2-s delay in between. A *velocity field* is calculated from these images and the extra image is deleted from the disk.
- 630.0nm- and 427.8nm images every 60 seconds
- unfiltered images every 15 minutes

At 1201 UT, new keograms are generated and at 1230 UT the new image data are copied to DAT-tape, which is replaced with a blank tape every two weeks. The data are copied to CDR-disks, after which the remaining image files at the station are deleted.

Real-time information about the operation can be acquired by utilising the station WWW server. The latest image with the 2D velocity field and an up-to-date keogram can be remotely observed (Figure 5.1).

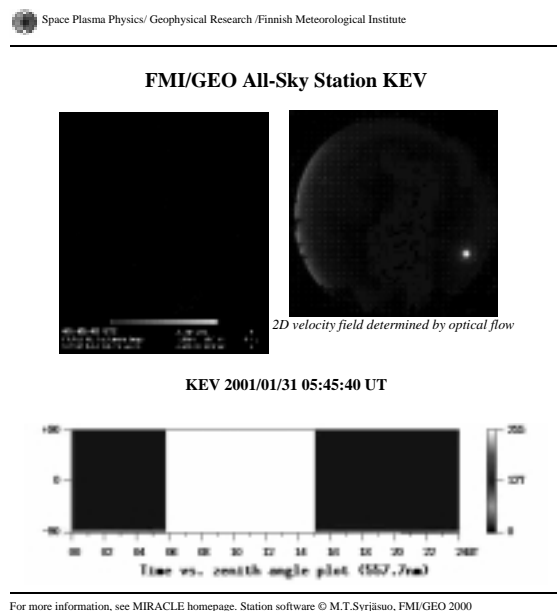


Figure 5.1. An example of real-time information.

5.2 USERS AND GROUPS

Only privileged users are able to control the operation of the station. In Unix environment this is accomplished by changing the file access permissions with `chmod` command.

The primary user who normally controls the station is called `asco` (All-Sky Camera Operator). Only the user `asco` and the members of the group `asco` can control the camera and the DAT-drive¹.

5.3 SOURCE CODES AND BINARIES

All software routines required to fully operate the all-sky camera station are collected into directory `/usr/local/ASC`. To include the binaries to the search path several symbolic links are created in `/usr/local/bin`. Table 5.1 lists the source directories.

Table 5.1 Directories in `/usr/local/ASC`.

<i>Directory</i>	<i>Description</i>
<code>Grabber_vX.YZ</code>	Frame grabber control software version X.YZ
<code>Keogram</code>	Software for creating keograms
<code>KeoMark</code>	Small image labels for keograms (pgm-images)
<code>Keo_texts</code>	Bottom label creator for keogram
<code>Kernel_vX.Y</code>	All-sky camera daemon <code>ascd</code> version X.Y
<code>Name_creators</code>	Routines for getting a valid name for e.g. keograms
<code>Sun_dip</code>	Sources for calculating the Sun angle
<code>Tools</code>	Additional routines such as <code>quickASC</code>
<code>MV1000</code>	MuTech MV-1000 driver (written by Jochen Karrer)

5.4 HARD DISKS

The hard disks in the station computer are arranged in such a way that the all-sky images are in the directory `/IMAGES` on a separate harddisk partition. The directory is owned by the user `asco`. The directory structure is illustrated in Figure 5.2.

¹Naturally `root` has privileges to do anything — also control the camera

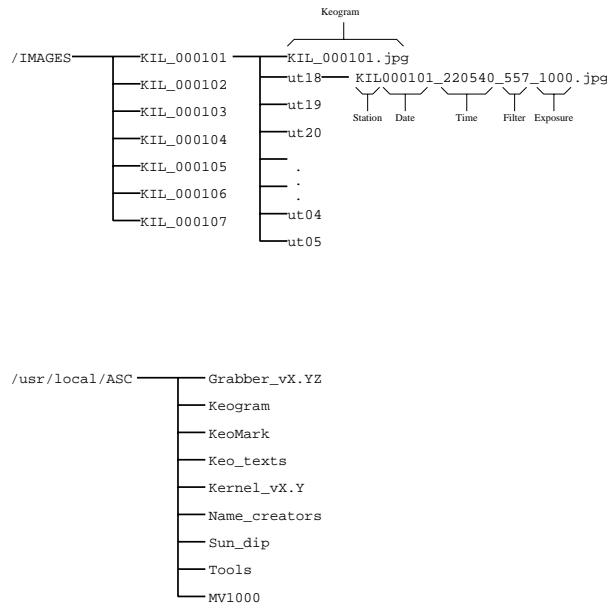


Figure 5.2. The directory structure.

5.5 CONFIGURING THE SOFTWARE

5.5.1 *System configuration*

Depending on the station, the network configuration [Welsh and Kaufman, 1995] varies: all stations utilising ISDN connections should also be configured to provide a modem connection as a backup, which is not necessary for stations with direct intranet or Internet connection.

The time zone is set to UTC at all stations, and `ntpd` is configured to receive the time from the GPS receiver via a serial port.

5.5.2 *Configuring the serial port*

The communication between the computer and the imager is performed through a standard serial port. A symbolic link `/dev/ASC` points to the serial port that is connected to the imager. If the imager is connected to `/dev/ttyS1`, the link can be created by a command

```
ln -s /dev/ttyS1 /dev/ASC
```

NOTE: the user `asco` needs permissions to use this port. The serial port settings are automatically configured by the all-sky camera software.

5.5.3 *All-sky camera daemon*

The all-sky camera daemon `ascd` calculates the sun angle by using the time and the knowledge of the station location. The location, which affects the file naming conventions and imaging schedule, is automatically determined from the computer hostname.

Flipping the captured image to the correct orientation (north up, east to the left) is accomplished by setting a few constants in a header file `stations.h`. The constants for the station Muonio are as follows:

```
#define MUO_lat      68.02
#define MUO_lon      23.53
#define MUO_HOR      HOR_NORM
#define MUO_VER      VER_FLIP
#define MUO_OFFSET  145
```

The correct flip configuration is automatically determined from the two constants `MUO_HOR` and `MUO_VER` during compilation time. In this case, the image is flipped vertically. To flip the image also in horizontal direction, `MUO_HOR` should be set to `HOR_FLIP`. Similarly, the vertical flip could be removed by setting `MUO_VER` to `VER_NORM`. The constant `MUO_OFFSET` is used to control the horizontal offset of the 512×512 all-sky image inside the 768×512 video frame.

Usually the daemon is automatically executed by `init`. However, one can run the daemon from the command line to check that the system really starts operating properly.

The daemon uses the file `/var/log/ascd.log` for logging its actions. The easiest way to monitor the operation is to open an extra window and use the command `tail` to show the latest lines of the log:

```
tail -f /var/log/ascd.log
```

The option `-f` “follows” the log (exit by pressing `CONTROL-C`).

5.5.4 *Configuring inittab*

The process `init` controls starting and stopping of `ascd`. This is accomplished by adding a line in the file `/etc/inittab`

```
as:23:respawn:/usr/local/bin/ascd
```

By sending a signal (command `telinit q`) `init` will re-examine `/etc/inittab`. Now, `init` automatically starts `ascd` and keeps it running all the time.

There are two commands `start_ascd` and `stop_ascd` that can be used to automatically perform the changes in `/etc/inittab` and sending the correct signals. For details about the process control initialisation, see the manual pages for `init` and `inittab`.

5.5.5 *Tape operations*

The script `store_images` is used to copy data from disk to tape. The script first examines the contents of `dat_log` in `asco`'s home directory to determine which images have already been copied, and then copies the missing images and updates the logfile.

5.5.6 *Frame grabber control software*

The routine `grabber` captures correctly exposed images and automatically adds texts to these new all-sky images. The software version v1.0 requires the operator to change the station information by hand. This is performed by editing the function `textit()` in the file `writer.c`. After the modifications one should re-compile `grabber`. Running `grabber` without any arguments lists the possible switches and shows the required form of usage.

After connecting all the cables one should test the connection by taking a sample image. There is a safety mechanism in the imager that powers the intensifier off if there is too much ambient light, but one should prefer dark rooms for testing. First, one should check whether the communication works at all; switch off the imager, configure the serial port, and read from the port to screen:

```
cat /dev/ASC
```

Switch the imager on, and after a while one should see a text "HOME : 1" appearing on the screen. This ensures that the communication works at least in one direction (from the imager to the computer).

The following commands can be used to verify bidirectional communication. First, the grabber is initialised, then the imager is configured (filter wheel position 4 contains no filter) and one image is captured and displayed on screen:

```
grabber -reset
grabber -passthru
grabber -power
grabber -filter 4
grabber -gain 0
grabber -open
grabber -full | xv -
```

At this point, if there is a video monitor in the setup, one should see the circular image of the sky. The last command reads a complete video frame through the frame grabber and opens `xv` to display the image². Next, one should test the integration:

²Pressing 'q' exits the program

```
grabber -integ 120  
grabber -full | xv -  
grabber -integ 520  
grabber -full | xv -
```

If everything works fine, one can reset the system:

```
grabber -reset
```

This reset command shuts down the image intensifier and closes the shutter.

6 MECHANICAL SERVICE AND MAINTENANCE

6.1 OVERVIEW

The operating season is limited by the Sun elevation; there is a break of a couple of months in mid-summer, when the ambient light level is too high for auroral imaging. The imagers are serviced once a year during this summer break which typically lasts from mid-April to the beginning of September.

6.2 YEARLY SERVICE — PREPARING FOR THE OPERATING SEASON

The imager contains mechanical devices such as the shutter and the filter wheel. These should be disassembled, lubricated and re-assembled. Especially the shutter can introduce problems during the operating season by jamming into half-open position. It is critical to tighten the shutter mounting screws properly, check the counter-spring *and* test the correct operation in real imager mounting position (ie. the imager pointing to zenith). The lens surfaces should be cleaned and checked for fractures or other damages that can occur during the transportation.

6.3 CHECKS DURING THE OPERATING SEASON

Although most of the operation is automatically executed by scheduled scripts, there are some cases in which human interference may be required:

Clock synchronisation. All stations use a local GPS receiver to adjust the computer clock. The daily keogram collection routine measures the time offsets between the institute WWW server and the station computers. In case of a GPS receiver malfunction, these offsets can be utilised to determine the correct time. The status of synchronisation to the GPS can be confirmed by monitoring the log file `/var/log/ntp`.

Imager focus. The screws that hold the optical elements in correct position tend to loosen during the season causing movement of lenses effectively unfocussing the imager. The reason to this is probably the vibrations caused by the mechanical shutter and the filter wheel. Thus, it is required to check the focus regularly by, for example, examining the star images captured once an hour during normal operation.

Filter wheel. It is possible that the filter wheel does not rotate properly due to an internal jam caused by loosened wiring. This can only be noticed if one examines individual images as it might not necessarily be apparent in keograms.

6.4 END OF SEASON

The imager should be unmounted from its support fixture and placed into the carrying case with the lens cap covering the fish-eye lens. The dome itself should be covered

with the specially manufactured cover.

6.5 USEFUL NOTES

Small parts such as nuts and screws are not in metric system and thus inconveniently available in Finland. For example, in most easily available allen-key sets the size of 0.050 is missing but it is required for servicing the solenoid.

6.6 UNDERSTANDING THE OPERATING SYSTEM AND THE SOFTWARE

In the scope of this report, it is not realistic to try to fully describe the Linux operating system. However, such knowledge is required if other than mechanical service has to be performed. An introduction to Linux and other unix-like systems can be found in *Welsh and Kaufman* [1995], *Todino et al.* [1993] and *Foxley* [1985]. Knowledge about C and Perl programming languages is required to be able to modify the imager control software, see e.g. *Kernighan and Ritchie* [1988]; *Kernighan and Pike* [1988]; *Wall et al.* [1996].

Details about setting the appropriate users and groups, configuring the communication between the imager and the computer and other information can be found in Chapter 5.

6.7 MOUNTING AND FOCUSING THE IMAGER

Once the imager is mounted in the dome, one should check the apertures of all lenses. The correct aperture settings, or F-stops, are listed in Table 6.1. One should note that the fish-eye lens and CCD camera lens are not “fully open”. If the fish-eye lens aperture is fully open, then there will be scattered light in the system. Opening the CCD lens fully will introduce significant vignetting at the edge of the image.

The imager is best focused by using images of starry sky. One can either use the computer to look at the images or utilise the video output of the CCD camera and connect a video monitor directly. The latter option is usually more convenient because the computer is in another room at all but Abisko station.

The focusing procedure can be summarised as

1. loosen the image intensifier locking screws
2. set the imager for focusing
 - (a) imager power on
 - (b) intensifier power on
 - (c) set maximum intensifier gain
 - (d) select “no filter”
3. focus by adjusting the intensifier and CCD lenses
4. tighten the image intensifier locking screws

First, one uses the station computer to set the imager for focusing: intensifier power on, maximum gain, filter selection to no filter and shutter open. Then, two of the lenses are focused to infinity (see Table 6.1). The intensifier lens (Canon 85mm/F1.2) is adjusted for best focus. Then the CCD lens (Fujinon 25mm/F0.85mm) is adjusted for best focus as well. The manual focusing of these two lenses is iterated until the optimal focus is found. Finally, one should capture a longer exposure of about 0.5–2 seconds with minimum gain (less noise) by using the computer to check the focus.

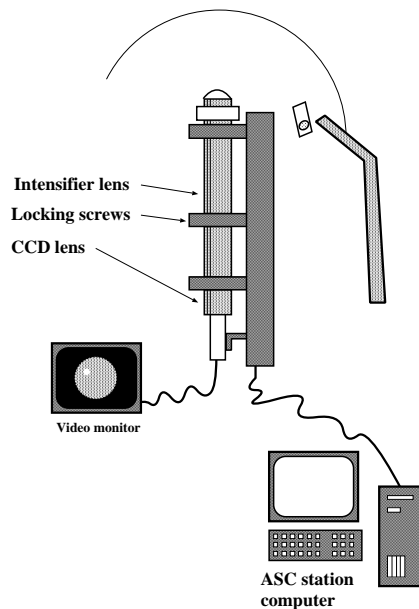


Figure 6.1. The recommended setup for focusing the all-sky imager

Table 6.1 Lens setup

<i>Lens</i>	<i>Model</i>	<i>Set aperture to</i>	<i>Focus</i>
Fish-eye lens	Canon 15mm/F2.8	F4	Focus to ∞
Intensifier lens	Canon 85mm/F1.2	F1.2	See section 6.7
Reimaging optics	Canon 100mm/F2	F2.0	Focus to ∞
CCD camera lens	Fujinon 25mm/F0.85	F1.4	See section 6.7

6.8 SAMPLE LOG FILES

6.8.1 Transferring keograms

This is an automatically generated email, the time offset in Kilpisjärvi is alarmingly large (malfunctioning GPS) and the free disk space at Sodankylä is low.

```
Date: Sun, 4 Feb 2001 12:32:36 GMT
From: Cron Daemon <root@sumppu.fmi.fi>
To: syrjasuo@sumppu.fmi.fi
Subject: Cron <syrjasuo@sumppu> transfer_keograms
```

```
Transferring keograms from all-sky stations...
Transferred file KIL_010204.jpg
KIL clock offset= 8.367830 seconds
Transferred file KEV_010204.jpg
KEV clock offset= -0.690114 seconds
Transferred file MUO_010204.jpg
MUO clock offset= 0.220823 seconds
Transferred file HAN_010204.jpg
HAN clock offset= -0.146682 seconds
Transferred file SOD_010204.jpg
All-sky station SOD
  Available free disk space: 15550 kB
  Used disk capacity      : 99 %
Transferred file LYR_010204.jpg
Updating WWW-pages
Creating keograms_feb01.shtml
```

6.8.2 Tape storage

/home/asco/dat_log. A few of the lines in the log file: the stored directory with the first and the last block used in storing are clearly indicated. Note the DAT-tape change (first block is zero).

```

.
.
/IMAGES/KIL_010223   At block 156116. - At block 166184.
/IMAGES/KIL_010224   At block 166184. - At block 172651.
/IMAGES/KIL_010225   At block 172651. - At block 178768.
/IMAGES/KIL_010226   At block 0. - At block 6848.
/IMAGES/KIL_010227   At block 6848. - At block 13598.
/IMAGES/KIL_010228   At block 13598. - At block 20085.
.
.

```

/home/asco/missing_log. The script `store_images` examines the contents of the directory `/IMAGES` and adds the data directories not found in `/home/asco/dat_log` to this log file. Note that there were several missing directories on 2001/02/23.

```

.
.
KIL_010221 at 12:30:01: Missing KIL_010220
KIL_010222 at 12:30:01: Missing KIL_010221
KIL_010223 at 12:30:00: Missing KIL_010213
KIL_010223 at 12:30:00: Missing KIL_010214
KIL_010223 at 12:30:00: Missing KIL_010215
KIL_010223 at 12:30:00: Missing KIL_010216
KIL_010223 at 12:30:00: Missing KIL_010217
KIL_010223 at 12:30:00: Missing KIL_010222
KIL_010223 at 12:30:00: Missing KIL_010110
KIL_010223 at 12:30:00: Missing KIL_010111
KIL_010223 at 12:30:00: Missing KIL_010112
KIL_010223 at 12:30:00: Missing KIL_010113
KIL_010224 at 12:30:01: Missing KIL_010223
KIL_010225 at 12:30:00: Missing KIL_010224
.
.

```

Tape failure. This is an automatically generated email if the tape storage fails:

```

Date: Wed, 28 Feb 2001 12:32:36 GMT
From: Cron Daemon <root@kilpisjarvi.fmi.fi>
To: asco@kilpisjarvi.fmi.fi
Subject: Cron <asco@kilpisjarvi> store_images

```

```

tar: Cannot write to /dev/nst0: No space left on device
Store to tape failed, what the... (Illegal seek)

```

6.8.3 *All-sky camera daemon log*

`ascd` was restarted in Kevo on Feb 15. The station location is determined from the

hostname and the connection to imager is accomplished. The station is in campaign mode until Feb 23.

```
.
.
Feb 15 11:18:52 kevo syslog: -----
Feb 15 11:18:52 kevo syslog: |   FMI/GEO All-sky camera software v1.12
Feb 15 11:18:52 kevo syslog: -----
Feb 15 11:18:52 kevo syslog: Path changed
Feb 15 11:18:52 kevo syslog: Station:  KEV
Feb 15 11:18:52 kevo syslog: Lat, lon:  69.76  27.01
Feb 15 11:18:52 kevo syslog: Initialising the grabber...
Feb 15 11:18:52 kevo syslog: Connection to imager ok
Feb 15 11:18:54 kevo syslog: *****
Feb 15 11:18:54 kevo syslog: **** C A M P A I G N      ****
Feb 15 11:18:54 kevo syslog: *****
Feb 15 11:18:54 kevo syslog: Current parameters:
Feb 15 11:18:54 kevo syslog:   Filter Exp(ms) Int(s) Gain
Feb 15 11:18:54 kevo syslog:   557.7nm 1000   10  0
Feb 15 11:18:54 kevo syslog:   630.0nm 2000   60  0
Feb 15 11:18:54 kevo syslog:   427.8nm 2000    0  0
Feb 15 11:18:54 kevo syslog: The WWW pages will be updated once in a minute
Feb 15 11:18:55 kevo syslog: Sun above horizon, capturing a darkframe.
.
.
Feb 23 16:28:07 kevo syslog: ---- Change in imaging parameters
Feb 23 16:28:07 kevo syslog: Current parameters:
Feb 23 16:28:07 kevo syslog:   Filter Exp(ms) Int(s) Gain
Feb 23 16:28:07 kevo syslog:   557.7nm 1000   20  0
Feb 23 16:28:07 kevo syslog:   630.0nm 2000   60  0
Feb 23 16:28:07 kevo syslog:   427.8nm 2000   60  0
Feb 23 16:28:07 kevo syslog: The WWW pages will be updated once in a minute
.
.
```

6.8.4 GPS synchronisation

Here are the last lines of `/var/log/ntp`. Note the small computer clock adjustments.

```
.
.
7 Mar 13:34:34 xntpd[536]: synchronized to GPS_NMEA(0), stratum=0
7 Mar 13:34:34 xntpd[536]: time reset (step) 0.281056 s
7 Mar 13:34:34 xntpd[536]: synchronisation lost
7 Mar 13:34:42 xntpd[536]: synchronized to GPS_NMEA(0), stratum=0
7 Mar 14:15:28 xntpd[536]: time reset (step) -0.317633 s
7 Mar 14:15:28 xntpd[536]: synchronisation lost
7 Mar 14:15:35 xntpd[536]: synchronized to GPS_NMEA(0), stratum=0
7 Mar 14:15:35 xntpd[536]: time reset (step) 0.303199 s
7 Mar 14:15:35 xntpd[536]: synchronisation lost
7 Mar 14:15:44 xntpd[536]: synchronized to GPS_NMEA(0), stratum=0
```

6.8.5 Campaign mode vs. normal mode

The imaging mode can be controlled by editing `/ASC_STATUS/parameters`. A normal configuration is the following:

```
#CAMPAIGN
#PAUSE
WWW
```

To change to campaign mode, one should uncomment the `CAMPAIGN`, after which the contents should look like this:

```
CAMPAIGN
#PAUSE
WWW
```

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