

## THREE YEARS EXPERIENCE WITH THE CASI IMAGING SPECTROMETER

M.C. Mueksch

ASIP/ECOSCAN, Plapphalde 2, 7033 Herrenberg, Germany

### PURPOSE:

A three years experience with the CASI imaging spectrometer is described. Operating the instrument under various difficult circumstances from lab status to full operationality, many experience could be gained of the performance of the instrument on nearly all type of objects usually observed in remote sensing.

Struggling with instrument and calibration problems the system could be further developed to a tool for the operational practice strongly regarding the applications. The system is primarily useful on all water, wetland, marine and coastal environments for which it was originally developed.

KEY WORDS: CASI-spectrometer, CCD, Calibration, spectrometer parameters, attitude compensations, spatial and spectral information

### 1. A HISTORICAL REVIEW

November 1988 after returning from the ASPRS/ACSM conference in Virginia Beach an information reached me about a new spectrometer type called CASI (Compact Airborne Spectrographic Imager). Its predecessor was the FLI/PMI, well known in oceanography.

Although the instrument was not yet fully developed and being in a lab status the system was offered officially for purchase.

My interest in the system was immediately brought up, since I have been working about 10 years ago in near infrared radiometry on tropical vegetation and coastal environments in Cameroon and Tanzania/Africa.

Half a year later I took part in the preparation of the first CASI mission in Northern Europe, Norway and Sweden within the EISAC/NORSMAP campaign. The CASI still in the lab status was flown in a Partenavia, but unfortunately the system failed, resulting in disappointments. Some days later it was mounted on a Merlin aircraft of the Norwegian SFT-Pollution Control behind a glass port hole. Whether calibrations with the glass plate were carried out is not known to me.

The system was functioning during a flight from Oslo to Bergen. The campaign lasted three weeks. The results were a documentation being available with the NERSC/Solheimsvik/Bergen, Norway.

Within the next three months a first prototype unit of the CASI was manufactured and a paid demo-flight was carried out upon my request in Germany around and within the Black Forest in August 1989. The system at that time had no roll compensation and therefore the largest part of the images presented the typical roll effects.

It also showed panoramic distortions, indicating that aircraft speed and integration time were not in coincidence. The system in this functional status produced low quality results.

Data sets were useless for further processings. Additionally images at that time had only an 8-bit sensitivity. Assuming that the system would be brought up to the promised status in the first production, a unit was ordered which was delivered in May 1990, looking forward even at that time for an own attitude sensor, the Zeiss SM 2000, seen during the ASPRS/ACSM-Denver conference in spring of this year.

In the following months the system was flown for various national organisations in Europe without any roll compensation. Due to favourable wind conditions most of the images were useful, but still in 8-bit version. The postprocessing produced - till today - calibrated images and spectra in the PCI-PIX format, not necessarily a good choice for a CASI operational monitoring. The PCI system is much more useful for high quality scientific-technical image processing than operational ones. Additionally there are only very few users in Europe compared with the 500 ERDAS users in Europe alone. Later an ERDAS-System was purchased which is working properly and operationally on CASI images.

### 2. CCD - AND CALIBRATION PROBLEMS

The system was delivered for 8 bit data, while 16-bit data was in development. 3 months after delivery of the CASI the 16-bit version came out. Unfortunately the manufacturer delivered an 8-bit PCI-version, so that I wrote a 16-bit display version myself for checking images and spectra included a transfer software on 9-track tapes.

Because the manufacturer previously delivered small amounts of demo data to an English user this user claimed further CASI monitorings also on 9-track tapes, disregarding that for a normal CASI mission it is absolutely uneconomical to produce 9-track tapes. It was not possible to convince this user, but he saw the increasing amount of 9-track tapes arriving. Format problems prohibited a quick and an effective data recording and evaluation.

CASI was called back for checks by the manufacturer 2 months after delivery in July 1990. Heavy spikes in the data were detected and calibration problems occurred.

A further mission in Europe was planned by the EC/JRC, Ispra some days after the check in Canada. The instrument came back, the mission carried out, but the data still showed spikes, even worse than before. The instrument went back to Canada again and was returned and certified to be function in August 1990.

Missions continued in Netherlands and Sweden. End of 1990 all data of the missions had been calibrated and evaluations brought out that spikes in the data had not been disappeared, even being stronger and much more unreliable.

The system was sent to the manufacturer back and finally frost was detected on the CCD, while powering up the instrument. The reason was that through a small hole water vapour was intruding and frost was forming on the CCD in an uncontrollable way during the cooling phase. It turned out that the hole was a manufacturing error. The hole was not closed, but the maximum cooling temperature lowered down under the temperature where frost begins to form on the CCD. Insisting on intensive tests the system was delivered back in June 1991, certifying that no spike was further developing. The manufacturer took the chance to test his methods intensively on my instrument to prevent further problems with instruments for other customers. I had to sacrifice several missions during these repairs and tests, while the manufacturer insisted on full payments without any reductions. So my CASI was the test instrument for all other CASI owners. The instrument was functioning from this time on.

### 3. THE RELATIONSHIP BETWEEN NUMBER OF BANDS, GROUND RESOLUTION, INTEGRATION TIME, AIRCRAFT SPEED AND APERTURE

The most critical parameters for operating a CASI is the spatial resolution, the number of bands, the integration time and the aircraft (ground) speed. From these 4 parameters the data quality is mainly depending, assuming the instrument is working correct.

Higher resolution with increased number of bands requires a longer integration time and a lower aircraft speed. All aircrafts used - all together 7 different types - had their minimum speed at 90 knots which even varies for different altitudes and temperatures. The speed strongly depends of the wind to gain an appropriate ground speed coming near to the required ground speed.

Because of the limitation of aircraft speeds the required speed for more than 8 bands and less than 2 m resolution is never reached. Consequently most images are underscanned and this means data loss.

The data loss is much more serious than the roll problem, because smaller objects may not even appear on the images although they are larger than the ground resolution.

The only way out of this, is to reduce the number of channels. Many experiments showed that with a number of 5 channels, a resolution of 2 m which is an altitude of approx. 5000 feet and a speed of 100 knots, sufficient full images can be gained.

It is logical that an overscan is even better and much more secure with the disadvantage of splitting the bandset into several subsets in case of large amounts of bands required, flying each subset consecutively.

This again limits the object or area size be flown, because aircraft hours are boosted up.

The CASI-spectral mode which produces 288 channels on one pixel of 39 on one scan line with dark spacings in between of 4,8 or 12 pixels has a fixed integration time of 204 milliseconds.

According to the parameter relationship the required aircraft speed to gain consecutive spectra without any gaps in between should lie around 50 knots and less in an appropriate altitude.

This speed cannot be performed by any conventional aircraft and only by a helicopter. The scans remains samples with gaps in between. But helicopter flight of CASI may be prohibited, because of high vibrations compensated by a special very expensive platform.

To find an economic relationship between these parameters, the aircraft flight hours and area size to be recorded, regarding outer circumstances such as illuminations, reflections, shadings and weather conditions, is very difficult with the CASI.

The instrument cannot be economically operated in the present functional status of those 4 parameters and consequently the current costs are very high for the customers to recover the costs of purchase.

Therefore CASI caused a drastic reduction of personel in my office in 1991, so that I am operating the CASI alone without any overheads now and this is economical, also for the customer.

A proper planned organisation does not need any further personel for operating the CASI and postprocessing the data as my experience shows.

It should be mentioned that the iris setting at the CASI objective is very important. Flying water and land with the same aperture will degrade the spectral resolution either of one of the targets. Therefore water needs a larger iris aperture than land.

Changing the aperture is only possible in taking the CASI camera head out of the platform. A motor driven iris is causing noises on the CCD in the present CASI status as experiences showed.

#### 4. REAL TIME ATTITUDE COMPENSATION VERSUS POSTPROCESSING ATTITUDE COMPENSATION

Many 8-bit conventional scanners have postprocessing roll corrections and with such a low sensitivity no major data loss or influence on the oblique look directions was emerging.

This is different for a 16-bit system. In a postprocessed roll correction the geometric location of the shifted scan line can be adjusted back to the nadir point by the recorded roll angle. This is a very simple operation and need a gyro, a digitizer or controller together with a software.

Such a geometric operation does not regard the pixel grey value information of the oblique situation. It only shifts the position of the pixel. A possible remedy is a nadir corrected grey value of the pixel. Such operations are known but remain approximation. Manipulations of this kind should be avoided. Presently the CASI can be equipped with such a postprocessing roll correction by the manufacturer.

To illustrate the effect of postprocessed roll correction at some examples: Assuming a typical agricultural row pattern such as maize to be scanned obliquely. How can the shadow difference between the oblique pixel and the nadir restored pixel be fully gained ?

Or, asuming even thinned out forest stands with long shadows, the situation is going to be worsen if stress and damage should be investigated. This additionally overlaid by underscans will cause spectrally and spatially very low resolution data even in spreading them to a 16-bit scale.

The only way out of this serious problem is a real time attitude platform which avoids obliqueness. The across track projective distortion from the optics is the only remaining deviation to be corrected in geometric processings. The Zeiss SM 2000 was investigated for this purpose.

A short calculation based on my experience with the roll effects gave that this equipment would help to overcome the problem. In deed many missions showed that roll is reduced in 95 %. A rest of 5 % is due to havier rolls trespassing the platform tolerances.

It has to be mentioned that a good compensation also depends of the aircraft used and the pilot who has to keep the altitude, low attitude angles, less movements of the aircraft and a constant and correct aircraft speed.

It should not be forgotten that in each instant of a few milli-seconds the aircraft must have the correct position while in aerial photography this condition occurs may be all 5 to 20 seconds when a photo is exposed. In CASI operations the rule for primary data aquisition is also valid that data must be recorded directely without any filter in between or as less filters as possible keeping data free of any manipulation.

#### 5. SPECTRAL OR SPATIAL INFORMATION

Satellite imagery users are spoiled in geometrically corrected images. We have to remember that a satellite platform is not affected by any weather conditions, thus being stable. This is different for airborne scanners especially if large scale maps are required.

The question remains wether a high resolution imaging spectrometer shall also deliver high spatial informations for which it is not designed. The CASI-scale ranges upward from 1:10 000 and any attempt to rectify an image on a larger scale than this causing difficulties in respect of rest distortions from the inertia of the real time compensation platform. It is therefore recommended to rectify images for scales upward of 1: 10 000.

Photogrammetrists are used to extract informations from smaller photo scales down to larger map scales. This cannot be done for airborne digital imagery and leads automatically to problems. If somebody likes to map vegetation she/he will be better served to use CIR photography.

My continous experience is that photogrammetrists/surveyors have different views of digital multispectral imagery than non-surveyors: The first are relying more on spatial information, the second more on spectral ones. The surveyors are driven much more by spatial requirements and accuracies while the non-surveyors are much more flexible.

A new justification for high accurate spatial information are the data entries into GIS, representing a digital map. But we have not yet thought how we can enter spectral information into a GIS. The CASI-spectral mode is forcing this.

The CASI is not an instrument for high spatial resolution requirements. These are even poor. The CASI is a spectrometer. Its power is the high spectral resolution with free bandsettings, primarily created for low object signals and high differentiations of colors. The spectral mode is not yet fully explored and even not understood by still many users.

Some are demanding both spatial and spectral information to a max. extend. This is overstressing the present technological possibilities and disregarding the various impacts on the records of unknown light and natural phenomenae which even have changed in our polluted world.

Image and GIS processing men of the "Screenie generation" are going to loose their relationship to nature, an increasing observation in students training in image processing of remote sensing.

Flying a scanner brings women/men back to nature and what it means to be helpless delivered to weather conditions and the various discrete scattering sources of the atmosphere under changing environmental conditions.

Relying much more on the spectral aspect of a spectrometer instead on the spatial one, remains trivial.

## 6. CONCLUSIONS

After nearly two years of bringing up the CASI from a lab to an operational status and flying the instrument operationally for one year now, the following characteristics and requirements for practical applications can be concluded:

- The system needs a far better performance of its main parameters which are the number of bands, the ground resolution, the integration times in relation to aircraft ground speeds and a better improvement of operating the iris.

- The high spectral and narrow band resolution is primarily useful on low signal objects such as water bodies and for very fine differentiations of colors (originally the CASI principle was developed for marine tasks).

- Its chlorophyll-red edge performance is the best one still existing.

- The spectral mode is an outstanding feature which presently no system has, but which needs much more research and practical applications and experiences.

- The system is easy to transport, to build into nearly each aircraft within a short time and simple to operate.

- The cost benefit relationship is tending to be economic, if no overheads are given and enough additional funds are available to close the gap between its performance and the requirements of the users. If the system is foreseen for special and permanent applications the cost-benefit relationship may be good.

- For any water, marine and coastal environmental monitorings, the system is far ahead of any existing one and will definitely play an important role in our world wide monitorings of water ressources, their situation and problems.

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