

DESIGN AND DEVELOPMENT OF THE COMPACT AIRBORNE IMAGING SPECTROMETER SYSTEM

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ABSTRACT: In recent years, the hyperspectral instruments with high spatial and high spectral resolution have become an important component of wide variety of earth science applications. The primary mission of the proposed Compact Airborne Imaging Spectrometer System (CAISS) in this study is to acquire and provide full contiguous spectral information with high quality spectral and spatial resolution for advanced applications in the field of remote sensing. The CAISS will also be used as the vicarious calibration equipment for the cross-calibration of satellite image data. The CAISS consists of six physical units: the camera system, the Jig, the GPS/INS, the gyro-stabilized mount, the operating system, and the power inverter and distributor. Additionally, the calibration instruments such as the integrated sphere and spectral lamps are also prepared for the radiometric and spectral calibration of the CAISS. The CAISS will provide high quality calibrated image data that can support evaluation of satellite application products. This paper summarizes the design, development and major characteristic of the CAISS.

KEY WORDS: CAISS, Vicarious Calibration Equipment, GPS/INS, Integrated Sphere, Spectral Lamp

1. INTRODUCTION

A wide variety of applications of imaging spectrometry have been proved using data from airborne system. With the recent appearance of commercial airborne hyper spectral imaging systems such as the CASI (Canada) and HYMAP (Australia), hyperspectral imaging systems are poised to enter the mainstream of remote sensing. Most of multispectral imaging system with high resolution such as KOREA Multi-Purpose SATellite (KOMPSAT), IKONOS and QuickBird produce images with a few relatively broad wavelength bands, even the aerial mapping camera system. On the other hand, hyperspectral imaging systems collect the image data simultaneously in many narrow, adjacent spectral bands. Also these measurements make it possible to derive continuous spectrum information for each image cell. The hyperspectral imaging systems with high spatial and spectral resolution have become an important component of wide variety of earth science applications such as environmental monitoring, forestry, agriculture, mineral exploration, and etc. However, in order to fully realize the potential of hyperspectral image data for such applications, it is necessary that calibration and validation of system and image level should be performed in the laboratory and field with calibration equipments and special targets.

In this study, we proposed the Compact Airborne Imaging Spectrometer System (CAISS) that has quite similar spectral characteristic to the KOMPSAT-2 Multi-Spectral Camera (MSC). The primary mission of the CAISS is to acquire and provide full contiguous spectral information with high quality spectral and spatial resolution for advanced applications in the field of remote sensing. Also we have a plan to use the CAISS as the vicarious calibration equipment for the cross-

calibration of satellite image data. This paper described the status of design and development of the CAISS and summarized its major specification.

2. COMPACT AIRBORNE IMAGING SPECTROMETER SYSTEM

2.1 System Description

The CAISS was jointly designed and developed as the hyperspectral imaging system by KARI and ELOP inc., Israel. The CAISS consists of six physical units: the camera system, the Jig, the GPS/INS, the gyro-stabilized mount, the operating system, and the power inverter and distributor. The CAISS configuration and assembly are shown in Fig. 1.

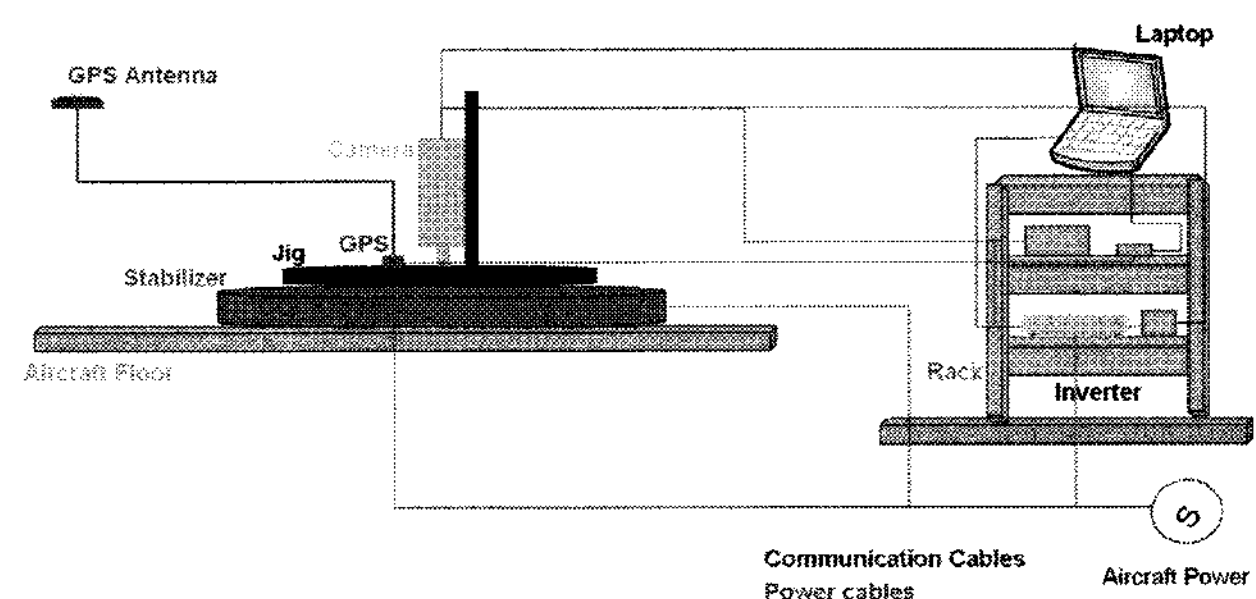


Figure 1. The CAISS assembly.

The CAISS is based on the DALSTAR 1M30 CCD camera made by DALSA. Attached to the camera there is a spectrograph that disperse the light coming from the fore optics into more than 60 spectral lines. The spectrograph disperses the light across the CCD lines in such a way that the instrument works as a line scanner in push-broom mode. For every line in the scene the spectrograph disperses the light so that the spectrum is

sampled instantaneously. The movement of the platform creates the second dimension of image and at the end of the flight line we actually have a data cube. The user has the ability to control the spectral configuration of the instrument and define for each band its center line and the Full Width Half Maximum (FWHM). Changing the flight altitude will change the GSD and the user would have the ability to simulate images with spectral and spatial resolutions similar to other sensors.

2.2 Camera System

The camera system of CAISS in Fig. 2 consists of the DALSTAR 1M30 digital camera, the ImSpector V10E imaging spectrograph, the PCI frame grabber, the power supply, and cables.

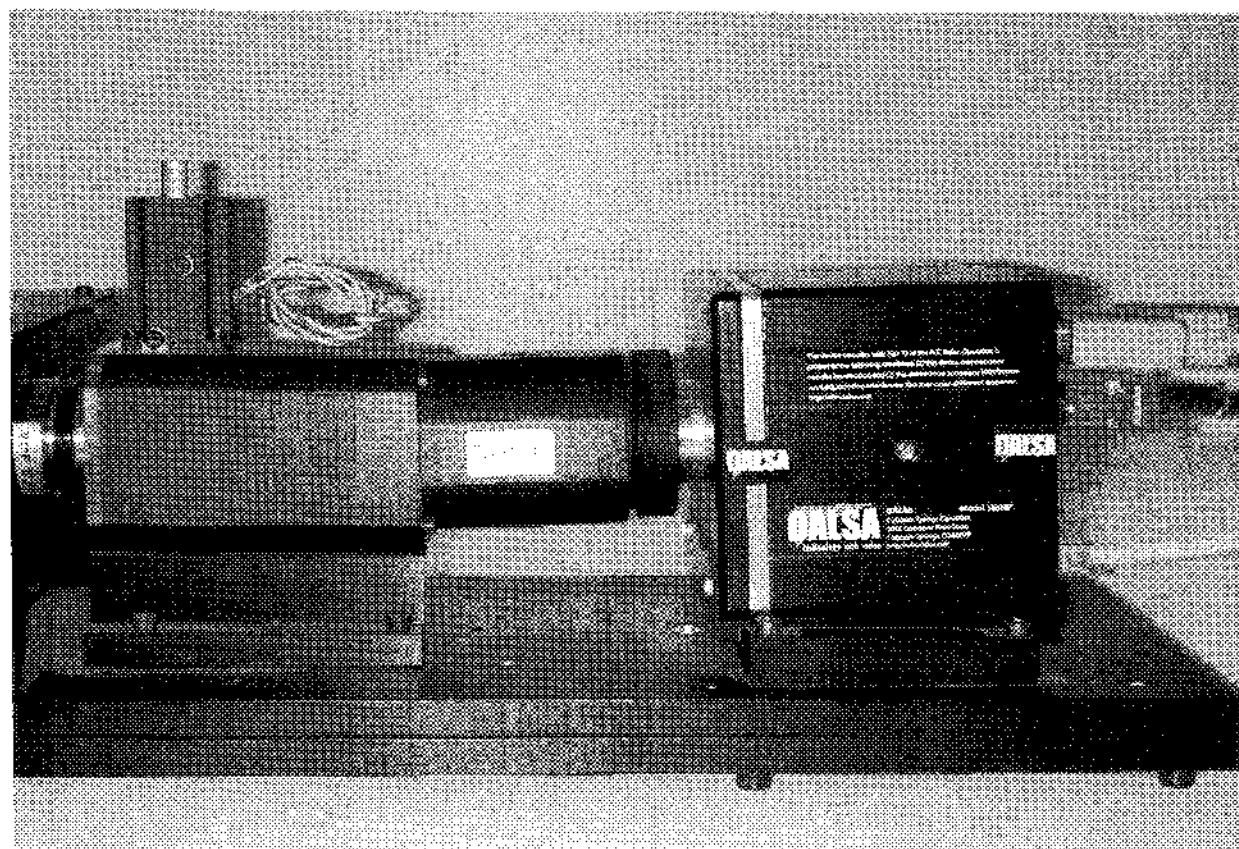


Figure 2. The Camera system of CAISS.

The DALSTAR 1M30 digital camera provides high-sensitivity 12 bit images with 1k x 1k spatial resolution at up to 30 frames per second (fps). The 1M30 is a frame transfer CCD camera using a progressive scan CCD to simultaneously achieve outstanding resolution and gray scale characteristics (DALSA, 2001). The numbers of spatial pixels are 1024 pixels and pixel size is 12 μm . Fig. 3 shows the basic operating principle of ImSpector. The ImSpector V10E image spectrograph was assembled with the DALSTAR 1M30 digital camera in order to acquire the full contiguous spectral information with high quality spectral and spatial resolution. In the camera system, we can control a spatial binning which is essentially aggregating pixels at detector level. Data can be spatially binned by 2 to provide 512 pixels. Also spectral binning is aggregating several spectral bands together.

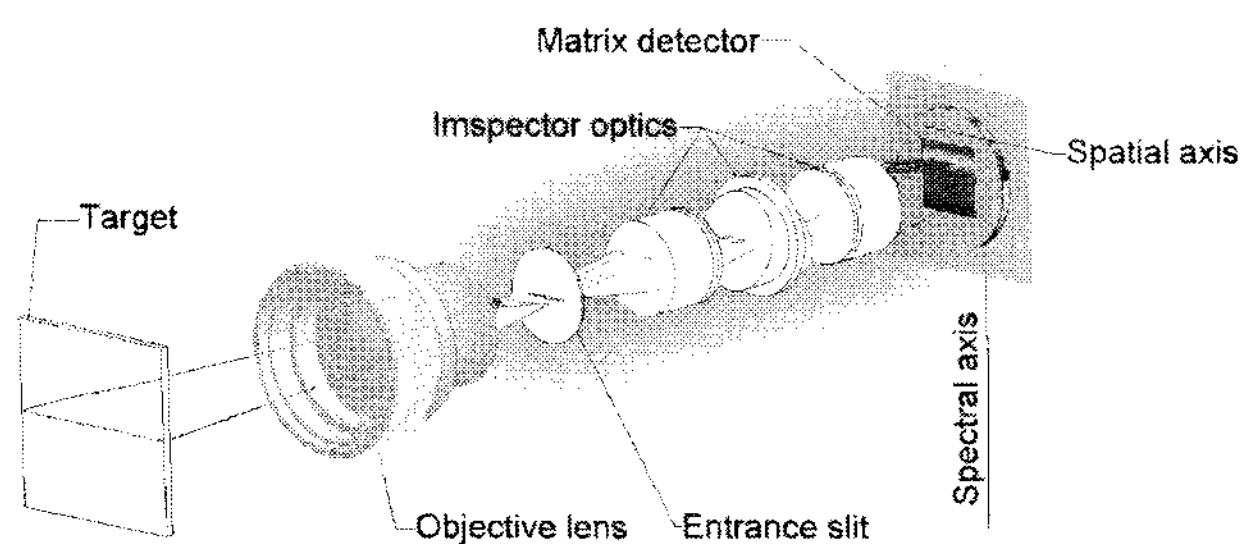


Figure 3. Operating principle of ImSpector

(Spectral Imaging Ltd., 2007).

2.3 Jig

The main mission of Jig is to mount the camera system on top of the gyro-stabilized mount. So the Jig was designed and manufactured as shown in Fig. 4 according to the gyro-stabilized mount GSM 3000 that was used the CAISS. The Jig contains an adapter plate for alignment and fixation of the camera system. After assembling the GPS and camera system to the Jig, it shall be mounted on top of the gyro-stabilized mount.

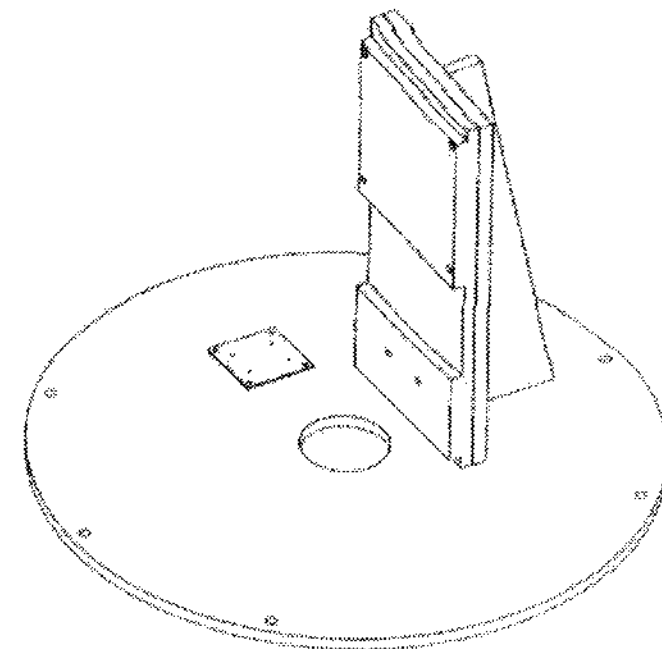


Figure 4. The jig configuration.

2.4 GPS/INS

The GPS/INS is an important component for airborne imaging system. The MIDG II which provides full INS solution will be used for geometric correction of acquired image data. The major specifications of MIDG II are that absolute accuracy of position is 2m CEP and absolute accuracy of velocity is typically better than 0.2 m/sec. Both angular rate and acceleration are 20 Hz at 3dB bandwidth (Microbotics Inc., 2005). The GPS receiver was communicated with computer via RS422 interface. The power of GPS receiver was supplied by separated connector interface.

2.5 Gyro-stabilized Mount

The gyro-stabilized mount is a platform for devices used in airborne imaging system. The primary purpose of gyro-stabilized mount is to stable support the aerial equipment and to compensate for the rotations (roll, pitch, and yaw movements) of the airplane during imaging. The advantages of gyro-stabilized mount for airborne imaging system are the drastic reduction of angular rates that are caused by turbulences in the atmosphere and elimination of momentary roll, pitch, and yaw angle errors.

After full consideration based on the requirement of design stage such the angular stabilization ranges, the compensable angular rates, the degree of stabilization of the horizontal axes, the compensable angular acceleration, and dimensions, we decided to accept the GSM 3000.

The GSM 3000 provides a stabilized platform in all three rotational axes. Instead of using mechanical gimbals and complex gear drives, roll and pitch stabilization is done by a hydraulic system consisting of four cylinders and two servo pumps. A third control loop

compensates the drift angle of the airplane and dynamically gyro-stabilizes deviations from heading using classic gear drives and bearings (SOMAG AG, 2006). The GSM 3000 platform mainly consists of four different groups of functionality, which are moving to each other: the base plate, the main body, the suspension ring, and passive vibration insulation ring. Fig. 5 shows the simplified structure and picture of the gyro-stabilized mount GSM 3000.

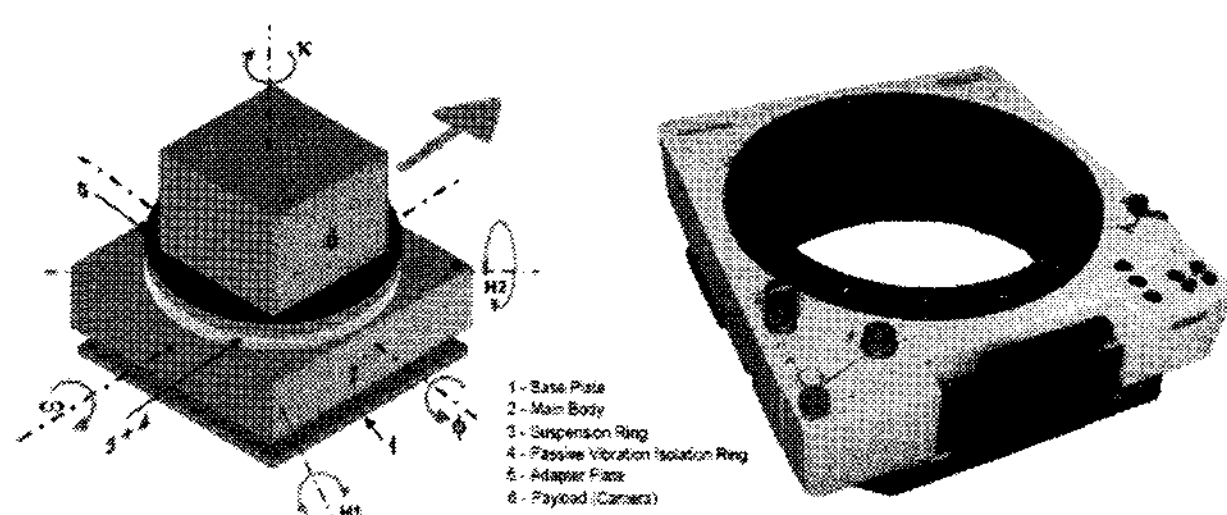


Figure 5. The structure and picture of the gyro-stabilized mount GSM 3000.

The adapter plate is a specially manufactured plate that joins the camera to the passive vibration insulation ring. It is the reason why we designed and manufactured the Jig. Another special adapter is also necessary to join the base plate of the gyro-stabilized mount to the window of the airplane floor.

2.6 Operating System

The operating system consists of the computer system and software. The computer system is based on a laptop computer with windows XP. The peripheral interface for the GPS/INS control, the camera system operation, the image data reception was defined. For example, the image data receiving interface is based on the PCMCIA card. The real-time imaging data will be directly recorded at the hard disk of laptop. It is also possible to use the external hard disk for real-time data storage during the imaging.

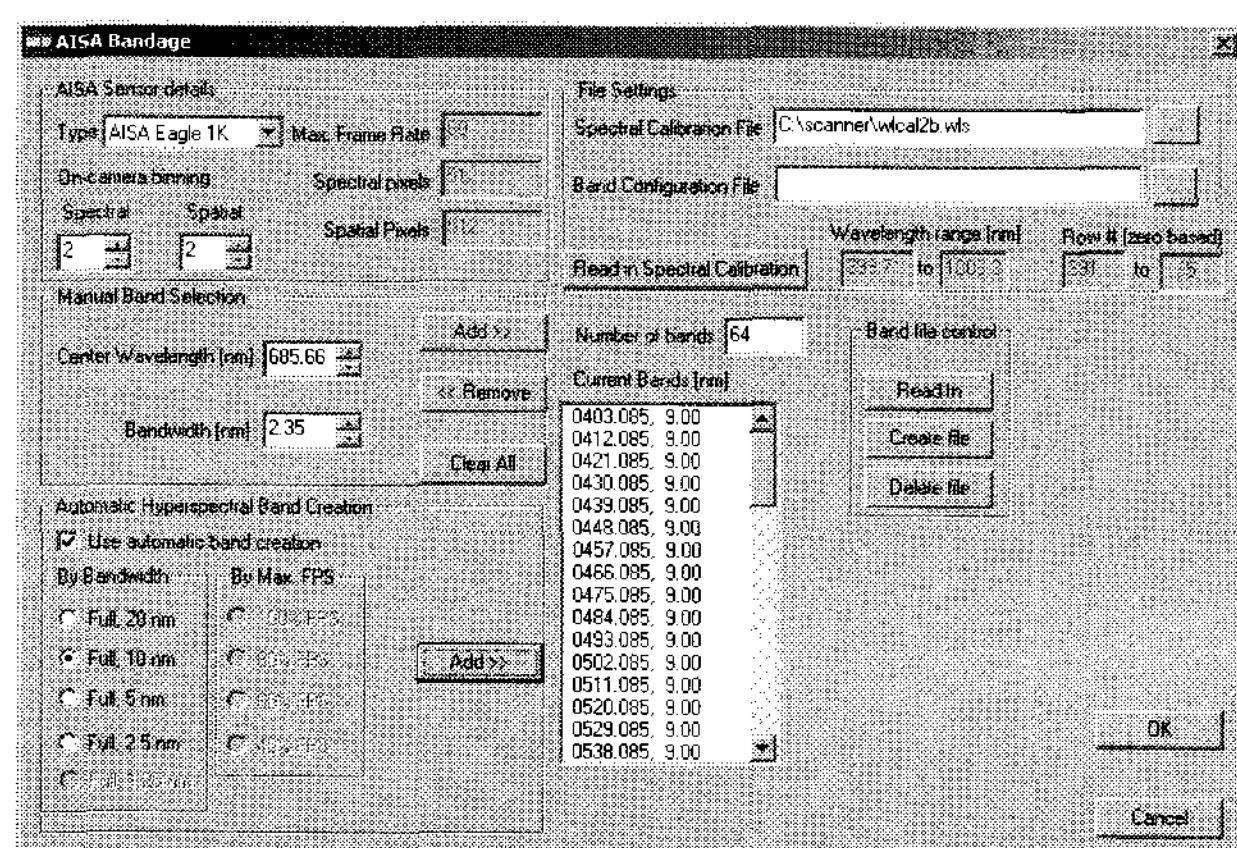


Figure 6. The Bandage software.

Two kinds of software that are provided by camera manufacturer will be used for system operation and data processing. For the operation of camera system, the

Bandage, the AISAComm, and the RSCube software will be used step by step. The Bandage software defines and creates the spectral band configuration such as Fig. 6. The purpose of AISAComm software is to establish the communication channel for the camera system and to control the system parameter such as the frame rate and integration time. The RSCube software in Fig. 7 is the camera operation software. It will be used to monitor the camera performance and watch a real-time display of what is being imaged during the mission.

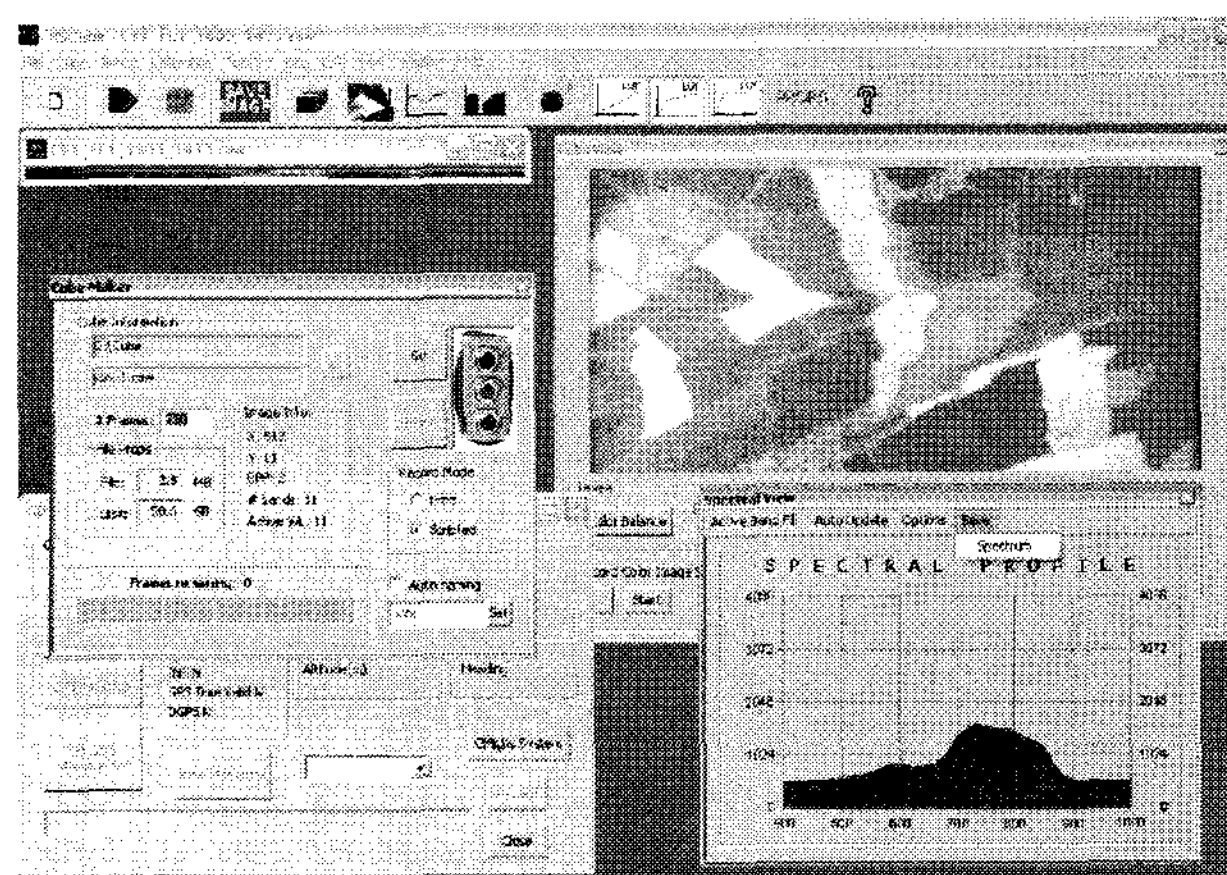


Figure 7. The RSCube software.

For the operation of GPS/INS, the MIDG II Sync and the MIDG II software will be used to synchronize time between laptop data and GPS/INS data and to facilitate immediate access to the MIDG II data for evaluation and test.

Meanwhile, the CaliGeo software and KARI Tools in ENVI software will be used for data processing. Fig. 8 shows the data processing flow by the GaliGeo software and KARI Tools in ENVI software. Radiometric and geometric correction should be done by the CaliGeo software with calibration, dark image, band configuration, and GPS/INS files.

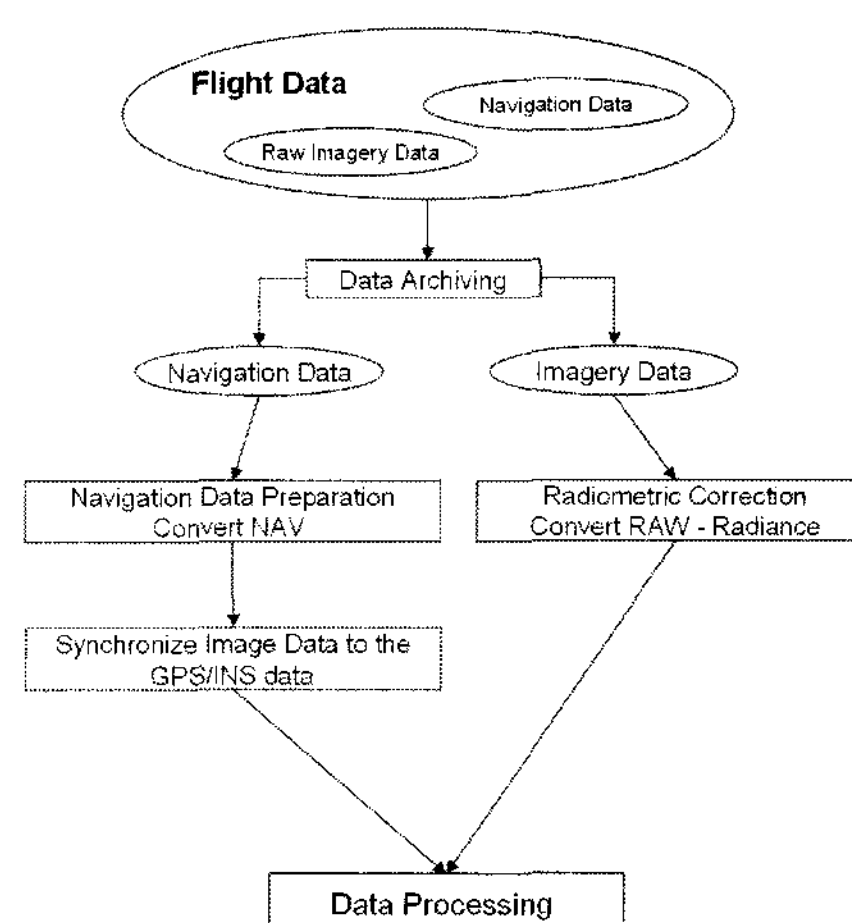


Figure 8. The data processing flow.

2.7 Power Inverter and Distributor

The power inverter is necessary to convert a DC power source to AC power for the CAISS operation during the flight because most of airplane only provides a DC power source. The DC power cable on the airplane will be directly connected with the power inverter. After the power converting, the AC power will be transmitted to each subsystem through the power distributor such as the multi-tap.

2.8 Calibration Equipments

The calibration equipments are not part of the CAISS. However, these equipments are an essential component of any imaging system. Fig. 9 shows the product tree of the calibration equipment for the CAISS. All calibration equipments including the optical table will be installed in the optical laboratory.

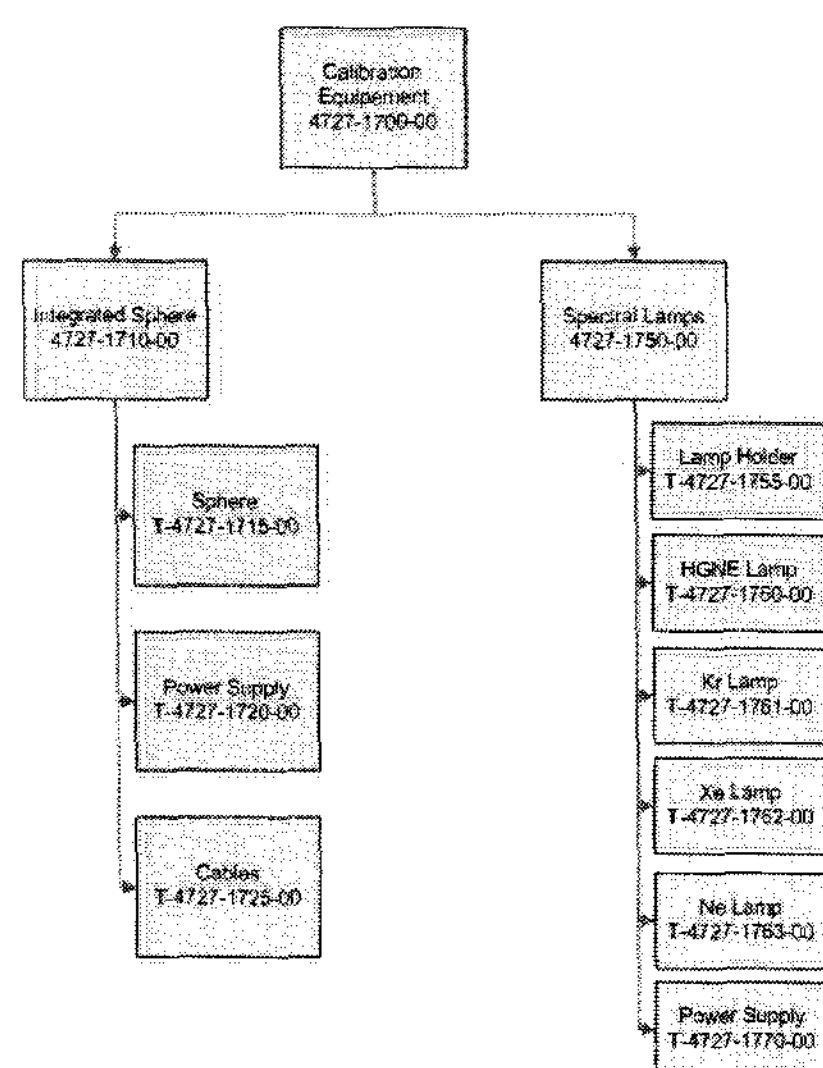


Figure 9. The calibration equipment for the CAISS.

The radiometric and spectral calibration of the camera system will be performed with the integrated sphere and the spectral lamps in the optical laboratory. Fig. 10 shows the process of preliminary experiment for radiometric and spectral calibration in ELOP Lab., Israel. Verification and calibration of the CAISS will be performed once again at KARI site after the delivery.

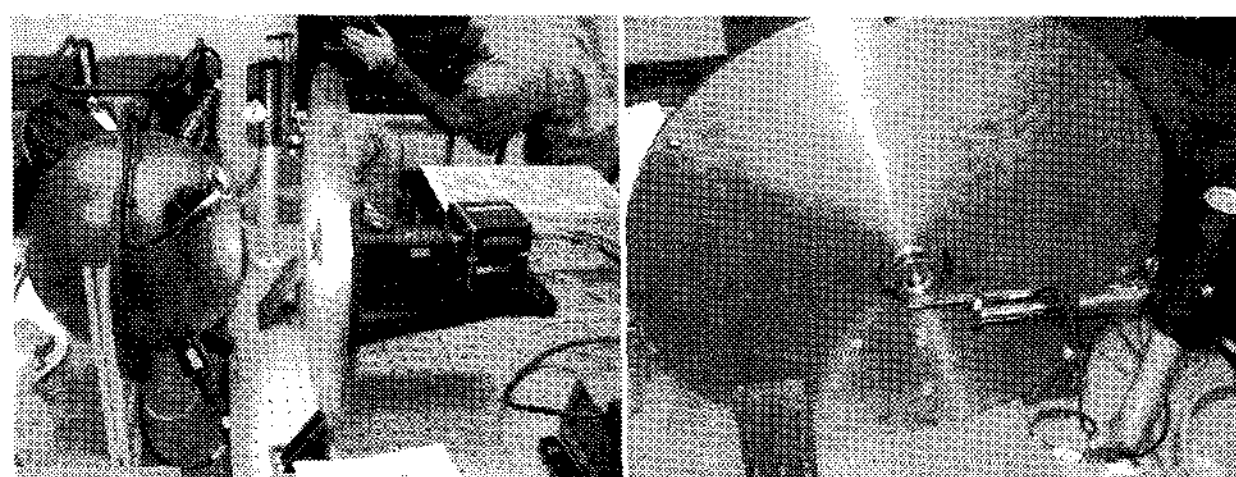


Figure 10. The experiment of preliminary calibration for the camera system.

3. SUMMARY

This paper summarizes the design, development and major characteristic of the CAISS. The proposed CAISS is a compact high performance imaging spectrometer which will meet full contiguous spectral requirement with high spatial resolution for advanced applications in the field of remote sensing. Also the CAISS has the ability to use as the vicarious calibration equipment for the cross-calibration of satellite image data because the CAISS will provide high quality image data with calibration files. The calibration equipment such as the integrated sphere and the spectral lamps will be installed and used for the radiometric and spectral calibration of the CAISS. The acceptance test of the CAISS at Israel site was carried out in September 2007. However, verification and calibration of the CAISS including the flight test will be performed once again at KARI site after the delivery.

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