Dual Imaging Readout Electronics for long-term Remote Sensing Measurements from CubeSats in Low-Earth-Orbits

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Introduction

Motivation

- CubeSats are cutting-edge **educational** and very effective technology and scientific **demonstration** platforms for remote sensing instrumentation
- **customized** payload **electronics** have to be developed depending on measurement tasks and requirements for science missions
- complex remote sensing payloads require **state-of-the-art performance** to provide the operational control and specific data processing for image sensors
- applications with high-resolution, high-speed imaging instruments, acquisition sequence control and image processing (e.g. data compression) force strong **real-time requirements** on the payload design
- limited downlink capabilities require the online **data reduction** of the system data rates
- scientific long-term measurements with remote sensing instruments become increasingly important for the modeling of the climate system and lead to a great interest for cost-effective reliable payload electronics with **short development** time and **maximum performance**

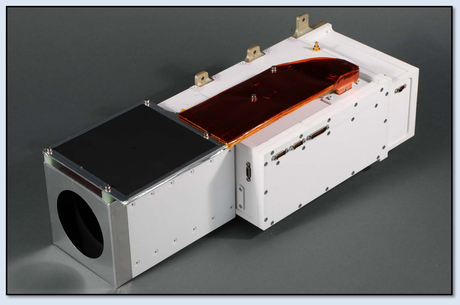


Figure 1: In-Orbit Verification - AtmoSHINE remote sensing instrument (launch date: 22-12-2018)

Impact

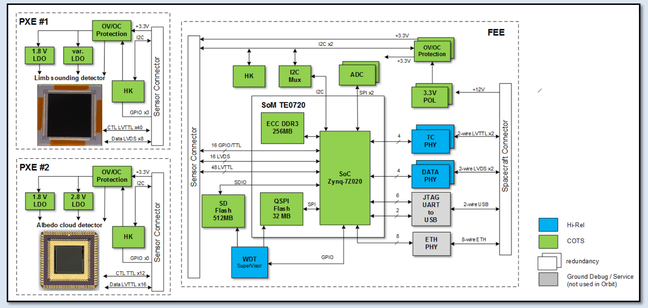
- high speed and high spatial resolution for long term temperature measurements of an atmospheric region
- optimizing of on-board data processing and retrieval routines
- reliable commercial off-the-shelf (COTS) electronics with state of the art technologies under space conditions

Electronics Design

Key features

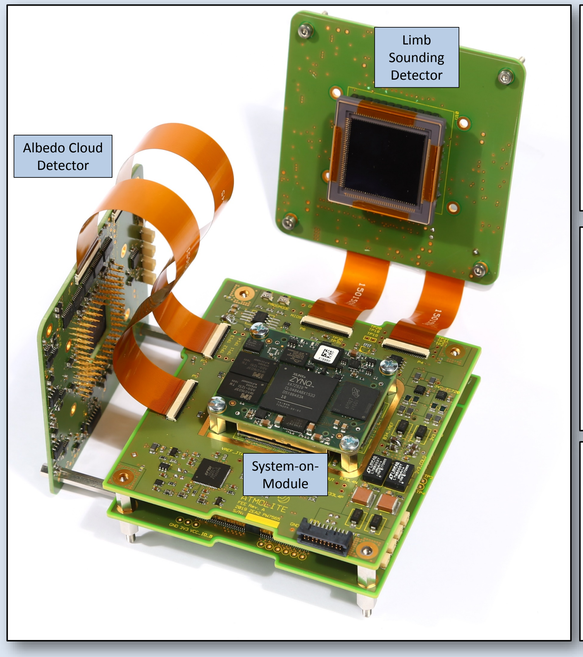
- radiation tolerant CubeSat sized electronics for several 2D scientific CMOS sensors
- high speed detector data acquisition, onboard data processing and storage, provide housekeeping data and interface to satellite bus
- based on a System-on-Module (SoM) with embedded processor, programmable logic and memory
- modular concept with **P**ro**X**imity **E**lectronics and **F**ront**E**nd **E**lectronics boards
- designed for mission lifetime > 3 years
- data pre-processing (pixel binning) and data reduction for daytime and nighttime measurements

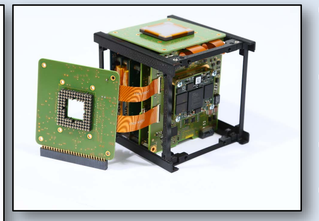
Block diagram

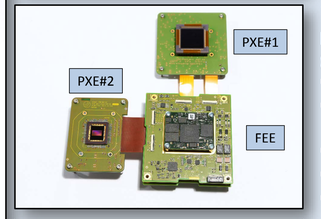


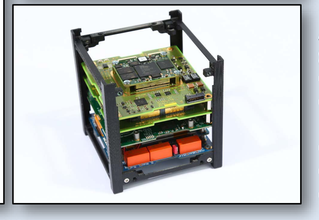
Hardware Implementation

Electronics Assembly









System-on-Module Architecture (TE0720-03-2IF)

- Processing system (PS): XC7Z020: Dual-core ARM Cortex-A9 MPCore™, 667MHz
- Programmable logic (PL): Artix-7 FPGA: 85K logic cells, 4.9 MB BRAM, 220 DSP slices
- Up to 1 GByte DDR3 SDRAM memory
- 32 MByte Quad SPI Flash NAND memory

Limb Sounding Detector (GSENS 400BSI)

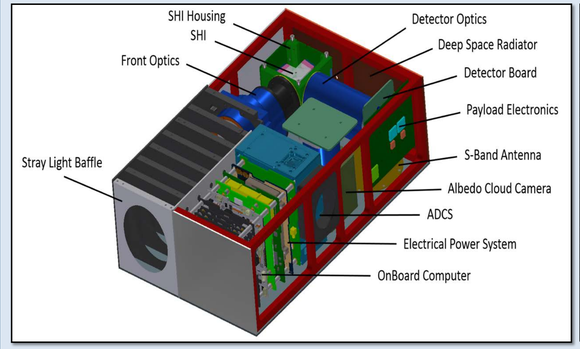
- Image Area: 2048 x 2048 pixels
- Spectral range: 380 – 850nm (QE=0.5)
- Pixel size: 11.0µm x 11.0µm
- Readout noise 1.6e- (rms)
- Dark current: <0.2 e- /pixels @ -50°C

Albedo Cloud Detector (HWK 1910A)

- Image Area: 1920 x 1080 pixels
- Spectral range: 420 – 800nm (QE=0.3)
- Pixel size: 5.04µm x 5.04µm
- Readout noise 1e- (rms)
- Dark current: 2.5 e- /pixels @ 20°C

Instrument Design

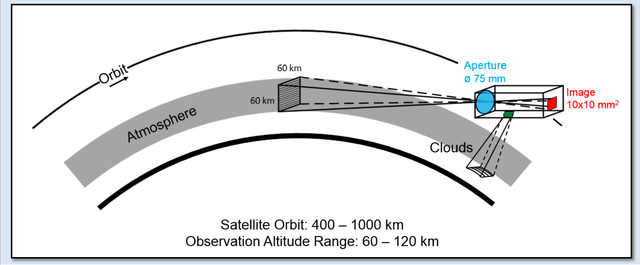
AtmoCube A1: 6U Dual Imager Concept



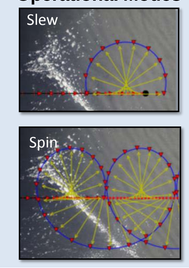
Specification

Optics		
	Aperture	Ø 75 mm
	Etendue (Throughput)	0.02 cm²sr
	Atmospheric limb image	60 km x 60 km
	Variable altitude range	60 km – 150 km
	Altitude resolution	< 1.5 km
	Spectral range	761 – 765 nm
	Max. resolving power (λ/Δλ)	18 500
Detector		
	image sensor	CMOS
	Number of pixels	2048 x 2048
	Quantum efficiency	0.7 at 760 nm
	Thermal control	deep space radiator
Instrument		
	Mass	< 3 kg
	Volume	~ 4 liters
	Power	< 8 W
	Data rate after binning	300 kbit/s
	Attitude control accuracy	0.003 deg (pitch)
	Operating temperature	-40°C to 50°C

Measurement Setup



Operational Modes



Summary

- **dual imaging** electronics based on a SoM architecture requires less development resources, improving reliability
- useful for a wide variety of remote sensing instruments in future LEO missions with capability of **at least 3 years of mission** lifetime
- negligible error rates over mission time using triplicated logic and reconfiguration of the SoM in combination with SEL protection
- analysis of the long-term behavior regarding SEU and SEFI interactions after the end of AtmoSHINE instrument mission is planned

References

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2. Friedhelm Olschewski, Martin Kaufmann, Klaus Mantel, Tom Neubert, Heinz Rongen, Martin Riese, Ralf Koppmann, "AtmoCube A1: airglow measurements in the mesosphere and lower thermosphere by spatial heterodyne interferometry," *J. Appl. Remote Sens.* **13**(2), 024501 (2019), doi: 10.1117/1.JRS.13.024501.
3. Kaufmann, M., Olschewski, F., Mantel, K., Solheim, B., Shepherd, G., Deiml, M., Liu, J., Song, R., Chen, Q., Wroblowski, O., Wei, D., Zhu, Y., Wagner, F., Loosen, F., Froehlich, D., Neubert, T., Rongen, H., Knieling, P., Toumpas, P., Shan, J., Tang, G., Koppmann, R., and Riese, M.: A highly miniaturized satellite payload based on a spatial heterodyne spectrometer for atmospheric temperature measurements in the mesosphere and lower thermosphere, *Atmos. Meas. Tech.*, **11**, 3861-3870, https://doi.org/10.5194/amt-11-3861-2018, 2018.