Imaging Systems for CubeSats

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Agenda

• Introduction of Malin Space Science Systems
• Overview of the ECAM Space Camera Platform
• Recent CubeSat proposals and studies
Malin Space Science Systems

• Who we are
  • Headquartered in San Diego
  • 27 years in the space business
  • 73 employees
• What we do
  • Imaging system development
  • Mission operations
  • Science data analysis
  • Micro Missions Systems
• Track record
  • Cumulative 100+ instrument years of deep space operations
  • Currently operating
    • Three cameras orbiting the Moon
    • Three cameras orbiting Mars
    • Four cameras on the surface of Mars
    • One camera orbiting Jupiter
  • NASA JPL Small Business Prime Subcontractor of the Year Award for 2015
MSSS Flight Experience

- 39 flight instruments
- 21 missions (Mars, Jupiter, Earth, Earth’s Moon, asteroid Bennu)
- 1,000,000+ images commanded & downlinked
- 760,000+ operational hours
Our Customers

- NASA Goddard Space Flight Center (LRO, Restore-L)
- NASA Jet Propulsion Laboratory (MSL, Mars 2020, Juno, etc…)
- Arizona State University (Mars2020, Psyche, Shadowcam)
- Lockheed Martin (OSIRIS-REx, Lucy)
- Naval Research Laboratory (RSGS)
- ITT Exelis (GOSAT)
- Northrop Grumman Innovation Systems (Classified programs)
- Boeing (Classified programs)
The Planetary CubeSats Symposium, August 16th, 2018

Engineering Camera (ECAM)

- Developed under MSSS IRAD, ECAM is a modular space camera platform built to strict NASA standards.
- While it was originally targeted towards engineering applications, ECAM systems have been used for:
  - In-flight diagnostics
  - Deployment/actuator monitoring
  - Space situational awareness
  - Science observations
  - Public outreach
  - Optical navigation

ECAM flight unit for OSIRIS-REx

Navcam star image in-flight

Stowcam image in-flight
ECAM Architecture—DVR

- DVR interfaces to cameras (power, data, commanding).
- DVR processes and stores data (Bayer pattern interpolation, compression, and buffering—from 8 to 32 Gbytes of flash).
- DVR provides one power (28 V) and one data interface to the S/C.
- DVR baseline I/F is SpaceWire, but it can accommodate any customer specified four-line LVDS or RS-422 interface.
- DVRs can be daisy-chained, making a DVR8 or DVR12, still with a single S/C command/data interface.
ECAM Architecture—Camera Heads

ECAM-C50
- 5MP CMOS sensor (color or B/W)
- 2.2µm pixel pitch
- (2592 x 1944)
- Rolling Shutter
- Commandable exposure

ECAM-P50
- 5MP CMOS sensor (color or B/W)
- 4.8µm pixel pitch
- (2592 x 2048)
- Global Shutter
- Commandable or Auto exposure

ECAM-IR3a
- VGA format uncooled microbolometer
- 17µm pixel pitch (640 x 480)
- Optional calibration flag

*Variety of standard optics available without NRE
Quality and Heritage

- ECAM system components meet the requirements of NASA EEE-INST-002, Level 2.
  - The parts list was approved by the GSFC Parts Control Board for the OSIRIS-REX program.
- ECAM hardware can be customized for different environments. Systems have been delivered for:
  - Deep space
  - Low Earth Orbit
  - Geosynchronous Orbit
- All standard ECAM subsystems have a NASA Test Readiness Level of 9.
ECAM Systems Delivered to Date
Recent CubeSat Imaging System Case Studies

- MSSS has recently proposed ECAM systems for several CubeSat SIMPLEx proposals:
  - Mars Micro Orbiter (MMO), Malin Space Science Systems
  - PrOVE, UM/NASA GSFC
- These illustrate that there are options for imaging systems that fit on CubeSats that also have heritage, reliability and performance.
Mars Micro Orbiter (MMO)

• PI: Mike Malin, MSSS
• Instrument Purpose:
  • To conduct global observations of Mars from orbit in visible and infrared wave-lengths to monitor its atmosphere.
• The payload consists of:
  • One visible camera
  • Two thermal IR cameras with a shared filter wheel
MNO Visible Camera—Description

- ECAM-C50 visible camera w/WFOV lens
  - 5MP CMOS sensor, 2.2µm pixel pitch (2592 x 1944)
  - Bayer Pattern Filter for RGB color
  - WFOV lens (55° x 76°)
- FPGA-based architecture
- 5V power, 100 Mbps SpaceWire interface
- Mass: 400g
- 57mm x 78mm x 108mm
MMO Thermal IR Cameras—Description

- Two ECAM-IR3a thermal infrared camera w/Mars2020 Mastcam filter wheel
  - VGA format with 17µm pixel pitch (640 x 480) Uncooled Microbolometer
  - 2 MFOV lenses (20° x 27°)
  - FPGA-based architecture
  - 5V power, 100Mbps SpaceWire interface
- Mass: ~1400g
- 91mm x 130mm x 108mm
MMO IR Optics

- The IR system integrates two cameras with a shared eight position filter wheel
  - Each camera can image through three bandpass filters.
  - Each camera has a calibration target as its fourth “filter”.
  - Heritage filter wheel driven by Cobham stepper motor.
  - One lens is optimized for 7.5 \( \mu m \) to 13 \( \mu m \), the other for 14 \( \mu m \) to 16.5 \( \mu m \).
  - The ability to adjust focus with filter thickness relaxes the axial chromatic correction.
Primitive Object Volatile Explorer (PrOVE)

- PI: Tilak Hewagama, UM
- MSSS’s contribution is VisCAM:
  - An ECAM-M50 with custom optics that provides 8m spatial resolution at 300km.
  - ECAM-DVR4 provides power conditioning, camera control, image processing, compression, and storage.
- Instrument Purpose:
  - Provide high spatial resolution mapping of a Jupiter-family comet surface and/or a new comet surface.
  - These maps will provide the first observations of a new comet surface.
VisCAM Instrument—Description

- ECAM-M50 visible camera w/ custom optics
  - 5MP Monochrome CMOS sensor, 2.2µm pixel pitch (2592 x 1944)
  - Custom 132mm, F/4.2 lens (1.9° x 2.5°)
  - FPGA-based architecture
  - 5V power, 100Mbps SpaceWire interface
  - Mass: 600 g
  - 57mm x 78mm x 164mm
Conclusion

• The MSSS ECAM architecture provides viable options for CubeSat applications where high reliability, heritage, and performance are required.
• ECAM system components are built to NASA reliability standards and are now flying on multiple missions (TRL 9).
• ECAM systems can be customized for a range of environments, applications, and configurations.
• This shows that imaging systems with science-driven performance that meet NASA deep space requirements can be compatible with CubeSat missions.