ECAM, a Modular Spaceflight Imaging System—First Flight Deliveries. M. A. Ravine[1], J. A. Schaffner[1] and M. A. Caplinger[1], [1]Malin Space Science Systems, Inc., P.O. Box 910148, San Diego, CA 92191, USA, e-mail: cameras@msss.com.

Introduction: Since 2009, Malin Space Science Systems, Inc. (MSSS) has used our extensive experience in science instruments to develop the modular, space qualified, ECAM imaging platform (Figure 1). While ECAM was originally conceived for engineering camera applications, its flexibile architecture makes it useful for science applications as well. MSSS has delivered four ECAM systems to four different customers and for widely varying missions and is under contract for two additional systems. The variety of real-world applications and interface requirements has proven the flexibility of the architecture, expanded the heritage of the common elements, and provided useful insight for further development. Through a custom, ECAM-derived camera development for NASA Goddard Space Flight Center, MSSS has qualified a new 2592 x 2048 format CMOS sensor with 4.8 µm pixels. In parallel with this custom design, MSSS is developing two new ECAM-compatible cameras based on this sensor (each available in color and monochrome versions); the two cameras provide different balances of volume/mass/power vs. performance/features.

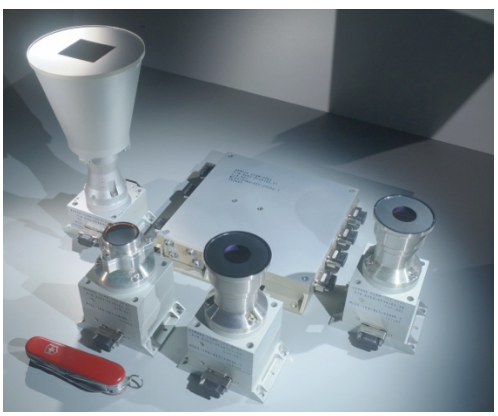

Figure 1. A flight ECAM 4-port Digital Video Recorder and visible CMOS and thermal IR Cameras (DVR4, center; CMOS camera head, left; IR camera heads, front and right; Swiss Army Knife for scale).

ECAM modular spaceflight imaging system platform: Each ECAM system consists of a DVR and one or more camera heads. Camera heads interface to the DVR through a standardized interface that provides power and data on a single cable, with pin counts minimized to reduce cable mass. Examples of delivered flight hardware are shown in Figure 1.

Digital Video Recorders (DVRs). There are three configurations of DVRs, supporting one, four, or eight sensor heads. DVRs include a 128MB volatile buffer and non-volatile buffers of 8, 16, or 32GB. The baseline system performs JPEG (lossy) and Huffman first-difference lossless compression. JPEG2000, LOCO-I, or H.264 compressors may also be implemented. The embedded soft-processor runs the instrument flight software, which implements the higher-level layers of the camera and spacecraft interface protocols and orchestrates all functions performed by the logic peripherals. A flight DVR4 board is shown in Figure 2.

Figure 2. A flight ECAM 4-port DVR PCB.

Visible Wavelength CMOS Camera. The ECAM-C50 acquires 2592 x 1944 format images with 2.2 µm pixel pitch; either Bayer pattern (color) or monochrome versions of this sensor are available. The C50 camera head weighs less than 250 g (without optics or mounting brackets).

Long-Wave Infrared Microbolometer Camera. The ECAM-IR3A uses an uncooled amorphous silicon microbolometer to acquire 640 x 480 format images with 17 µm pixels in the Long Wave Infrared band (8-13µm wavelength). It has a similar (though somewhat larger) mass and form-factor as the C50. An image taken with one of these cameras is shown in Figure 3.

Optics. For the visible camera (C50), there are four standard lens options, ranging from ~90° to 15° fields of view. These optics are fixed focus and are athermalized to provide stable performance over a wide temperature range. There are two standard LWIR lenses, with fields of view of ~20° and ~60°.

Interface. The DVR data interface to the spacecraft is comprised of eight LVDS differential pairs (RS-422 optional) in each direction, split across redundant connectors with independent drivers and receives. The interface is implemented in programmable logic, allowing substantial customization. For the units already delivered, interfaces have included SpaceWire, low-speed asynchronous, and high-speed synchronous, with both RS-422 and LVDS at the electrical level.

TRL. Flight ECAM systems have been assembled, qualified, and delivered, bringing all components of the baseline ECAM system to TRL 8. With the lauch of OSIRIS-REx in September of 2016, the DVR and visible cameras will be at TRL 9. The IR camera is expected to fly in early CY2017, at which point it will also be at TRL 9.

Figure 3. A thermal IR image of the Moon taken with an ECAM IR3A camera.

ECAM flight deliveries: MSSS delivered three flight ECAM systems in CY2015 and CY2016. They are as follows:

OSIRIS-REx TAGCAMS (Lockheed Martin). The Touch-and-Go Camera System (TAGCAMS) is a multi-purpose imaging system installed on the OSIRIS-REx asteroid sample return mission [2]. TAGCAMS consists of a DVR8 and three C50 camera heads each with ECAM medium field of view (MFOV) lenses. One camera will monitor the delivery of the sample from the asteroid Benuu to the Earth sample return capsule (StowCam, see Figure 4); the other two cameras will image the asteroid and background star field to support optical navigation when the spacecraft is in the vicinity of the asteroid (NavCam). OSIRIS-REx is scheduled for launch in September, 2016, with first operation of these cameras shortly thereafter.

Undisclosed customer #1. The second delivered flight ECAM system is a DVR4 with four camera heads: one C50 color visible camera, and three IR3A thermal infrared cameras (Figure 1). The visible camera has a narrow field lens; the IR cameras have a combination of wide- and narrow-field lenses. The system could operate all the cameras in a streaming mode over three parallel SpaceWire ports to the spacecraft. Launch for this system is expected in early CY2016

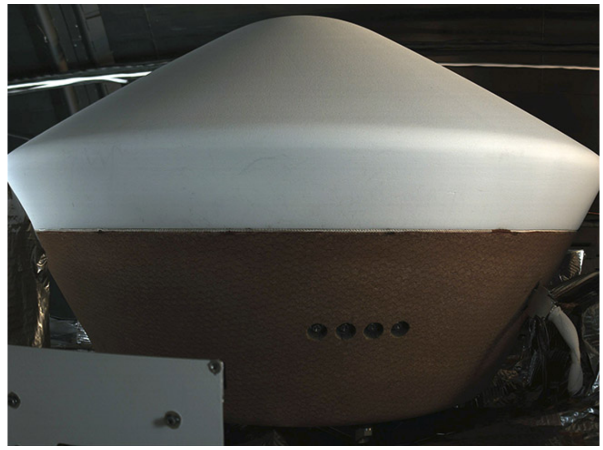

Figure 4. An image of the OSIRIS-REx sample return capsule taken by StowCam after integration with the spacecraft.

Undisclosed customer #2. The third flight ECAM system is a DVR1 system with a single camera head: a C50 color visible camera with a narrow field lens. This system provides after-the-fact knowledge of acquisition time to within 1 ms.

Lessons learned: While each of these programs had their own unique aspects, the recurring theme between them was the need to allocate somewhat more attention to interface and requirements definition early in the program. As expected, each customer had unique interface requirements; Despite this, all could be accommodated with customized FPGA logic, using the single, flexible, data interfaces of the DVR (the only unique hardware configuration being the selection of LVDS or RS-422 drivers and receivers).

References: [1] Schaffner, J. A., M. A. Ravine and M. A. Caplinger (2014), Int'l Workshop on Instrumentation for Planetary Missions, Abstract #1114. [2] Drake, M. J et al., American Geophysical Union, Fall Meeting 2011, abstract #P42A-03.