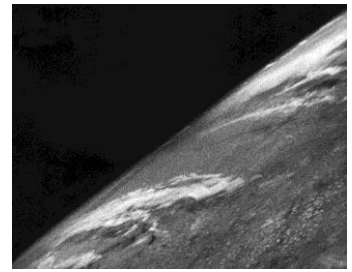
The "Tick-Tock" Model
Ecliptic's Space Camera Approach

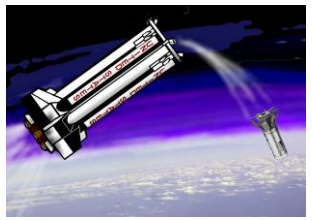
Rouben Sahakian
Ecliptic Enterprises Corporation
1 June 2022

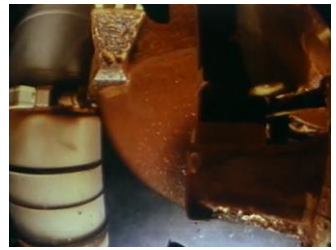
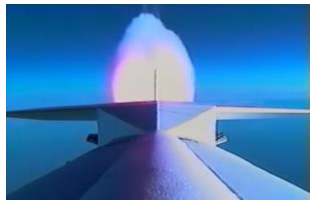
Ecliptic Enterprises Corporation Proprietary

Some of the Early Images and Videos

- 1940s: Early US-based testing of captured German V-2s (Film-based Cameras)
- 1960s and early 1970s
  - Most human space missions (US & USSR) broadcasted live video
  - Saturn Rockets had color film pods returned to Earth by parachute
- 1977 - 2011: Nearly all Shuttle missions broadcasted interior color video, and in later missions exterior video
- 1990s - present day: Live color video (internal and external) has been broadcast from the ISS
- 1992 - 1993: First video systems that were precursors to Ecliptic's RocketCam™ were done by Orbital Sciences Corp. for three Pegasus rockets
- 1998 - 2001: Crosslink Inc. (ex-OSC) produces battery-powered systems with one color analog NTSC camera and analog NTSC transmitter….RocketCam™

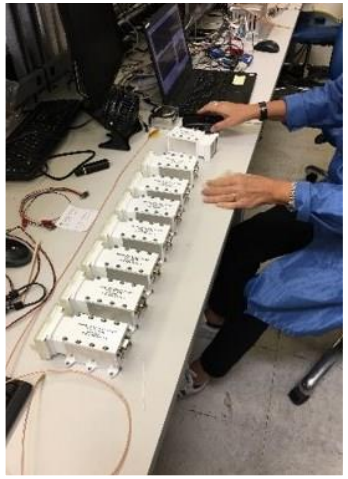




Ecliptic, BlastOff! and Crosslink

- BlastOff! (1999 – 2001) Pasadena, CA
  - Started by Bill Gross (founder of the Internet "incubator" firm IdeaLab) as a stealth company to define and execute the first commercial lunar lander mission
  - Combining world-class space systems and Internet technologies with the Hollywood approach to projects
  - Leading lunar scientists, Apollo astronauts, spacecraft engineers, Internet gurus, and Hollywood advisors (Cameron and Spielberg) worked side-by-side
    - CEO of BlastOff: Dr. Peter Diamandis (X-Prize)
  - In just 6 months, it had 50 employees, a baseline mission and system design, prototyped cameras and rovers, and a rocket on order
  - The dotcom bubble crashed, and doors had to be closed in 2001



- Ecliptic Enterprises Corp. (2001 – present)
  - Upon BlastOff! closing its doors, 11 engineers with the help of angel investor, Peter Sperling, started Ecliptic Enterprises Corp.
  - Peter's only rule: start a new product oriented commercial space firm
    - Not interested in a traditional aerospace company
    - Be disruptive
  - Business Approach
    - Lean and mean, with systems emphasis
    - Product focus (vs. engineering services)
      - Core product family with limited design options
      - Earth – Moon – Mars focus
    - Firm Fixed Price (FFP) catalog pricing (value-based)
      - No cost-plus work
    - Rapport with customers
      - Commercial – Civil – Defense (~all-U.S.)
      - Work with primes vs. directly with government
    - NASA not in series with business plan
  - Within a month of its doors opening, Ecliptic purchased the RocketCam™ product line from Crosslink

Ecliptic Background
Products

Tick – Innovate Tock – Improve/Optimize

- Core products
  - RocketCam™ family of onboard video systems
  - Payload and experiment control and data-handling systems
  - Sequencer systems for spacecraft ejection timing, control and telemetry capture
- Over 160 systems launched
  - ~55% on rockets, ~45% on spacecraft
- Tick Tock Approach to avionics and sensors architecture, circuit board designs, embedded software and firmware implementation
- Significant use of COTS approaches and standards; tailored parts programs
- Heritage commercial to rad-hard versions
- Interfaces proven to be compatible with dozens of rocket and spacecraft platforms
- Considerable successful experience in GEO and cislunar regimes

>100 customers and >400 contracts in 19+ years

Nearly all contracts FFP

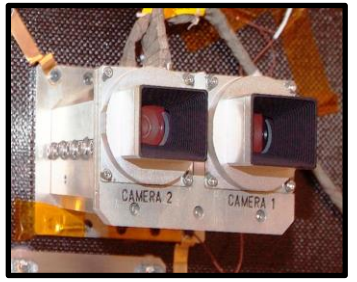
>75 advanced avionics units & >500 cameras launched

Ecliptic Background
Pseudo Tick-Tock

Analog Video System
2001

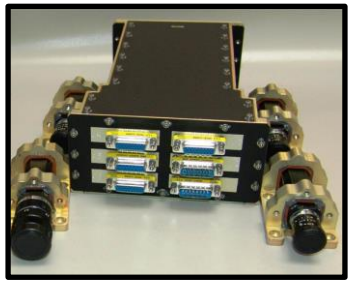
Integrated Video Assembly
2003

Digital Video System – cPCI
2004
Up to 6 Cameras, 1-Channel
Data prioritization and Camera Sequencing



GeoCam - Custom
2005
Dual Camera – JPEG2000
Digital Video for GEO Satellites

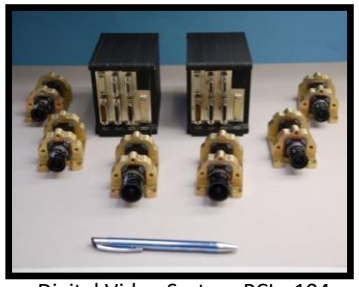
Digital Video System – cPCI
2006
Multiple Cameras and Instruments
Visible, SWIR, LWIR, Spectrometer



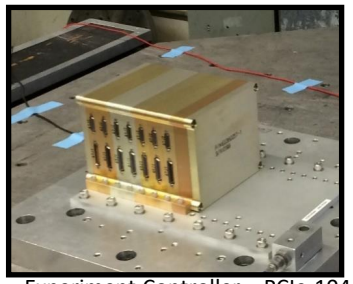
Digital Video System - cPCI
2007
Up to 8 Cameras, 1-Channel
64GB SSD, Realtime and Store/Forward

Microprocessor

RISC MCU/DSP

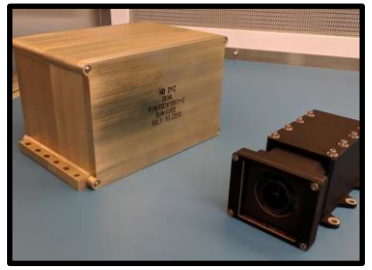


Digital Video System PCIe-104
2009
Up to 8 Cameras, 4-Channels
256GB SSD, Realtime and Store/Forward

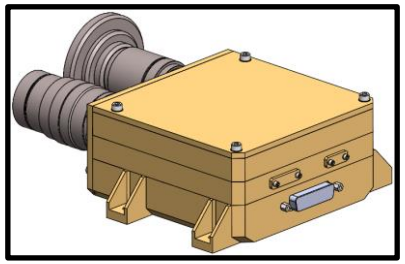


Experiment Controller – PCIe-104
2011
Video, Motor Control, DAC
Realtime and Store/Forward

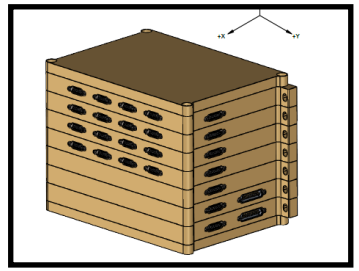
Deployment Sequencer – PCIe-104
2016
Small Satellite Deployer and Video
Deployment of 60 Satellites on Falcon 9



4K HD Digital Video System – PCIe-104
2016
Up to 8 Cameras, 4-Channels
256GB SSD, 12MP Cameras
Realtime and Store/Forward



4K HD Video / 24MP Still
2020
Multi Sensors and Multiple Sensor Types
Up to 6 Sensors Panoramic Views
Smart Cameras



Data Management
2021

FPGA Virtex5

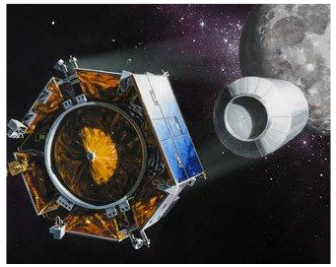
FPGA UltraScale

Ecliptic Background
Mission History

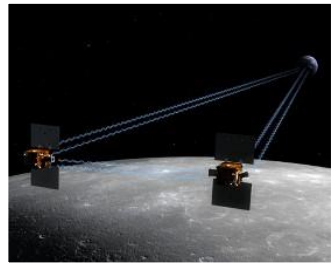
> 30 launches | Multiple US customers
2003+ | Launch Vehicles
Video, payload control, data handling

Various | ~20 missions
2005+ | Rockets and spacecraft
Video, payload control, data handling

> 10 GEO Sats | Three US customers
2007+ | Comsat, tech-demo
Video, expt. control



LCROSS | NASA Ames
2006-2009 | Lunar impact
Complete payload control

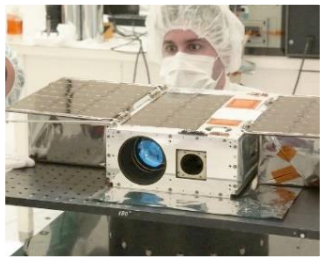


GRAIL A, B | JPL
2008-2012 | Lunar gravity
Video and imaging

>12 Cygnus | Orbital/NG
2010+ | ISS cargo
Video, expt. control

ROSA on ISS | DSS
2012-2017 | Array demo
Complete expt. control

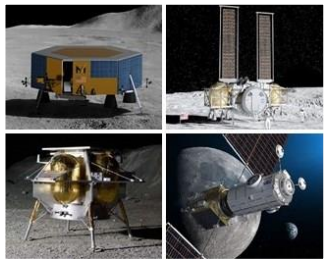
SHERPA | Spaceflight
2016-2018 | Rideshare
60 of 64 deployments



ASTERIA | JPL
2016-2017 | Exoplanets
Imaging electronics

2 LEOs, 2 GEOs | MELCO
2017+ | Comsat, tech-demo
Video, expt. Control
(launching 2021+)

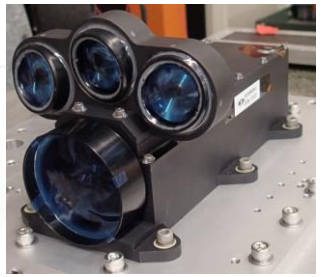
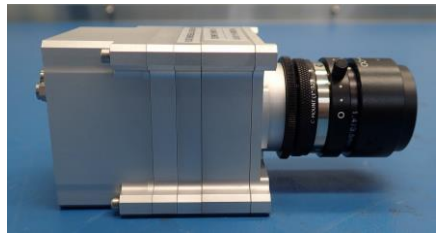
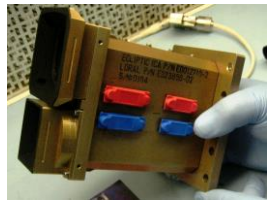
Various | Various
2019+ | Experiment Controller
Complete Experiment Control
Data Acquisition Controller and
Power Control Units

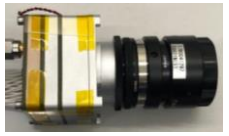


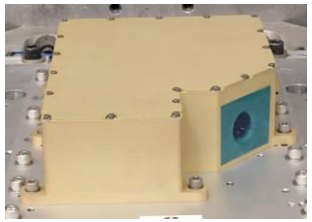
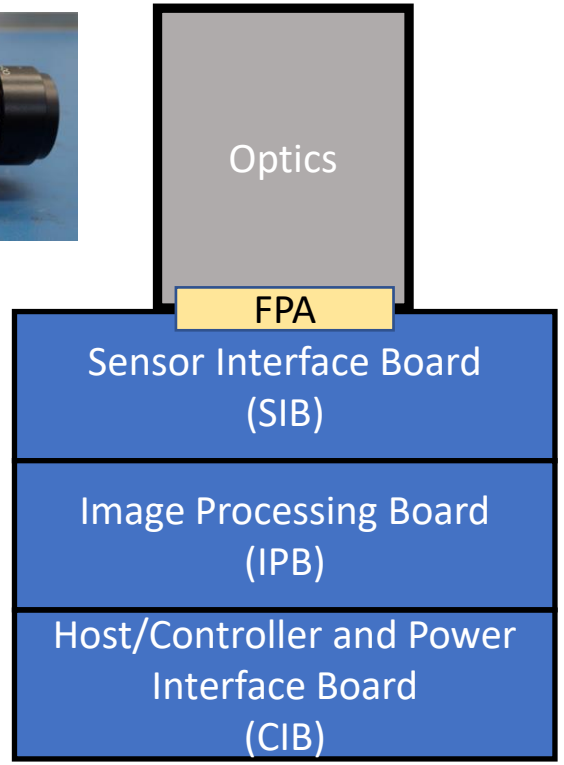
Lunar & cislunar | Nine missions
2020+ | Cargo and crew delivery, logistics
Payload control, video
(launching 2022+)

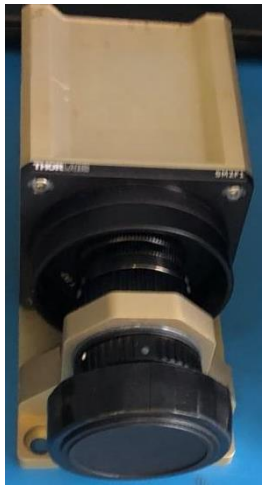
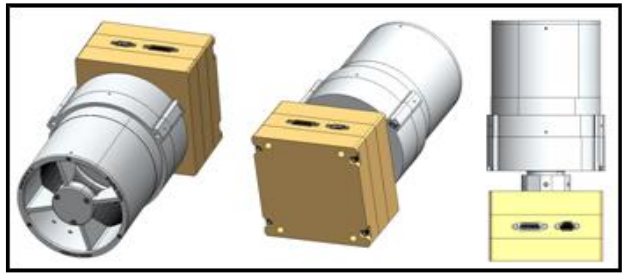
Ecliptic's Cameras
Remote Interface Unit (RIU) plus FPA

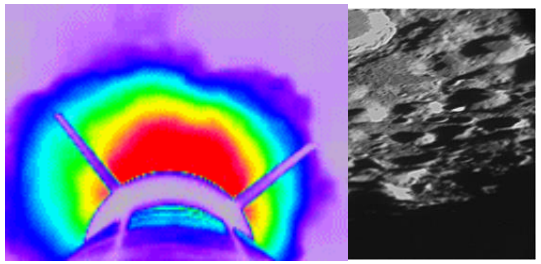
- The RIU was developed to add smart capabilities to sensor front-ends
  - COTS to Space Grade 15 yr. mission life
  - Interface Board to DVC
  - Image Processing Board
  - Sensor/FPA Interface Board
    - Visible 2MP to 24MP, 4 fps to 500fps
    - LWIR, SWIR, Cooled MWIR
    - Multispectral, Spectrometers
    - Customer Defined Focal Plane Array (FPA)
  - Images as CCSDS Packets are generated at the camera/sensor and sent to the DVC



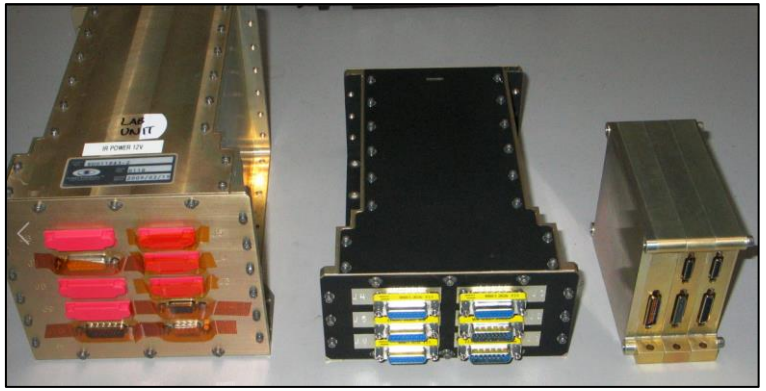



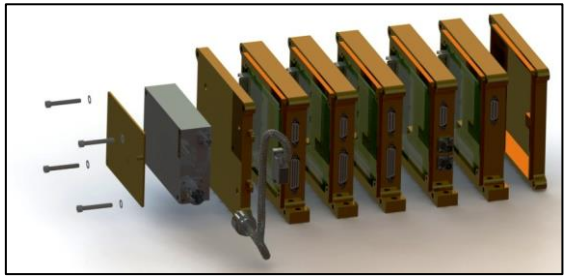





See The Results – The Controller Digital Video System (DVS)

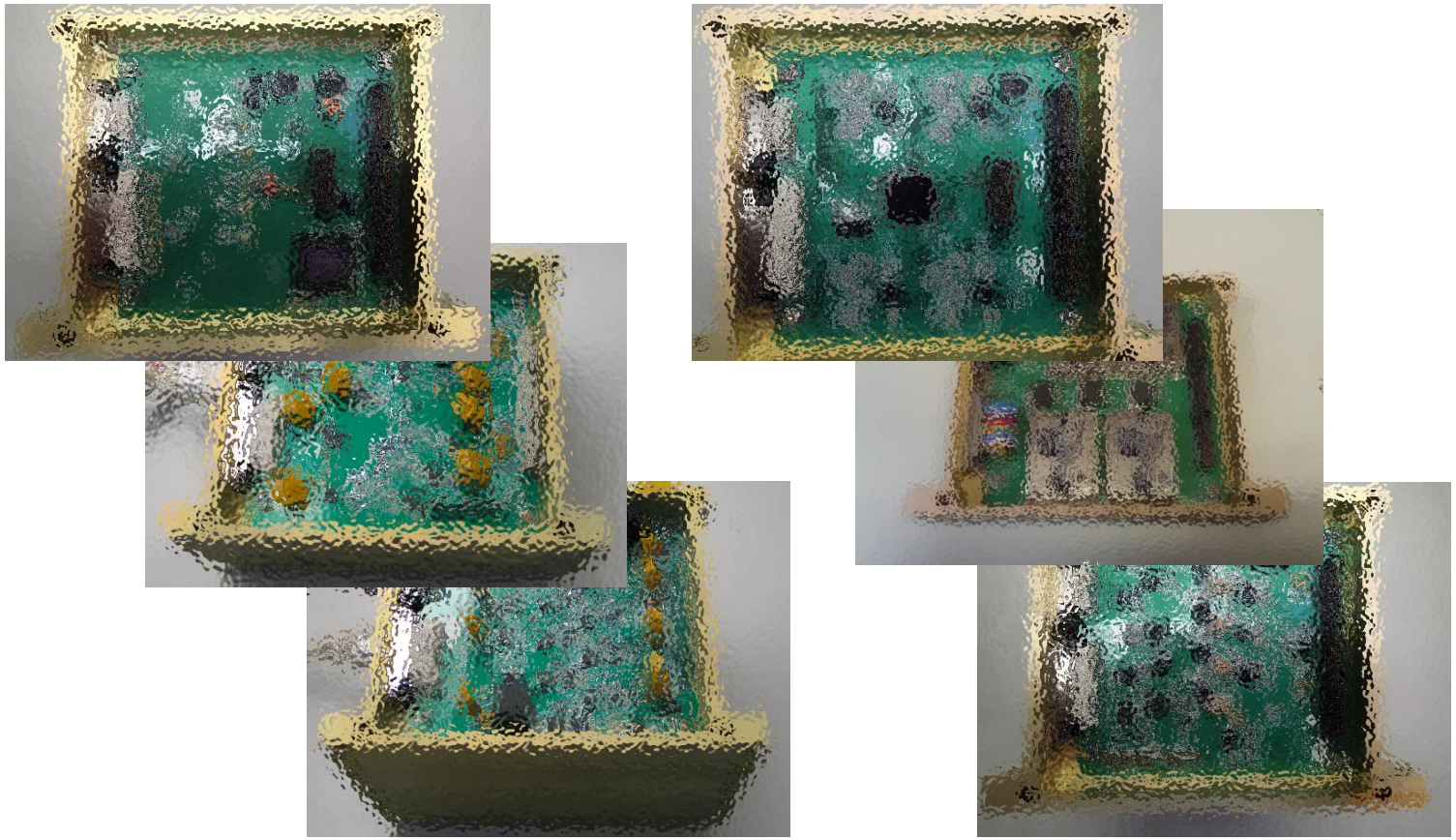
- Ecliptic's Controllers are slice based
  - Manages and controls data flow
  - Multiple Host Interfaces; Multiple Instrument Control
  - Advanced Sequencer for "System Engineers" to program mission specific information
  - Developed for customers who want COTS but need DOTS
  - COTS to Space Grade 15yr. life parts program
  - Minimal configuration
    - Power Support Board
    - Telemetry and Control Board
    - 256GB and 64GB onboard storage (optional)
  - Digital Video System
    - Add Video Compression Boards (JPEG2000, H.264, H.265, and Lossless)
  - Payload/Experiment Controller System
    - Motor Controller Board
    - Analog Telemetry Board
    - Serial Digital Board
    - 8 Port Gig-E Board



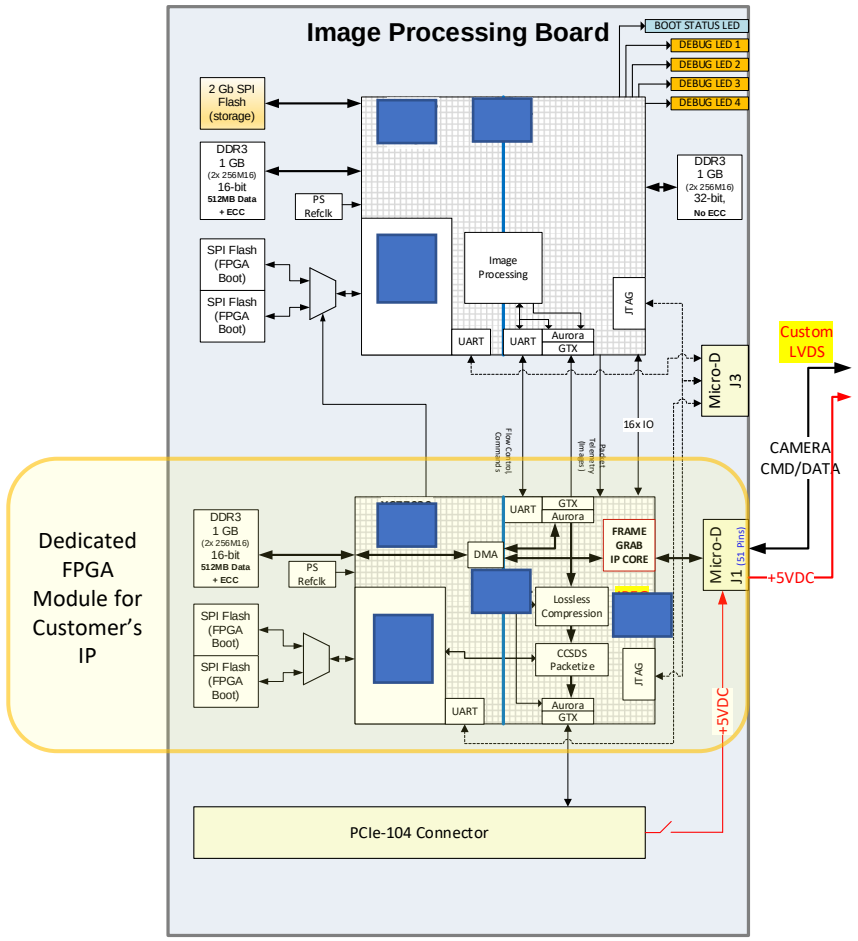


Wide Selection of Boards

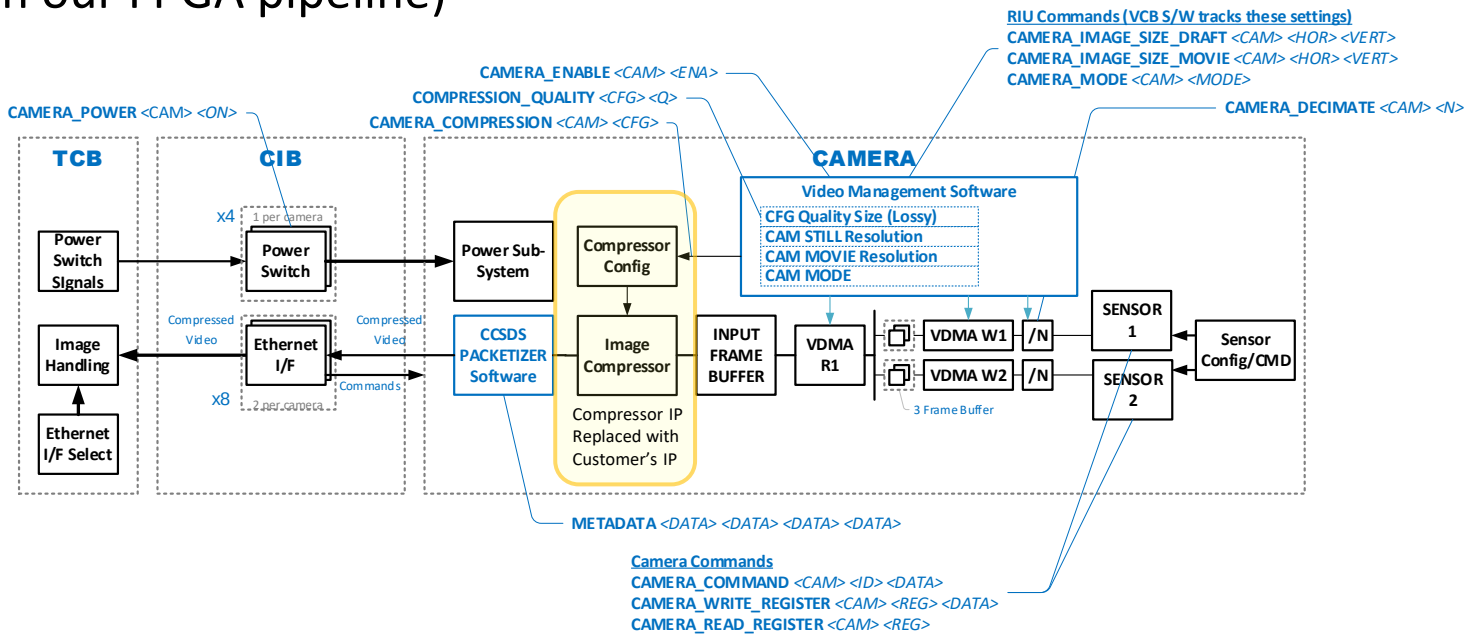
- Power Support Boards (Various)
- Telemetry and Control (T&C) Board
- Video Compression Boards (Various)
- Image Processing Board (Various)
- Solid State Drive Board
- Serial Digital Board
- Battery Support Board
- Value Driver Board
- Motor Control Board
- 1553 Interface Board
- Dual SSD Board with Cold Spare
- Half-Bridge Controller Board
- Actuator Drive Board
- Analog Telemetry Board
- Deployment Actuator and Monitor Board
- Deployment Sequencer Board



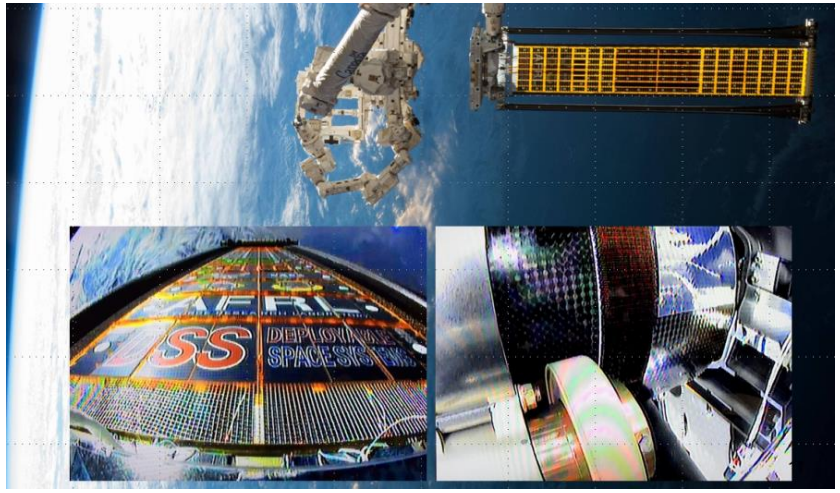
Data Pipeline (Edge Computing)

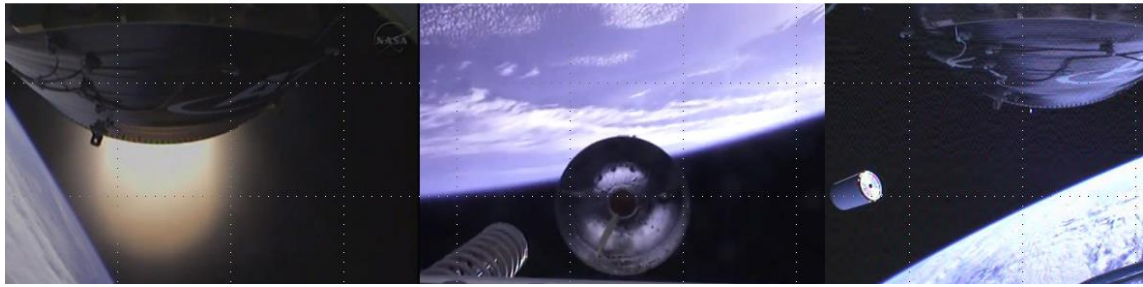


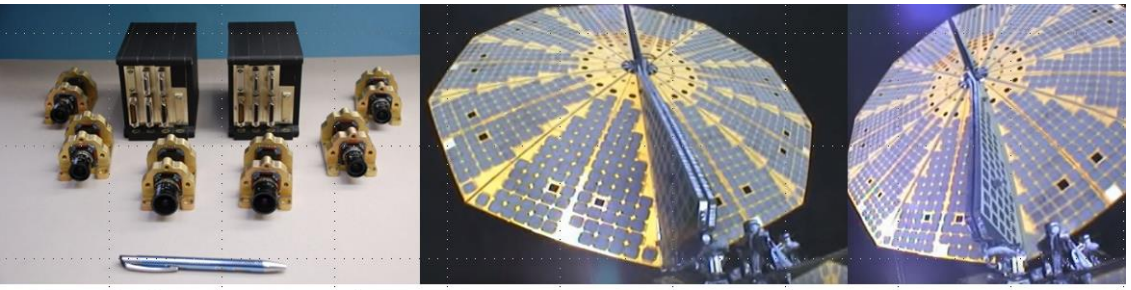
- Integration of Program Specific IP written by Ecliptic, Customers, and/or Vendors
  - Data Analytics
  - AI
  - Navigation
  - SSA
- Loosely Coupled (Separate FPGA) or Tightly Coupled (Embedded in our FPGA pipeline)

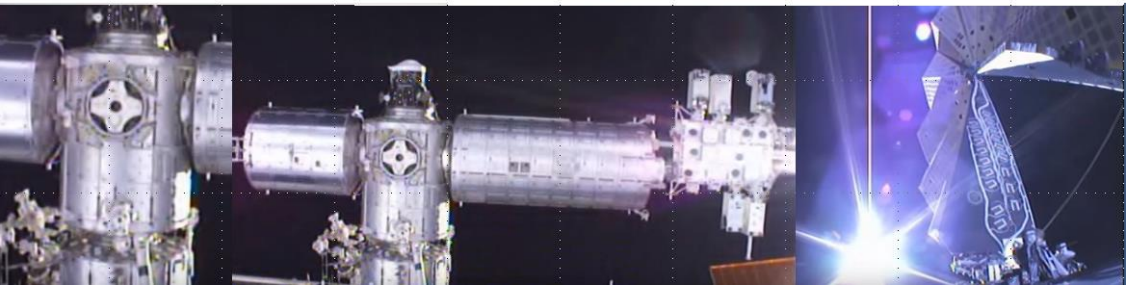


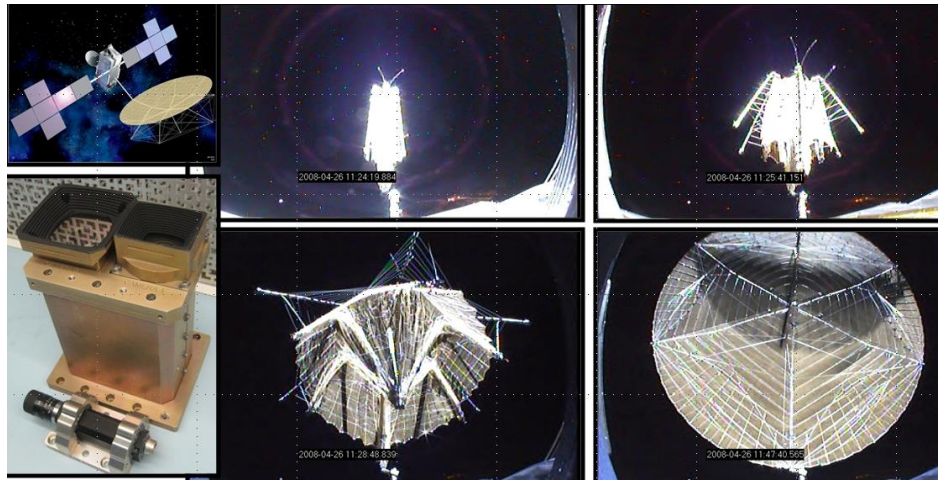
The Different Views of Ecliptic Digital Video System

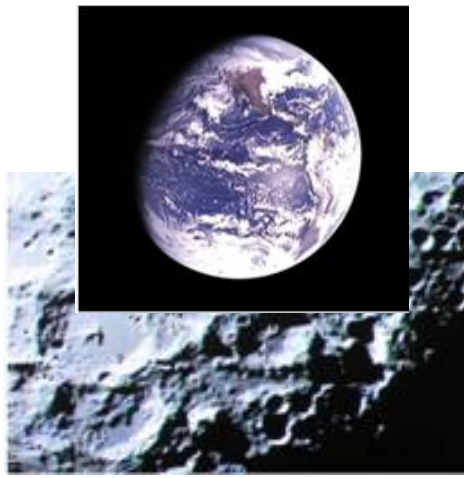












Ecliptic Enterprises Corporation Proprietary

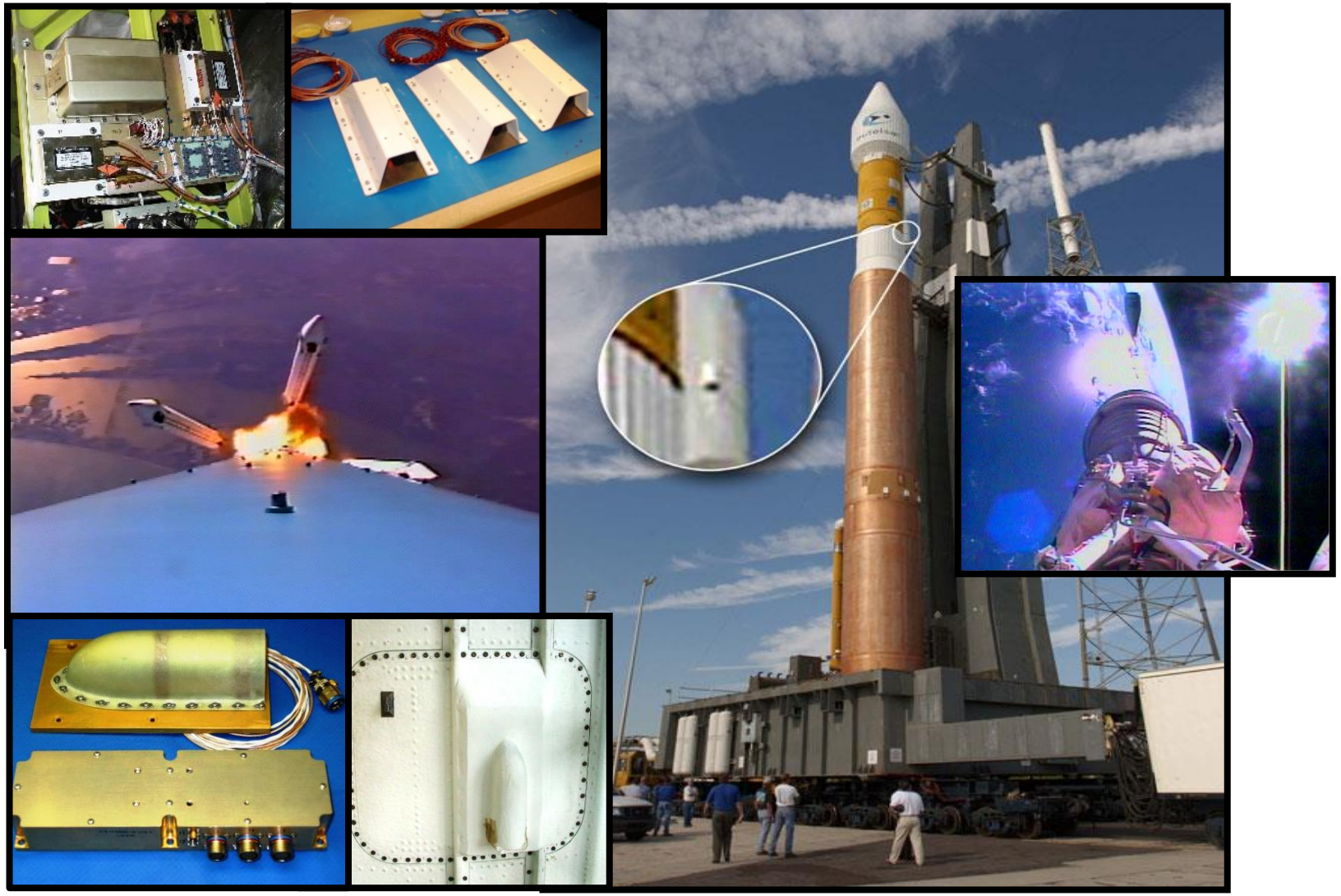
Get The Picture (2001 – 2005)
Analog Video

Analog Video System - 2001

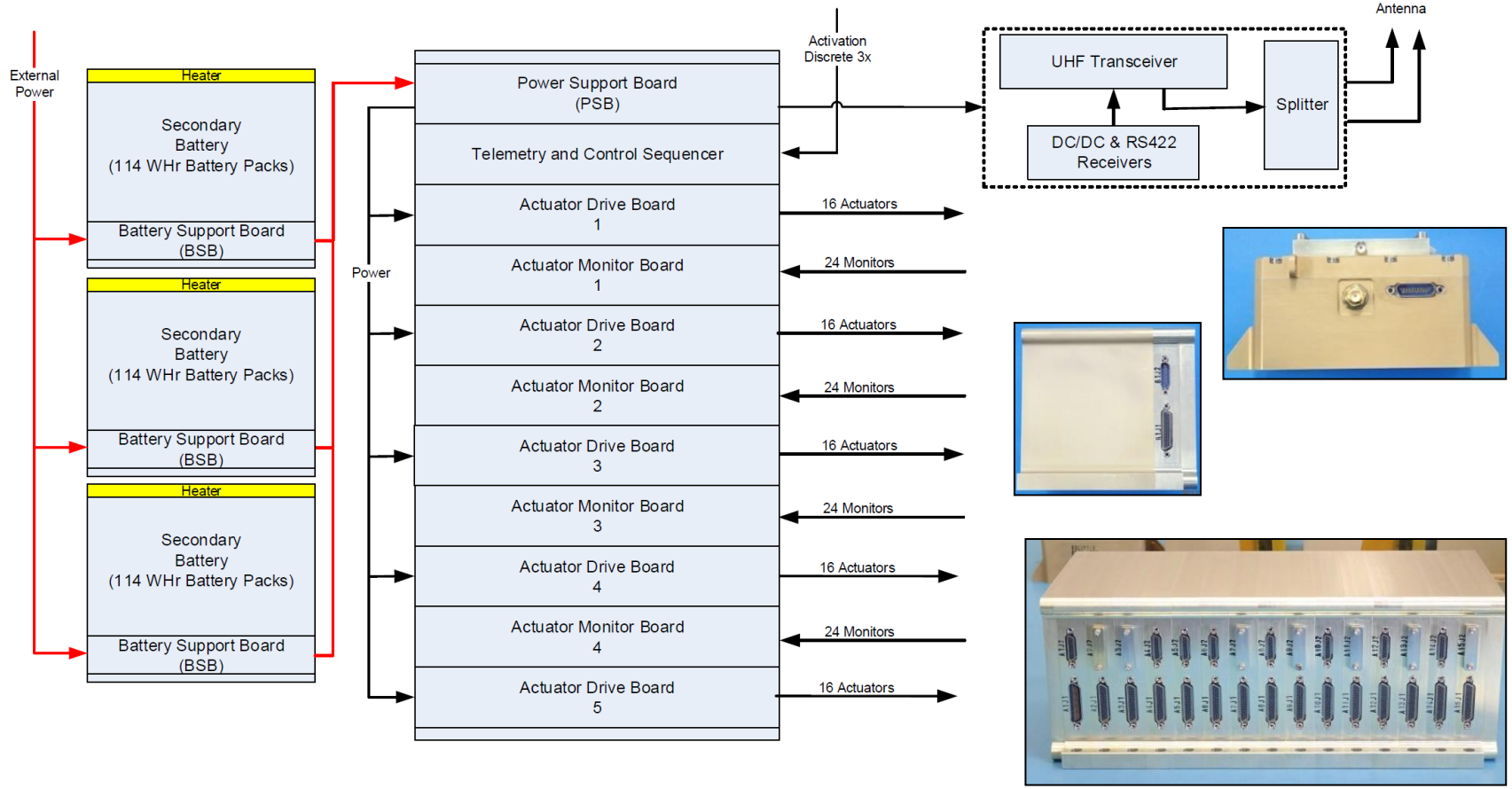
- Individual Components
  - NTSC Cameras and Pods
  - Analog Video Transmitters
  - Battery Packs

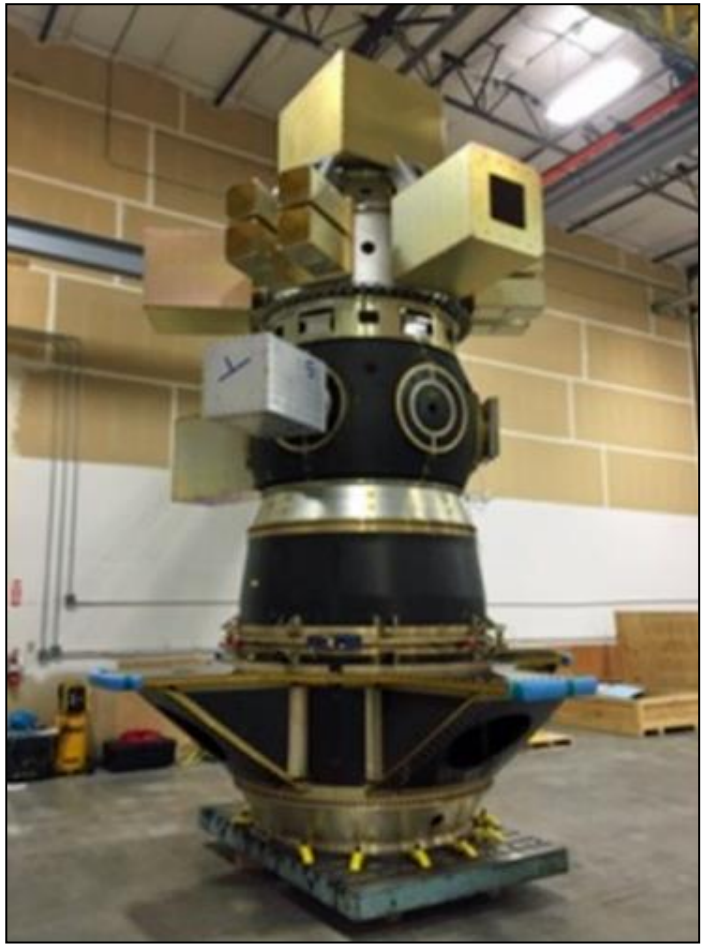
Integrated Video Assembly - 2003

- Analog Video Transmitter, Battery Pack, and Support Electronics combined into common chassis

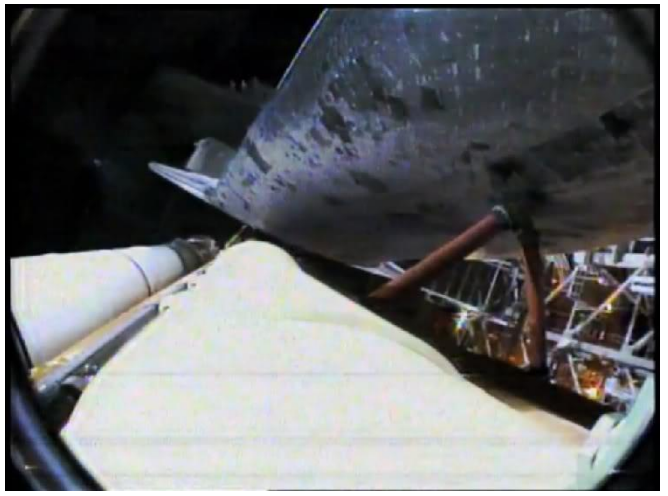


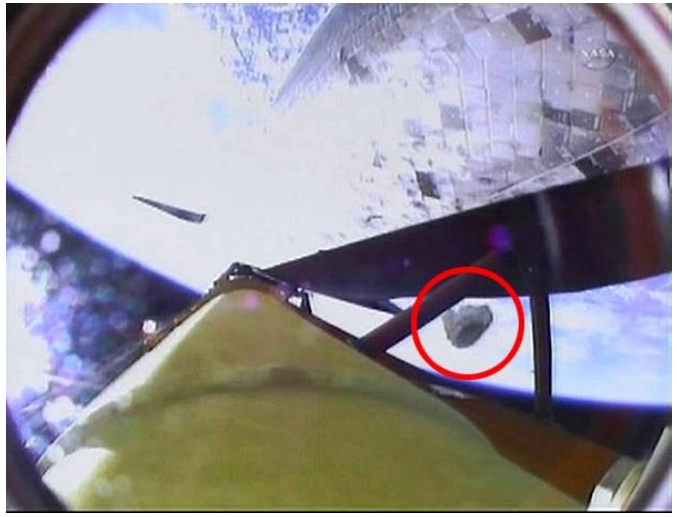
Spaceflight SSO-A Satellite Deployment Avionics

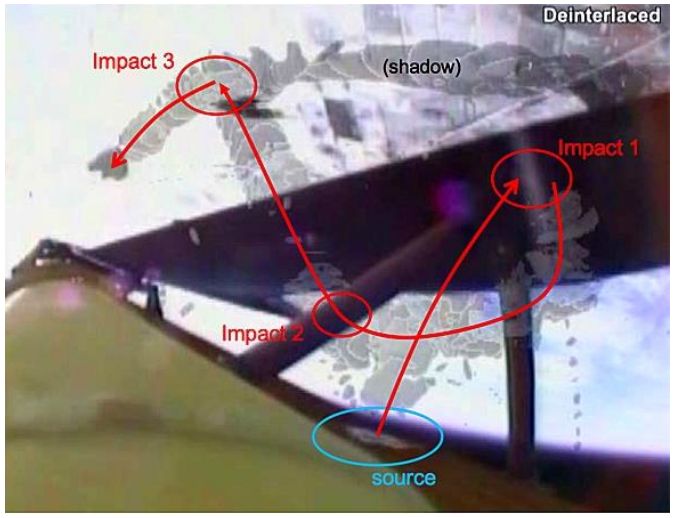




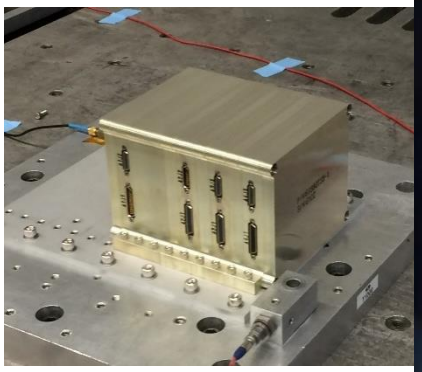
Space Shuttle Debris Monitoring

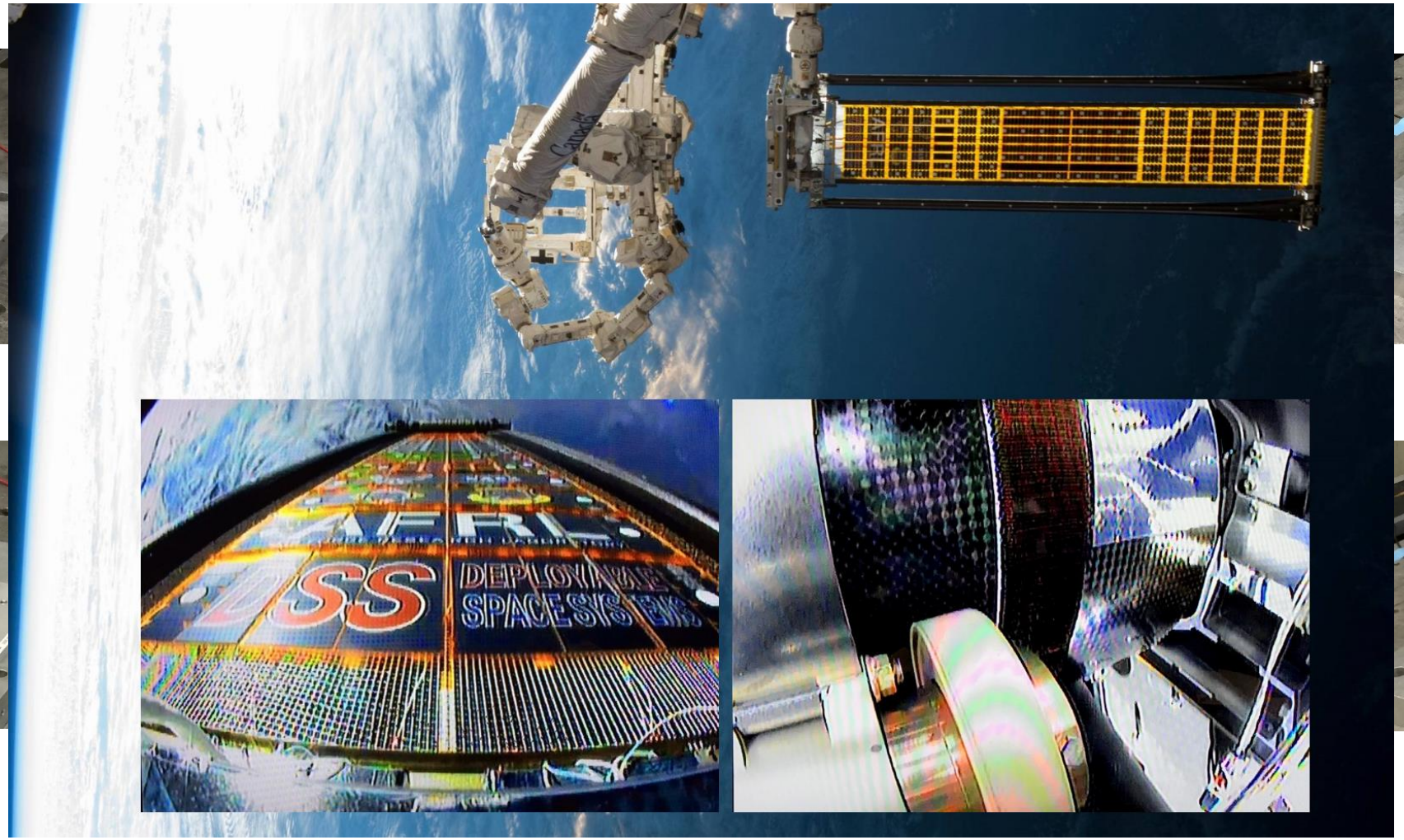


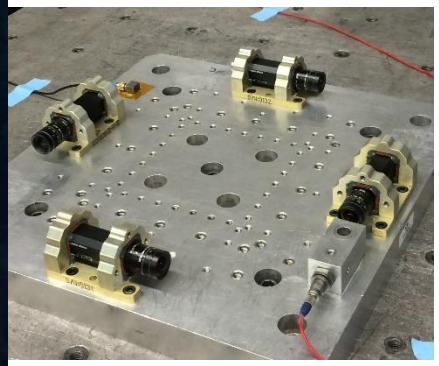


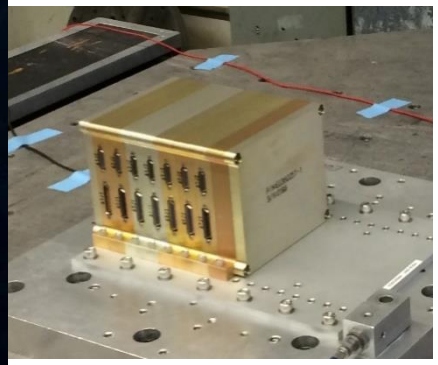


Roll Out Solar Array (ROSA) on ISS (2012-2017)

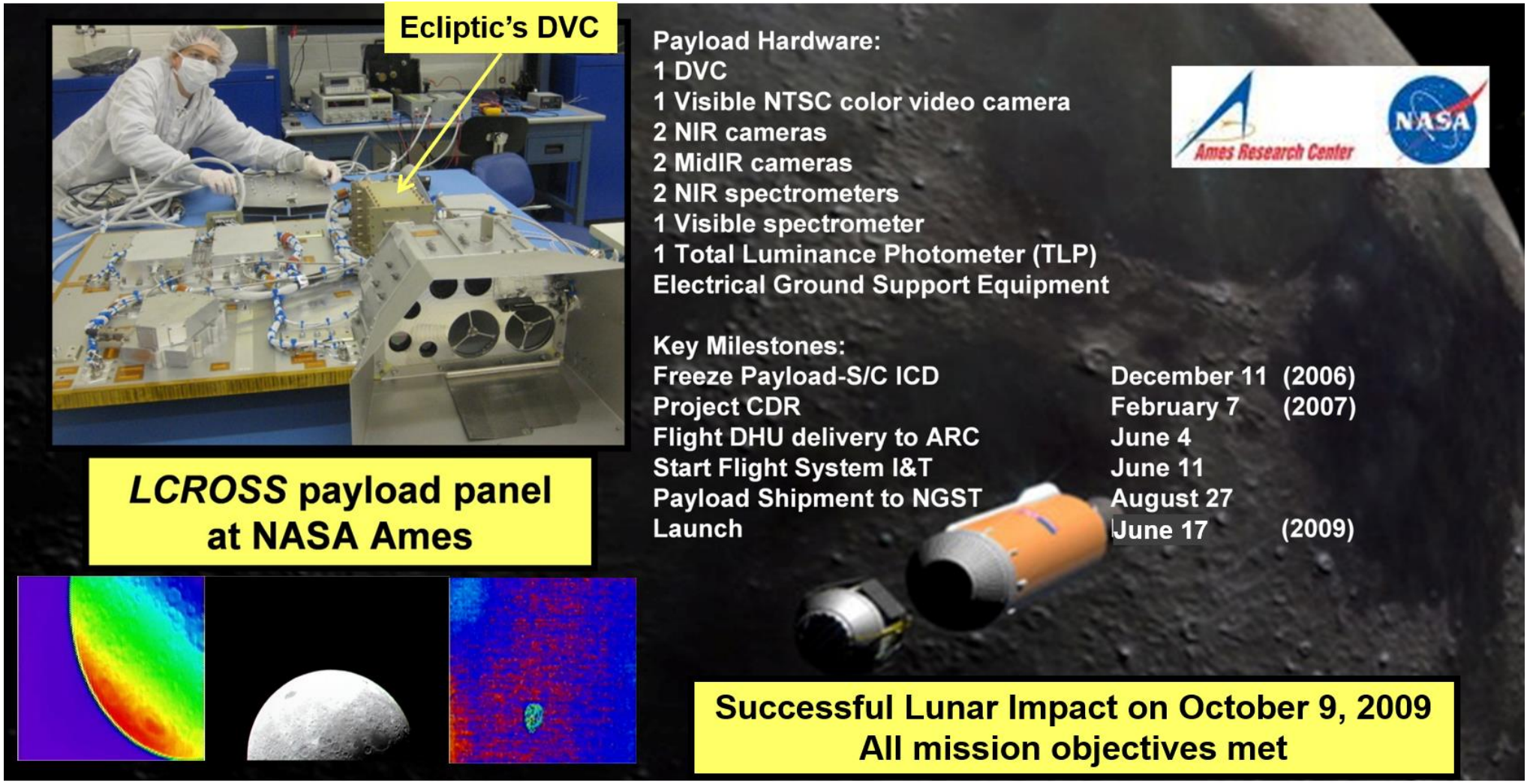






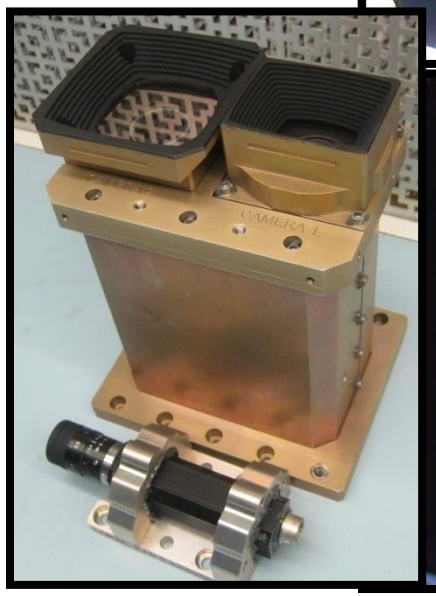


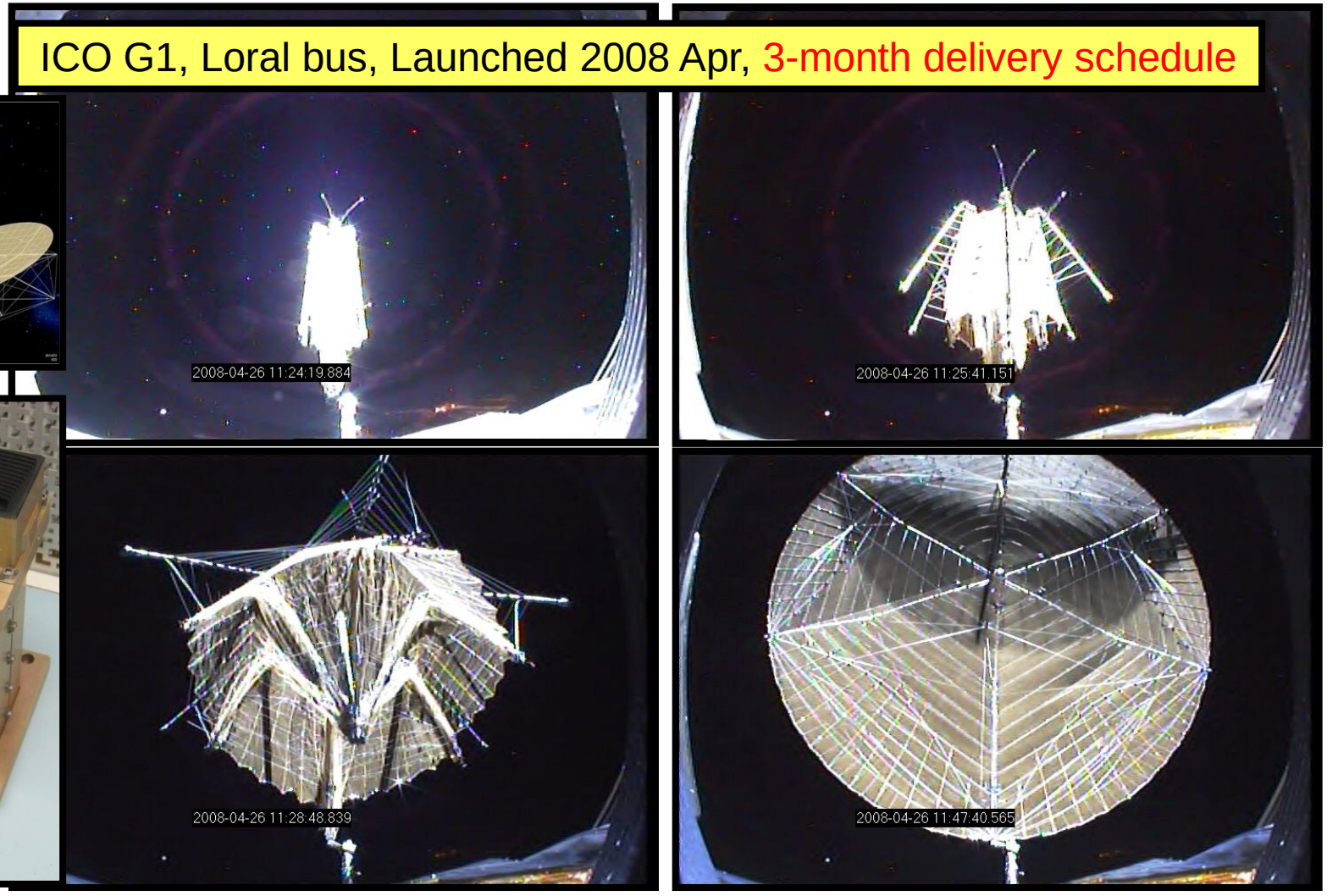
Instrument Controller on *LCROSS* Lunar Impactor (2009)



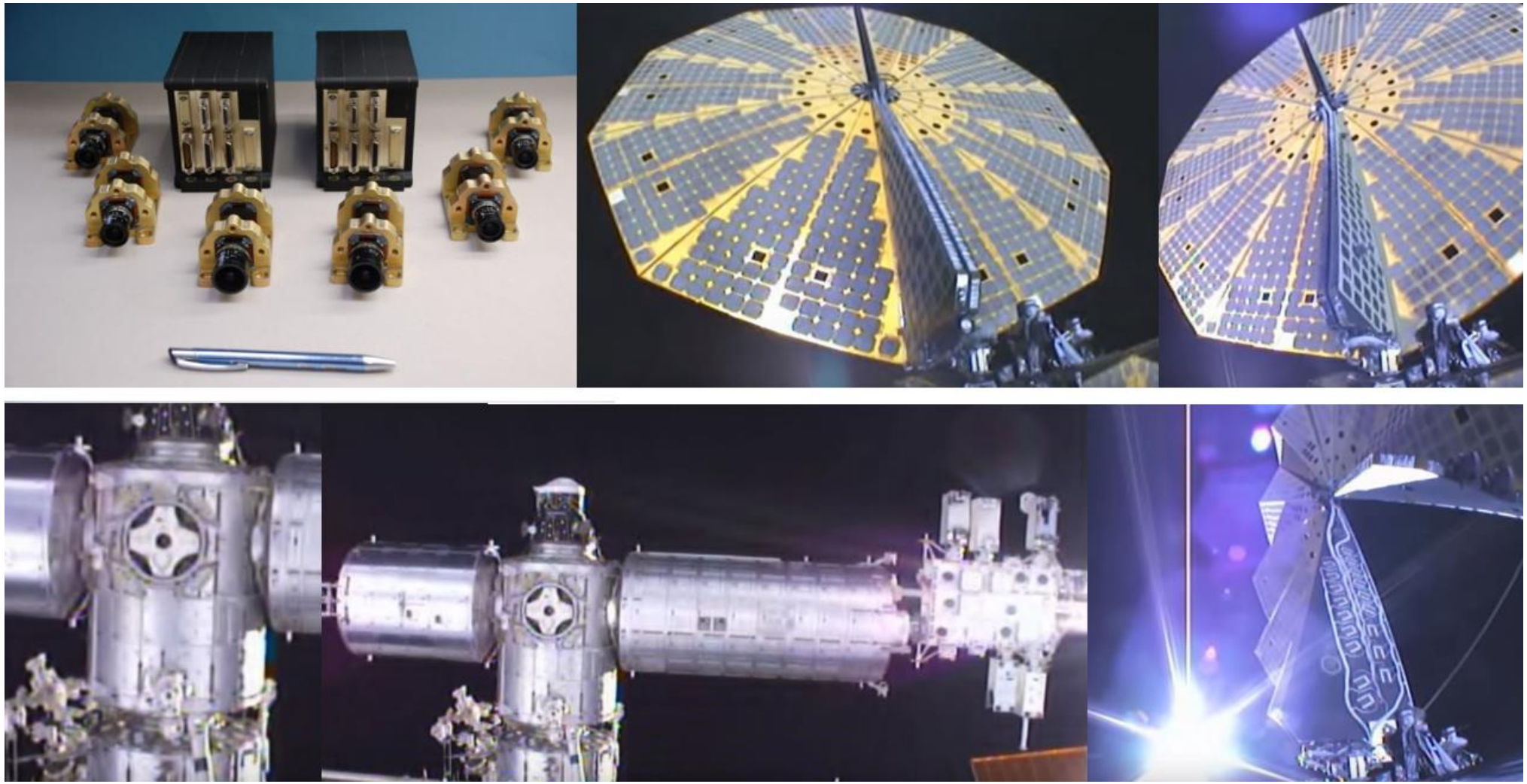
Ecliptic Hosted GEO Deployment Cameras (2008)

ICO G1, Loral bus, Launched 2008 Apr, 3-month delivery schedule

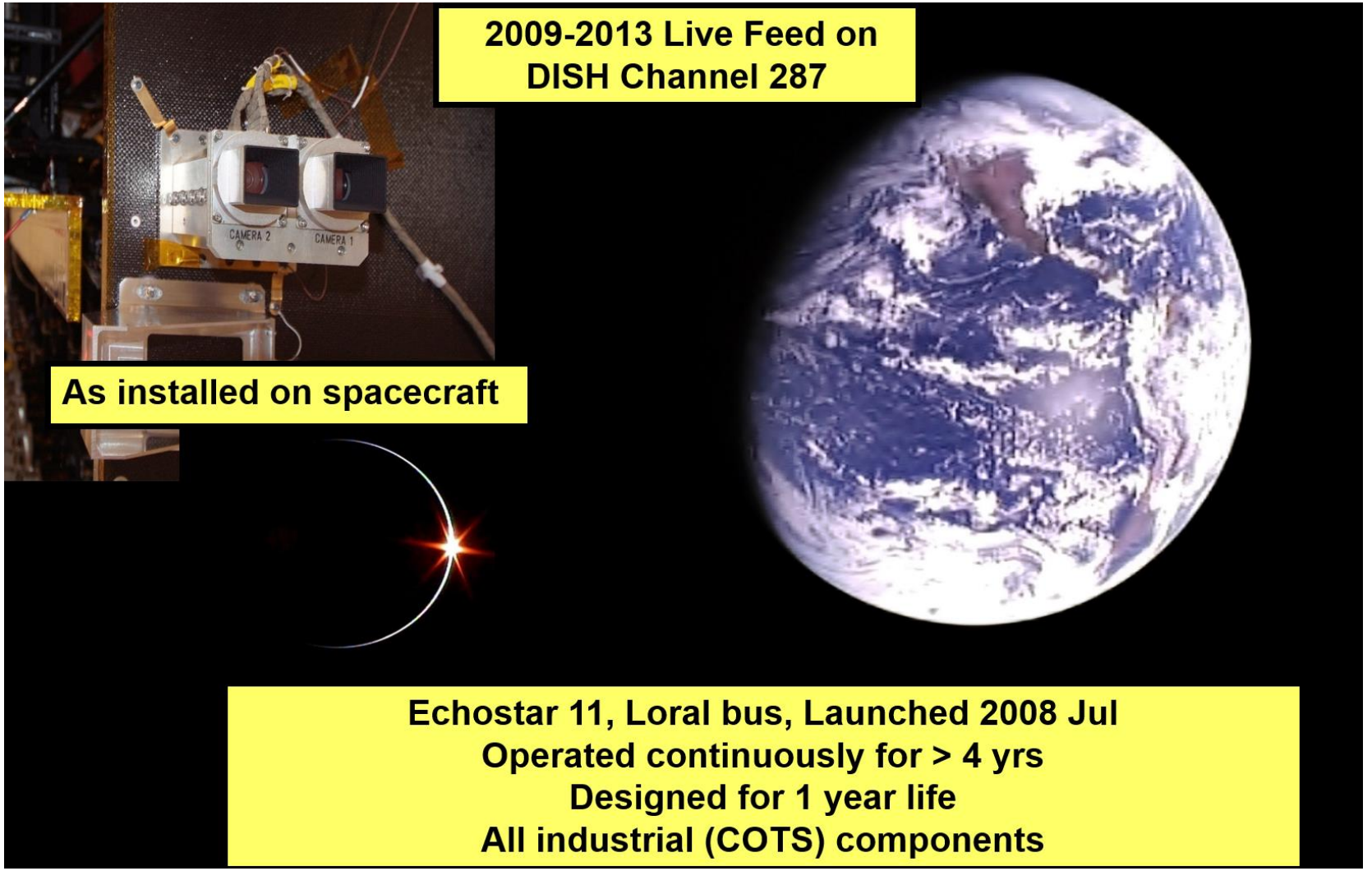




Orbital's Cygnus Cargo Vehicle



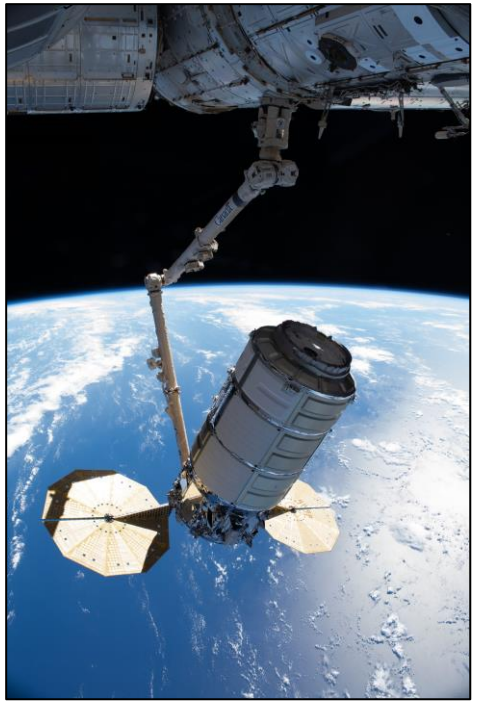
Ecliptic Hosted GEO Payload Experience (2009-2013)

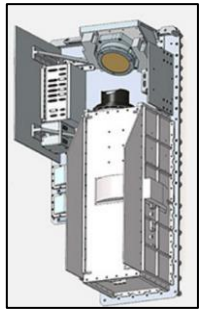


RocketCam Analog Videos

Experiment Controller (2020)

- Experiment Controller
  - Power Distribution
  - Telemetry & Control
  - Host Interface
    - Slow and high-speed links
  - Image Processing Board
  - Customer Algorithm Board
  - Serial Digital Board
    - IMUs, Temp Sensors, etc.
  - Analog Telemetry Board
  - Customer Provided Board
    - Ruggedized and integrated into the stack



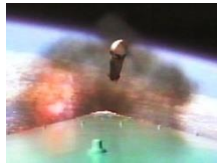


Product Evolution
2001 to 2022

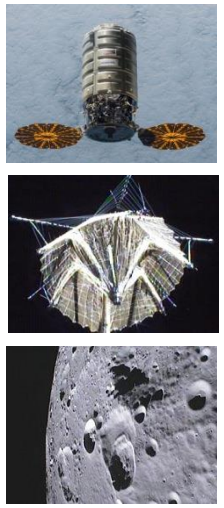
Key contributions to two recent AIAA *Small Satellite of the Year* awardees
***LightSail 1* (2015)**
***ASTERIA* (2018)**

- **~110 rocket launches (orbital and suborbital)**
- **~45 spacecraft (LEO, ISS, MEO, GEO, lunar)**

Analog Video Systems

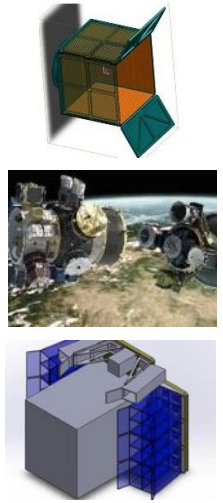


Standard-Definition Digital Video Systems



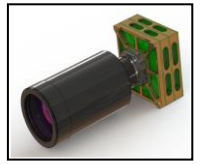
Payload/Experiment Control Systems

Advanced Reconfigurable Sequencing Systems

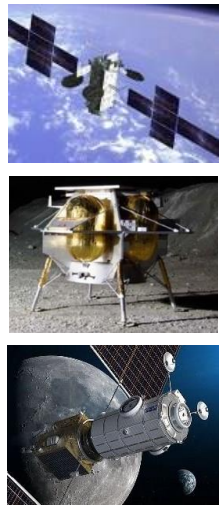


CubeSat Systems and Subsystems

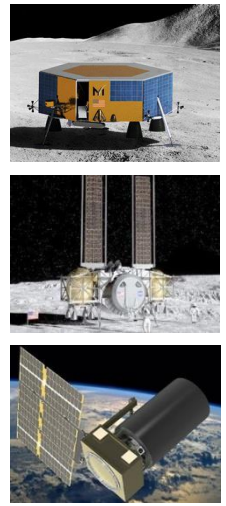
CubeSat/Small Satellite Smart Cameras



4K High-Definition Digital Video Systems



4K High-Definition Digital Video Systems + Payload/Experiment Control Systems



ECLIPTIC