TechSat I

InFocus
The World. InFocus.

PUMPKIN INCORPORATED

TS
Transparent Sky

SOUTHERN STARS

GE

NVIDIA

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SUPERNOVA-Beta / InFocus TechSat I

- Demonstration/Validation of SUPERNOVA design (Pumpkin)

- High-resolution earth-imaging experiments (InFocus / Transparent Sky)

- Self-imaging, community functions (Southern Stars)
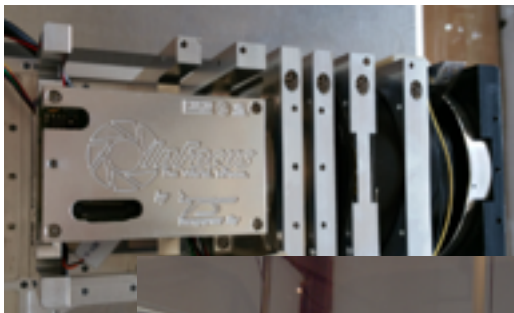
Objectives (SUPERNOVA-Beta)

- Bus validation
- (Multiple) payload integration validation
- Validation of Communications Systems
    - Vulcan Wireless
    - Globalstar
- Validation of C2 System
    - Beaglebone-based
    - Software router
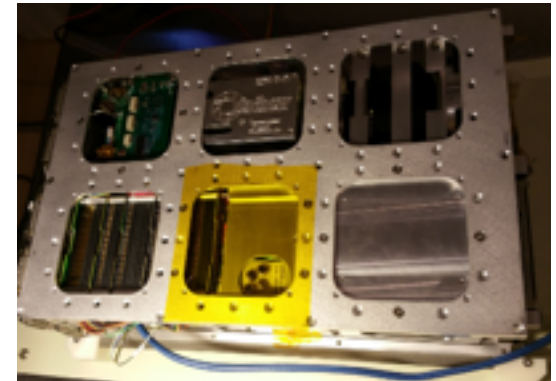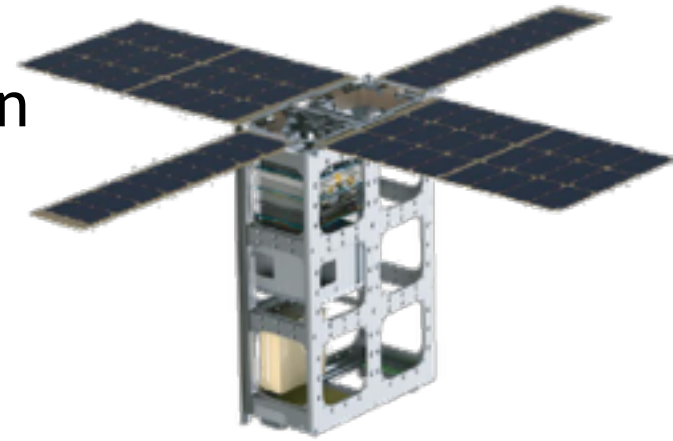
Objectives (InFocus, Transparent Sky)

- Real-time image processing experiments
- Use of embedded CPU/GPU on orbit
- Improvements to imaging via coupled processing control pipeline, only feasible on-board
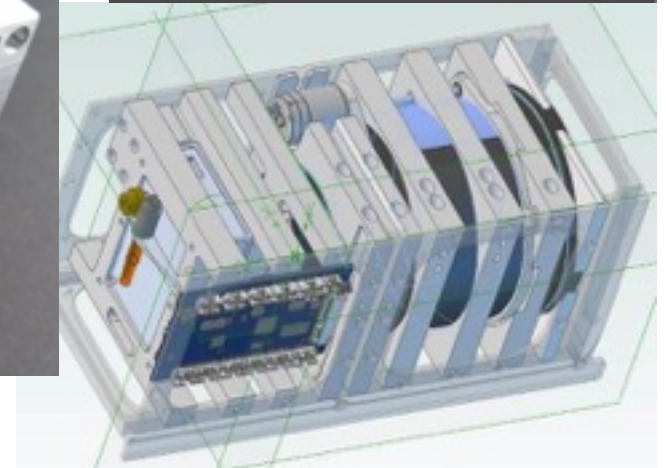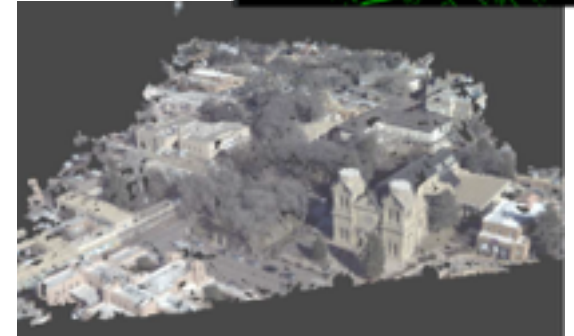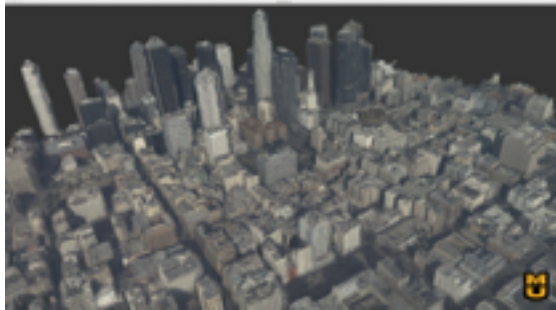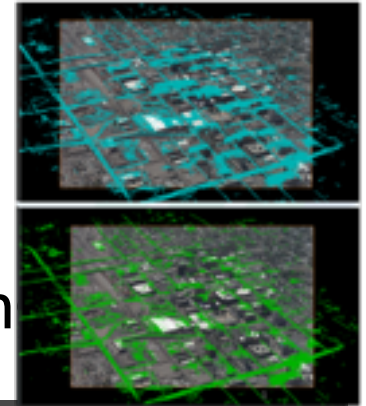
Objectives (SkyCube, Southern Stars)

- Reflight of improved hardware developed for CrowdFunded SkyCube in 2012-2014

- Intended to provide consumer-grade Earth imagery, "tweets from space", inflatable de-orbit device

- Deployed from ISS by Nanoracks 28 Feb 2014; two confirmed contacts
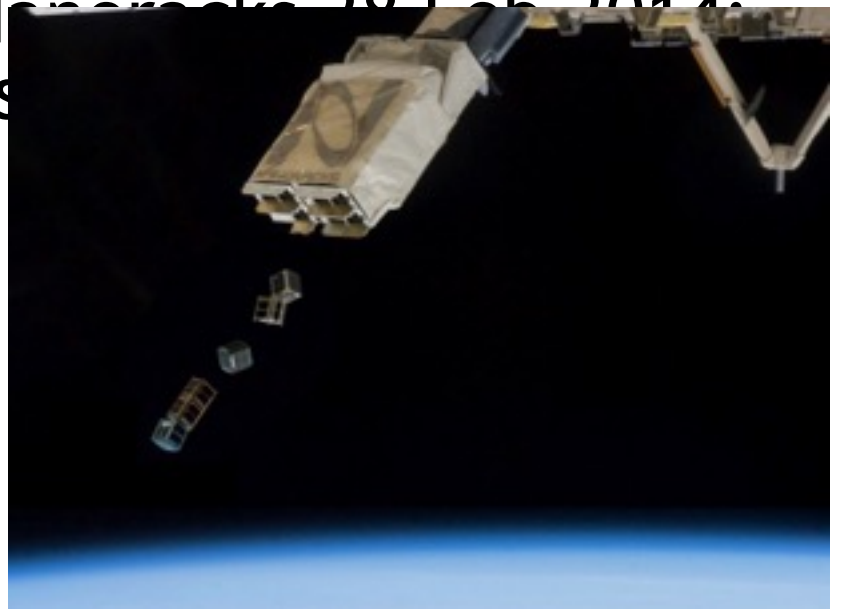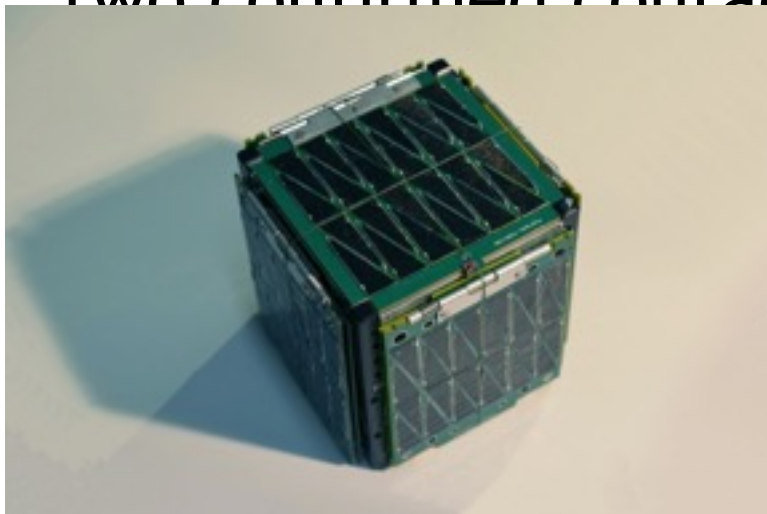
Unprecedented Time-To-Build

- 4 months from first concept meeting to delivery/ Flight Qual/ Integration with LV

- Numerous experimental items
  - Some made it – some didn't

- Unprecedented level of integration
  - System had to allow InFocus sensor to ultimately control ADACS
  - Communications/routing challenges with experimental hardware/ software until delivery
  - CPU/GPU integration in development from suppliers during spacecraft integration
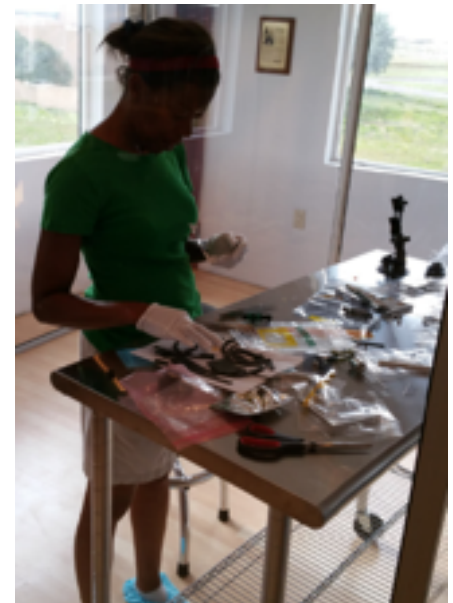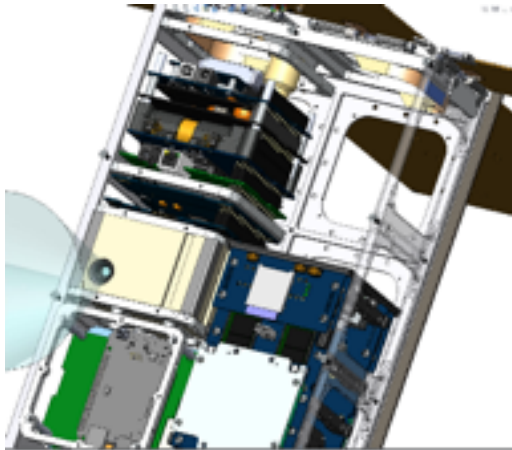
Six-U Performance Enhanced Rad-tolerant NanOsat Vehicle Architecture

- Developed under DoD RIF for Navy SPAWAR
- SUPERNOVA is a mission-agnostic bus designed for rapid, and simplified, integration of a wide variety of payloads.
- Well documented, standard interfaces.
  - Bus : Payload
  - Space Vehicle : Ground (MC3 compatible)
- Flight Software created in collaboration with Naval Research Lab (government rights, fully open to government users)
- Flight Software built upon the successful NRL Colony I QbX missions using Pumpkin's 3U bus.

SUPERNOVA-Beta Features

- Extremely rigid structure (6U: 197Hz @ 12kg) tested and validated at AFIT

- Supersymmetric design for ease of bus, payload & sensor integration

- 100x100x100mm Unit Cells support any and all CubeSat-compatible subsystems

- High-rel deployable 64W solar array

- All six faces available for Space Access Ports (SAPs)

- Full GSE interface (USB, Ethernet, charging, etc.)

SUPERNOVA-Beta Features (cont.)

- C&DH: 1GHz Debian Linux processor, running a mix of C and python

- Bus Interfaces: UARTs, I2C, SPI, USB, GPIO

- Payload Interfaces: Ethernet, UARTs, 3.3/5/12/VBATT switchable power

- Primary comms: VWI S/S @ 1Mbps

- Secondary comms: GlobalStar

- 3,000cc+ available to payload(s)

Beta – Before Environmental Test Attempted

- SUPERNOVA-Beta was a pre-release version of the bus,
  - NRL software was not yet complete
  - Environmental Test had not been attempted.
- Pumpkin built FSW on the fly
- Spacecraft completed flight qualified at ORS/AFRL in Kirtland prior to integration with LV
  - 3-axis Vibration
  - Bake-Out
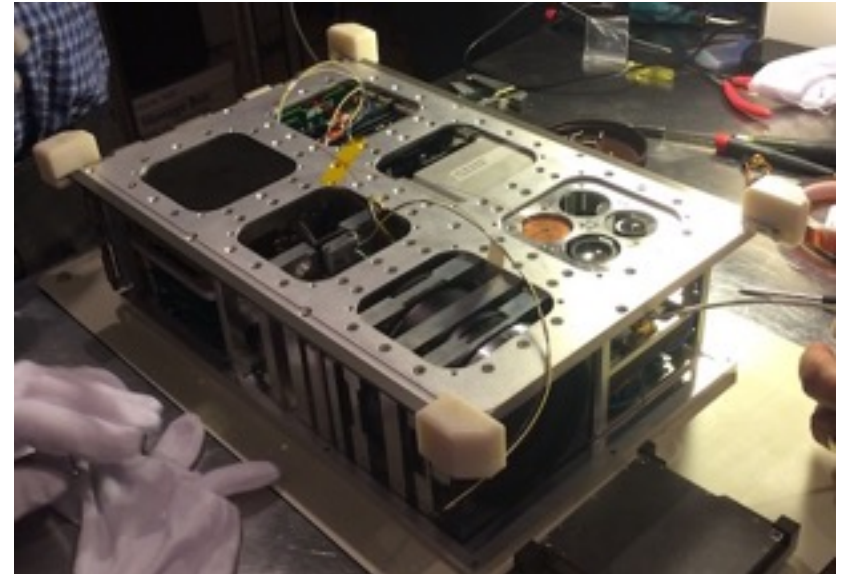- Full Version (1.0) of SUPERNOVA is now available

Rapid Integration of Payload by following Bus ICD

- Two payloads were developed independently
  - Independent of each other
  - Independent of Pumpkin bus
- Integration of both payload was completed in ten days
  - Electrical and FSW
  - Mechanical
- Well thought out interfaces
- Well documented ICD
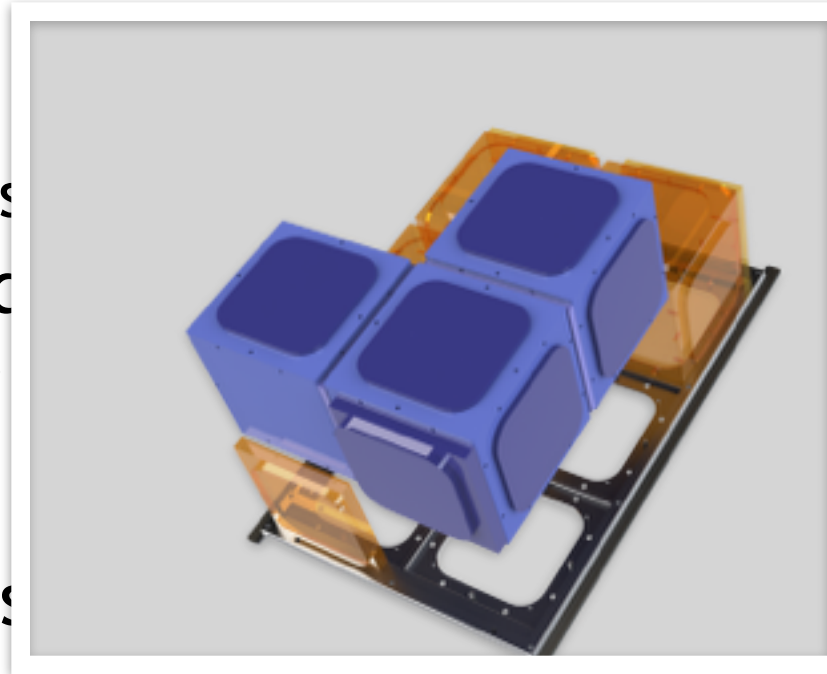
SkyCube 2 Payload

- Redesigned hardware!
  - Beefier Microcontroller
  - Removable Storage, IMU
  - StenSat Beacon Radio
  - Custom Monopole Antenna
  - Improved cameras
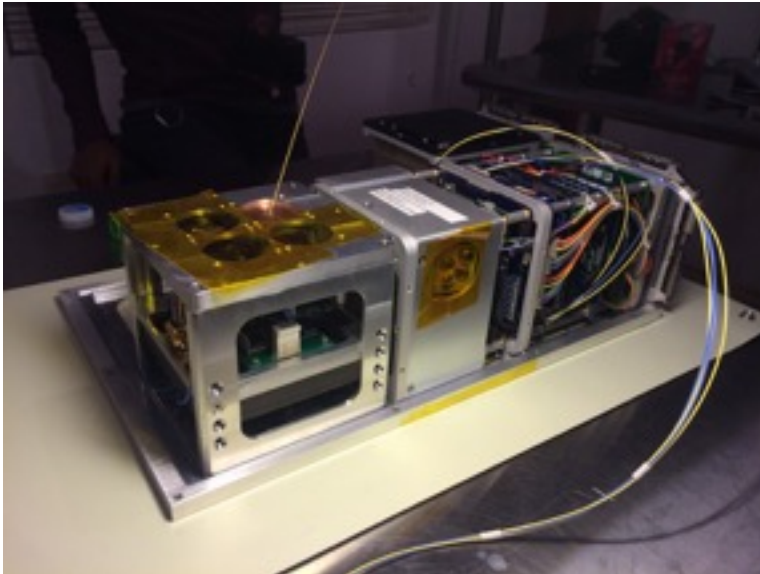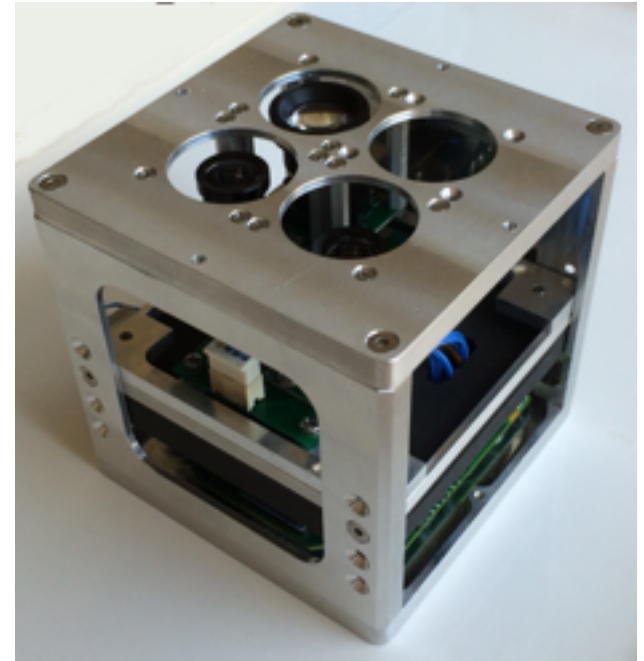
InFocus Sensor Block Diagram

USB3 Cam

PixeLINK D725U 5MPix camera

Perkin-Elmer 600mm Catadiopter Lens

GE CCG010 COM10 Module with nVidia K1 Processor

ComTech COM10 interface board

Power/ Interface board

To S/C C2 and router
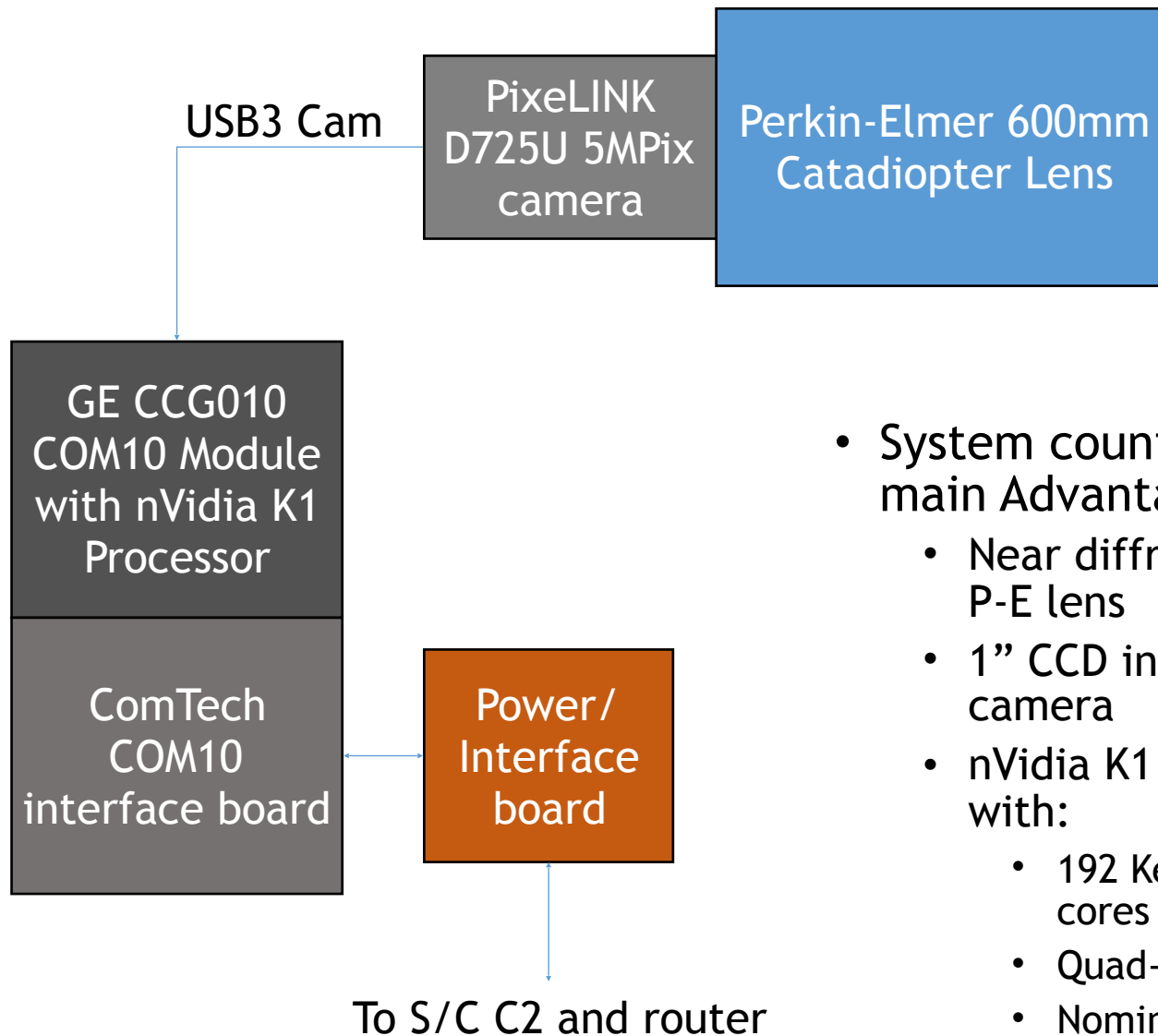
- System counts on 3 main Advantages:
  - Near diffraction-limit P-E lens
  - 1" CCD in PixeLINK camera
  - nVidia K1 processor with:
    - 192 Kepler GPU cores
    - Quad-core ARM
    - Nominal 375 GFLOPS

InFocus Sensor Construction

- Camera system is floating design decoupling lens and camera from frame in floating
  - Milled housing with PORON 4790-79-20093-04 compressed padding

- Construction and test of integrated camera/processor/ interfaces/heat spreader

- Power consumption measured varying between off-1W-4W-12W.

- All libraries, interfaces, and switchin functions demonstrated accessible a tested based upon prior airborne applications.

InFocus algorithms

- General flow:
  - Initial aim based upon ADACS data
  - Capture sequence of images while stabilizing ADACS
  - Enhance resolution from sequence
  - Optionally construct camera extrinsics/construct models
  - Optionally correct pointing based upon recognized features
- Proven airborne algorithms installed and tested in CPU/GPU (Transparent Sky and U. Missouri)
- (Note: video accompanying this slide)
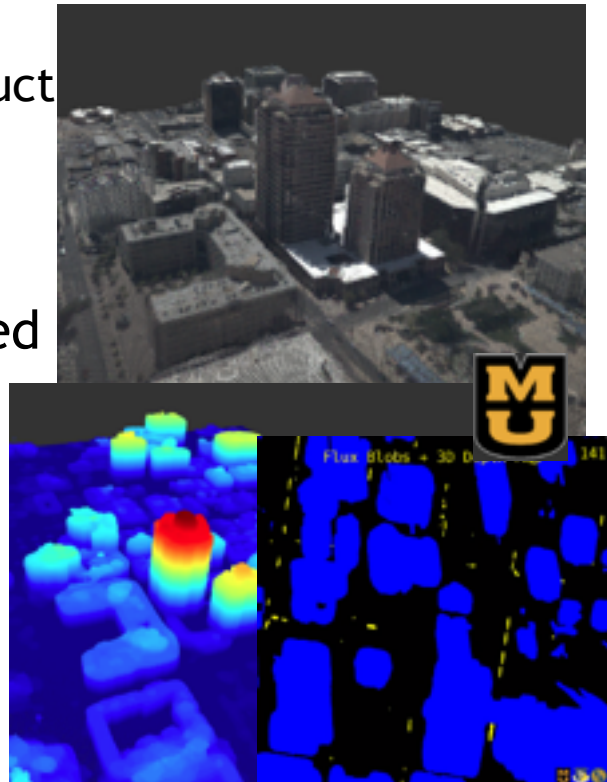
Timeline To Conclusion

- Concept – mid-April
- Delivery to ORS – 3 Sep 2015
- Spacecraft was #2 payload on ORS-4
    - Launched 3 Nov 2015
    - Less than successful orbit injection (see graphic)

Lessons Learned

- Nothing ventured / nothing gained
  - Although the launch was 'free,' we were substantially out-of-pocket for all other costs.
  - Still, we do not regret the decision as we delivered on all the parts within our control.
- Work with people you know and trust
  - It worked well for us.
- FCC / NOAA licensing process needs improvement.
  - "Why didn't you start this process two years ago?"

Appreciation

- Thanks to ORS
  - for the launch opportunity
  - and for environmental test / Flight Qual.
- Thanks to SPAWAR
  - for their encouragement
- Thanks to Universal Space Network (SSC)
  - Establishing and testing comms on their network
- Southern Stars and Sterk Solutions
  - Solving NOAA and FCC licensing
- Especially thanks to Deborah Suddarth
  - for welcoming the team in her home.

What's Next

- Other missions are being planned using Pumpkin SUPERNOVA bus
- InFocus and Transparent Sky will repeat this mission to build their business
  - Investment opportunity
  - Seeking ride opportunities
- Proven design and team
- Future sats will be even more capable
  - Newer X1 nVidia processor
  - Higher data rate comms
  - Seek more airborne testing opportunities