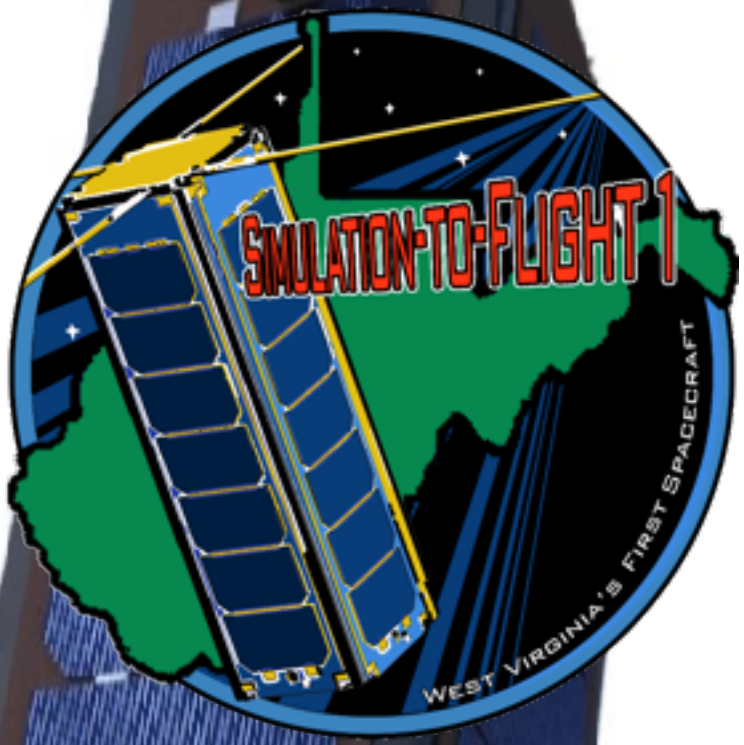
# Simulation-to-Flight 1
# NASA IV&V

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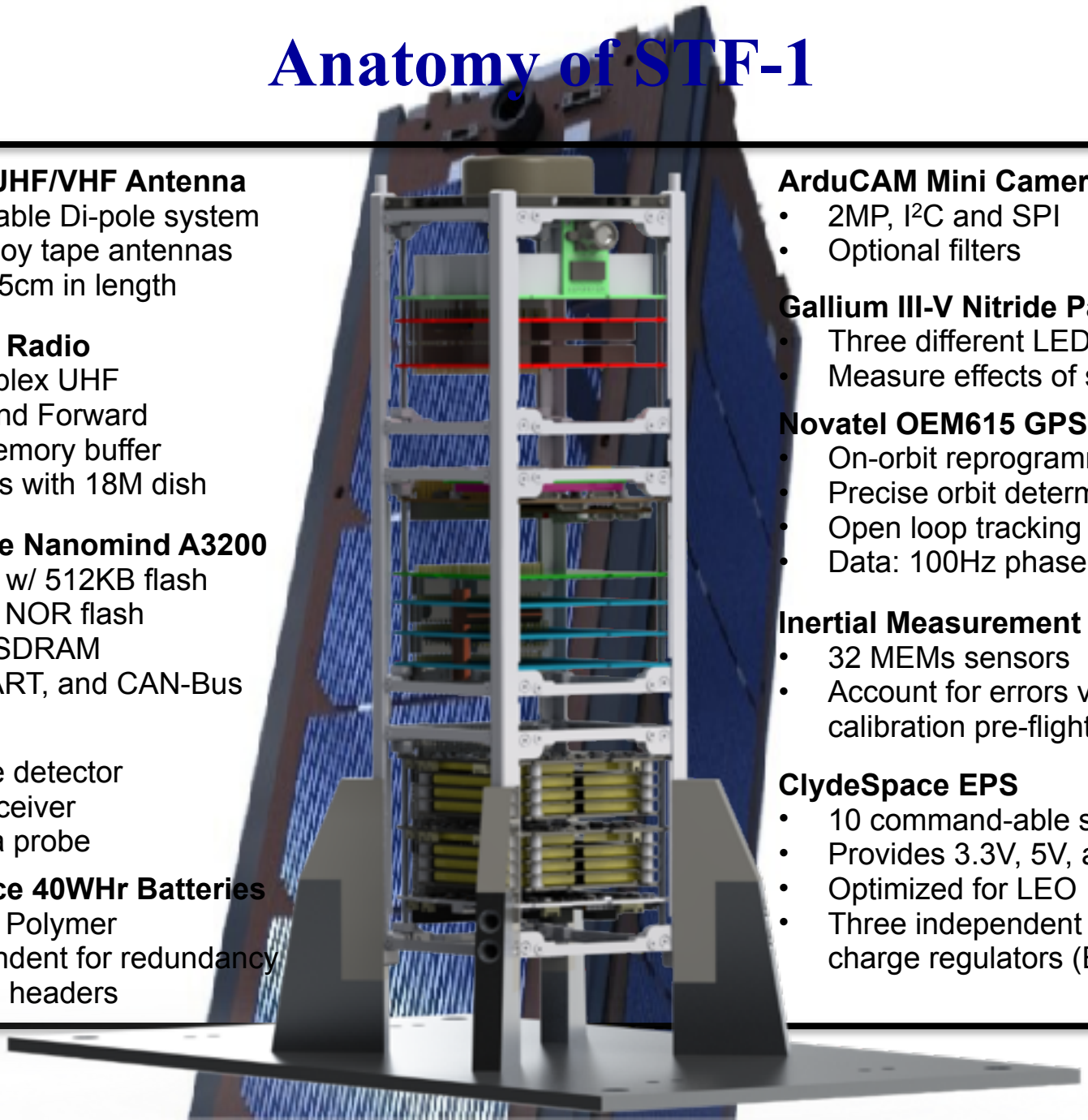
# Simulation-to-Flight 1
## West Virginia's First Spacecraft

- NASA CubeSat Launch Initiative (CSLI)
  - ELaNa XIX, Rocket Labs USA
  - 85 inclination at 500km altitude
  - Mission Readiness Review: March 2017
  - Delivery: April 2017
  - Launch: June 2017
- Partnering with GSFC/WFF Small Satellite Teams
- NASA Independent Verification and Validation (IV&V)
  - C&DH hardware/software, integration and testing
- West Virginia University (WVU)
  - Science payload hardware and software
- West Virginia Space Grant Association (WVSGC)
  - Statewide outreach

# Mission Objectives

| STF-1 NOS³ | Primary Objective | NASA IV&V |
|---|---|---|
| GPS and IMU | Science Objective 1 | WVU MAE |
| Space Weather | Science Objective 2 | WVU Physics & Astronomy |
| III-V Nitride Materials | Science Objective 3 | WVU LCSEE |
| Earth Viewing Camera | Science Objective 4 | NASA IV&V |
| STEM Education | Outreach Objective | WVSGC |

# Anatomy of STF-1



**ISISpace UHF/VHF Antenna**
- Deployable Di-pole system
- Four alloy tape antennas
- Up to 55cm in length

**L3 CADET Radio**
- Half duplex UHF
- Store and Forward
- 4GB memory buffer
- 3.0Mbps with 18M dish

**GomSpace Nanomind A3200**
- AVR32 w/ 512KB flash
- 125Mb NOR flash
- 32MB SDRAM
- $I^2C$, UART, and CAN-Bus

**Physics**
- Particle detector
- VLF receiver
- Plasma probe

**ClydeSpace 40WHr Batteries**
- Lithium Polymer
- Independent for redundancy
- Internal headers

**ArduCAM Mini Camera**
- 2MP, $I^2C$ and SPI
- Optional filters

**Gallium III-V Nitride Payload**
- Three different LED carriers
- Measure effects of shielding

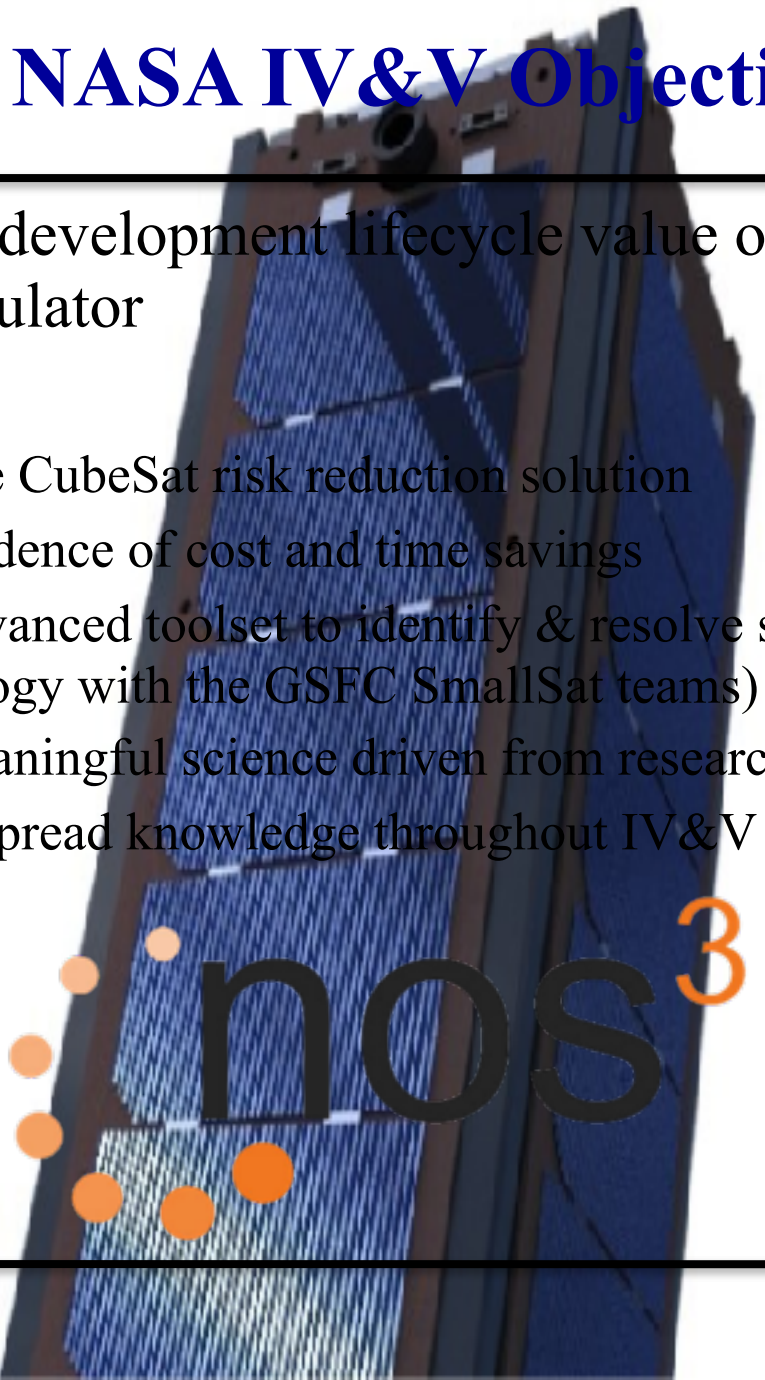
**Novatel OEM615 GPS**
- On-orbit reprogrammable
- Precise orbit determination
- Open loop tracking
- Data: 100Hz phase, TEC, S4

**Inertial Measurement Unit**
- 32 MEMs sensors
- Account for errors via calibration pre-flight

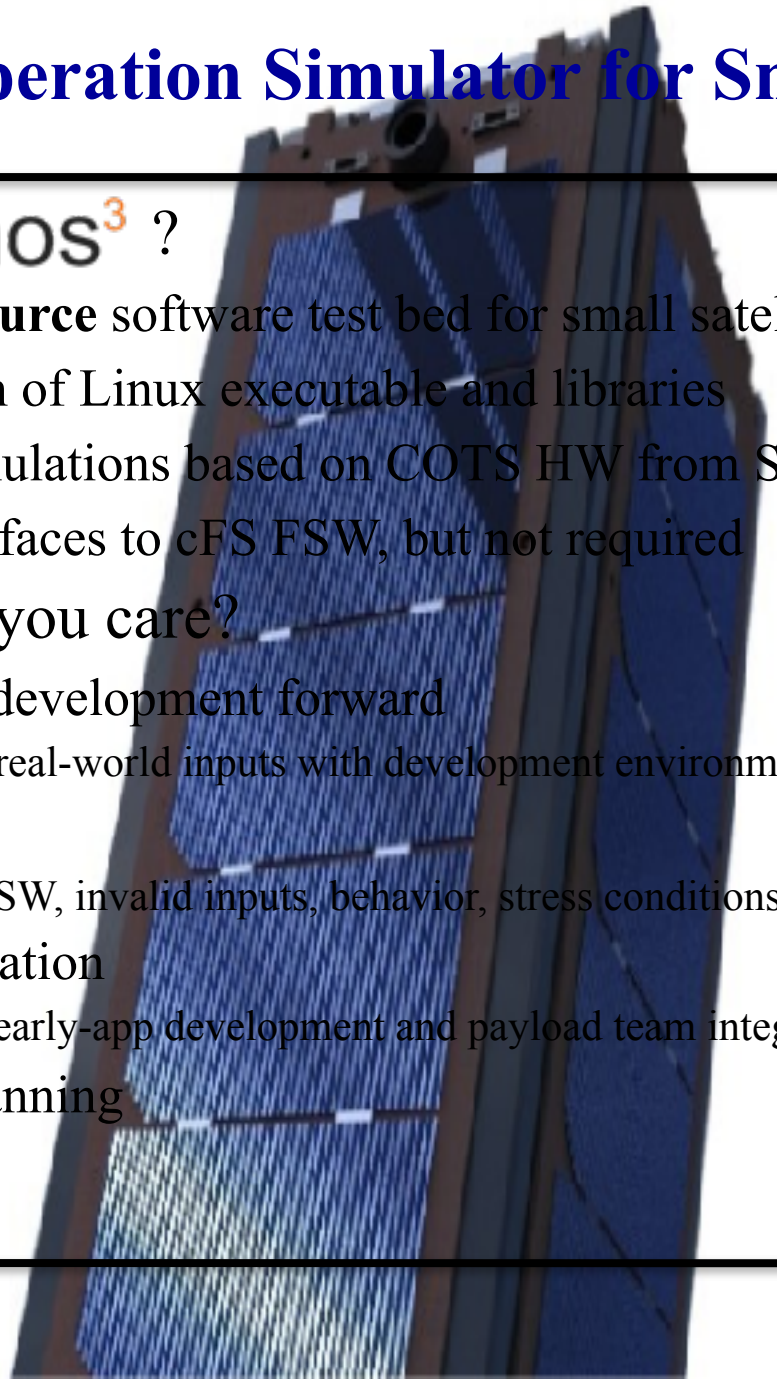
**ClydeSpace EPS**
- 10 command-able switches
- Provides 3.3V, 5V, and 12V
- Optimized for LEO
- Three independent battery charge regulators (BCRs)

# NASA IV&V Objective

- Demonstrate development lifecycle value of a software-only SmallSat simulator
- Objectives
  - Open source CubeSat risk reduction solution
  - Produce evidence of cost and time savings
  - Develop advanced toolset to identify & resolve software issues (Share this technology with the GSFC SmallSat teams)
  - Perform meaningful science driven from research institutions
  - Foster and spread knowledge throughout IV&V Program

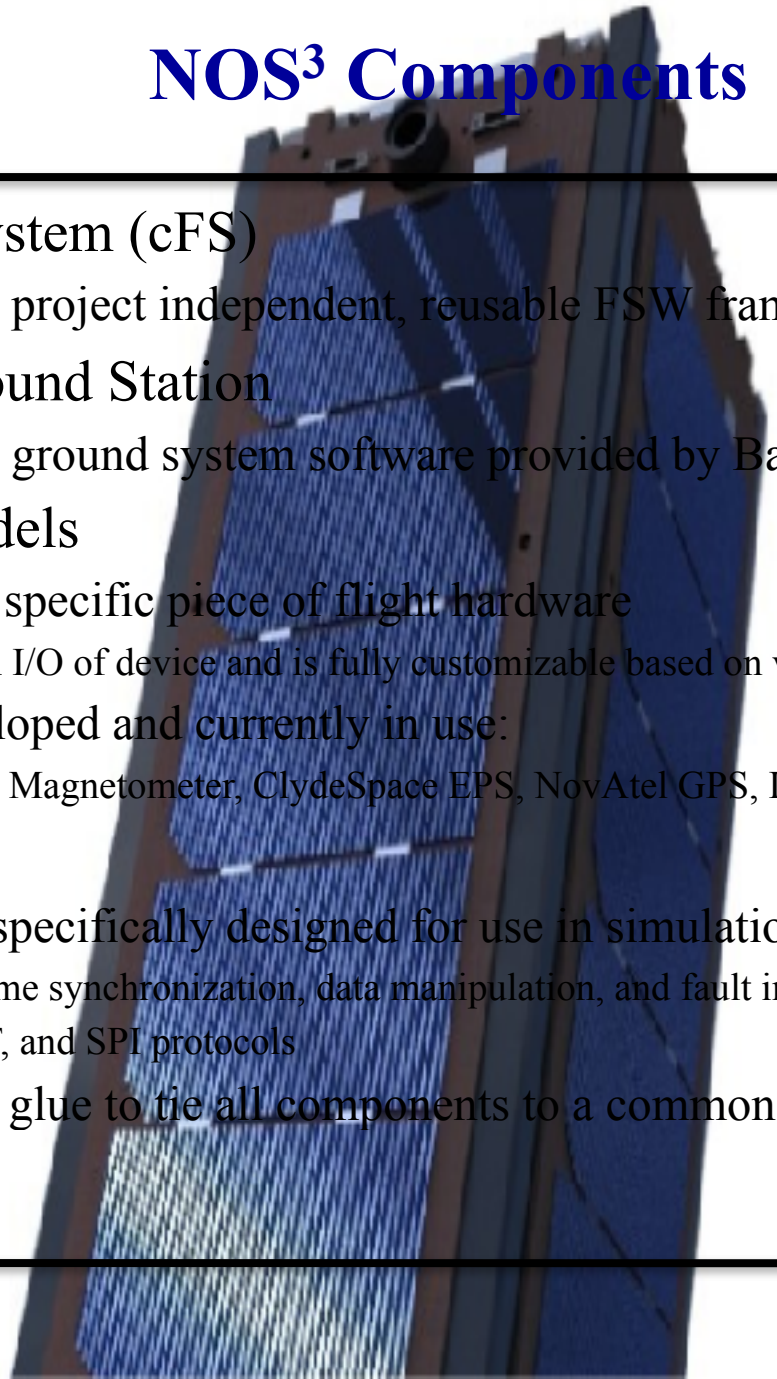


# NASA Operation Simulator for Small Satellites



- What is nos3 ?
  - An **open source** software test bed for small satellites
  - A collection of Linux executable and libraries
  - Current simulations based on COTS HW from STF-1
  - Easily-interfaces to cFS FSW, but not required
- Why should you care?
  - Shift FSW development forward
    - Provides real-world inputs with development environment
  - FSW V&V
    - Testing FSW, invalid inputs, behavior, stress conditions
  - FSW Integration
    - Used for early-app development and payload team integration
  - Mission Planning

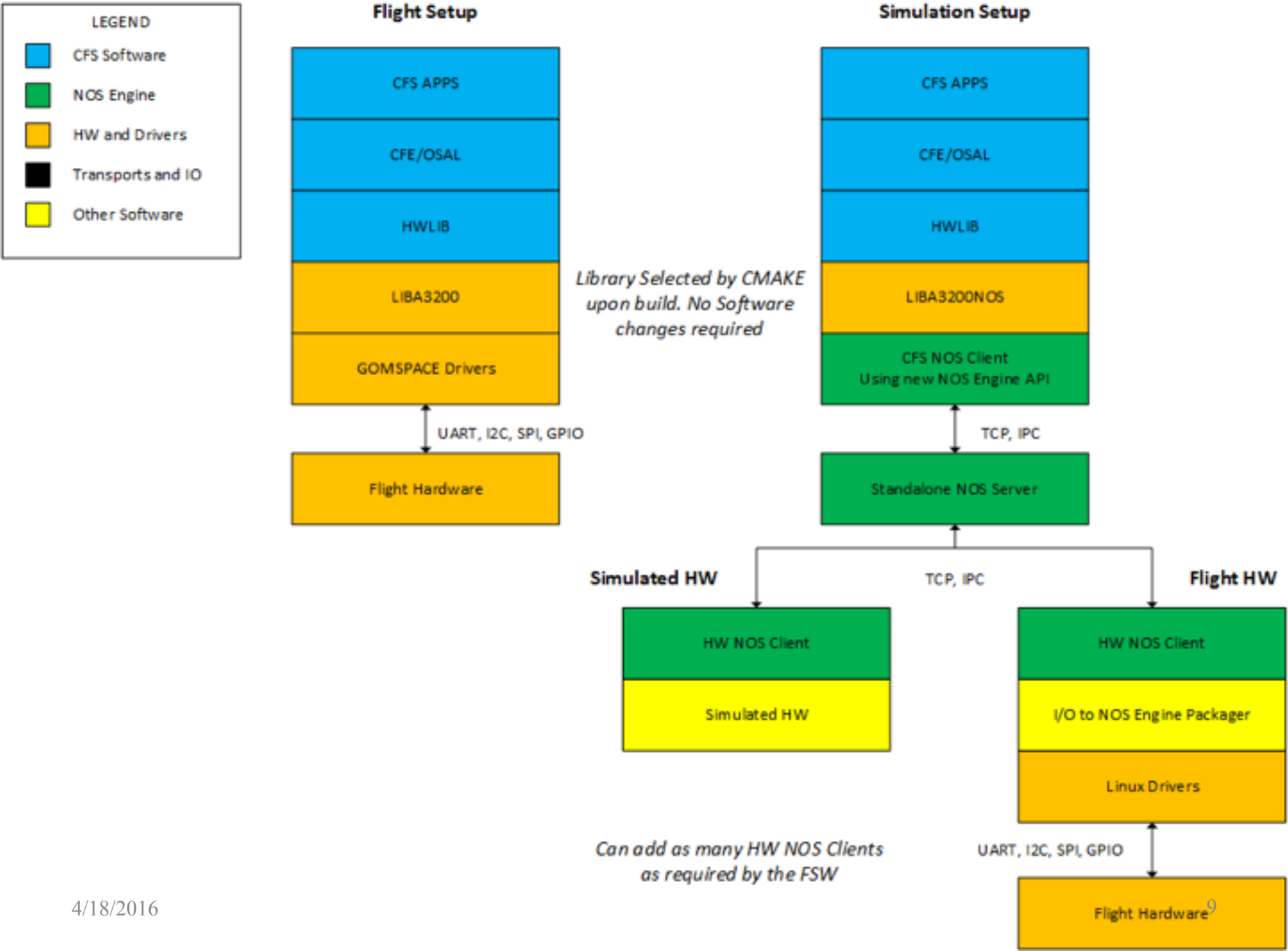
# NOS$^3$ Components



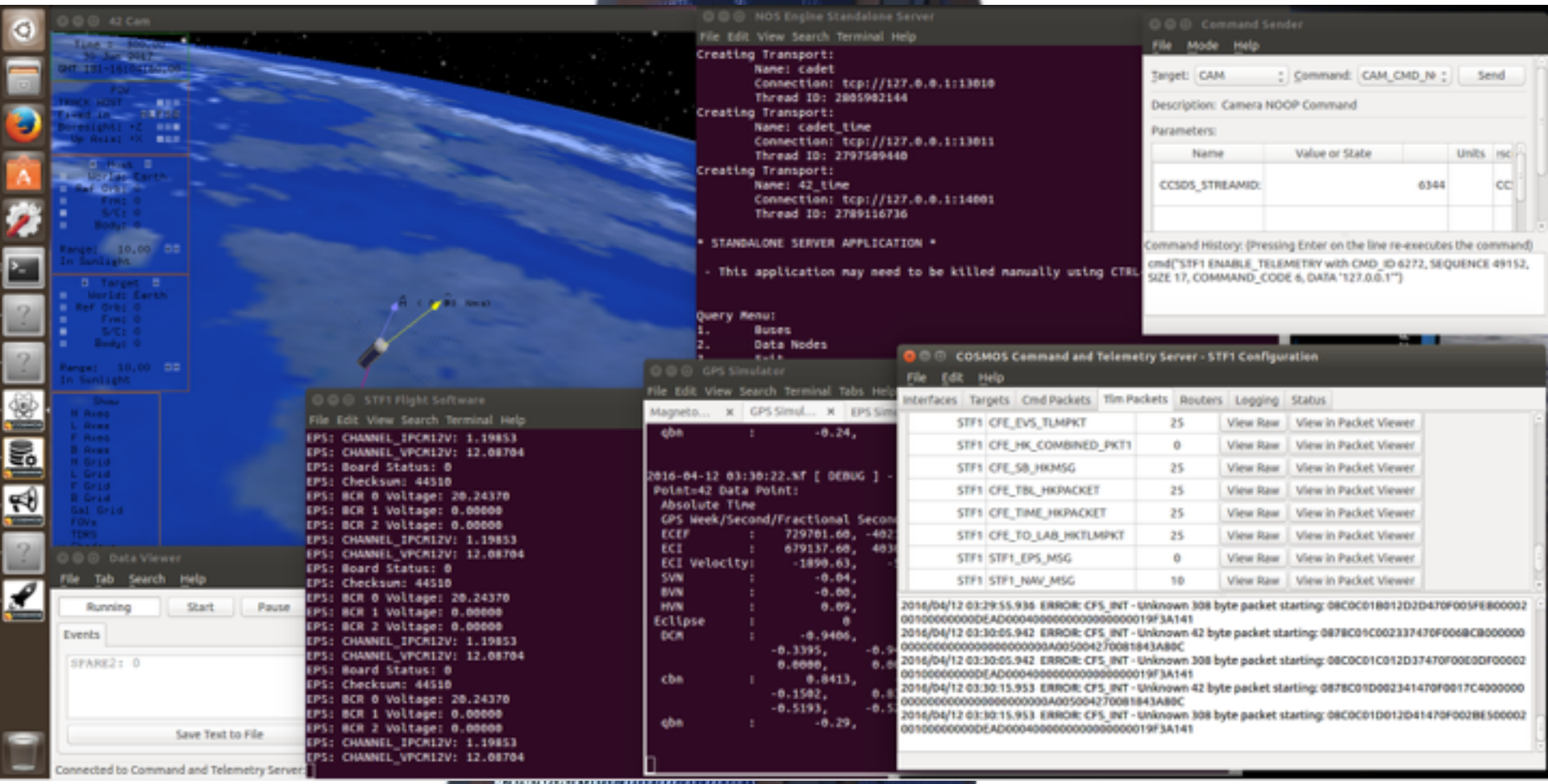
- Core Flight System (cFS)
  - Open source, project independent, reusable FSW framework
- COSMOS Ground Station
  - Open source, ground system software provided by Ball Aerospace
- Hardware Models
  - Written for a specific piece of flight hardware
    - Focuses on I/O of device and is fully customizable based on vendor options
  - Models developed and currently in use:
    - Honeywell Magnetometer, ClydeSpace EPS, NovAtel GPS, ISISpace Antenna
- NOS Engine
  - Middleware specifically designed for use in simulation
    - Includes time synchronization, data manipulation, and fault injection
    - $I^2C$, UART, and SPI protocols
  - Serves as the glue to tie all components to a common interface

# NOS³ Components

- Orbit, Inview, and Power Planning
  - Utilize current or projected TLEs to project contact windows
- Vagrant
  - Virtual machine is created on-the-fly by the user
  - Provides full development environment with all capabilities
  - Additional scripts to build and run FSW with simulators provided
- 42
  - Open source, NASA GSFC developed, visualization and simulation tool for spacecraft attitude and orbital dynamics
  - Serves as an environmental data provider
    - For example provides magnetic field data based on current location

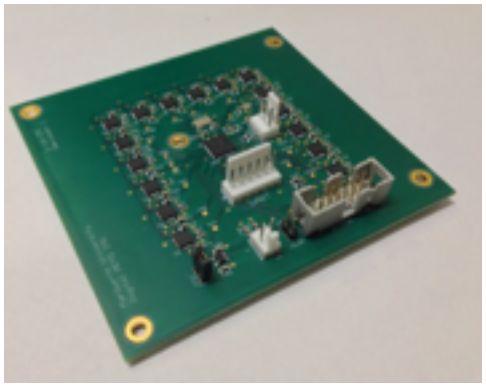

LEGEND
CFS Software
NOS Engine
HW and Drivers
Transports and IO
Other Software
Flight Setup
CFS APPS
CFE/OSAL
HWLIB
LIBA3200
GOMSPACE Drivers
UART, I2C, SPI, GPIO
Flight Hardware
Library Selected by CMAKE upon build. No Software changes required
Simulation Setup
CFS APPS
CFE/OSAL
HWLIB
LIBA3200NOS
CFS NOS Client
Using new NOS Engine API
TCP, IPC
Standalone NOS Server
Simulated HW
TCP, IPC
Flight HW
HW NOS Client
Simulated HW
HW NOS Client
I/O to NOS Engine Packager
Linux Drivers
UART, I2C, SPI, GPIO
Flight Hardware
Can add as many HW NOS Clients as required by the FSW

# NOS³ In Action

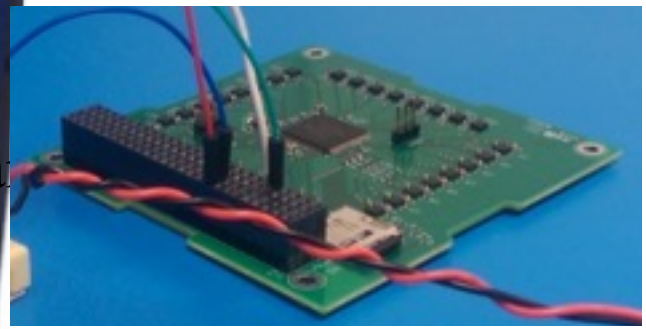


# MEMS IMU Swarm

- Designed to overcome Size, Weight, and Power (SWaP) constraints
- Large cluster of redundant MEMs IMUs
- Developed under Small Satellite Technology Partnership (SSTP)
- Gen-2 flew on the sounding rocket MUSIC on March 1st
- Gen-3 is custom-built for STF-1 in the PC104+ form factor
- Calibrated on student designed rate tables a temperature chambers
- Storing raw data for analysis on ground



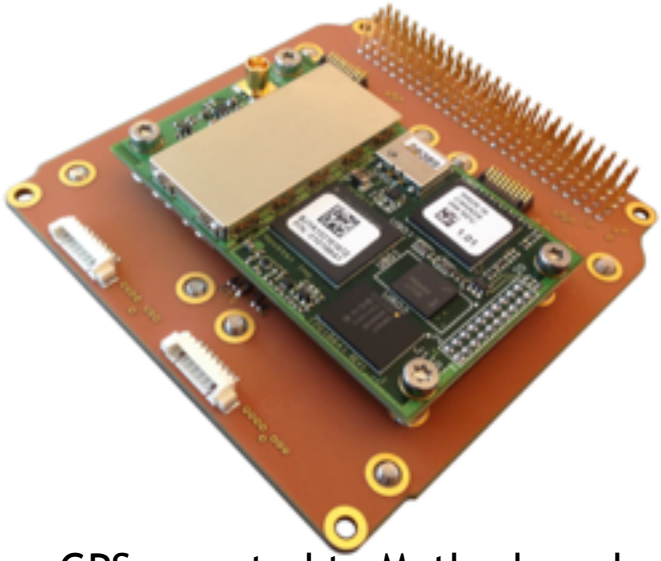
Gen-2



Gen-3

# GNSS Receiver and Precise Orbit Determination

- NovAtel OEM615 GPS Receiver
- Dual frequency L1/L2 receiver
- Focus to develop and assess estimate strategies that will maximize POD accuracy from data obtained during duty-cycled operations
- Provide PVT to C&DH
- Post processing utilizes NASA JPL's GIPSY-OASIS package



GPS mounted to Motherboard

# Space Environment and Weather

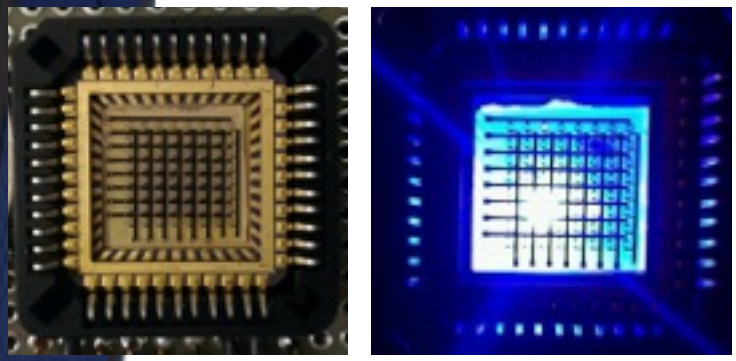
- Characterize the environment in which the STF-1 mission will operate
- A Langmuir probe to measure local electron density and temperature contrasted with regional GPS TEC
- A VLF receiver to monitor the PSD of low-frequency waves driving the electron flux
- Measurement at times of intense solar and/or ionospheric activity
- Comparable payloads flew on sounding rocket MUSIC

WVU ROCKSAT LP and VLF

VLF Detector

# III-V Nitride-Based Materials

- Precision optoelectronic sensor module containing arrays of LEDs and PDs can be used for short-range distance measurement and shape rendering
- Due to the harsh environment, shielding is usually needed
  - This shielding effects the range of these sensors
- Levels of shielding will be tested over time to determine the optimum amount
  - Current and voltage data collected
- Fabricated by students at WVU



Fabricated array of LEDs

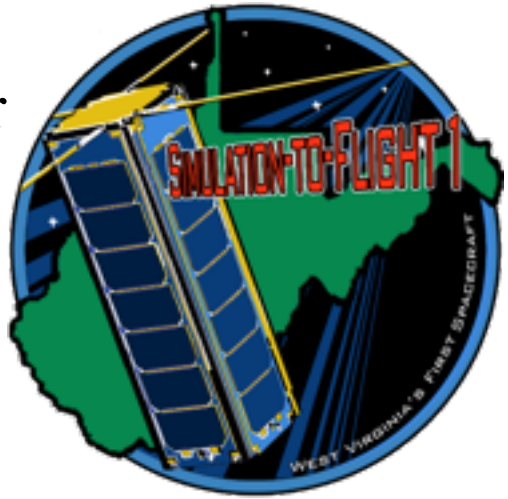
# Earth Science Camera

- ArduCam Mini OV2640
  - 2MP Sensor
  - Filters can be applied pre-flight
- Able to change settings on orbit
  - Fully command-able via I2C and SPI
- Allows us to:
  - Verify deployment operations
  - Assess COTS product in space environment
  - Observe Earth's surface and atmosphere over mission lifetime

ArduCam-Mini

# Statewide Outreach Plans and Programs

- Website and Blog (www.stf1.com)
- Spaceflight Mission Development course for WVU Undergraduates
- STF-1 Mission Patch design competition
- Educator's Guide for teachers of K-12 students
- NASA-Produced materials on space exploration, satellite operation, Space Station facts, etc.
- Cardboard and 3-D printable models
- Student Partnership for Advancement of Cosmic Exploration (SPACE)





INDEPENDENT VERIFICATION AND VALIDATION PROGRAM
NASA
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WEST VIRGINIA SPACE GRANT CONSORTIUM
Thanks to our partners!
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