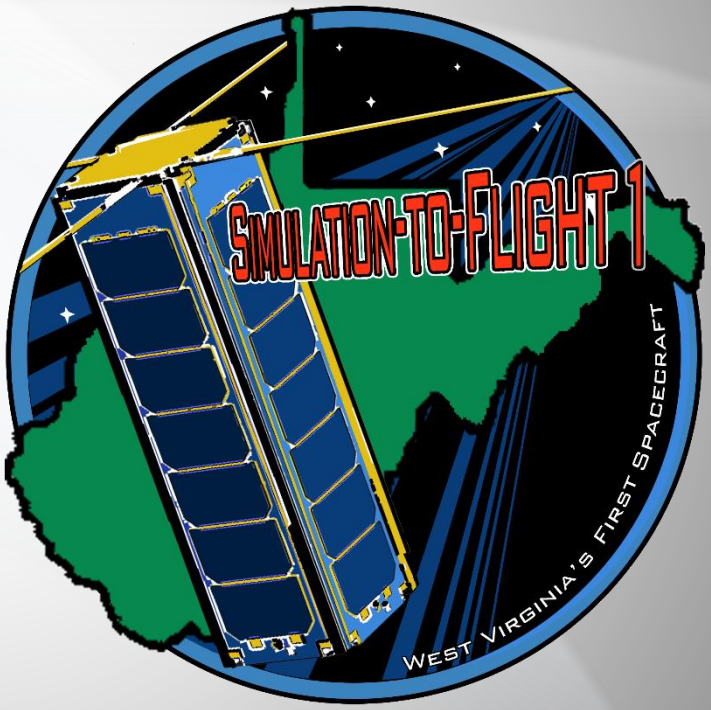
NASA Operational Simulator for Small Satellites (NOS^3)



NASA IV&V Independent Test Capability (ITC) Team
Mr. Scott Zemerick
Scott.Zemerick@TMCTechnologies.com

TMC² TECHNOLOGIES

Agenda

STF-1 Intro

- ITC Intro
- NASA IV&V CubeSat
- C&DH FSW Architecture

NOS^3

- V1.0
- Architecture
- Simulators

Conclusion

- Next Steps
- Questions

Independent Test Capability (ITC) Introduction

NASA IV&V Independent Test Capability (ITC)

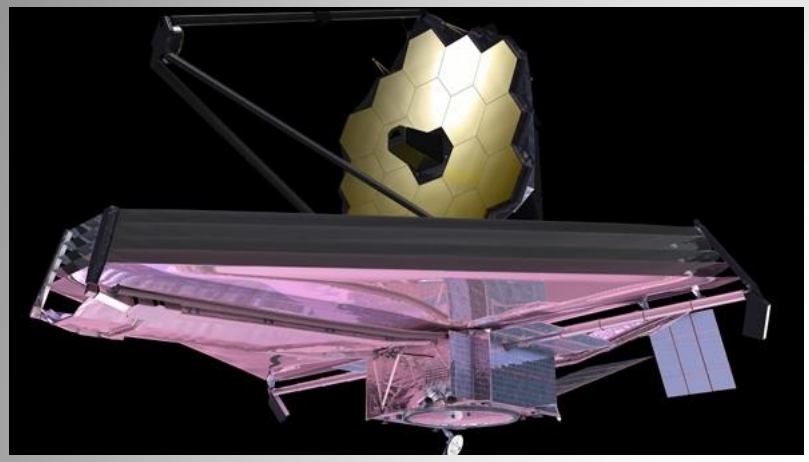
Charter

Acquire, develop, and manage adaptable test environments that enable the dynamic analysis of software behaviors for multiple NASA missions

Dynamic Analysis is performed on flight software to verify software behavior

NASA IV&V Independent Test Capability (ITC)

JIST



JWST Integrated Simulation & Test

S3

SLS Software-Only-Simulator

Automation and virtual deployment

JSTAR
Jon McBride Software Testing & Research Lab
NASA IV&V
5000 NASA Blvd. Fairmont, WV 26554
www.nasa.gov/centers/ivv

QEMU RAD750 Model

Wind River Simics Modeling

Small Sats

NOS3

Simulation-to-Flight (STF-1) Introduction

Simulation-to-Flight (STF-1)

NASA IV&V ITC & West Virginia University (WVU) 3U Cubesat

- NASA Cubesat Launch Initiative (CLI) proposal submitted and accepted – NASA will pay manifest for future launch
- First WV Cubesat
- ITC is responsible for C&DH hardware/software, integration (hw/sw), and all testing
- WVU is responsible for payload hardware and software
- STF-1 is a "GSFC Cubesat" – partnering with GSFC/WFF and Dellingr Cubesat Team
- Current Launch Ready Date is August 2016 – not yet manifested – prefer polar orbit

Simulation-to-Flight (STF-1)

- **Primary Objective – Showcase simulation technologies developed at IV&V**
- Secondary Objectives – WVU Research into space weather, rad-hard materials, navigation instruments (GPS and IMUs), and camera

Sponsored by:

NASA

JSTAR NASA
Jon McBride
Software Testing & Research Lab

TMC2 TECHNOLOGIES

Orbital ATK

WVHTC FOUNDATION

NASA WEST VIRGINIA SPACE GRANT CONSORTIUM

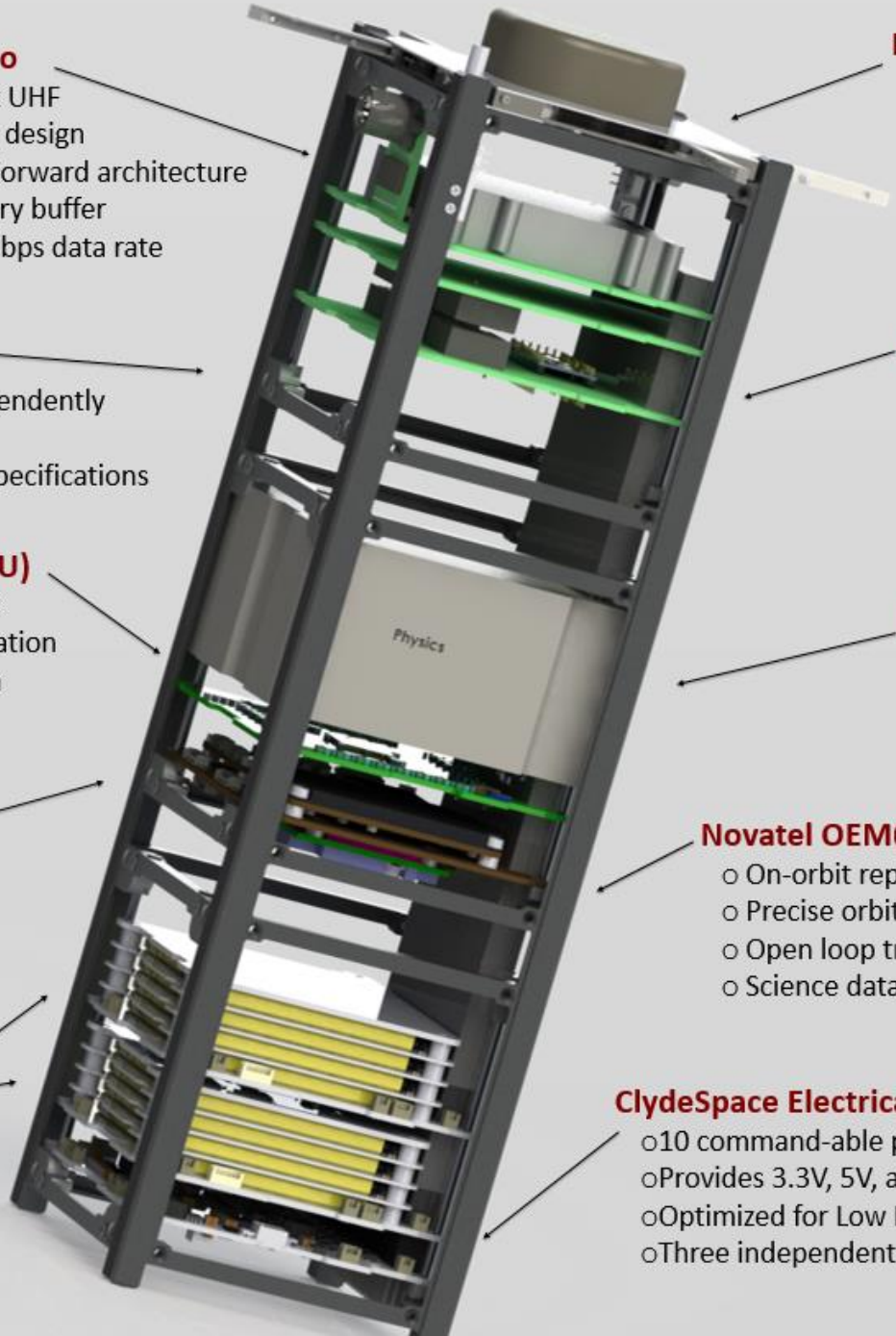
Simulation-to-Flight (STF-1)

STF-1 Flight Software / Hardware Design

- Working closely with the GSFC Dellingr 6U cubesat team
- FSW is Core Flight System (cFS)
  - Dellingr reuse, specifically on the radio cFS application
- ITC designed solar panel PCBs (Dellingr-based)
- Most hardware same as other GSFC cubesats

Hardware	Status
Onboard Computer	Received
Solar Cells	Received
Power System	Ordered – 10 Week Lead Time
Chassis	Ordered – Unknown Lead Time
ITC Designed Solar Panel PCBs	Designed – Out for Quote
Radio	Ordered – 6 Month Lead Time
Clean Room	Procured and Setup for Ribbon Cutting
Deployable Antenna	Ordered – Unknown Lead Time
Camera	Received

Anatomy of STF-1



Camera
- Mounted to a PC104 protoboard
- Optional filters to provide earth science data

CADET Radio
- Half duplex UHF
- Low power design
- Store and Forward architecture
- 4GB memory buffer
- Up to 22 Mbps data rate

ISISpace Chassis
- Modular structure
- Each unit can be assembled independently
- COTS component
- Compatible with P-POD Cal-Poly specifications

Inertial Measurement Unit (IMU)
- Micro Electro-Mechanical Systems
- Accounts for errors through calibration
- High quality inertial sensing with a MEMs IMU cluster

GomSpace Nanomind A3200
- High-performance AVR32
- 512KB build-in flash
- 125Mb NOR flash
- 32MB SDRAM
- I^2C, UART, CAN-Bus

2 x ClydeSpace Batteries
- Lithium Polymer
- 80 Watt Hours Total
- Two independent boards for redundancy
- Internal heaters

ISISpace UHF/VHF Antennas
- Deployable antenna system
- Four alloy tape antennas
- Up to 55cm in length
- Includes 30mm diameter center through-hole for pass-through

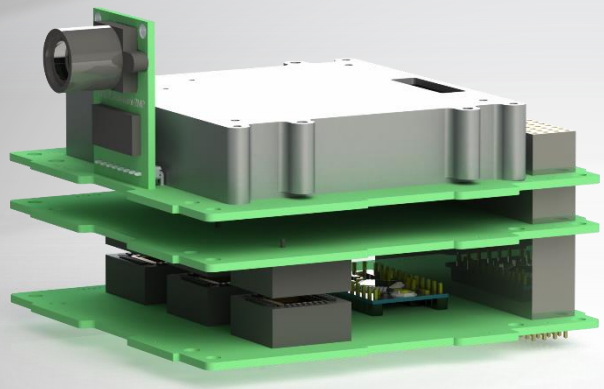
LCSEE
- Two PC104 Boards
- Fits directly into stack without modification
- Three different LED carriers with different shielding levels

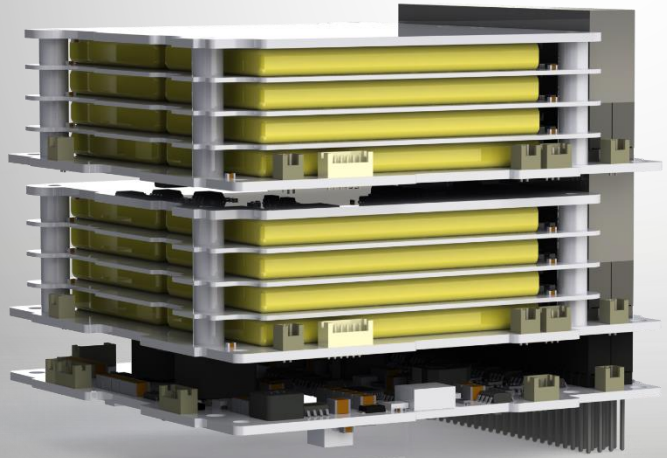
Physics Payload
- Particle detector
- VLF receiver
- Plasma Probe

Novatel OEM625 GPS
- On-orbit reprogrammable
- Precise orbit determination
- Open loop tracking
- Science data products: 100-Hz phase, TEC, S4

ClydeSpace Electrical Power System (EPS)
- 10 command-able power switches
- Provides 3.3V, 5V, and 12V
- Optimized for Low Earth Orbit (LEO)
- Three independent battery charge regulators

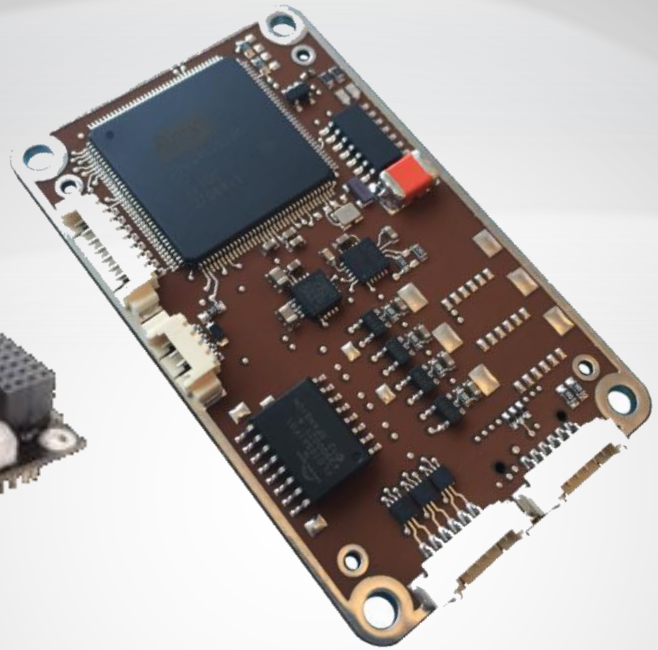
Simulation-to-Flight (STF-1)

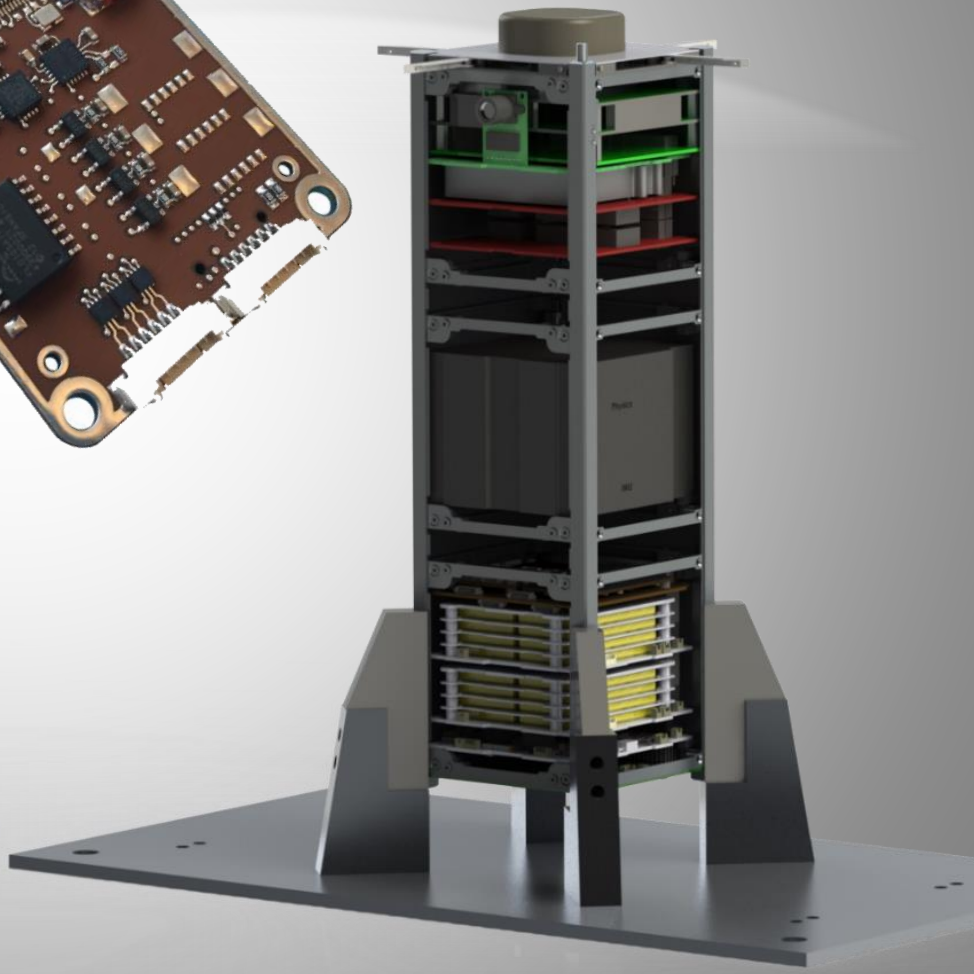




NOS^3

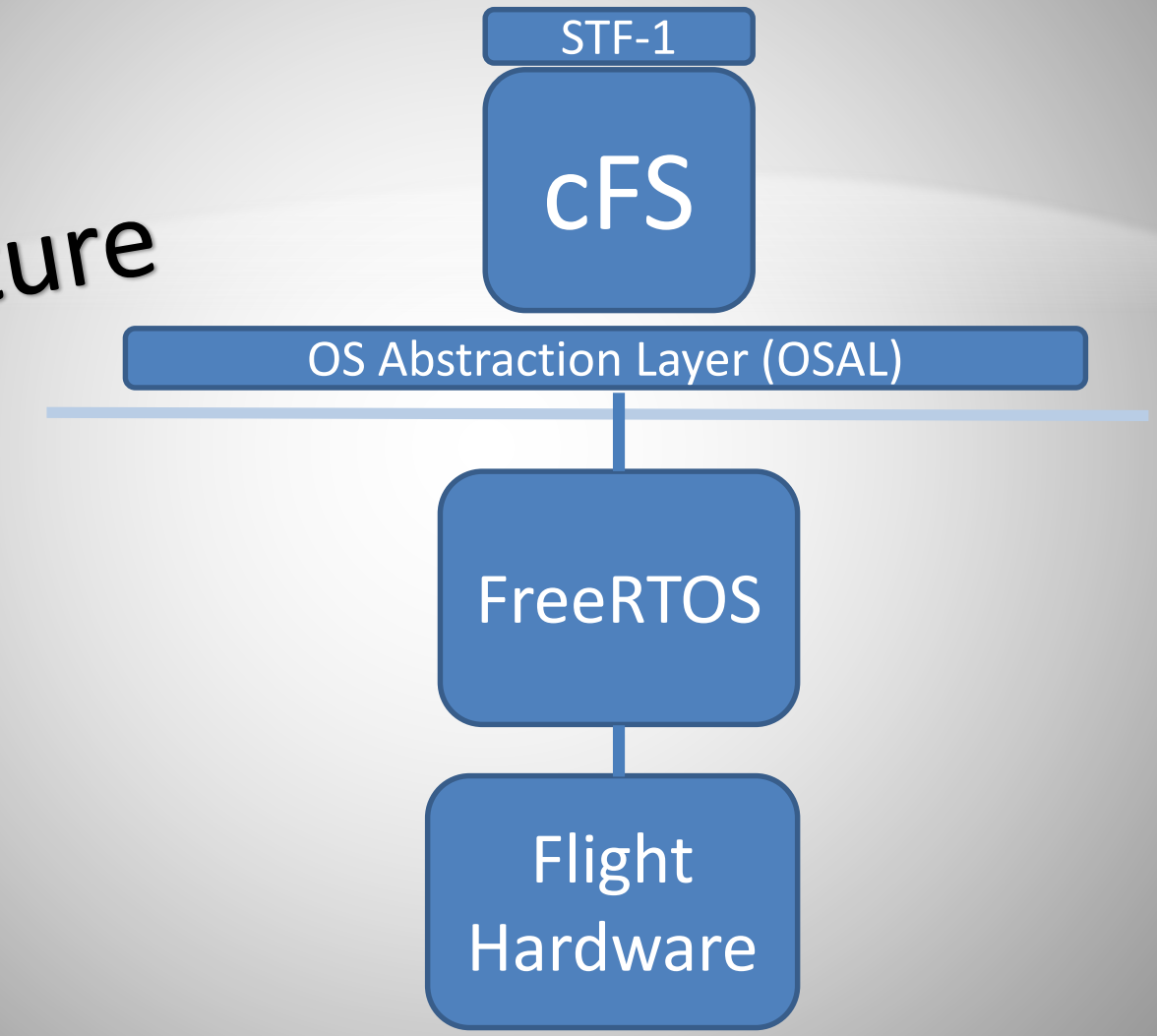
Simulation-to-Flight (STF-1)





Simulation-to-Flight (STF-1)

FSW Architecture



NASA Operational Simulator for Small Satellites (NOS^3) Introduction

NOS^3

What is NOS^3?

- A software test bed for small satellites
- Based upon STF-1 hardware, but sufficiently generic
- Easily-interfaces to cFS FSW, but cFS not required
- Currently open-loop, closed loop planned
- Openly distributed solution Ready-to-Run (RTR) – Looking for Users!
- A collection of Linux executable and libraries

What is it used for?

- FSW early-development – NOS^3 provides real-world inputs to FSW
- FSW V&V – Testing FSW, invalid inputs, behavior, stress conditions
- FSW Integration – Used for early-app development and payload team integration
- Mission Planning – Example: power analysis

NOS^3 Ready-to-Run (RTR)

Leverage ITC virtual deployment technologies

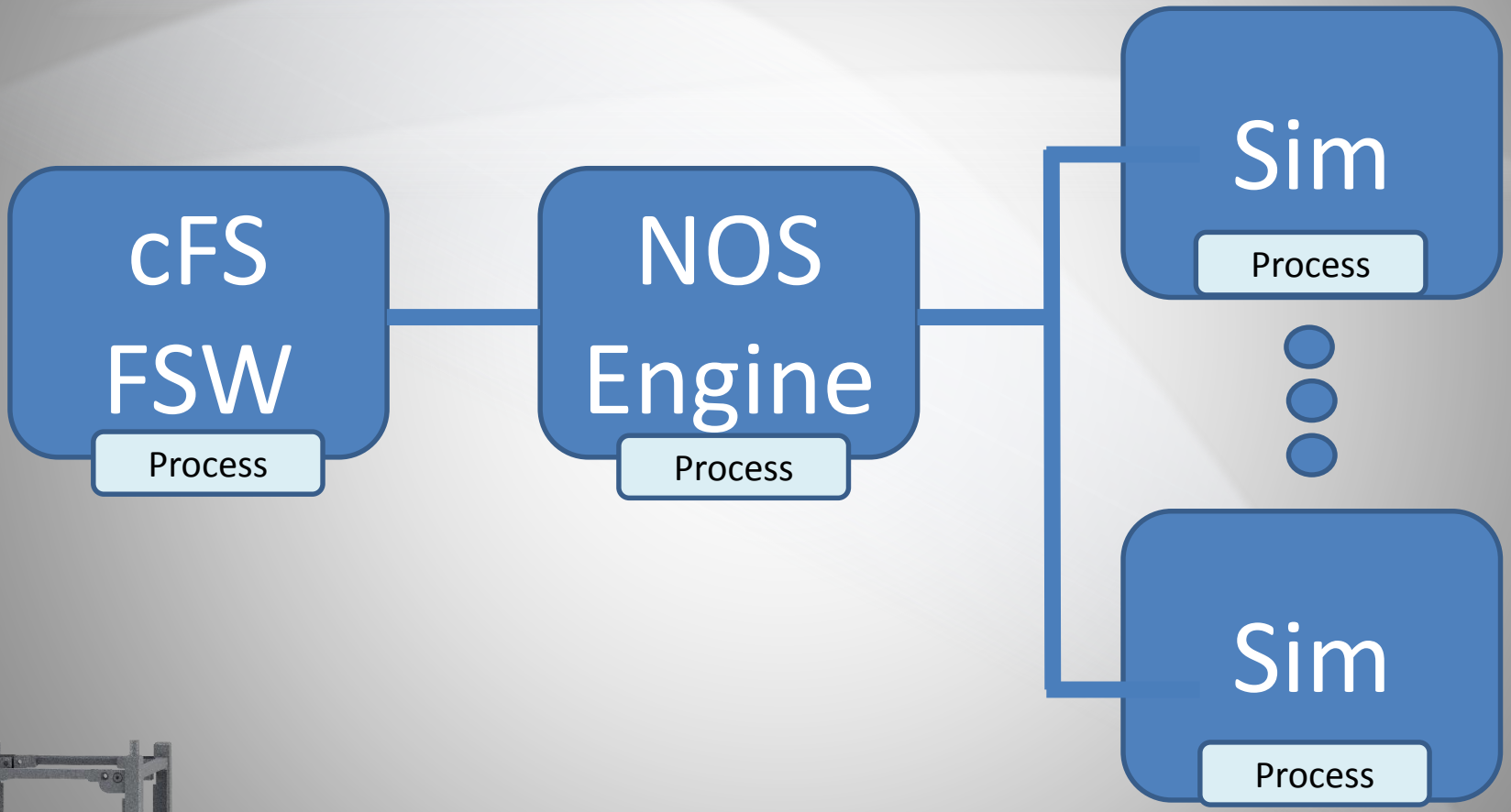
- ITC does NOT distribute virtual machines
- Virtual machines are built on-the-fly by the user
- Deployment Steps
  - Obtain files ITC
  - Install virtual machine provisioner such as Virtual Box
  - Run 1 Command – generates virtual machine
  - Login to virtual machine and build cFS with RTR script

Ready-to-Run (RTR) for…

- cFS development environment
- NOS^3 environment
- Ground system software
- Software integration testing

NOS^3

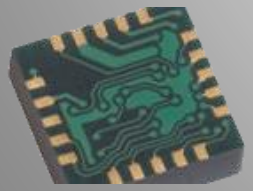
Linux Software Architecture



NOS^3

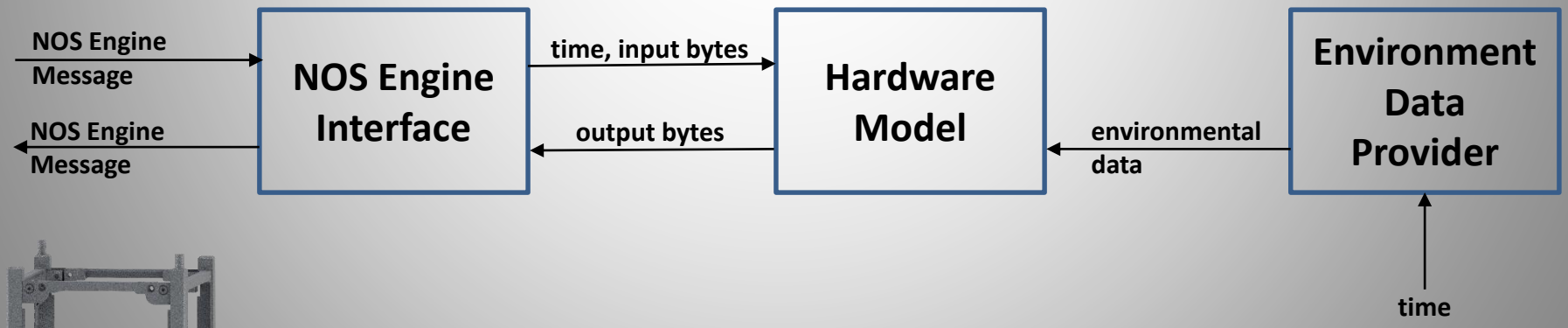
NOS^3 v1 Included Simulators

Simulator	Hardware Modeled	Sim Usage
Magnetometer	Honeywell HMC5843	FSW data source for development
Electrical Power System (EPS)	Clydespace Gen III	Power analysis – software control of switches
GPS	Novatel	FSW data source for development and software commanding of GPS
Camera	ArduCam Mini OV2640 SPI/I2C	FSW data source for development and large data packet handling

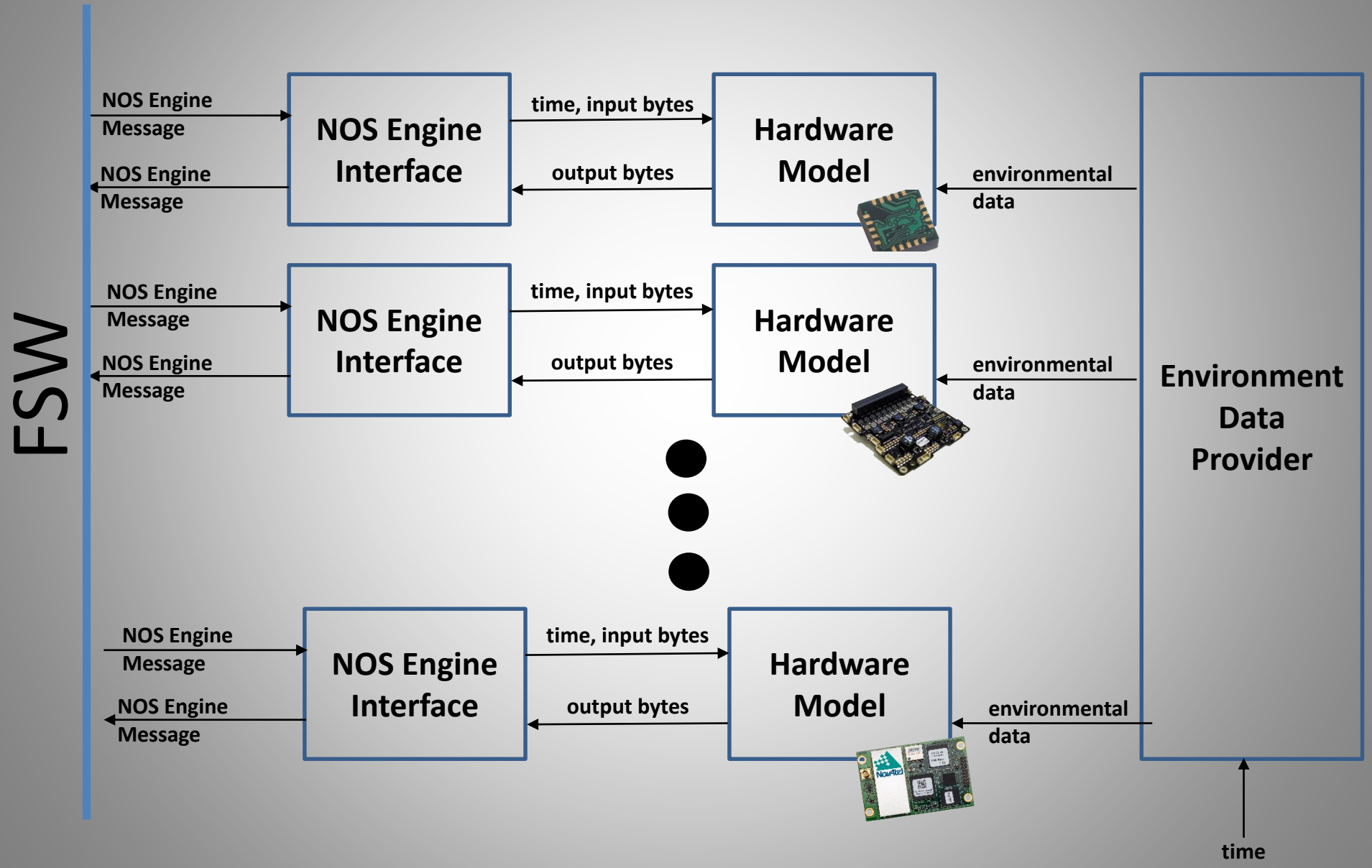


NOS^3 Components

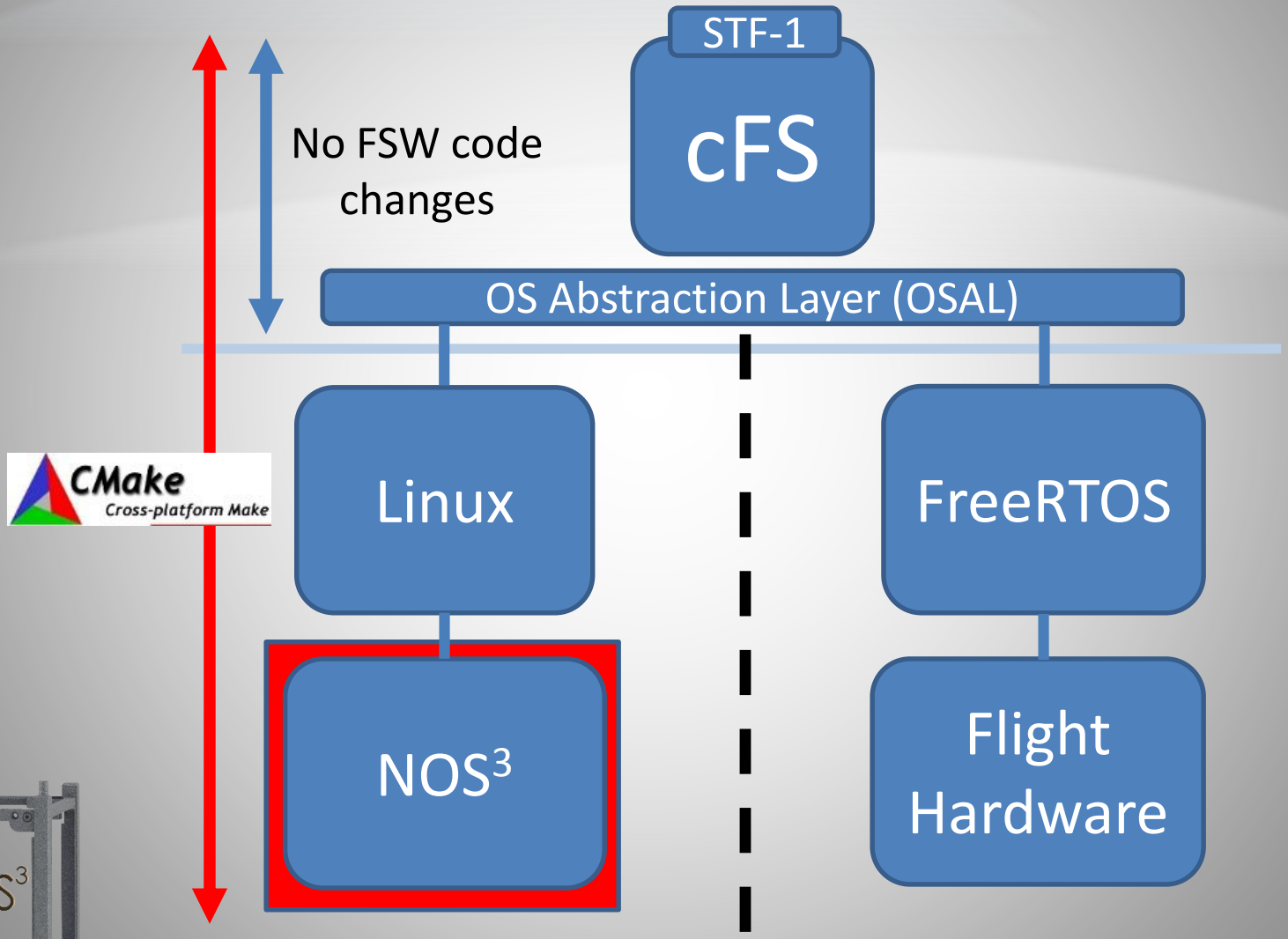
Component	What is it?	How is it used?
NASA Operational Simulator (NOS) Engine	*Engine* is ITC-developed message passing middleware designed specifically for use in simulation. Includes time synchronization, data manipulation, and fault injection.	Serves as the NOS^3 glue to tie all components together into a common interface to FSW
Hardware Model	A model for a specific piece of flight hardware, often focusing on the inputs/outputs of the device from the FSW perspective.	Serves as virtual hardware in order to provide FSW with an accurate representation of its data
42	42 is an open-source general purpose simulator developed at NASA Goddard Space Flight Center for spacecraft attitude and orbit dynamics.	Serves as an *Environment Data Provider* – chosen to provide magnetic field data and positional data as inputs to the magnetometer and GPS simulators



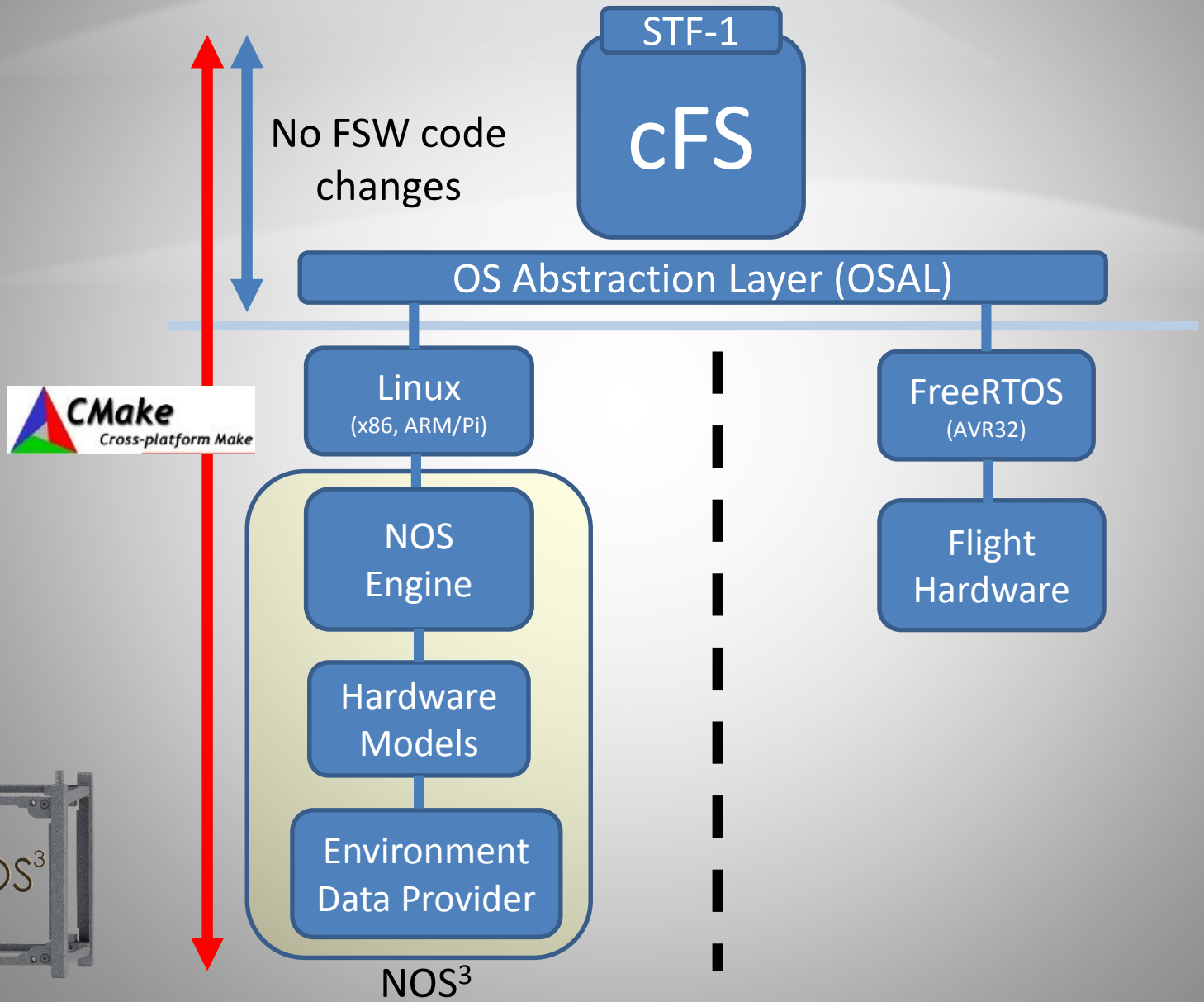
NOS³ Components



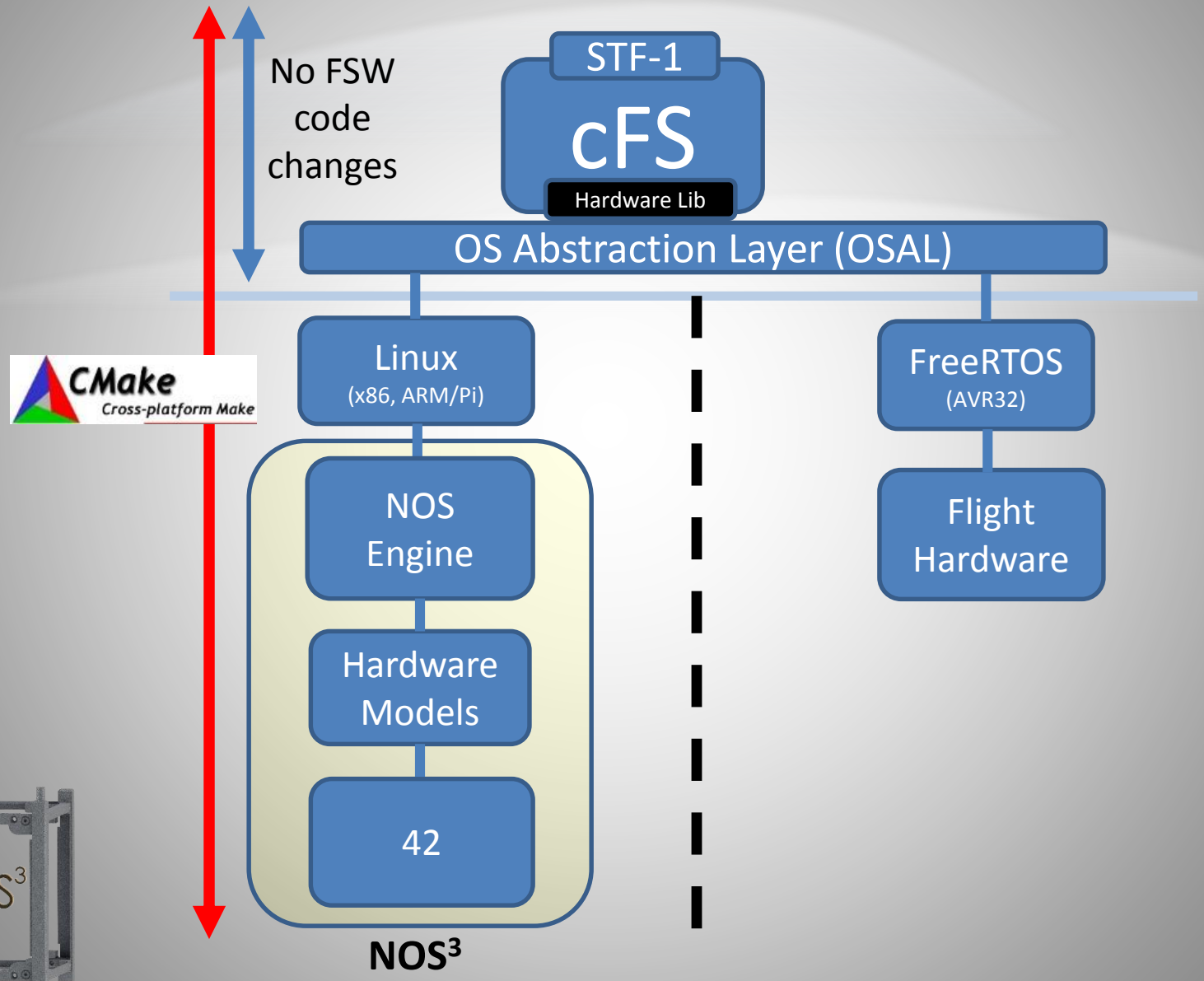
STF-1 FSW + NOS^3



STF-1 FSW + NOS^3



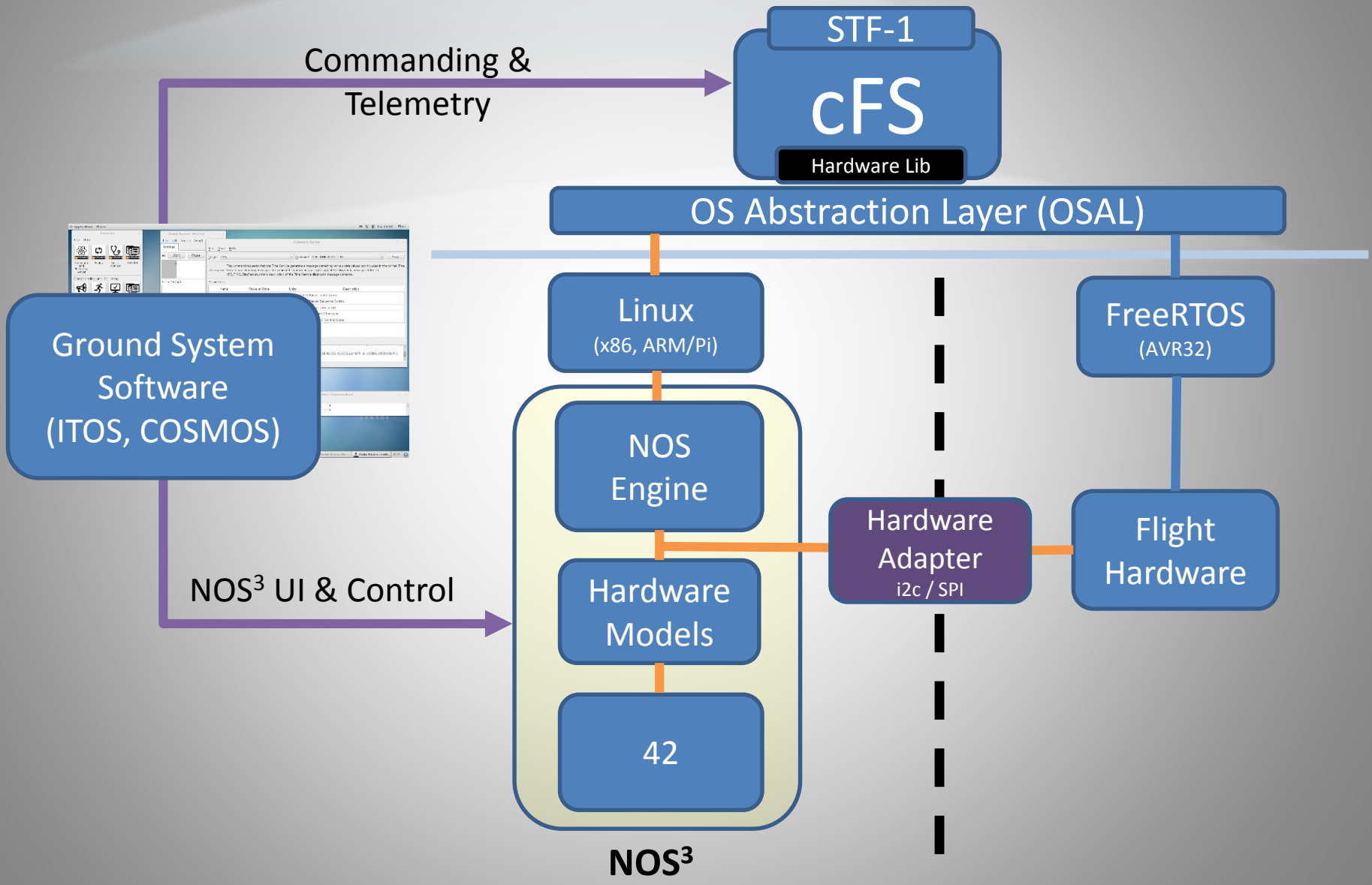
STF-1 FSW + NOS^3



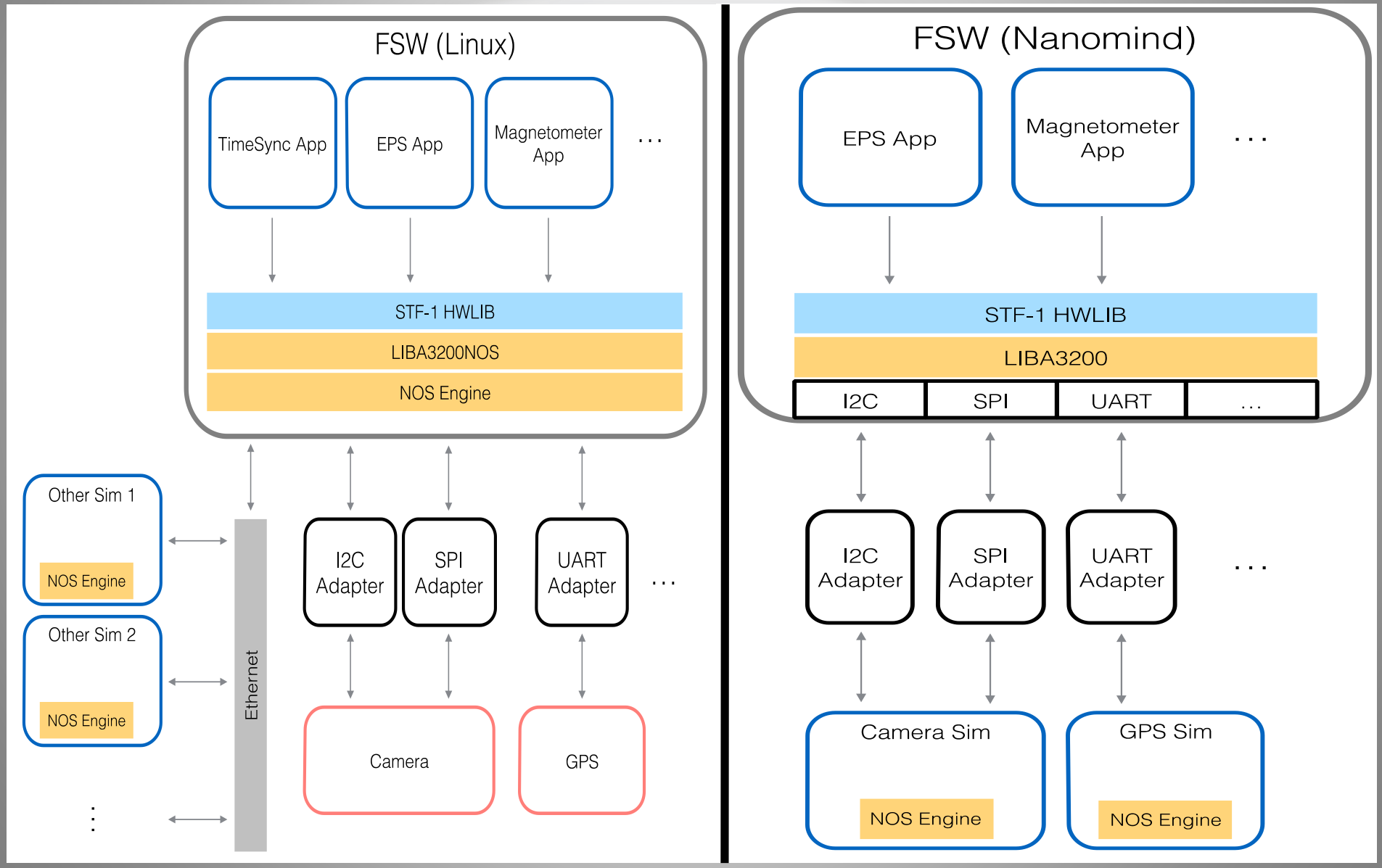
Future Plans – NOS^3 v2

Capability	Description
3 Axis Gyroscope Simulator (In Progress)	InvenSense MPU-3300
Temperature Sensors (In Progress)	I2C Temperature Sensors
Electrical Power System (EPS) Sim Maturity (In Progress)	Add battery sim to Clydespace Simulator
UHF Radio Simulator (under consideration)	L3 Cadet Radio
Visualization / User Interface	Provide the user with a generic NOS^3 user-interface.
Integrate with Ground System Software	Currently looking into COSMOS and ITOS.
Tighter 42 Integration	Programmatically sync FSW time to 42 time so that NOS^3 hardware models and FSW are in sync

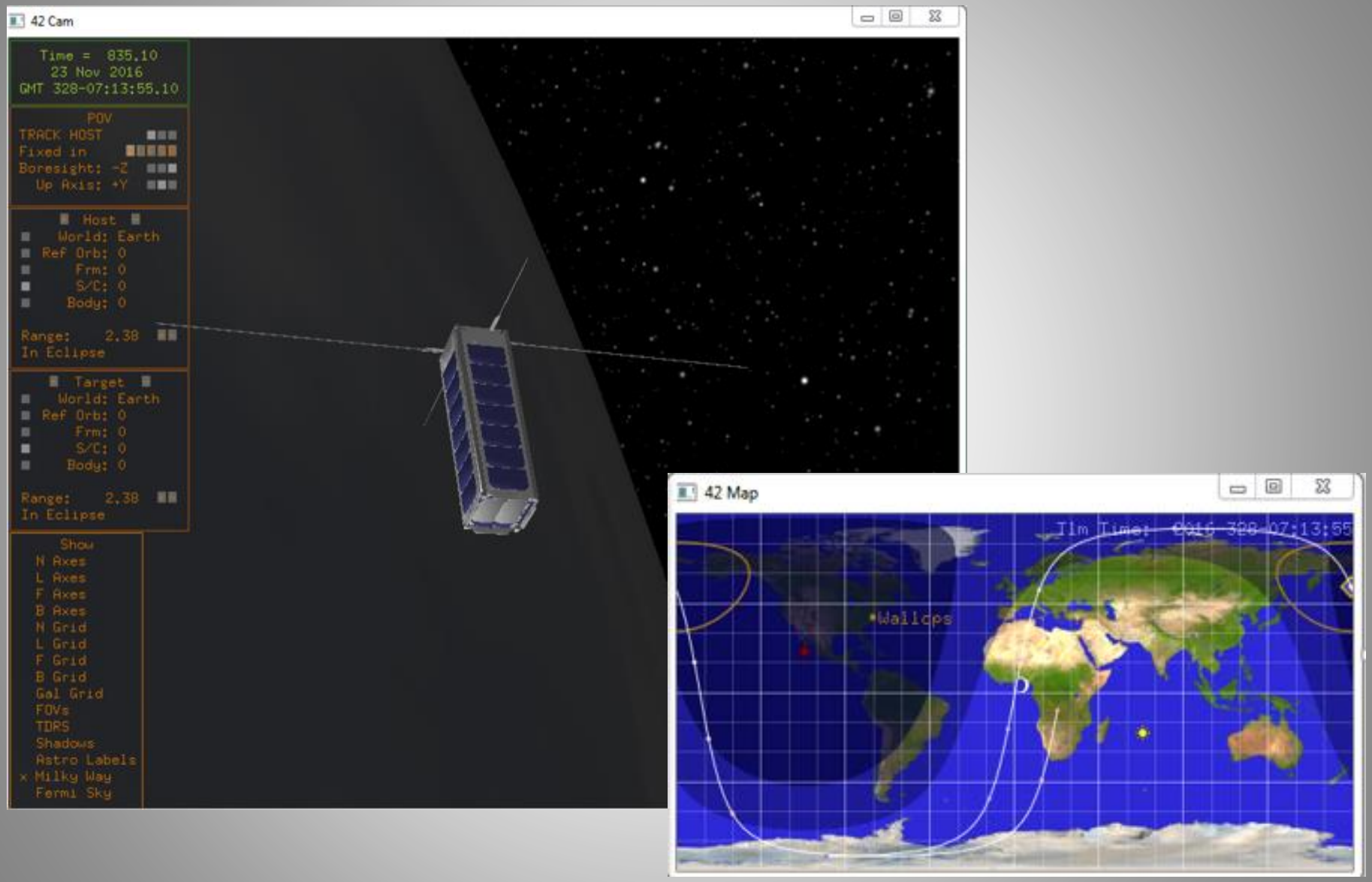
NOS³ Work In Progress



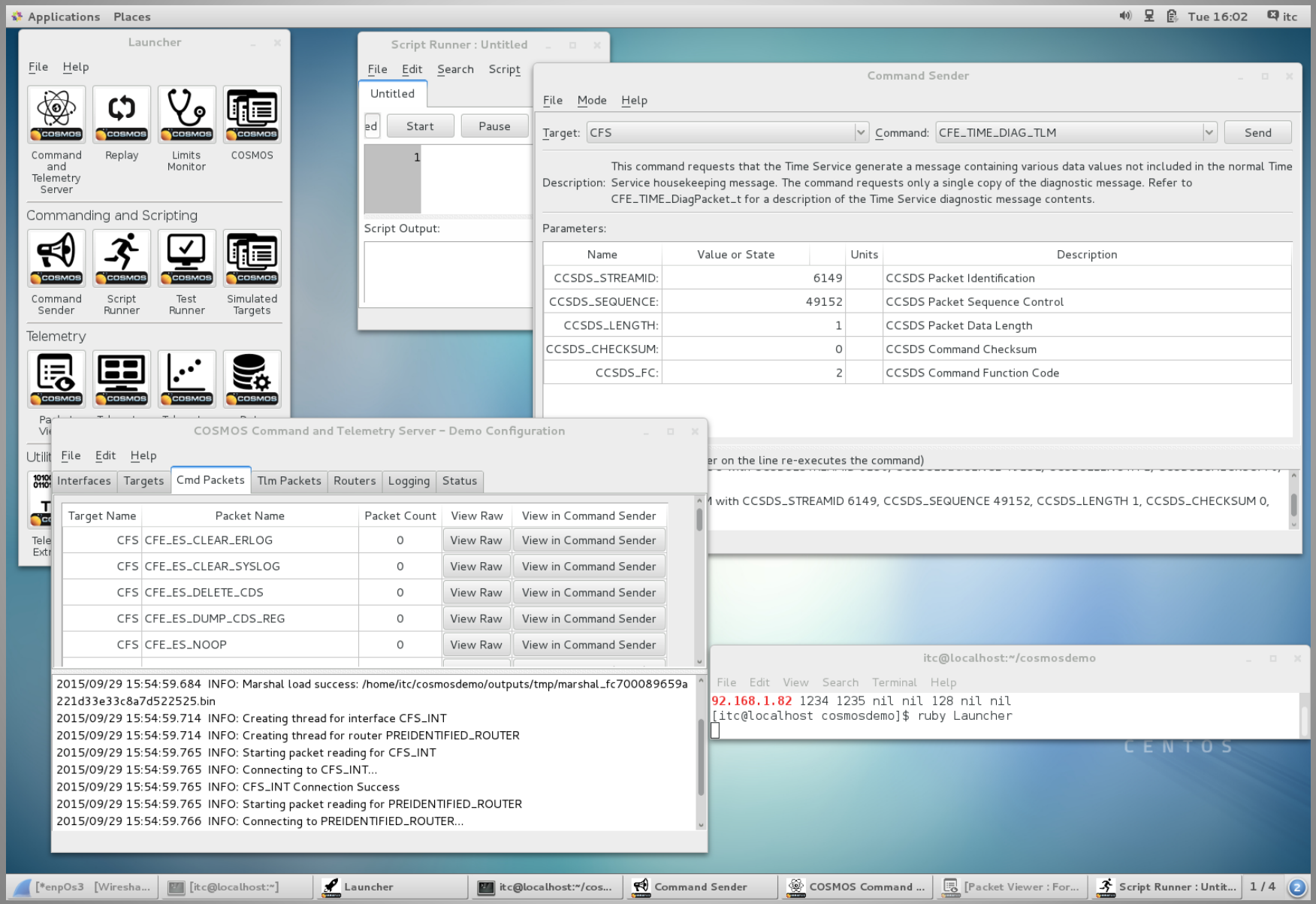
NOS³ Work in Progress



NOS³ Visualization



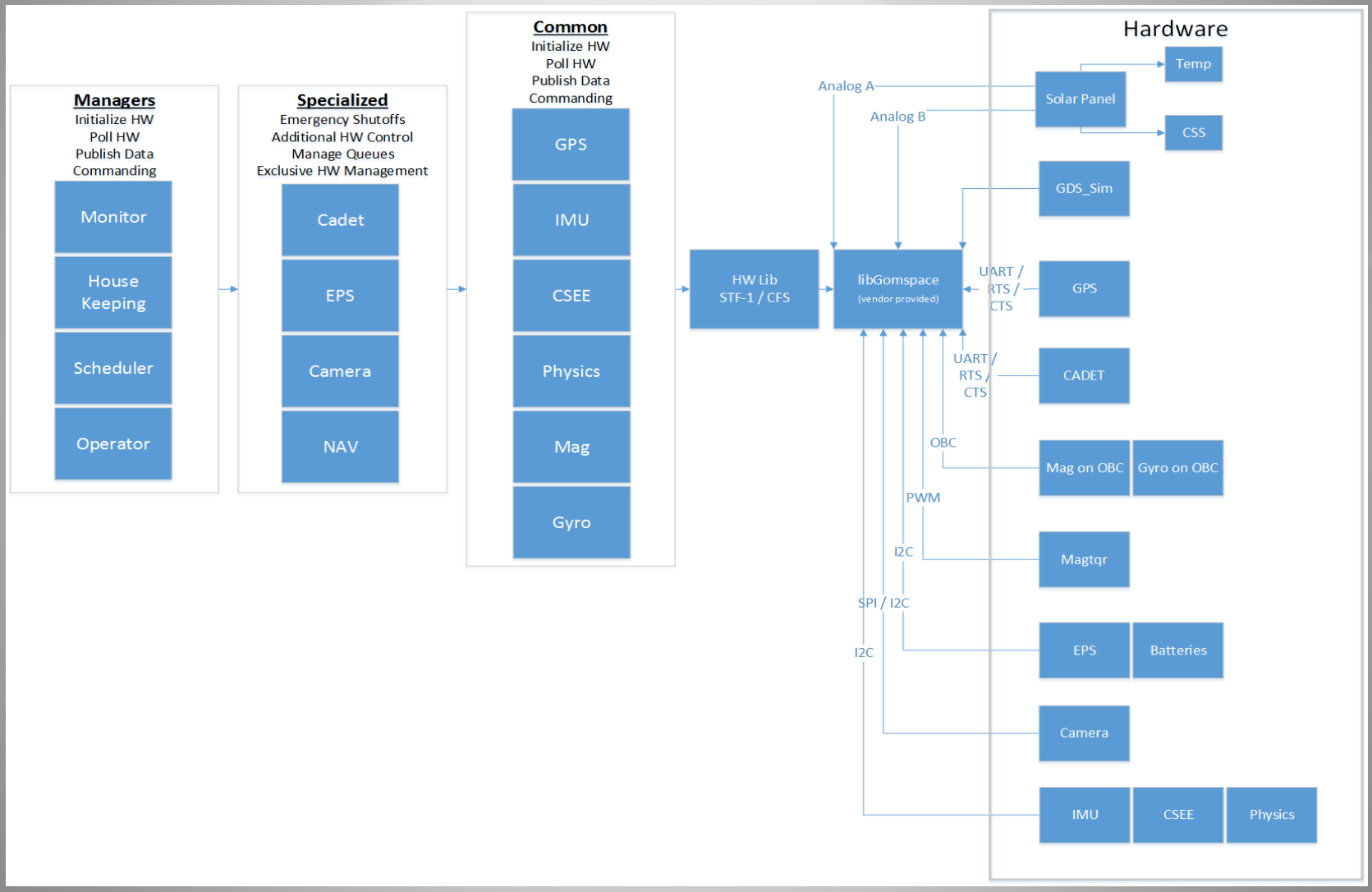
NOS³ Ground System Integration



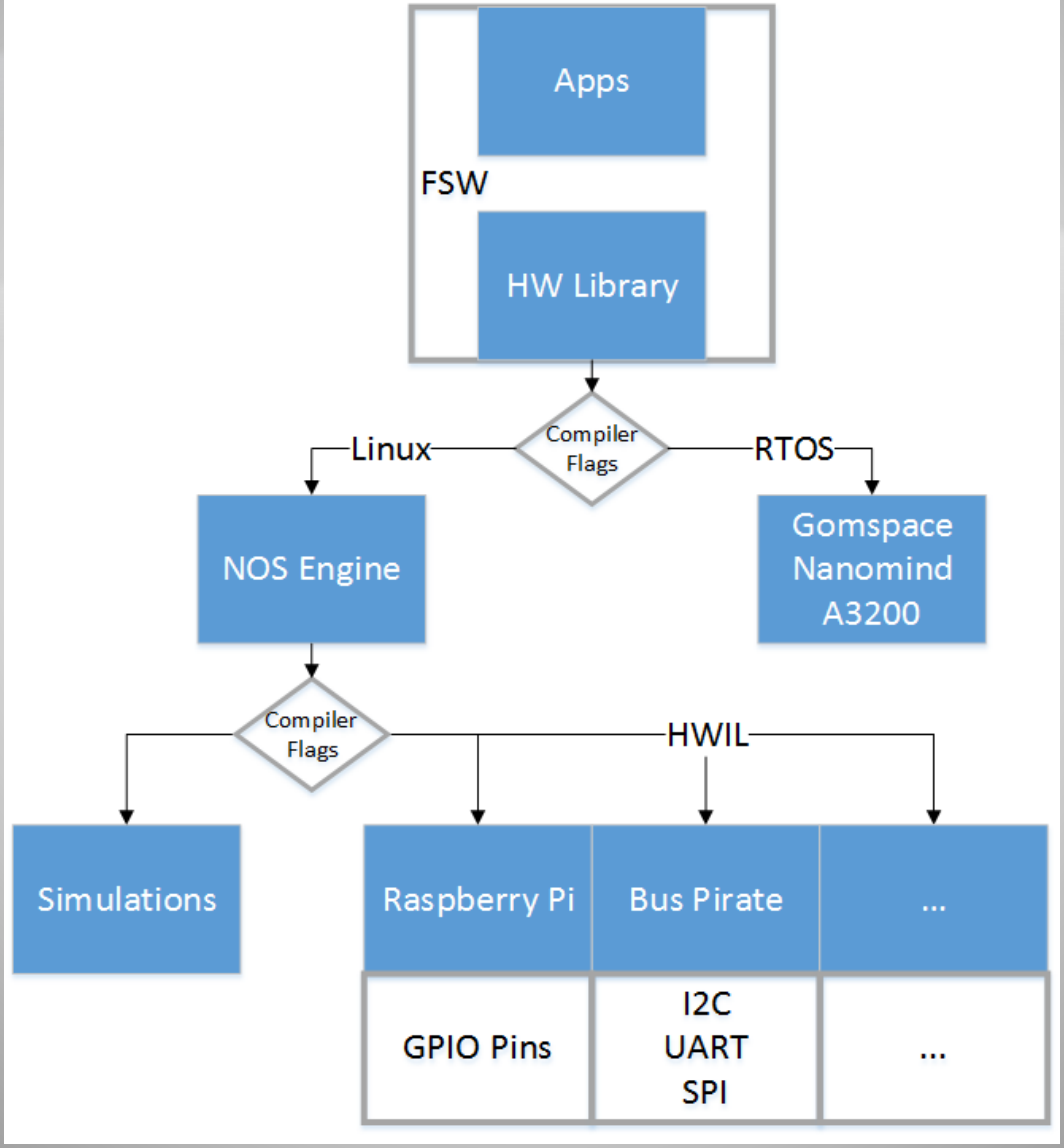
Questions?

Backup Slides

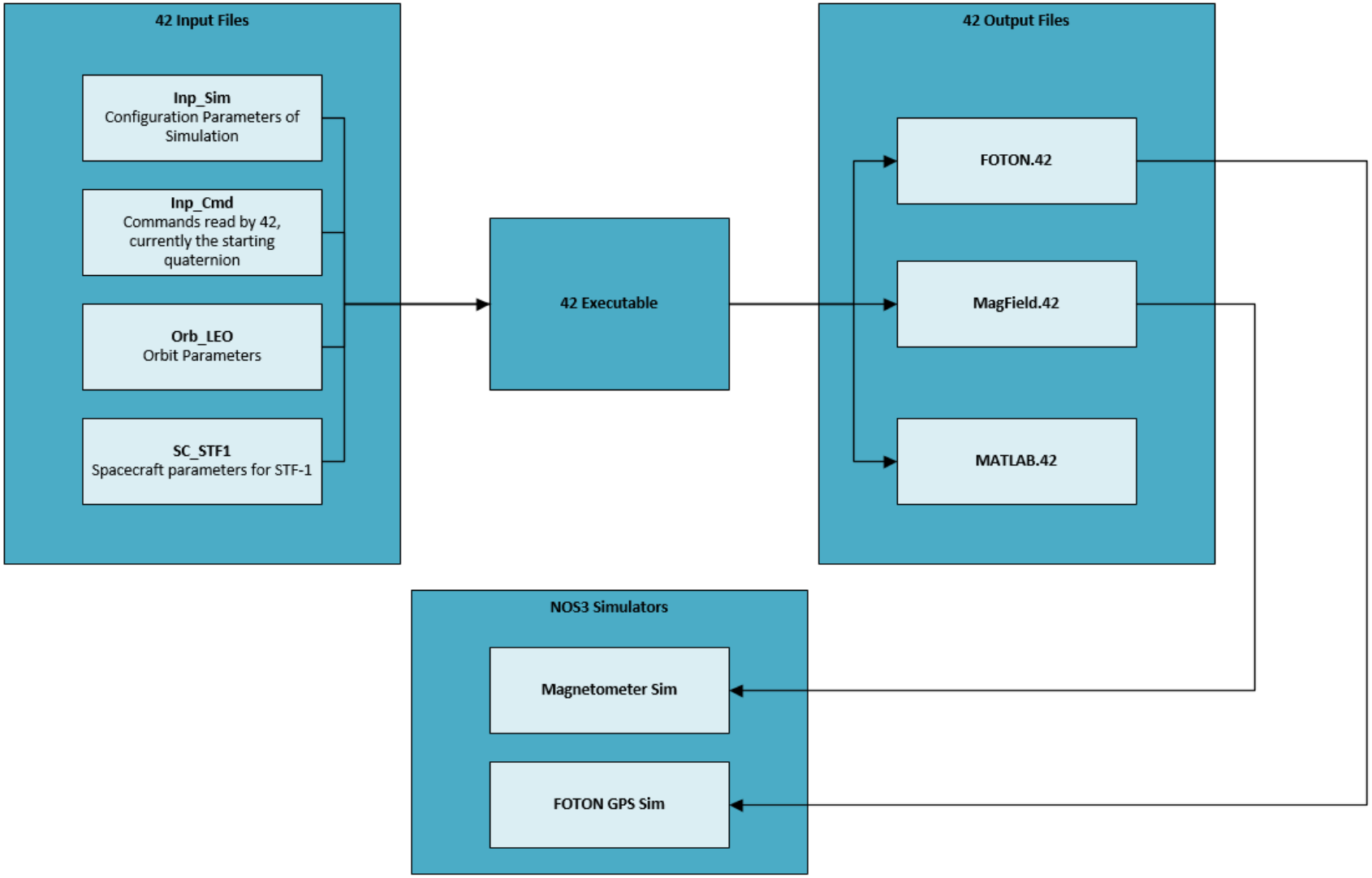
NOS³ FSW Architecture



NOS^3 FSW Architecture



NOS^3 42 Integration



EPS Simulator