Rapid Development and Test for UKube-1 using Software and Hardware-in-the-Loop Simulation

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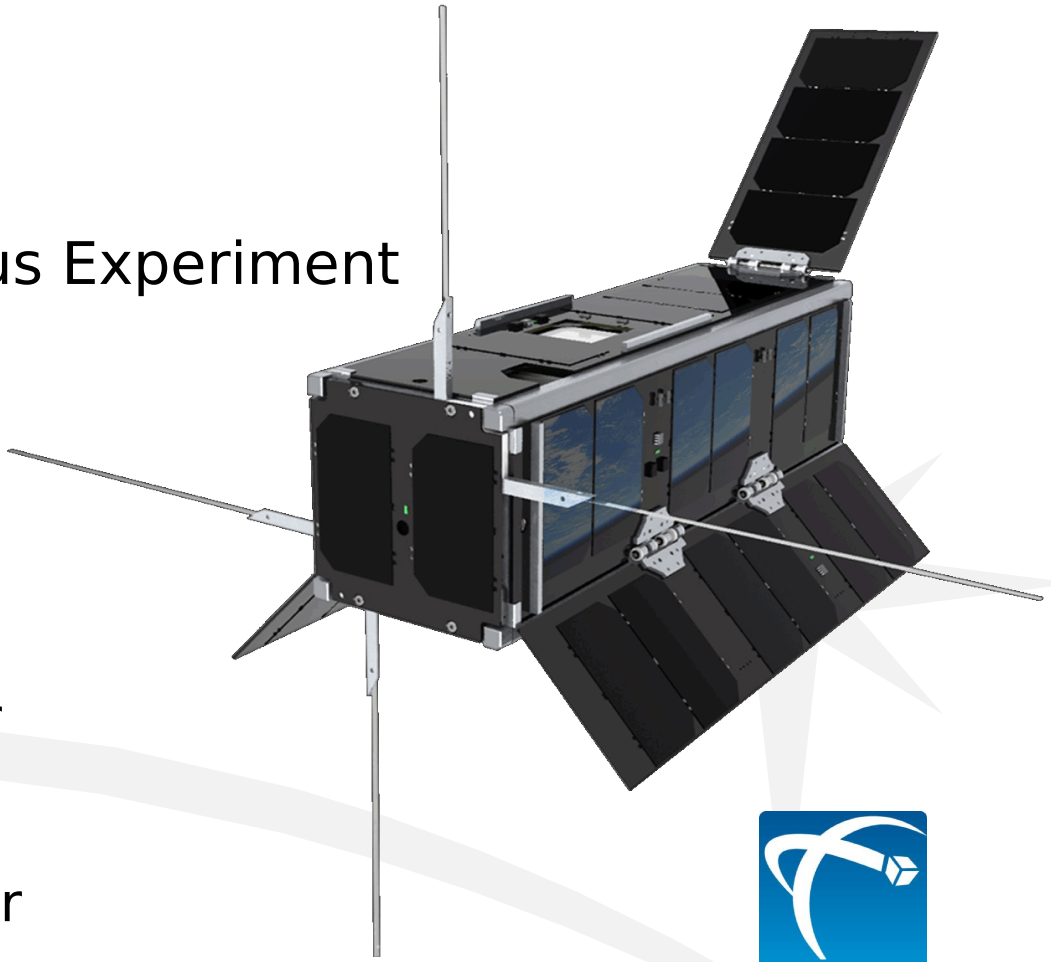
UKube-1

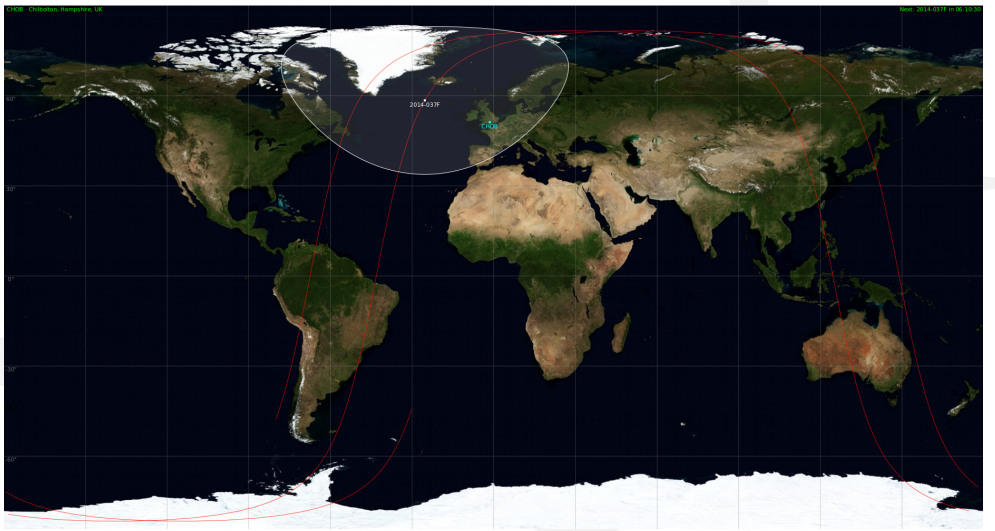
- United Kingdom Universal Bus Experiment
- 3U CubeSat
- Five payloads
  - C3D – imager
  - JANUS – radiation
  - MIC – FPGA-based processor
  - TOPCAT – GPS occultation
  - FUNTRX – AMSAT transceiver
- Experimental platform (e.g. S-Band Transmitter)



- Launched 8th July 2014

Operational Challenges

- Many challenges common to CubeSats
- Low link budget
  - One (primary) ground station
  - Low up/downlink bandwidth
  - Short passes
- Lots of data
  - Many experimental systems
  - Multi-MB of payload data
- Limited operations
  - As “hands-off” as possible
  - Need flexible control over low-level aspects of system
  - Need lots of automation: time-based, orbit based, event-based, onboard scripting



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Validating Operations

- Very limited partial engineering model of satellite
  - Intended for ground station validation
  - Does not include many platform elements
  - No payloads included
- Cannot use EM for operations support
  - e.g. script or schedule validation
- Cannot use EM for operator training
  - Too incomplete for basic platform operations
  - Main operational focus is payloads
- **Need a simulation of the spacecraft to support operations**

Spacecraft Simulation

- Typical satellite simulators are expensive
  - Timing-accurate
  - High-fidelity
  - Linked with complex models of hardware and space environment
  - Time consuming to create

- “CubeSat approach” to simulation
  - Functionally accurate
  - Not timing accurate
  - Only essential hardware functions simulated
  - Modular
  - Permit hardware-in-the-loop to add fidelity

GenerationOne Software

- UKube-1 flight software
  - GenerationOne Software Development Kit and Tooling
  - Component-based
  - All components abstracted from underlying platform
  - Components portable across platforms and operating systems without modification
  - Rapid assembly of flight software
- Operating system abstraction
  - Real-time tasking abstraction based on widely-accepted, robust model (RCM)
- I/O and Device Abstraction
  - Based on CCSDS standards for onboard interfacing abstraction

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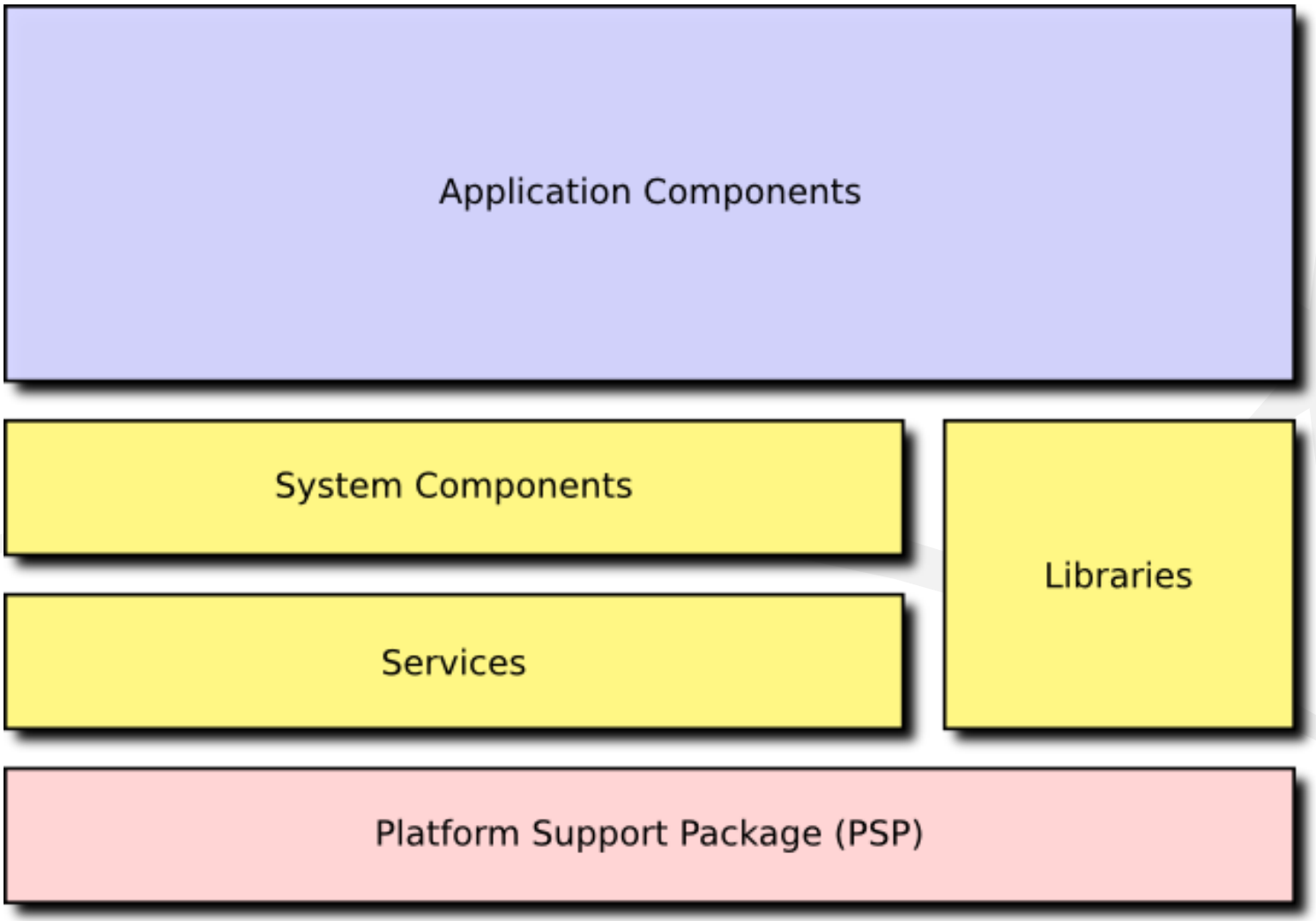
GenerationOne Architecture



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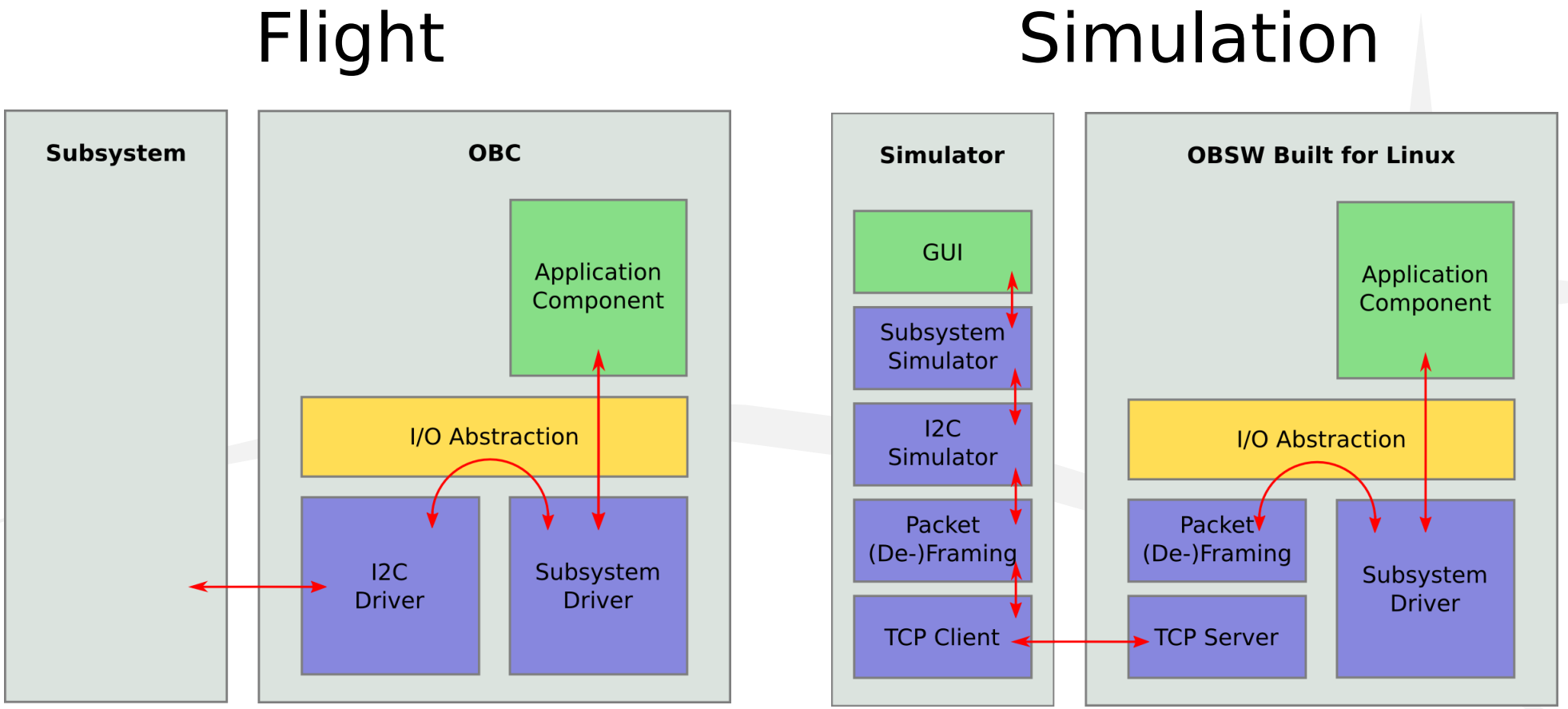
Abstraction for Simulation

- Abstraction features of GenerationOne were crucial for simulation
  - Rebuild flight software for target simulation platform (e.g. desktop Linux)
  - Component implementations do not change
  - Assembly of application components does not change
- Can swap low-level bus interfacing components without affecting subsystem code
  - Replace onboard I^2C bus with TCP/IP to simulator

Hardware Simulation



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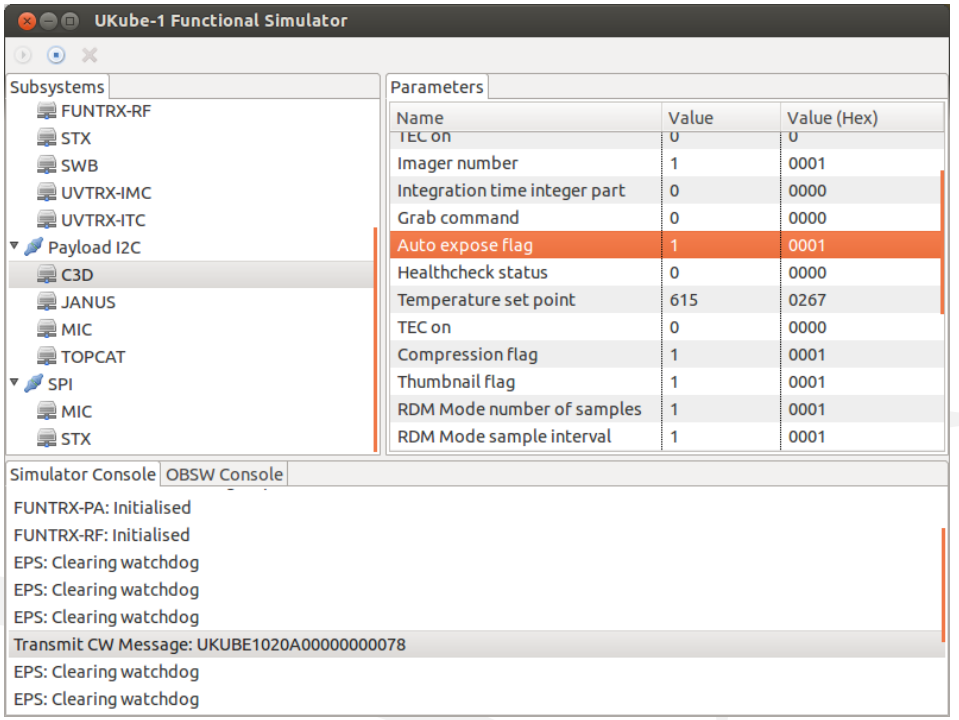
UKube-1 Simulator

- Modular simulator
- Implemented in Java (e4)
- Allows control of simulation
- Interaction with hardware devices
  - In real time
- Monitoring of simulated hardware status
  - Error alerts etc.
  - Invalid conditions (e.g. over-power)
- Interface to Mission Control Software identical to flight system



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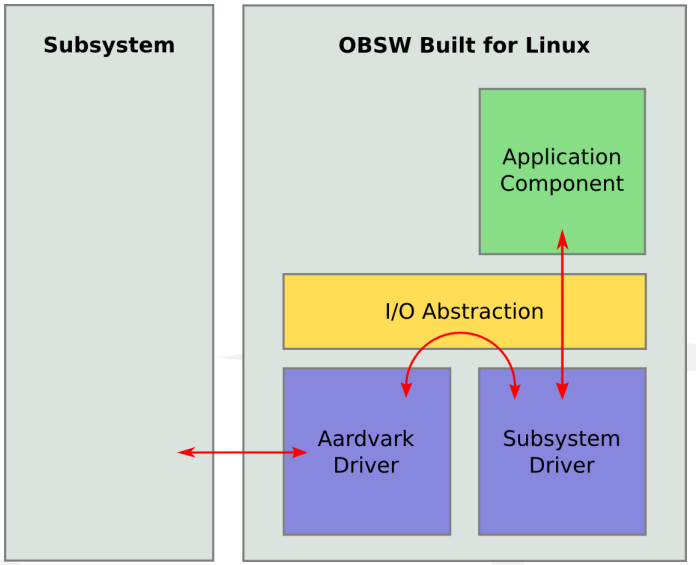
Hardware in the Loop

- The same principles can be used to include hardware in the loop
- GenerationOne support for USB to bus adapters
  - e.g. USB to I2C – Total Phase Aardvark
- Pick and choose which hardware to place in the loop
- Can also run flight software on OBC and simulate all subsystems
- Also useful for development, testing, prototyping etc.



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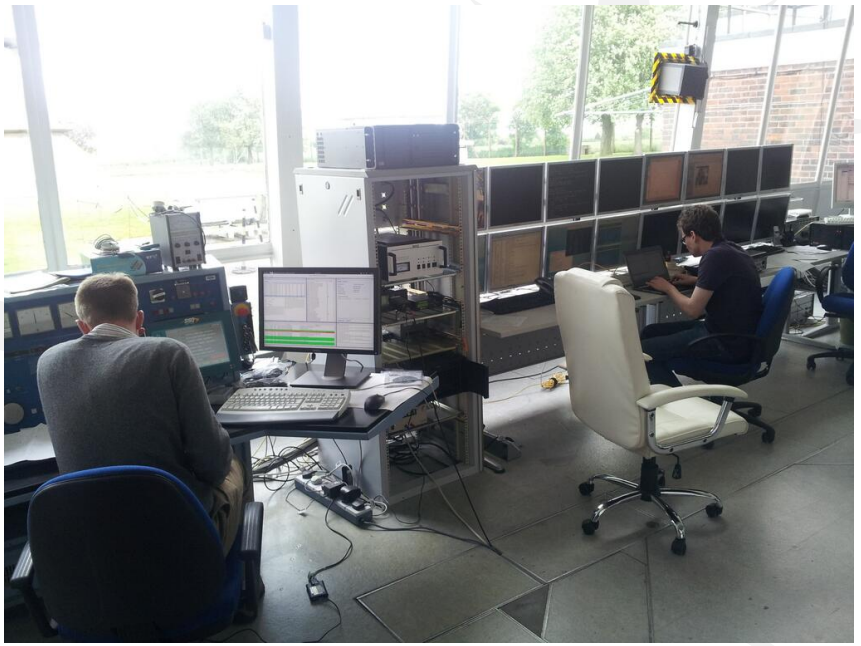
Simulator in Use

- Simulator in regular use at the UKube-1 Mission Operations Centre
  - Rutherford Appleton Laboratory (RAL Space) team
  - LEOPS based at Chilbolton Observatory
- Operations team very pleased with results
- Excellent cost-benefit trade-off



Conclusions

- Simulation can be a useful tool for
  - Operation planning and support
  - Other development phases
- From cost-benefit trade-off we suggest that a functional simulation is best
  - Not timing accurate
  - In some cases results must be carefully interpreted
  - Significantly cheaper than timing-accurate simulation
- Higher fidelity can be achieved through insertion of hardware in the loop
- A well-designed software framework makes using the flight software for simulation trivial
- Currently generalising UKube-1 simulation framework for use on other missions

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Question, comments or suggestions

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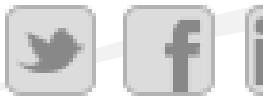

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