Integrating Advanced Payload Data Processing in a Demanding CubeSat Mission

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CubeSat mission capability

- Nano-satellites missions are **increasing in capability**
  - Constellations
  - Distributed ground segment
  - Ground segment
  - Onboard autonomy
  - Advanced payloads
- What makes an **advanced payload**?
  - Challenging concept of operations
  - High-data rate
  - Requirement for substantial onboard processing

- How can advanced payloads be incorporated into a mission?
  - Whilst controlling risk
  - Minimising AIT complexities
  - Without requiring complex operations on the ground

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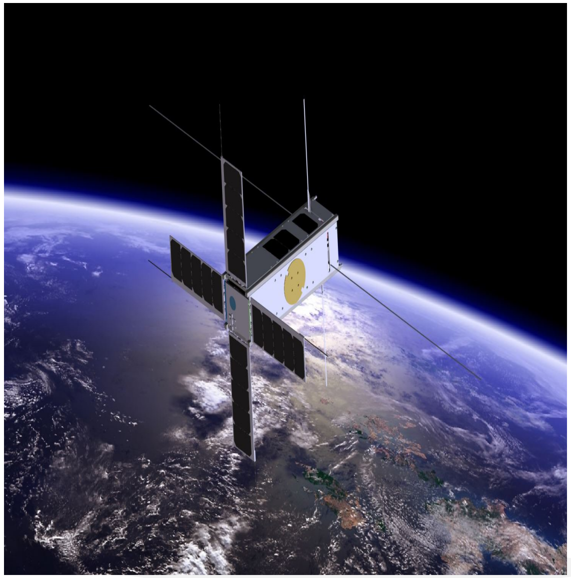
The PICASSO mission



- Atmospheric science mission
- Led by by the Belgian Institute of Space Aeronomy
  - Managed by European Space Agency
  - Clyde Space leading spacecraft manufacture
  - Bright Ascension leading software work
  - Imager by VTT
- Main target is **science of the upper atmosphere**
  - Stratospheric Ozone distribution
  - Mesospheric Temperature profile
  - Electron density in the ionosphere
- Two instruments
  - Miniaturised **hyperspectral imager** for solar disc imaging in the limb
  - Multi-needle **Langmuir probe**

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PICASSO mission challenges

- Hyperspectral imager produces a lot of data
  - **640 Mbps** during measurement period
  - Data must be windowed (in real time)
  - Then compressed (not real time, between measurements)
  - Then archived onboard before next available downlink
  - S-band downlink permits 1Mbps
- **Timing** of measurement periods is critical
  - Measurements must be taken in the limb
  - All measurements must be precisely timestamped
  - Using GPS as a time source
- **Attitude** during measurements is critical
  - Largely handled by ADCS
  - Coordination of ADCS with platform and payload operations is critical

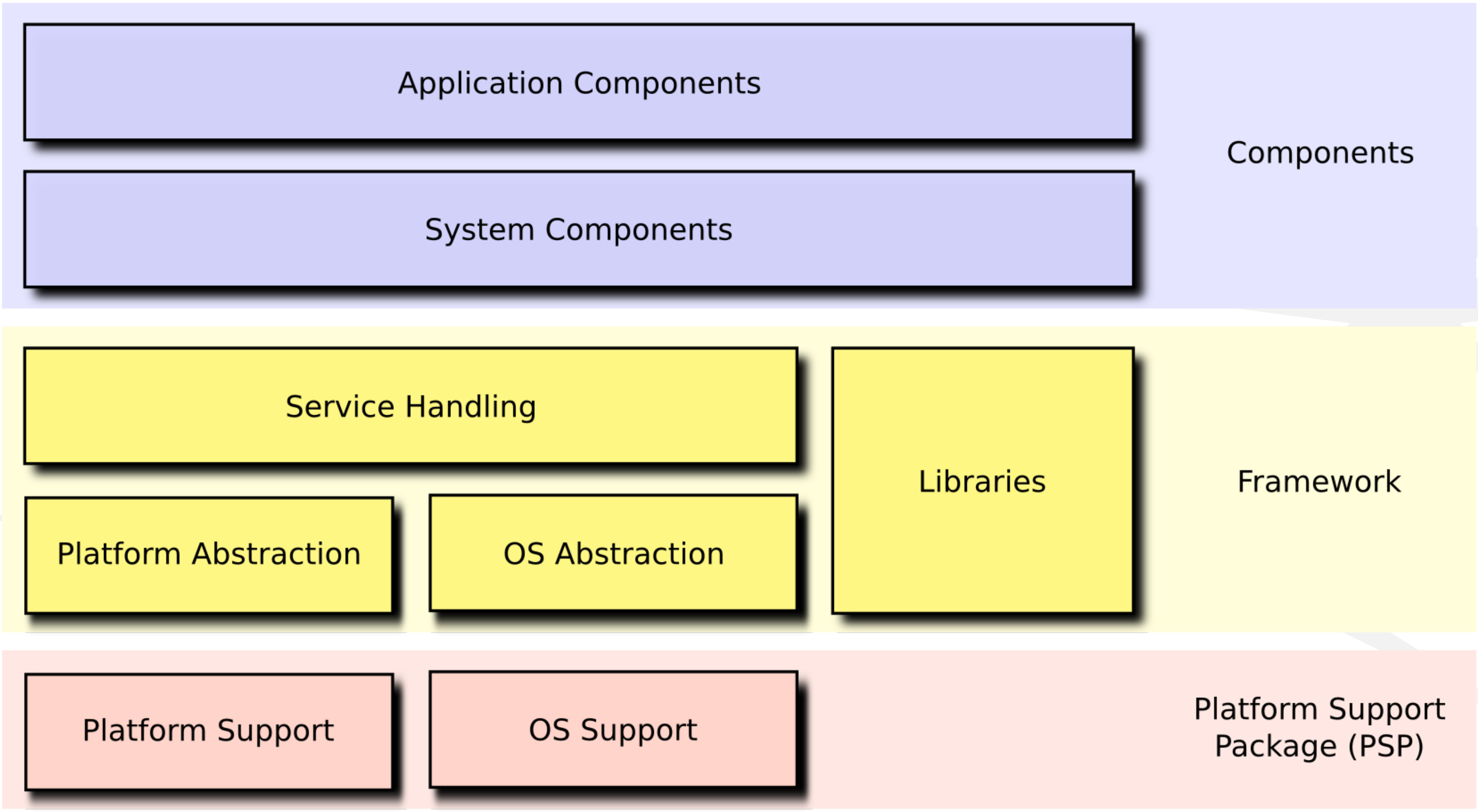
PICASSO functional architecture

- High performance computer necessary for payload data handling
  - Large **memory** requirements
  - Large **mass storage** requirements
  - High-speed **I/O** interface required
  - High-performance **processing** required for real-time windowing
- Trade space for payload processing is very different to platform
  - Platform computing requirements
    - Dependable
    - Real time
    - Low power
    - Requirements for memory/performance are low
- Selected separate platform and payload computers
  - Platform: GOMspace Nanomind
  - Payload: Xiphos Q7
- Results in a **distributed architecture** on board

GenerationOne flight software

- GenerationOne is a **software development kit** for flight software
  - A framework and tooling to allow software to be built quickly and easily
  - A library of validated components for common onboard functions
- GenerationOne is **component-based**
  - Allows clean and easy reuse of heritage code
  - Easy integration of new functionality
  - More streamlined testing and integration
- GenerationOne is **model-based**
  - Allows tooling to “understand” your software
  - Ground software and onboard software can share the same model
  - Enables lots of automation and code generation
- Software architecture **cleanly abstracts** different parts of the system
  - Hardware independence
  - Operating system independence
  - Protocol independence

GenerationOne architecture



Example software components

- **Subsystem components**, represent hardware
  - EPS, battery, ADCS, payload
  - Support for many off-the-shelf hardware subsystems
  - Clyde Space, GOMspace, ISIS and more
- **Data handling and monitoring components**
  - Sampling, data pool, aggregation, logging, monitoring, statistics
  - Support for most common onboard monitoring functions
- **Communications components**
  - Packet handling, telemetry reporting
  - Support for a number of different communications protocols
  - Includes support for ECSS PUS, CFDP and more to come
- **Automation components**
  - Absolute and relative time scheduling, orbit-based scheduling
  - Event-based automation
  - Onboard scripting
- **Mission-specific custom components**
  - Mode management, deployment sequencing

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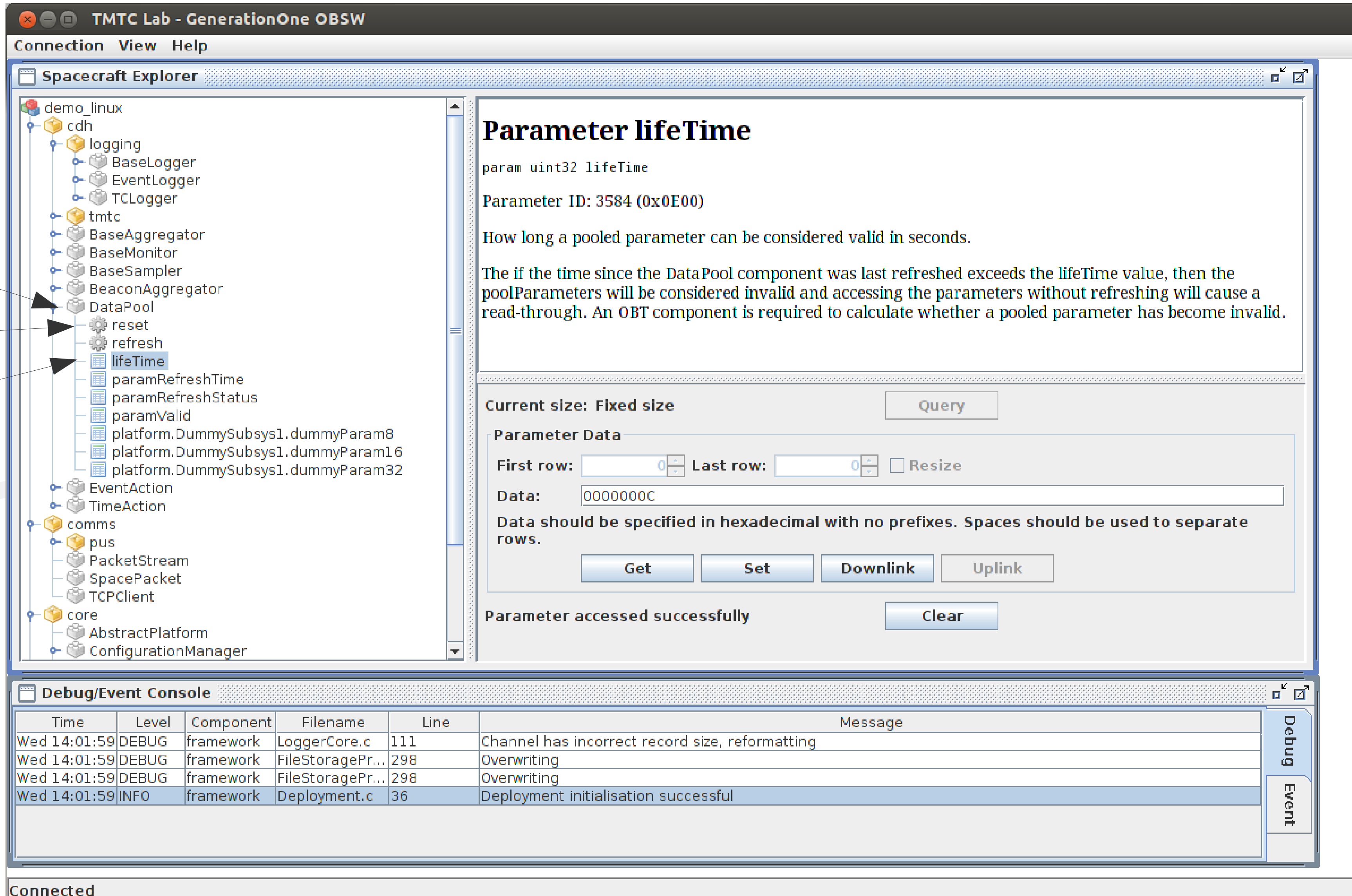
Component interface from ground

Component

Action

Parameter

Model captures all information



GenerationOne and distributed systems

- GenerationOne will be used on multiple computers or subsystems
- Captured as part of the **same model**
- Component framework distributed across all computers
- Communications between the computers allow components to interact
  - Independent of location
  - Independent of communications protocol
- Ground software “sees” a single spacecraft
  - Uniform operations across multiple onboard computers/subsystems
  - Component physical location not hidden but not usually an issue for operations
- Easier and more flexible **development**
  - Can move components around to suit the mission
  - Adapt to changing requirements
  - Introduce new computers/subsystems without a large architectural impact
- Simplify **AIT**
  - Uniform way of testing and integrating
- Simplify **operations**

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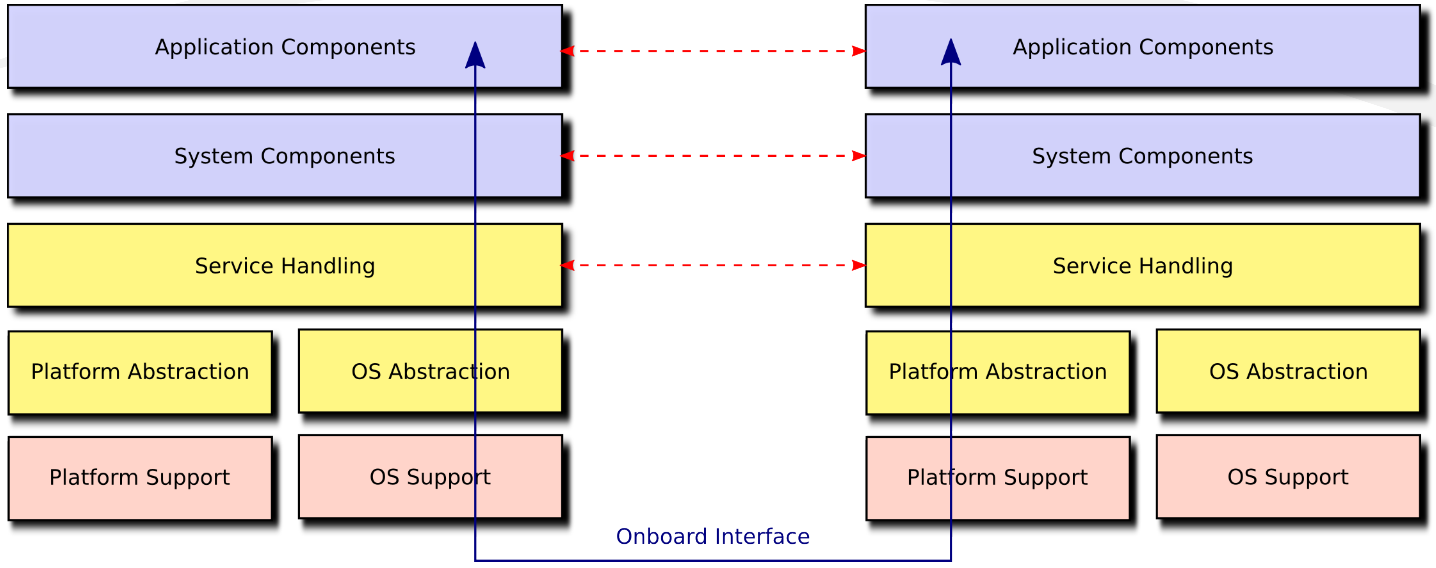
Distributed software architecture

- Components interact using the standard **component interface**
  - Actions
  - Parameters
  - Events
- Component interface is dispatched using **framework services**
  - Framework services are themselves provided by system components
  - Communications stack built from components
  - Makes component interface services modular and technology-independent



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Technology independence

- Component-based technology makes **complete stack modular**
  - Hardware platform
  - Operating system
  - Drivers and subsystem interfaces
  - Communications protocols
- Permits the use of **standard network protocols** for routing
  - CCSDS Space Packets
  - Internet Protocol
  - CubeSat Space Protocol
- Permits development and test to be **independent of technologies**
  - e.g. communications technology, architecture, topology, platform, OS
  - Adapt to requirements change
  - Rapid development
  - Carry out software testing and AIT at a high level – more efficient

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GenerationOne for PICASSO

- Distributed extensions for GenerationOne are being used on PICASSO
- **Two onboard computers** each using GenerationOne
  - Platform computer hosts majority of operational software
  - Main mission management on platform computer
  - Payload operations, data processing and downlink on payload computer
  - Payload computer not always powered
- Model-based distributed approach is **streamlining development** and AIT
  - First stage integration can be done with simulated computers (using PCs)
  - Second stage integration seamless due to abstraction
  - Tests are independent of physical architecture and protocols
- PICASSO **operations simplified** through use of the model
  - More efficient operations
  - Easier to achieve automation and “lights out” operations

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Lessons for other missions

- Within the context of highly-integrated nano-satellites distributed systems can be a **powerful approach**
  - Good solution to handling high-performance, advanced payloads
  - Existing CubeSat missions already use distributed architectures for this reason
- Distributed systems **introduce complexity**
  - Introducing a network protocol has limited impact on managing complexity
  - At a high-level test and operations must account for multiple systems
- Using a **model-based solution** does help manage complexity
  - Even a simple model can help
  - Can start with a technology-dependent model
- **Technology-independence** and **modularity** further help improve development and test process
  - Help manage change and make better use of development/test time
- A model can also be used to help **manage assurance**
  - Tracing of requirements, design, test etc.
- GenerationOne SDK is available for use on your mission

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Speak to us

Question, comments or suggestions

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generationone flight software development kit