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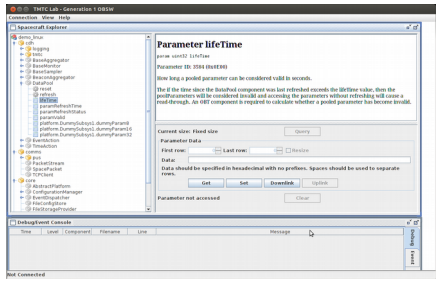
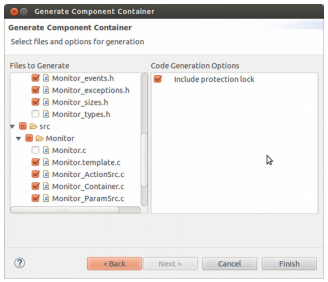
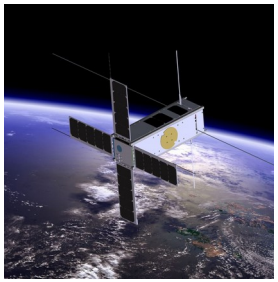
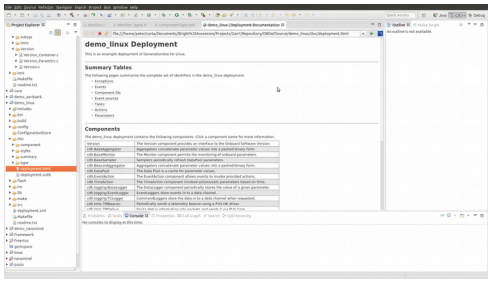
Integrated Flight-Ground Software for Rapid Mission Development

Mark McCrum, Alex Mason, Peter Mendham





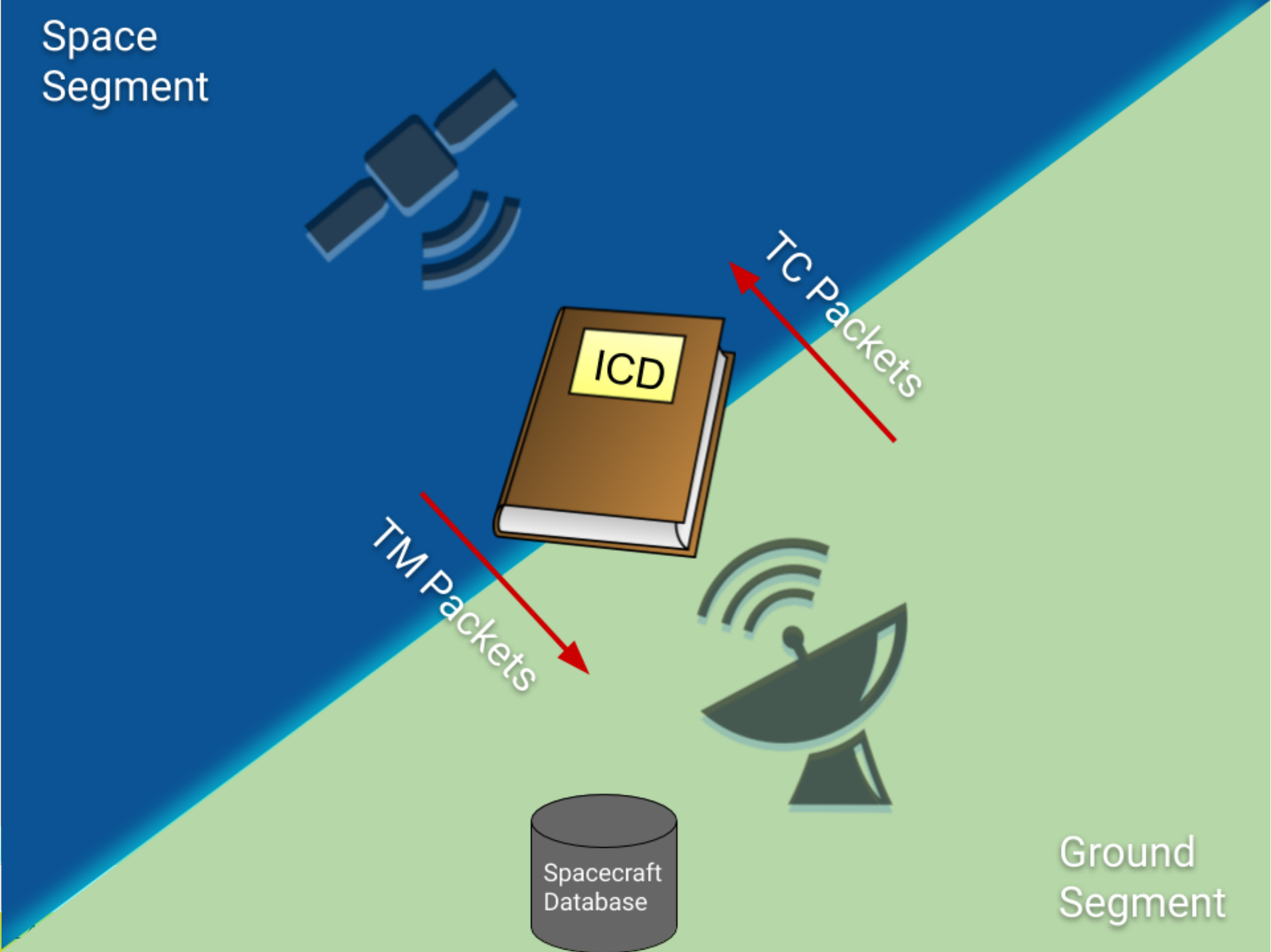




generationone

About us

- **Space technology company** specialising in software
  - Based in Scotland, UK
- Founded in 2011
- Experience with a wide range of **upstream software**
  - Flight
  - Mission control/operations
  - Simulation
- Mixture of software **products and services**
  - Supplying products to nano-satellite missions worldwide
  - Partnered with spacecraft integrators offering full software service
  - Ongoing R&D projects and consultancy with ESA, UKSA and others


Space
Segment
ICD
TC Packets
TM Packets
Spacecraft
Database
Ground
Segment

Typical Space System

- Interface specified at the level of telecommand and telemetry packets
  - Impoverished view of the functionality provided
  - High level patterns of interaction not readily captured
  - Labour-intensive
  - Error-prone
  - Hard to change (particularly across organisational + contractual boundaries)
  - Complicates operation + automation
- Problems
  - Doesn’t scale well
  - Doesn’t support rapid, agile development

Some alternative approaches ...

CCSDS

The Consultative Committee for Space Data Systems

Mission Operations

EUROPEAN COOPERATION
ECSS
FOR SPACE STANDARDIZATION

CSP

PUS

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GenerationOne

- **GenerationOne** is a core software technology and reference architecture
  - Applied to onboard software through a **Flight Software Development Kit**
  - Applied to operations through **Mission Control Software**
- GenerationOne addresses the key challenges by combining
  - **Model-based** software engineering
    - Model captures software at an architectural level
  - **Component-based** software engineering
    - Software is built from regularly structured modules (components)
  - A **service-oriented** architecture
    - Interactions between components conducted using services

- GenerationOne was not solely designed up-front
  - Started simple with features introduced gradually
  - Has been iterated and improved upon
  - Uses experience from many projects and missions
  - Features tested in a practical environment
  - Continues to be extended and improved

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Characteristics of GenerationOne

- **Model-based** software engineering
  - Permits machine comprehension of software architecture
  - Enables tooling to assist with software development
  - Tools can also be used to assist with product/quality assurance
  - Model describes architecture across flight and ground
  - Model used across life-cycle from early development to end of operations
- **Component-based** software engineering
  - Key enabler for re-use
  - Each component includes implementation, tests and documentation
  - Complete system built from components
  - Lightweight underlying framework connects and supports components
  - Many (most) components portable across platforms and operating systems
- **Service-oriented** architecture
  - Provides consistent semantics for component interactions
  - Enables low level parts of software to be expressed as components
  - Raises the semantic level of operations
  - Separates interaction semantics from implementation protocol

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Example software components

- **Subsystem components**, represent hardware
  - EPS, battery, ADCS, payload
  - Support for many off-the-shelf hardware subsystems and OBCs
  - AAC Microtec, Clyde Space, GOMspace, ISIS, Pumpkin, Vorago and many 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
- **Automation components**
  - Absolute and relative time scheduling, orbit-based scheduling
  - Event-based automation
  - Onboard scripting
- **Mission-specific custom components**
  - Mode management, deployment sequencing, orbit counting

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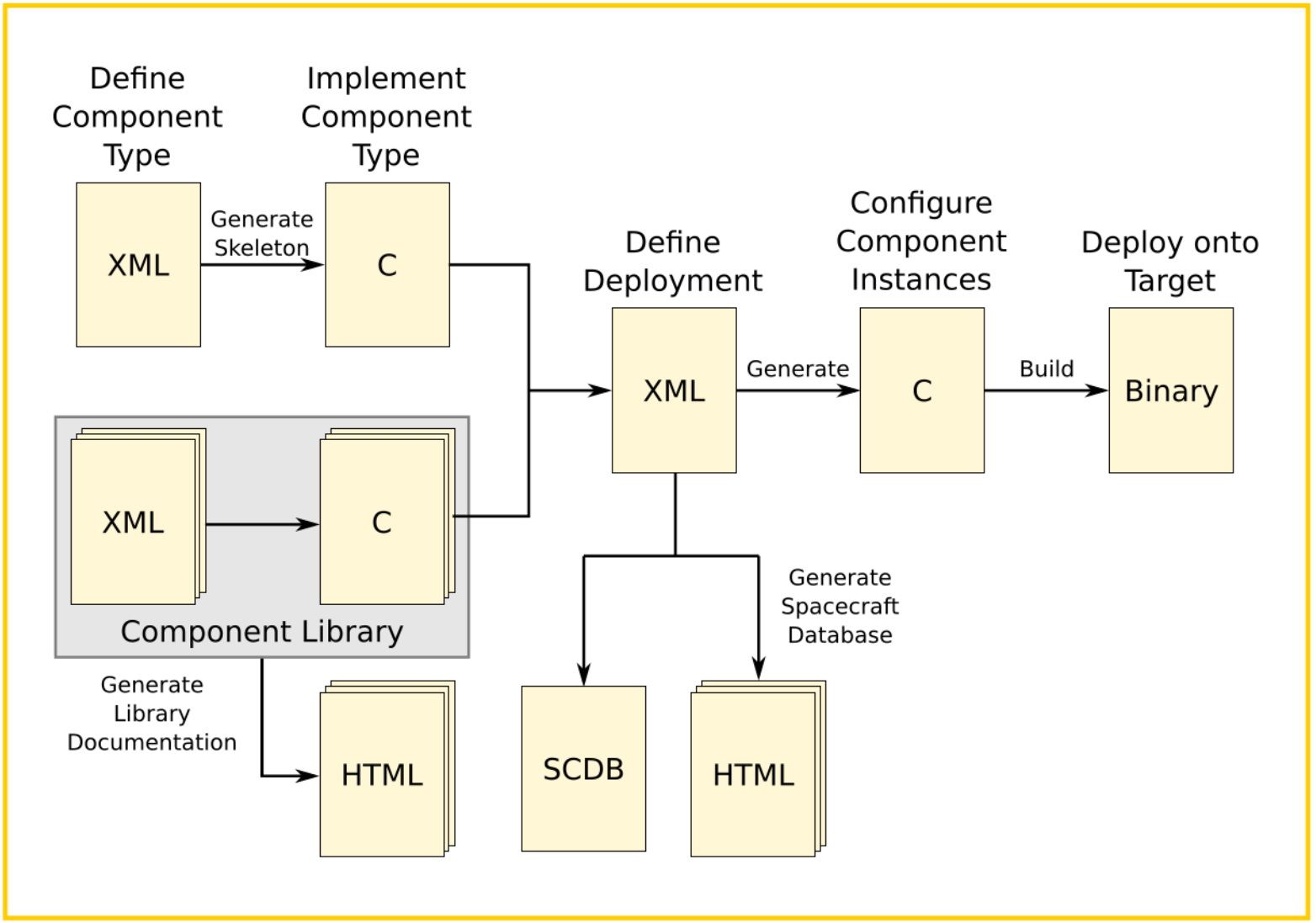
Typical workflow



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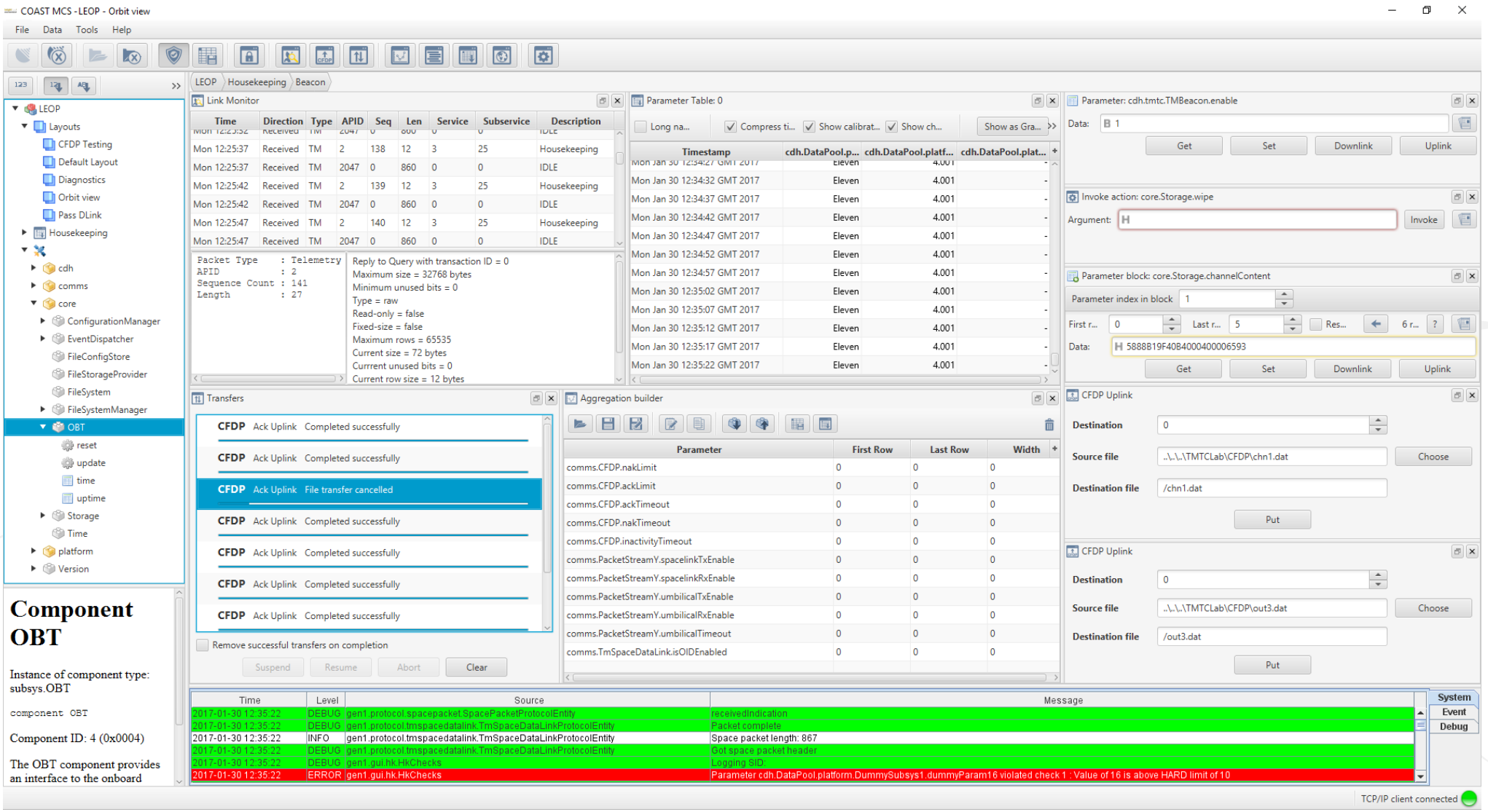
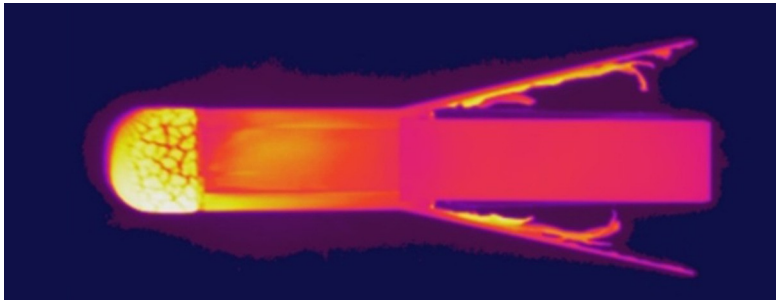
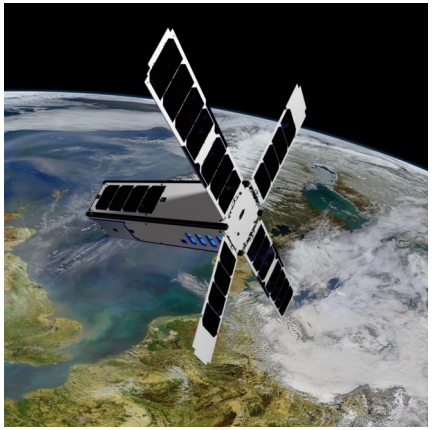
MCS View

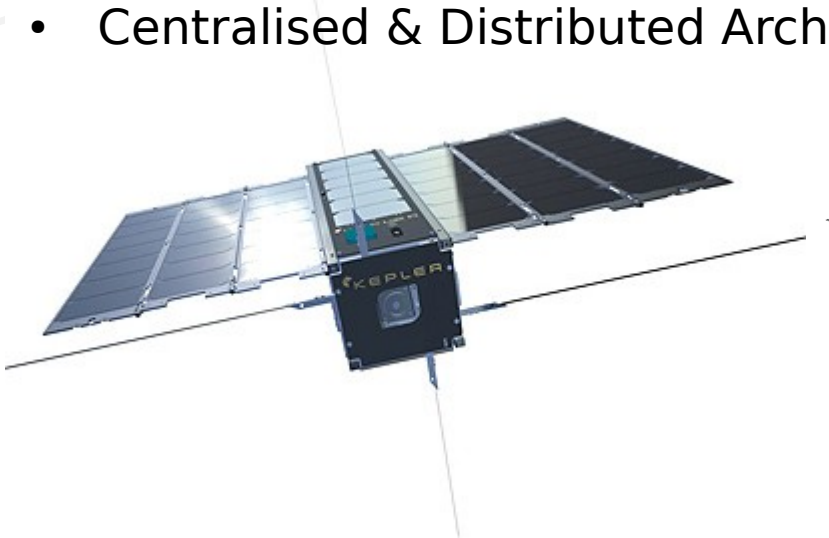

COAST MCS - LEOP - Orbit view
File Data Tools Help
LEOP Housekeeping Beacon
Link Monitor
Parameter Table: 0
Parameter: cdh.tmtc.TMBeacon.enable
Invoke action: core.Storage.wipe
Parameter block: core.Storage.channelContent
Transfers
Aggregation builder
CFDP Uplink
Component OBT
Instance of component type: subsys.OBT
component OBT
Component ID: 4 (0x0004)
The OBT component provides an interface to the onboard
TCP/IP client connected

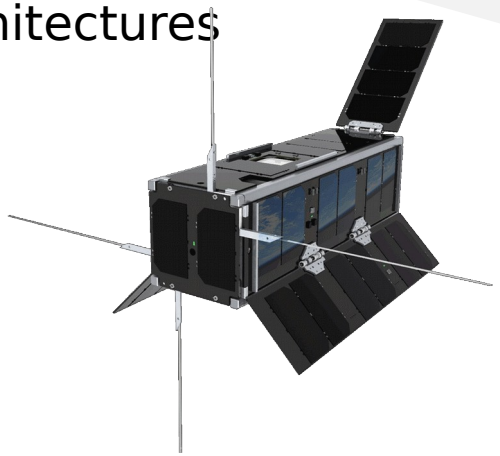
Results

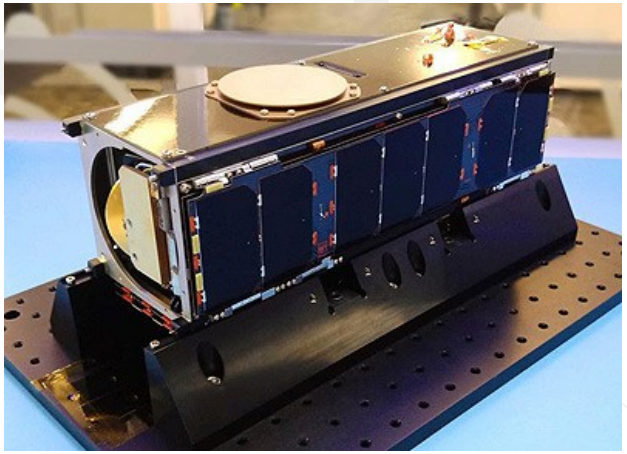




- 10 Diverse Cubesat missions within the company
  - Small team, rapid development
- 8 Satellites currently operating with gen1 technology
- Application Diversity
  - Commercial, Science, Education
- Platform & Technology Diversity
  - AAC-Clyde, Pumpkin, GOM Space, Custom
  - Linux, RTEMS, FreeRTOS, Bare metal
  - ARM, x86, Leon-2, SPARC, MSP430
- Centralised & Distributed Architectures







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Conclusion

- Move towards a more unified treatment of space and ground through a shared functional architectural model
  - Facilitates **rapid iteration**
  - Raises the **semantic level** of the space / ground interface for improved **operability**, **autonomy** and **scalability**

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Backup slides

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Interface to a component

- **Actions**
  - Commands/operations/methods
  - Can 'invoke' from onboard or ground
- **Parameters**
  - Data fields/attributes
  - Can 'get' or 'set' (if not read-only) from onboard or ground
- **Exceptions**
  - Status code
  - Returned by synchronous operations (e.g. get/set/invoke)
  - Indicates abnormal or unusual operation, usually an error
- **Events**
  - Issued asynchronously and usually logged onboard
  - Indicates abnormal or unusual operation, usually an error

- This is the interface that is “seen” from ground
- Components can be grouped together to form a logical hierarchy

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The GenerationOne approach

- Provide common functions off-the-shelf as **software components**
  - Model captures the available component types
- Flight software rapidly **assembled** from these components
  - Within the “glue” of the GenerationOne framework
  - Model captures the architecture resulting from component assembly
- The software can therefore be **tailored for the mission**
  - Which components are used
  - How many of each type of component is used
  - The ways in which components are connected together
  - Custom components for the mission
- Component framework is relatively simple
  - Not flying a lot of unnecessary complexity
- Component interfaces follow regular structure
  - Limits issues caused by component interactions

- **Reduce** development **time**, **cost** and **risk**
  - Software **available earlier** to support AIT

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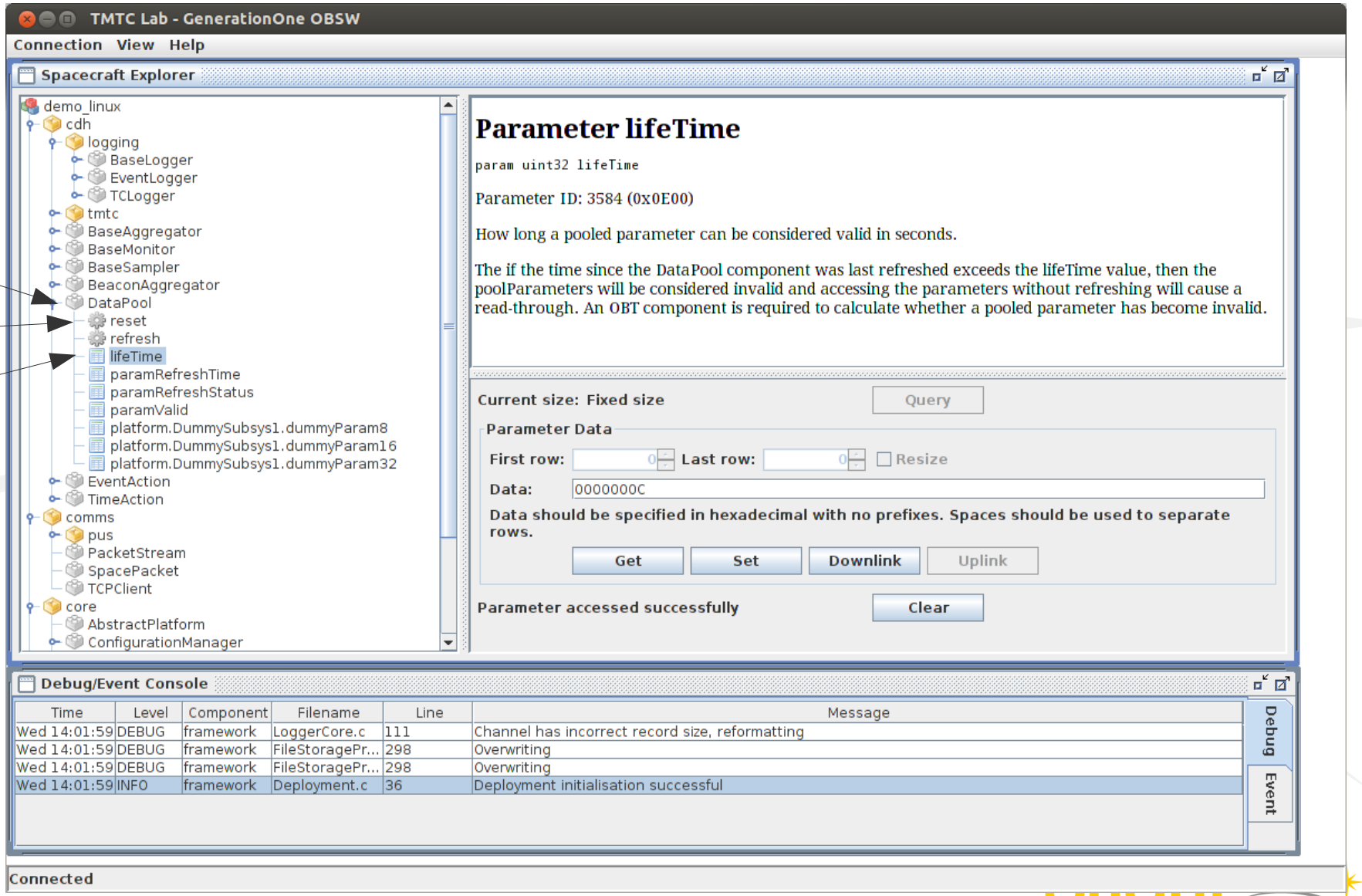
Component interface from ground



Components and services

- A component interface and a service are on different semantic levels
- Component interfaces (as defined by the OSRA)
  - Describe *what*
  - For example
    - An attribute
    - An event
  - Bindings bind a *thing* to a *thing*
    - e.g. an attribute to an attribute
- Service interfaces (as defined by MO and, to a lesser extent, SOIS)
  - Describe *how*
  - For example
    - Parameter service
    - Event service
  - Bindings bind a *mechanism* to a *mechanism*