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Development of a Flexible Nanosatellite Mission Control System Using Agile Development Methodology

Richard Duke, Brian Stewart, Ben Taylor, Christopher P. Bridges, Simon Fellowes and Guglielmo Aglietti

r.duke@surrey.ac.uk

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Rome, Italy***

Previous University of Surrey Satellites based around a custom design for each individual satellite.

In 2015 a new system was required for multiple missions. It was an ideal opportunity to consolidate support for;

- Spacecraft operations
- S/C development and testing
- Communications research
- University and amateur cubesat community
- Teaching

Requirements

Summary of main requirements:

- Multiple simultaneous connections needed
- Easy to adapt to different spacecraft
- Multiple users; operators; AIT engineers, System Engineers; Students
- Mission critical operations vs accessibility for students
- Varying levels of automation (teaching vs lower operations cost)
- Expandable for the future

Data Connections

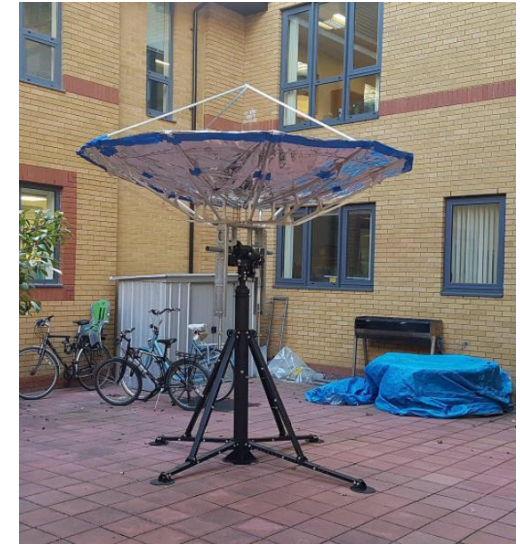
Dual VHF / UHF



Software Testbeds



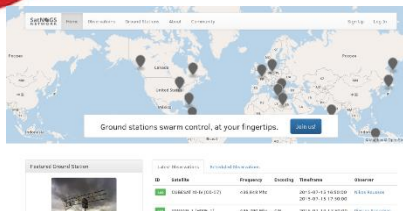
3 Metre Dish



Mission Operations Centre



Amsat Community



AIT



Partner Groundstations



Agile Development strategy used

- It aims to produce good results by promoting close teamwork, over fixed processes.
- It values working software (especially early prototypes) over heavy documentation.
- It integrates the customer or end user during the development phase and welcomes input and change requests even late in the development to make sure that the output works well.
- It makes the assumption that that requirements and plans will change and therefore this can be expected and planned for.

Especially suitable when full requirements may not be fully described at the start of the project

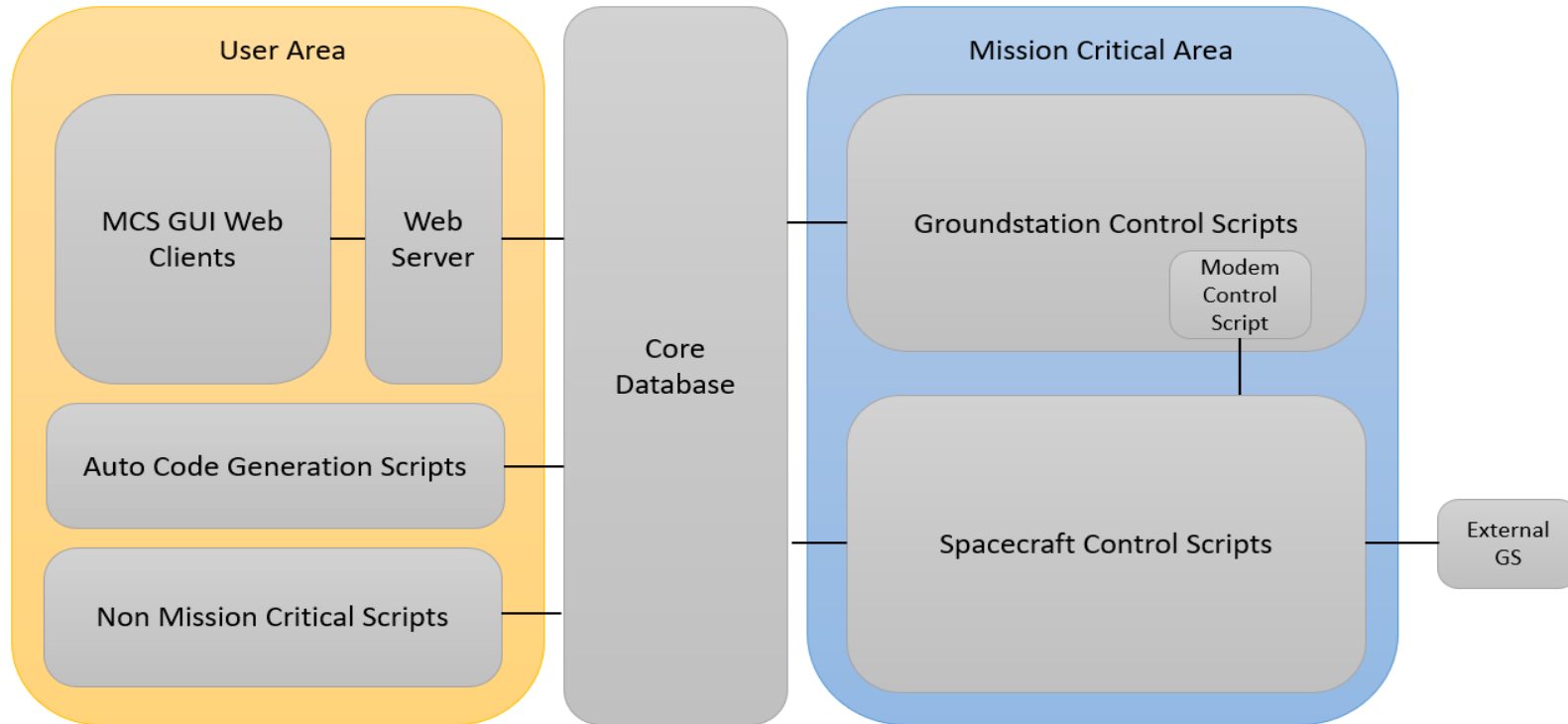
Empowers developers and concentrates focus on good engineering rather than process

With agile development the architecture of the system is critical to make sure it can cope with changing requirements.

We placed a relational database (PostgreSQL) at the core of the system with standard SQL language used to access data.

- Based on industry standard technology.
- Databases are designed to be accessed simultaneously and connected to multiple different types of systems.
- Everything is logged by default. Traceability of commands from first development all the way to end of life.


‘Mission Critical’ and ‘User’ programs are separated.



The mission critical system programs can be tightly controlled, while allowing rapid development for the rest of the system.

Easy to set up safe access via database to allow students to develop new systems without risk to key operations.

All groundstations and spacecraft are accessed by the user through the same interface



Mission Control

- MCS Status
- SpaceCon
- GroundCon
- Telemetry Viewer
- Raw Telemetry
- File Download
- File Upload
- Spacecraft
- Groundstations
- Tasks
- Processes
- TLE Management
- File Decode
- C3D2 Decode

Groundstation Console

Sat, 25 Nov 2017 10:42:10 GMT

CAWS AISat STK-BB

Groundstation

Ident: STK-BB

Type: DUAL_YAGI

Tracking:

State: Waiting

Transmit Allowed:

Long / Lat: Lon:-0.579629° Lat:51.23595°

Catalog No:

Designator: ALSAT 1N

TLE Line 1: 1 41789U 16059G 17329.09796546 .00000142 00000-0 36194-4 0 9992

TLE Line 2: 2 41789 98.1479 29.4528 0028787 12.4934 347.6985 14.64103533 62150

Spacecraft

ID: 8

Ident: AISat

Description: Algeria Nano Satellite

Orbit No: 3838

Location: Lon:159° Lat:32°

Altitude: nullkm

Range: 9835825.0km

Tracked Spacecraft

| Pri | Spacecraft |
|-----|------------|
| 0 | QB50p1 |
| 1 | AISat |
| 3 | STRaND |

Event Viewer

☐ Summary ☐ Detailed

- TL 10:41:06 FreqDeviation = 57351
- TL 10:41:06 down_count = 2726
- TL 10:41:06 RSSI = 75
- TL 10:41:06 up_count = 0
- DN 10:41:06 Strandciever-Get critical telemetry
- TL 10:41:06 FreqDeviation = 57351
- TL 10:41:06 down_count = 2726
- TL 10:41:06 RSSI = 75
- TL 10:41:06 up_count = 0
- DN 10:41:06 Strandciever-Get critical telemetry
- TL 10:41:05 filetransfer_block_id = 0
- TL 10:41:05 flight_code_location_id = 0
- TL 10:41:05 eps_power = 5452
- TL 10:41:05 reboot_cause = 9
- TL 10:41:05 unixtime = 1467362101 secs
- TL 10:41:05 safe_reason = 0
- TL 10:41:05 eps_battery = 8165
- TL 10:41:05 safe_mode = 0
- TL 10:41:05 uptime = 30901 secs
- TL 10:41:05 software_ident = 9
- DN 10:41:05 Safety-OBC Health
- TL 10:41:05 filetransfer_block_id = 0
- TL 10:41:05 flight_code_location_id = 0
- TL 10:41:05 eps_power = 5452
- TL 10:41:05 reboot_cause = 9
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- TL 10:41:05 eps_battery = 8165
- TL 10:41:05 uptime = 30901 secs
- TL 10:41:05 software_ident = 9
- DN 10:41:05 Safety-OBC Health
- TL 10:41:05 TLM_TBRD = 22.002476

Rotator Control

| Spacecraft | Mode | Requested | Actual |
|------------|------|--|--------|
| Azimuth | 16° | <input type="text" value="Override"/> <input type="button" value="Set"/> 90° | 38.00° |
| Elevation | -44 | <input type="text" value="Override"/> <input type="button" value="Set"/> 0° | 75.00° |

Transmit Control

Requested Band:

Radio Band:

Relay Band:

Actual Band:

OK to Transmit:

Radio Control

| Frequency | Mode | Requested Frequency | Actual Frequency |
|-----------|--|---------------------|------------------|
| Transmit | <input type="button" value="Set"/> <input type="text" value="Doppler Adjust"/> | | |
| Receive | <input type="button" value="Set"/> <input type="text" value="Doppler Adjust"/> | 437653182kHz | 0kHz |

Transmit Control

Requested State:

HPA State: null

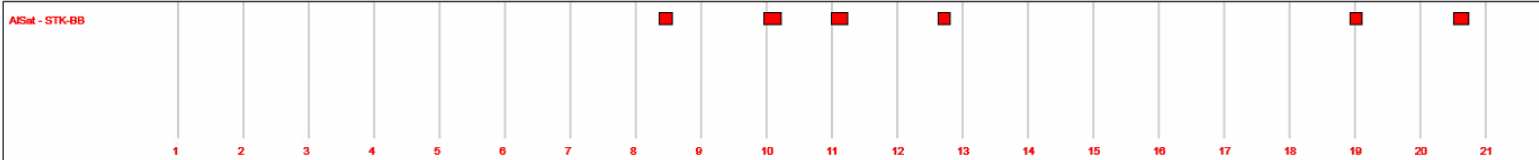
HPA Lockout:

HPA Safemode:

Relay State: VHF


Upcoming Predictions

AISat - STK-BB



Upcoming Predictions

The user interface is based on a standard web interface. Commanding is primarily done via command stacks.



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- C3D2 Decode

Spacecraft Console

Sat, 25 Nov 2017 10:38:11 GMT

CAWS Alsat_EM STK-BB

Key Telemetry

| Time | Channel | Value |
|---------------------|-------------------------|-----------------|
| 2017-11-25 10:36:36 | flight_code_location_id | 0 |
| 2017-11-09 12:14:17 | i2c_recovery_counter | 0 |
| 2017-11-25 10:36:36 | filetransfer_block_id | 0 |
| 2017-11-09 12:14:17 | i2c_traffic_counter | 296825 |
| 2017-11-25 10:36:36 | software_ident | 9 |
| 2017-11-25 10:36:36 | eps_power | 5418 |
| 2017-11-25 10:36:36 | eps_battery | 8156 |
| 2017-11-25 10:36:36 | safe_mode | 0 |
| 2017-11-25 10:36:36 | unixtime | 1467361832 secs |
| 2017-11-25 10:36:36 | uptime | 30632 secs |

User Telemetry

| Time | Channel | Value |
|---------------------|---------------------|----------|
| 2017-11-22 12:30:08 | ext_flash_device_id | 16250871 |
| 2017-11-25 10:36:36 | reboot_cause | 9 |
| 2017-11-25 10:36:36 | safe_reason | 0 |

Telemetry Scroll

| Time | Channel | Value |
|----------|---------------|------------|
| 10:36:36 | FreqDeviation | 57352 |
| 10:36:36 | RSSI | 75 |
| 10:36:36 | down_count | 2699 |
| 10:36:36 | up_count | 0 |
| 10:36:36 | TLM_TBRD | 22.002476 |
| 10:36:36 | TotalPower | 5365 mW |
| 10:36:36 | VPCMBATV | 8.111776 V |
| 10:36:36 | FreqDeviation | 32791 |
| 10:36:36 | RSSI | 76 |
| 10:36:36 | down_count | 2696 |
| 10:36:36 | up_count | 0 |
| 10:36:35 | TLM_TBRD | 22.002476 |

Transmission Queue

| ID | Task | Release Time | State | Notes | Actions |
|-------|---------------------|---------------------|-----------|---------------|---------|
| 36396 | Initiate Upload | 2017-11-25 01:36:37 | Success | Commands Sent | Copy |
| 36395 | Finalise Block | 2017-11-25 01:36:07 | Success | Commands Sent | Copy |
| 36394 | Initiate Upload | 2017-11-25 01:35:44 | Success | Commands Sent | Copy |
| 36393 | OBC Health | 2017-11-25 01:34:49 | Success | Commands Sent | Copy |
| 36392 | Resume non critical | 2017-11-25 01:34:49 | Success | Commands Sent | Copy |
| 36391 | Clear Safe Mode | 2017-11-25 01:34:48 | Success | Commands Sent | Copy |
| 36390 | PCM Reset | 2017-11-25 01:34:37 | Cancelled | Cancelled | Copy |
| 36388 | OBC Health | 2017-11-25 01:32:40 | Success | Commands Sent | Copy |
| 36387 | Resume non critical | 2017-11-25 01:32:40 | Success | Commands Sent | Copy |
| 36386 | Clear Safe Mode | 2017-11-25 01:32:40 | Success | Commands Sent | Copy |
| 36385 | PCM Reset | 2017-11-25 01:32:32 | Cancelled | Cancelled | Copy |

Add Task

| Task | Add to Queue |
|------------------------------------|----------------|
| 10174-Debug Startup | > Add to Queue |
| 11057-TFSC strx file transfer test | > Add to Queue |
| 13115-Start Gold code Flash 0 | > Add to Queue |
| 13116-Start Flash 1 app | > Add to Queue |
| 13117- | > Add to Queue |
| 14591-Get flight code id | > Add to Queue |
| 14594-Clear Safe Mode | > Add to Queue |
| 14595-Resume non critical | > Add to Queue |
| 14651-WOD Close File Test | > Add to Queue |
| 16197- | > Add to Queue |

Create Task

| | |
|------------------|-------------------|
| Send Telecommand | Request Telemetry |
| Uplink Test | Sync Time |
| Strand Poll | |

Task Viewer

Task ID = 36435

Task Ident = Get flash crc - block 2 - 35764 - 30735FF

Description = MANUAL

State 72 - Commands Sent

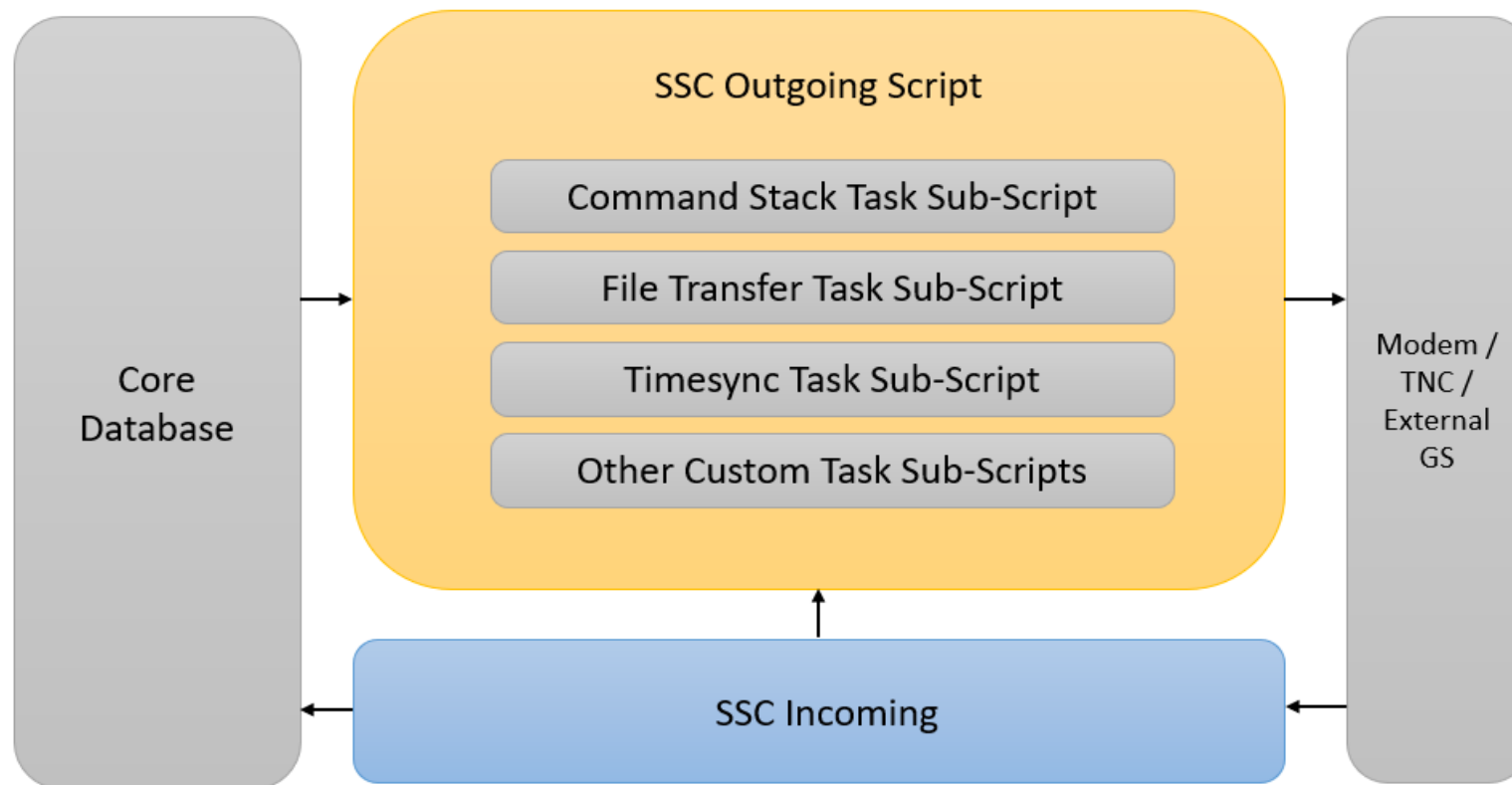
| Command | Message | Ack | Retry | State |
|---------|--------------------|-----|-----------------|---------|
| 166281 | 40 - Get flash crc | Yes | checksum = 1032 | 99 0 72 |
| 166281 | 40 - Get flash crc | Yes | checksum = 1032 | 99 0 72 |

Event Viewer

Summary Detailed Clear Hide

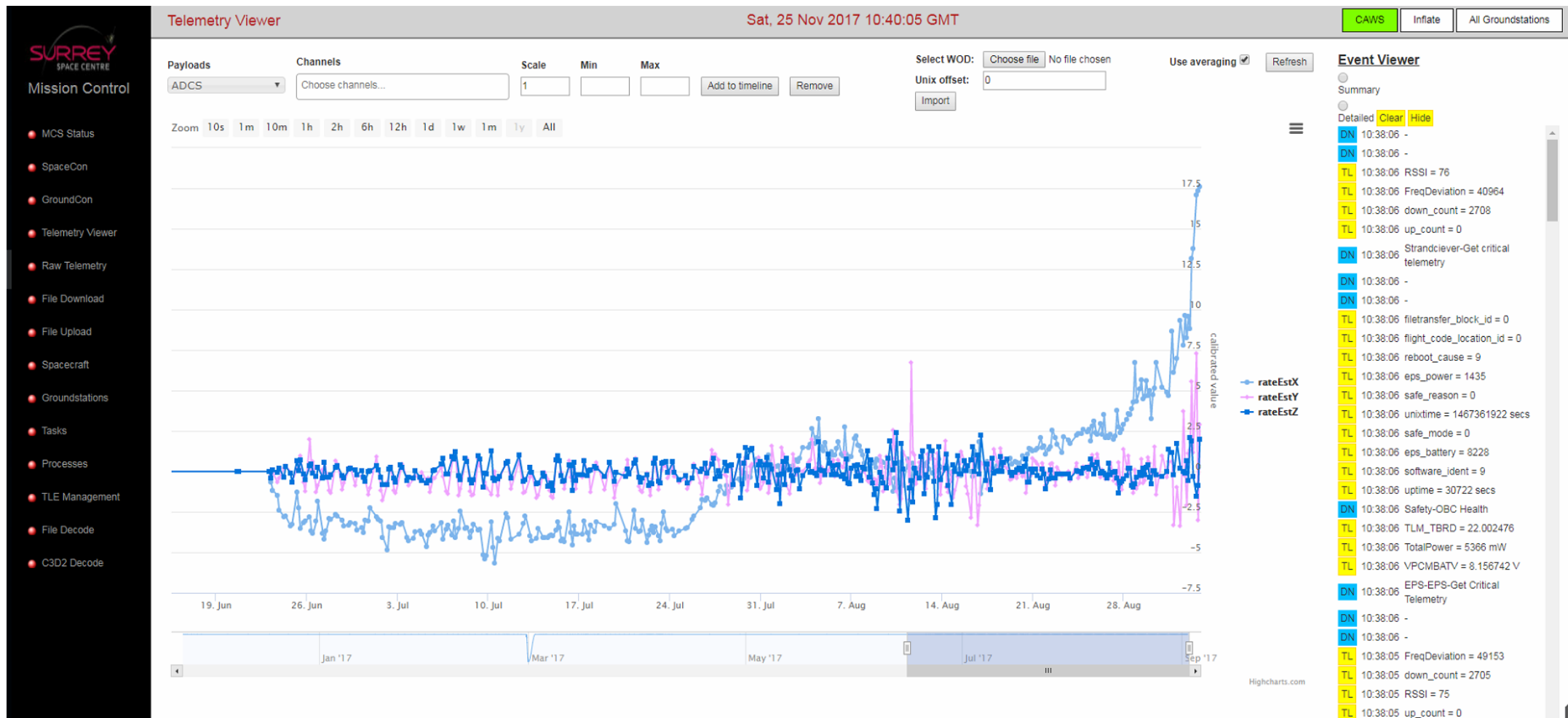
- 10:36:36 -
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- 10:36:36 FreqDeviation = 32791
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- 10:36:35 -
- 10:36:35 filetransfer_block_id = 0
- 10:36:35 flight_code_location_id = 0
- 10:36:35 eps_power = 5418

Each task is a self contained plugin script allowing custom scripting if required.



Three standard scripts are used to cover almost all requirements

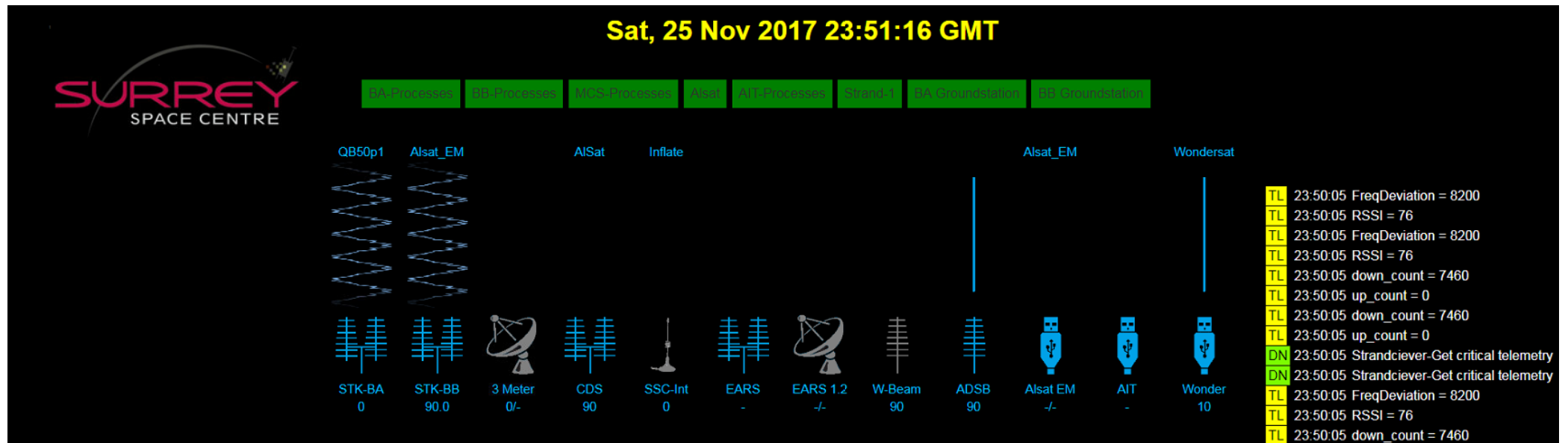
Incoming data sets can be plotted graphically as soon as the data is received. Very useful during the testing phase!



User Interface

Custom displays can be built independently without affecting other systems.

This is especially important for teaching and outreach, allowing screens that can demonstrate real-time status of both ground and space segments



Full Missions

- Alsat
- Inflatesail

Build and Test

- Remove Debris (VBN Cubesat)
- CubeSail
- SME Sat

Heritage Missions

- Strand
- DeorbitSail

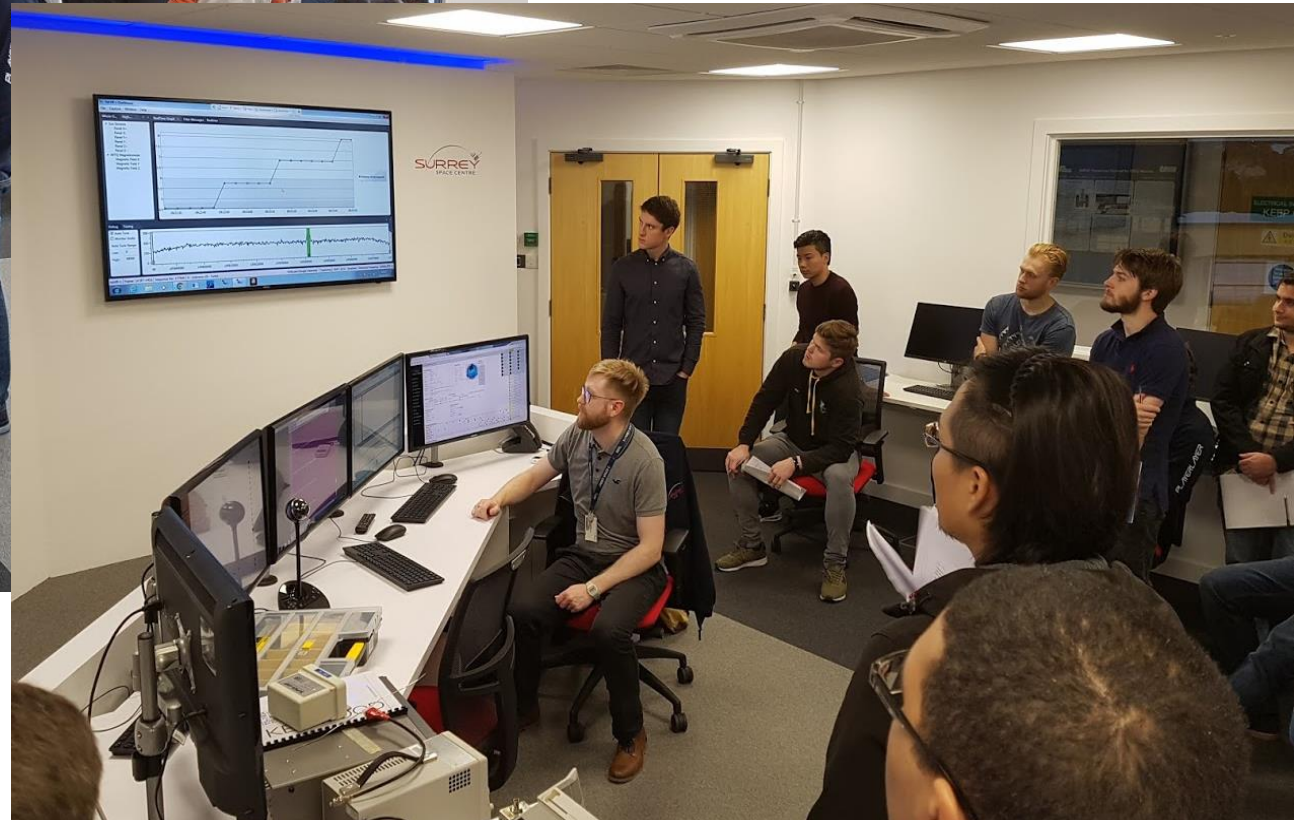
+ various amateur and university cubesat support

Used in Simulation Mode with engineering module to train operators

Installed at ASAL (CDS) in Algeria for primary groundstation



Mission Operations Training

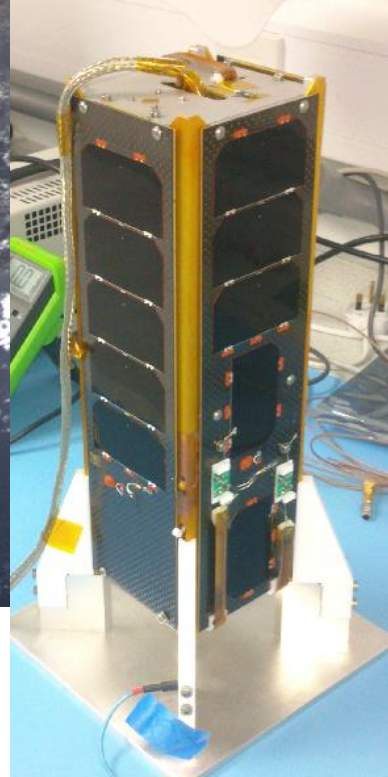
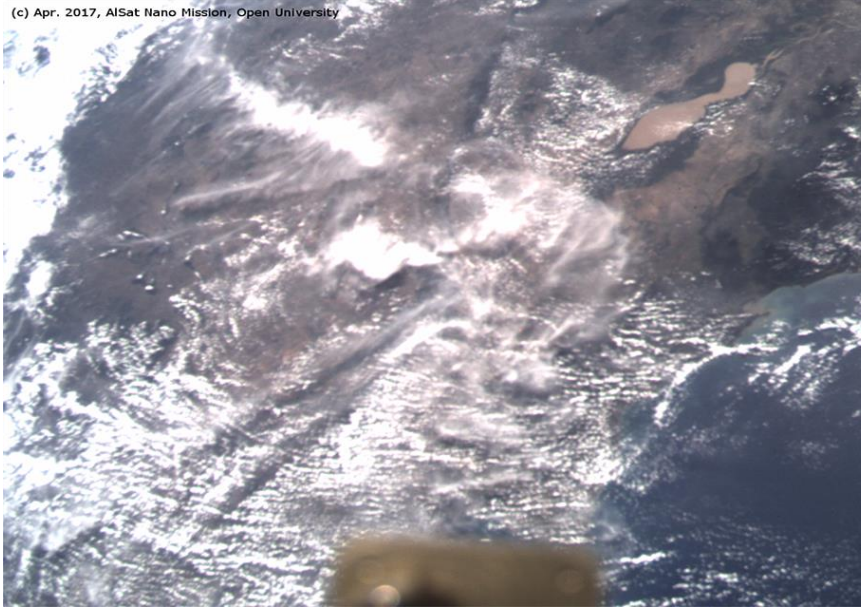


Recommendations from Development

- Agile development allowed us to have early initial capability, increasing the testing time with the spacecraft. Software issues were found early and fixed instead of late in the development.
- Initial architecture is critical. Make sure you have a flexible core that can cope with changing requirements. Use of a standard database / interface has helped
- Combining test software and on orbit control software provides a huge timesaving in training and provides confidence that the mission control system will work once in orbit.
- Agile helped with project schedule challenges; make sure the whole system is there, then improve.

Thank You! Questions?

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