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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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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



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



Amsat Community



Liter Howards Provide Havandee



Mission Operations Centre



Partner Groundstations



3 Metre Dish



AIT





Development Strategy

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.



User Interface

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

	Groundsta	tion Console						Sat, 25 N	ov 2017 10:42:1	I0 GMT						CAWS AISa	t STK-BB
SURREY															Event \	Viewer	
SPACE CENTRE	Groundstati	ion				Spaced	raft			Tracked						ary ODetailed Clear H	ide
Mission Control	Ident	STK-BB				ID	8	~	3	Spacecraft						1:06 FreqDeviation = 5	
	Туре	DUAL_YAGI				Ident	AlSat		F	Pri Spacecraft					TL 10:4	1:06 down_count = 272	:6
MCS Status	Tracking	AlSat 🔻				Descriptio	n Algeria Nano			0 QB50p1					TL 10:4	1:06 RSSI = 75	
	State	Waiting					Satallite			1 AlSat						1:06 up_count = 0	
SpaceCon	Transmit	Auto	•			Orbit No	3838			3 STRaND					DN 10:4	1:06 Strandciever-Get of telemetry	ritical
GroundCon	Allowed					Location	Lon:159° Lat:32	2°							_	1:06 FreqDeviation = 5	
	Long / Lat	Lon:-0.579629°	Lat:51.23595°			Altitude	nullkm		- A							1:06 down_count = 272	
Telemetry Viewer	Catalog No			·		Range	9835825.0km									1:06 RSSI = 75	5
- David Talana ka	Designator	ALSAT 1N														1:06 up_count = 0	
Raw Telemetry	TLE Line 1 1 41789U 16059G 17329.09796546 .00000142 00000-0 36194-4 0 9992															1:06 dp_count = 0 Strandciever-Get (ritical
File Download	TLE Line 2	2 41789 98.1479 2	9.4528 002878	37 12.4934 347.	6985 14.64103533										DN 10:4	1:06 telemetry	
		62150													TL 10:4	1:05 filetransfer_block_	jd = 0
File Upload															TL 10:4	1:05 flight_code_locatio	n_id = 0
. 0	Rotator Con		Description	A street	Radio Conti		Mada	Description of Co							TL 10:4	1:05 eps_power = 5452	1
Spacecraft	spac	cecraft Mode	Requested	Actual	Frequ	-	Mode	Requested Fr	equency Actual Free	luency					TL 10:4	1:05 reboot_cause = 9	
Groundstations	Azimuth 16°	Override •	Set 90°	38.00°	Transmit	5	Bet Dopper Adjus	t 🔻							TL 10:4	1:05 unixtime = 146736	2101 secs
	Elevation -44	Override •	Set 0°	75.00°	Receive 43764	6000.0kHz	Set Dopper Adjus	t • 437653182kH	z OkHz						TL 10:4	1:05 safe_reason = 0	
Tasks															TL 10:4	1:05 eps_battery = 816	5
	Transmit Co	ontrol			Transm	t Control										1:05 safe_mode = 0	
Processes	Requested Band	i			Requested	State										1:05 uptime = 30901 se	
TLE Management	Radio Band				HPA State	null Te	ogale									1:05 software_ident = 9	
- nee management	Relay Band				HPA Locko											1:05 Safety-OBC Healt	
File Decode	Actual Band				HPA LOCKO											1:05 filetransfer_block_	
	OK to Transmit															1:05 flight_code_locatio	-
C3D2 Decode					Relay Stat	VHF	Toggle									1:05 eps_power = 5452	
																1:05 reboot_cause = 9	
	Upcoming F	Predictions														1:05 unixtime = 146736	2101 secs
	AlSat - STK-BB												•	-		1:05 safe_reason = 0	
																1:05 safe_mode = 0	-
																1:05 eps_battery = 816 1:05 uptime = 30901 se	
																1:05 uptime = 30901 se 1:05 software_ident = 9	
																1:05 Safety-OBC Healt	
		1	2 3	4	5 6	7	8 9	10 11	12 13	14 15	16 17	18 19) 20	21 :		1:05 TLM_TBRD = 22.0	002476
																	-
	Upcoming F	Predictions															

8



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

	Spacecraft Cons	sole		Sat, 25 Nov 2017 10:38:11 GMT									CAWS Alsat_EM STK-		
REY PACE CENTRE															Event Viewer
	Key Telemetry			- 1	User Telemetry				- Telemetry	y Scroll					Summary Detailed Clear Hide
on Control	Time	Channel	Value		Time	Channel	Value		Time		Channel	Value			DN 10:36:36 -
	2017-11-25 10:36:36	flight_code_location_id	0		2017-11-22 12:30:08	ext_flash_device_id	1625	0871	10:36:36		FreqDeviation	57352			TL 10:36:36 FreeDeviation = 57352
222.00000	2017-11-09 12:14:17	i2c_recovery_counter	0		2017-11-25 10:36:36	reboot_cause	9		10:36:36		RSSI	75			and the second
Status	2017-11-25 10:36:36	filetransfer_block_id	0		2017-11-25 10:36:36	safe_reason	0		10:36:36		down_count	2699			TL 10:36:36 down_count = 2699
	2017-11-09 12:14:17	i2c_traffic_counter	296825						10:36:36		up_count	0			TL 10:36:36 RSSI = 75
eCon	2017-11-25 10:36:36	software_ident	9						10:36:36		TLM_TBRD	22.00247	76		TL 10:36:36 up count = 0
	2017-11-25 10:36:36	eps_power	5418						10:36:36		TotalPower	5365 mV			
ndCon	2017-11-25 10:36:36	eps_battery	8156						10:36:36		VPCMBATV	8.111776	۶V		DN 10:36:36 Strandciever-Get critical telemetry
	2017-11-25 10:36:36	safe_mode	0						10:36:36		FreqDeviation	32791			
netry Viewer	2017-11-25 10:36:36	unixtime	1467361832 se	cs					10:36:36		RSSI	76			DN 10:36:36 -
icity vicvici	2017-11-25 10:36:36	uptime	30632 secs						10:36:36		down_count	2696			TL 10:36:36 filetransfer_block_id = 0
To James a day of									10:36:36		up_count	0			TL 10:36:36 flight_code_location_id =
elemetry				*					* 10:36:35		TLM_TBRD	22.00247	76		
	4				4)	4					•	TL 10:36:36 eps_power = 5418
ownload															TL 10:36:36 unixtime = 1467361832 s
	Transmission Que	eue													 TL 10:36:36 reboot cause = 9
pload	ID Task							Rel	lease Time	State	Notes	Actio	ons		TL 10:36:36 eps_battery = 8156
1. A. M.	36396 Initiate Upload						Cop	y > 201	7-11-25 01:36:37	Succe	commands Sent				TL 10:36:36 safe_mode = 0
craft	36395 Finalise Block						Cop	oy > 201	17-11-25 01:36:07	Succe	ess Commands Sent				
	36394 Initiate Upload						Cop	y > 201	17-11-25 01:35:44	Succe	ess Commands Sent				TL 10:36:36 safe_reason = 0
dstations	36393 OBC Health						Cop	and the second s	7-11-25 01:34:49	Succe	ss Commands Sent				TL 10:36:36 software_ident = 9
	36392 Resume non crit	cal					Cor	Contract of Contra	7-11-25 01:34:49	Succe	ess Commands Sent				TL 10:36:36 uptime = 30632 secs
	36391 Clear Safe Mode						Cop		7-11-25 01 34 48	Succe					DN 10:36:36 Safety-OBC Health
	36390 PCM Reset						Co		17-11-25 01:34:37						
sses	36388 OBC Health														DN 10:36:36 -
							Cop	and the second se	17-11-25 01:32:40	Succe					TL 10:36:36 TLM_TBRD = 22.002476
	36387 Resume non crit						Cop		17-11-25 01 32:40	Succe					TL 10:36:36 TotalPower = 5365 mW
anagement	36386 Clear Safe Mode						Cop	Name of Street, or other Designation of the Owner, which we design at the Owner, which we design	7-11-25 01:32:40	Succe	ess Commands Sent				✓ TL 10:36:36 VPCMBATV = 8.111776 V
ecode			10.00												DN 10:36:36 EPS-EPS-Get Critical
	Add Task		CI	reate Task			ask Viewer								Telemetry
Decode	Debug	٣		Send	Request	Ta	sk ID = 36435								DN 10:36:36 -
	10174-Debug Startup	> Add to Qu	eue ^	Telecommand		Та	sk Ident = Get fl	ash crc - block	(2 - 35764 - 30735	5FF					TL 10:36:36 FreqDeviation = 32791
	11057-TFSC strx file tran	sfer test > Add to Qu	eue			De	scription = MAN	ILIAI							TL 10:36:36 RSSI = 76
	13115-Start Gold code F	ash 0 > Add to Qu	eue	Uplink Test	Sync Time		ate 72 - Comma								TL 10:36:36 down_count = 2696
	13116-Start Flash 1 app	> Add to Qu	eue				alo 72 - Ourlind	nuo oon							TL 10:36:36 up_count = 0
	13117-	> Add to Qu	ieue	Strand Poll		c	Command	Message		Ack	Retry	State			10:36:36 Strandciever-Get critical
	14591-Get flight code Id	> Add to Qu	ieue			1	66281	40 - Get fla	ash crc	Yes	checksum = 1032	99	0	72	DN 10:36:35 -
	14594-Clear Safe Mode	> Add to Qu	ieue				66281	40 - Get fl:	ash cre	Yes	checksum = 1032	99	0	72	TL 10:36:35 filetransfer_block_id = 0
	14595-Resume non critic		ieue				00201	40 - 081 14		100	CHECKSUIII = 1052	33		-	TL 10:36:35 flight_code_location_id =
	14651-WOD Close File 1														TL 10:36:35 ens nower = 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!

	Telemetry Viewer			Sat, 25 Nov 2017 10:40	:05 GMT		CAWS Inflate All Groundstations
SURREY SPACE CENTRE	Payloads	Channels	Scale Min Max		Select WOD: Choose file No file chosen Unix offset: 0	Use averaging 🖉 🛛 Refresh	Event Viewer
Mission Control	ADCS •	Choose channels	Add	d to timeline Remove	Import		Summary
MCS Status	Zoom 10s 1m 10m	1h 2h 6h 12h 1d 1w 1m	ly All			≡	Detailed Clear Hide DN 10:38:06 -
SpaceCon							TL 10:38:06 RSSI = 76
GroundCon						17.5	TL 10:38:06 FreqDeviation = 40964 TL 10:38:06 down_count = 2708
Telemetry Viewer							TL 10:38:06 up_count = 0 DN 10:38:06 Strandciever-Get critical telemetry
Raw Telemetry						12.5	telementy
File Download						10	DN 10:38:06 - DN 10:38:06 - TL 10:38:06 filetransfer_block_id = 0
File Upload				TL 10:38:06 flight_code_location_id = 0			
Spacecraft			7.5 a	TL 10:38:06 reboot_cause = 9			
			75 🗧 🛶 rateEstX	TL 10:38:06 eps_power = 1435			
Groundstations			rateEstY → rateEstZ	TL 10:38:06 safe_reason = 0 TL 10:38:06 unixtime = 1467361922 secs			
Tasks				1	- And - And -	2.5	TL 10:38:06 safe_mode = 0
		also a start	at the second second second	nd when here	Maria Maria	hi.	TL 10:38:06 eps_battery = 8228
Processes		MAN MAN	MAINAMAN	WI WARA AND IN			TL 10:38:06 software_ident = 9
TLE Management		11111.AAA. 17AAAA	AND THAT AND STATE AND	A 1 41 A	Manda Alta a sa		TL 10:38:06 uptime = 30722 secs
		falsen marches	A. a. a. hand had		1 1 1	-2.5	DN 10:38:06 Safety-OBC Health TL 10:38:06 TLM TBRD = 22.002476
File Decode		Lesser 1	1 1 2 malitaria an Ilahalasan			-5	TL 10:38:06 TLM_TBRD = 22.002476 TL 10:38:06 TotalPower = 5366 mW
C3D2 Decode		• • • • • • • • • • • • • • • • • • • •					TL 10:38:06 VPCMBATV = 8.156742 V
	19. Jun	26. Jun 3. Jul 10. Ju	17. Jul 24. Jul	31. Jul 7. Aug	14. Aug 21. Aug 28	-7.5 Aug	DN 10:38:06 EPS-EPS-Get Critical Telemetry
	-						DN 10:38:06 -
		I	DN 10:38:06 -				
	4	Jan '17	VMar '17	May '17	Jul 17	Sep '17	TL 10:38:05 FreqDeviation = 49153
						Highcharts.com	TL 10:38:05 down_count = 2705 TL 10:38:05 RSSI = 75
							TL 10:38:05 up_count = 0



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





Mission Heritage

Full Missions

- Alsat
- Inflatesail

Heritage Missions

- Strand
- DeorbitSail

Build and Test

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

+ various amateur and university cubesat support



Alsat-1N

Used in Simulation Mode with engineering module to train operators

Installed at ASAL (CDS) in Algeria for primary groundstation







Mission Operations Training





Development Strategy

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?

