



CubeSat Flight Software Workshop

FSW Development Process

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Agenda

- **FSW Development Process Overview**
- **FSW Subsystem Level Process**
 - Requirements Phase
 - Prototyping
 - Design Phase
 - Implementation Phase
 - Version Control
 - Verification Phase
 - Delivery Review
 - Change Requests and Maintenance
- **Component Level Process**
 - Software Design Document
 - Implementation
 - Unit Testing
 - Integrated Testing
 - Code Analysis and Review
 - Checklist
- **Status Reports**
 - Weekly Progress Summary
 - Issue Tracking

FSW Development Process Overview

Student CubeSat Project Timeline

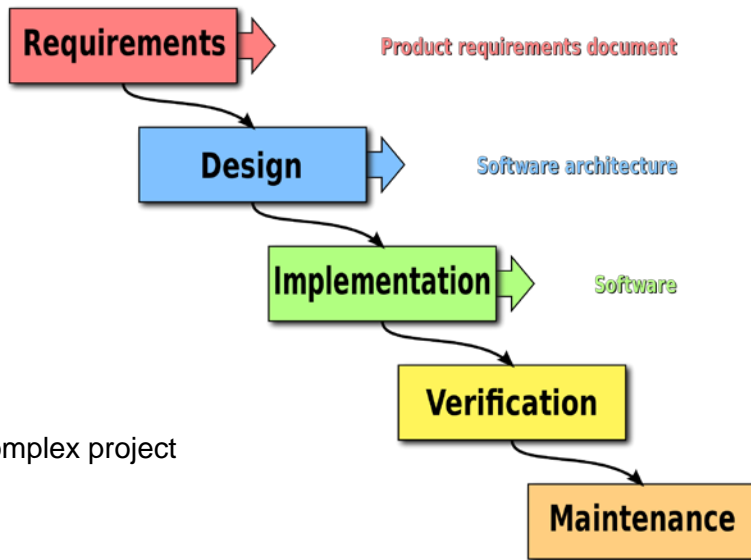


FSW Development Process Overview

Why is it important to have a development process?

Increases: -

- Reliability
 - Testability
 - Maintainability
 - Portability
-
- Waterfall model fits in line with deadline driven development
 - The right level of process is important
 - Too much process can bog you down
 - Too little process makes it impossible to manage a complex project
 - Either can lead to bad outcomes



Waterfall Model (Peter Kemp / Paul Smith [\[CC BY 3.0\]](#))

FSW Development Process Overview

Development Phases

Requirements

- Provide measurable constraints and characteristics from concept of operations

Design

- Provides blue print for software implementation given a set of requirements

Implementation

- Provides a testable product for verification

Verification

- Ensures implementation functionality and correctness

- Each phase has a review to ensure readiness for the next phase and address any issues

FSW Subsystem Level Process

Requirements Phase

- Why is it important to gather requirements: -
 - Map from concept of operations to specific capabilities that can be designed and implemented
 - Manages assumptions
 - Heads off disagreements/misunderstanding between designers/implementors and their stakeholders
 - "That's not what I wanted you to build!" Or
 - "That's not how I assumed it would work!"
 - Provides the structure for
 - Measuring progress of design and implementation
 - Verifying that we have built/delivered what is needed

FSW Subsystem Level Process

Requirements Derivation

- Understand project level requirements and concept of operations (ConOps) i.e. what is needed for the project
 - Decompose into various software components at high level
 - Functional breakdown rather than design
- Artifact: Requirements specification document
- Conduct review of requirements

Example requirement

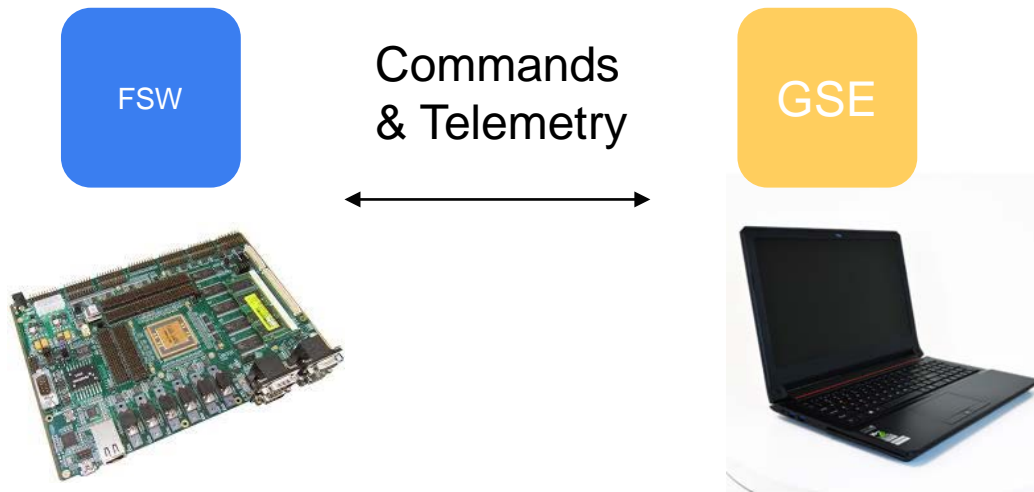
FSW Interfaces						
REQ ID	Short Title	Level 4 Requirement	Rationale	L3 Parent	V&V Strategy	V&V Plan
L4-FSW-1	Radio Uplink Interface	The FSW shall interface with the XYZ radio over an SPI connection to perform uplink for ground commands and files	FSW must provide software interface to receive uplinked data	L3-FSW-34, L3-FSW-35	Test	Test uplink frame formats with GDS. Both command and file uplink frames will be tested for appropriate decoding and execution. Part of FSW Rel-1.0 integrated testing.

What makes a good requirement?

FSW Subsystem Level Process

Proof of concept and Prototyping

- Target OS and hardware platform
- Compile and execute software on target
- Communicate over planned interfaces
- Data bandwidth and performance analysis



FSW Subsystem Level Process

Design Phase

- Trade studies and prototyping
- Component list
 - Services
 - Communication
 - Hardware managers
 - Hardware drivers
 - Guidance and control
 - Science
 - Fault protection and mode management
- Various design views
 - Block diagrams
 - Sequence diagrams
 - Data flow diagrams
 - State transition diagrams
 - Class diagrams
- Resource utilization, performance and concurrency issues discussion
- List of planned releases

Conduct design review

Artifact: software architecture and design documentation

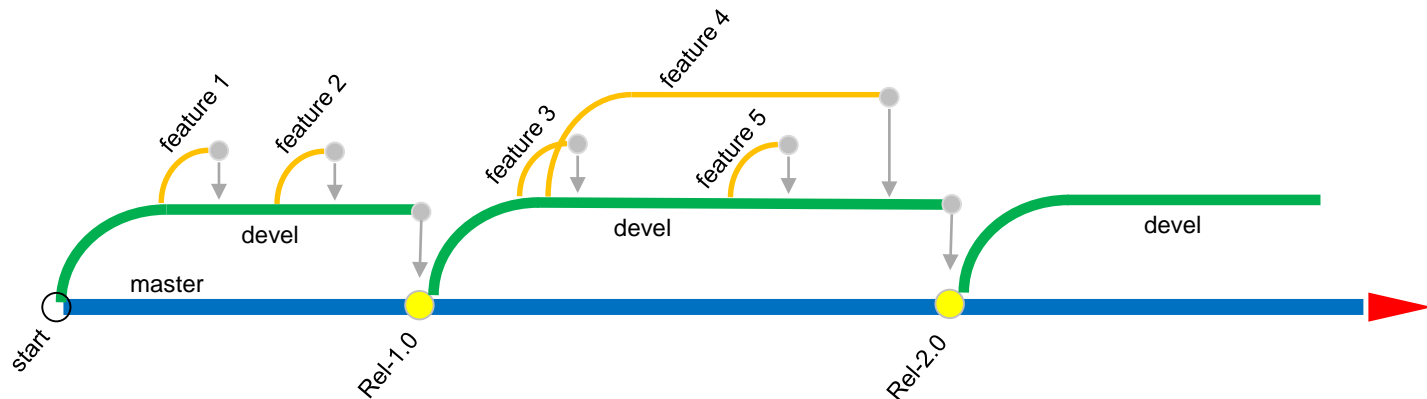
FSW Subsystem Level Process

Implementation Phase

- Coding
 - With good design, this should not be too complicated
 - May require design updates
 - Majority of design expected to be completed in design phase
- Unit Testing
 - Component level
- Deployment
 - Functional integration of software components
- Conduct code reviews

FSW Subsystem Level Process

Version Control



- = Master Branch
- = Devel Branch
- = Feature Branch
- ↓ = Branch Merge
- = Release Tag

Git Workflow

FSW Subsystem Level Process

Verification Phase

- Critical to overall software functionality and mission success
- Catching bugs early is cheaper and easier to fix
- Driven by requirements verification
 - Performed using test scripts executed against a release deployment

Artifact: Requirements verification and validation matrix

REQ ID	Short Title	Level 4 Requirement	Rationale	L3 Parent	V&V Strategy	Status	V&V IDs
NEASC-L4-FSW-3	Data Storage Interface	The FSW shall interface with the non-volatile data storage memory on board the flight CDH unit for read/write access for atleast 4 GB] bytes.	FSW needs access to this memory to manage science and engineering data	NEAS-FS-L3-32	Test	PASS	jpl_ffs-VI-1 thru jpl_ffs-VI-7, prmDb-VI-1

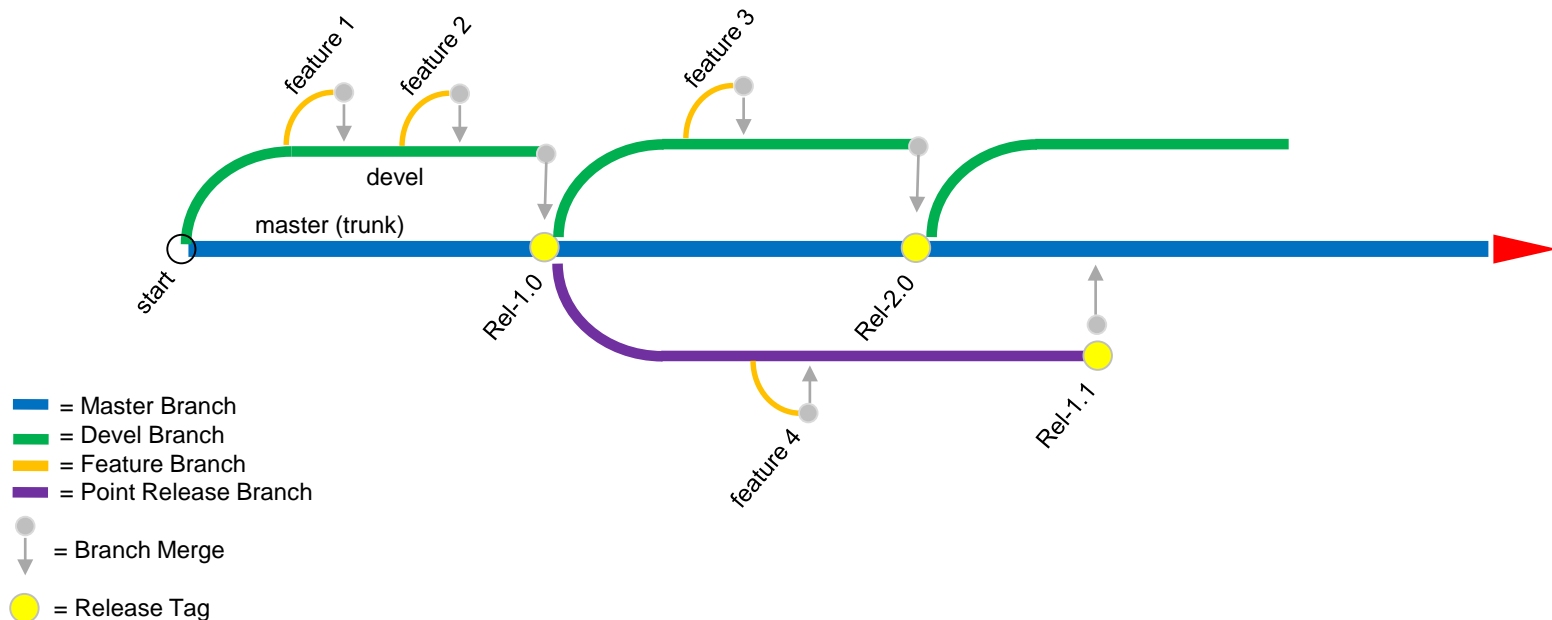
FSW Subsystem Level Process

Delivery Review

- Release description document (RDD)
 - Change log
 - Version Identification
 - Project Overview and Release Description
 - Controlling Documents
 - Test Reports
 - Requirements Verification Summary
 - Idiosyncrasies and Known Issues
 - Problem Disposition
 - Detailed Contents
- Users guide
 - Operational constraints
 - Usage guidelines
- Software design documents

FSW Subsystem Level Process

Change Requests and Maintenance



Component Level Process

Software Design Document

- Component overview
- Component level requirements
- Design
 - Component block diagram
 - Sequence, dataflow, state transition, class diagrams
 - Port List
 - Custom data types
 - State
 - Port Behaviors
 - Commands
 - Telemetry
 - Events
- Unit Test Output and Coverage Results
- Reference datasheets and other technical documents as applicable

Component Level Process Implementation

- Port handler behaviors
- State management
- Command handlers
- Telemetry & events
- Topology integration
- Build with deployment

Component Level Process

Unit Testing

- F Prime unit test harness
- Traceability to component level requirements
- Code coverage analysis
- Unit test output and coverage results

Component Level Process

Integrated Testing

- Test venue
- Test scripts
- Test reports
- Requirements V&V

MPCS Monitor (121) cubesat_session

File View Utilities Preferences Advanced Help

Status	Product Status	Command	Channel List	EVR	Performance	Memory Scrub	Power Switch Channels	RCS Channels	Message
Source	Name			ERT	SLC/L	Level			
45	FSW	XACT_PWR_STATE_UPDT		2019-10-17 23:19:47.113	000000144-18159	ACTIVITY_H			RACT updated power state on power channel 1 to POWERED_OFF_12V
47	FSW	PowerSwitchManager_PowerStateChange		2019-10-17 23:19:47.184	000000144-18553	ACTIVITY_H			Power channel 1 state set to CHD_EVR_OFF
48	FSW	XACT_PWR_STATE_UPDT		2019-10-17 23:19:47.184	000000144-18553	ACTIVITY_H			RACT updated power state on power channel 1 to POWERED_OFF_12V
49	FSW	PowerSwitchManager_PowerStateChange		2019-10-17 23:19:47.184	000000144-18462	ACTIVITY_H			Power channel 1 state set to CHD_EVR_OFF
50	FSW	ModeMgrInitTimeout		2019-10-17 23:20:05.822	000000162-86504	ACTIVITY_H			BMF mode countdown completed
51	FSW	ModeMgrSWtoStable		2019-10-17 23:20:05.822	000000162-86790	ACTIVITY_H			FSW boot marked as stable in System
52	FSW	ModeMgrSafeSequence		2019-10-17 23:20:06.801	000000163-87639	ACTIVITY_H			Execution of safe mode sequence invoked from location: (default)
53	FSW	ModeMgrSafeSequence		2019-10-17 23:20:06.801	000000163-87642	ACTIVITY_H			Mode Manager has changed from PREV_MODE_HIT to NEW_MODE_SAFE
54	FSW	CS_IsSequenceActive		2019-10-17 23:20:16.911	000000163-88718	WARNING_LO			No sequence active
55	FSW	ModeMgrSafeState		2019-10-17 23:20:16.911	000000163-88837	WARNING_H			Sequence failed to complete
56	FSW	ModeMgrSafeSequence		2019-10-17 23:20:16.911	000000163-89182	WARNING_H			Fault response requested: FaultID 0x20000000, Fault Status: F0_DISABLE
57	FSW	ModeMgrSafeSequence		2019-10-17 23:20:16.911	000000163-89182	WARNING_H			Fault response requested: FaultID 0x20000000, Fault Status: F0_DISABLE
58	FSW	ModeMgrSafeSequence		2019-10-17 23:20:16.911	000000163-89182	WARNING_H			Fault response requested: FaultID 0x20000000, Fault Status: F0_DISABLE
59	FSW	SPWManager_RMAPPReadResult		2019-10-17 23:20:19.144	000000176-37798	ACTIVITY_LO			RMAPP read of address 0 returned a value of 3735928593
60	FSW	SPWManager_RMAPPReadResult		2019-10-17 23:20:19.144	000000176-37798	ACTIVITY_LO			RMAPP read of address 0 returned a value of 3735928593
61	FSW	SPWManager_RMAPPReadResult		2019-10-17 23:20:19.144	000000176-37798	ACTIVITY_LO			RMAPP read of address 0 returned a value of 3735928593
62	FSW	SPWManager_SpaceWireError		2019-10-17 23:20:40.811	000000186-01488	WARNING_H			Received error status ERR_RX_EEP (code 0) from driver
63	FSW	SPWManager_SpaceWireError		2019-10-17 23:20:40.811	000000186-01488	WARNING_H			Received error status ERR_RX_EEP (code 0) from driver
64	FSW	SPWManager_SpaceWireError		2019-10-17 23:20:40.811	000000186-01488	WARNING_H			Received error status ERR_RX_EEP (code 0) from driver
65	FSW	SPWManager_RMAPPReadResult		2019-10-17 23:21:16.445	000000214-82287	ACTIVITY_LO			RMAPP read of address 46 returned a value of 1377141624
66	FSW	SPWManager_RMAPPReadResult		2019-10-17 23:21:16.445	000000214-82287	ACTIVITY_LO			RMAPP read of address 46 returned a value of 1377141624
67	FSW	SPWManager_RMAPPReadResult		2019-10-17 23:21:16.445	000000214-82287	ACTIVITY_LO			RMAPP read of address 46 returned a value of 1377141624
68	FSW	SPWManager_RMAPPReadResult		2019-10-17 23:21:24.165	000000251-21585	ACTIVITY_LO			RMAPP read of address c1 returned a value of 233884719
69	FSW	FS_ACT_H		2019-10-17 23:21:37.117	000000274-47180	ACTIVITY_H			1588323295: Successfully mounted NVFS partition 1 in 137662235 usec
70	FSW	FS_ACT_H		2019-10-17 23:21:49.802	000000286-82715	ACTIVITY_H			1588323295: Successfully mounted NVFS partition 2 in 132701518 usec
71	FSW	FS_ACT_H		2019-10-17 23:21:49.802	000000286-82715	ACTIVITY_H			1588323295: Successfully mounted NVFS partition 2 in 132701518 usec
72	FSW	FS_ACT_H		2019-10-17 23:21:49.802	000000286-82715	ACTIVITY_H			1588323295: Successfully mounted NVFS partition 2 in 132701518 usec
73	FSW	SPWManager_SpaceWireError		2019-10-17 23:22:18.699	000000325-83721	WARNING_H			Received error status ERR_RX_EEP (code 0) from driver

Not Passed Not filtered FSW.SSE Realtime

2019-03-07 01:15:29.008	FSWSR	0000002983.27062	MPCS	FIT INFO	***** Beginning Testxact00Cmd05 *****
2019-03-07 01:15:29.008	FSWSR	0000002983.27062	MPCS	FIT INFO	Test Case Description:
2019-03-07 01:15:29.008	FSWSR	0000002983.27062	MPCS	FIT INFO	Send command 5
2019-03-07 01:15:29.008	FSWSR	0000002983.27062	MPCS	FIT INFO	
2019-03-07 01:15:29.008	FSWSR	0000002983.27062	MPCS	FIT INFO	EHA found/verified XACT_CMD_ACCEPT_COUNT (XACT-0275) is DN 32
2019-03-07 01:15:29.008	FSWSR	0000002983.27062	MPCS	FIT INFO	Sending FSW Command (number=218): XACT_NO_OP
2019-03-07 01:15:29.946	FSWSR	0000002983.27062	MPCS	FSW CMD	XACT_NO_OP
2019-03-07 01:15:29.543	FSWSR	0000002983.27062	MPCS	LOG INFO	General
2019-03-07 01:15:32.103	FSWSR	0000002992.83012	FSW RT	EVR COMMAND OpCodeDispatched	OpCode 0xF605 dispatched to port 7
2019-03-07 01:15:32.339	FSWSR	0000002992.83012	FSW RT	EVR COMMAND OpCodeCompleted	OpCode 0xF605 completed
2019-03-07 01:15:35.008	FSWSR	0000002993.09743	MPCS	FIT INFO	Expected command stages: 'success'=True (expect=True)
2019-03-07 01:15:35.008	FSWSR	0000002993.09743	MPCS	FIT INFO	
2019-03-07 01:15:35.008	FSWSR	0000002993.09743	MPCS	FIT INFO	
2019-03-07 01:15:35.008	FSWSR	0000002993.09743	MPCS	FIT INFO	MTAK_PASS
2019-03-07 01:15:35.210	FSWSR	0000002993.09743	MPCS	LOG INFO	Performance
2019-03-07 01:15:35.210	FSWSR	0000002993.09743	MPCS	LOG INFO	Performance
2019-03-07 01:15:36.008	FSWSR	0000002993.09743	MPCS	FIT INFO	MTAK_PASS
2019-03-07 01:15:36.008	FSWSR	0000002993.09743	MPCS	FIT INFO	EHA found/verified XACT_CMD_ACCEPT_COUNT (XACT-0275) is DN 33
2019-03-07 01:15:36.008	FSWSR	0000002993.09743	MPCS	FIT INFO	wait 5 seconds

Component Level Process

Code Analysis and Review

- Static analysis tools
 - Coverity
 - Semmle
 - Power of 10 rules
 - GCC (compiler)
- Code peer review
- GitHub pull request

Component Level Process Checklist

Component: FSW/Components/FSWImageManager Component Owner: John Component Contributors: Mike, Peter		
	Status	Notes
Modeling		
Model generated in MagicDraw with interfaces defined	YES	
Component auto-coded using component autocoder	YES	
Auto-coded component builds successfully for SPHINX platform	YES	
Implementation		
Behaviors, states, commands, telemetry, and events implemented	YES	
Component builds with the topology	YES	
Deployment		
Static analysis of code performed using SCRUB	YES	
Component Unit Tested	YES	
Executes with topology on SPHINX platform without any issues	YES	
Close-Out		
SDD generated	YES	
Component reviewed by peer(s)	YES	Peers: David
All open issues and action items related to the component have been addressed and closed out	YES	

Status Reports

Weekly Progress Summary

- Highlight accomplishments and progress
- Indicate delays in receivables
- Describe pending items
- Estimated upcoming release delivery date
- Describe current progress against development plan schedule
- Communicate problems to stakeholders early on to facilitate timely action

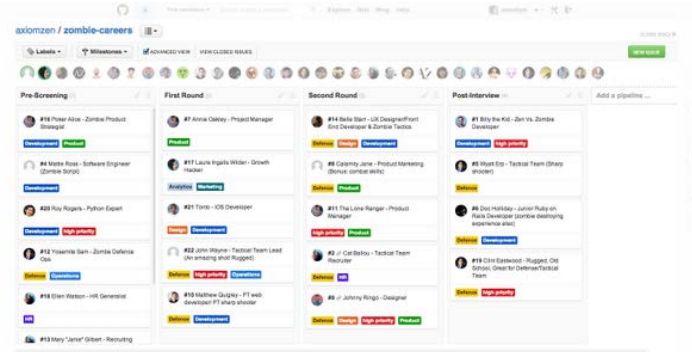
Status Reports

Issue Tracking

- Track current progress to know how we're doing
- Estimate delivery dates and forecast delivery slips early on

Task Name	Percent Complete (%)	Work Item	Estimate	Actual Completion Date	PTSR Region V3 Date	PTSR Region V2 Date	Original Due
FSW Rel 2.0 Build, Execution and Integrated Testing	200	FSW Rel 2.0 Delivery	2	8/12/17			8/12/17
SPI Interface Testing	200	FSW Rel 2.0 Delivery	1	5/26/18			1/2/18
Power Switch Testing	200	FSW Rel 2.0 Delivery	1	5/16/17			5/16/17
Propulsion Interface	200	FSW Rel 2.0 Delivery	4	5/29/18			5/13/18
Power EPS testing with FSW	200	FSW Rel 2.0 Delivery	1	5/29/18			5/13/18
Temp sensor testing with ADC	200	FSW Rel 2.0 Delivery	1	11/9/17			10/11/17
Update Groundstation with AMPCC SOAP format	200	FSW Rel 2.0 Delivery	1	1/16/18			1/1/18
Update Groundstation and ECU converter database files (Rel 2.0)	200	FSW Rel 2.0 Delivery	1	1/29/18			1/19/18
Update bar book map for Sphinx (EM)	200	FSW Rel 2.0 Delivery	1	10/13/17			10/13/17
Update and test the system with full BSB MANC flash	200	FSW Rel 2.0 Delivery	1	11/9/17			11/9/17
Test MANC-Prop Component with EDU	200	FSW Rel 2.0 Delivery	2	1/9/18			1/9/18
FSW Rel 2.0 Build, Execution and Integrated Testing	200	FSW Rel 2.0 Delivery	4	5/13/18			5/13/18
FP Manager	200	FSW Rel 2.0 Delivery	2	3/5/18			3/13/18
Mode Manager	200	FSW Rel 2.0 Delivery	2	3/13/18			3/13/18
FP State Manager	200	FSW Rel 3.0 Delivery	2	4/12/18			4/1/18
FSW Rel 3.0 Build, Execution and Integrated Testing	200	FSW Rel 3.0 Delivery	4	4/17/18			4/17/18
Test external Electronics Interface	200	FSW Rel 4.0 Delivery	4	8/7/18			5/15/18
FP State Manager Updates	200	FSW Rel 4.0 Delivery	2	8/7/18			5/15/18
Update Groundstation and ECU converter Database Files for Flight	200	FSW Rel 4.0 Delivery	1	8/29/18			6/15/18
Re-map power switches and ADC Channels	200	FSW Rel 4.0 Delivery	1	7/5/18			4/26/18
FSW Rel 4.0 Build, Execution and Integrated Testing	200	FSW Rel 4.0 Delivery	3	8/23/18			7/5/18
Payload interface updates	200	FSW Rel 4.1 Delivery	1	9/12/18			9/12/18
Bootloader for Volatiles+FSW	200	FSW Rel 4.1 Delivery	1	10/15/18			9/16/18
FSW Rel 4.1 Build, Execution and Integrated Testing (Payload interface only)	200	FSW Rel 4.1 Delivery	4	10/19/18			10/19/18
MANC interface updates for fault protection	200	FSW Rel 4.2 Delivery	2	10/15/18			10/15/18
MANC Duty Cycling	200	FSW Rel 4.2 Delivery	2	10/15/18			10/15/18
Int Temperature Conversion	200	FSW Rel 4.2 Delivery	1	4/15/19			4/15/19
Int v2.1 Rmk updates in FSW	200	FSW Rel 4.2 Delivery	2	10/12/19			4/15/19
Update Image Run Process	50	FSW Rel 4.2 Delivery	1	4/28/19			4/28/19
FSW Rel 4.2 Build, Execution and Integrated Testing (MANC interfaces only)	50	FSW Rel 4.2 Delivery	2	5/25/18			5/25/18
Prop interface updates for fault protection	200	FSW Rel 4.3 Delivery	4	6/28/19			6/28/19
FSW Rel 4.3 Build, Execution and Integrated Testing (Prop interfaces only)	0	FSW Rel 4.3 Delivery	1	7/28/19			7/28/19
Run Files, updates and change requests post FSW Rel 4.0	0	FSW Rel 4.0 Delivery	1	5/13/19			5/13/19
FSW Rel 5.0 Build, Execution and Integrated Testing	0	FSW Rel 5.0 Delivery	1	10/15/19			10/15/19

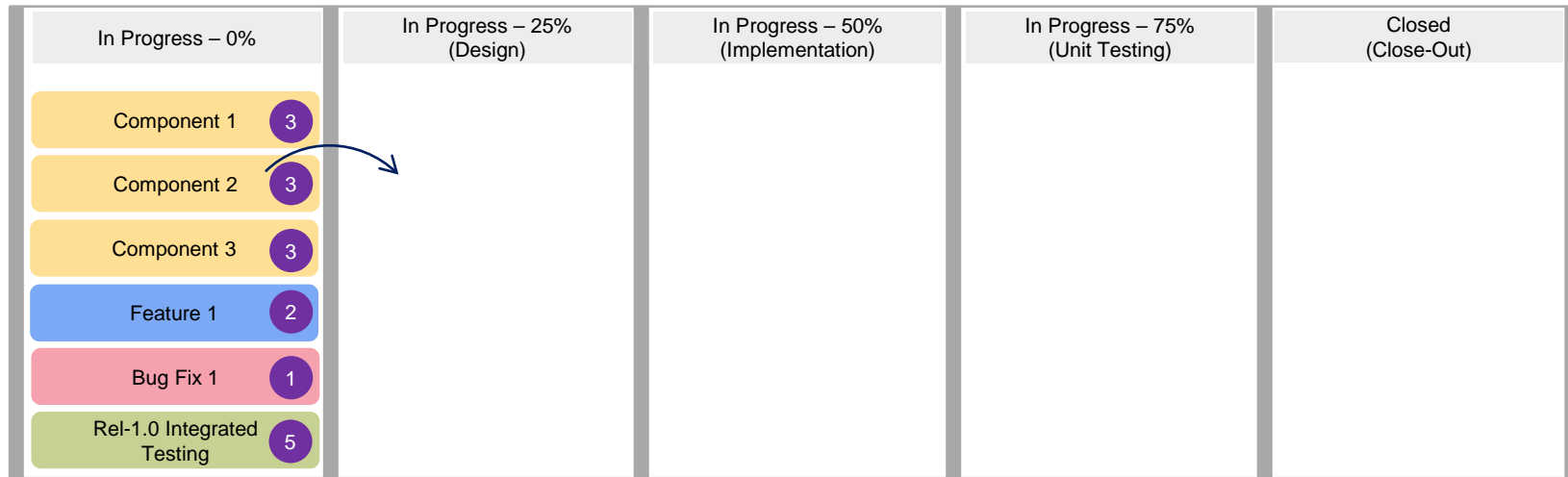
Completion Points



ZenHub Pipelines

Status Reports

Issue Tracking



Total Planned Completion
Points for Rel-1.0 = 17



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