ESL Electronic Systems Laboratory

Satellite Review Meetings

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Introduction

- Purpose of review meetings
  - Facilitate communication between design team (students), management/reviewers (academics) and the customer (sponsor)
  - Ensure all contributing factors and reasonable design options have been considered
  - Ensure the design meet the requirements as outlined in the Product Specification
- The design team responsibility
  - Provide an accurate, concise overview of the design to-date and facilitate productive discussions
- The reviewers responsibility
  - To assess the design to ensure it can be produced, tested and operated as required by the customer

Types of Reviews

- Requirements Definition
  - Mission Design Review (MDR)
- Conceptual Design(s)
  - Preliminary Design Review (PDR)
- Detail Design
  - Critical Design Review (CDR)
- Development and Qualification
  - Qualification Readiness Review (QRR)
- Flight Readiness
  - Flight Readiness Review (FRR)

Mission Design Review

- Overview of mission requirements
  - Evaluate and consolidate all requirements
- Possible mission solution(s)
  - Proposal of bus hardware components
  - Present potential payload(s)
  - Mission orbit analysis
  - Initial power, mass, volume and link budgets
- Time line for project development
  - Determine critical milestones
- Budget proposal
  - Determine financial feasibility and constraints
- Major challenges
  - Present and discuss potential problems & solutions foreseen

Preliminary Design Review

- Conducted after preliminary design(s) effort
  - ➢ First opportunity of client to observe contractor's hardware and software design solution
  - ➢ Contractor must present and explain all design changes, since the initial technical proposal (MDR)
- Include all configuration items of project
  - ➢ Evaluate the design progress made
  - ➢ Evaluate the technical adequacy of design(s)
  - ➢ Evaluate the risk resolution on a technical, cost and schedule basis
  - ➢ Evaluate the performance to the requirements solution
- Establish the physical and functional interfaces
  - ➢ Ensure consistency and technical adequacy of the top level design and test approach
  - ➢ Focus on compatibility of the design requirements
- Approval of pre-design for final development

Critical Design Review

- Presentation of Final Design
  - Contractor must present and explain the detail design of all configuration items for cost, schedule and performance
  - Reviewers must critically evaluate the final design solution
  - Focus on new hardware development solutions
- Risk Analysis and Mitigation Plan
  - Outline all technical and programmatic issues foreseen
  - Present the requirements compliancy table
- Assembly, Integration and Test Plan
  - Step-by-step detailed procedure of satellite construction
- Management Plan
  - List of people involved in the project and their contribution
  - Outline the financial budget available to complete the project
  - Present the project timeline and major milestones
  - List of long lead items

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Qualification/Flight Readiness Review

- Qualification/Flight Test Plans
  - Environmental tests: RF, thermal, vacuum and vibration
  - Functional tests: AIT procedures
  - Explain purpose of all the planned tests ?
  - Motivate why it will be tested ?
- Facilities and Resources
  - Specifications and people requirement
  - Hazards and risks – present all mitigation steps
- Present the Test results
  - Assess results for qualification/flight acceptance (go/no go)
  - Present a way forward and proposed solutions for failed tests
- Receive Certification
  - Safe to proceed at an acceptable risk

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Preparing for Design Review

- Schedule design review
  - 1 month prior, arrange meeting facilities
- Publish agenda
  - 3-4 week prior, assign areas of responsibility to team
  - Invite subject matter experts as reviewers
- Distribute design review packages
  - 2 week prior
- Conduct dry runs
  - 1 week prior
- Final dry run
  - 1 day prior

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Design Review Participants

- **Chairperson**
  - Co-ordinate the design review preparations
  - Conduct the review meeting
  - Monitor the follow through of actions from the meeting
  - Must be a senior engineer with understanding of design process, but not directly involved to remain objective
- **Design Team** (2-5 persons)
  - Must provide details of the design process and design
  - Only key persons for entire review, others attend only when needed
  - Appoint a lead engineer for the review to introduce the details and to lead the technical discussions, typically the principal project engineer
  - Appoint a secretary to record the DR minutes, typically the QA engineer
- **Subject Matter Experts** (2-5 persons)
  - They are not directly involved in the design, but suitable to be reviewers
  - May include representatives from manufacturing, test and safety, quality and reliability, finance and purchasing
- **Customer** (1-5 persons)
  - The customer may mirror the subject experts with their own experts

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Design Review Package Contents

Typical DR package content:

- Current Product Development Specification (PDS)
- Applicable engineering data, i.e. calculations, simulations, test results, budgets, etc.
- Competitive analysis of existing products
- Drawings, schematics, layouts, breadboards, mock-ups and prototypes
- Project progress and timelines
- Project risk analysis
- Description of unusual requirements and design elements with associated high risk

Design Review Agenda

- **Welcome & Introduction** (< 5%, Chairperson)
  - Allows participants to introduce themselves
- **Explain Design Review Purpose & Process** (< 5%, Chairperson)
  - Participants will be asked to provide objective, constructive input
- **Background** (~10%, Lead Engineer)
  - Outline of project objectives and significant requirements
  - Design overview, leading into more detail of the major components
  - Competitive analysis with alternative concepts
  - Significant problems and risks
- **Detailed Interactive Discussion** (~60%, Lead Engineer facilitate)
  - Presentation and discussion of all major components
  - Demonstration of the products or models, if available
  - Validation of assumptions and assessment of product risk
  - Highlight areas of concern and recommendations
- **Discussion of Project Management** (<10%, Project Manager)
  - Overview of schedule, timelines and milestones
  - Status of budget
  - Assessment of project risk
- **Wrap-Up** (~10%, Chairperson, Lead Engineer and Secretary)
  - Discussion of recommendations
  - Review of action items (list Review Item Discrepancies – RIDs)

Review Item Discrepancy

- All reviewers must submit their RIDs
  - Submit all within 1 week from Review Meeting
  - A RID template is provided to standardise the feedback
- RID Template Contents
  1. Review document reference (e.g. Payload ICD)
  2. RID reference (e.g. CDR-RID-JAXA-001)
  3. Initiator (Reviewer)
  4. Page, Section (e.g. Page 10, Section 5.2.3)
  5. RID title (e.g. Payload power)
  6. Discrepancy (e.g. Description of issue)
  7. Proposed Solution (Reviewer suggestion)
  8. Project team Answer (TBD Contractor response)
  9. Project team Action (TBD Contractor proposed solution)
  10. Recommendation (TBD Reviewer response/acceptance)
  11. Acceptance (TBD by Project management)

RID Example

Document Reference	RID Reference	Initiator	Page, Section	RID Title	Discrepancy	Proposed Solution	Contractor Answer	Action	Recommend	Answer accepted?
ADCS Design Report	CDR-RID-VKI-01	F. Singarayar	Page 1, Cover page	status and date	The status and date on the cover page is not of version 2.0	Please correct.	Agreed. Will update version, date and status information on cover page	Update cover page. Version is now 2.1 and status released. Version 2.0 is draft submitted for CDR. Slight changes (see other RIDs for Design Document) from 2.0 to 2.1		
ADCS Design Report	CDR-RID-VKI-02	F. Singarayar	Page 6, Section 1	attitude control requirement	Not all the sensors require a pointing accuracy of +/- 10 deg and pointing knowledge of +/- 2 deg. This is only for the INMS, which is the most stringnet.	Wording here should be changed to reflect this.	The introduction section will be updated with more recent information. The QB50 science unit requirements will be mentioned as well as the ADCS design requirements	Change wording to reflect actual SU requirements. Add reference to the QB50 ADCS design requirements		
ADCS Design Report	CDR-RID-VKI-03	F. Singarayar	Page 9, Section 5.3.1	location of CSS	The location of where the CSS should be placed on each of the panels should be indicated if it is important.	Please clarify.	The location does not matter, but pointing direction and obscuration matters. Solar cells should be mounted so that it points in the +X, -X, +Y, -Y, +Z, -Z directions. Not all sensor have to be mounted or used, but at least 3 facets should be covered, and at least one sensor in each axis (either +X or -X should be covered). In the case of only 3 CSS, the sensing range of the CSS will be diminished (it won't work for all angles). There is a configuration setting that specifies which sensor is in which direction (or not used). Will add this information to the section on the CSS	Add specific mention of the pointing direction, obscuration and configuration of the CSS.		
ADCS ICD	CDR-RID-VKI-05	F. Singarayar	Page 2, Introduction	attitude control requirment	same as before - Not all the sensors require a pointing accuracy of +/- 10 deg and pointing knowledge of +/- 2 deg. This is only for the INMS, which is the most stringnet.	Please correct the wording here to reflect this.	The introduction section will be updated with more recent information.	Change wording to reflect actual SU requirements.		
ADCS ICD	CDR-RID-VKI-06	F. Singarayar	Page 2, Introduction	launch altitute	Initial launch altitude is not 350km for certain. It's a range from 350 - 400km.	Please update this.	Will remove mention of specific initial altitude	Remove mention of specific initial altitude. In stead of saying: "initial altitude at 350km down to…", replace with "initial altitude down to…"		
ADCS ICD	CDR-RID-VKI-07	F. Singarayar	Page 15, Section 4.6	requirements on the host satellite	Since this is an ICD FROM Surrey TO the CubeSat teams, shouldn't the wording be in such a way that the host satellite is required to respect certain intertia and CoM if it was interested in using the SSC ADCS?	Instead of "will", maybe use "should" or "shall"	Agreed. Will change wording	Changed "will" to "shall" in section 4.6		
ADCS ICD	CDR-RID-VKI-08	T. Scholz	p. 11, Section 4.2	Connector type	The connector type should be specified in more detail by giving part name from the manufacturer.	Please update.	Agreed. Will add connector part numbers.	Add connector part numbers to section 4.2 and 4.3		
ADCS ICD	CDR-RID-VKI-09	T. Scholz	p. 12, Section 4.4	GPS patch antenna fixation	Will the antenna be glued to the structure and if yes, please give suitable types of glue or refeer to the datasheet if the information is given there	Please update.	Yes it will be glued. Any space qualified epoxy can be used	Add the sentente "The antenna shall be fixed to the satellite structure by attaching the bottom shielding of the patch antenna to the satellite surface with epoxy." to section 4.4		

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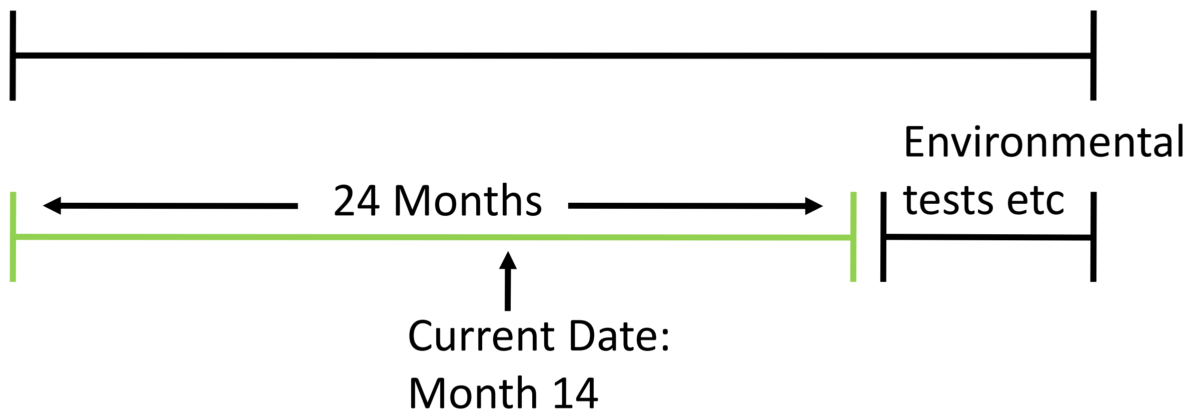
Example: ZA-Aerosat CDR

Timeline:



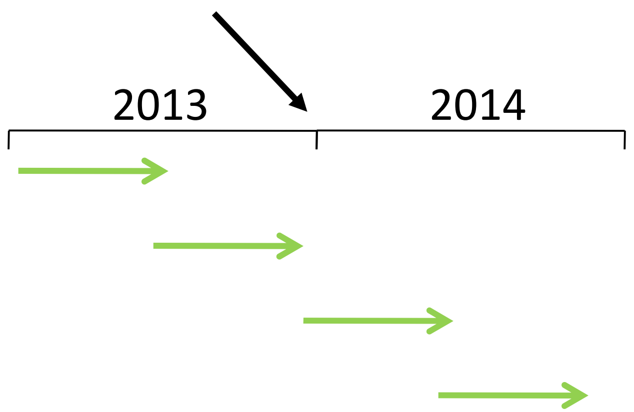
Main Tasks:

-In-house component development

-Satellite design

-Software (Ground and Flight)

-Integration and testing



Example: ZA-Aerosat CDR

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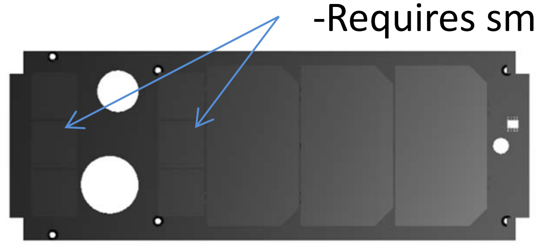
- Scheduling and planning
- Functionality and design
- Structure and physical layout
- Budgets
- Challenges and uncertainties

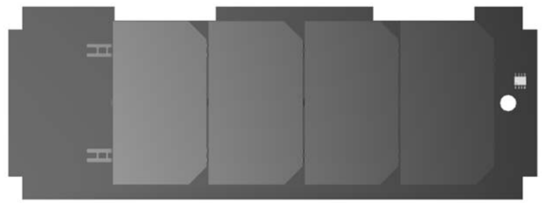
Power:

- Commercial EPS
  - Flight proven
  - 3 Switched outputs
  - 8.2V (Adjustable) Battery voltage
  - 1800mAh Battery
- Commercial Solar panels
  - Flight Proven
  - 1 Custom PCB with holes for camera lenses
    - -Requires small cells



Overall solar cell area per panel: $0.01m^2$

- 2 Custom PCBs with holes/cutouts for deployment mechanism



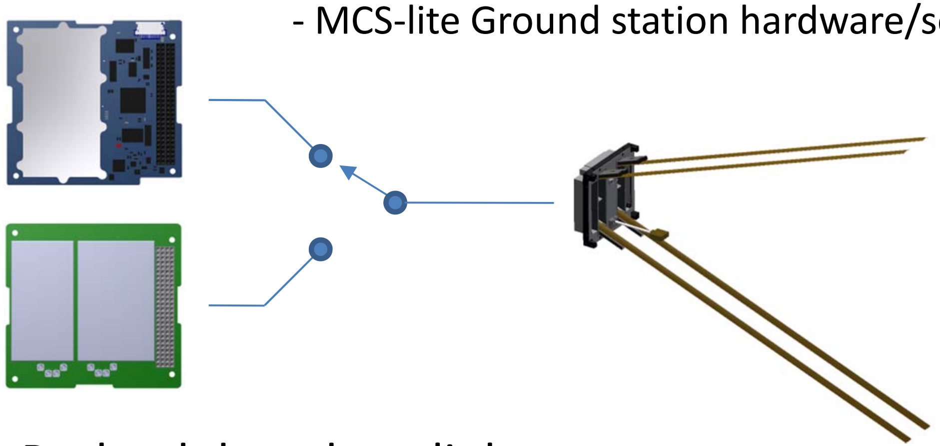
CDR Summary

Example: ZA-Aerosat CDR

Communications:

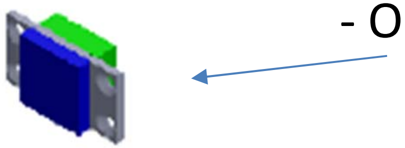
-Beacon/Telemetry/Telecommand

- VHF Uplink/UHF Downlink
- MCS-lite Ground station hardware/software



-Payload data downlink

- UHF Downlink
- Optional S-Band txmitter



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Example: ZA-Aerosat CDR

Scheduling and planning

Functionality and design

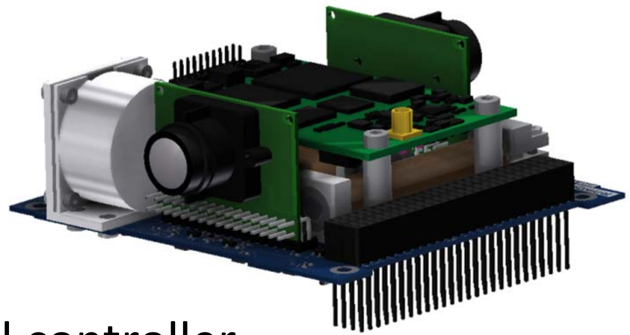
Structure and physical layout

Budgets

Challenges and uncertainties

ADCS

- Magnetic detumbling



- Pitch momentum wheel controller
- Deployable Magnetometer
- External coarse sun sensors
- Space GPS receiver

Sensor	Type	Range/FOV	Accuracy (RMS)
Magnetometer	3-Axis MagR	± 60 µT	< 40 nT
Sun sensor	2-Axis CMOS	Hemisphere	< 2˚ peak
Nadir sensor	2-Axis CMOS	± 45˚	< 2˚ peak
Course sun sensor	6 Photodiodes	Full sphere	< 10˚
Rate sensor	MEMS	± 75˚/sec	< 0.05˚/sec

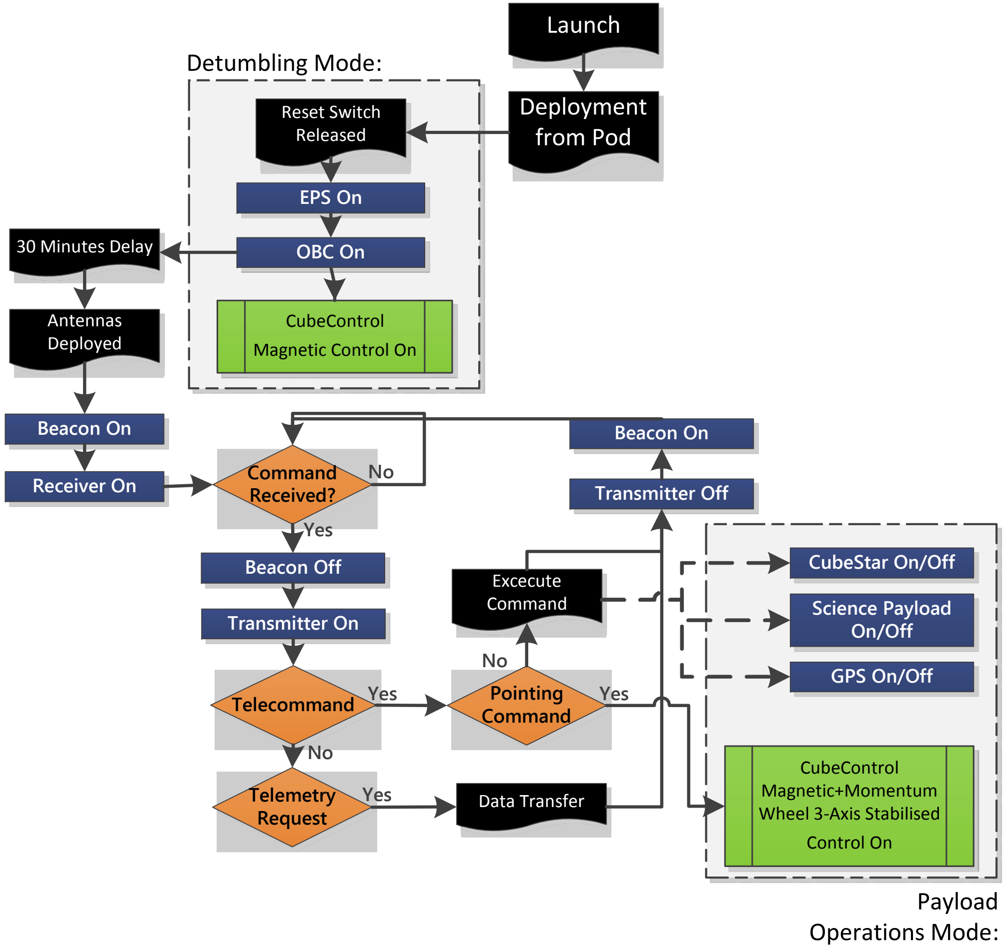
Actuator	Type	Range/FOV	Accuracy (RMS)
Momentum Pitch Wheel	BLDC Motor	± 2 mNms	< 0.01 mNms
Magnetorquers	Ferro-magnetic rods & air coil	± 0.2 Am^2	< 0.0002 Am^2

Example: ZA-Aerosat CDR

- Scheduling and planning
- **Functionality and design**
- Structure and physical layout
- Budgets
- Challenges and uncertainties

ADCS

-Sequence of operations:



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Example: ZA-Aerosat CDR

Scheduling and planning

Functionality and design

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Challenges and uncertainties

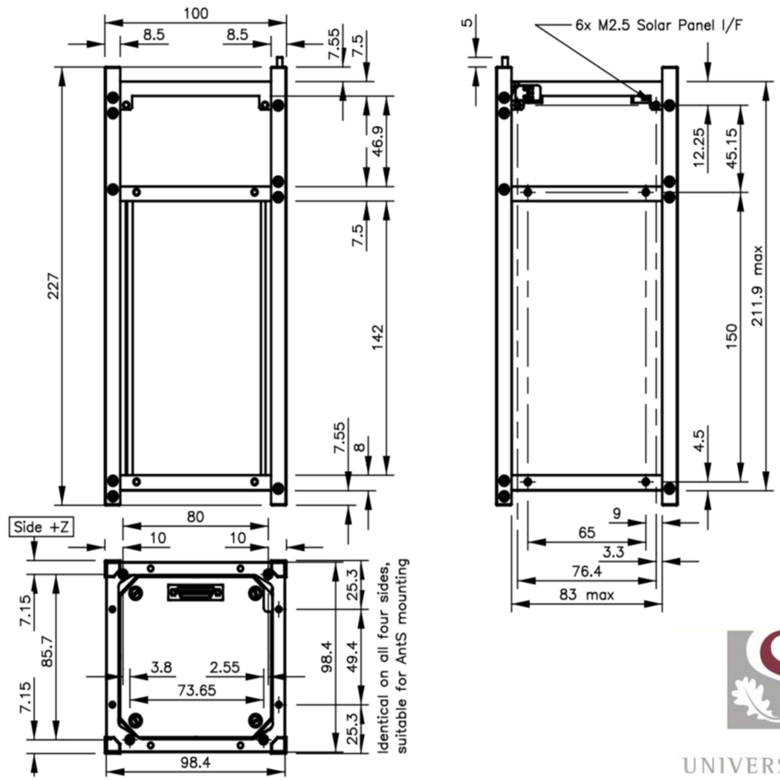
Payload:

- Passive aerodynamic stabilisation
  - Monitor sensors/actuators
  - Analyse effect of antennas
- QB50 science payload
  - Sensors kept RAM pointing
  - OBC redundant interface
- ESL CubeStar star tracker
  - Only eclipse
  - Capture images for analysis on earth
  - Compare measurements with satellite estimated orientation
- Gravitational Wave sensor experiment

Example: ZA-Aerosat CDR

Structure:

- ISIS supplied
- Compatible with pod and science unit
- Standard 1U Solar panels with custom PCB mounting
- Integration jig



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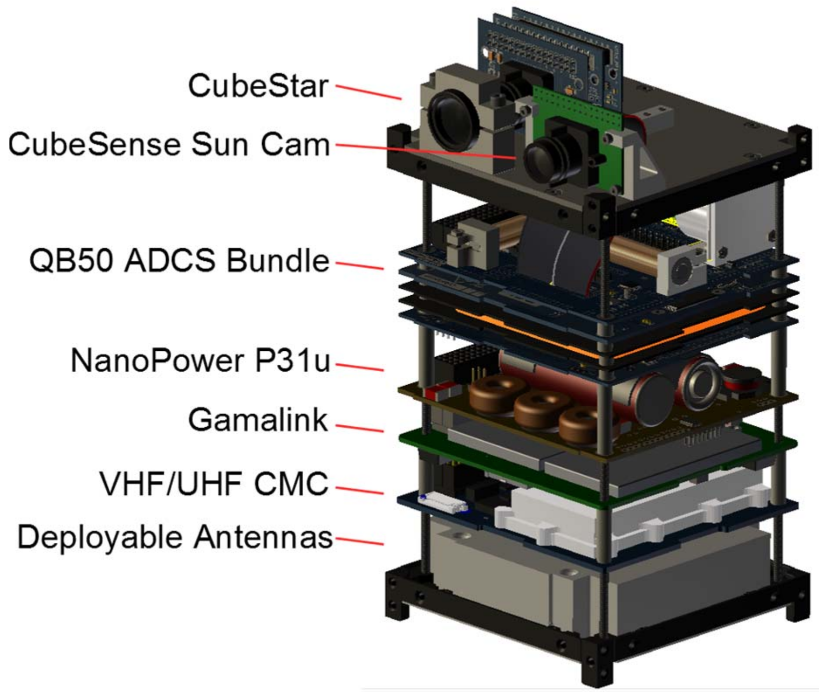
Example: ZA-Aerosat CDR

Layout:

- Star tracker/Sun camera placement/mounting
- Comms antenna cable/switching/compensation network
- Solar panels – custom holes
- GPS patch antenna placement



ZA-Aerosat CDR Summary

Mass Budget:

Subsystem	Mass(g)	Comments
Structural	200	
Power	400	
ADCS	290	Possible added mass for integration
OBC/OBDH	100	PiggyBack board still to be built
Communications	355	Antenna deployment hardware still to be built
Payload	345	QB50 Science payload only according to spec
Thermal	150	Estimate only
Subtotal	1840	
Integration	5%	
Total	1932	
Target	2000	
Margin	3.5%	

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Example: ZA-Aerosat CDR

Power Budget (Detumbling/Y-Spin Controller):

Subsystem	Average Power	Duty Cycle	Average Orbital Power
EPS	125mW	100	125mW
OBC	165mW	100	165mW
VHF Receiver	190mW	100	190mW
UHF Transmitter	8000mW	<3	240mW
GPS	1000mW	5	50mW
CubeControl			
Electronics	171mW	100	171mW
Torquers	1800mW	10	180mW
Total power required			**1121mW**

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Example: ZA-Aerosat CDR

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- Scheduling and planning
- Functionality and design
- Structure and physical layout
- **Budgets**
- Challenges and uncertainties

Power Budget (RAM Pointing + Payloads):

Subsystem	Average Power	Duty Cycle	Average Orbital Power
EPS	125mW	100	125mW
OBC	165mW	100	165mW
VHF Receiver	190mW	100	190mW
UHF Transmitter	8000mW	<5	400mW
GPS	1000mW	5	50mW
CubeControl			
Electronics	171mW	100	171mW
Torquers	1800mW	5	90mW
Wheel (Maintain H)	119mW	100	119mW
CubeSense	114mW	68	78mW
Science Payload	500mW	100	500mW
CubeStar	<500mW	<1	<5mW
Total power required			1893mW

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Example: ZA-Aerosat CDR

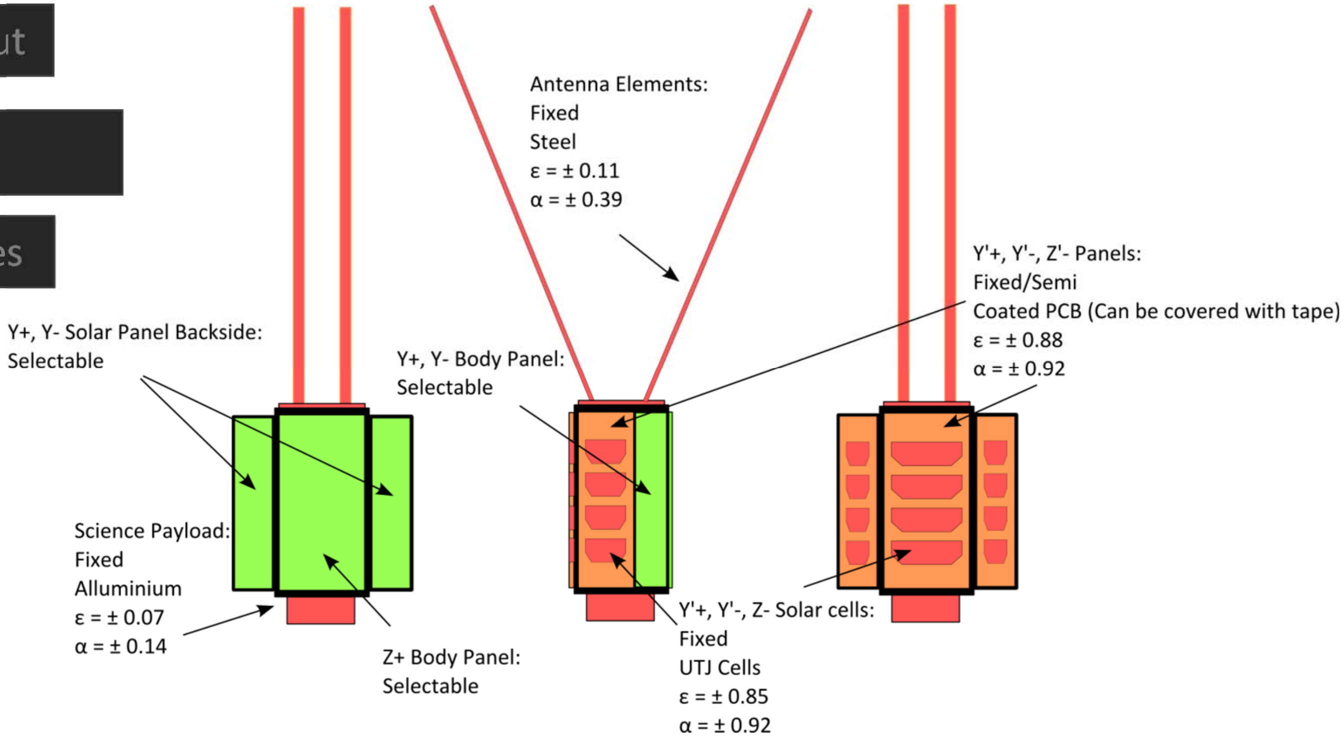
Power Budget:

Satellite Mode	Satellite Power Consumption	Power required from batteries (90% Efficiency)	Power required from solar cells (90% Efficiency)	Incident solar power required (28.3% Efficiency)	Power Generated	Margin
Detumble Mode	1121mW	1246mW	1384mW	4890mW	6.2W	21%
Payload Operation Mode	1893mW	2103mW	2337mW	8258mW	10.2W	19%

Example: ZA-Aerosat CDR

Thermal Analysis:

- Solar panels decoupled thermally



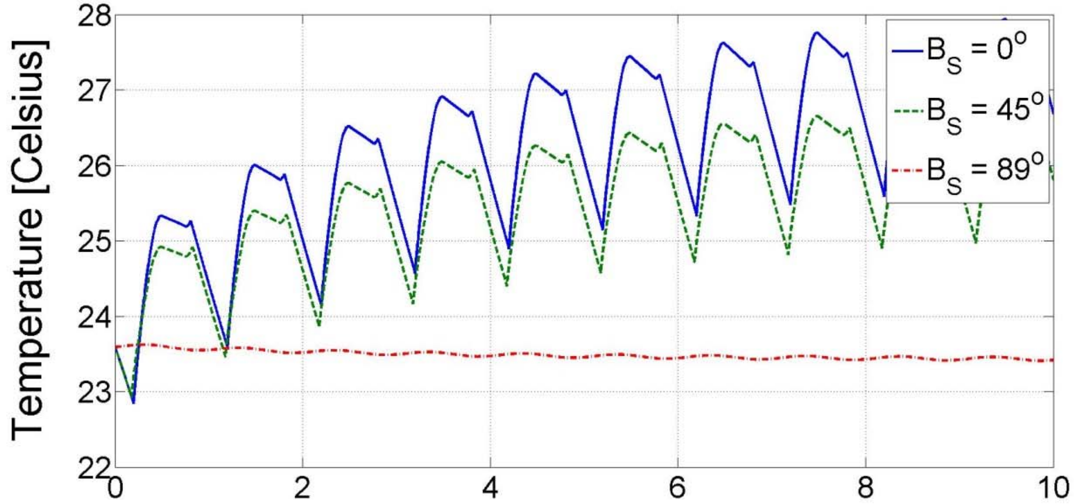
Y+, Y-, Z-:	Thermal insulators
Z+:	ε= 0.2, α = 0.05
Back of solar panels:	ε= 0.8, α = 0.6

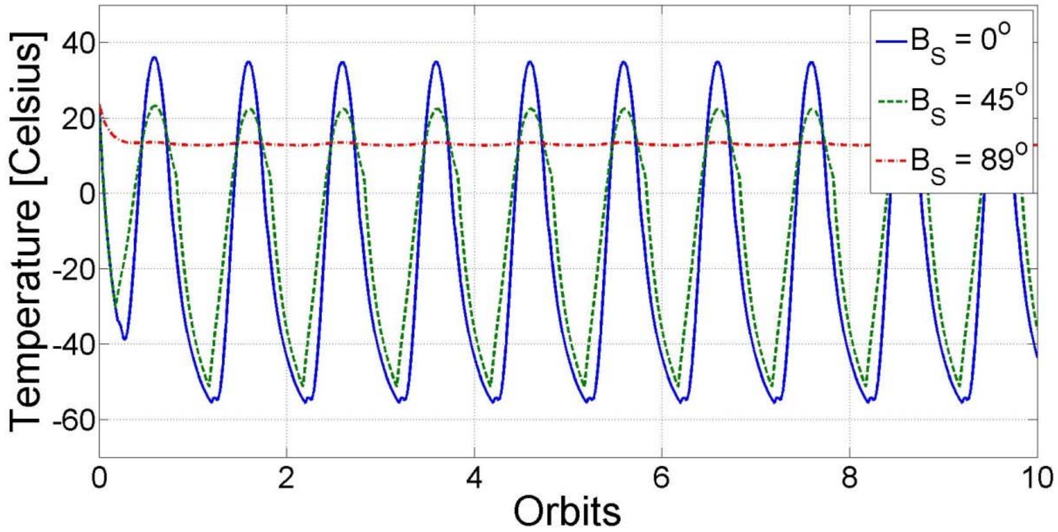
Example: ZA-Aerosat CDR

- Scheduling and planning
- Functionality and design
- Structure and physical layout
- **Budgets**
- Challenges and uncertainties

Thermal Analysis:

Satellite body





Solar Panels

CDR Summary

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Example: ZA-Aerosat CDR

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Scheduling and planning

Functionality and design

Structure and physical layout

Budgets

Challenges and uncertainties

Main Tasks which are still TBD/TBC:

-Satellite design

- **Layout/Component placement complete**
  - GPS & S-band patch antennae still to be placed
- **Structural Design**
  - Camera-module brackets complete
  - Thermal materials to select
  - Solar panel hinges to be manufactured
- **Procurement of COTS components to be done ASAP**
  - Solar panels flight proven and available
  - EPS flight proven and available
  - 2U ISIS structure

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Example: ZA-Aerosat CDR

Scheduling and planning

Functionality and design

Structure and physical layout

Budgets

Challenges and uncertainties

Main Tasks:

-In-house component development

- **ESL ADCS bundle complete**
  - Magnetometer thermal issue still to solve
- **CPUT deployable antennas functional prototype**
  - Container/Trapdoor design complete
  - Flight access hatch
  - BeCu antenna shaping and heat treatment

Example: ZA-Aerosat CDR

Main Tasks:

-Software (Ground and Flight)

- **Ground software MCS-lite solution**
- **Flight software FreeRTOS**
  - Being developed by MSc Student

-Integration and testing

- **Harnessing TBD**
- **Flight panel connector TBD**
  - Compatible with CPUT antenna container