Structural Design Concept

KISPE Space

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OSSAT Structure Design Problem Statement

What are we trying to do and why?

Problem Statement

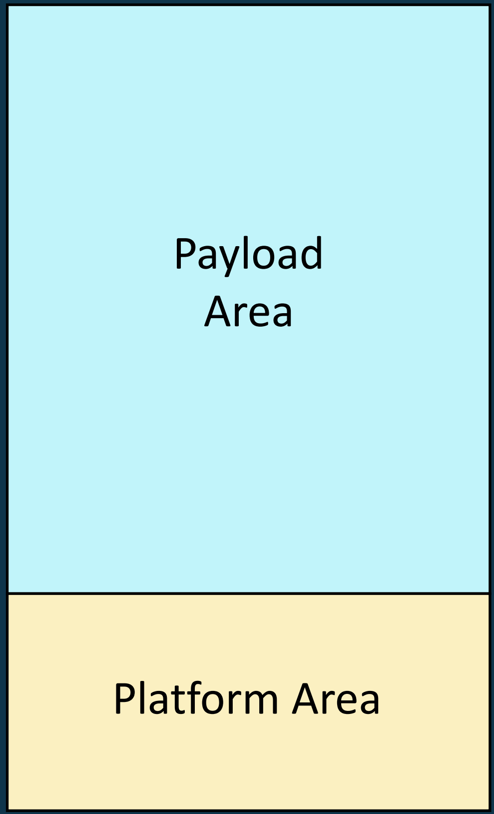
- The Open Source Satellite (OSSAT) is intended to be an open source, 25-250 kg microsatellite platform which is capable of servicing a wide variety of applications.
- The OSSAT structure poses an interesting design challenge as it needs to be capable of accommodating different payloads with minimal redesign for different missions.
- We believe, to achieve the aim of accommodating various payload types, there should be a clear delineation between the platform and payload in the structure.

Problem Statement

- Units that do not change between missions will be placed in the platform area and any equipment that is required only for individual applications will be placed in the payload area.

- The structure needs to be designed so that it is easy to scale depending on the size and needs of the payload.

- A key objective of the OSSAT programme is to reduce the size of the platform. This will be achieved by integrating as many as possible of the platform specific units into a single entity which will be the core avionics.



Problem Statement

- We are really looking for novel and innovative ideas to solve our problem. Is there something that can be done that hasn't yet been seen before in the space domain? Can we leverage ideas from other domains?

- No space experience? Don't worry! We aren't only looking for people who have experience in the space industry. There should be enough information in this pack to point those without experience in the right direction – and you can always drop us a line with any questions!

- The designs can be generated in any sensible format, whether that be sketches, engineering drawings or CAD models. We are interested in the conceptual design at this stage.

- For those of you who want to flex your CAD muscles then there are some free CAD packages out there including:
  - OnShape (https://www.onshape.com/en/products/free)

Open Source Satellite Structure Requirements

What things do we need to consider?

Core Avionics Box (1)

- The OSSAT Core Avionics Box will encompass units that you would typically find within a satellite, so you only need to include a single box for this item.
- It will also have built in redundancy so only one of these boxes will be needed within the concept.
- For those of you who are interested, the OSSAT Core Avionics Box will include the functionality of the following components:
  - Onboard computer
  - GPS receiver
  - Magnetorquer driver electronics
  - Reaction wheel driver electronics
  - Propulsion controller (if required by application)
  - Star tracker electronics
  - Inertial measurement units
  - Transceiver units
  - Power control and distribution unit

Core Avionics Box (2)

- The key part of the design of the OSSAT Core Avionics Box is that it is not to change between missions!
- The items that might change are the peripheral units described in the platform and payload components list in the upcoming slides depending on the mission type.
- One idea we had, since this aspect shouldn't change, was whether the Core Avionics Box could form an integral part of the structure, potentially providing loading paths between the platform and payload sections.
  - This is not to say that this is the only way to provide these loading paths so interesting alternatives to this idea are definitely encouraged!

Generalised Component List

- To allow you to see what kind of volume is needed for the platform and payload sections, the following slides provide descriptions of each of the units needed and what section they should fall into.
- The descriptions and datasheets are to provide information to allow you to appropriately size the various items.
  - They are representative parts that we have chosen. At this stage in our programme we have not yet selected what peripherals are going to fly. The inclusion of specific units is intended to be merely for representative purposes and does not mean that that unit will be used in the final OSSAT design.
- We have taken an optical Earth Observation imaging payload as the starting point for the structural design.

Platform Component List (1)

Unit	Quantity	Approx. Mass (kg)	Size	Notes
Core Avionics Box	1	4.5	Approximate volume of 0.015 m^3 or 15 litres.	The approximate volume for the avionics box has been given. The shape of this is for you to decide!
Reaction Wheels	4	See datasheet	NewSpace System's NRWA-T065 reaction wheel - Datasheet	Tetrahedral configuration using angles provided on slide 32.
Magnetorquers	3	See datasheet	NewSpace System's NCTR-M016 torque rod - Datasheet	One in each of the spacecraft body axis.
Magnetometers	2	See datasheet	NewSpace System's NMRM magnetometer - Datasheet	Generally positioned away from magnetorquers.
Battery	1	1.5	Representative box with dimensions: 170 x 200 x 100 mm	

- These items should all be housed within the platform area.

Platform Component List (2)

Unit	Quantity	Approx. Mass (kg)	Size	Notes
Separation System	1	See datasheet	15 inch separation system - Datasheet	Fixed to the centre of an external face of the OSSAT.
Solar Array	-	3 kg/m^2	Use the following solar cell if you want to make a detailed solar panel model - Datasheet	See slide 14 for more information.
Star Tracker Optical Head	2	See datasheet	Auriga SA – Datasheet (only need to model the star tracker optics)	Positioned according to slide 30.
Sun Sensors	4	See datasheet	NewSpace System's NCSS-SA05 Datasheet	Positioned according to slide 30.
S-band Antenna	4	See datasheet	Datasheet	Positioned according to slide 28.
GPS Antenna	1	See datasheet	NewSpace System's NANT-PCLT1 Datasheet	Positioned according to slide 28.

- These items should all be housed within the platform area.

Earth Observation Payload

Unit	Quantity	Approx. Mass (kg)	Size	Notes
Imaging Payload	1	25	A cylindrical volume with height: 750 mm and diameter: 400 mm. One circular face of the cylinder must have an external field-of-view.	This payload volume encompasses all of the payload electronics and processing units and can therefore be modelled as a simple cylinder.
X-band Transceiver	2	1.0	Representative box with dimensions: 175 x 120 x 50 mm	Should be placed in payload area.
Payload Power Control Unit	1	See datasheet	AAC Clyde's Starbuck Micro - Datasheet	A power interface for the payload. Should be placed in payload area.
Payload Data Storage	1	1.5	Representative box with dimensions: 150 x 75 x 30 mm.	Should be placed in payload area.
Payload Battery	1	1.5	Representative box with dimensions: 170 x 200 x 100 mm	A payload battery for additional payload power requirements. Should be placed in payload area.
X-band antenna	2	See datasheet	SpaceTeq's Xhorn-18 antenna : Datasheet	Positioned according to slide 28.

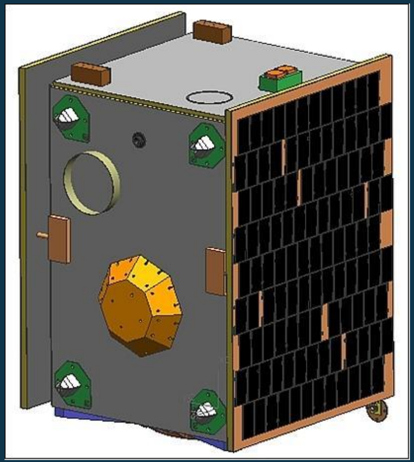
- These items should all be housed within the payload area.

Minimum Solar Panel Area

- In order to generate power, the OSSAT will need to have solar panels.

- Our preference is for these to be mounted on the body of the satellite rather than as deployables.

- The minimum area of the solar panels needs to be ~ 1.2 m^2, distributed around the different faces of the satellite.
  - The exact sizing and positioning of solar panels will depend on the spacecraft's power requirement and orbit.
  - The concept designs should try and meet this solar panel area requirement but not let it be a major limitation that will inhibit innovative ideas.



Example Body Mounted Panel - Source

Application-Specific Requirements

What about other mission types?

Application-Specific Requirements

- If you have devised a concept for the Earth Observation satellite, time to see if it can be repurposed to accommodate some different missions!
- These additional applications introduce some interesting additional features into the satellite.
- The specific Earth Observation payload items will need to be removed and replaced with the specific payload units for the new applications.
- The aim is to have a structure that can accommodate a variety of payloads with minimal reconfiguration between missions.

Orbital Manoeuvring Vehicle (OMV)

- The next challenge is seeing if your concept can accommodate an Orbital Manoeuvring Vehicle (OMV) mission. What needs to change and what can stay the same?
- An OMV is a spacecraft which carries a number of smaller satellites which it then deploys into different orbits. In the context of the OSSAT, this would likely mean carrying a number of CubeSats.
- The need to carry these CubeSats will drive the design of the structure. For each CubeSat a dispenser is required which will need to be attached either to the outside faces of the satellite or contained within the structure.
- This application will also need a propulsion system to transfer between different orbits. This means a propellant tank and thrusters must now be incorporated into the design.

OMV Payload Units

Unit	Quantity	Approx. Mass (kg)	Size	Notes
CubeSat Dispensers	At least 4-6	4 kg per dispenser and payload satellite.	ISIS Space's 3-Unit ISIPOD - Datasheet	4-6, 3U CubeSat dispensers should be accommodated. These could be attached externally or contained within the structure with an external field-of-view to deploy the satellites. The dispenser placement will also need to consider the solar panels.
Propellant Tank	1	20 kg (tank and fuel)	Approximate volume: 20 Litres.	The approx. volume has been provided. The shape can change depending on design.
Thrusters (orbit transfer and de-orbit manoeuvres)	4	0.33 kg/thruster	Aerojet Rocketdyne's MR-103G 1N- Datasheet	Assume four thrusters are required pointing in the same direction to conduct orbit transfers. These thrusters should be pointed in the same direction as the separation system.

- These items should all be housed within the payload area.

Debris Removal Mission (1)

- Another challenge is seeing if your concept can accommodate a debris removal mission. What needs to change and what can stay the same?
- The aim of a debris removal mission is to rendezvous with a piece of space debris, capture the object and then transfer to a lower orbit where the debris will be released to burn up in the atmosphere.
- Debris removal missions require a range of additional sensors, all pointed along the same direction, in order to identify and approach the target object. The units that must be placed on the same external face have been marked with *External Field-of-View* (EF). These will be considered as part of the payload in the context of the OSSAT.

Debris Removal Mission (2)

- Such a mission will also require a capture mechanism. Many different forms of capture mechanisms have been proposed. For the OSSAT structure concept, we will keep a volume of payload space free to accommodate a range of capture mechanisms.

- A debris removal mission will also require a propulsion system to rendezvous with the target object and conduct orbit transfers. A propellant tank and multiple thrusters will therefore also need to be included.

Debris Removal Payload Units

Unit	Quantity	Approx. Mass (kg)	Size	Notes
Capture Mechanism (EF)	1	N/A	A cylindrical volume with diameter: 450 mm and height: 400 mm. Positioned in the centre of an external face.	We will assume a 'keep out' volume where a range of capture mechanisms could be accommodated.
Narrow Angle Camera (EF)	1	See datasheet	Kairo Space's 22m camera - Datasheet	Used to take pictures of the target object. Must be on same face as capture mechanism and other payload sensors.
Wide Angle Camera (EF)	1	See datasheet	O.C.E Technology's miniature aerospace camera - Datasheet	Used to image target objects at close range.
Infrared Camera (EF)	1	See datasheet	Malin Space Science Systems ECAM-IR1 - Datasheet	Used to image target object when out of sunlight.
Lidar Device (EF)	1	0.5	Representative volume: 60 x 60 x 70 mm	Used to construct 3D images of target object at close range.

- These items should all be housed within the payload area.

Debris Removal Payload Units

Unit	Quantity	Approx. Mass (kg)	Size	Notes
Illuminator (EF)	1	0.3	Representative volume: 70 x 70 x 50 mm	Used to illuminate the target at close range for optical imaging.
Payload Data Storage	1	1.5	Representative box with dimensions: 150 x 75 x 30 mm.	Should be placed in payload area.
Propellant Tank	1	20 kg (tank and fuel)	Approximate volume: 20 Litres.	The approx. volume has been provided. The shape can change depending on design.
Thrusters (for rendezvous and docking procedures)	8	0.33 kg/thruster	Aerojet Rocketdyne's MR-103G 1N- Datasheet	One thruster is required on each corner of the structure to conduct rendezvous manoeuvres, enabling manoeuvring in all directions.

General Spacecraft Structure Design Guidelines

Full of hopefully helpful hints and tips!

Spacecraft Structure Design

- The following slides describe some of the general requirements of a spacecraft's structure that remain relatively consistent despite the mission type.

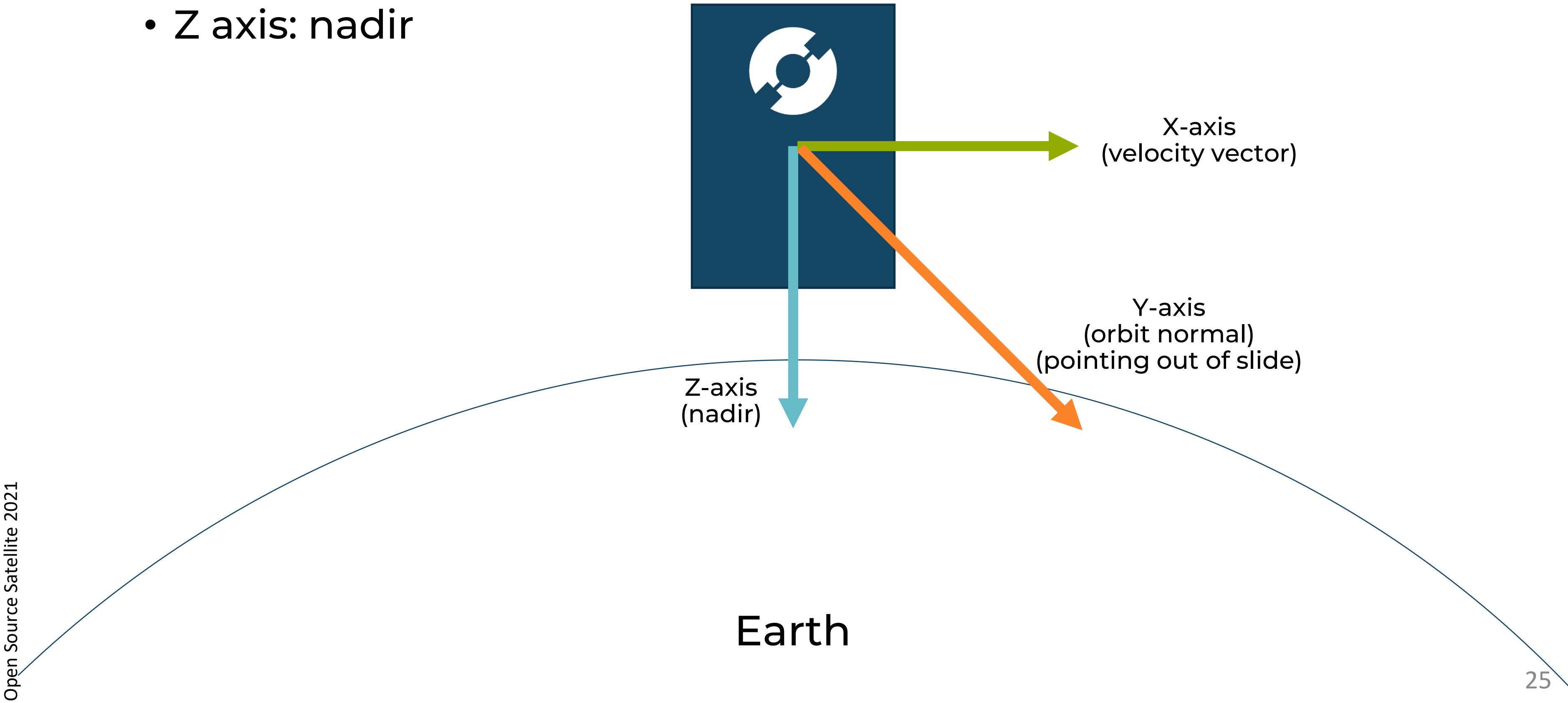
- These are intended to give those of you less familiar with satellite design some useful pointers!

- In our experience, these form the basis of structural design requirements, but don't let them constrain you! As mentioned at the start, we are really keen to explore suggestions of novel alternatives to some of the standard practices presented here!

Spacecraft Axes

Spacecrafts use the x, y and z axis as their frames of reference:

- X axis: velocity vector
- Y axis: orbit normal
- Z axis: nadir



Satellite Aperture Faces

- On a satellite, a variety of units requires an external field-of-view. This equipment often has to be pointed in a certain direction.
- This then drives the positioning of such units with respect to the spacecraft’s attitude during normal operations.
- For an Earth-orbiting satellite with a payload that requires pointing at the Earth (e.g. Earth Observation mission), this would then become the satellite surface that the rest of the units’ positions are defined with respect to.
- The following slides give some general unit positioning considerations.

Peripheral Unit Positioning: Antennas

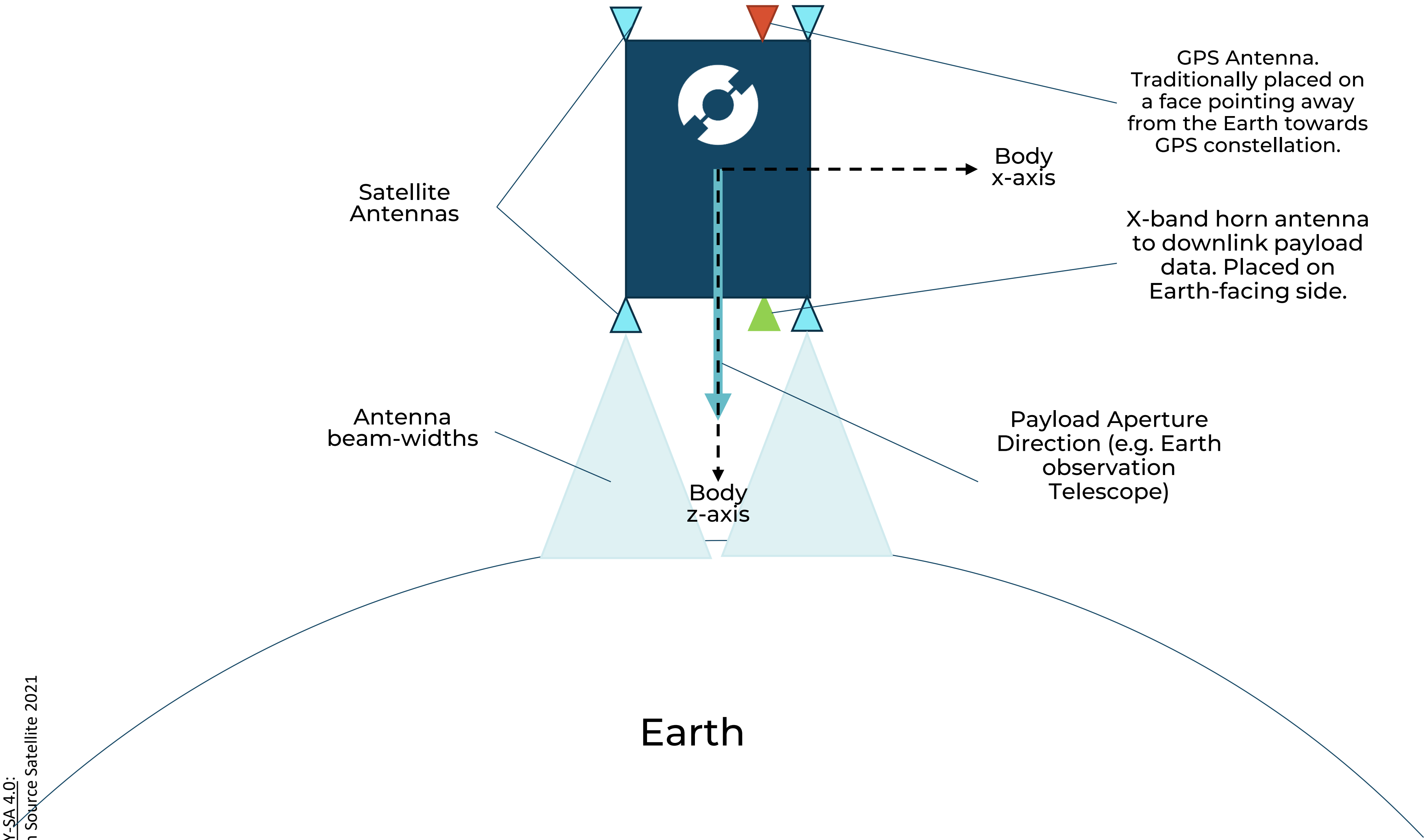
- A spacecraft requires antennas in order to communicate with the ground.

- These are typically placed on the surface that would most often be pointed towards the Earth. This means that the spacecraft does not need to change attitude in order to contact the ground.

- For an Earth Observation mission, these antenna could be placed pointing along the same direction as the payload telescope. Additional antenna may also be placed on other surfaces so the spacecraft can be contacted if it suffers a failure and is not pointed in the correct direction.

- An example diagram is given on the next slide.
  - Note: Antenna placement is not crucial for this design challenge as they can be placed on most external surfaces.

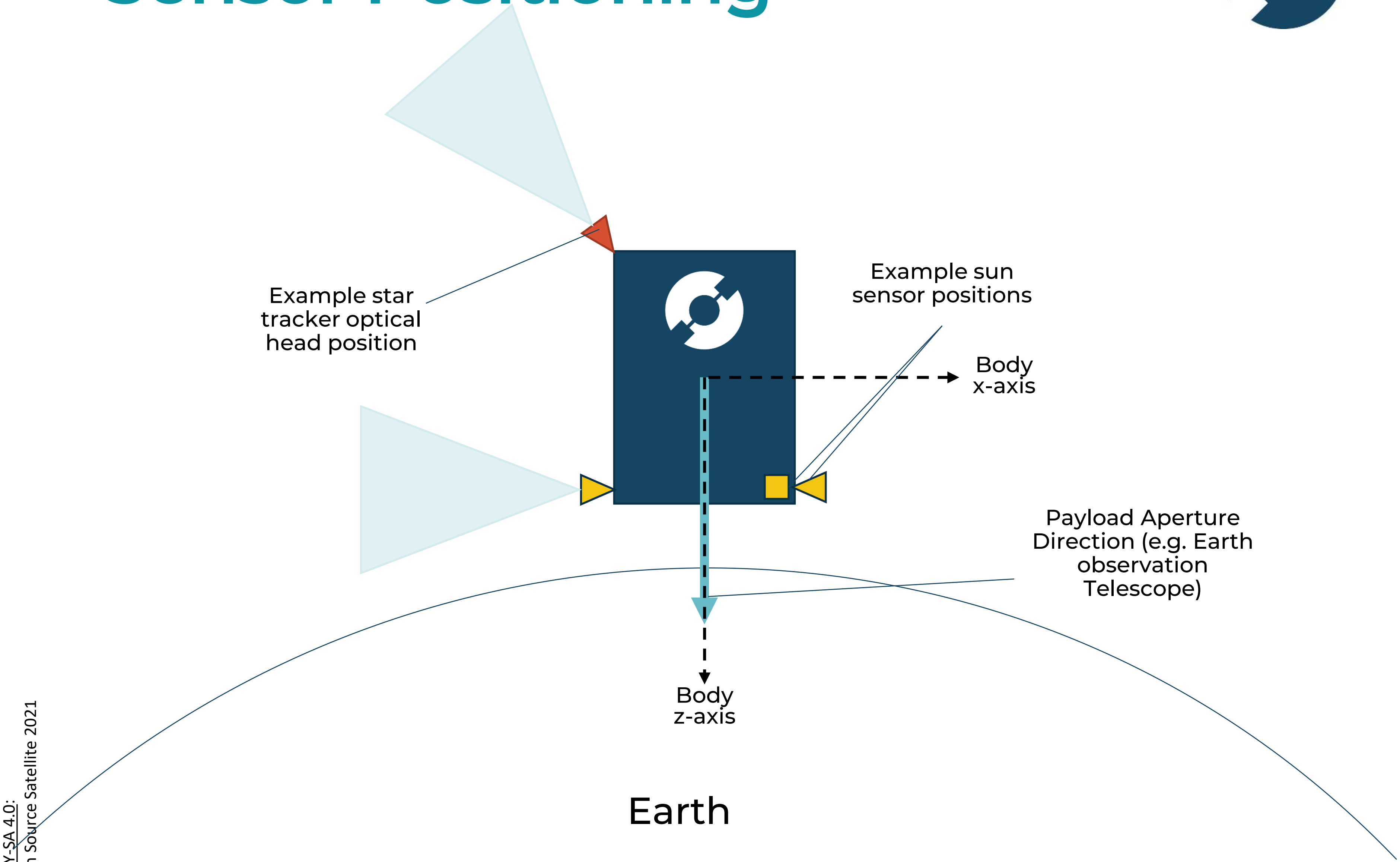
Example Antenna Positioning



Peripheral Unit Positioning: Sensors

- A spacecraft requires a variety of sensors in order to determine its attitude with respect to the environment.
- Sun sensors and star trackers require external views.
- A star tracker will typically be positioned on a surface that is most often pointed away from the Earth, towards deep space (it needs to see the stars!).
- Sun sensors will be positioned on surfaces that experience the most exposure to sunlight (they need to see the Sun!).
- The ultimate positioning of such units is however completely dependent on the particular orbit of the mission and the spacecraft AOCS and is therefore not crucial for these structure concepts.

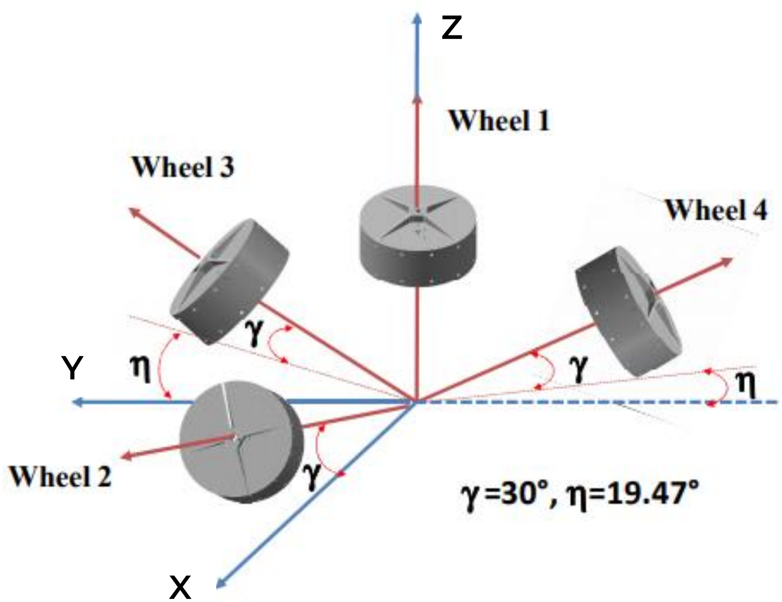
Sensor Positioning



Actuator Positioning

- Spacecraft require actuators in order to change their attitude and/or transfer between different orbits.
- The actuators must be carefully positioned to provide the required control over the spacecraft.
- Magnetorquers exert a torque on the spacecraft by interacting with the Earth's magnetic field.
  - To provide control in 3-axis a magnetorquer must be placed in each of the body x, y and z-axis.
  - They should typically be positioned away from the magnetometers to reduce the interference between the two types of unit.
- Reaction wheels are used to change the spacecraft's attitude. Four reaction wheels are most commonly placed in a tetrahedral configuration to provide 3-axis control even in the event of one of the wheels failing. Details of this configuration are provided on the next slide.

Reaction Wheel Configuration



Example Tetrahedral Reaction Wheel Configuration - [Source]

The tetrahedral reaction wheel configuration is preferred as in the event of a single wheel failure, control over all 3-axis of the spacecraft is still possible with the remaining wheels.

The tetrahedral configuration also enables the generation of twice as much torque in each of the body axis compared to a standard 3-wheel design.

The figure on the left is one possible tetrahedral reaction wheel configuration. It is called the tetrahedral configuration as the rotation axis of each of the wheels point along one of the vertices of a tetrahedron.

The x, y and z axis shown are the body-fixed axis of the spacecraft. The angles describing the orientation of these wheels can be used in your structure concepts.

It is the direction of the spin axis of reaction wheels that is important, rather than their position within the spacecraft. They are however typically placed on a single level, far from the centre of mass as this results in a more favourable mass distribution.

Launch Vehicle Fairings & Integration

- A spacecraft must fit inside of the fairing envelope of the launch vehicle that it is going to use.
- The OSSAT will need to fit inside of a wide range of launch vehicle fairings. Launcher datasheets will be provided with this slide deck. These documents can be used to determine the maximum dimensions of the structure concept.
- A satellite also requires a separation system which is how it is attached to the launch vehicle. An example of a separation system that should be used for the structure concepts is given on slide 12

Centre of Mass Considerations

- The centre of mass has a number of implications on the operation of the spacecraft.
- Launch vehicle providers will typically have a requirement on the position of the centre of mass with respect to the separation system.
- For this level of concept design, the centre of mass should be as close to the centreline of the satellite as possible. This centreline should be taken as running along the centre of the satellite, through the centre of the separation system.
- Thruster positioning with respect to the centre of mass is also important. The propulsion system should be designed such that the resultant thrust vector acts approximately through the centre of mass.

Please feel free to contact a member of our team if you have any questions!

Good luck! We can't wait to see what you come up with!

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