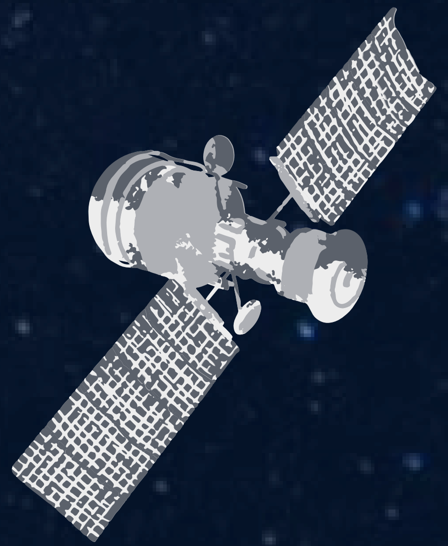
# Problem Statement

## 3. Material Selection, Design and Finite Element Analysis of CubeSat Structure

*(Design & Modelling and Materials Design and Process Optimisation)*

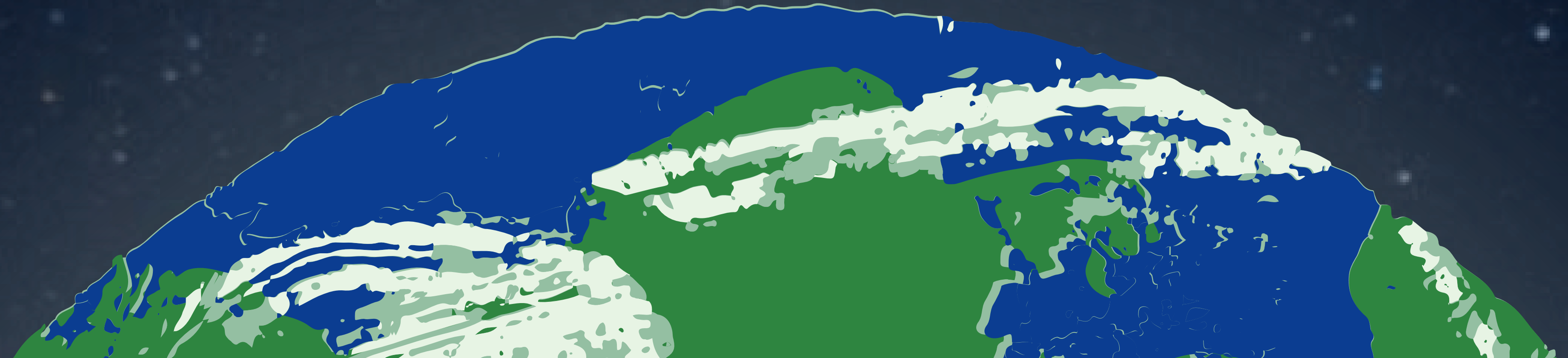
**Description:** CubeSats are miniature satellites used for space research, Earth observation, and communication. They typically have a standardised size of 10x10x10 cm and are deployed in low Earth orbit. Designing a CubeSat structure that can withstand the harsh conditions of space while minimising weight is crucial for mission success.

# Material Selection, Design and FEA of CubeSat

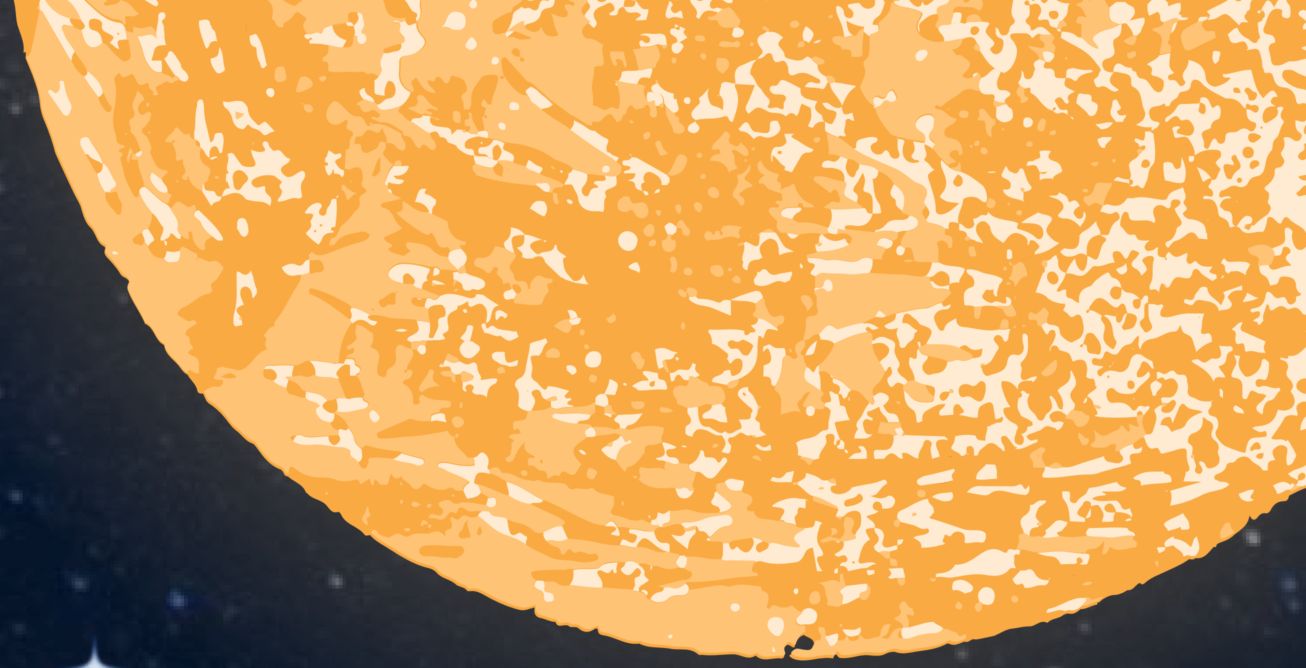


IITISOC'24 - D&M3

Design & Modelling



# ABOUT



- CubeSats are small satellites with a standard cubic form factor of 10 cm x 10 cm x 10 cm, weighing about 1 kg, known as 1 unit (1U).

- Space environment, with its vacuum, atomic oxygen, UV radiation, charged particles, and extreme temperatures, demands careful material selection and structural integrity in CubeSat design.

- Our project focuses on selecting the most suitable material for CubeSats by evaluating mechanical and thermal properties. We'll perform Finite Element Analysis to assess performance under space conditions. Emphasizing weight management and cost analysis, we'll ensure materials meet strength, thermal stability, and cost-effectiveness criteria, providing valuable groundwork for future CubeSat development.

# Primary CubeSat Constraints

## Mechanical Properties

- Load Bearing:
  - Must endure static and dynamic loads during launch.
  - Key Parameters: Modulus of elasticity, Poisson's ratio.
- Strength and Stiffness:
  - Requires high yield strength and fracture toughness.
  - Key Parameters: Yield strength, density, fracture toughness.
- Weight Management:
  - Crucial for mission feasibility.
  - Key Parameter: Material density.

## Thermal Properties

- Thermal Stress:
  - Wide temperature range: +80°C to -20°C.
  - Key Parameter: Coefficient of Thermal Expansion.
- Thermal Mass:
  - Manages heat absorption and release to protect hardware.

# Shortlisted Materials:

## Aluminum (AL6061-T6)

Advantages
- Corrosion-resistant
- Lightweight and strong
- Good thermal conductivity

Limitations
- Lower strength than Al7075
- High thermal expansion
- Brittle in extreme cold

## Aluminum (AL7075-T6)

Advantages
- High yield strength for robust structures
- Low outgassing reduces contamination
- Commonly used in space missions

Limitations
- Lower corrosion resistance; needs coating
- Difficult to machine and weld
- Higher cost and limited availability

## Stainless steel (AISI 304)

Advantages
- Excellent shock absorbance
- High strength and corrosion resistance
- Thermal stability

Limitations
- Difficult machinability
- Higher density
- Poor thermal conductivity

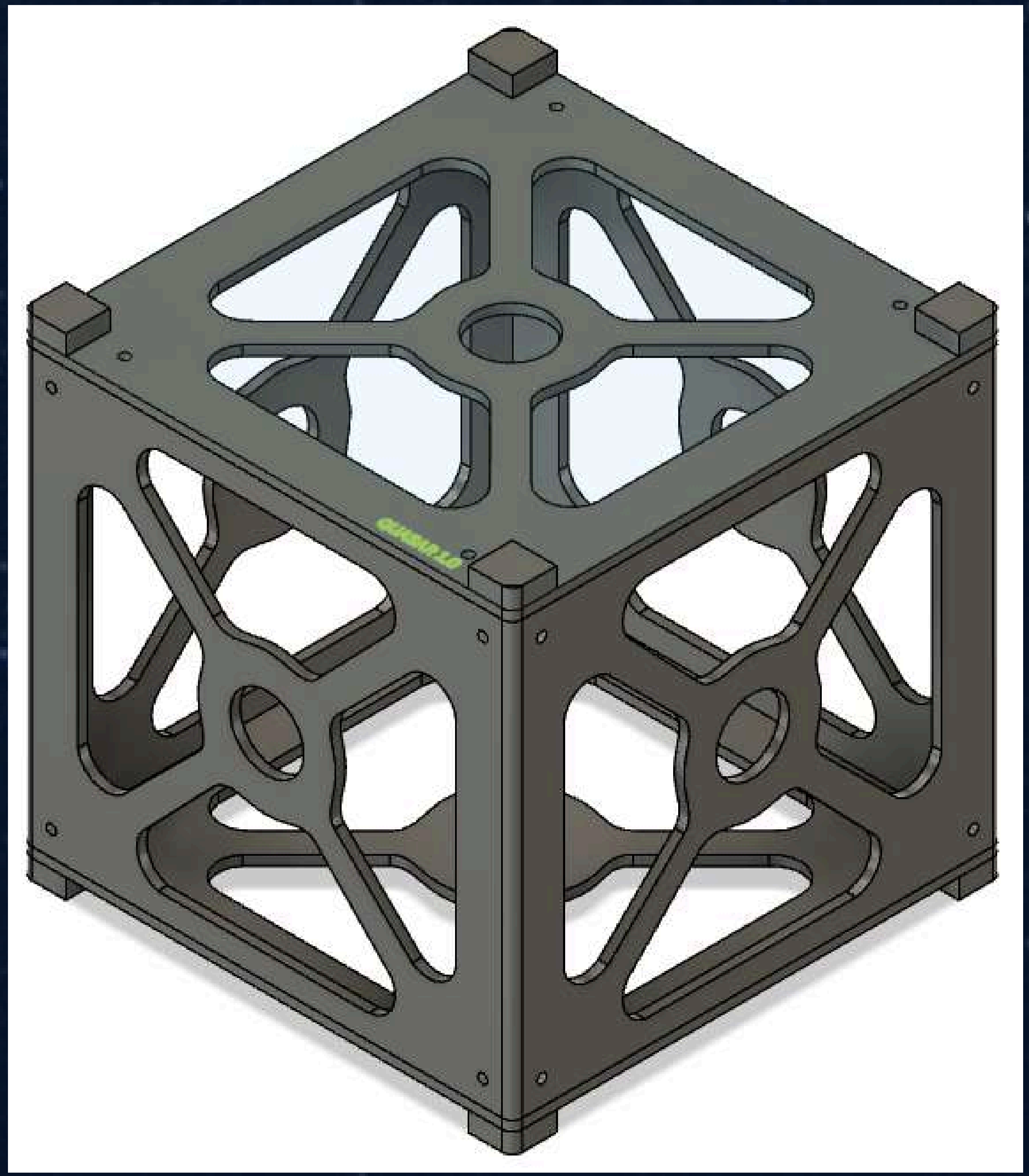
# Design - QUASAR 1.0

### OVER ALL DIMENSIONS

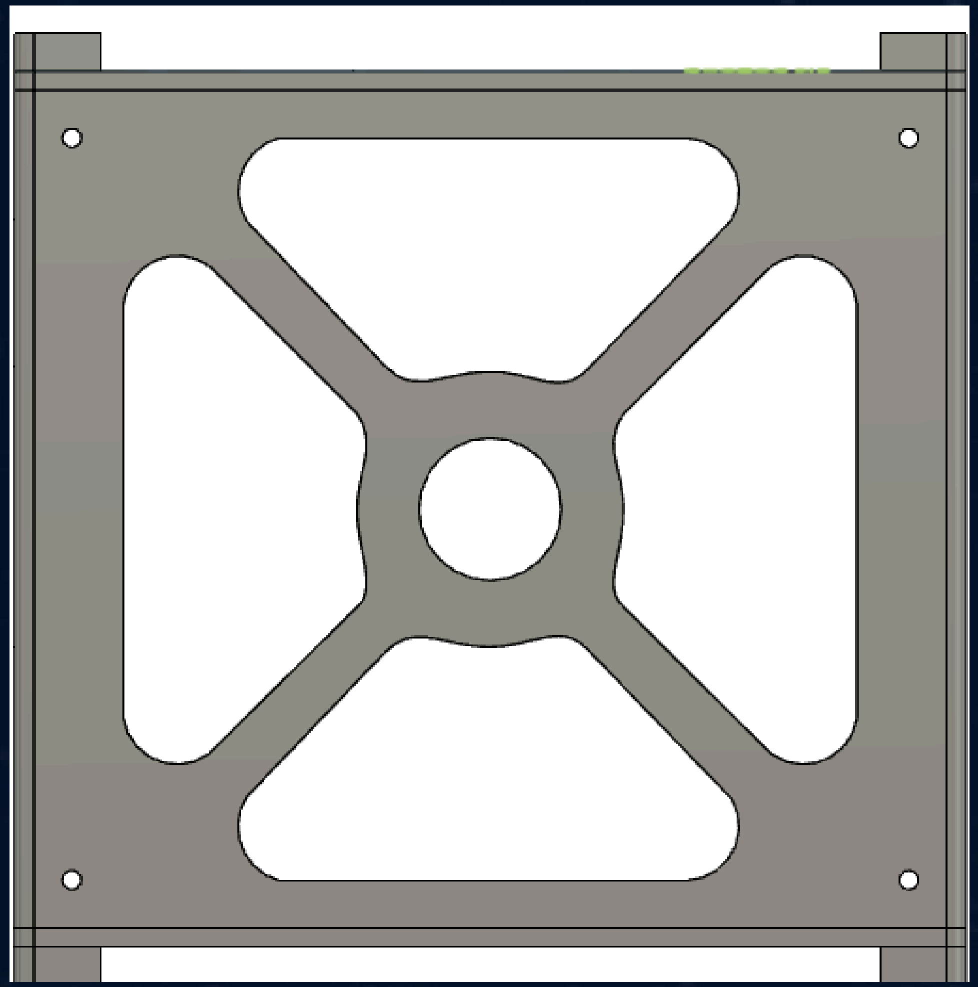
- Size: 10x10x10 cm
- Panels Thickness: 2mm
- Inside Spacing for hardware: 9.5x9.5 cm
- Solar Panel Mounting Hole: Diameter: 2mm
- Component Clearance: 1-2 mm
- Central Hole Radius:7.5mm

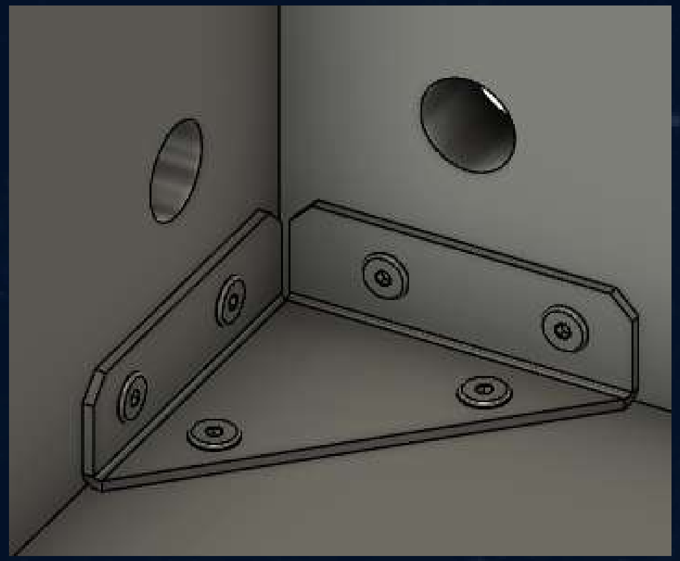
### STEEL FASTNERS , MOUNTING: ALUMINIUM BASES

- Corner Brackets: 1088A31, 1 per corner
- Screws: 90585A019, 6 per corner
- Quantity: 8 (4 top, 4 bottom)
- Dimensions: 9x9mm (max 1 cm)
- Height: 4 mm



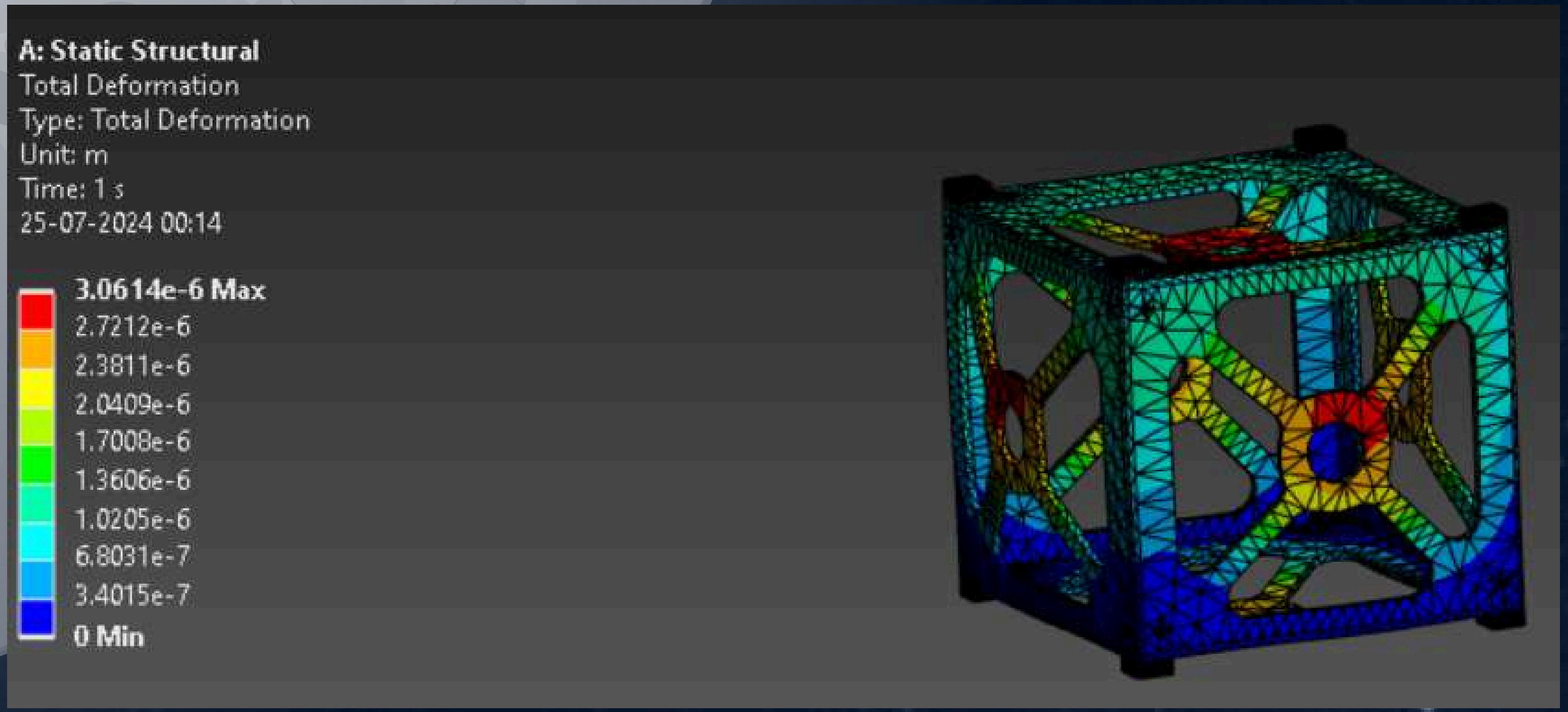
# Functionality and Reasoning

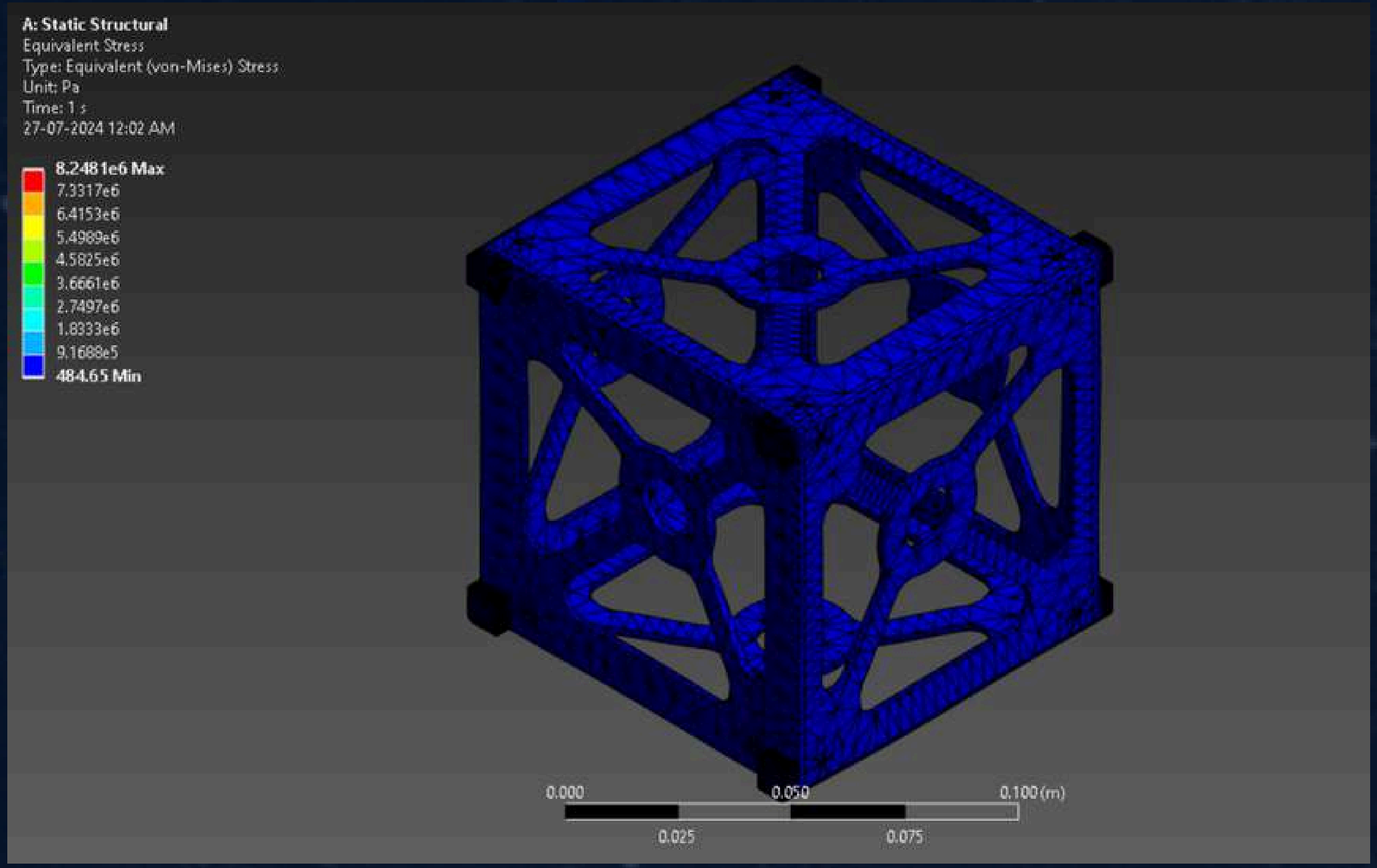


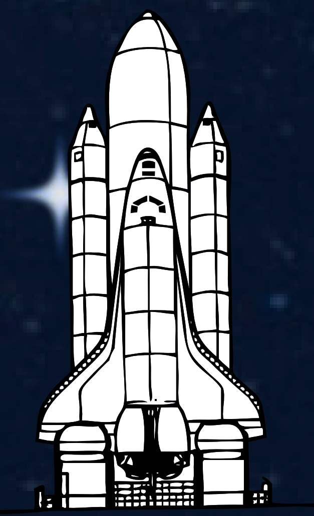


- **'X' Configuration of 6 frames**: Even stress distribution, enhanced structural integrity
- **Fillets in Joints:** Reduce stress concentrations
- **Central Hole:** Weight reduction and Thermal management (airflow, thermal straps/heat pipes)
- Why circular - Even stress distribution and minimize crack risk
- **Bases:** Eight square bases for stability/spring deployment mechanism

# Stress Analysis



## Significance

Stress analysis ensures CubeSat structural integrity during launch by identifying potential weaknesses, verifying the design's ability to withstand forces, and making design adjustments to enhance durability and reliability.

## Boundary Conditions

Applied boundary conditions simulate launch environments: 10g acceleration in three directions, 83 N spring force on bottom stands, and 7 N impulse force opposite to spring force.

## Results

The analysis showed a maximum stress of 8.28 MPa and maximum deformation of 3×10^(–6) m, indicating the structural response under specified conditions.

## Interpretation of Results

The CubeSat's design withstands launch forces, showing adequate stress and minimal deformation, confirming structural robustness and suitability for space deployment.

# Thermal Analysis

## Significance

Thermal analysis ensures the CubeSat's components operate within safe temperature limits in orbit, preventing overheating or freezing, which could impair functionality or cause damage.

## Boundary Conditions

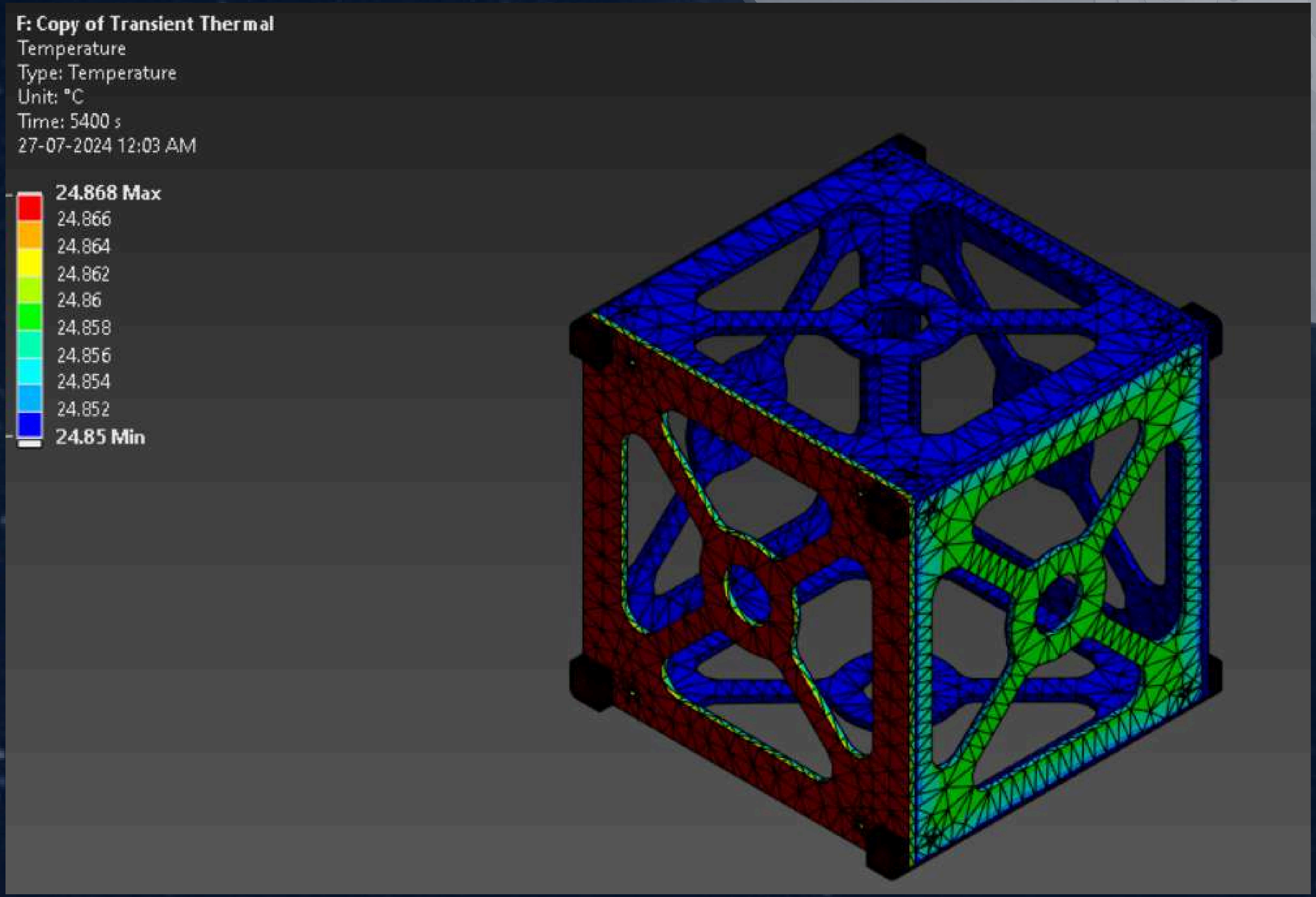
The CubeSat experiences 1366 W/m² solar flux, 237 W/m² from albedo, and 368 W/m² Earth IR, with 1.875 W from internal components, and an initial internal temperature of 298 K

## Results

The analysis revealed maximum and minimum temperatures of 24.868°C and 24.85°C, respectively, indicating temperature stability during the 90-minute orbit.

## Interpretation of Results

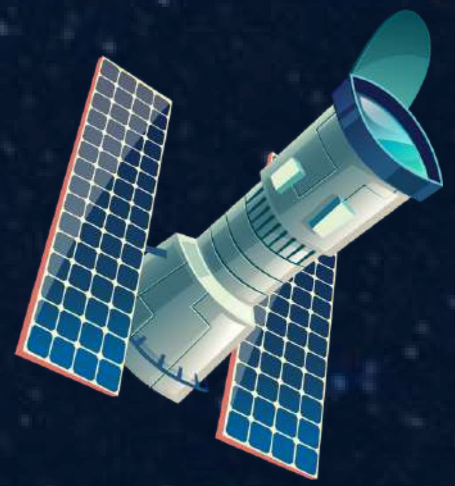
The CubeSat maintains stable temperatures within operational limits during extreme hot and cold cases, confirming thermal design adequacy for its orbital environment.



# Modal Analysis

| | Mode | Frequency [Hz] |
|---|---|---|
| 1 | 1. | 1160.3 |
| 2 | 2. | 1196.8 |
| 3 | 3. | 1210.9 |
| 4 | 4. | 1242.4 |
| 5 | 5. | 1246.9 |
| 6 | 6. | 1331. |
| 7 | 7. | 2708.9 |
| 8 | 8. | 2721.9 |
| 9 | 9. | 2786.1 |
| 10 | 10. | 2819.4 |

## Significance



Modal analysis ensures that the CubeSat's natural frequencies are above critical thresholds to avoid resonance with launch vibrations, which could lead to structural failure.

## Boundary Conditions

The CubeSat's base is treated as a fixed end, and the analysis calculates the first ten natural modes to assess the structural response.

## Results

The first mode frequency is 1160.3 Hz, significantly above the 100 Hz minimum required for CubeSats, confirming structural resilience.

## Interpretation of Results

The CubeSat's high fundamental frequency indicates it is structurally sound and capable of withstanding launch vibrations, ensuring safe travel in the spacecraft.

# CubeSat Cost Analysis

| Component | Quantity | Cost (Including Machining) |
|---|---|---|
| AL6061-T6 Frame | 6 | $390 |
| Stainless Steel Bracket | 8 | $930 |
| Stainless Steel Support | 8 | $425 |
| Stainless Steel Screw | 48 | $5 |
| Total Cost | | $1750 |

Materials (per kg)

- Stainless Steel 304 Coil: $2.50
- Aluminium Plate 6061 : $3.28

Key Takeaways:

- High Cost: Stainless Steel Brackets
- Frame Material: Aluminium 6061
- Cost Reduction Opportunities: Optimize brackets usage
- Note: Component costs include manufacturing expenses as per online quotations.

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# Mission complete

Thank You !