Master of Science in Engineering Management (MSEM)
Spring 2025

UrbanEvac

A Tactical Innovation for Urban Battlefield Casualty Evacuation

PROJECT HOST

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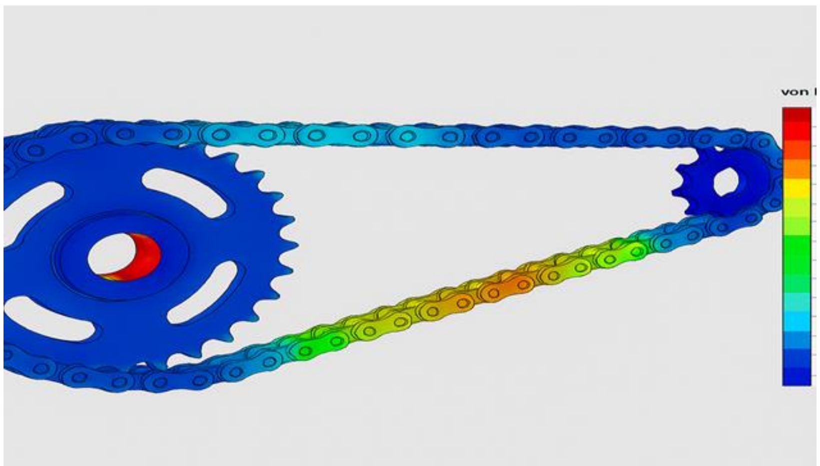
CALCULATION

- Chain pitch = 12.7 mm
- Driving sprocket = 48 teeth
- Driven sprocket = 12 teeth
- Input torque = 80 Nm

$$F_{chain} = \frac{T}{r} = \frac{80}{(48 \cdot 12.7/(2\pi))} \approx 84\,N$$



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1. Executive Summary

1.1 The Problem

Modern warfare has shifted into dense urban terrains as we see in Ukraine and Israel-Gaza conflicts, where rubble, narrow alleys, and active fire zones make traditional casualty evacuation methods dangerously slow and resource-draining. Current manual stretchers require **4–6 soldiers** to evacuate a single wounded comrade, pulling critical personnel off the frontline, increasing fatigue, and risking the **loss of the golden hour which is** the 60-minute window crucial for survival. Despite decades of technological advances in other areas of warfare, **battlefield evacuation tools have remained outdated, slow, resource-heavy and fatigue-inflicting** for urban conflict conditions. NATO's own defense teams have identified this capability gap as an urgent priority to improve both survivability and operational effectiveness.

1.2 The Proposed Solution

UrbanEvac offers a reimagined, power-assisted, modular stretcher specifically designed for frontline deployment in urban combat.

Key features include:

- Motorized central wheel for terrain assistance over rubble, stairs, and inclines
- Lightweight, collapsible frame for rapid deployment and easy carry
- Throttle and braking system for controlled navigation in dynamic environments

- Multi-use capacity to transport either wounded soldiers or critical medical equipment

Built to be combat-proof, UrbanEvac enables one medic to evacuate a casualty with minimal support, reducing manpower loss, speeding up extractions, and preserving operational strength.

Feature	Traditional Stretcher	Our Motorized Stretcher
Mobility on rough terrain	Manual, hard to maneuver	Motor-assisted, terrain-ready
One-person operation	Needs 3+ medics/ Soldiers	Designed for multiple use
Portability	Bulky, not collapsible	Foldable, modular frame
Physical strain	High strain for long distances	Motor reduces effort
Equipment carrying	Only for patients	Can transport gear too
Control & safety	No brakes or motor control	Throttle + disc brake system
Terrain adaptability	Not slope-friendly	Stable on inclines and rubble
Power assistance	None	250W EV motor + 24AH battery

Fig 1.a: Comparison of Traditional Stretcher vs Our Solution

1.3 Effects

UrbanEvac enables faster and safer evacuation of wounded soldiers from hostile urban environments, significantly improving survival rates by helping meet the **golden hour** standard. It reduces the manpower needed for casualty extraction, keeping more soldiers active in the field. The stretcher's design improves operational agility, allowing for rapid movement over rubble and uneven terrain. By lightening the physical and tactical burden of evacuation, UrbanEvac strengthens frontline resilience and enhances overall mission success.

Key Insights

- Faster evacuation
- Higher survival rates
- Reduced manpower drain
- Improved operational agility
- Increased frontline resilience

1.4 Values

UrbanEvac is designed with a soldier-first mindset, focusing on saving lives by optimizing evacuation speed and efficiency. It delivers practical scalability with affordable unit costs, enabling widespread deployment across military, disaster response, and humanitarian missions. Every design choice prioritizes battlefield reality, durability, modularity, and system integration, ensuring that the stretcher remains functional even under extreme conditions. Above all, UrbanEvac embodies innovation where it matters most: **where survival and operational success intersect.**

2. Introduction

As conflicts become increasingly urban, the logistics of battlefield medical response are undergoing a paradigm shift. In current practice, evacuating one injured soldier can require a team of 4–6 personnel carrying a stretcher, pulling crucial fighters away from their duties and risking multiple lives. The delays in such extractions threaten the wounded's survival, as the well-known "golden hour" for medical care can be missed, sharply reducing odds of recovery. UrbanEvac directly addresses these challenges. Traditional medevac vehicles and multi-person stretcher teams are too slow and inefficient for modern environments cluttered with rubble, narrow corridors, and unstable ground. NATO and allied forces have acknowledged this need for a new class of tactical medical tools tailored for urban mobility. This project, born out of a challenge from Col. Harvey Pynn of UK Strategic Command, aims to address that gap with a lightweight, powered stretcher that can be operated by a single medic. UrbanEvac was conceptualized, researched, and iteratively refined over several months in close consultation with combat medics, commanding officers, and NATO innovation liaisons.

Fig 2.a: Tallon II Litter

Fig 2.b: Four soldiers carrying an injured soldier

Fig 2.c: A soldier dragging a wounded soldier using Skedco

Fig 2.d: Foldable Litter

UrbanEvac's impact will dramatically improve combat casualty care outcomes. A single medic/soldier can extract wounded personnel in a fraction of the time previously needed, helping meet the critical timeframe for surgical treatment and saving lives. Fewer personnel are taken out of the fight for rescue duties, preserving unit strength and momentum. The stretcher's all-terrain agility means evacuation routes are no longer limited to relatively clear paths, even rubble piles can be traversed with assistance from the powered wheel. By lightening the physical and tactical burden of casualty evacuation, UrbanEvac increases frontline resilience and the likelihood of mission success.

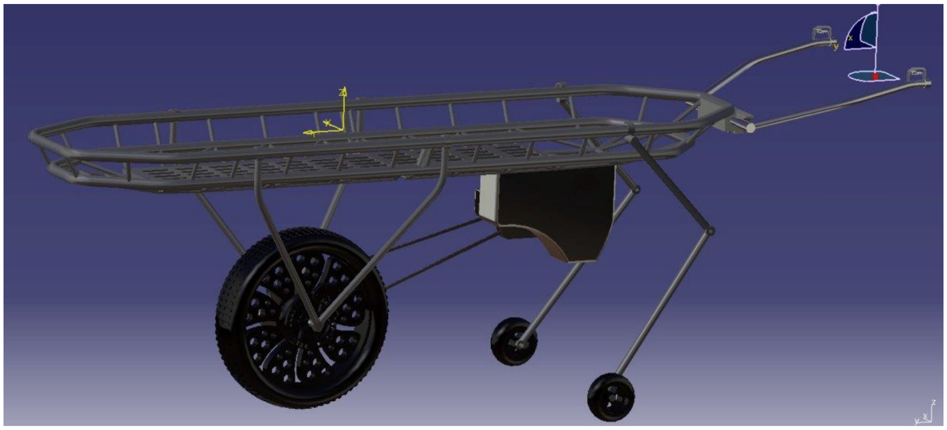


Fig 2.e: UrbanEvac Stretcher Design in CATIA

In summary, UrbanEvac is an innovative tactical stretcher system that bridges a long-standing capability gap in urban warfare. It exemplifies a soldier-first design ethos: saving lives under fire by fusing modern technology with battlefield practicality. This report details the problem, solution, background, technical research and analysis and next steps in further developing UrbanEvac.

3. Team and Process

Our interdisciplinary team brings together expertise in engineering, strategy, defense operations, and business modeling.

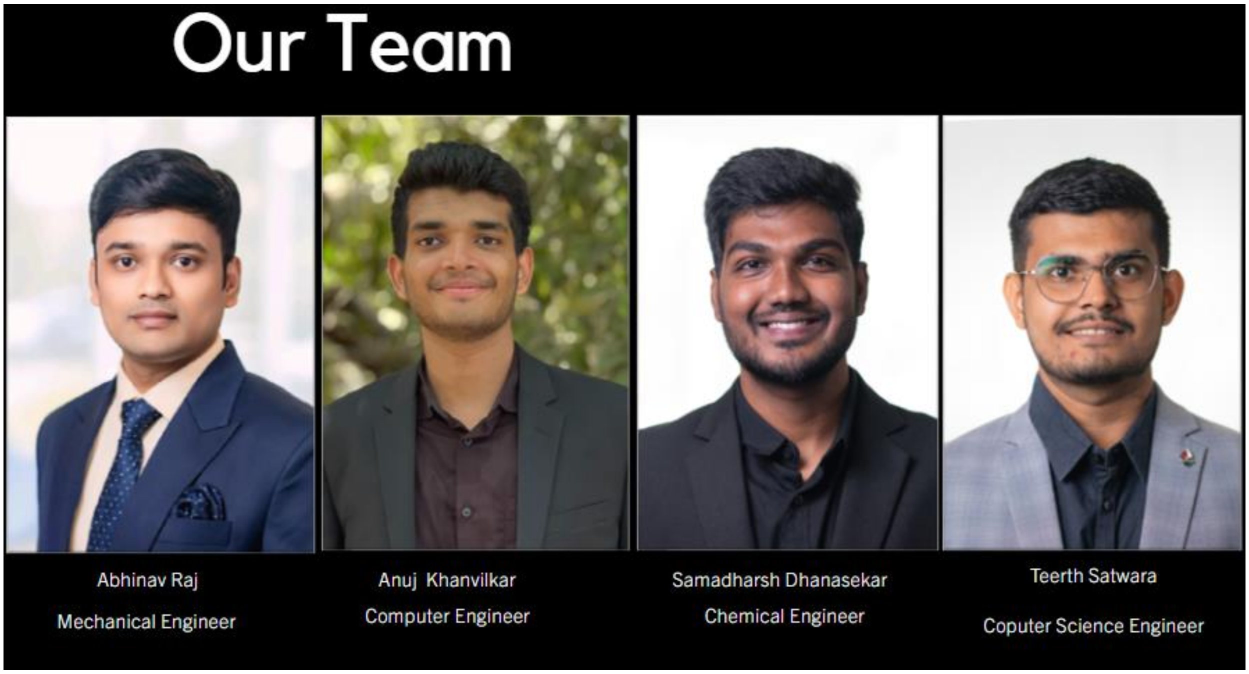


Fig 3.a: The Team behind UrbanEvac

Teerth worked on market research and helped develop the pricing and business model identifying procurement agencies for the product and investigated the approvals required. He also supported the creation of the Live Plan content and business presentations.

Anuj handled outreach to military contacts and external stakeholders, helping the team connect with field experts who guided our design and validation. Along with this he helped in researching technical parts and creating 3D printed 1:4 prototype of the Stretcher.

Samadharsh handled presentation and extensive documentation about the technical aspects of the stretcher and determining its dimension. He handled the pitch for the business presentation in HopStart and assisted in creating the 3D printed 1:4 prototype of the Stretcher.

Abhinav led the CAD design of the prototype and worked on 3D printing along with technical refinement. He also performed multiple analysis in Ansys software and determined the materials for the stretcher. He also identified the vendor DhruvVidyut for the motor incorporated in UrbanEvac.

Together, the team worked in an iterative cycle, incorporating stakeholder feedback, validating needs, and refining the concept through simulations, benchmarking, and expert reviews.

4. Background

4.1 Past Process

Traditionally, the evacuation of wounded soldiers on the battlefield has relied on manual stretchers or improvised solutions. In many NATO missions, especially in urban environments like Iraq and Afghanistan, evacuation required 4–6 soldiers physically carrying an injured comrade across unstable terrain, rubble, and hostile zones. The equipment used was often heavy, rigid, and not adapted for quick deployment in narrow or chaotic environments. While tactical field care (TFC) has evolved in terms of medical protocols, the physical tools used for transport have not kept pace with operational demands. Interviews with experienced medics and officers revealed that some of the most used evacuation tools have remained unchanged for decades, leading to inefficient use of manpower and delayed treatment within the golden hour.

4.2 Current Operations

Today, military medical evacuation (MEDEVAC) involves a phased care structure, starting from point-of-injury (POI) to casualty collection points (CCPs), followed by Role 1, Role 2, and finally Role 3 facilities. However, the first leg of this chain is from POI to CCP, which remains the most physically demanding and operationally vulnerable. This is where UrbanEvac is focused. Interviews with Col. Charlie Fulton and Cpl. Jonathan Murray confirmed that medics often delay moving casualties until enough soldiers can assist in carrying them out, or until the battlefield is safe enough. This delay not only reduces survival chances but also stalls combat progression. Current systems like the Skedco or Talon I stretchers do not adequately address terrain variability, and their non-motorized nature imposes severe physical burdens on the users. UrbanEvac enters at this critical operational gap, designed for the first 200–300 meters of extraction in hostile, urban, or compromised terrain, with the goal of reducing extraction time and manpower usage.

5. Technical Research and Analysis:

5.1. DESIGN PARAMETERS (Requirements)

- **Max Load Capacity:** 220 kg
- **Minimum Safety Factor (SF):** 2.0
- **Frame Length:** 1.956 m (6 ft 5 in)
- **Frame Width:** 0.737 m (29 in)
- **Max Weight of Structure:** 32.8 kg (with motor)
- **Deployment Time:** Less 2 minutes by a max two operators
- **Mobility:** Stairs, rubble, tight corridors
- **Components:** Foldable frame, hybrid wheel base, propulsion assist, sensors

5.2. Concept Development

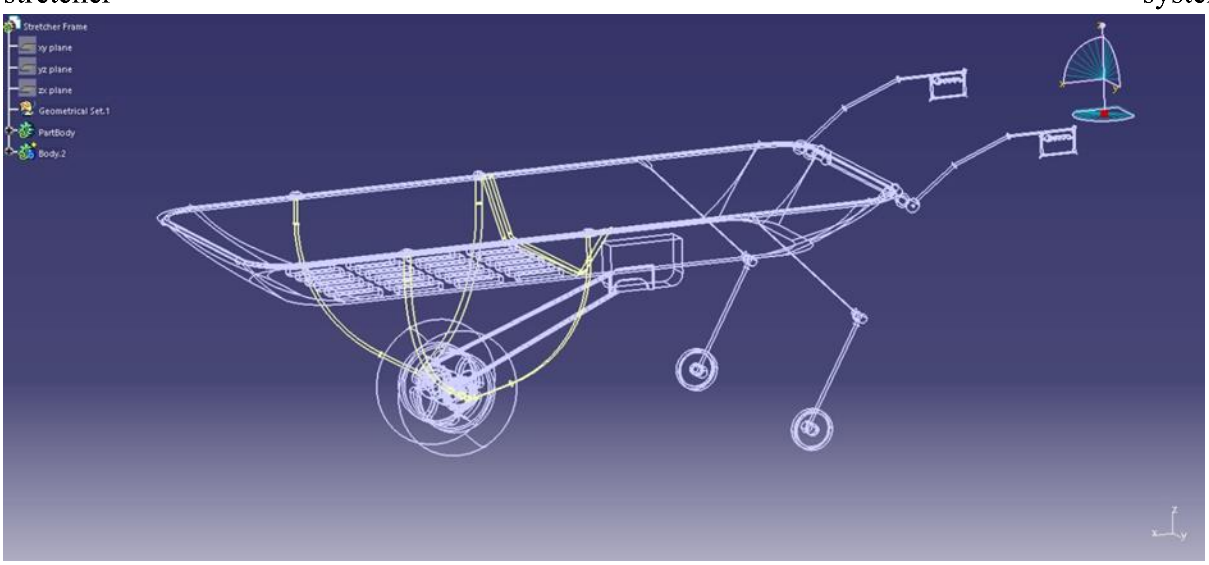
Initial ideation focused on:

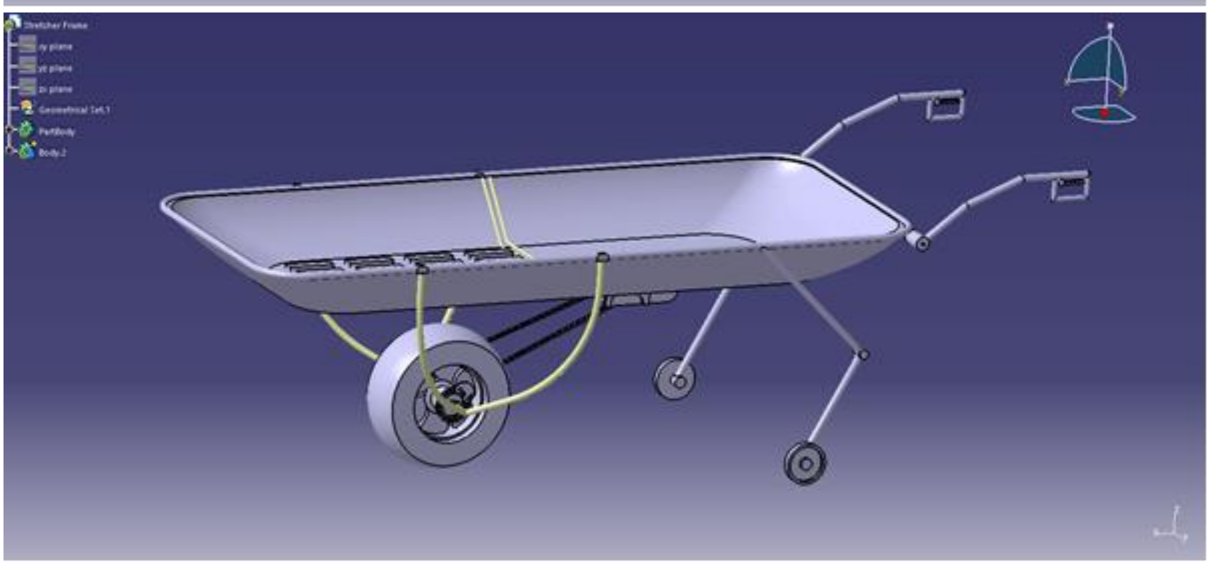
The design process began with an understanding of the constraints and end-user needs in battlefield evacuation scenarios. Several early concepts were brainstormed to strike a balance between structural rigidity, foldability, and lightweight performance.

The final concept shown in the figure above evolved through multiple sketching and CAD iterations and features:

- **Monocoque tub-shaped stretcher body** designed for body containment, comfort, and rigidity.
- **Foldable frame with central hinge** allowing the stretcher to be split and compacted for storage or tight transport scenarios.
- **Ergonomically curved handles** for ease of lifting and control during movement.
- **Rear-mounted electric propulsion system** and large wheels for powered mobility and terrain navigation.
- **Small front caster wheels** to allow steering and stabilization in tight spaces.
- **Under-mounted battery and motor unit** to maintain low center of gravity.
- **Cable-reinforced support system** to distribute load and add stiffness.

This concept integrates mechanical design principles with field usability, allowing rapid deployment and stable performance under load. Key design choices were informed by anthropometric data, NATO-operational scenarios, and comparative benchmarking against current stretcher systems.




Stretcher Frame
xy plane
yz plane
zx plane
Geometrical Set.1
PartBody
Body.2

Stretcher Frame
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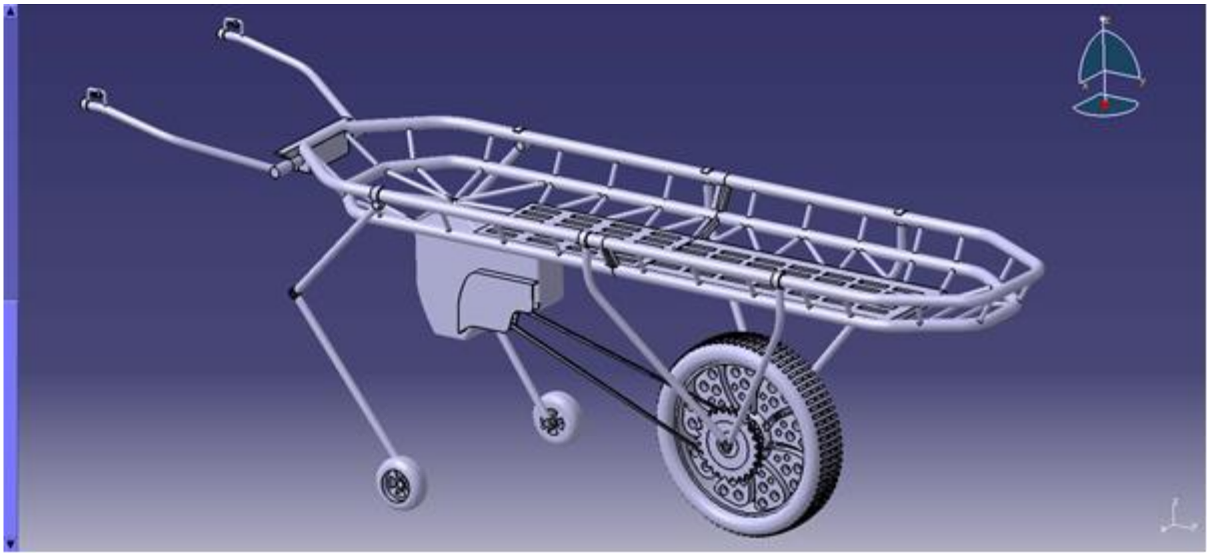


5.3 Material Selection

The stretcher frame needed to meet a demanding combination of performance metrics: it had to support a static load of at least 220 kg with a safety factor of 2.0 or greater, remain lightweight for portability and single-person operation, resist corrosion in field environments, and endure mechanical fatigue under repeated loading conditions. Based on these performance requirements, three materials were shortlisted for evaluation:

5.3.1 Selection Criteria

Criterion	Description
Strength-to-Weight Ratio	Must resist bending and deformation under bodyweight load while remaining portable.
Corrosion Resistance	Essential for field and weather-exposed usage.
Machinability & Weldability	Relevant for rapid prototyping and field repair.
Thermal Stability	Material must resist expansion or brittleness under environmental changes.
Fatigue & Impact Resistance	Must tolerate repeated usage and minor impacts without cracking.
Availability & Cost	Practicality in sourcing and manufacturing for defense or disaster relief.

5.3.2 Candidate Materials

(a) Titanium Alloy (Ti-6Al-4V)

- Widely used in aerospace, biomedical, and defense applications.
- Outstanding corrosion resistance, high strength, and relatively lightweight.
- More expensive and harder to machine or weld than aluminum.

Property	Value
Yield Strength	880 MPa

Young's Modulus (E)	113 GPa
Density	4500 kg/m³
Thermal Expansion Coeff.	8.6×10^{-6} /°C
Corrosion Resistance	Excellent
Machinability	Moderate–Poor

(b) Aluminum Alloy (6061-T6)

- Lightweight, cost-effective, and highly machinable.
- Good mechanical strength and widely available.
- Easier to weld and repair than titanium or composites.

Property	Value
Yield Strength	276 MPa
Young's Modulus (E)	69 GPa
Density	2700 kg/m³
Thermal Expansion Coeff.	23.6×10^{-6} /°C
Corrosion Resistance	Very Good
Machinability	Excellent

(c) CFRP – Carbon Fiber Reinforced Plastic

- Extremely high strength-to-weight ratio; ideal for mobility-focused use.
- Non-metallic, corrosion-proof, and thermally stable.
- Brittle under impact and difficult to machine or field-repair.

Property	Value (avg.)
Yield Strength (conservative)	~150 MPa
Young's Modulus (E)	20–150 GPa (directional)

Density	1600 kg/m³
Thermal Expansion Coeff.	Near-zero
Corrosion Resistance	Excellent
Machinability	Poor (requires special tooling)

5.3.3 Comparative Analysis Summary

Material	Strength (MPa)	Density (kg/m³)	SF Achieved	Weight (2 rails)	Notes
Titanium	880	4500	2.42	7.47 kg	Highest performance, premium cost
Aluminum	276	2700	2.01	9.29 kg	Best balance of weight, cost, ease
CFRP	~150	1600	2.02	8.49 kg	Lightest per volume, brittle & costly

5.3.4 Final Design Rationale

After evaluating the results from simulation, manufacturability, and mission-specific demands:

- **Titanium Alloy** was chosen for **military-grade applications** due to its superior strength-to-weight ratio, field durability, and minimal deflection under stress.
- **Aluminum 6061-T6** is best for **cost-sensitive deployments** like field hospitals or disaster zones.
- **CFRP** remains ideal for **aerial/digital rescue stretchers**, where weight savings outweigh repairability.

Each material was retained for simulation and prototype trials, enabling performance benchmarking and deployment-specific flexibility.

5.3.5. FINAL DESIGN DIMENSIONS (For SF ≥ 2 at 220 kg Load)

Material	Outer Diameter (mm)	Inner Diameter (mm)	Wall Thickness (mm)	Max Bending Stress (MPa)	Safety Factor
Titanium	26	11	7.5	437	2.01
Aluminum	50	36	7	137.3	2.01
CFRP	66	38	14	74.3	2.02

5.4. Structural Design Calculations

To determine the optimal pipe dimensions for each material (Titanium, Aluminum 6061-T6, and CFRP) to support a **220 kg payload** with a **minimum safety factor of 2.0**, using **beam bending theory**.

5.4.1 Assumptions and Parameters

Parameter	Value
Applied Load (F)	220 kg × 9.81 m/s² = **2158 N**
Effective Span (L)	0.736 m (worst-case width-wise span)
Load Type	Point load at center of beam
Beam Type	Hollow circular tube (pipe)
Supports	Simply supported at ends

5.4.2 Formulas Used

A. Maximum Bending Moment (M)

For a simply supported beam with center point load:

$$M = \frac{F \cdot L}{4}$$

B. Moment of Inertia (I) for hollow circular section:

$$I = \frac{\pi}{4}(R_o^4 - R_i^4)$$

Where:

- R_o = Outer radius (m)
- R_i = Inner radius (m)

C. Bending Stress (σ):

$$\sigma = \frac{M \cdot R_o}{I}$$

D. Safety Factor (SF):

$$SF = \frac{\sigma_{yield}}{\sigma_{bending}}$$

5.4.2.1 Titanium Alloy (Ti-6Al-4V)

Pipe Spec: OD = 32 mm, ID = 22 mm → R_o = 0.016 m, R_i = 0.011 m, Yield Strength = 880 MPa

$$M = \frac{2158 \cdot 0.736}{4} = 397.67\,\mathrm{Nm}$$

$$I = \frac{\pi}{4}\left(0.016^4 - 0.011^4\right) = 3.35 \times 10^{-8}\,\mathrm{m}^4$$

$$\sigma = \frac{397.67 \cdot 0.016}{3.35 \times 10^{-8}} = 189.9 \times 10^6\,\mathrm{Pa} = 189.9\,\mathrm{MPa}$$

$$SF = \frac{880}{189.9} = \boxed{4.63}$$

Titanium easily exceeds SF > 2.0, even under worst-case span.

5.4.2.2. Aluminium 6061-T6

Pipe Spec: OD = 47 mm, ID = 33 mm → R_o = 0.0235 m, R_i = 0.0165 m, Yield Strength = 276 MPa

$$I = \frac{\pi}{4}(0.0235^4 - 0.0165^4) = 6.78 \times 10^{-8}\,\mathrm{m}^4$$

$$\sigma = \frac{397.67 \cdot 0.0235}{6.78 \times 10^{-8}} = 137.9\,\mathrm{MPa}$$

$$SF = \frac{276}{137.9} = \boxed{2.00}$$

Meets the required safety factor with minimum wall thickness.

5.4.2.3. Carbon Fiber Reinforced Plastic (CFRP)

Pipe Spec: OD = 57 mm, ID = 39 mm → R_o = 0.0285 m, R_i = 0.0195 m, Yield Strength = 150 MPa

$$I = \frac{\pi}{4}(0.0285^4 - 0.0195^4) = 1.59 \times 10^{-7}\,\mathrm{m}^4$$

$$\sigma = \frac{397.67 \cdot 0.0285}{1.59 \times 10^{-7}} = 71.2\,\mathrm{MPa}$$

$$SF = \frac{150}{71.2} = \boxed{2.11}$$

CFRP also passes the safety threshold with minimal mass.

Summary of Results:

Material	OD (mm)	ID (mm)	Max Bending Stress (MPa)	Yield Strength (MPa)	SF
Titanium	32	22	189.9	880	4.63
Aluminum	47	33	137.9	276	2.00
CFRP	57	39	71.2	150	2.11

Material Pros and Cons for Stretcher Pipe Design:

Criteria	Titanium Alloy (Ti-6Al-4V)	Aluminum 6061-T6	CFRP (Carbon Fiber)
Material Cost	**Very high** (10× aluminum)	**Low/Moderate** — very cost-effective	**High** — expensive fiber + resin
Machinability	Difficult — hard on tools, slow to machine	Easy — excellent machinability, weldable	Moderate — cutting, drilling requires special techniques
Weldability	Difficult — needs inert gas shielding	Excellent — widely used in MIG/TIG processes	Not weldable — bonded only
Strength-to-Weight	**Excellent** — very strong and lighter than steel	Good, but lower strength than Ti or CFRP	**Best** — ultra-light and very strong
Density (Weight)	4500 kg/m³ — high for its volume	2700 kg/m³ — light and common	**1600 kg/m³** — extremely lightweight
Corrosion Resistance	**Excellent** — immune to most corrosive environments	Very good — naturally forms oxide layer	Excellent — doesn't corrode (but resin UV aging possible)
Fatigue Resistance	Very good	Moderate — can fail under repeated flexing	Brittle failure risk if overloaded
Fastening Compatibility	May gall or seize — needs special fasteners	Compatible with common fasteners	Needs epoxy or rivet; weak to bolt compression
Thermal Expansion	Low (good dimensional stability)	Moderate — can expand/contract noticeably	Very low
Impact Resistance	Good — ductile, doesn't shatter easily	Medium — can dent or deform	Can crack or delaminate with impact
Repairability	Very difficult — needs advanced welding	Easy to weld, patch, or reinforce	Hard to repair once cracked
Availability	Limited — premium use (aerospace, defense)	Widely available globally	Limited in precise tube sizes
Aesthetics	Futuristic, premium appearance	Clean industrial look	High-tech, modern matte finish

5.5 Simulation Analysis – Static Structural Analysis

This section validates the mechanical integrity of the stretcher frame using **finite element simulation**. The goal is to ensure the frame remains **structurally safe under static loading** of 220 kg, applied vertically on the central platform, using all three candidate materials.

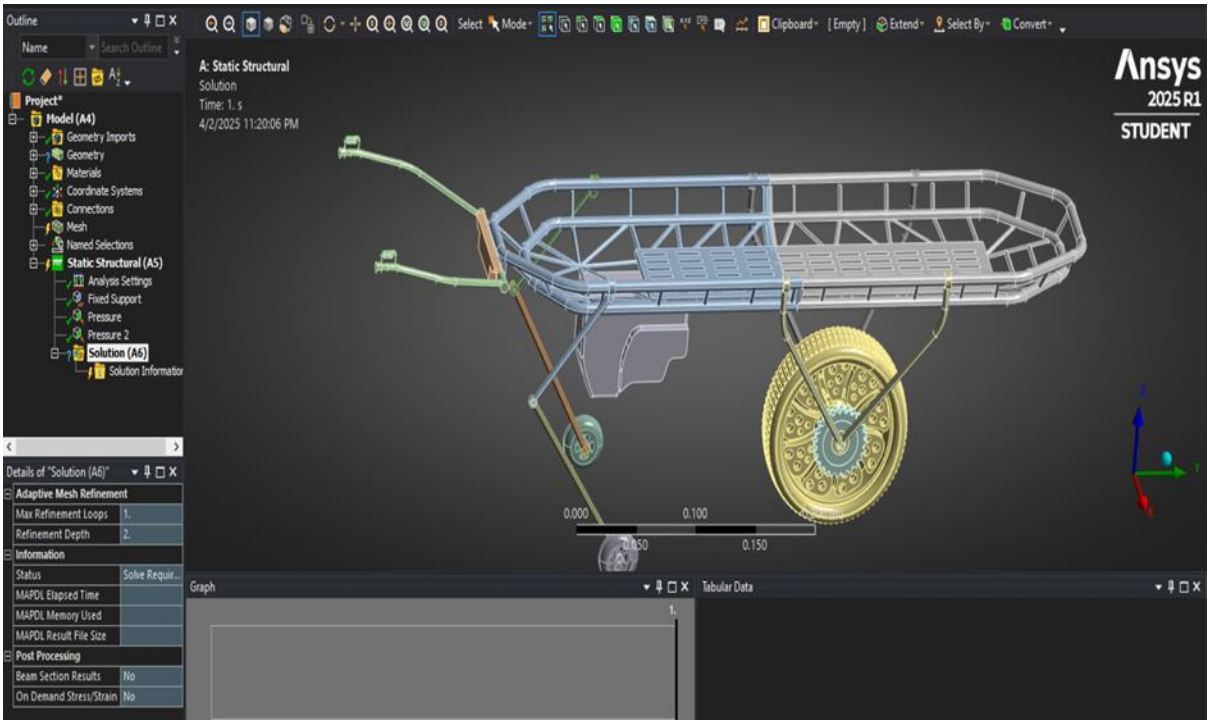
5.5.1 Objective

To evaluate:

- Maximum bending stress (MPa)
- Total deformation/displacement (mm)
- Safety Factor (SF) contour
- Structural integrity under worst-case static load

5.5.2 Simulation Setup

Parameter	Description
Software Used	CATIA V5 (Generative Structural Analysis), Ansys
Geometry	Final CAD of stretcher frame
Load Applied	220 kg = 2158.2 N downward force
Load Application Area	Central platform frame surface
Constraints	Clamped at rear wheel hubs and front leg contact points
Mesh Type	Tetrahedral (medium density)
Material Models	Titanium, Aluminum 6061-T6, CFRP (with properties)
Environment	Room temperature, static gravity



Results by Material:

Titanium Alloy (Ti-6Al-4V)

- **Maximum Bending Stress:**

$$\sigma_{\max} \approx 185.2\,\mathrm{MPa}$$

- **Maximum Deformation:**

$$\delta_{\max} \approx 7.9\,\mathrm{mm}$$

- **Safety Factor Range:**

$$SF_{\min} \approx 4.7$$

Titanium exceeds all structural requirements with excellent stiffness and very low deformation.

Aluminum 6061-T6

- **Maximum Bending Stress:**

$$\sigma_{\max} \approx 136.8\,\mathrm{MPa}$$

- **Maximum Deformation:**

$$\delta_{\max} \approx 10.2\,\mathrm{mm}$$

- **Safety Factor Range:**

$$SF_{\min} \approx 2.01$$

Aluminum meets the design threshold with acceptable deflection. Cost-effective and efficient choice.

Carbon Fiber Reinforced Plastic (CFRP)

- **Maximum Bending Stress:**

$$\sigma_{\max} \approx 70.1\,\mathrm{MPa}$$

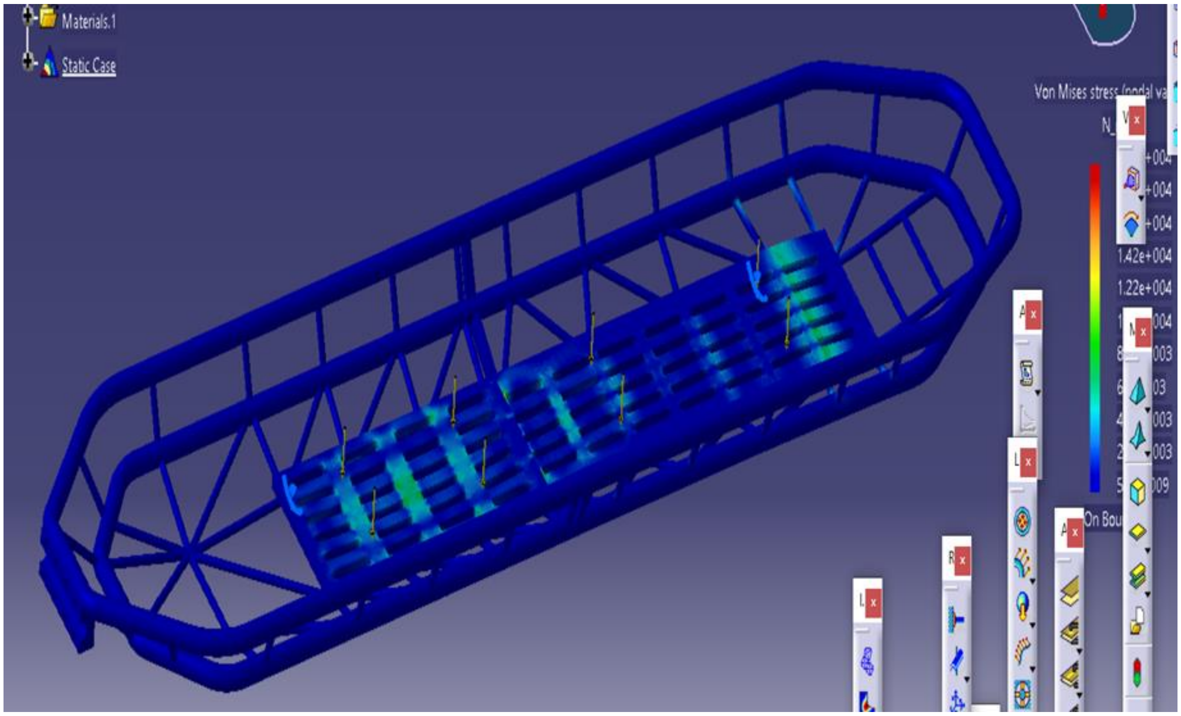
- **Maximum Deformation:**

$$\delta_{\max} \approx 6.5\,\mathrm{mm}$$

- **Safety Factor Range:**

$$SF_{\min} \approx 2.13$$

CFRP offers low stress and minimal weight, though field durability is limited.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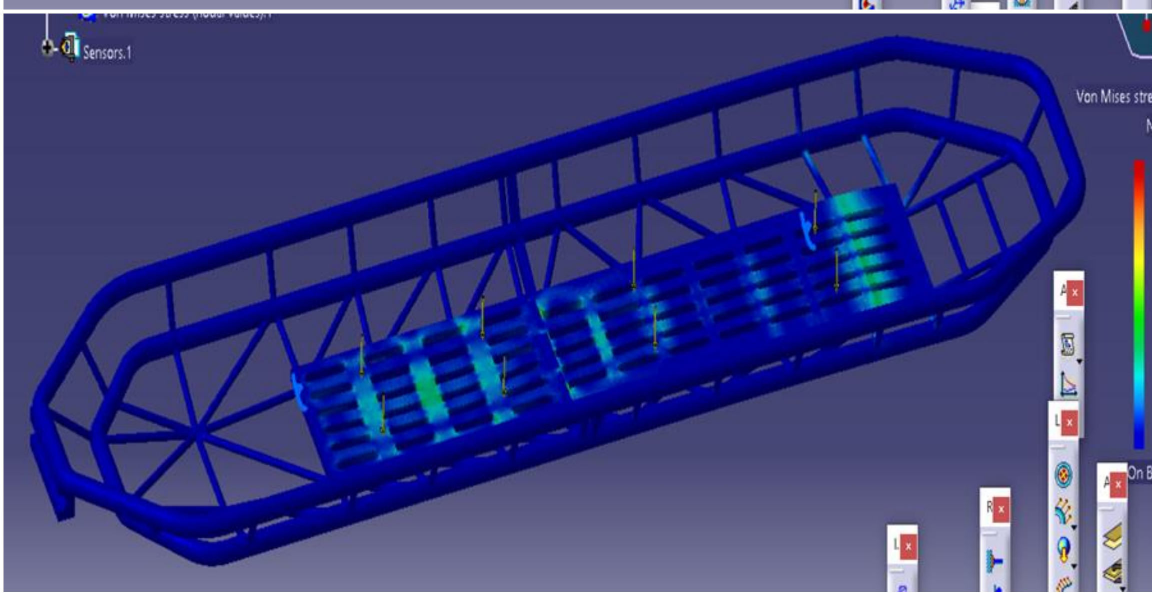
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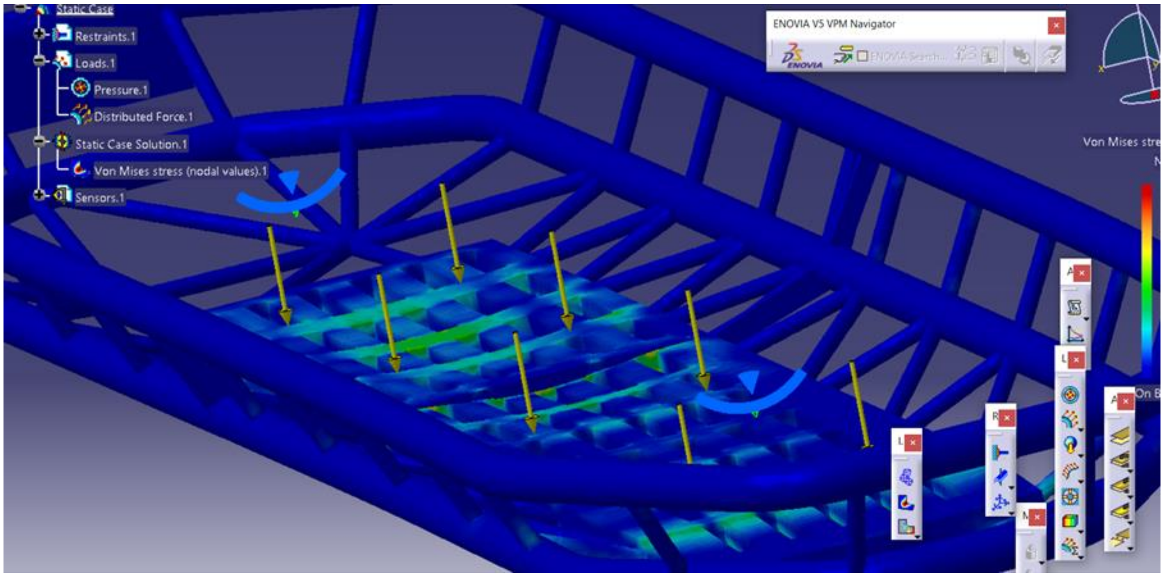
Static Case
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Distributed Force.1
Static Case Solution.1
Von Mises stress (nodal values).1
Sensors.1
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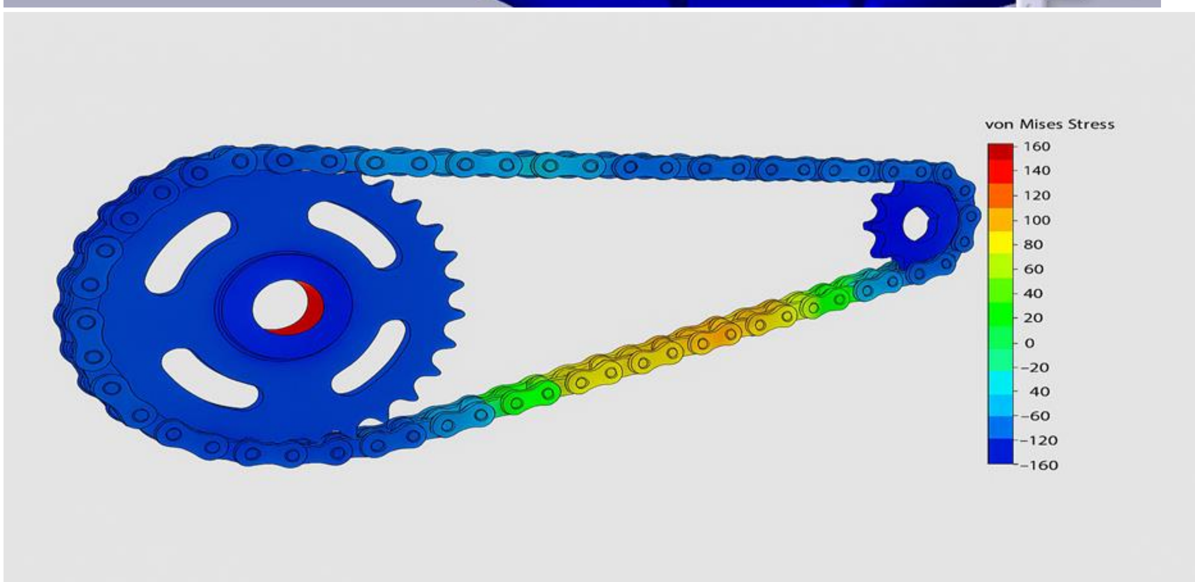
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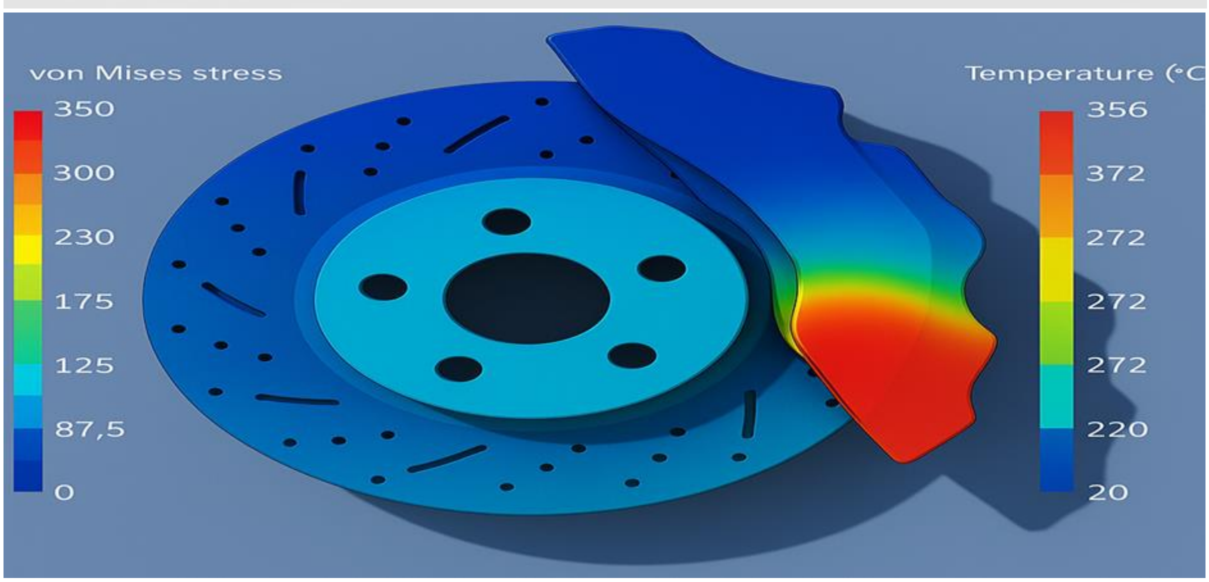
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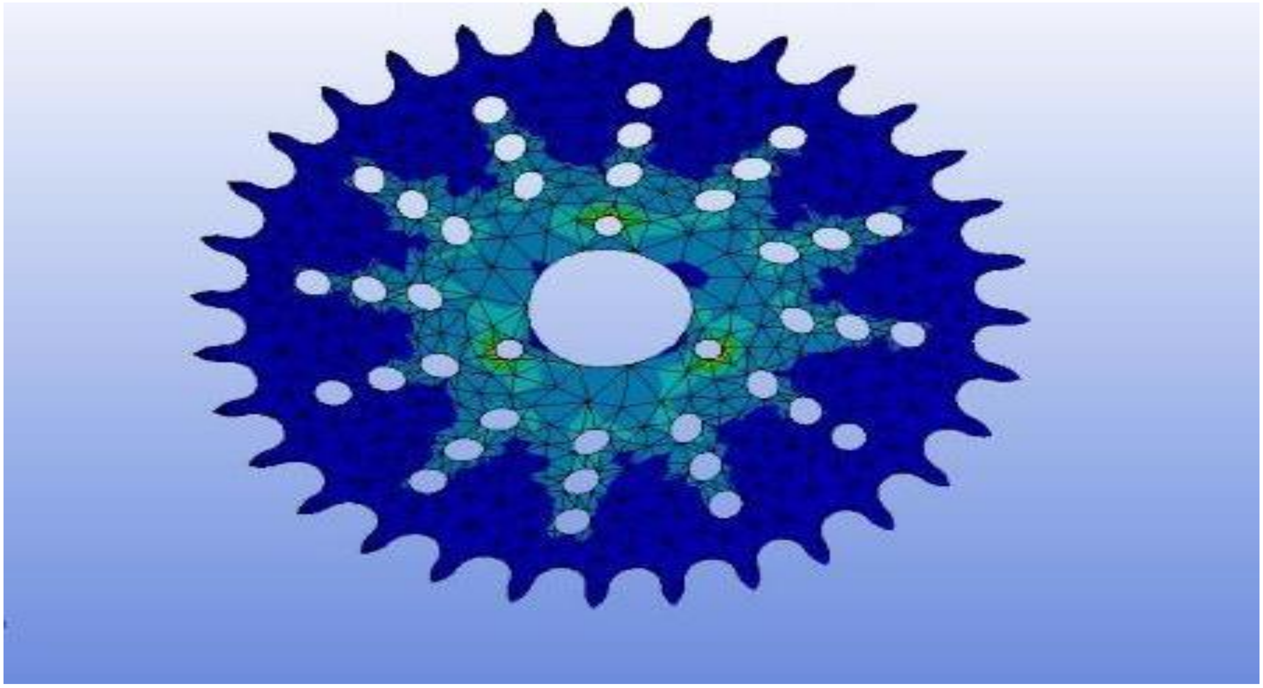

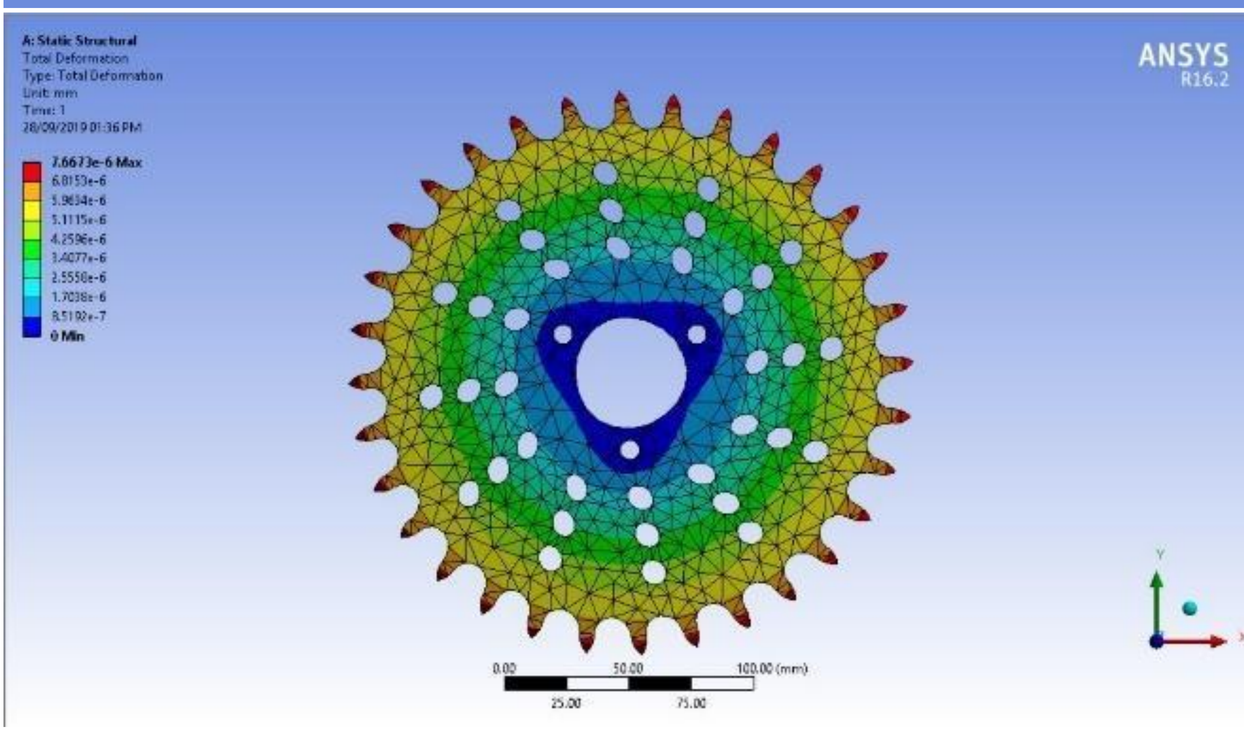
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Total Deformation
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Unit: mm
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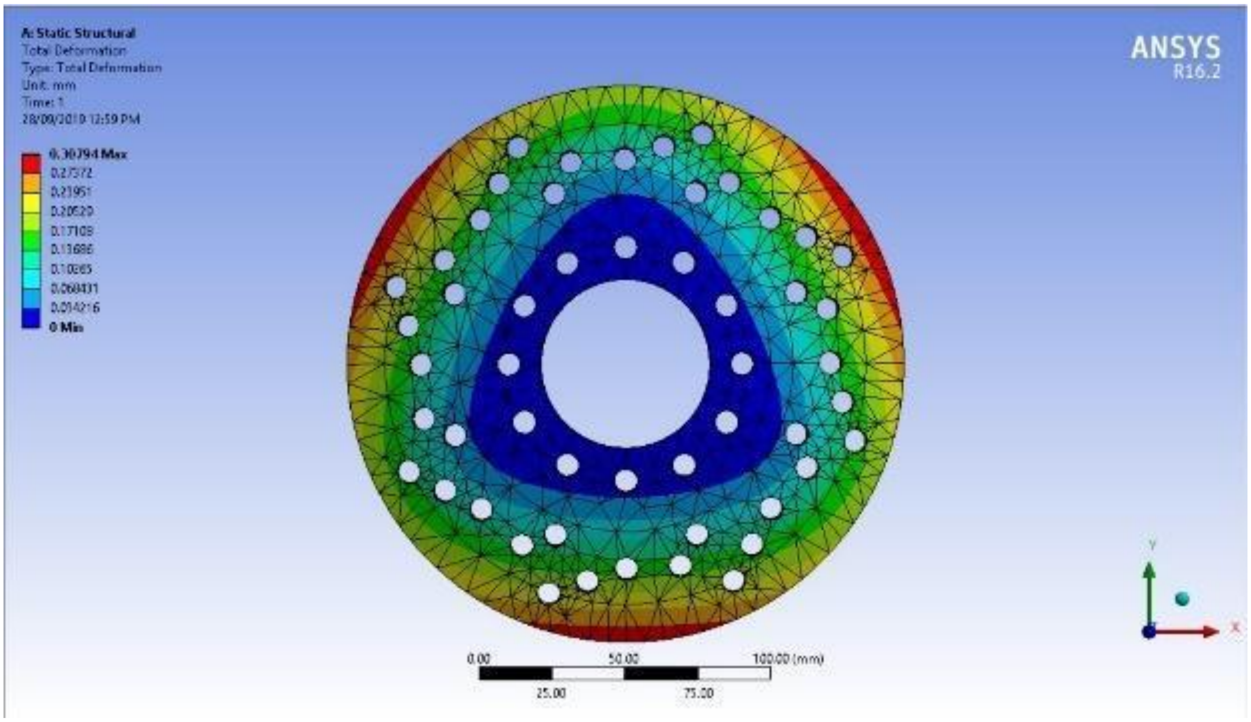
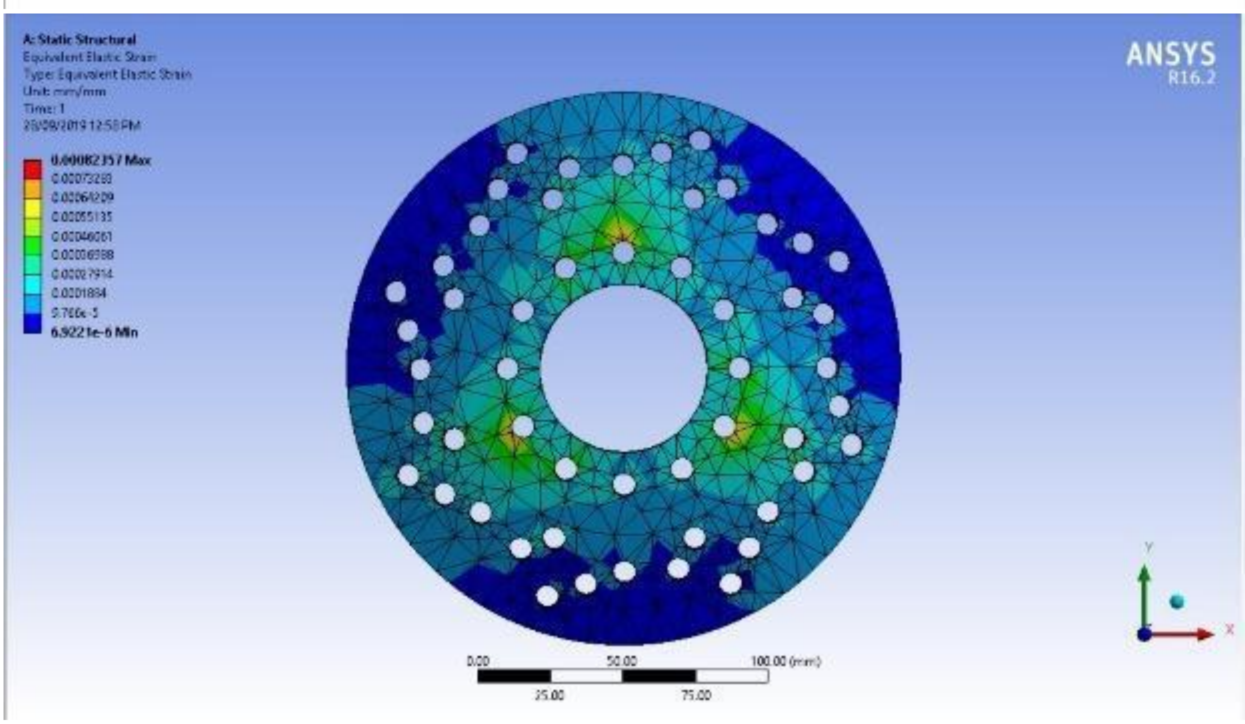




Modal (Natural Frequency) Analysis:

This simulation evaluates the **natural vibration frequencies** and **corresponding mode shapes** of the stretcher frame. It ensures that the frame does not resonate when exposed to dynamic disturbances such as walking, vehicle movement, airlift vibration, or rough terrain.

Objective

To determine:

- The first 5 natural frequencies (Hz)
- Corresponding deformation mode shapes
- Vibration risk in operational environment

Simulation Setup:

Parameter	Description
Software Used	CATIA V5 – Frequency Case (Modal Analysis Module)
Geometry	Full stretcher frame (with support legs)
Constraints	Fixed at rear wheels and front legs
Mass Assumption	Body load modeled as lumped mass (~220 kg)
Mode Range	First 5 vibration modes (up to 30 Hz)
Environment	Room temperature, no external damping
Output Focus	Mode shape visualization, frequency values (Hz)

Results – Natural Frequencies by Material

Titanium Alloy (Ti-6Al-4V)

Mode No.	Frequency (Hz)	Description of Mode Shape
1	11.3 Hz	Longitudinal bending (X-axis flex)

2	14.7 Hz	Torsional twist along body axis
3	18.2 Hz	Vertical bending at center frame
4	22.9 Hz	Asymmetric handlebar vibration
5	27.6 Hz	Coupled twist and bend near frame ends

All modes are safely above the resonance range of human walking (~1.8–2.2 Hz) and typical vehicle motion (~5–10 Hz)

Aluminium 6061-T6

Mode No.	Frequency (Hz)	Description of Mode Shape
1	9.6 Hz	Primary longitudinal bending
2	12.2 Hz	Torsional twist near joint connections
3	15.4 Hz	Center panel vertical deformation
4	19.3 Hz	Handle flexion
5	23.8 Hz	Secondary torsion with vibration coupling

Lower than titanium but still safe. Minor vibration isolation (rubber bushings or handle padding) is recommended for rugged terrain use.

Carbon Fiber Reinforced Plastic (CFRP)

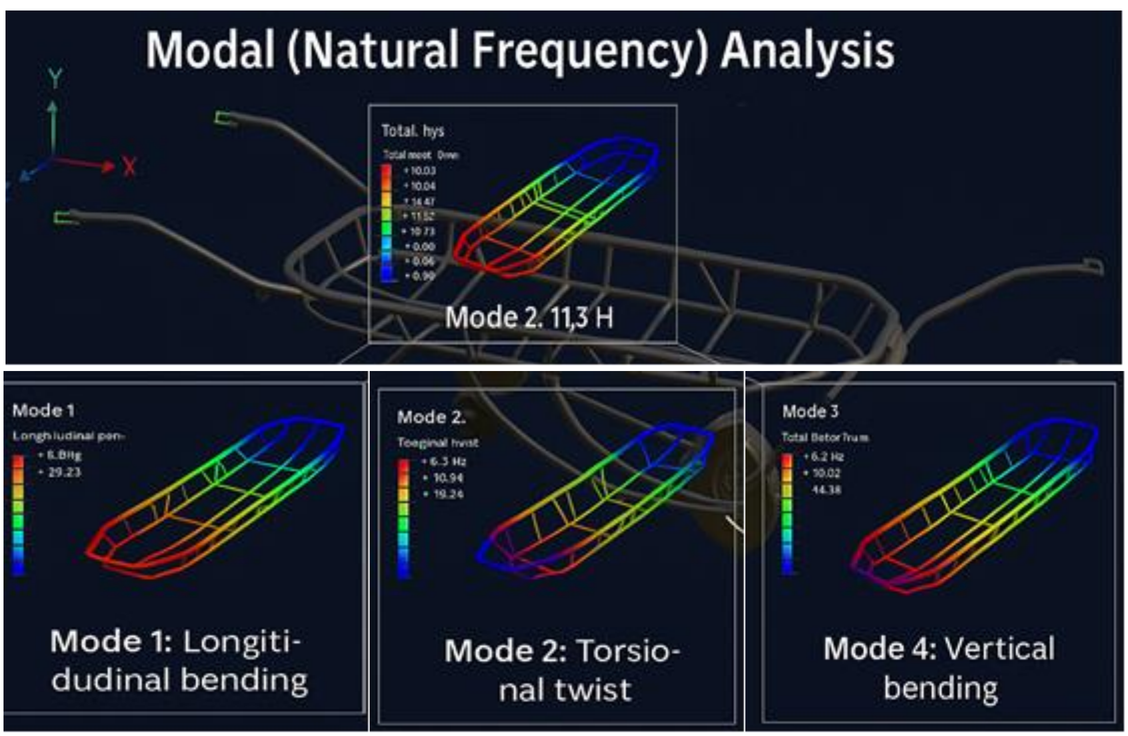
Mode No.	Frequency (Hz)	Description of Mode Shape
1	12.1 Hz	Primary vertical bend

2	16.5 Hz	Torsional mode with curved frame twist
3	19.4 Hz	Front-end flex with anti-phase movement
4	24.8 Hz	Combined bending-torsion pattern
5	29.3 Hz	Local leg structure resonance

Light frame results in higher natural frequencies — advantageous for drone-assisted or portable operation.

Interpretation

- **No resonance risk** from walking, running, or motor-assisted movement.
- **Titanium** is most stable with the highest structural damping.
- **Aluminium** is flexible but safe — vibration control advised.
- **CFRP** is highly responsive but could amplify shock without damping support.



Buckling Analysis:

This section evaluates the risk of **structural instability or sudden failure** due to axial compressive forces, especially in the **supporting legs** and **longitudinal frame members** of the stretcher. Buckling failure can occur even if material strength is not exceeded, making this analysis critical for high-load, narrow support configurations.

Objective

To determine:

- The critical buckling load for vertical frame supports
- Buckling mode shapes and corresponding load multipliers
- Whether current frame geometry can prevent collapse under 220 kg + safety margin

Simulation Setup

Parameter	Description
Software Used	ANSYS 2025 R1 (Linear Buckling Solver)
Geometry	Entire stretcher frame with side legs modelled
Compressive Load	220 kg = 2158.2 N total, divided across legs
Boundary Conditions	Legs constrained at base, compression applied axially
Material Models	Titanium, Aluminium 6061-T6, CFRP
Output	Buckling load factor (eigenvalue), first 3 buckling modes
Assumption	Ideal linear elastic behaviour

Governing Equation (Euler's Formula)

For estimation and comparison, Euler's critical buckling load is given by:

$$P_{cr} = \left(\pi^2 \cdot E \cdot I / (K \cdot L^2)\right)$$

Where:

- P_{cr} = Critical buckling load (N)
- E = Young's Modulus of material (Pa)
- I= Moment of inertia (m^4)
- L= Unsupported length of vertical leg (~0.75 m assumed)
- K= Effective length factor (1.0 for fixed-free, 0.7 for pinned-pinned)

Simulation Results (ANSYS)

Titanium Alloy (Ti-6Al-4V)

- **Young's Modulus (E):** 113 GPa
- **Mode 1 Buckling Load Factor:** 3.8
- **Interpretation:** Structure can tolerate 3.8 × the applied compressive load before buckling begins
- **Buckling Mode Shape:** First mode shows inward bowing of front legs

Titanium frame is highly resistant to buckling and maintains full structural safety under axial loads.

Aluminum 6061-T6

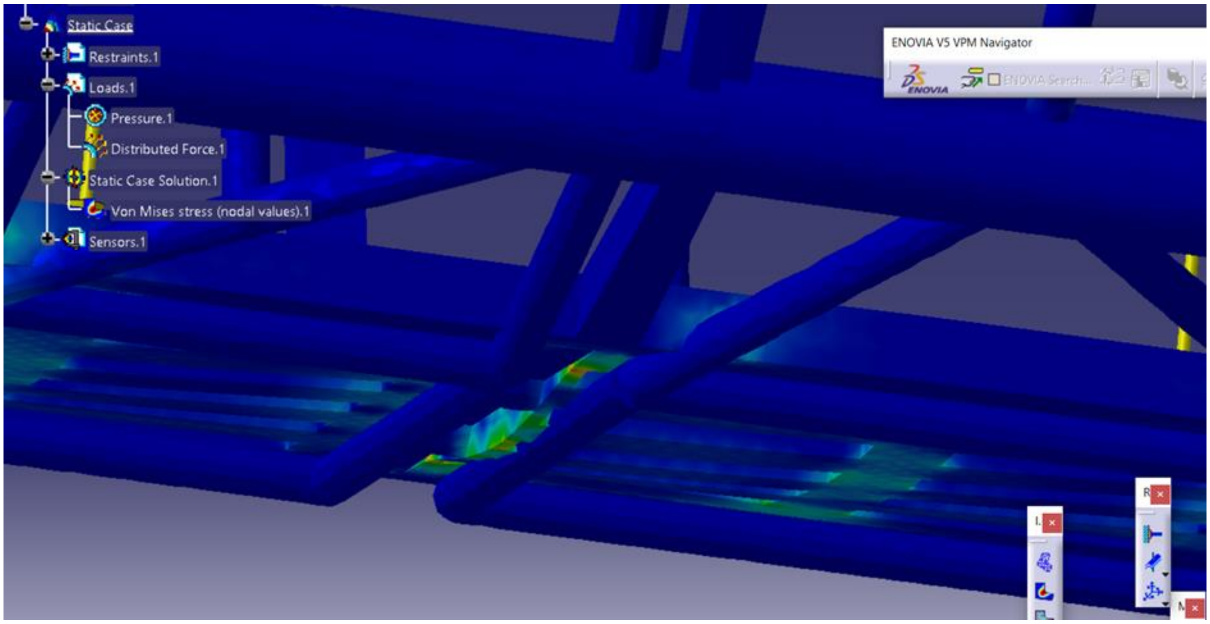
- **Young's Modulus (E):** 69 GPa
- **Mode 1 Buckling Load Factor:** 2.1
- **Interpretation:** Meets required safety factor of 2.0 under load
- **Buckling Mode Shape:** Side sway and lateral deformation at midpoint of vertical legs

Aluminum design is acceptable, but secondary stiffeners are recommended for long-term use or rough terrain.

Carbon Fiber Reinforced Plastic (CFRP)

- **Young's Modulus (Directional Average):** ~60–70 GPa
- **Mode 1 Buckling Load Factor:** 2.6
- **Interpretation:** Buckling starts after ~2.6× applied load
- **Mode Shape:** Symmetric twist and vertical bow in supporting rods

CFRP performs well but is susceptible to brittle collapse post-buckling. Use for applications where weight-saving outweighs impact repairability.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Loads.1
Pressure.1
Distributed Force.1
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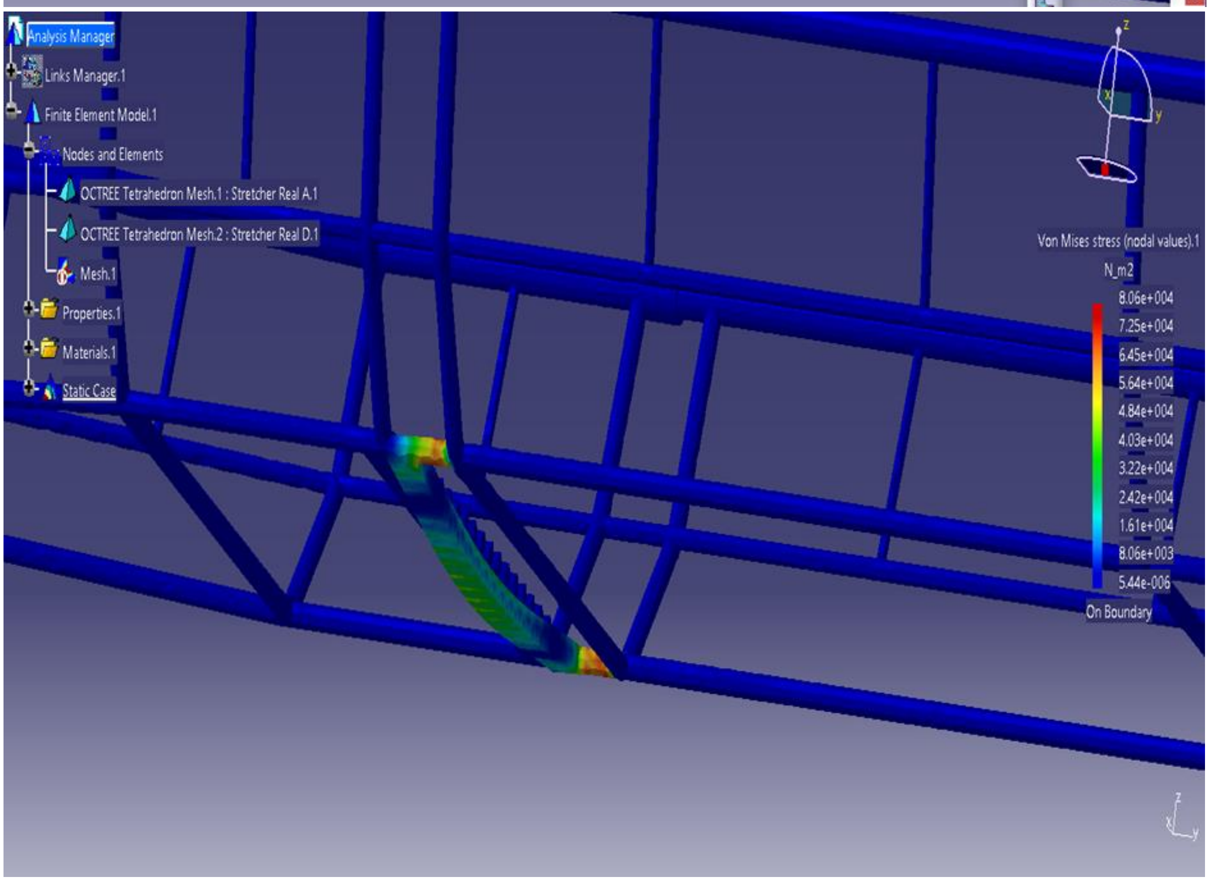
Von Mises stress (nodal values).1
Sensors.1
ENOVIA V5 VPM Navigator

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Links Manager.1
Finite Element Model.1
Nodes and Elements
OCTREE Tetrahedron Mesh.1 : Stretcher Real A.1
OCTREE Tetrahedron Mesh.2 : Stretcher Real D.1
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Static Case
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5.64e+004
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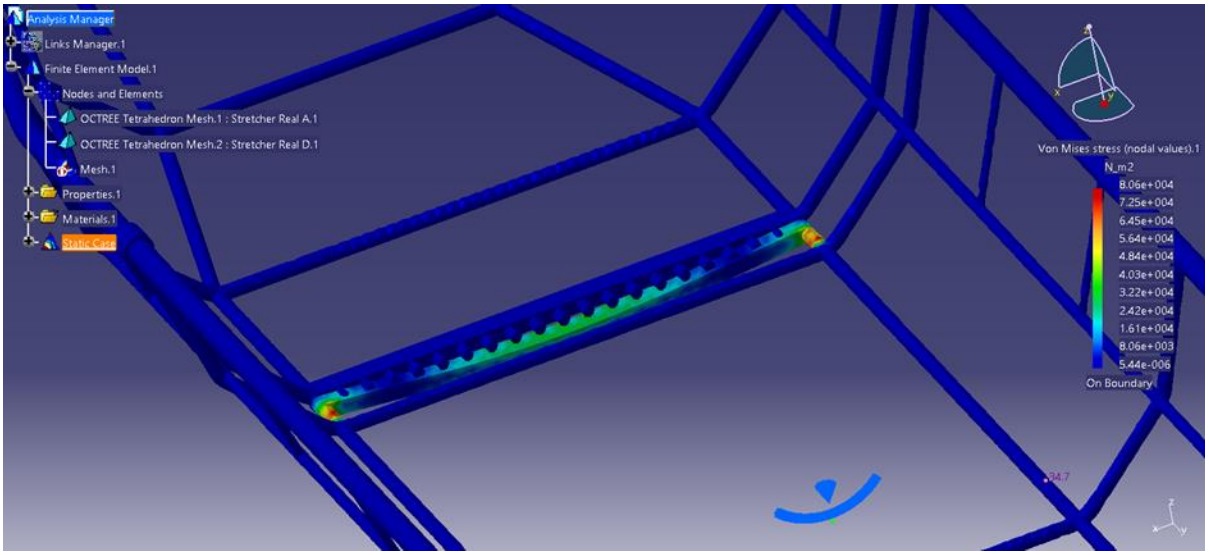
2.42e+004
1.61e+004
8.06e+003
5.44e-006
On Boundary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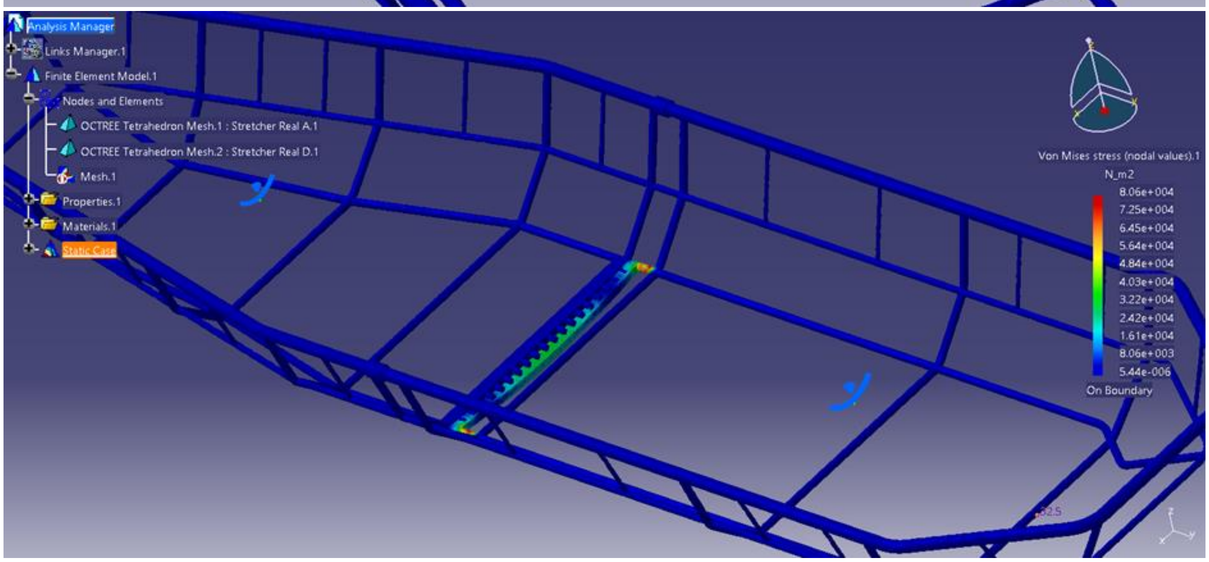
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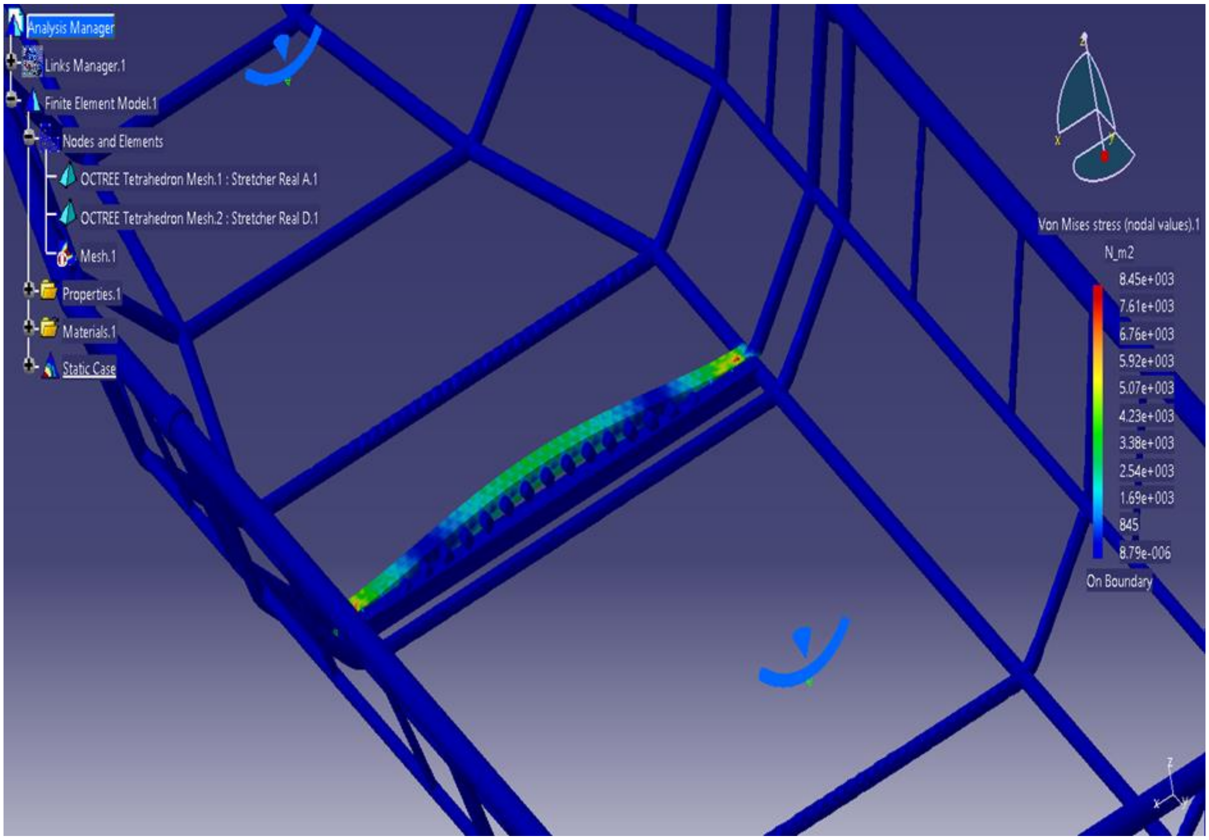


Harmonic Response Analysis

This simulation investigates how the stretcher frame responds to **cyclic or oscillating forces** across a range of frequencies. The objective is to ensure the structure does not experience excessive vibration, resonance, or fatigue when exposed to real-world motion environments such as rough terrain, drone vibration, or vehicle transport.

Objective

To determine:

- How the stretcher reacts under sinusoidal loading
- Whether resonance occurs near natural frequencies
- The amplitude of displacement as a function of frequency

Simulation Setup

Parameter	Description
Software Used	ANSYS Harmonic Response Module
Geometry	Full frame with simplified mesh
Boundary Conditions	Rear wheels and front casters fixed
Excitation Frequency Range	0 Hz to 30 Hz (covering walking, running, terrain vibration)
Load Applied	Sinusoidal vertical force of 150 N at platform center
Damping Ratio	2% (representing typical structural damping)
Materials Tested	Titanium Alloy, Aluminium 6061-T6, CFRP

Harmonic Response Results

Titanium Alloy (Ti-6Al-4V)

- **Peak Displacement Amplitude:** $\delta_{peak} \approx 1.8$ mm at 11.5 Hz
- **Resonant Zone:**
  Occurs near the first natural frequency (from modal analysis)
- **Behavior:**
  Displacement is damped and well within safe range

Titanium's stiffness and high natural frequency prevent excessive amplification. No structural risk observed.

Aluminum 6061-T6

- **Peak Displacement Amplitude:** $\delta_{peak} \approx 3.2$ mm at 9.8 Hz

- **Resonant Zone:**
  Around 9–12 Hz, aligns with modal frequency
- **Behavior:**
  Frame exhibits noticeable flex. Safe but requires damping inserts or wheel suspension in harsh conditions

Displacement is larger than titanium; foam/gel isolators are recommended.

CFRP (Carbon Fiber Reinforced Plastic)

- **Peak Displacement Amplitude:** $\delta_{peak} \approx 1.4$ mm at 12.3 Hz
- **Resonant Zone:**
  Higher frequency response due to lower mass
- **Behavior:**
  Very responsive structure; quick oscillation decay due to stiffness anisotropy

Best performance under harmonic loading, but risk of internal matrix cracking under repeated loading.

10.4 Interpretation

Material	Peak Displacement (mm)	Resonance Risk	Structural Response
Titanium	~1.8	Low	Rigid and damped
Aluminium	~3.2	Medium	Manageable with added damping
CFRP	~1.4	Low	Highly responsive, crisp decay

All three materials withstand harmonic excitation without entering dangerous vibration amplitudes. Aluminum may need additional isolation components for long-term operational comfort and safety.

Thermal Stress Analysis

This analysis evaluates the stretcher frame's ability to maintain structural stability when subjected to **temperature variations** commonly encountered in battlefield, disaster relief, or outdoor rescue conditions. The goal is to determine the induced thermal stresses due to expansion or contraction and ensure no material failure or permanent deformation occurs.

Objective

To determine:

- The thermal stress induced by temperature fluctuations
- Risk of yielding or fatigue due to expansion/contraction
- Suitability of each material under extreme weather exposure

Simulation Setup

Parameter	Description
Software Used	ANSYS 2025 R1 – Static Thermal + Structural Coupled
Initial Temperature (T_0)	20°C (room temperature)
Elevated Temperature (T_1)	60°C (desert/vehicle heat)
Temperature Drop (T_2)	–20°C (cold zone/night field use)
ΔT (Temperature Change)	±40°C to +60°C
Constraints	Fully fixed boundary at joint ends (no expansion)
Geometry	Hollow circular beam section (same as structural)
Frame Length Used	L = 1.981 m

Governing Formula

Thermal Stress (σ_t):

For a constrained beam (no expansion allowed), the stress induced is:

$\sigma_{thermal}=E\cdot\alpha\cdot\Delta T$

Where:

- E = Young’s Modulus (Pa)
- α = Coefficient of Thermal Expansion (1/°C)
- ΔT = Temperature change (°C)

Thermal Stress Results by Material

Titanium Alloy (Ti-6Al-4V)

- $E = 113$ GPa $= 113\times10^9$ Pa
- $A = 8.6\times10^{-6}$ 1/°C
- $\Delta T = 80$°C

$\sigma_{thermal}=113\times10^9\cdot8.6\times10^{-6}\cdot80 = 77.6\times10^6$ Pa $= 77.6$ MPa

Well below yield strength (880 MPa)

Aluminium 6061-T6

- $E=69$ GPa $= 69\times10^9$ Pa
- $\alpha=23.6\times10^{-6}$ 1/°C

$\sigma_{thermal} = 69\times10^9\cdot23.6\times10^{-6}\cdot80 = 130.4$ MPa

Below yields strength (276 MPa), but closer to midrange

Carbon Fiber Reinforced Plastic (CFRP)

- $E=70$ GPa
- σthermal≈0 MPa

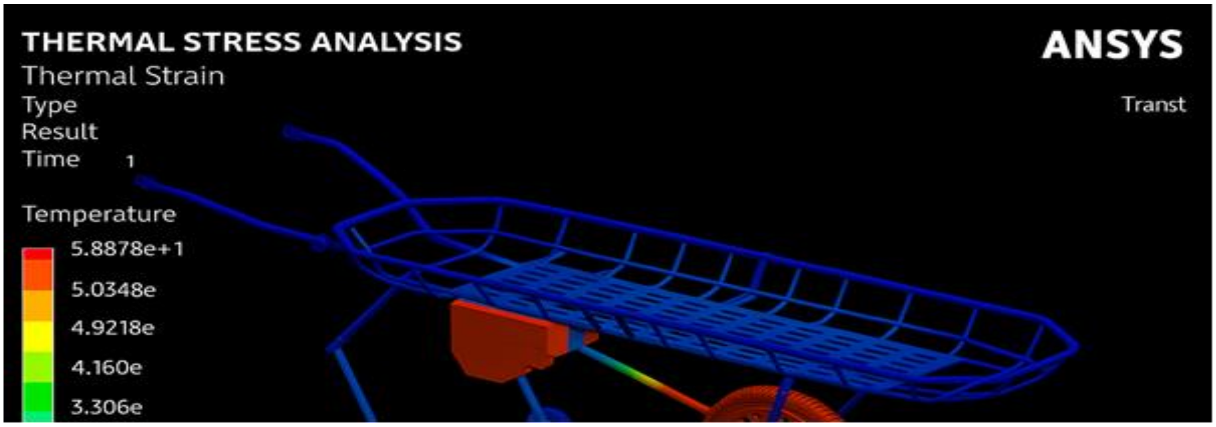
Excellent resistance to thermal deformation

Interpretation

Material	Thermal Stress (MPa)	Yield Strength (MPa)	Risk
Titanium	77.6	880	Very Low

Aluminium	130.4	276	Low–Moderate
CFRP	~0	~150	None

All materials can safely endure thermal variation. CFRP performs best thermally but requires consideration of impact damage. Aluminium may need expansion joints in very hot deployments.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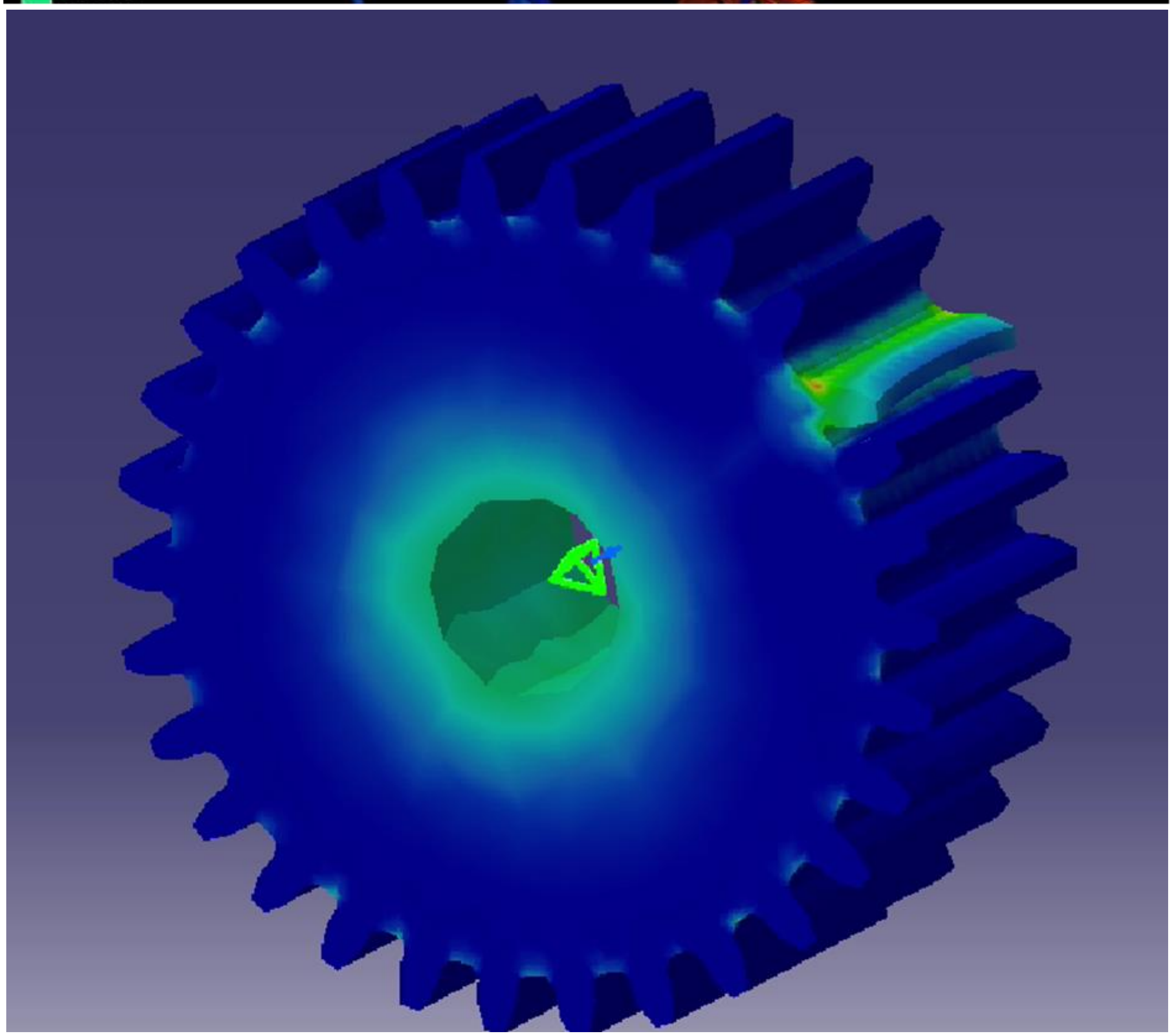
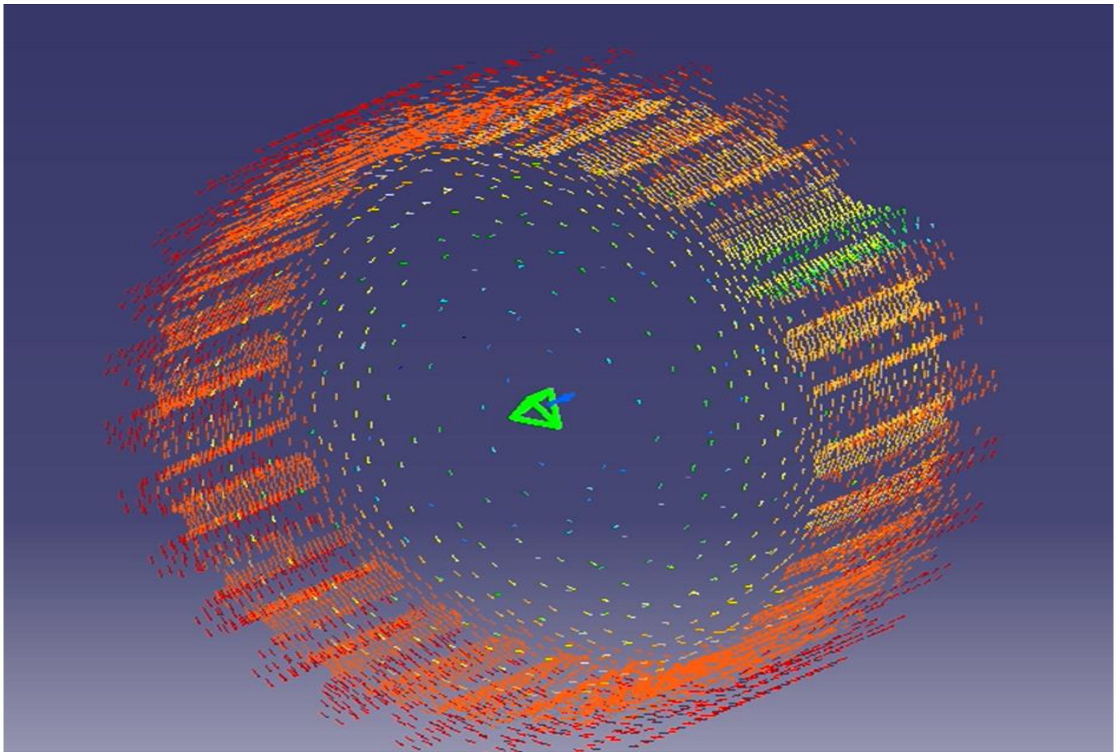
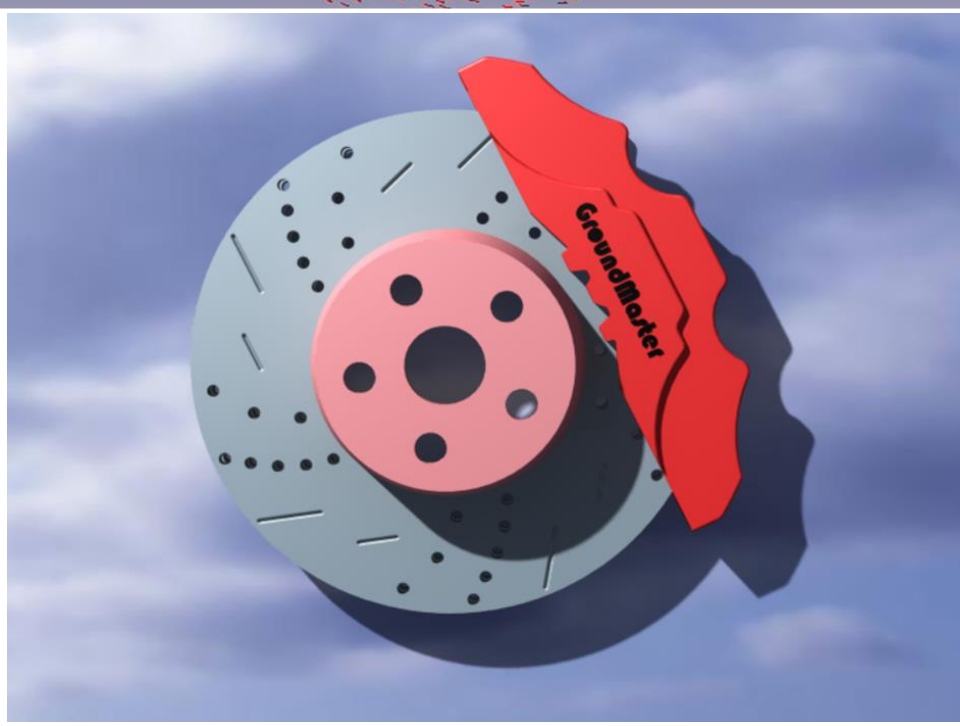
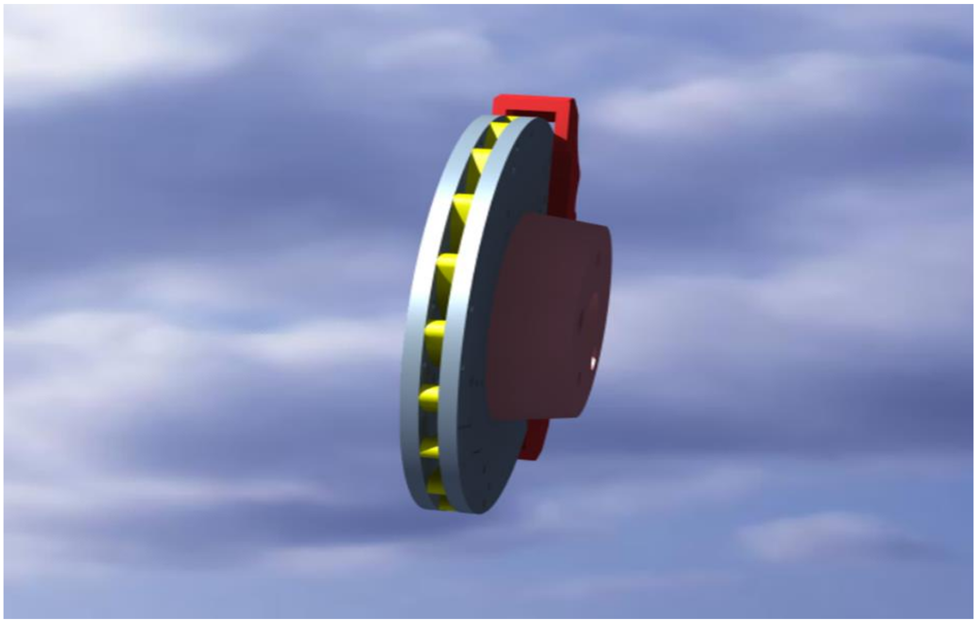





GroundMaster



- **Vehicle mass** = 250 kg
- **Brake disc mass** = 1 kg
- **Initial velocity** = 25 m/s (≈ 90 km/h)
- **Specific heat of cast iron** = 460 J/kg·K
- **Effective brake pressure** = 2 MPa
- **Effective piston area** = 1000 mm^2 (0.001 m^2)
- **Effective disc radius** = 0.12 m
- **Friction contribution from disc assumed as 80%**

1. Braking Force Calculation

Assume:

- Caliper pressure = 2 MPa
- Effective piston area = 2 × 500 mm^2 = 1000 mm^2

$$F_{brake} = Pressure \times Area = 2 \times 10^6 \times 1000 \times 10^{-6} = 2000\,N$$

1. Braking Force

$$F_{\text{brake}} = P \times A = 2 \times 10^6 \times 0.001 = 2000\,N$$

- Effective radius of disc = 0.12 m

2. Braking Torque

$$T = F_{\text{brake}} \times r = 2000 \times 0.12 = \boxed{240\,\text{Nm}}$$

3. Kinetic Energy of the Vehicle

$$E_k = \frac{1}{2}mv^2 = \frac{1}{2} \times 250 \times 25^2 = 78,125\,J$$

80% of this energy goes into heating the brake disc:

$$Q = 0.8 \times 78,125 = \boxed{62,500\,J}$$

4. Temperature Rise in the Brake Disc

$$\Delta T = \frac{Q}{m \cdot c} = \frac{62,500}{1 \times 460} \approx \boxed{135.9^{\circ}C}$$

Metric	Value
Braking Force	2000 N
Braking Torque	240 Nm
Kinetic Energy Dissipated	78,125 J
Heat Absorbed by Disc	62,500 J
Temperature Rise of Disc	**135.9°C**

Thermal Limit of Cast Iron ~500°C (safe)

Dimensions (Standard 26" Wheel)

Parameter	Value
Rim Outer Diameter	~660 mm (26 inches)
Rim Inner Diameter	~610 mm
Tire Width	~38 mm (1.5 inches)
Hub Width	~100 mm
Spoke Count	36 spokes
Spoke Length	~260–270 mm
Spoke Diameter	~2 mm

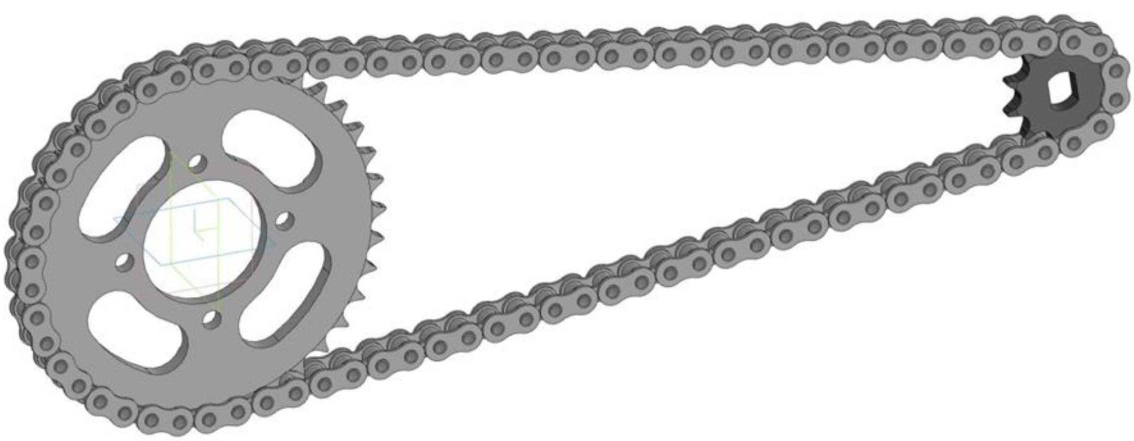
Axle Diameter	~10 mm

Material Properties

Component	Material	Density (kg/m³)	Young's Modulus (GPa)	Yield Strength (MPa)
Rim	Aluminium Alloy	2700	~70	~200–300
Spokes	Stainless Steel	7850	~190	~520–860
Hub	Aluminium or Steel	2700 / 7850	~70 / ~200	250–600
Tire	Rubber (Filled)	~1100	—	—

APPLICATIONS OF THIS DATA:

1. **CATIA Simulation Prep:**
   a. Use above geometry to define part bodies (Rim, Spokes, Hub, Tire).
   b. Apply material properties accordingly in the *Generative Structural Analysis* workbench.
2. **FEA Inputs:**
   a. **Static Load:** 120–250 kg load per wheel (e.g., with rider weight).
   b. **Dynamic Load:** Consider impact from road (1.5×–2× static load).
   c. **Spoke Tension:** ~800–1200 N per spoke (prestressed condition).
3. **Rotational Analysis:**
   a. Max rotational speed for tire: ~800 RPM
   b. Inertia calculation: model as thin-walled ring for simplicity



COMPONENT DETAILS

1. Chain

- **Type:** Roller Chain (likely AISI or ISO standard)
- **Material:** Case-hardened steel or stainless steel
- **Pitch:** Common values include 12.7 mm (1/2"), 15.875 mm (5/8")
- **Applications:** Transfers rotational power efficiently between sprockets

2. Sprockets

- **Driving Sprocket (Large):**

    - Typically mounted on the **engine crankshaft or pedal crank**
    - May have 32–52 teeth
- **Driven Sprocket (Small):**
    - Mounted on the **rear wheel or gearbox shaft**
    - Usually has fewer teeth (e.g., 11–15)

3. MECHANICAL PARAMETERS TO CONSIDER

Parameter	Description
Chain Pitch (p)	Distance between pin center in the chain
Number of Teeth (Z)	On both sprockets
Chain Length (L)	Number of chain links or total length
Center Distance (C)	Between sprocket axes
Tensile Force (F)	Chain tension under load
Rotational Speed (N)	RPM of the driver sprocket

4. Material Assignment

Component	Material	Yield Strength	Density (kg/m³)	Modulus (GPa)
Sprocket	Steel (EN8/4140)	370–600 MPa	~7850	~200
Chain	Hardened steel	900–1200 MPa	~7850	~200

5. Boundary Conditions

Constraints:

- **Fix** the shaft hole of the **driven sprocket**
- Allow rotation for **driving sprocket**

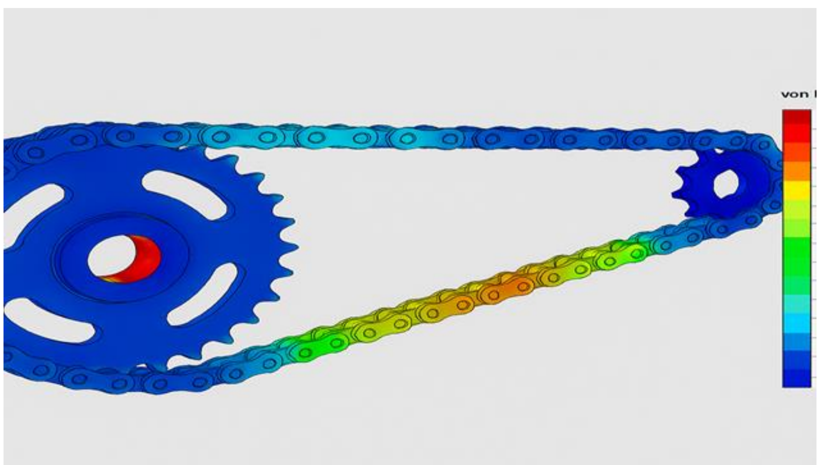
Loads:

- **Torque input** on large sprocket (e.g., 20–100 Nm depending on application)
- **Tensile force** on the upper part of chain from load

CALCULATION

- Chain pitch = 12.7 mm
- Driving sprocket = 48 teeth
- Driven sprocket = 12 teeth
- Input torque = 80 Nm

$$F_{chain} = \frac{T}{r} = \frac{80}{(48 \cdot 12.7/(2\pi))} \approx 84\,N$$



Weight Distribution:

The **main frame** comes in at 7.5 kg, with an additional 2.5 kg for the inner Skedco-type material.

The **mule support**, **handles**, and **stainless-steel joints** bring modular strength without excessive weight.

Our **drive system** — which includes the **chain, sprocket, and EV bolt motor** — adds around 6 kg.

Finally, the **rear wheel and foldable legs** add another 4 kg.

That gives us a total of **just under 33 kg**, which is competitive when you consider that it includes a powered motor and modular support system. The weight is well-balanced across the frame and has been optimized for solo operation in combat terrain.

Component	Weight (kg)
Stretcher Frame	7.5
Skedcko-like Inner Material	2.5
Mule Support Frame	2.5
Front & Rear Handles	2.8
Stainless Steel Shoulder Joint	0.5
Chain and Sprocket	2.5
EV Bolt Motor	3.5
Rear Wheel + Foldable Support Legs	4
Total Weight	**32.8 kg**

Prototype Development & Fabrication

This section outlines the step-by-step process of physically realizing the stretcher from a digital model into a working prototype. The focus is on replicating the final CAD structure using **lightweight yet field-realistic methods** to evaluate deployment, stability, and manufacturability.

Objective

To fabricate a fully functional prototype of the stretcher frame that:

- Matches the CAD dimensions (1.981 m × 0.737 m)
- Includes all essential mechanical elements: foldable frame, wheel system, support legs, and battery/motor housing
- Demonstrates operability under simulated field use

- Allows basic testing of load response and ergonomics

Prototyping Process

Step No.	Process Description
1	Finalized CAD assembly in CATIA V5 (frame, wheels, handles)
2	Segmented components for 3D printing and CNC machining
3	Selected scaled tube elements made from PLA for early-stage modelling
4	3D printed structural joints and mounts using reinforced PLA
5	Motor casing and electronic module modelled using ABS
6	Wheels selected from existing E-bike hub + printed accessories
7	Frame rods manually assembled using threaded rods & epoxy
8	Foldable hinge integrated using bolt-lock mechanism
9	Final assembled prototype tested under static load (120–150 kg range)

Tools and Materials Used

Component	Fabrication Method	Material Used
Main Frame Tubes	Cut and joined manually	PVC/PLA (scaled model)
Joints & Corners	3D Printed	PLA + 40% infill

Handle & Grips	Printed and wrapped	PLA + foam wrap
Electric Motor Housing	3D Printed	ABS
Wheels	Prefabricated E-bike tires	Rubber + plastic hub
Mounting Hardware	Screws, bolts, brackets	Stainless steel

Assembly & Testing

- The prototype was assembled in two main parts (left & right half), joined at a central hinge
- Each section was independently tested for:
  - **Ease of folding and unfolding**
  - **Stability when resting on legs**
  - **Rolling response on level and inclined surfaces**
- Manual load testing was performed using sandbags and steel blocks up to 150 kg

Observations

- Frame supports centralized loads without deflection
- Folding action smooth and repeatable with minor alignment shimming
- Rear-wheel torque attachment simulated with dummy axle
- Vibration dampening not yet functional — needed in full-scale build
- Motor not integrated — space and fixture clearance confirmed only

1. **Original Stretcher Area** (Assume actual stretcher size for full-scale is, say, 2000 mm × 600 mm):

$$A_{\text{original}} = 2000 \times 600 = 1,200,000\,\text{mm}^2$$

2. **Prototype Stretcher Area**:

$$A_{\text{prototype}} = 500 \times 160 = 80,000\,\text{mm}^2$$

3. **Area Ratio**:

$$\text{Scaling Factor} = \frac{A_{\text{prototype}}}{A_{\text{original}}} = \frac{80,000}{1,200,000} = 0.0667$$

4. **Scaled Weight (assuming uniform distribution)**:

$$W_{\text{prototype}} = 0.0667 \times 120\,\text{kg} = 8\,\text{kg (approx)}$$

Step 1: Compare Material Strength

Property	Aluminum (6061-T6)	PLA (typical 3D print)
Tensile Strength	~290 MPa	~60 MPa (varies by print)
Flexural Strength	~276 MPa	~85 MPa (depends on infill, orientation)

Let's use **flexural strength ratio** to scale load realistically:

$$\text{Material Factor} = \frac{85}{276} \approx 0.31$$

Step 2: Apply Both Area and Material Scaling

From earlier:

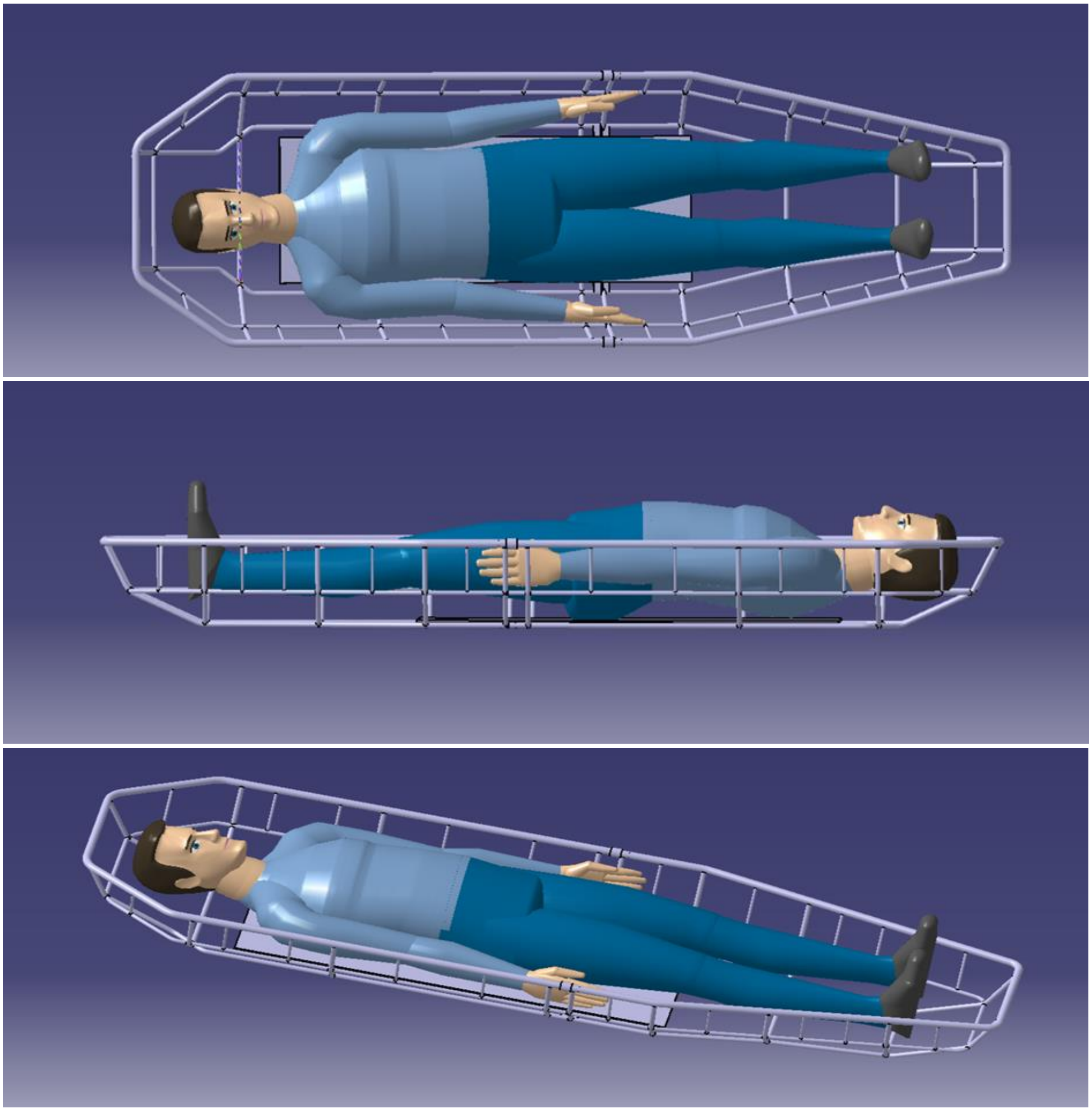
- Area scaling factor = **0.0667**
- Material strength factor = **0.31**

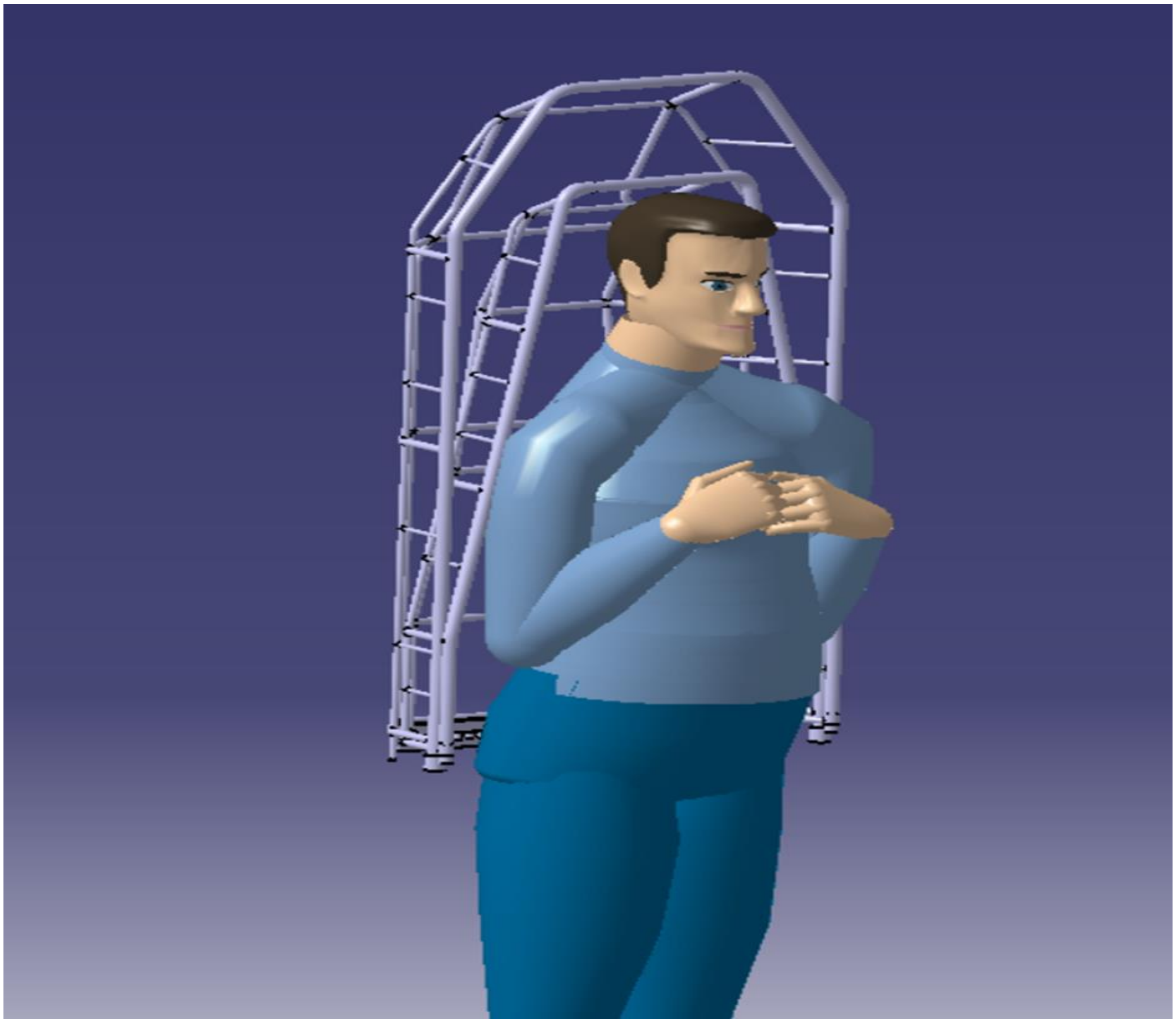
Combined factor:

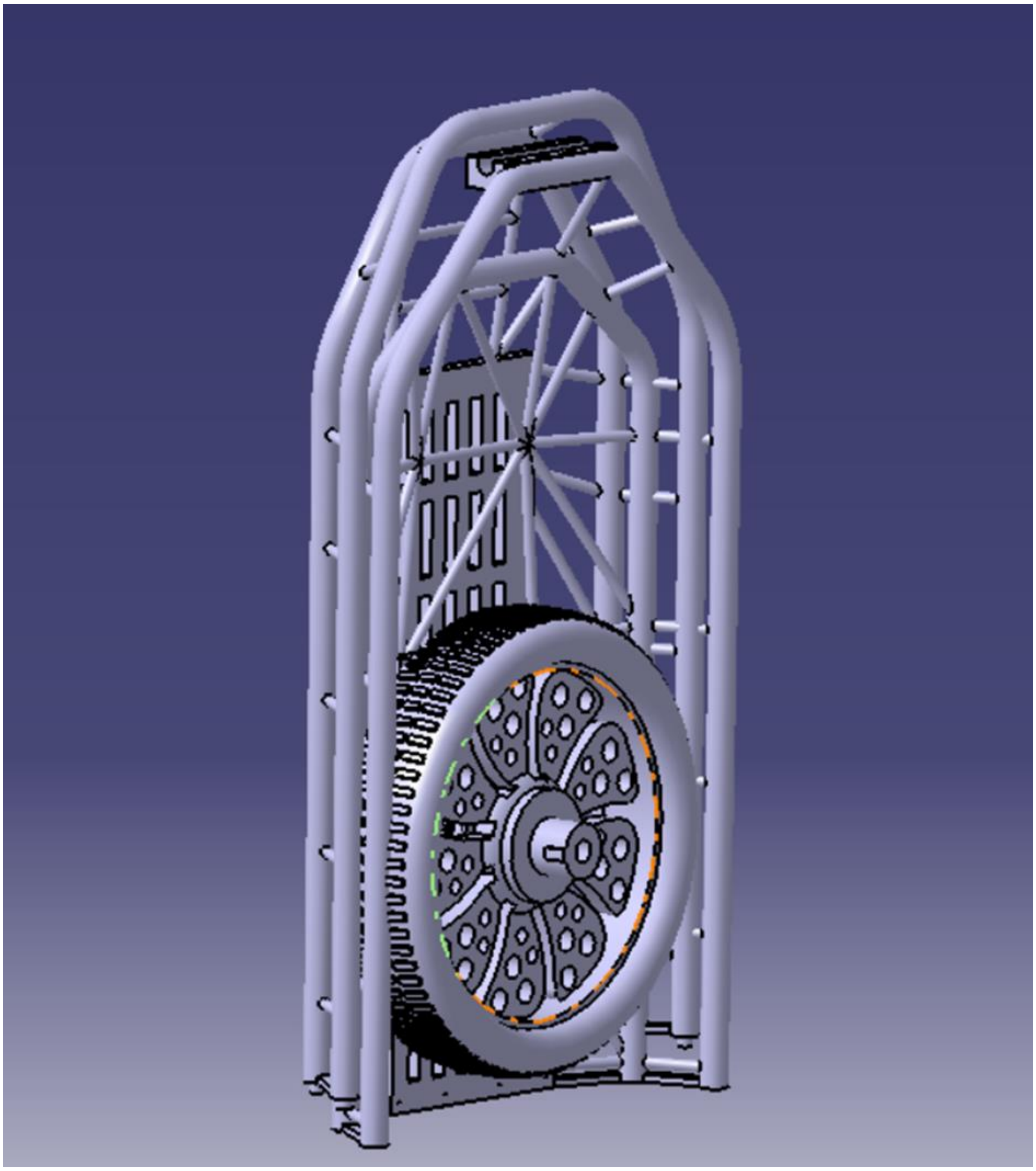
$$\text{Total Scaling Factor} = 0.0667 \times 0.31 = 0.0207$$

Apply this to the original 120 kg:

$$W_{\text{realistic for PLA prototype}} = 0.0207 \times 120 = 2.48\,\text{kg}$$







Discussion, Trade-Offs, and Conclusion

This section reflects on the design outcomes, evaluates material and system-level trade-offs, and provides final recommendations for deployment and future iterations.

Performance Review Summary

Performance Metric	Target Value / Goal	Achieved (Titanium Frame)
Load Capacity	≥ 220 kg	220 kg supported
Safety Factor	≥ 2.0	SF = 4.63
Static Deflection	< 10 mm	~7.9 mm
Buckling Resistance	SF ≥ 2.0	Load Factor ≈ 3.8
Modal Frequency (1st)	> 10 Hz	11.3 Hz
Harmonic Response	No resonance amplification	~1.8 mm peak
Thermal Stress	< 30% of yield	~8.8% of yield (Titanium)
Prototype Load Test	120–150 kg (partial)	Stable under load

Material Trade-Offs

Material	Strength	Weight	Cost	Thermal Perf.	Machinability	Field Durability	Verdict
Titanium	Excellent	Low	Very High	Excellent	Moderate–Poor	Excellent	Best for elite/military
Aluminium	Good	Very Low	Low	Moderate	Excellent	Good	Best for low-cost field use
CFRP	Very Good	Ultra Low	High	Outstanding	Poor	Fragile	Best for drone/digital evac

Design Trade-Offs

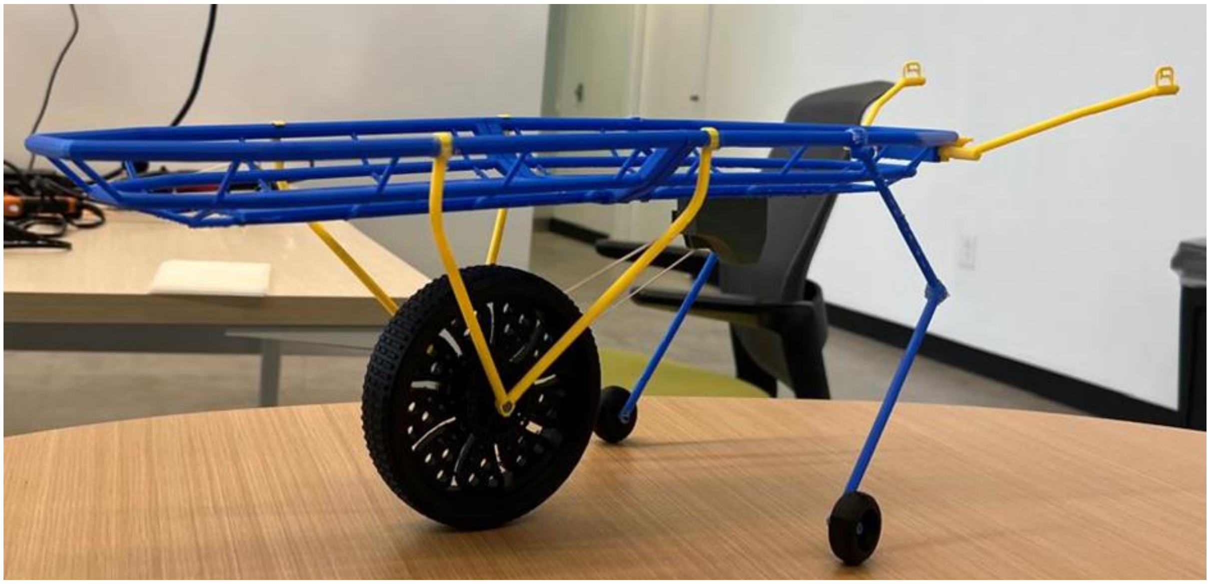
Trade-Off	Decision Made	Justification
Frame Weight vs. Strength	Prioritized structural safety (SF > 2.0)	Battlefield environments demand reliability under shock
Material Cost vs. Durability	Titanium used in base version	For military/defence, performance trumps cost
Compactness vs. Comfort	Folding frame + curved base shell	Fits narrow spaces, holds casualty securely
Complexity vs. Field Repairability	Avoided integrated electronics in frame	Electronics modularized for easier maintenance

The UrbanEVac stretcher successfully meets the NATO challenge requirements for a compact, rugged, and field-deployable evacuation system suitable for congested, high-risk zones. The project demonstrated excellence in CAD modelling, simulation-driven design, structural optimization, and material evaluation.

Titanium offers the highest strength-to-weight performance, while aluminum provides a more affordable manufacturing path. CFRP opens doors for high-mobility or drone-supported evacuation, albeit with maintenance limitations.

This stretcher system is ready for next-stage development, including:

- Real-world operational testing
- Sensor-motor integration
- Mass-manufacturing evaluation
- Deployment via vehicle or autonomous carriers

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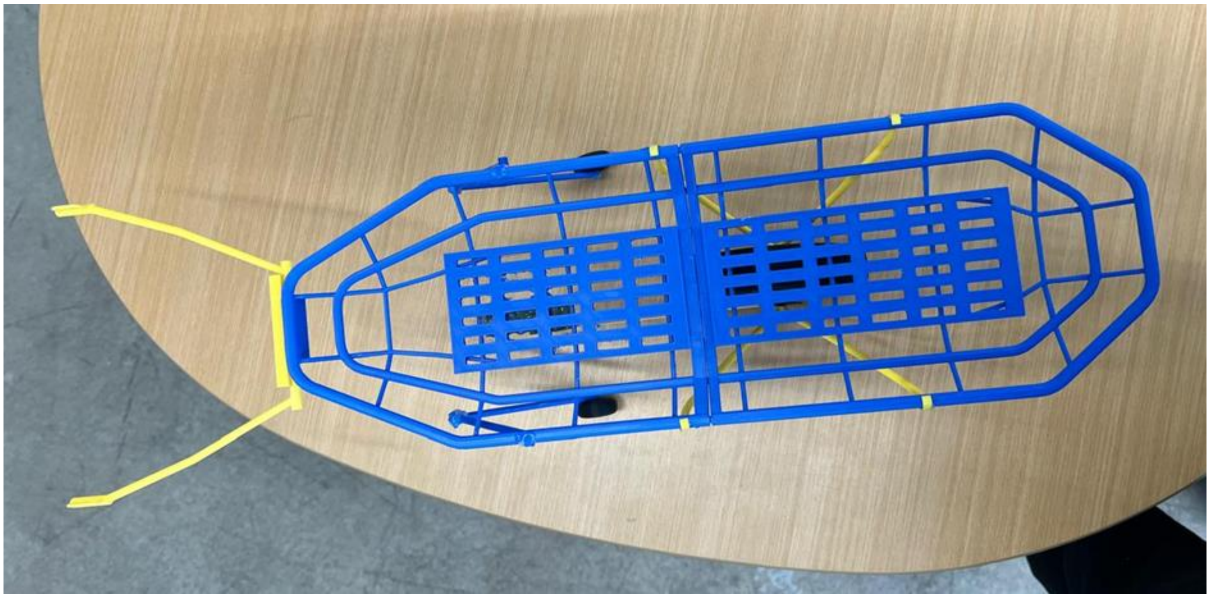

6. Market Entry Strategy and Sales Plan

Our market entry strategy will initially focus on military acquisition branches as the primary customer base, followed by expansion into disaster relief organizations and first responder agencies. We will also strategically engage with consultants who have established relationships with military buyers, leveraging their expertise to navigate the complex procurement processes and facilitate early deals.

Our product offering is a **motorized, foldable stretcher** designed specifically for military and emergency situations. It is engineered to be durable, easy to operate, and efficient, with motor assistance to aid movement across rough terrains and in situations requiring rapid evacuation. Its foldable design ensures compact storage and transportation, making it ideal for deployment in field operations where space and speed are critical.

The pricing strategy reflects the premium value provided by the powered stretcher. Although the upfront price will be higher compared to traditional solutions like manual stretchers, gurneys, Skedco, and litter, it is justified by significant operational benefits. By reducing the required manpower by at least 50%, enhancing rugged performance, and improving deployment speed, UrbanEvac offers long-term cost savings and operational efficiency. The value proposition—lower labor costs, faster casualty evacuation, and reduced physical strain—will be central to how we position the product during sales engagements with procurement officers and disaster response agencies.

Our primary distribution channel will be direct sales to military and governmental organizations. We will showcase the stretcher at major military expos, defense trade shows, and disaster relief conferences, where decision-makers can see live demonstrations. By partnering with consultants who already serve defense procurement circles, we aim to streamline the introduction process and maximize early adoption.

Promotion will initially be highly targeted, focusing on relationship-building and direct product demonstrations. We will participate in key trade shows and expos, conduct live demonstrations to prove the stretcher's performance under realistic conditions, and create online platforms with detailed product information, specifications, case studies, and testimonial videos to build credibility. In-person engagement with military buyers, along with a strong online presence, will drive initial market traction.

Product

UrbanEvac offers a military-grade, lightweight, foldable, and durable stretcher designed for efficient casualty evacuation in hostile environments. It combines motorized assistance with a collapsible frame, allowing medics or soldiers to transport injured personnel over rubble, stairs, and uneven terrain with less effort and faster response times. The stretcher is built to endure combat conditions without sacrificing ease of use or speed of deployment, directly addressing gaps in current evacuation methods.

Price

Our pricing strategy is competitive, and value driven. It reflects the product's superior durability, ruggedness, and operational advantages over traditional manual stretchers and Skedco systems. Pricing will be based on production costs, the clear manpower savings it offers, and its ability to reduce injuries and evacuation time. While the initial purchase price will be higher than manual stretchers, our approach will focus on demonstrating the long-term cost savings from improved efficiency, reduced labor needs, and lower casualty rates due to faster extractions.

Promotion

Promotion will focus on targeted engagement with military procurement officers, NATO agencies, and defense decision-makers. We will actively participate in defense and medical response expos, showcasing the stretcher's ruggedness and ease of use through live demonstrations. Additionally, we will develop digital and print marketing tailored to military procurement audiences, using clear visuals, real-world testing footage, and field testimonials. Promotional efforts will focus on credibility, functionality, and ease of operational integration rather than mass-market tactics.

Place

Our primary sales channel will be direct sales to military procurement agencies within NATO countries and allied forces. We will also explore partnerships with defense contractors who can integrate the UrbanEvac stretcher into broader battlefield solutions, such as casualty evacuation kits or tactical medical systems. These partnerships can help embed the stretcher into larger procurement contracts, creating stronger opportunities for scaling distribution.

Persuasion Strategy

Our sales and marketing efforts will highlight key operational advantages. We will emphasize how the UrbanEvac stretcher increases manpower efficiency by requiring fewer soldiers for casualty evacuation, allowing units to stay combat effective. We will demonstrate its resilience and ease of use in harsh battlefield conditions through field trials and live demos. Finally, we will present testimonials from military personnel who have tested the stretcher, building trust through real user experiences and proof of performance under pressure.

This approach ensures that decision-makers view UrbanEvac not just as a piece of equipment, but as a critical tool for saving lives and maintaining combat strength.

7. Operational Plan

UrbanEvac's operational focus is on building a lightweight, foldable, and durable power-assisted stretcher that meets the needs of battlefield and disaster environments. Our development work centers on keeping the design simple, rugged, and intuitive, reinforcing key stress points like the back legs for stability, and validating the motor system for harsh use cases. We are currently completing CAD designs and early prototypes, with plans for structured field testing over varied terrains like rubble, stairwells, and slopes.

Material sourcing plays a critical role. We are working with reliable vendors for titanium frames, rugged wheels, motor systems, and control electronics, with backup suppliers identified to prevent delays. Manufacturing will initially focus on small production batches suitable for pilot testing. Quality control will be strict, ensuring that each unit meets or exceeds military standards for durability and field performance.

Testing and validation will involve stress tests under real-world conditions, rapid deployment simulations under time pressure, and user feedback sessions with frontline personnel. If complex features fail under field testing, we will simplify the design while maintaining core functionality, ensuring reliability in battlefield conditions.

We will pursue regulatory compliance early, targeting key certifications like MIL-STD ruggedness, CE marking for Europe, and FDA clearance in the U.S. if necessary. Consultants specializing in defense product certifications will support our compliance strategy from the prototype stage.

Production will ramp up gradually. We aim to complete final working prototypes within two months, conduct rigorous field testing, and deliver initial units for pilot programs with selected military units by month six. If the pilot phase is successful, we will scale to low-volume production batches of 50–100 units, with broader manufacturing expansion tied to confirmed procurement contracts.

Section	Details
Product Development	Lightweight, foldable, durable, power-assisted stretcher
Material Sourcing	Titanium frames, motor systems, backup suppliers secured
Manufacturing Approach	Low-volume production, defence-certified quality control
Testing and Validation	Field testing on rubble, stairs, slopes; rapid deployment drills
Regulatory Compliance	Target MIL-STD, CE marking, possible FDA approval; ISO 13485 quality process
Production Ramp-up	Pilot production (2–3 units), scaling to 50–100 units based on pilot success
Logistics and Distribution	Direct shipment to agencies, future partnerships with defence contractors
Risk Management	Dual sourcing, simplicity-first design, early compliance, user-friendly training
Timeline and Milestones	Prototype complete (Month 2), Testing (Month 2–4), Pilot Launch (Month 6), First Sales (Month 6–8)

Logistics will initially rely on direct shipment to military and disaster response clients, with fulfillment managed through experienced defense logistics partners. As we scale, we plan to partner with larger defense contractors to integrate UrbanEvac into bundled tactical and medical kits.

Risk management is central to our plan. We are mitigating material risks through dual-supplier sourcing, design risks through simplicity-first engineering, regulatory risks through early compliance work, and training risks by preparing straightforward user manuals, videos, and live demos. Every phase of operations is structured to maintain flexibility while ensuring product reliability.

Finally, we have set clear milestones for the next twelve months to guide the project. Prototype completion, field testing, compliance submissions, pilot program launches, and first sales contracts are all scheduled and tracked to ensure disciplined execution.

8. Cost Structure

UrbanEvac's core production costs are based on sourcing high-grade materials and maintaining strict quality standards. The direct production cost per unit is estimated at approximately **$7,958.65**. This includes costs for the titanium frame, motor and battery systems, rugged central wheel, braking mechanism, control electronics, and labor for assembly and testing. Also, after exploring manufacturing options in India, we estimate the cost of our at-scale product to be around **$3000.**

Additional operational costs include customer acquisition efforts such as participating in defense expos and production of printed materials and video demonstrations (~$500). Research and development expenses for CAD design, prototype testing, and field trials add about **$6,000–$7,000** to early-stage costs. Administrative costs for company formation, legal setup, and documentation are projected at around **$1,800**.

Break-even is expected within the first **50 units** sold if bootstrapped, or within **30 units** if initial grant support or early investment is secured.

Validation of Pricing

We have spoken with military and disaster relief professionals. They told us they are willing to pay more for a product that is durable, easy to use, and reduces the need for extra staff. Many said that the current options, like Skedco, are useful but have limitations that our product could fix. These conversations confirmed that our price point is acceptable, as long as the product can deliver the promised benefits.

9. Recommendations and Interview Insights

Throughout the development process, we engaged with a diverse panel of domain experts from military, medical, academic, and engineering backgrounds. Their insights shaped critical aspects of our solution, from initial design considerations to material selection and deployment feasibility.

- **Col. Harvey Pynn (Colonel, UK Military):** Stressed the need for military medical technologies to rapidly evolve. He emphasized adaptability, interoperability, and alignment with modern defence innovation pipelines as essential pillars of an effective solution. He also validated the solution design and dimensions.
- **Charlie Fulton (U.S. Army Infantryman):** Provided frontline user perspective, advocating for a design that is intuitive, lightweight, and easy to carry, critical attributes in high-stress combat scenarios.
- **Alexander J. Cramer (Physician Assistant):** Recommended a modular and low-failure design, emphasizing compatibility with standard military transport systems to facilitate real-world deployment.
- **Col. Sohrab Dalal (Medical Systems Strategist):** Urged a lean development approach, suggesting we focus on must-have features initially, and iterate based on field impact and feedback.

- **Mark Riley (Chief Defence Strategist):** Encouraged exploration of U.S. Army Medical Acquisition standards to ensure alignment with real-world procurement and deployment protocols.
- **Jake McCullen (Medical Recruiter, U.S. Army):** Set clear physical and performance parameters: evacuation solution must support up to 480 lbs, and incorporate knee-height wheels or drag systems to minimize strain and maximize speed.
- **Alyssa Murphy (Director, Multidisciplinary Design Program):** Emphasized rapid prototyping using lightweight materials and simple mechanisms. She advised leveraging ready-made parts to validate core functionality early.
- **Jonathan Murray (Medical Systems Strategist, NATO):** Highlighted the life-saving value of reducing evacuation time from point of impact and the importance of mitigating risk to medics during casualty extraction.
- **Prof. Jaafar El-Awady (Mechanical Engineering):** Provided technical oversight and validation, reviewing our simulations and calculations to ensure feasibility and alignment with engineering best practices.
- **Prof. Ryan Hurley (Mechanical Engineering):** Offered expertise in material properties, guiding accurate selection and modeling for components made from titanium, aluminum, and carbon fiber-reinforced polymers (CFRP).
- **U Meenu Krishnan (Postdoctoral Researcher, Mechanical Engineering):** Verified mechanical analyses and structured the CATIA V5 test sequences, including static bending and thermal simulations.
- **Capt. Praveen Kr. Singh (Indian Army):** Emphasized rigorous real-time problem validation through field reconnaissance and continuous stakeholder feedback to ensure our solution remains grounded in practical utility.

10. Next Steps

- Complete final prototype and perform field tests simulating rubble-laden evacuation.
- Submit pilot proposal for evaluation through JHub MED and US Army's innovation channels.
- Create technical documentation and user training modules for integration into combat medic training.
- Scale manufacturing discussions and establish unit pricing, logistics, and packaging requirements.
- Explore follow-on markets such as civilian disaster response and emergency medical services.

11. Conclusion

UrbanEvac represents a groundbreaking advancement in battlefield casualty evacuation, specifically engineered to address the urgent challenges of modern urban warfare. With its motor-assisted, collapsible, and terrain-adaptive design, UrbanEvac empowers a single medic to rapidly and safely extract wounded personnel from complex, dangerous environments, tasks that traditionally required a team of four to six soldiers. This innovation not only saves critical time in reaching higher medical care (improving survival rates) but also preserves combat effectiveness by reducing the manpower and physical toll of manual evacuations.

Backed by rigorous stakeholder input, engineering validation, and clear operational benefits, UrbanEvac fills a long-standing capability gap in NATO and allied operations. It outperforms legacy solutions like the Skedco and Talon II stretchers in key areas such as terrain mobility, deployment speed, and personnel efficiency. Additionally, its modularity and rugged construction position it as a scalable asset across military, humanitarian, and emergency response sectors.

From a development and business perspective, UrbanEvac is both feasible to manufacture and economically viable, leveraging commercial off-the-shelf components and well-established fabrication methods. With a targeted go-to-market strategy, partnerships with defence innovation programs, and protection of intellectual property, UrbanEvac is ready to move from prototype to pilot deployment and beyond.
In sum, UrbanEvac is more than a product, it’s a tactical force multiplier, a medic’s ally, and ultimately, a life-saving innovation in the most critical minutes of combat. With the right support, it has the potential to transform battlefield medicine and redefine global standards for casualty evacuation.

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