Team 21: SALUS
ME 292C / DESINV 190
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Analytical Prototype/Model

To develop our smart pepper spray prototype, analytical modeling plays an important role in optimizing both safety and performance. Two primary areas we wanted to focus was **Finite Element Analysis (FEA) for structural integrity** and a **Drop Test for reliability**. These models support our design decisions and enable early validation of core functional requirements.

First, we utilize FEA analysis to evaluate the mechanical integrity of the pressurized pepper spray container under various stress conditions, particularly during actuation and deployment. This analysis specifically focuses on external forces without failure, enhancing user safety and product reliability.

Secondly, we performed two drop tests utilizing FEA analysis to evaluate the structural integrity of the pepper spray shell. The drop heights were based on the assumption the user would most likely drop the device when it is at hip level or chest level. This analysis aims to confirm that the device does not yield when dropped at different heights.

Together, these models guide key design choices such as material selection, geometry optimization, and component sizing, while minimizing the need for costly physical iterations.

1. “Grab Test”

Motivation/Purpose: The motivation behind this analytical model stems from the critical need to ensure structural integrity and user safety in high-stress situations. A self-defense device like a smart pepper spray is likely to be used under intense psychological pressure, during which users may exert excessive or unintentional force on the device. This could include tightly gripping, squeezing, or even dropping the device while trying to activate it quickly.

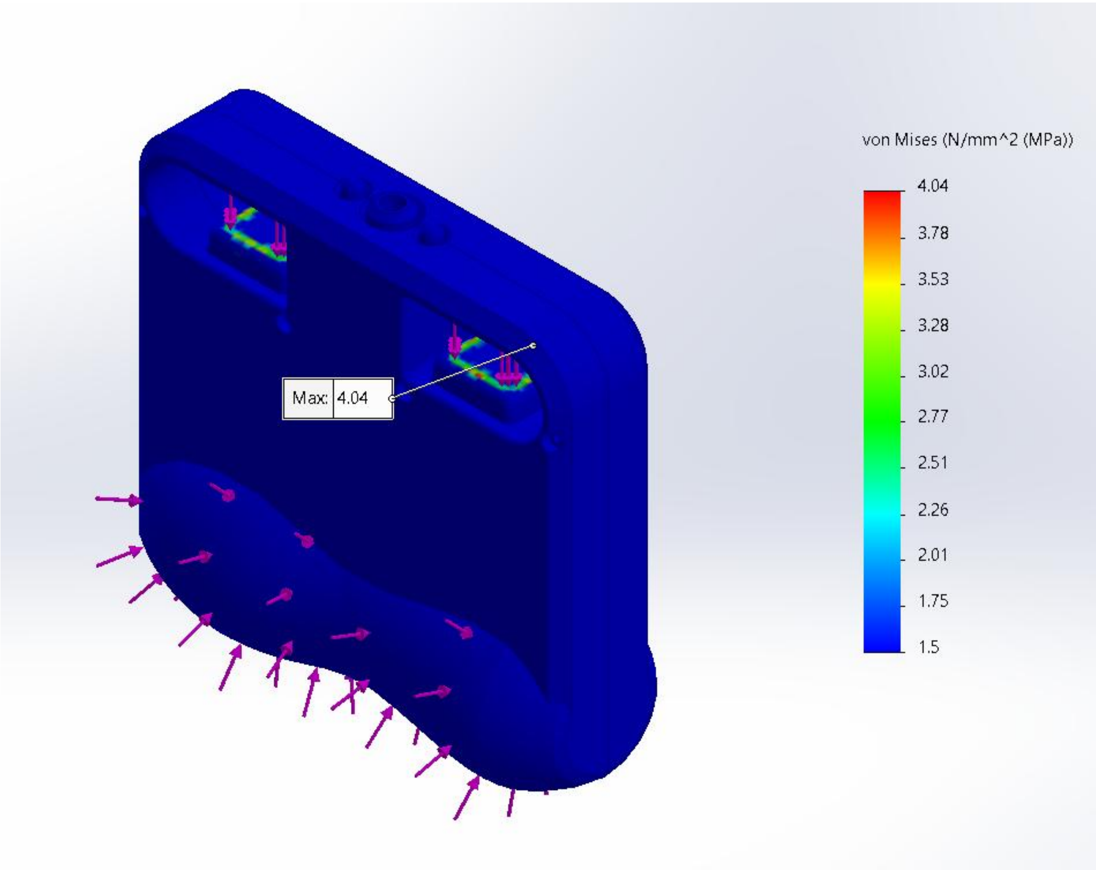
As a result, the design must incorporate a high safety factor well above typical consumer product standards. Structural failure during a moment of crisis would not only render the device ineffective but could also pose direct harm to the user. We plan to apply Finite Element Analysis (FEA) to evaluate the mechanical response of the pepper spray housing and internal components under worst-case loading scenarios.

By quantifying stress concentrations and identifying potential failure points, this model helps ensure the product is robust, reliable, and durable, even in unpredictable real-world conditions. This analysis directly informs decisions on material selection, wall thickness, and overall geometry, all of which contribute to maximizing the product's functional safety and user confidence.

Model Documentation:

- Assumptions: the user will apply forces on the handle in the highlighted area.

In addition, for simulation, we will assume a uniformly distributed load of **50kg,** as typical men's grip strength is around ~50kg. Which translate to approximately 500N.



The simulation showns that the maximum stress applied to the model is only 4 MPa which is way below the yield strength of the ABS plastic (40~50MPa). This value indicates the safety factor of ~10 which is way above the safety standard.

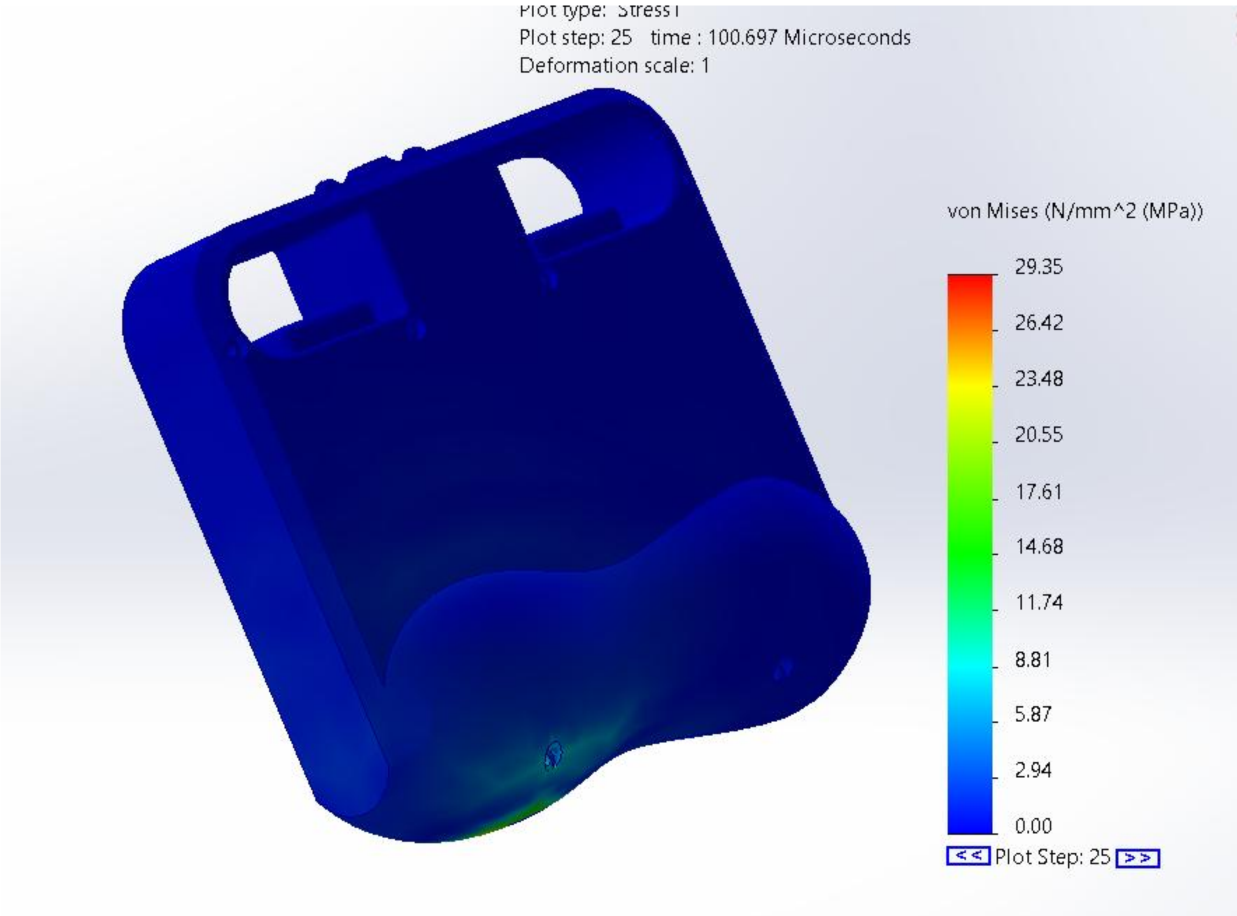
Key Findings

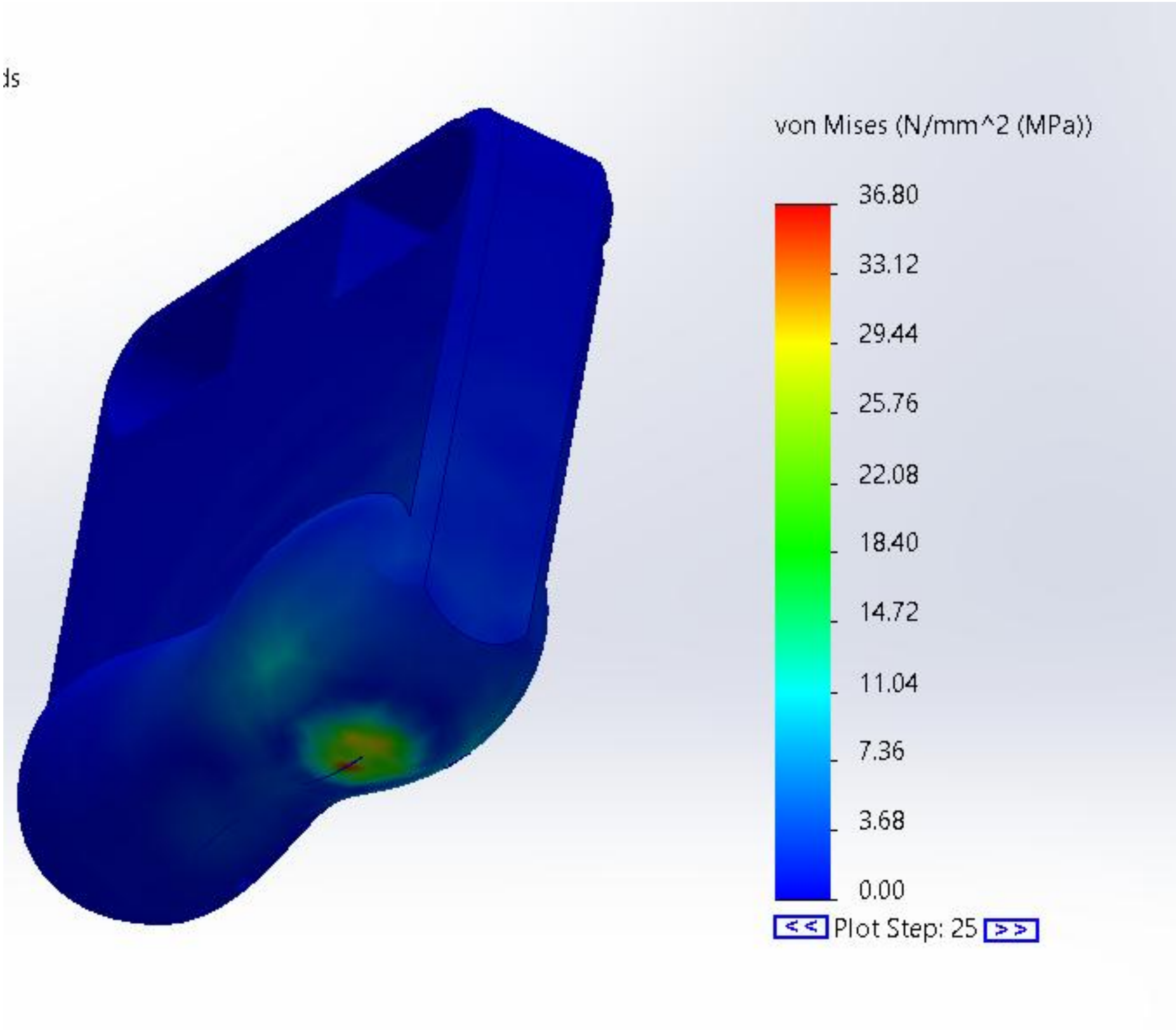
- Finite Element Analysis (FEA) was conducted assuming a maximum gripping force of 500 N (equivalent to ~50 kg)
- The stress was applied to user contact areas identified from typical usage grip zones.
- Simulation results show a maximum von Mises stress of 4.04 MPa, which is significantly lower than the yield strength of ABS plastic (40–50 MPa).
- The calculated safety factor is approximately 10, indicating robust structural integrity and high resistance to failure even under extreme user-applied forces.
    - These findings validate the mechanical reliability of the pepper spray housing, ensuring safe and durable performance in high-stress situations.

2. Drop Test

Another Concern was the integrity of the shell itself. If it were to be dropped, would it be strong enough to absorb the impact without fracturing?

In order to understand this a drop simulation was conducted in SolidWorks Simulation. A 3 ft and 5ft simulation was conducted, 3ft which assumes the spray was dropped at hip height and 5ft assuming it was dropped from chest level.





These simulations show that at 3ft the maximum stress was found to be 29.35 MPA and 5ft was found to be 36.80 MPA. Given that the yield strength of ABS is (40 - 50 MPA), this design should survive impacts from 3 ft and 5ft.

Key Findings

- A Finite Element Analysis (FEA) drop test was conducted at hip height and chest height, respectively 3 feet and 5 feet.
- The simulation assumes an perfectly rigid floor, providing a worst case scenario for contact
- Simulation results show a maximum von Mises stress of 29.35 and 36.8, which is below than the yield strength of ABS plastic (40–50 MPa).
- The calculated safety factor is greater than 1, indicating that the device meets the necessary bottomline for safety.

- These findings validate the mechanical reliability of the pepper spray housing after drops but do indicate room for improvement.
- Results will most likely indicate lower stress when the casing is fully packed with electrical components.