ME 338 Machine Elements Engineering Design Project (EDP)
Final Design Report (FDR)

1. **Team Name:** Houston Dynaco

2. **Teammate Names (LAST, First) and Role/Responsibility**

Teammate (LAST, First)	Role/Responsibility
Salazar, Ethan	Project Manager
Saldana, Eli	Fabrications Engineer
Thind, Tegh	Test Engineer
Khatlani, Ammaar	CAD Engineer
Draksharam, Sidharth	Lead Designer

3. **(25 pts) Vehicle Build Specifications:** Briefly describe your 'wheels-down' final build. Explain what your team featured or focused on in the final design. Provide graphics and photos with descriptive captions depicting the vehicle design elements and manufactured vehicle components. Using correct units, provide data and details on the vehicle including:

   a. Dimensions and Layout (number of wheels, wheelbase, track width)
      i. 4 wheels
      ii. 247.5mm wheelbase
      iii. 147mm inch track width
   b. Wheels (size, style, mounting type, composition)
      i. 63mm inch OD
      ii. Race car style
      iii. Mounted with small axles and screws
      iv. Rubber composition
   c. Chassis (material, manufacturing method, mass)
      i. PETG
      ii. Additive manufacturing (3D printing)
      iii. 300g
   d. Powertrain (drive configuration, transmission type, final gear ratio)
      i. RWD
      ii. No transmission
      iii. 4.55:1
   e. Steering and suspension (configuration, type, maximum steering angle)
      i. FW steering
      ii. Ackerman
      iii. 40-degrees max steering angle
   f. Electronics (make-model of all components)
      i. Motor – traxxas stinger 20 turn
      ii. Controller/Receiver – spektrum dx3 channel 2.4 Ghz Dsmr
      iii. Servo – Miuzei mz996
      iv. Battery – Eco Power NiMh battery
   g. Performance (measured values for curb weight, power to weight ratio, acceleration, top speed, deceleration, ground clearance, turning radius, range)
      i. 730g curb weight
      ii. 28.8 W/kg power to weight
      iii. 2.9 m/s^2 acceleration
      iv. 27mph top speed (ideal)

v. 1.8 m/s^2 deceleration
vi. 6.25mm ground clearance
vii. 711.2mm turning radius
viii. Range = 9 miles runtime = 28 mins

4. **(25 pts) Vehicle Design Specifications:** Briefly describe the theory, modeling, and experimentation used to design and build the three major subsystems (chassis, powertrain, steering). As an example, with a vehicle steering system, there is a governing equation used to calculate the wheel angle to produce a desired turning radius (theory). This relationship could be used to calculate a range of maximum angles to produce a range of minimum turning radii (model). And finally, a rolling chassis test could be used to determine the vehicle turning radius (experiment). Comment on the agreement of theory, modeling, and experimentation for the three main subsystems.

Chassis Subsystem
Theory: The design of the chassis aims to provide a lightweight yet rigid structure to support the components and withstand forces during operation. The aerodynamic "F1 vibe" design helps reduce drag and stabilize the vehicle. Basic principles of structural mechanics (e.g., beam theory) were used to ensure rigidity while minimizing weight. The 3D-printed material was selected to provide adequate strength for the expected loads while keeping the weight low.
Modeling: The chassis was CAD-designed to optimize geometry for strength and aerodynamics. Finite element analysis (FEA) was used to evaluate stress distributions under loading conditions such as motor torque and cornering forces. The shape of the chassis was inspired by F1 cars, emphasizing a low center of gravity and balanced weight distribution.
Experimentation: After printing, the chassis underwent structural integrity tests, including drop tests and load testing, to ensure it could handle forces from the motor and turning. Observations from rolling chassis tests confirmed that the 3D-printed material maintained structural stability during operation.
Comment on Agreement: Theoretical predictions from FEA modeling closely matched experimental results, confirming that the chosen geometry and material were suitable for the application.

Powertrain Subsystem
Theory: The powertrain comprises a motor connected to the rear axle via a spur and pinion gear system. The governing equation for torque transmission is $T = r \cdot F$, where T is the torque, r is the gear radius, and F is the force transmitted by the gear teeth. The gear ratio was calculated to ensure efficient power delivery while balancing speed and torque requirements.
Modeling: The gear ratio was optimized using calculations to achieve the desired vehicle speed and acceleration. Motor specifications, such as voltage and current limits, were used to estimate the power output and resulting rear-wheel force. Computational modeling was employed to evaluate gear mesh efficiency and predict drivetrain losses.
Experimentation: The powertrain was tested by running the motor at various speeds and measuring the vehicle's acceleration and top speed. Testing confirmed that the chosen gear ratio provided sufficient acceleration and matched theoretical predictions for top speed.
Comment on Agreement: Experimental results aligned with theoretical and modeled outputs, indicating the motor and gear system functioned as intended.

Steering Subsystem
Theory: The steering system uses a servo motor connected to a linkage system that rotates the front wheels. The governing equation relates the wheel angle θ to the turning radius R: $R=L/\tan(\theta)$ where L is the wheelbase. Calculations determined the maximum and minimum turning radii based on the servo's range of motion.
Modeling: The geometry of the steering linkages was designed in CAD to optimize steering angles while maintaining mechanical simplicity. Servo specifications were used to model the angular displacement of the front wheels. A range of turning radii was simulated to ensure sufficient maneuverability.

Experimentation: Rolling chassis tests were conducted to measure the turning radius at various servo inputs. Adjustments were made to the steering linkages to fine-tune alignment and ensure smooth operation. The experimental turning radius closely matched the modeled values.
Comment on Agreement: The modeled and experimental data for turning radii showed strong agreement, validating the design of the steering system.

Overall, the theory, modeling, and experimentation for all three subsystems were consistent. The iterative process of design, simulation, and testing allowed for an efficient and effective vehicle build.

5. **(25 pts) Schedule**: In outline format depicted below, update the schedule of your RC racecar including details on the status of all major phases:

   a. Design Phase: (from-to) – COMPLETE
   i. 08/26/2024 – 09/30/24
   b. Build Phase: (from-to) – COMPLETE
   i. 09/30/2024 – 11/11/2024
   c. Test Phase: (from-to) – COMPLETE
   i. 11/11/2024 – 12/02/2024
   d. Deliver Phase (from-to) – COMPLETE
   i. 12/02/2024 – 12/10/2024

6. **(25 pts) Cost**: In outline format depicted below, calculate the cost of your RC racecar including details on prices, identified source, availability, and order status of all major subsystems:

   a) Wheels
      a. $25
      b. Amazon
      c. Readily available
      d. Ordered and arrived
   b) Chassis
      a. Free
      b. Made at TIW
      c. Readily available
      d. Final draft created
   c) Powertrain
      a. $15
      b. Ordered on amazon and bought at local hobby shop (spur gear, pinion gear, axle shaft, shaft collars)
      c. Readily available
      d. Final assembly done
   d) Steering
      a. $5
      b. Ordered on amazon and assembled at TIW (shafts, nuts, bolts)
      c. Readily available
      d. Final assembly done
   e) Electronics
      a. N/A (provided)
   f) Labor
      a. Design at $55 per hour
         i. around 5 hours = $275
      b. Fabrication at $35 per hour
         i. around 20 hours (3d printing, assembly) = $700

    c. Testing at $45 per hour
        i. around 2 hours = $90

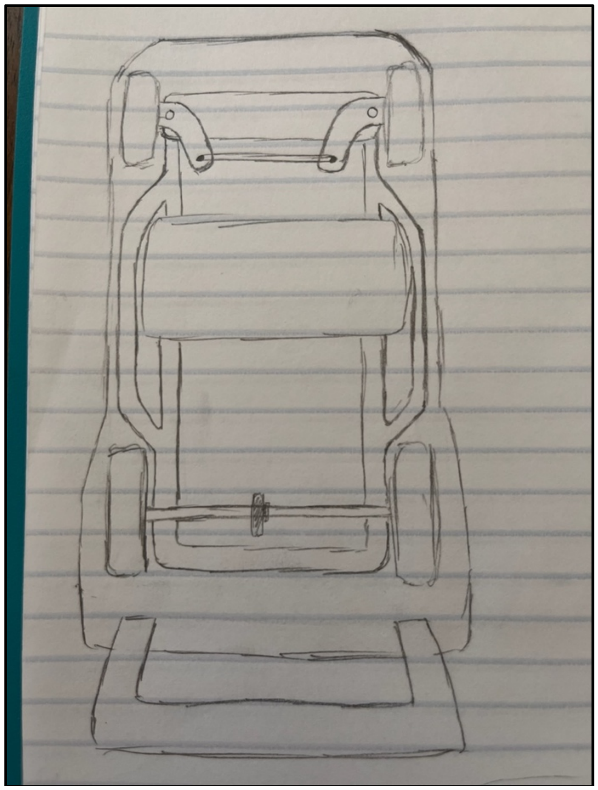
7. **Results**: Based on observations and performance at the Golden Gear race, state the results of racing at Shigley Speedway.

    a. Fastest lap [sec]: 7.6 seconds
    b. Races completed [#]: 1
    c. Laps completed [#]: 5

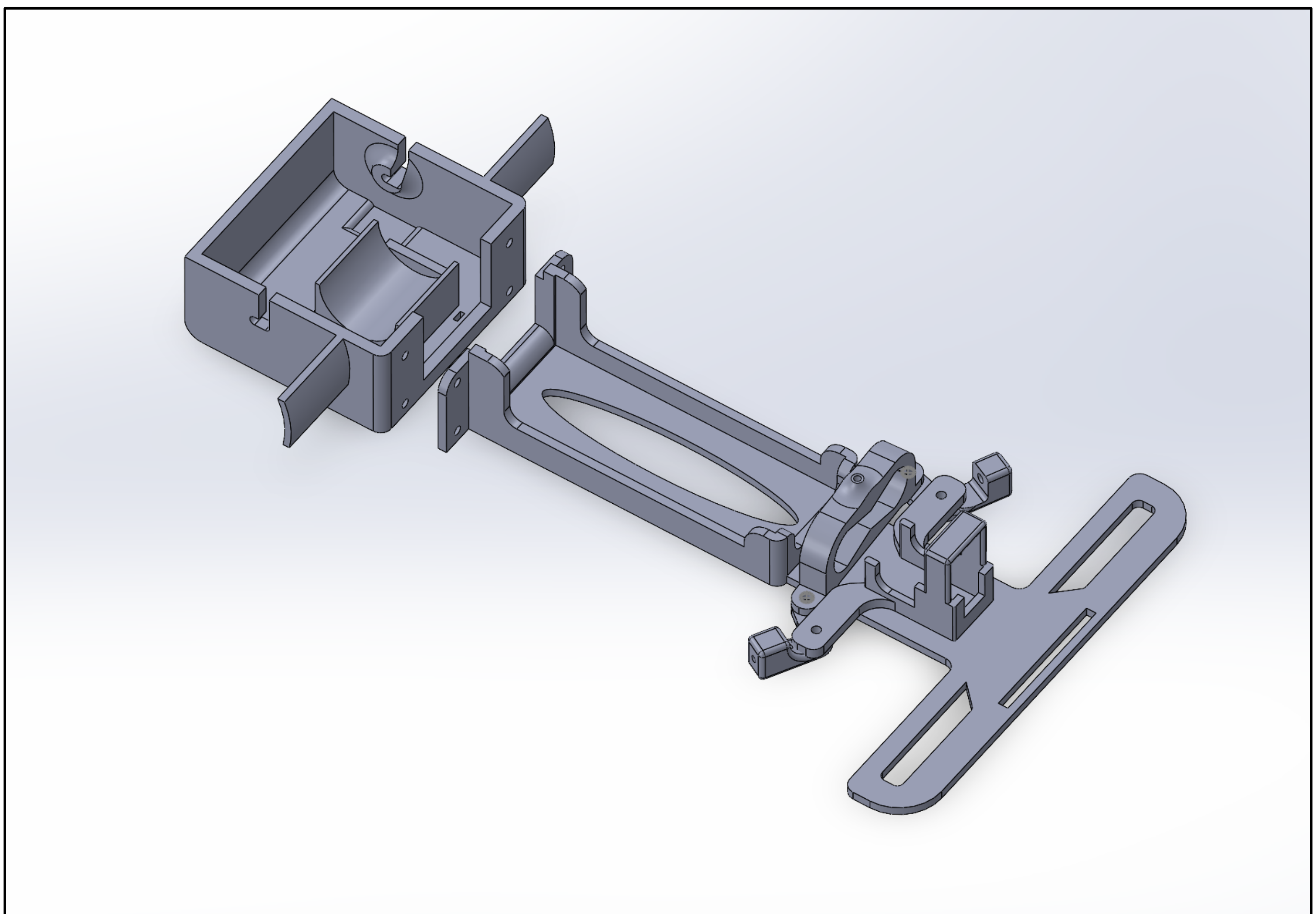
    d. Post-race car status: Powertrain inoperable after race. Back axle came loose, and the clearance was not allowing the back axle to rotate. Likely source of error was the spacers used to allow for back clearance. Use of suspension would likely solve this issue.

    e. Reflection: Reflecting on the RC car design project, we thoroughly enjoyed the creative freedom and technical challenge of designing and CADing the chassis and shell. It was rewarding to see the concept materialize into a functioning car, especially knowing it was built without suspension, which added complexity to achieving durability and performance. We're most proud of how the design balanced functionality and simplicity, particularly the integration of the durable item box, ensuring robustness for storage while maintaining the car's streamlined profile. If we were to revisit the project, we would refine the design process by dedicating more time to iterative testing and fine-tuning the chassis for optimal performance under stress. Additionally, we would incorporate feedback loops earlier to ensure alignment. Through this project, we learned the importance of balancing aesthetics and functionality in engineering design and how critical early prototyping is to avoid downstream challenges. For the team inheriting the project, we recommend focusing on enhancing the durability of the box's attachment points and exploring lightweight material alternatives to improve overall performance. Iterative testing on various terrains would also be invaluable for identifying and mitigating weak points in the design.

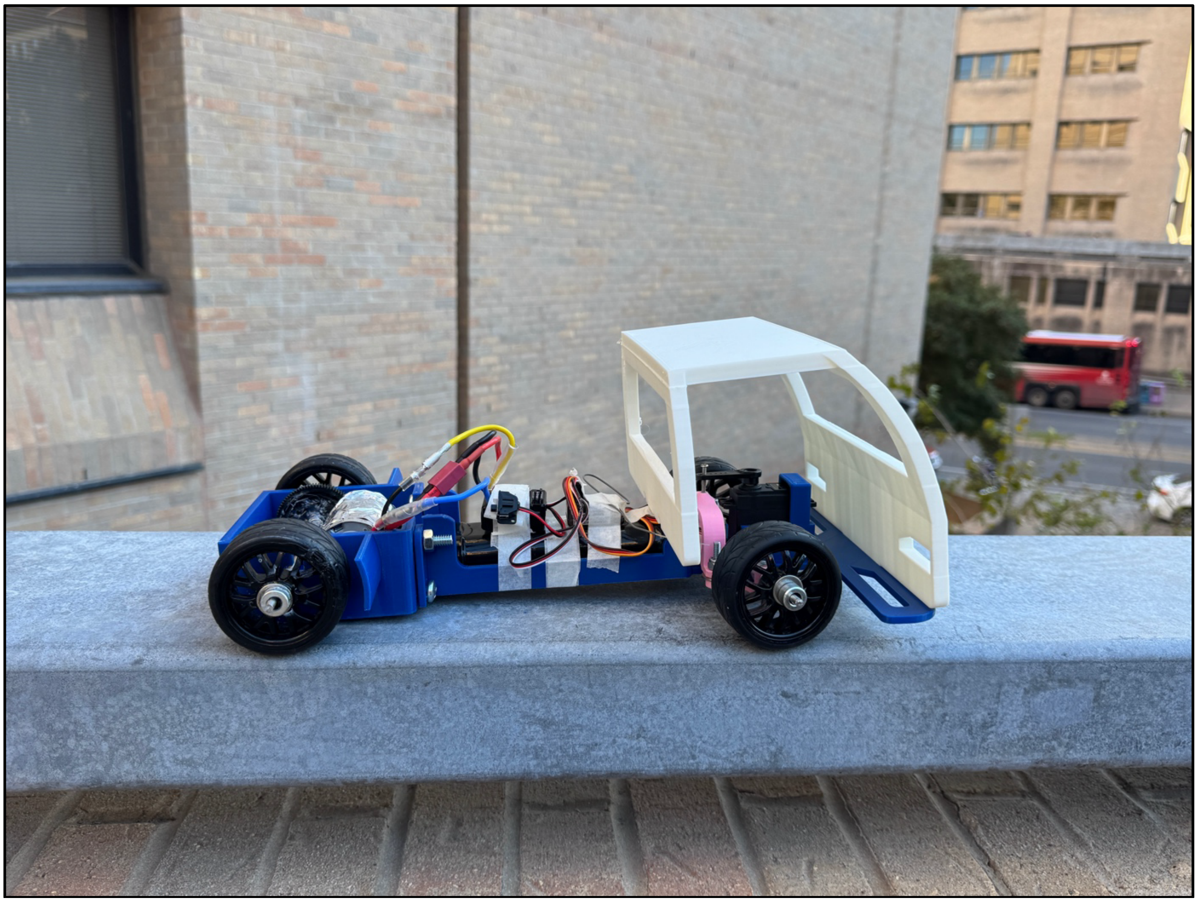
    f. Concept-Design-Build-Race: present four captioned graphics - one of your concept sketches, one of the designs (CAD or detailed design sketch), a high-quality oblique view of your final car, and one of your entire team with 'someone' holding the car.



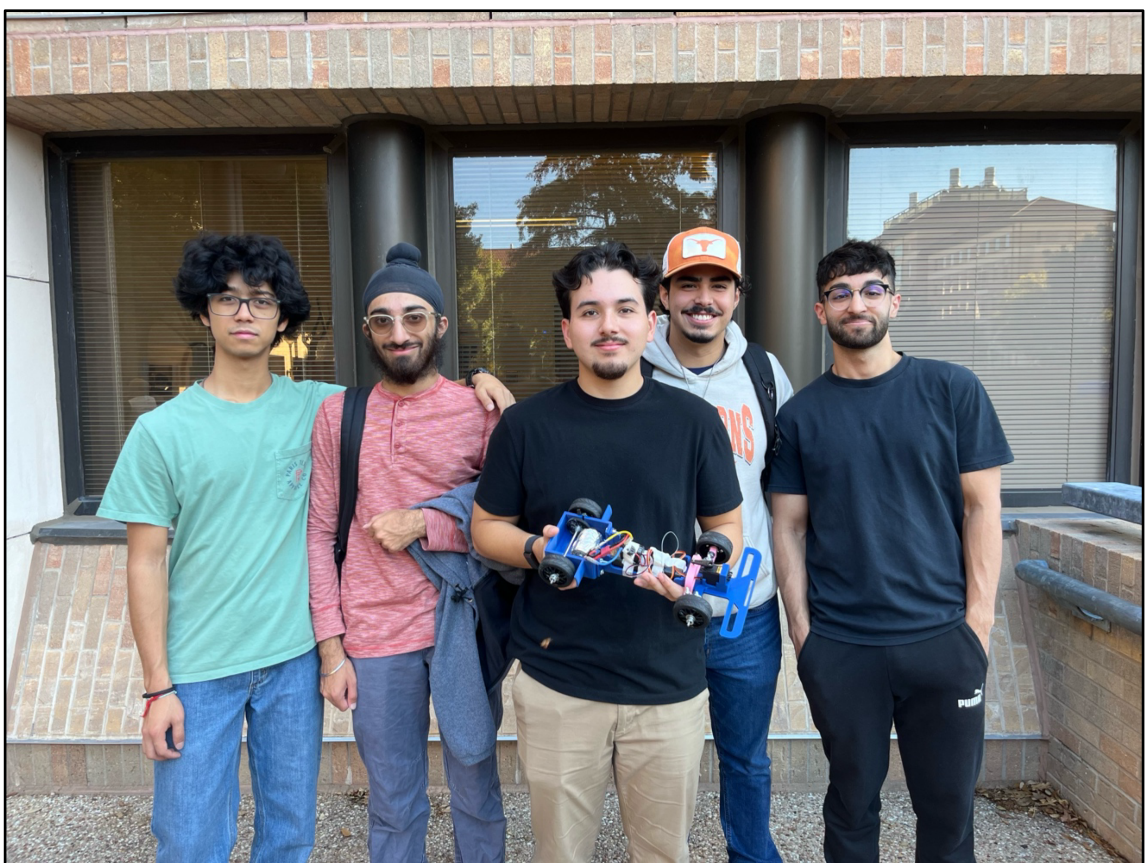
Initial concept sketch – September 12, 2024



Car design in SOLIDWORKS – September 30, 2024



Final car – December 9, 2024



Team Houston Dynaco on race day – December 9, 2024
L to R: Sidharth Draksharam, Tegh Thind, Ethan Salazar, Eli Saldana, Ammaar Khatlani