AER403 Walking Robot Project

**Project Overview**

In Winter 2025, our AER403 design team was challenged to design, analyze, and manufacture a walking robot powered by a Tamiya 4-Speed Crank Axle Gearbox. The mechanism had to convert the gearbox's rotary motion into a stable, efficient gait over a three-meter course. The goal was not only to achieve fast, reliable locomotion but also to develop a design that was manufacturable, energy-efficient, lightweight, and simple to transport

Walking robots can traverse uneven terrain and obstacles where wheeled robots fail. Our team focused on a four-legged configuration, which requires careful gait coordination for balance while maintaining simpler dynamics than bipedal systems.

---

**Design Objectives**

An objective tree defined four primary goals:

1. Manufacturability – minimal, easily fabricated components.
2. Functionality – speed and durability to win a 3-m race.
3. Efficiency – low power consumption given the limited output of the gearbox.
4. Simplicity – small, light, and portable design

These objectives became the criteria for evaluating candidate mechanisms.

---

**Concept Development & Analysis**

Five mechanisms were conceived and modeled using MotionGen, a kinematic simulation tool, and MATLAB for velocity and displacement analyses:

- Concept 1: Six-bar linkage – produced smooth, near-horizontal foot motion and stable walking, but required a complex ternary coupler and multiple links.
- Concept 2: Four-bar linkage – compliant with Grashof's law; produced controlled rocking motion and useful non-uniform velocity profiles.
- Concept 3: Multiple four-bar parallelogram linkages – aimed for uniform leg motion but suffered from link collisions and toggle points.
- Concept 4: Four-bar with legs 180° apart – minimized time each foot spent in the air, but motor-link collisions and high angular velocities risked excessive motor strain.
- Concept 5: Four-bar with shared motor joint – eliminated collisions, maintained 180° out-of-phase foot motion, reduced vertical foot movement, lowered motor strain, and kept the design simple and symmetrical

A Best-of-Class scoring chart evaluated each concept for manufacturability, efficiency, speed, and simplicity. Concept 5 scored highest (8/8) and was selected for fabrication.

---

## Final Design & Manufacturing

CAD modelling in OnShape defined the gearbox housing and two primary linkages: a straight link and a boomerang-shaped link acting as the robot's legs. Key design details included:

- A minimalist carriage with side walls only, reducing weight and material usage.
- Adjustable notches and a central slit in the walls to precisely align the gearbox shaft and linkages.
- A motor shim and movable screw holes to fine-tune gearbox height and linkage geometry.
- Laser-cut MDF components from a single 12”×12” sheet, with tolerances matched to the cutter's specifications

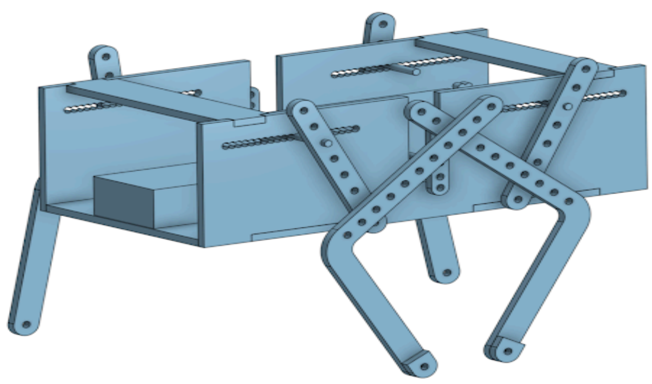

**Figure 1.** CAD model of the four-bar linkage walking robot with boomerang legs.

After assembly, the team observed toggle points and excessive foot lift. A MATLAB animation of the final design demonstrating its motion and velocity analysis can be viewed here. By repositioning fixed joints closer to the center and lengthening foot extensions, they reduced wobble and improved stability. Small rubber strips were added for traction on the slippery race surface as shown in Figure 2.

**Figure 2.** Perspective view of the final walking robot prototype.

## Results & Competition Performance

The final robot demonstrated smooth, efficient gait and high stability. During the in-class race on April 8, 2025, it finished first among the entire second-year aerospace undergraduate cohort with an A+ grade, outperforming other teams that faced issues such as instability, link interference, and slow speed.

**Skills and Takeaways**

This project honed both technical and soft skills:

- Technical: CAD design, MATLAB programming for kinematic analysis, mechanism synthesis, and manufacturing with laser cutting.
- Professional: teamwork, communication, time management, and critical thinking.
- The experience provided valuable insight into the integration of mechanical design, analysis, and fabrication, strengthening our preparation as future aerospace engineers.

---

**Supplementary materials.** The complete technical report comprising MATLAB scripts (Concepts 1–5 and the final design), CAD exports, and the full reference list is available here: **AER403_WalkingRobot_FullReport**. This work was conducted by the AER403 team at **Toronto Metropolitan University** : **Gaber Soltan**, **Joshua Bishun**, **Gabriel Siraco** and **Joseph Falzon** (Winter 2025).