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1. Desired Needs

- **Constant Force During Expansion:** Passive spring fixtures cause load spikes as cages expand, corrupting data. The system must actively maintain force within ±5 lbs throughout expansion.
- **Adaptability and Affordability:** Fixtures must accommodate varied TLIF/ALIF cage geometries dynamically, at about $500 versus $100,000+ for dedicated biaxial machines.

2. Major Constraints

a) **Safety/Regulatory:** Frame must withstand 2000 N without yielding; testing must meet ASTM F1717 and ISO 12189 requirements for FDA 510(k) submissions.
b) **Risks:** Actuator misalignment introduces shear errors; PEEK interfaces are slippery and delay load measurement of the load cell, leading to frame damage.
c) **Global Impact:** Affordable, reliable fixture accelerates safer implant development for millions of spinal patients worldwide.
d) **Manufacturability:** CNC machining of Al 6061 frame balances strength and cost; LBO-500 with 500 lbs measurement capacity; Arduino-based control keeps the system simple and accessible.
e) **Quality Control/Marketability:** Load cell calibrated against reference loads; PID gains validated empirically. Sub-$500 UTM-retrofit form factor is commercially.

3. Engineering Standards

a) **Components:** Load cell calibrated to ASTM E74; actuator meets IEC 60529; Arduino/motor driver comply with CE/FCC EMC requirements.
b) **Device Performance:** ASTM F1717 and ISO 12189 define force magnitudes, fatigue cycles, and acceptance criteria the fixture must replicate.
c) **Emergent Standards:** This project could seed new ASTM protocols for active closed-loop force control during expandable implant testing, not yet addressed in existing standards.

4. Ethical, Environmental, and Societal Concerns

Most importantly, inaccurate passive-fixture data risks unsafe implants reaching patients. Societally, high testing costs exclude smaller manufacturers; an affordable retrofit democratizes rigorous validation. Environmentally, PEEK and aluminum have modest footprints but require proper end-of-life management.

5. Active Teamwork and Leadership

a) **Collaboration:** Each member worked independently on their portion and brought ideas together through weekly meetings, ensuring everyone had ownership and ideas reflected to the project.
b) **Delegation:** All members shared equal responsibility, working individually or as a group as needed to reach each goal together.
c) **Goals/Deadlines:** The team ensured all tasks were completed before each deadline and reported progress to the mentor every week to stay on track.
d) **Feedback:** The project was hands-on and self-directed, Each member had decision-making responsibility over their area, which made for a strong personal learning experience.

6. Motivating Factors

a) **New Knowledge:** Our mentor's hands-off teaching style pushed us to independently research and solve every challenge ourselves, from circuits and Arduino coding to PID setup and tuning.
b) **Self-Initiation:** Clearly defined roles and deadlines meant one member's completed work directly enabled the next person to begin theirs, keeping momentum across the project.
c) **Persisting:** Initial force spikes during cage expansion made PID control seem unworkable, but trial-and-error empirical testing identified reliable gain values.

7. Most Innovative and Entrepreneurial Ideas

The system measures force on a spinal cage in real time during expansion or retraction, which is unavailable in standard passive fixtures. The full setup costs around $500 and can be packaged as a sellable product set, delivering biaxial-level testing at a fraction of existing machine costs. The Python display is intuitive and automatically saves all test data as a CSV file, ready to use in any lab without additional software.