Assistive Wheelchair-Mountable Projectile Launcher

Acceptance and Delivery Review

5/24/23

Team 06

David Barsoum • Alex Kaneko • Alex Chen • Nathan Lam

CEO *CTO* *CIO* *CMO*

5.5 million

Problem Statement

- Wheelchair use is prevalent in the USA
  - ~5.5 million American adults have used a wheelchair at some point (Taylor, 2018)
- Wheelchair use is often associated with arm mobility issues, especially in the shoulders (Curtis et al., 1998)
  - Causes inability/difficulty performing basic movements, such as throwing
  - Large obstacle in enjoying play with pets and loved ones

Existing Products

- Some wheelchair-mountable ball launchers already exist
    - Some potentially difficult to operate for clients with low mobility
- Some devices exist for launching flying discs, but none are designed for those who use wheelchairs for mobility

No wheelchair-mountable devices exist for launching flying discs.

Figure 1 (from top to bottom): Ball launchers by Ameye et al. (2014) and the Cerebra Innovation Centre (2019) designed for their respective clients.

Requirements for Launching System and Mount

Subsystem		Launching System	
Requirement #	*Level*	*Requirement Type*	*Requirement Statement*
1	1	Functional	The device must have a range of 20 feet.
2	1	Physical	The device must not put any hazardous moving parts within reach of the client while mounted.
3	1	Functional	The device must be able to launch frisbees.
4	2	Functional	The device must be able to launch balls.
5	2	Functional	The device must have an adjustable range.

Subsystem		Wheelchair Mount	
Requirement #	*Level*	*Requirement Type*	*Requirement Statement*
1	1	User	The client must be able to mount the device to the wheelchair independently.
2	1	Physical	The device must be able to stay mounted to the wheelchair during any routine movements.
3	1	Physical	The device must maintain the balance of the wheelchair during any routine movements.
4	2	Functional	The device must extend at most 2 feet from the side of the wheelchair when mounted.
5	3	Functional	The device must be mountable to multiple different types of wheelchairs.

Requirements for Electronic Control System and Universal Constraints

Subsystem		Electronic Control System (ECS)	
Requirement #	*Level*	*Requirement Type*	*Requirement Statement*
1	1	User	The switch must be operable with minimal hand movement only.
2	1	Functional	The device must be powered with at most 1 primary battery.
3	2	Functional	The electronic control system must engage on 90% or more of switch presses.
4	2	Physical	The device must be able to run for at least 20 minutes before needing to be recharged.
5	3	Functional	The system must be able to run under rainy conditions.

Subsystem		Universal Constraints	
Requirement #	*Level*	*Requirement Type*	*Requirement Statement*
1	1	Cost	All materials must not exceed $200 in cost.
2	1	Physical	The device must not exceed the size of a 3’ x 3’ x 3’ box.
3	2	Physical	The device must not exceed 30 pounds in weight.
4	2	Documentation	There must be documentation with every subsystem with the intent of allowing a future group to continue work on this project.
5	3	Physical	The device must be aesthetically pleasing to stakeholders by majority vote.

Designs at PDR

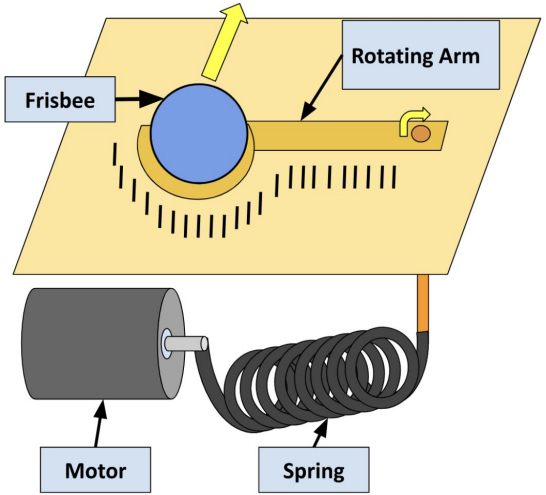


Figure 2: Side-arm launcher design

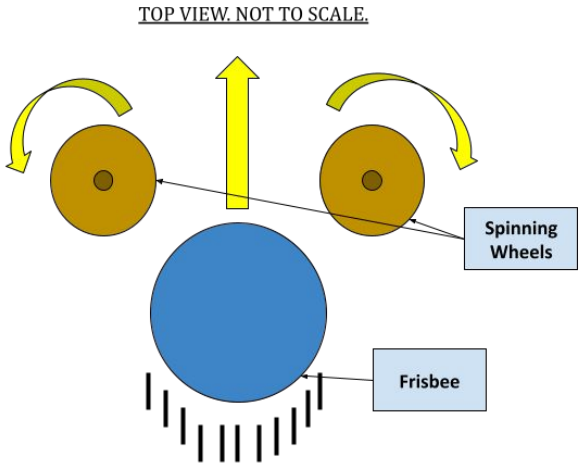


Figure 3: Flywheel launcher design

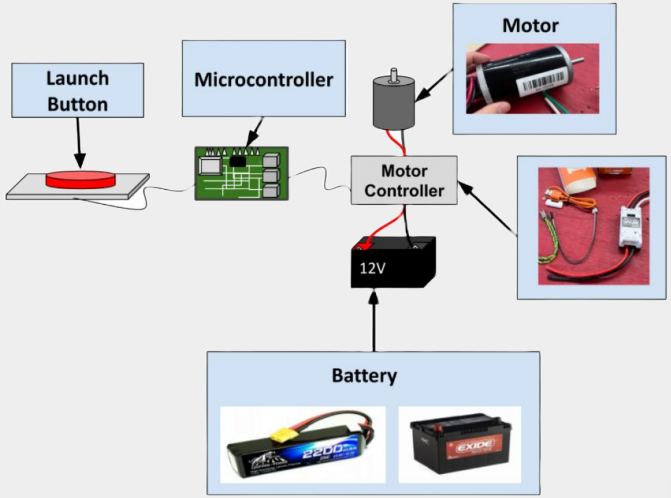


Figure 4: Electronic Control System

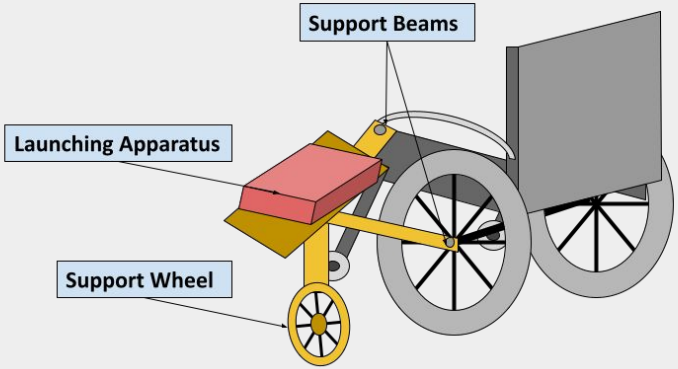


Figure 5: Wheelchair mount

Designs at CDR

- We decided to choose the side-arm design:
  - Launches disks of varying size
  - Creates spin on the frisbee which makes it travel far
  - Not wasting unnecessary energy
- Utilizes spring potential energy to wind up and fling the frisbee forward, as shown in Figures 6.1 to 6.3.

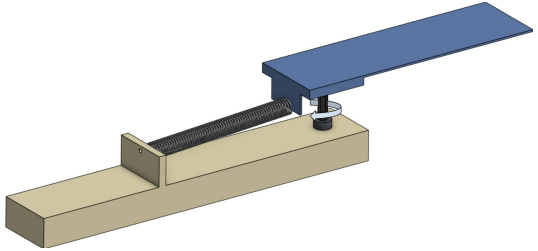


Figure 6.1: Launcher in its unstretched state

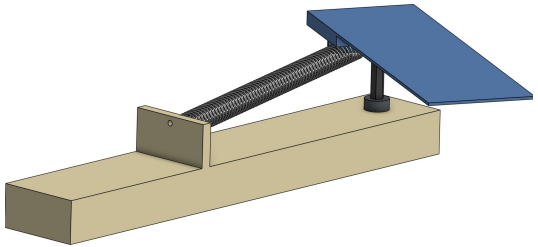


Figure 6.2: Launcher during the “winding up” phase

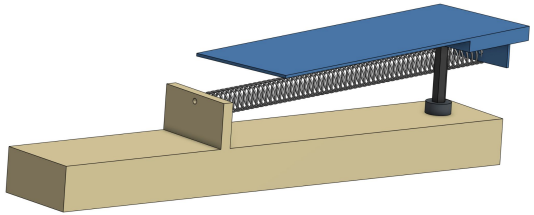
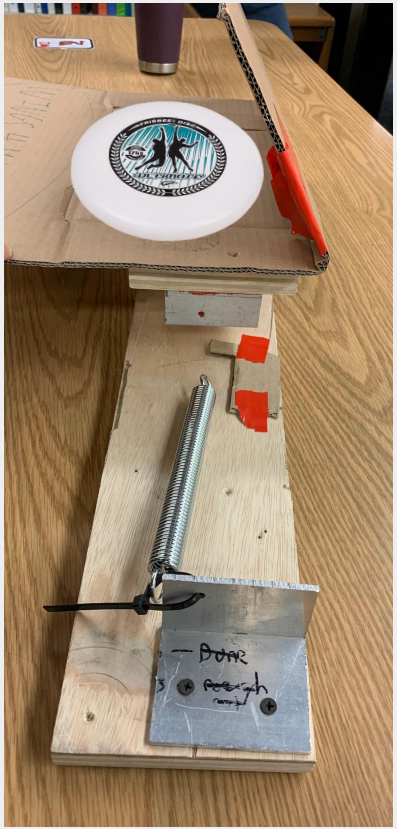


Figure 6.3: Launcher at final position, ready for release.

Figure 7: Implementation of the launcher with a cardboard arm, holding a frisbee.



Designs at CDR (continued)

We also made significant changes to the electronic control system:

- Added an on/off switch in tandem with the launch button
- Added a Step-Down to control the voltage of the battery
- **Incorporated a directional switch**

The directional switch allows the motor to turn in both ways. This gives the launcher more flexibility in how it winds up.

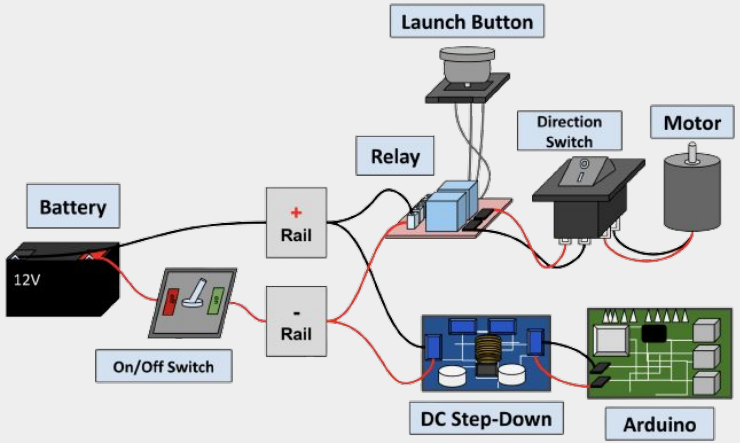


Figure 8: Wiring of the ECS

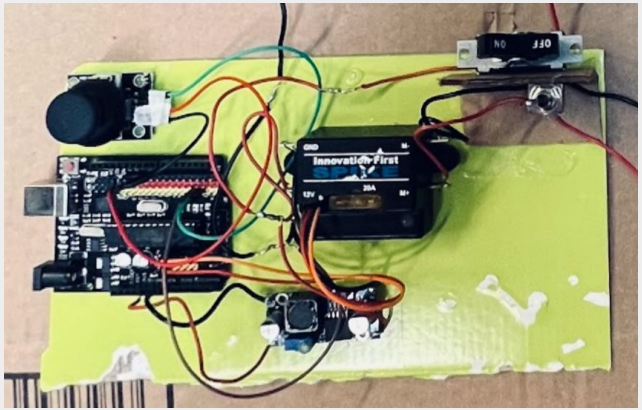


Figure 9: Implementation of the ECS

Motorizing the launcher

- Although pulling back the arm and launching it does work, it's inaccessible to those in wheelchairs who have poor arm mobility. Therefore, a motor is needed to turn the arm for the user
- We ran into the challenge of making the motor turn the arm exactly 180 degrees, and then let the arm release freely.
- Our solution to problem was using a **slip gear**.
    - Gear with teeth missing → the gear will turn until it reaches its bald part, releasing the mechanisms

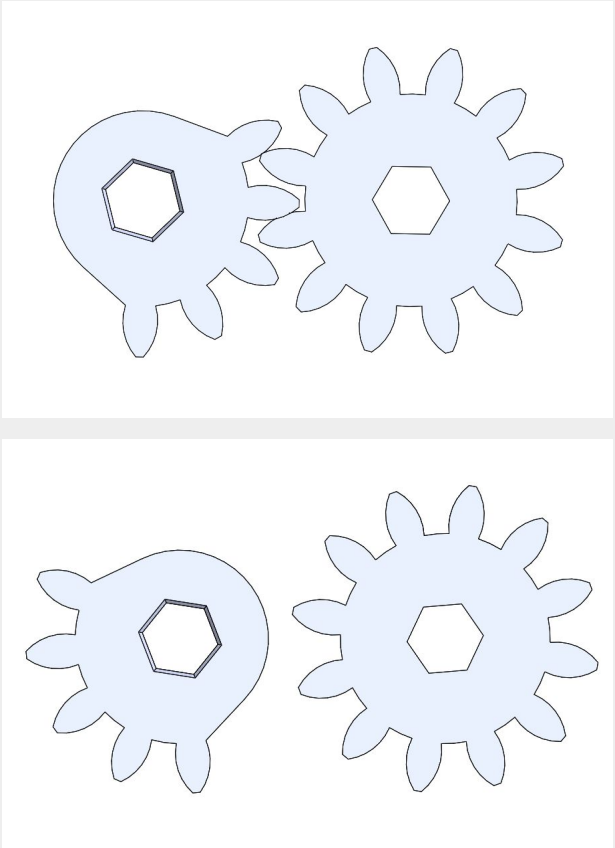


Figure 10: Slip gear in configurations transferring rotation (top) and allowing free spinning (bottom)

3D Printed Gear Launcher

- We created CAD models and 3D printed gears
- Printed them out of a variety of different materials (carbon-composite or normal plastic)
- Custom measured holes and bores to fit motor and hex shafts as needed
- Adjusted gear ratios for proper force to rotate arm and stretch spring

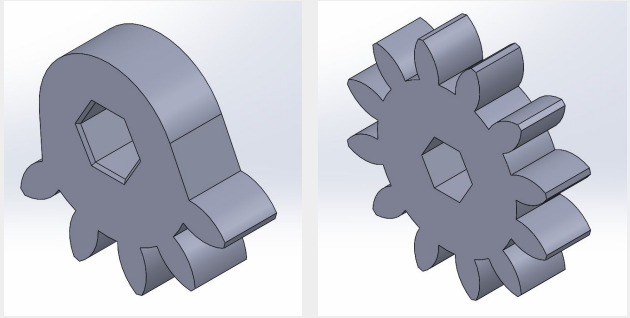


Figure 11: CAD models of slip gear (left) and full gear right)

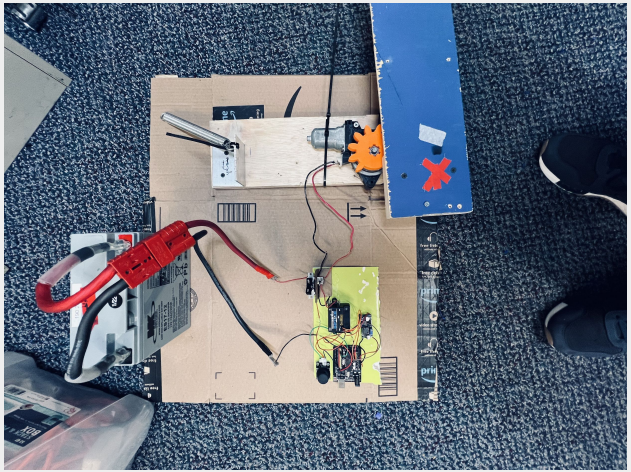


Figure 12: Prototype of launcher with 3D-printed gears.

Switching the gears

- Although the launcher was successful with the plastic gears, they weren't always reliable
  - Gears were jammed
  - **Plastic gears exploded from the force of the spring**
- Thus, we decided to switch to more durable and reliable gears: **metal gears**.

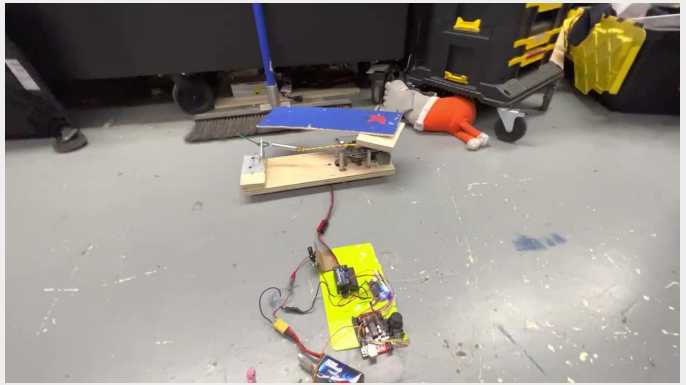


Figure 13: Video of 3D-printed gear failing while testing the device.

Mount

- 4 possible designs: two mounted on the side of wheelchair, two mounted on front.

Side Mounts

Figure 10: Side-extending mount

Figure 12: One-arm extending mount

Front Mounts

Figure 11: Tray table mount

Figure 13: Side-Hinge mount

A design study was conducted to determine whether side-mounts or front-mounts were more stable when holding weight.

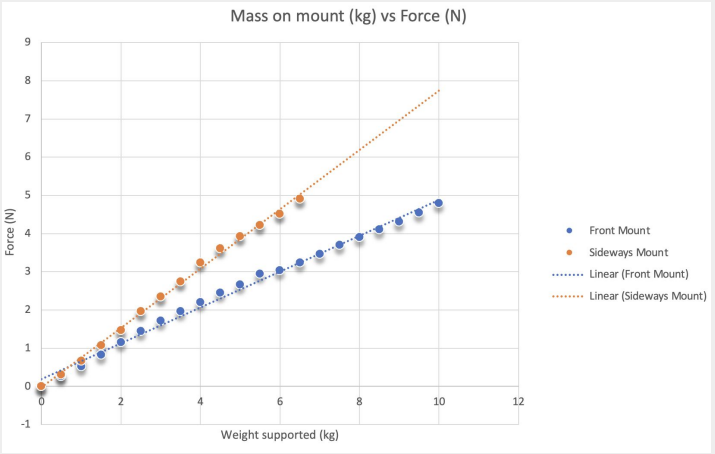


Figure 14: Downward force using front mount (blue) vs side mount (orange)

Front mounts have less downward force, so they **support weight better** than side mounts.

Testing the mounted launcher + finalizing features

- We tested both front-mount designs with the launcher. However, the one-arm extending mount shook significantly when a frisbee is fired, decreasing the distance of the launch due to energy loss.
- Therefore, we decided to go with the **tray-table design mounting design**.
- We also put the electronic control system in a box to keep the electronics away and safe.

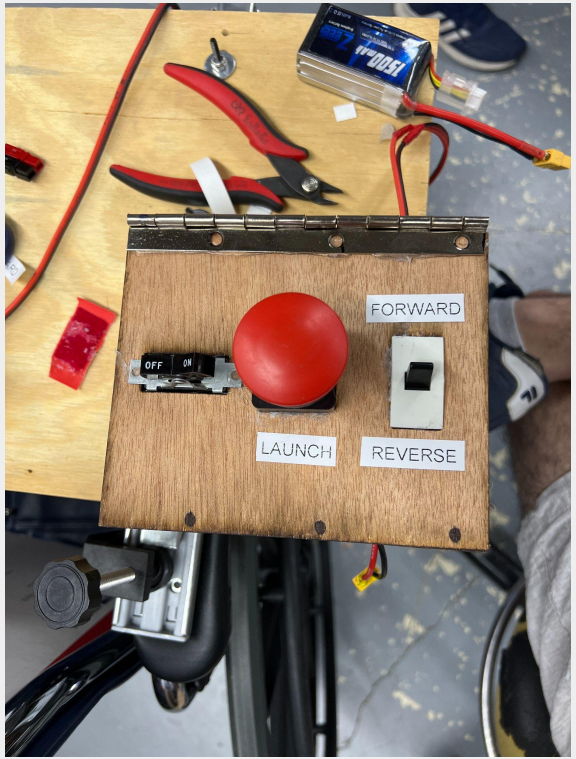


Figure 15: Electronic control system compact in a box

Final Prototype

FINAL Requirements for Launching System and Mount

Subsystem		Launching System		
Requirement #	*Level*	*Requirement Type*	*Requirement Statement*	***Final Prototype***
1	1	Functional	The device must have a range of 20 feet.	Pass
2	1	Physical	The device must not put any hazardous moving parts within reach of the client while mounted.	Pass
3	1	Functional	The device must be able to launch frisbees.	Pass
4	2	Functional	The device must be able to launch balls.	Pass
5	2	Functional	The device must have an adjustable range.	Fail

Subsystem		Wheelchair Mount		
Requirement #	*Level*	*Requirement Type*	*Requirement Statement*	***Final Prototype***
1	1	User	The client must be able to mount the device to the wheelchair independently.	Fail
2	1	Physical	The device must be able to stay mounted to the wheelchair during any routine movements.	Pass
3	1	Physical	The device must maintain the balance of the wheelchair during any routine movements.	Pass
4	2	Functional	The device must extend at most 2 feet from the side of the wheelchair when mounted.	Pass
5	3	Functional	The device must be mountable to multiple different types of wheelchairs.	Pass

FINAL Requirements for Electronic Control System and Universal Constraints

Subsystem		Electronic Control System (ECS)		
Requirement #	*Level*	*Requirement Type*	*Requirement Statement*	***Final Prototype***
1	1	User	The switch must be operable with minimal hand movement only.	Pass
2	1	Functional	The device must be powered with at most 1 primary battery.	Pass
3	2	Functional	The electronic control system must engage on 90% or more of switch presses.	Pass
4	2	Physical	The device must be able to run for at least 20 minutes before needing to be recharged.	Pass
5	3	Functional	The system must be able to run under rainy conditions.	Fail

Subsystem		Universal Constraints		
Requirement #	*Level*	*Requirement Type*	*Requirement Statement*	***Final Prototype***
1	1	Cost	All materials must not exceed $200 in cost.	Pass
2	1	Physical	The device must not exceed the size of a 3’ x 3’ x 3’ box.	Pass
3	2	Physical	The device must not exceed 30 pounds in weight.	Pass
4	2	Documentation	There must be documentation with every subsystem with the intent of allowing a future group to continue work on this project.	Pass
5	3	Physical	The device must be aesthetically pleasing to stakeholders by majority vote.	Pass

Future Work

- Adapt arm for other projectiles
- Develop more robust and versatile mounting
- Castings + barriers for more user safety

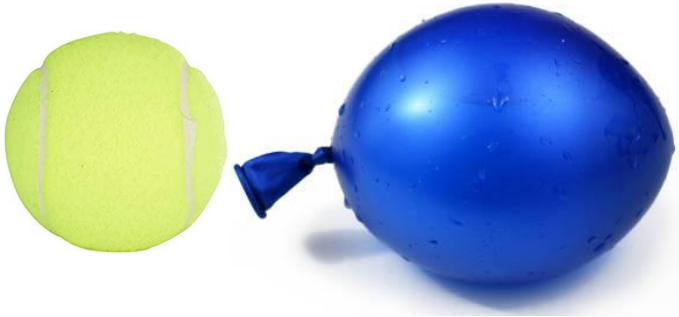


Figure 16: Possible projectiles for future

Lessons Learned

- Device should ideally be manufactured with high-strength materials
  - Plastic gears broke (Figure 17)
- More measures required to ensure client safety

Figure 17: A collection of plastic gears that broke

References

Ameye, G., Foubert, F., Vandemaele, L., & Aguilera, C. M. (2014, May 13). Detachable Ball Launcher. Instructables. https://www.instructables.com/Detachable-ball-launcher/

Curtis, K. A., Drysdale, G. A., Lanza, R. D., Kolber, M., Vitolo, R. S., & West, R. (1999). Shoulder pain in wheelchair users with tetraplegia and paraplegia. Archives of Physical Medicine and Rehabilitation, 80(4), 453–457. https://doi.org/10.1016/S0003-9993(99)90285-X

Glass, H. G., & Glass, H. G. (1991). Disk launcher (United States Patent No. US4984556A). https://patents.google.com/patent/US4984556A/en?q=(disk+launcher)&oq=disk+launcher

Roberts, E. (2019, August 15). Fetch! Special shooter helps boy play ball with his beloved dog. Swindon Advertiser. https://www.swindonadvertiser.co.uk/news/17840278.special-ball-shooter-helps-disabled-swindon-boy-play-fetch-assistance-dog/

Taylor, D. M. (2018). Americans with disabilities: 2014. US Census Bureau, 1–32.

Whidborne, F. (2013). Launching device for clay targets (European Union Patent No. EP2446217B1). https://patents.google.com/patent/EP2446217B1/en?q=(clay+pigeon)&oq=clay+pigeon