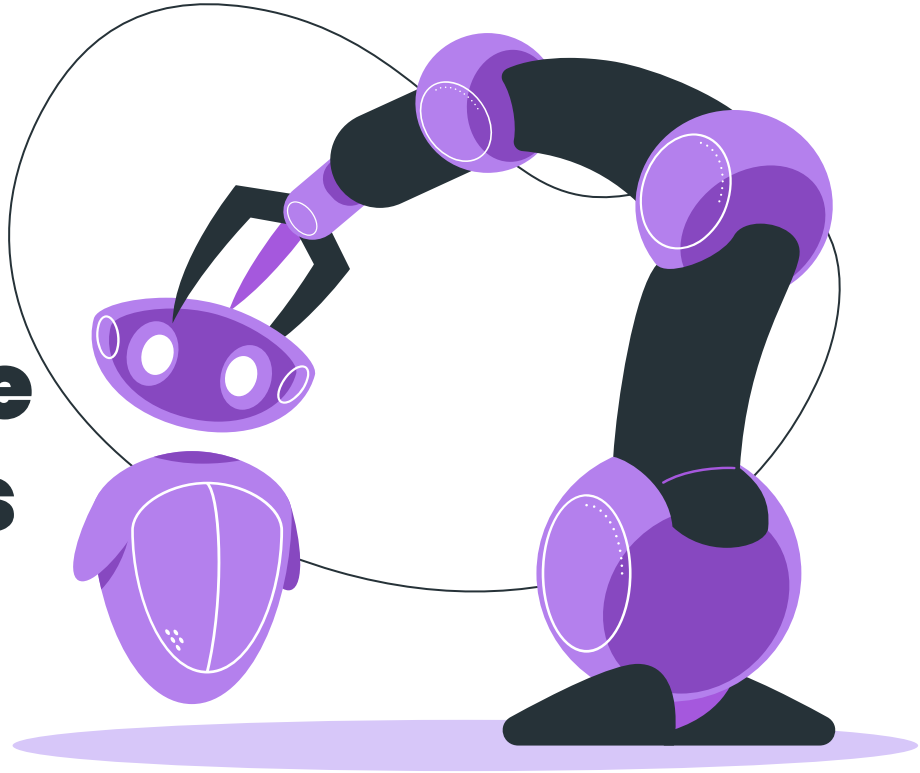
FTC #22377 SigmaCorns FRC #900 Zebracorns

Mechanical Masterpieces: Exploring Unique Design Solutions



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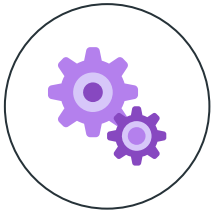
First in *FIRST*

Mechanisms and More

Concepts

Drivetrains

All robots need some form of locomotion to get from Point A to B



Differentials

The complexities of two motors and two degrees of freedom

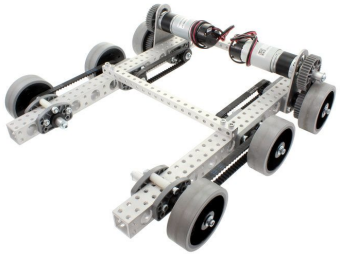
Simulation

Testing everything from your laptop before you start building

Common Drivetrains

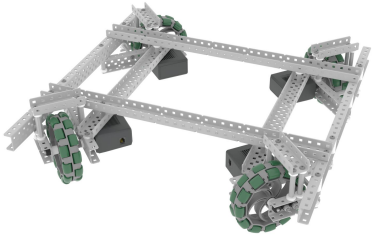
Mecanum

Holonomic drive base common in FTC



Tank Drive

Higher traction, WCD more common in FRC



X-Drive

Equal power each way, most seen in VEX

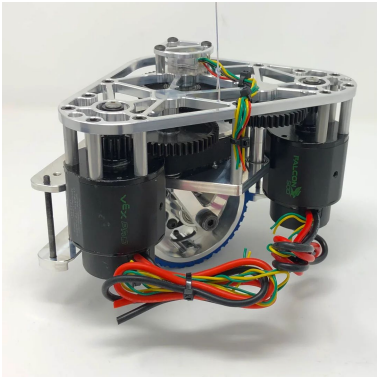
Tank Tread

Why?

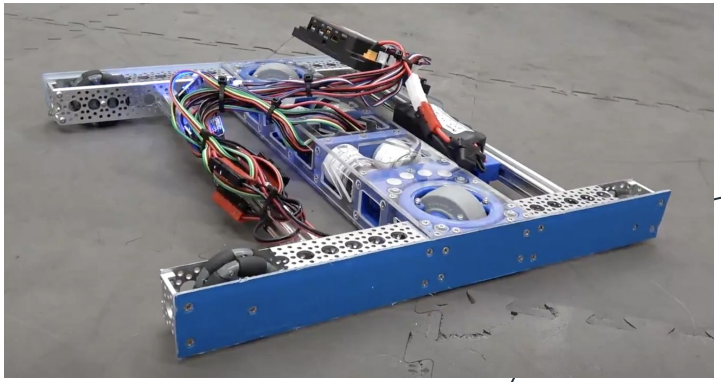
Swerve

Coaxial Swerve

- High Traction
- High Maneuverability
- Complex
- High Maintenance



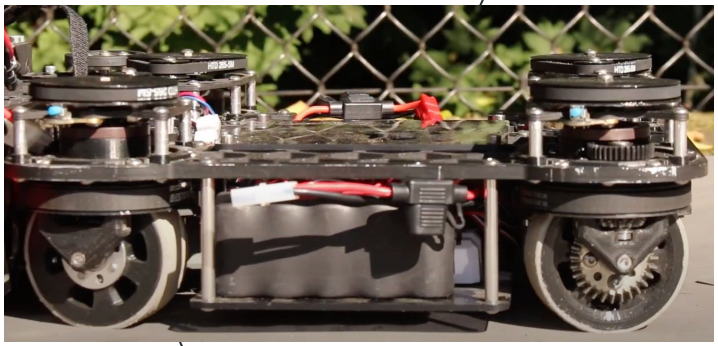
SDS MK4i



FTC 11115 Gluten Free (2019)

Differential Swerve

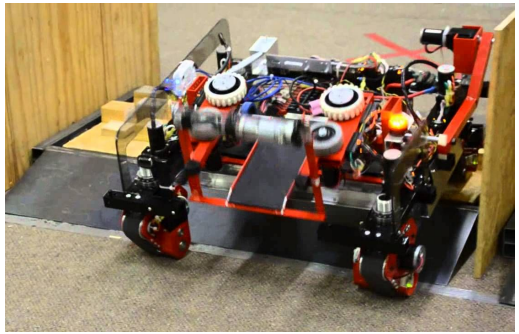
- Motor Limitations
- Very Complex
- Necessitates Complex Manufacturing



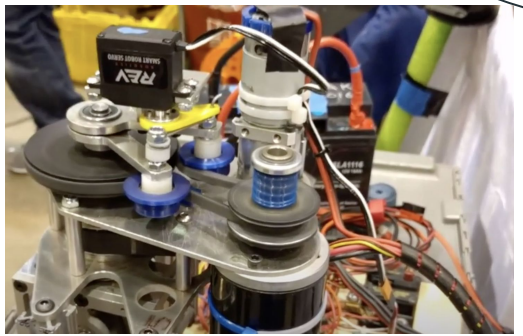
FTC 16379 Kookybotz (2022)

Swerve Variations

FTC 22155 Runtime Terror (2024)

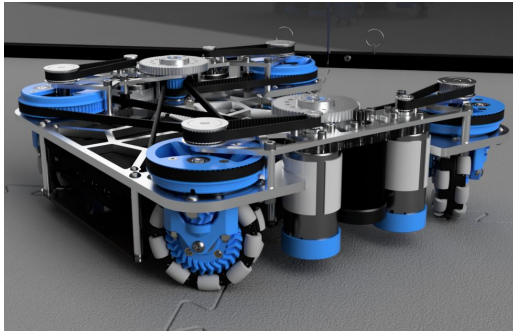


FRC 4143 MARS/WARS (2016)



FRC 1640 DEW Robotics (2017)

FRC 1533 Triple Strange (2016)

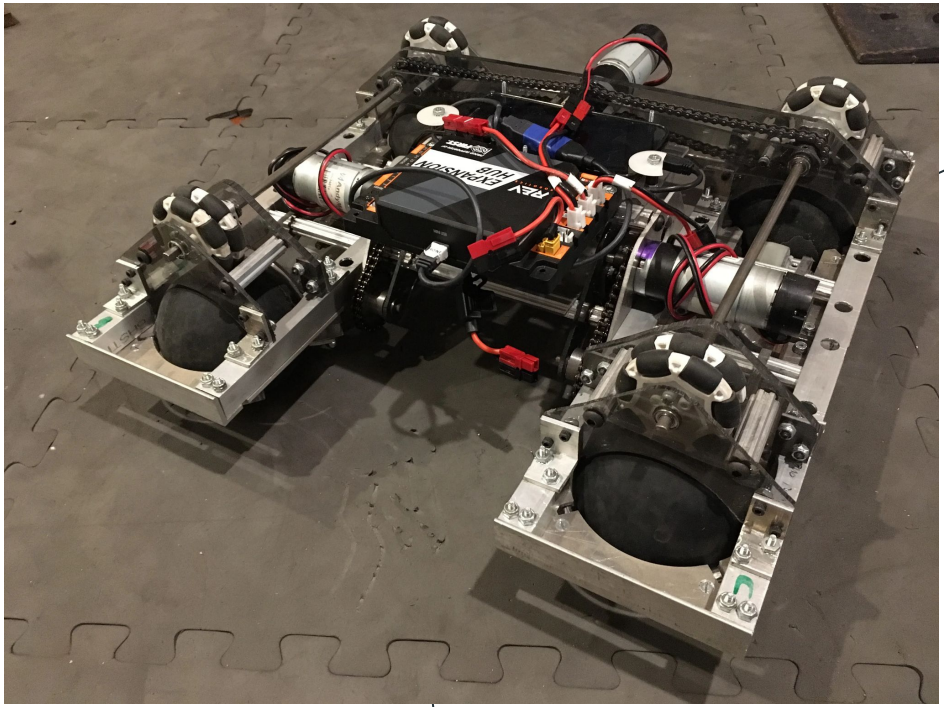


FTC 16460 GEarheads (2024)

Ball Drive

Exceedingly rare drivetrain to find due to rare COTS materials needed and complicated design

- Manageable with 3 Motors
- Difficult to design
- Custom Manufacturing



FTC 4042 Nonstandard Deviation (2018)

Gears

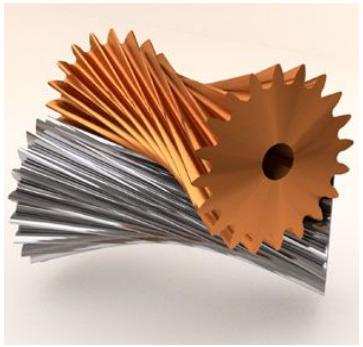
Zero

Hypoid

Worm

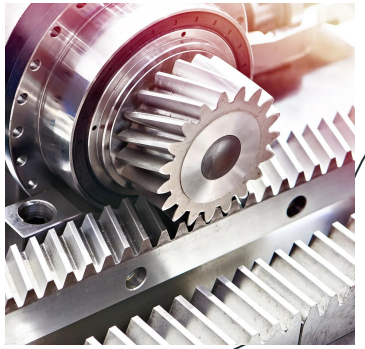
Miter

Involut
e



Hyperboloidal

Herringbone

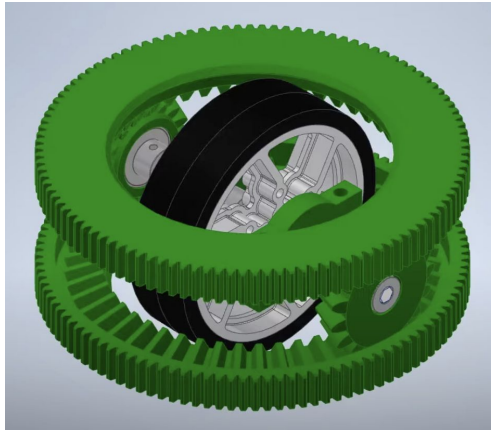


Racks

Differentials

Bevel Differentials

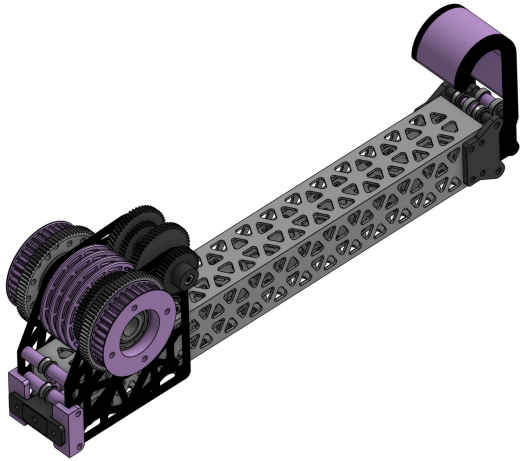
- Compact
- Uses 3 bevel gears in series



Egan (2020)

Spur Differentials

- Wider
- Finds usage in niche situations
- Involves 6 spur gears meshing together
- More complex to design

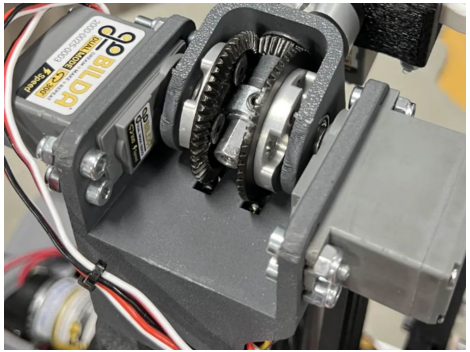


FTC 22377 SigmaCorns (2024)

Differential Wrist

Differential Wrists involve three bevel gears meshing, typically attached to a claw

- Minimizes impact from Servos to moment of Inertia
- Allows for independent control of pitch and yaw
- Easier packaging of claw or end effector mechanism



5661 Wolves Robotics (2025)

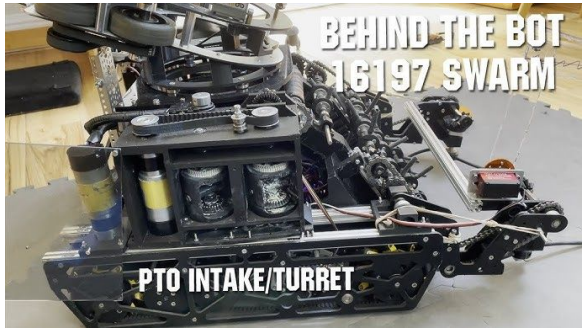
FTC 22377 SigmaCorns (2025)

Differential PTO

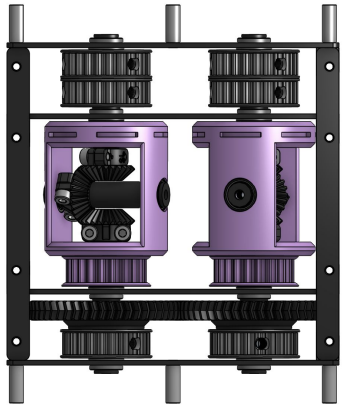
Differential PTO typically involves 2 differential pods.

On one side, the 2 of the internal bevel gears are geared together, while on the other, 2 are belted together.

- Equally takes in two inputs on anywhere on the PTO
- Input power can be divided in any way between two outputs
- The gears reverse direction while the belt carries the same direction



FTC 16197 SWARM (2021)



FTC 22377 SigmaCorns (2025)

Differential Elevator

Pros

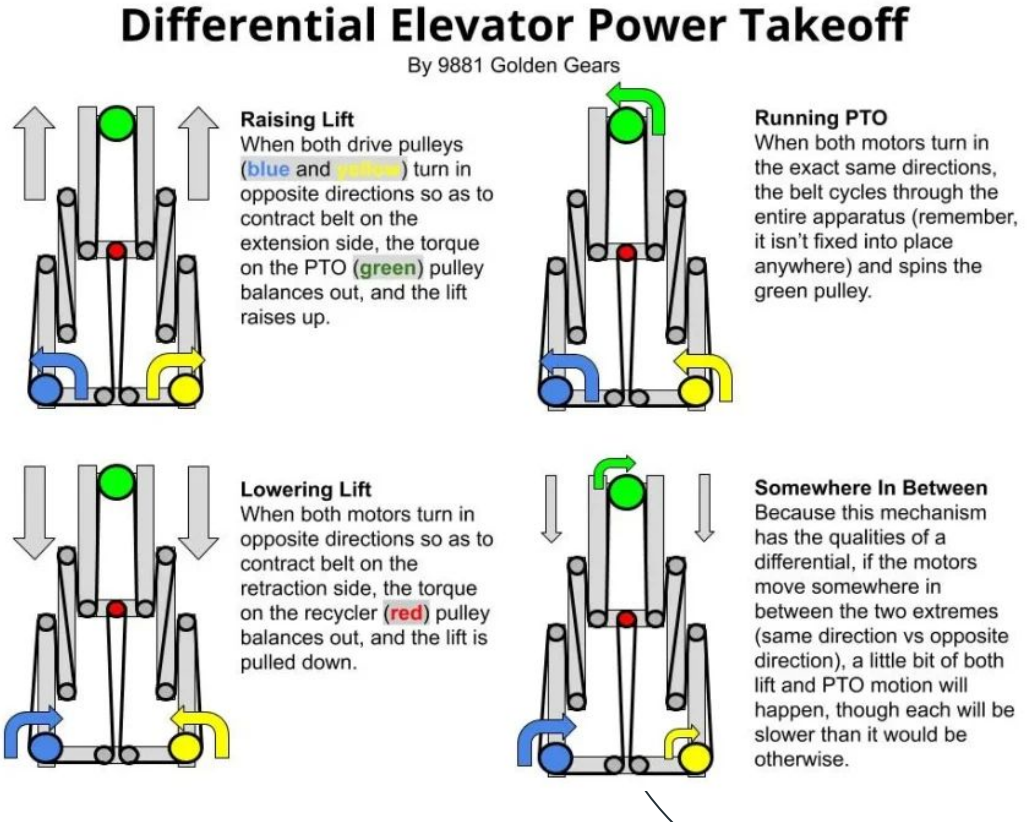
- Saves motors
- Light & compact
- Transfer motor power to end of slides

Cons

- Hard to rig
- Needs more complicated code
- Tuning required

Considerations

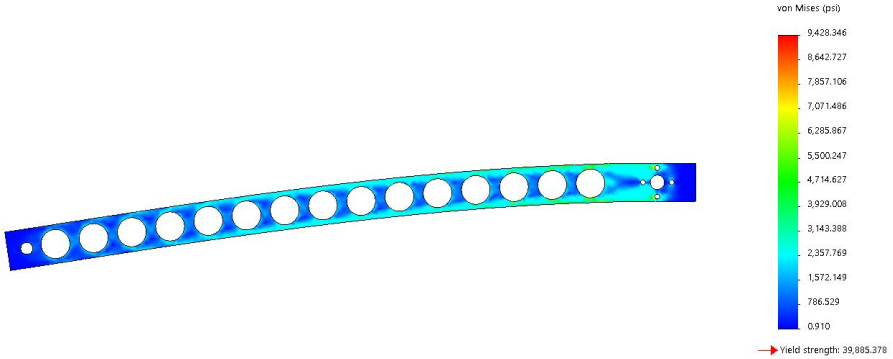
- Use chain + tensioners
- Ideal for elevator+wrist, 2 DOF arms



Finite Element Analysis

Finite Element Analysis (FEA) is a way to display stress points across a rigid structure to ensure a part is capable of supporting the loads applied to it.

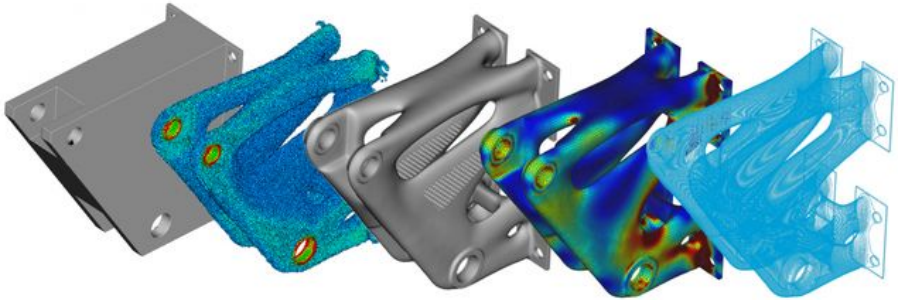
- Applications like Fusion360 and Ansys support FEA
- Easy to display and confirm a part's stability
- Can also be used to simulate magnetic, hydrodynamic, and aerodynamic properties



Topology Optimization

Topology Optimization is a way that calculates and generates pocketed areas based on parameters such as loads and fixed points.

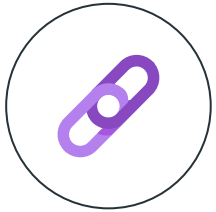
- Supported by Ansys and others
- Attempts to maximize weight efficiency



2 Beyond *FIRST*

More than Just Robots

Power Transmission



Cycloidal Gears

High gear reduction in a small form factor

Strain Wave Gears

Precision and pricy gears

Capstan Drive

I’m sure you’ve all seen Aaed Musa’s video

Cycloidal Gearbox

High-reduction gearbox using rolling and eccentric motion

Pros

- Very high torque
- Backlash-free (near zero)
- Smooth motion
- Compact for high gear ratios (stackable)

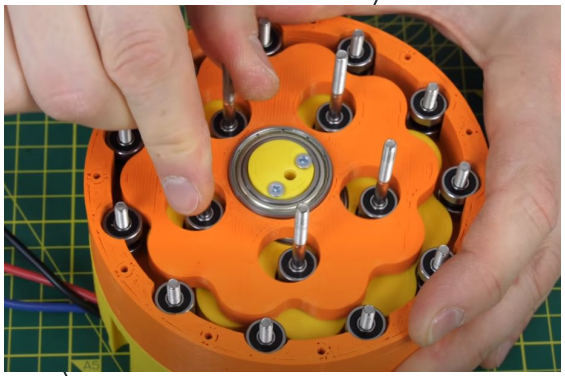
Cons

- Complex to machine
- Heavy vs. planetary
- Expensive (off-the-shelf)

Use Cases

- Articulated robot arms (like industrial robots)
- Applications needing precise, powerful, and compact joints

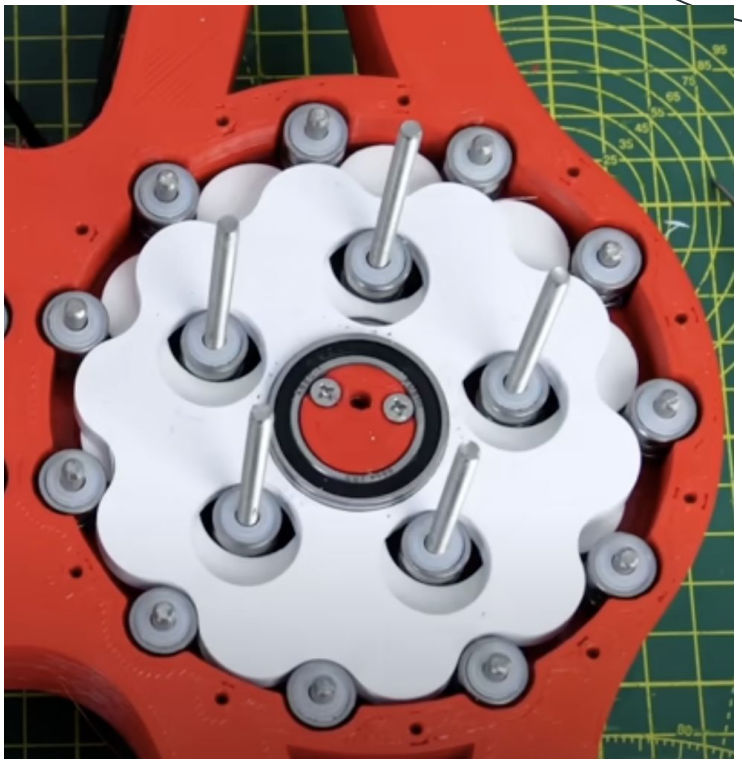
FTC 20700 SNAP (2022)



James Bruton (2022)

Examples

FRC 118 Robonauts (2025)

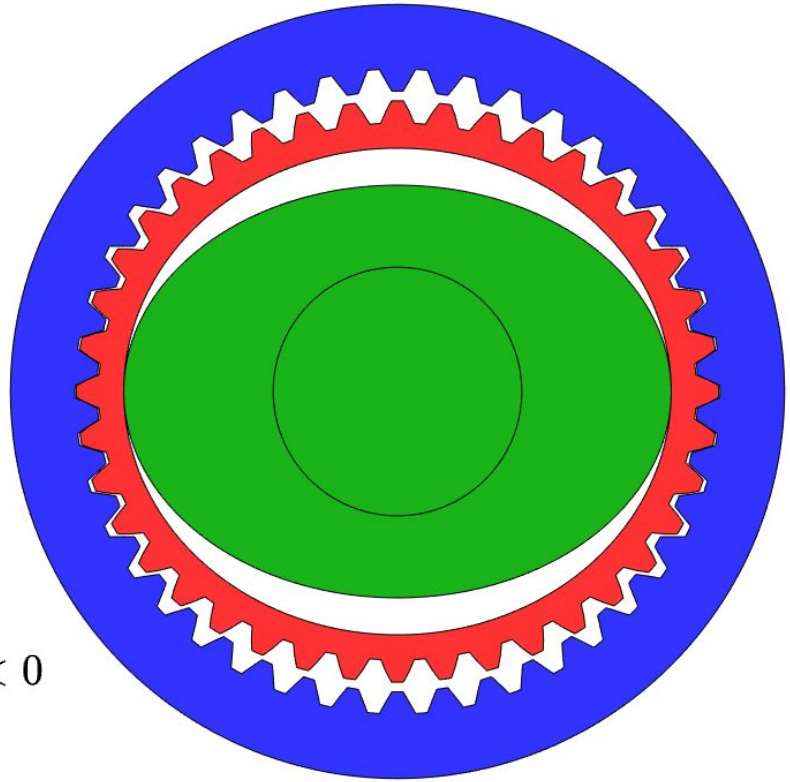


James Bruton

Strain Wave Gearbox

A flexible spline rolls over a rigid spine with a rolling profile internal to the flexspline.

- High Precision
- Zero Backlash
- Extremely Compact
- Complicated Manufacturing
- Very Expensive

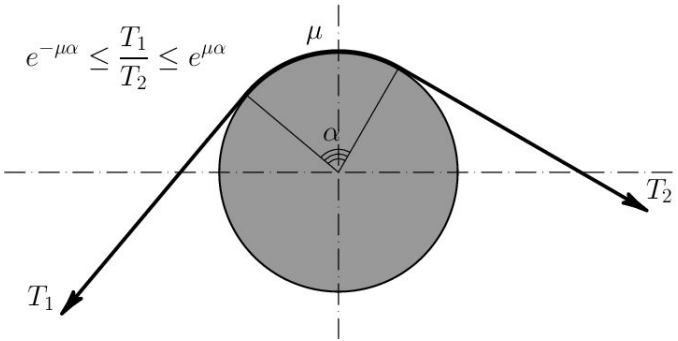


$$R = \frac{\text{flex spline teeth} - \text{circular spline teeth}}{\text{flex spline teeth}}, \quad -1 < R < 0$$

Capstan Drive

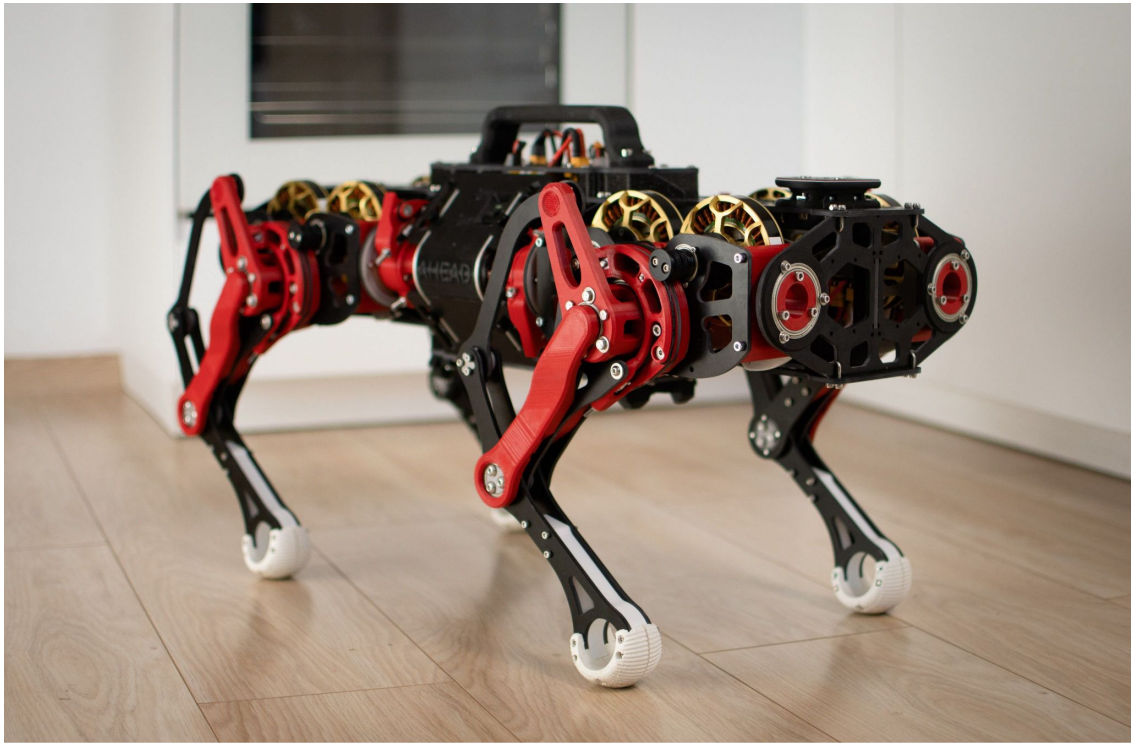
Instead of using gears, Capstans use string held by friction

- Zero Backlash
- Easy to Manufacture
- Requires strings of suitable D:d ratio



FTC 14872 Orbit Knights (2025)

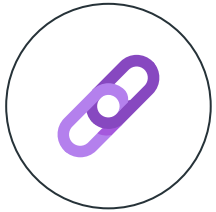
Examples



Stanley the Robot Dog

Aaed Musa

Automotive Tech

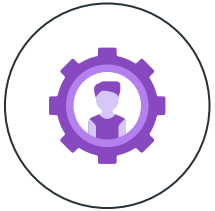


Torque Converter

Uses fluid coupling to help reduce driver effort

Geared CVT

Prototype combining smooth ratios of a CVT with efficiency/ durability of a manual.



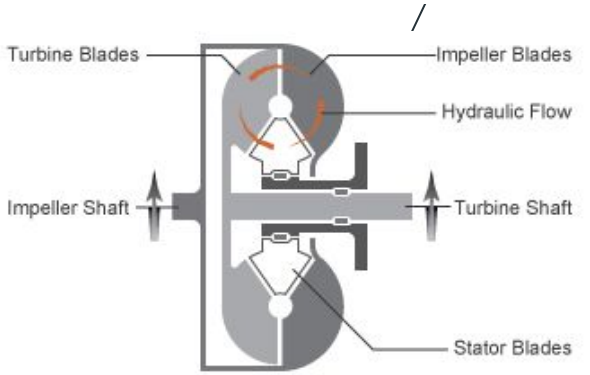
eLSD

Electronically manage torque distribution for traction and stability.

Torque Converters

Torque converters are a type of fluid coupling used to transfer rotating power, often used in automatic transmissions.

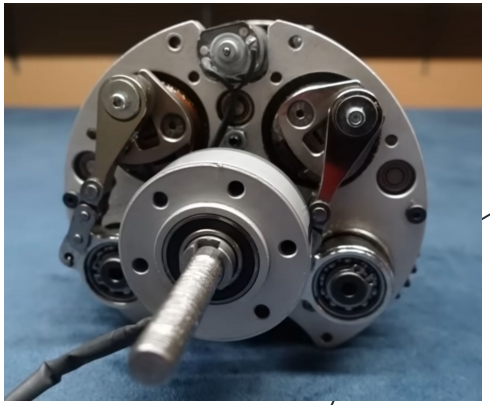
- The impeller in a torque converter acts like a centrifugal pump, flinging fluid outwards.
- The curved blades of the turbine forces the fluid to change direction.
- A stator redirects the fluid exiting the turbine to prevent it from hitting the impeller directly.

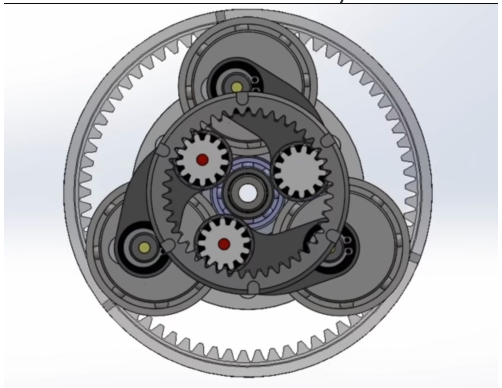


Geared CVT

The efficiency and reliability of a tooth-on-tooth geared transmission, with the smoothly variable gear ratios of a CVT – a 'holy grail' level promise!

- Traditional CVTs use belts that transfer power through friction, which makes them unreliable
- This prototype uses an external planet gear set to transfer power through a linkage to an internal planet gear set.
- Instead of adjusting the tension of the belt, the geared CVT adjusts the linkage to change its leverage for the ratio.





eLSD

An eLSD (electronic limited-slip differential) system makes sure each wheel is receiving sufficient torque by use of an electronic control unit (ECU), rather than in passive like standard limited-slip differentials.

- Uses sensors and electronic controls to limit wheel slip.
- Applies braking or torque to individual wheels for better traction.
- Reacts faster and more precisely than mechanical LSDs.

3

Manufacturing

Bringing an Idea to Life

Manufacturing Types

1

Additive

Examples include 3D Printing, like FDM, SLS, SLA, and more.

2

Subtractive

Examples include machinery like 5-axis machines, laser cutters, etc.

Selective Laser Sintering (SLS)

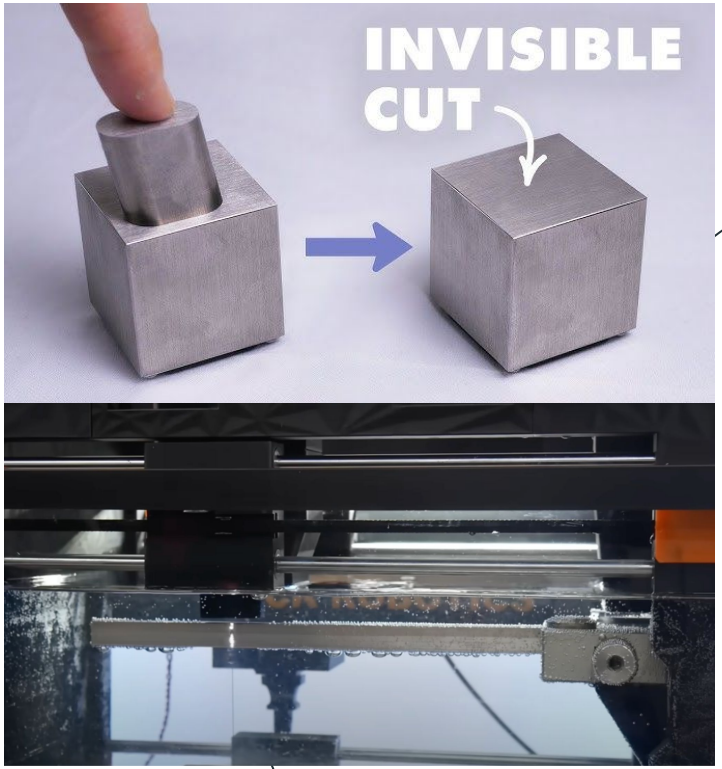
Selective Laser Sintering uses a laser to sinter pellets together in specified areas to create a solid shape

- Access to materials including metals
- Ability to create complex geometries
- Very toxic to breathe in
- Incredibly Expensive

Wire EDM

Wire Electrical Discharge Machining uses a wire of conductive material to discharge high voltages in a dielectric solution to erode materials with incredible tolerance.

- Very Low Tolerances
- Only works with conductive materials
- Works very well with materials difficult to machine, like Titanium and Tungsten



Morlock (2024)

Questions?