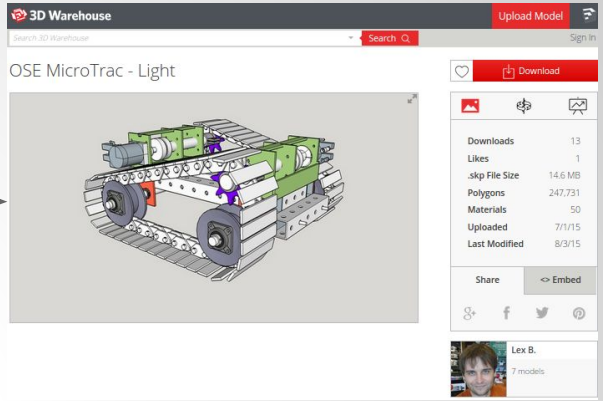
Bulldozer Modules: Table of Contents

Preface: Approach and Bulldozer Design. Collaboration Goals.
Download CAD

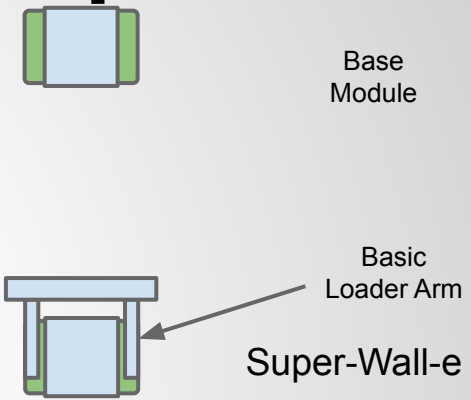


1. Modularity Proofs of Concept
2. Bulldozer
    a. Universal Rotor (Drive) Module
        i. Round Clamp Module
    b. Track Module
        i. Idler Module
        ii. Tensioner
    c. Lift Arms
    d. Bulldozer Blade
        i. 6 Way Blade
        ii. Loading Bucket Modification
    e. Hydraulic Controls Module (separate doc)
    f. Universal Loader Arm
    g. Universal Quick Attach
    h. Rotation Pivot
        i. Rotary Module - for blade angle, groundhug pivot, universal rotor mount, 360 degree backhoe
    i. Swing Module
    j.
3. Configurations
4. Controls
    a. Parallel to Series Conversion - for effective use of available power

1. BOM -
2. Size Scalability
    a. 1 track unit - 112 hp maximum
    b. 2 track units - 224 hp maximum
    c. 3 track units - 336 hp maximum
3. Universal Drawbar / Quick Attach
    a. Keyline Plow (another document)
    b. Offset Rail
    c. Universal Seeder
    d. Pipe Layer attachment
    e. Bale unroller
    f. Belt spreader
    g. Compost Tea Injector
    h. Universal Seeder
    i. Biochar Injector
    j. Power Harrow
4. Backhoe

Modularity Proofs of Concept 1

1. Scalability of single MicroTrac from 27 hp to 81 hp on a single set of tracks
2. Modular loader arms and cylinders with configurable and reattachable pivots
    - Both for arms and for cylinders
    - Low and high configurations
3. Modular Cab
    - Power control range from 27 to 168 hp
    - Mountable on front, back, side, top, or anywhere that modular tubing allows
    - Can control anything from backhoe, microtractor, bulldozer, etc.
4. Modular pivot
5. Ready conversion from 3-unit machine to individual units
    - Sidecar MicroTrac configuration
    - Rear MicroTrac Configuration
6. Loader curl-based backhoe
7. Extensible backhoe

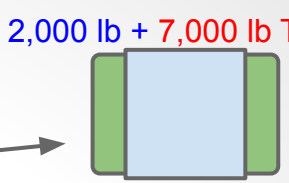


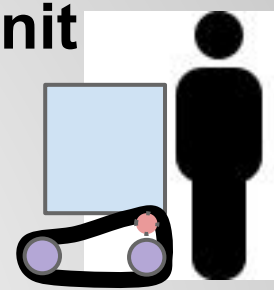
Modularity Proofs of Concept 2

1. Adjustable width with space in between for straddling capacity
    - Ex. Nut picker, berry picker, or straddling ditches
2. Movable cab -
    - cab is entirely modular
    - can be offset to the side, or mounted elsewhere for reconfiguration
3. 3” pivot with modular chain
    - Tilt of bulldozer blade
    -
4. 18” pivot
    - 360 degree backhoe
    - Groundhug pivot for 3rd microtractor
5. Super Quick Attach

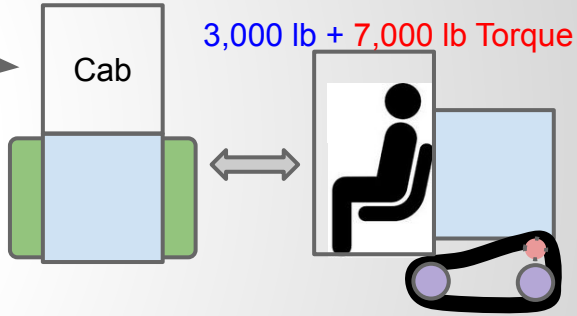
Modularity Concept 1: Scalability of Base Unit

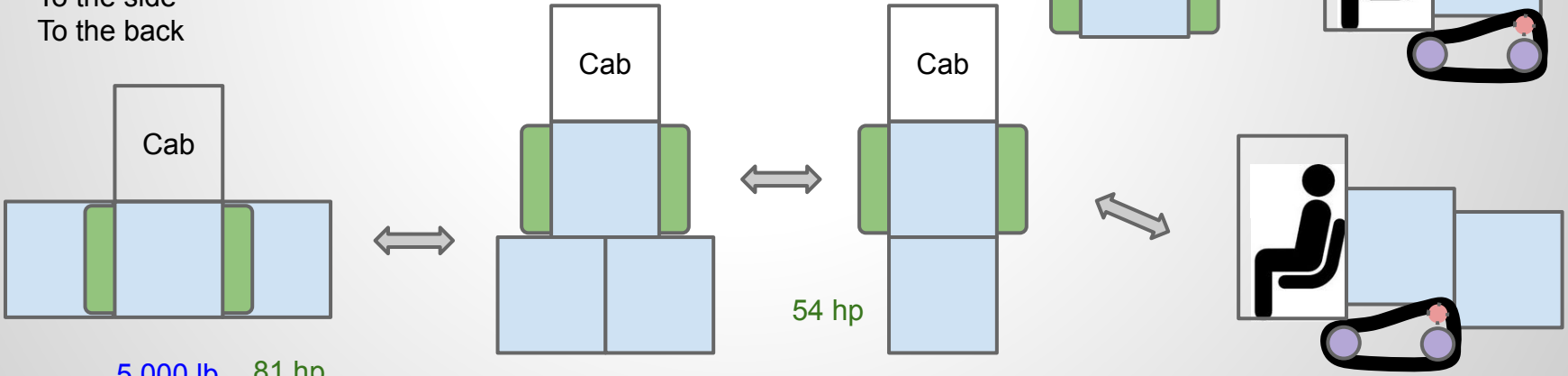
- Start with base unit
  - Scalability of single MicroTrac unit from 27 - 81 hp
  - Single set of tracks
  - Operator rides behind
- Add driver cab
  - Provides safety above 27 hp
  - Contains parallel/series drive circuit for 2 speeds
  - Cab can control 3 Power Cubes initially
    - Scalable to 6 Power Cubes
- Add Power Cubes
  - To the side
  - To the back





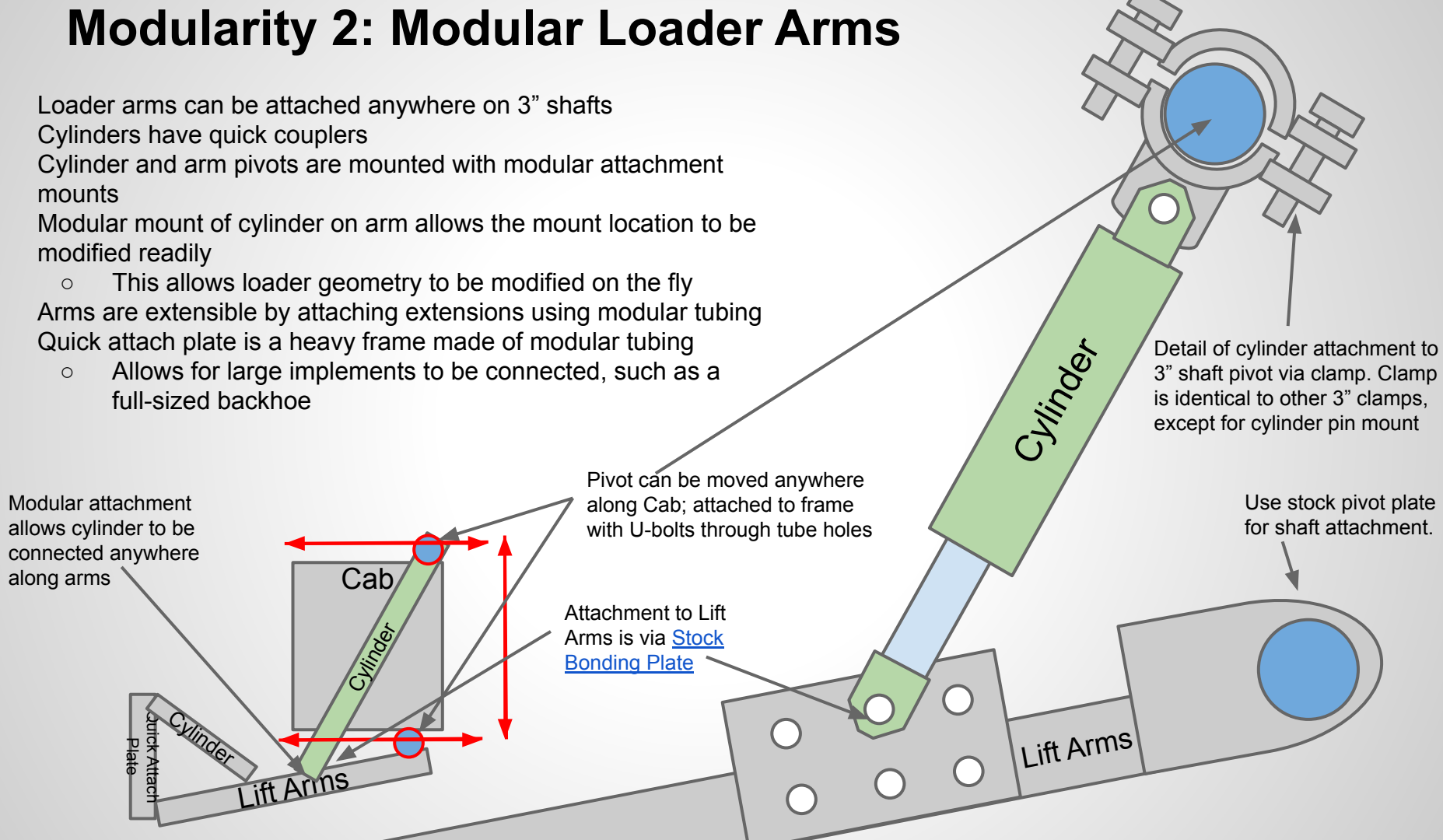
Base Module





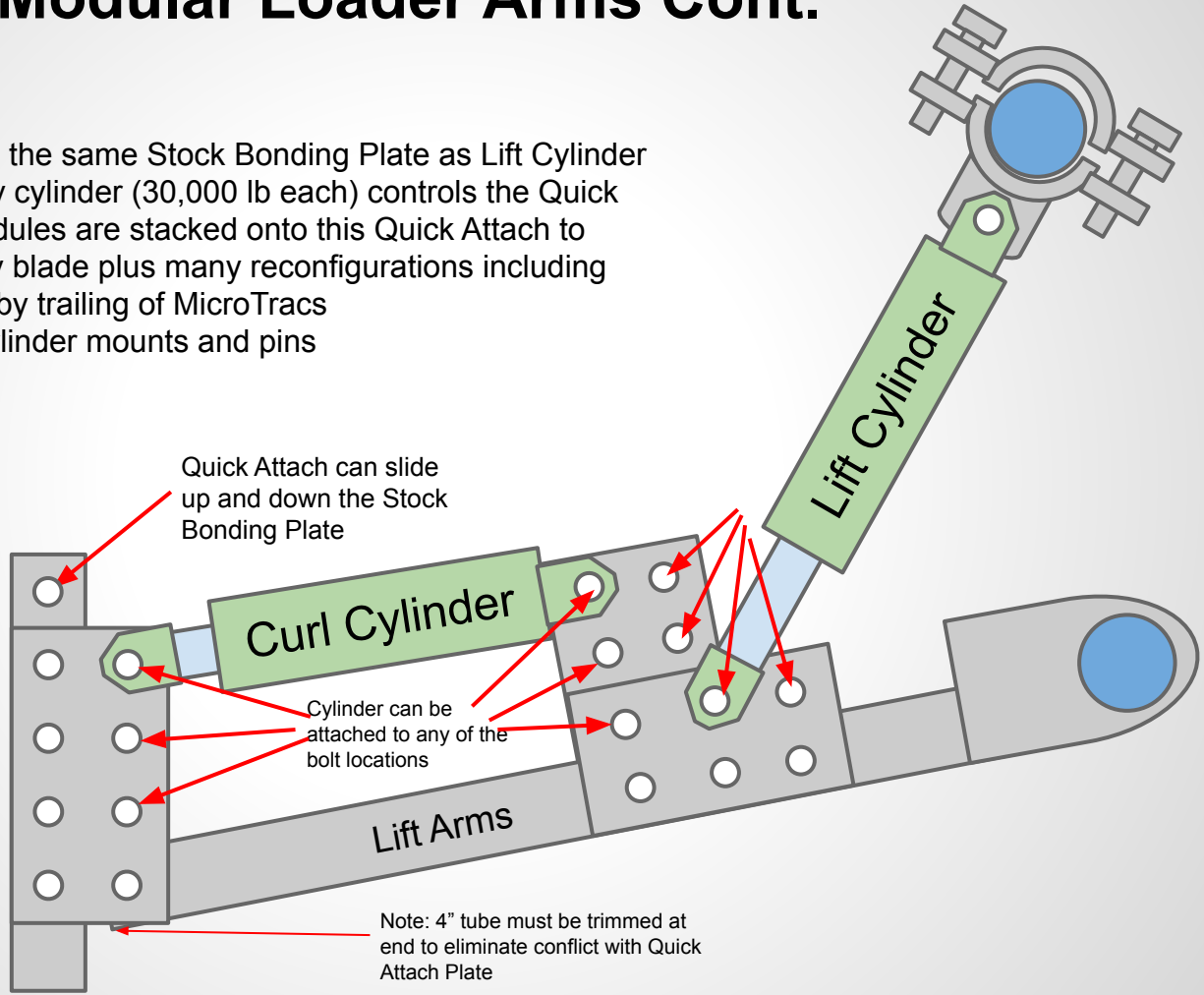
Modularity 2: Modular Loader Arms

- Loader arms can be attached anywhere on 3” shafts
- Cylinders have quick couplers
- Cylinder and arm pivots are mounted with modular attachment mounts
- Modular mount of cylinder on arm allows the mount location to be modified readily
  - This allows loader geometry to be modified on the fly
- Arms are extensible by attaching extensions using modular tubing
- Quick attach plate is a heavy frame made of modular tubing
  - Allows for large implements to be connected, such as a full-sized backhoe



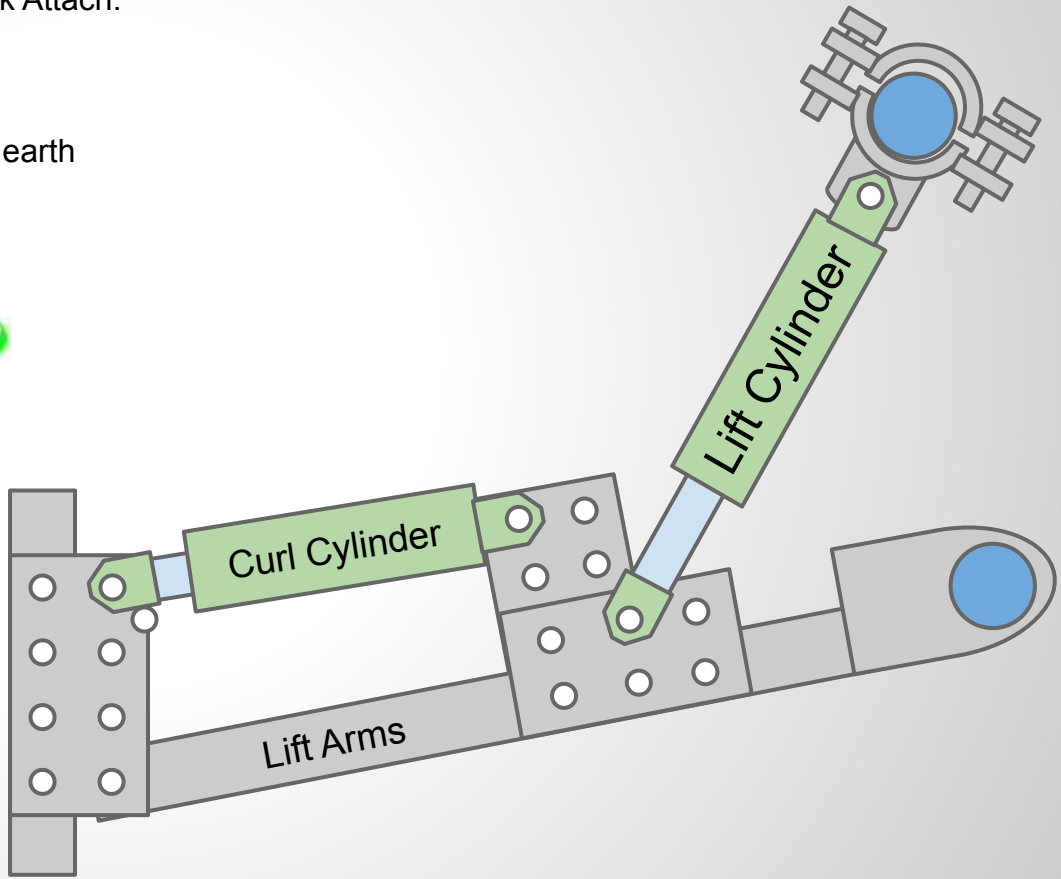
Modularity 2: Modular Loader Arms Cont.

- Attach curl cylinder to the same Stock Bonding Plate as Lift Cylinder
- Strategy: super heavy cylinder (30,000 lb each) controls the Quick Attach Plate, and modules are stacked onto this Quick Attach to achieve up to a 7 way blade plus many reconfigurations including scaling to larger size by trailing of MicroTracs
- Flexible location of cylinder mounts and pins



Modularity 2: Modular Loader + Quick Attach

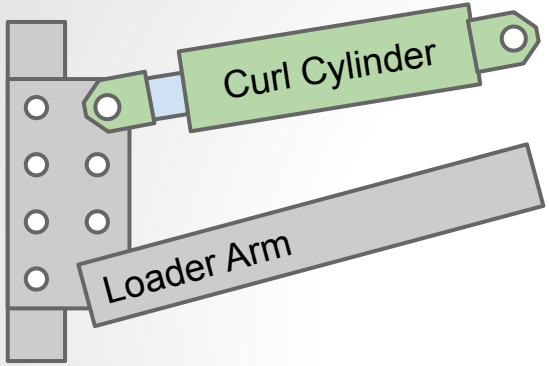
- Other heavy duty modules can be attached to the Quick Attach:
  - Rotation pivot
  - Side-to-side pivot
  - Backhoe
  - Sides for blades and buckets - high capacity for earth moving or pushing in bulldozer application
  - Universal Implement Mount
  - 3 Point Hitch with PTO
- For the Bulldozer 7 way blade: application:
  - Lift cylinder is used for up and down of blade
  - Curl cylinder is used for pitch
  - Side to side pivot is used for angle of blade
  - Rotating pivot is used for blade tilt

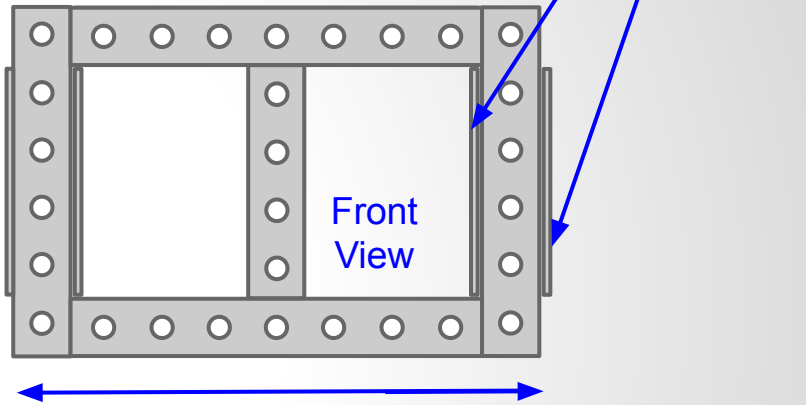


Modularity 3: Quick Attach Plate

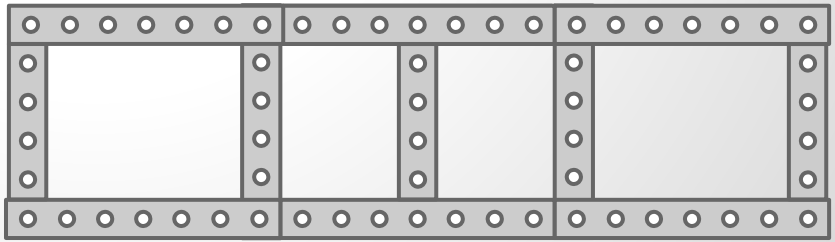
- Third point of development is the quick attach plate
  - Must be wide enough for loader arms to attach to outer verticals

Side View

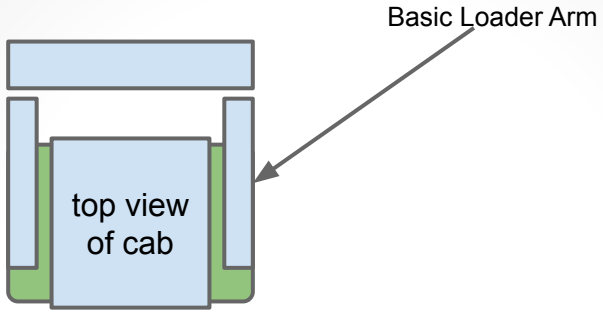


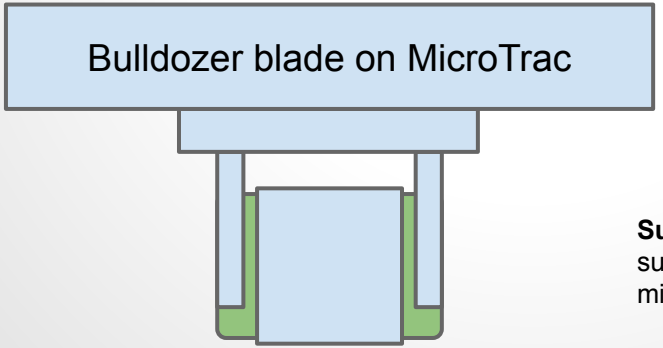


- Quick attach plate can be extended, doubled, or modified as needed:
  - Universal implement attach for the front
  - Universal drawbar attachments
  - Bulldozer blade
  - Backhoe
  - Trailing connection between MicroTrac units
  - Connection fo 2 MicroTracs for road grader application



Example: Use of loader arms on MicroTrac

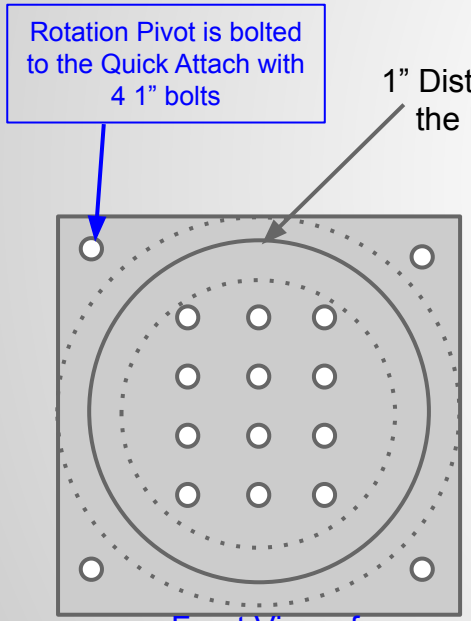




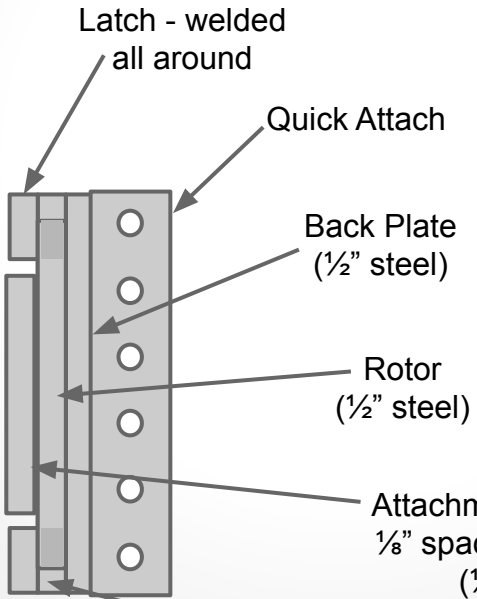
Super-Wall-e: a basic microtractor with a supersized bucket or blade. Used for minor grading operations

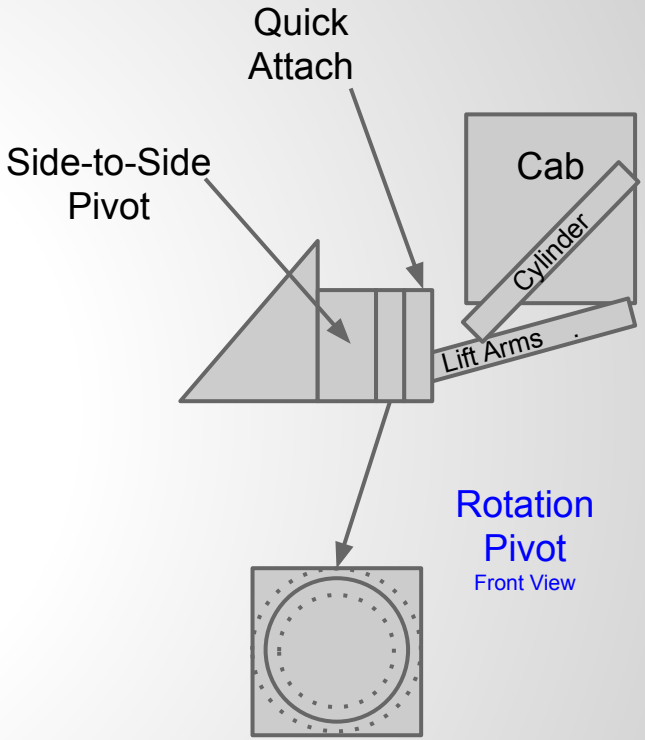
Modularity 4: Rotation Pivot

- Rotation pivot has a relatively low profile
- Simplest implementation is a circle cut in a square where the square serves as a form for the rotation
- This has an advantage over industry standards: when angled, the blade can also be pitched (curled)



Front View of Rotation Pivot (24” square)

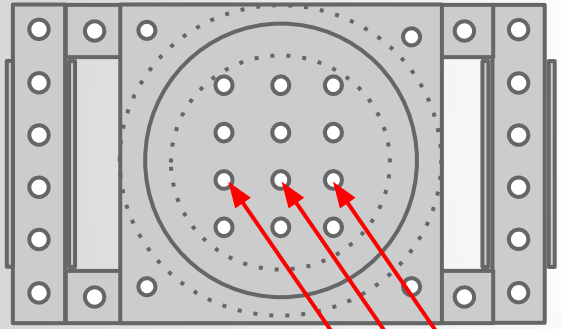




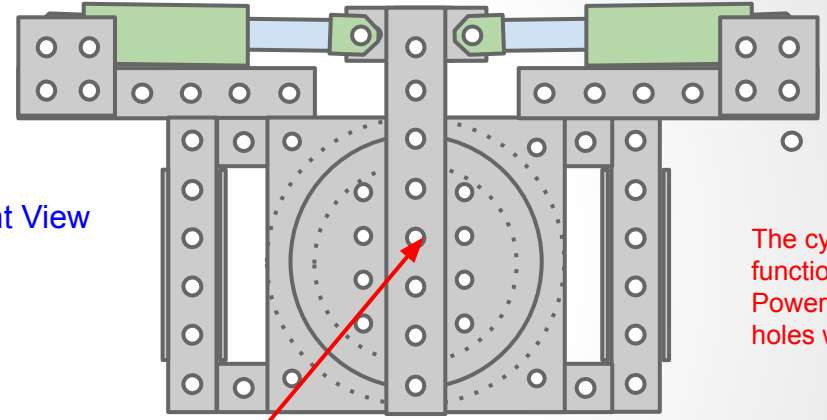
Attachment Plate has 1” nuts welded into it to allow attachment of further modules

Modularity 4: Rotation Pivot 2

- Rotor is bolted on to the Quick Attach Plate
  - Rotation function is thus completely modular
  - It could be used on the Quick Attach or between Power Cubes



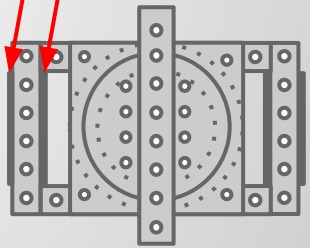
Front View



The cylinder attach plates could now function as a connection to another Power Cube - the quick attach is 9 holes wide just like the Power Cube.

Here, this tube has been added for pivot motion with cylinders,for a bulldozer blade tilt application

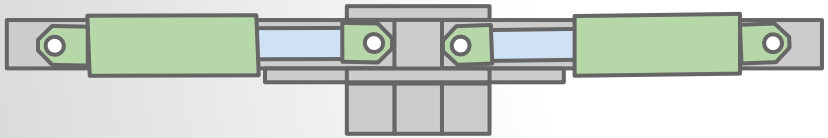
Bolt pattern allows connection of any intermediary tubes to make connection easy. These holes are really welded in bolts.



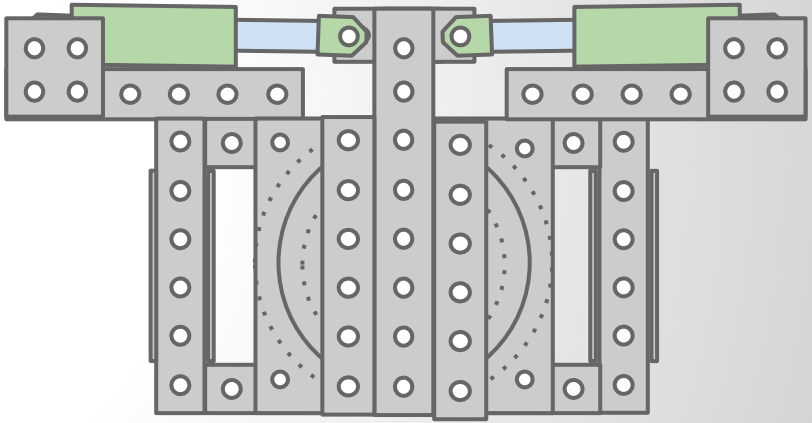
This configuration can be used for interconnect of 2 Power Cubes to allow ground-hugging

Modularity 4: Rotation Pivot Top View

- Rotor is bolted on to the Quick Attach Plate
  - Rotation function is thus completely modular
  - It could be used on the Quick Attach or between Power Cubes



Top View



Front View

Tractor Construction set Controls Overview

Note: hydraulic design moved to separate document

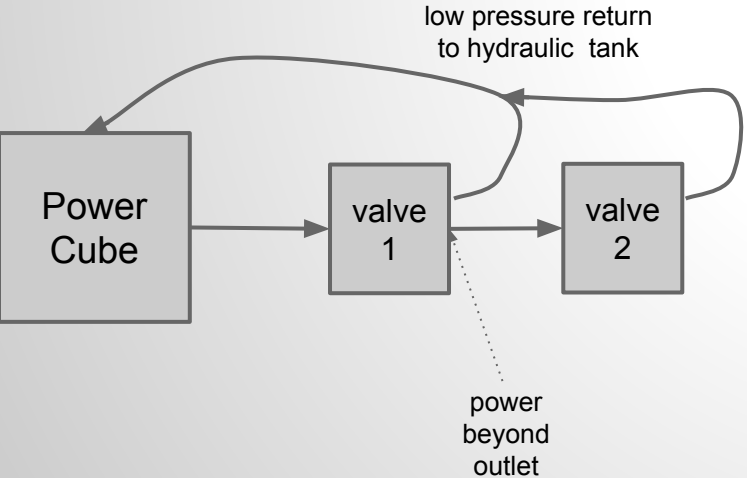
Requirements

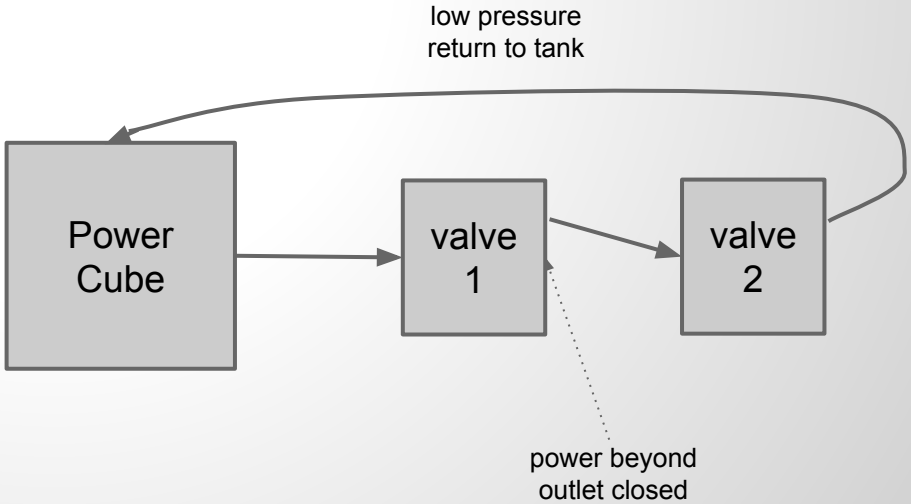
- To create a true construction set for heavy equipment, the controls have to be:
  - **Flexible** - capable of controlling various functions and implements
  - **Multiscale** - applicable anywhere from 1 to 100 hp per actuator by both allowing a range of fluid flow (0-40 gpm)
  - **Stackable** - multiple modules may be stacked for higher throughput
  - **Modular** - quick-coupled interchangeable for modification and different use
  - **Open Source** - design explanations allow for time-binding (general semantics) on design effort
  - **Multispeed** - achieves multiple speeds via hydraulic circuit, not gears
  - **Automatable** - designed for 60’ sylvopasture
- Practically speaking:
  - To optimize drive system, controls allow for Parallel or Series circuit operation on one.
    - This allows for multiple speeds
    - Slow mode uses 1-6 Power Cubes with 6 motors in parallel
    - Fast mode uses 2 Power Cubes per motor in a parallel configuration

Control Valve

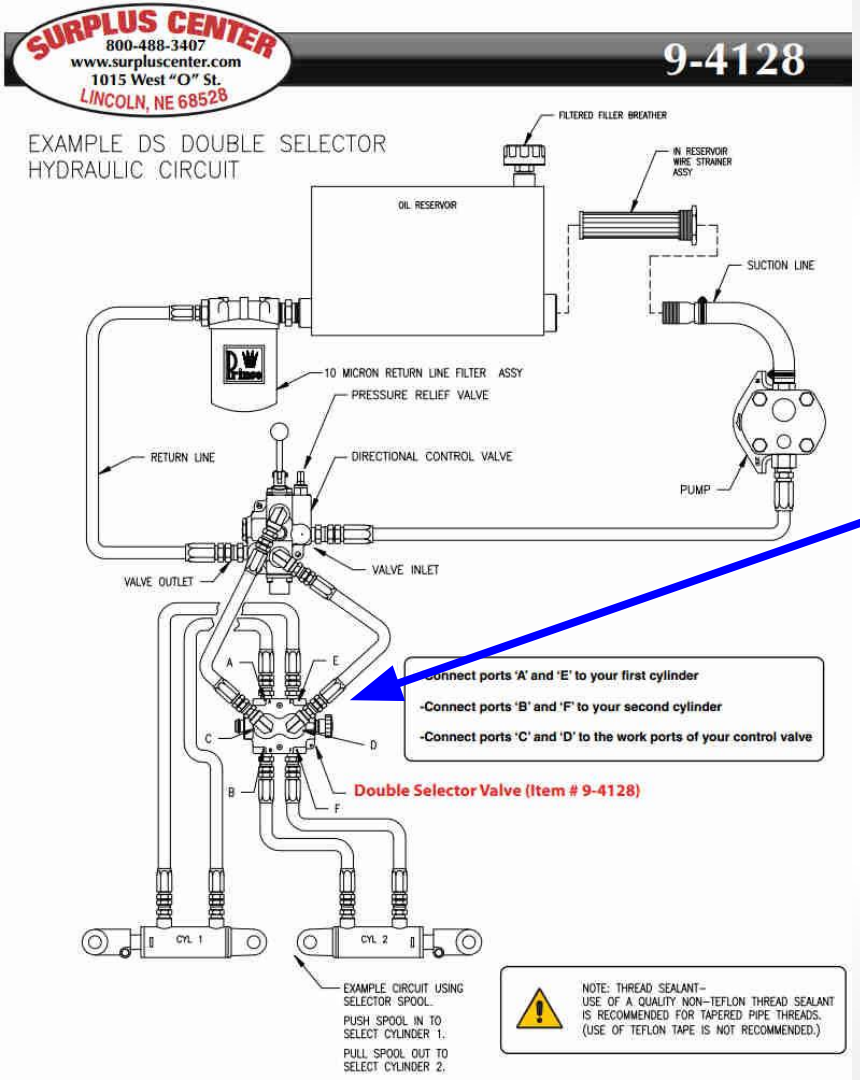
[45 GPM Control Valve]

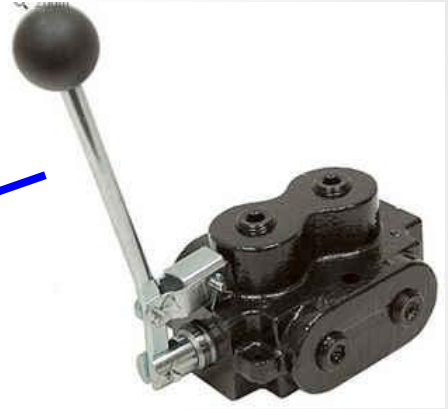
- **Bidirectional**: allows forward and reverse flow to the outlet ports
- Must be used with a Power Beyond plug if there are valves downstream. Otherwise, use a return line.
  - When Power Beyond is utilized, the return line must still be used from this valve
- However, when Power Beyond is used - only Valve 1 or Valve 2 can be used at a time.





Selector Valve Circuit





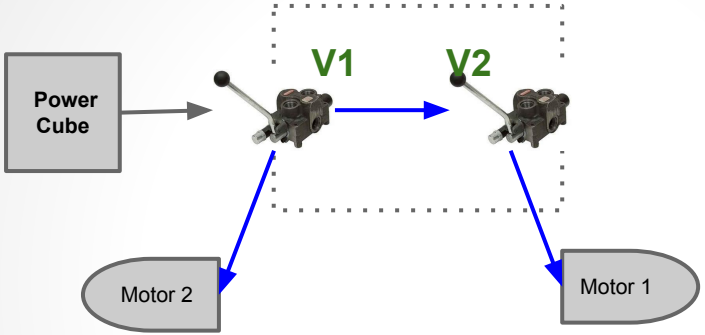
[40 GPM selector valve]

Controls Overview 2

Deployment

- Start with Cab and single Power Cube controlling 2 motors.
  - Parallel drive with series valves - allows one speed

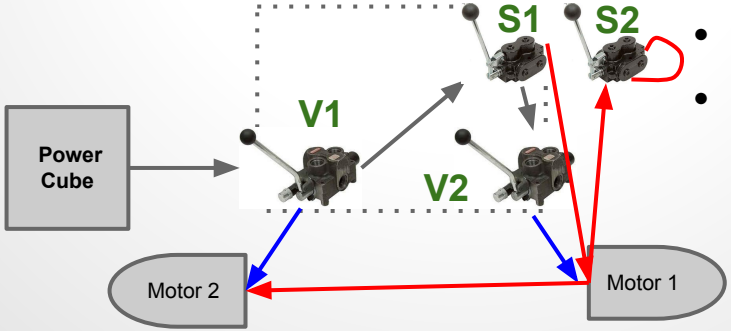
- broken line shows location of cab



- Each valve, situated on the left and right sides of the operator - is operated by one hand
- Forward and reverse is available
- Pushing one valve forward and one valve back makes the bulldozer spin in place

45 GPM Control Valve

work the system to allow both parallel and series operation of motors

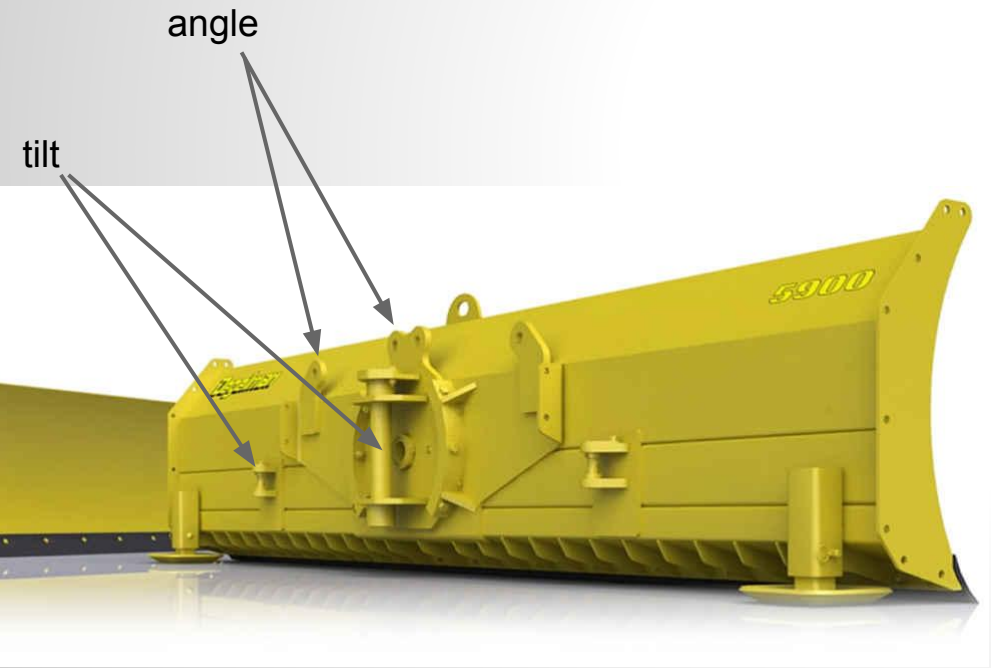


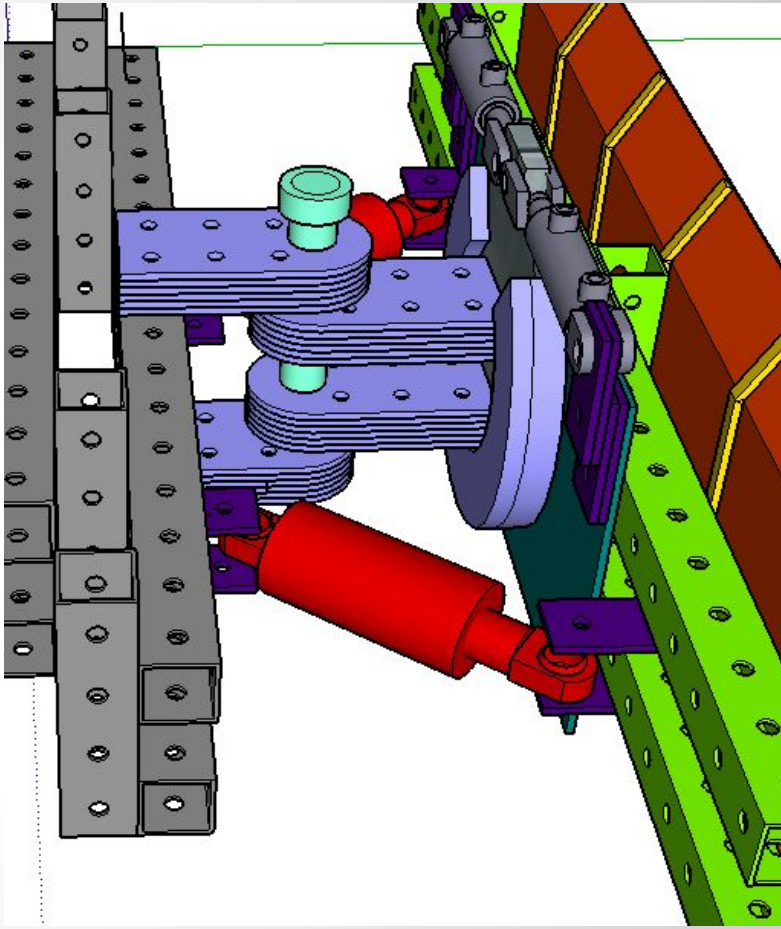
- Selector valves S selects parallel operation just like above, or routes to a new series circuit
- S1 and S2 have to be pushed in tandem to activate the circuit (see circuit detail)

8 Way Blade

8 way blade means up-down, pitch (curl), tilt right-tilt left, angle right or left.

- Cat D5 Blade - 9 or 10’ wide, 40” tall
- Cat D6 Blade - 11-14’ wide

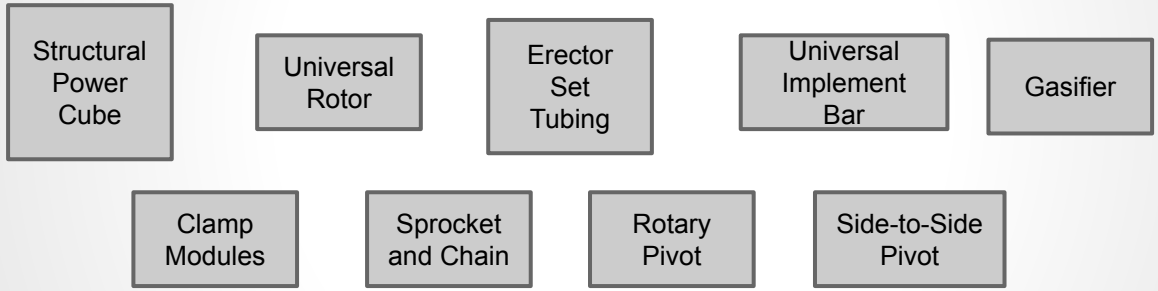




- Former OSE work by Leandra

Approach

- To attain modularity and a Construction Set approach core to the GVCS, We follow module-based design using accepted modules, and we are building upon these to make modification easy. Thus, a large number of machines can be built in parallel

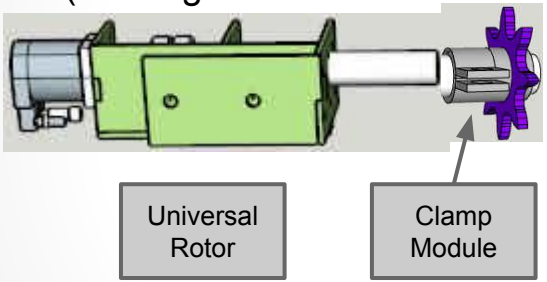


- To eliminate shaft machining, we are using heavy duty clamp modules for attaching rotor implements
- By making the tractor platform highly flexible, we can stack several functions in one pass. Ex: haying for pelletized charcoal making, charcoal injection, compost tea injection, manure spreading, bale unrolling, keyline plowing, rotary hoeing, and tree planting in one pass.

Universal Rotor Clamps

Concept: using clamp collars instead of drilled pin holes or milled keyways allows for high torque connections for wheels and other components allowing for rapid disconnect and for elimination of shaft machining.

- Existing Rotors on MicroTrac have 3” shaft. Clamp collar has not been used - just a ½” pin through since the rotor shaft was too short for the clamp collar. We can extend existing clamp collar so clamp is on both sides, by lengthening the shaft (welding a 6” extension on one side and 3” on the other)



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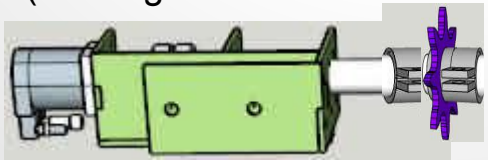
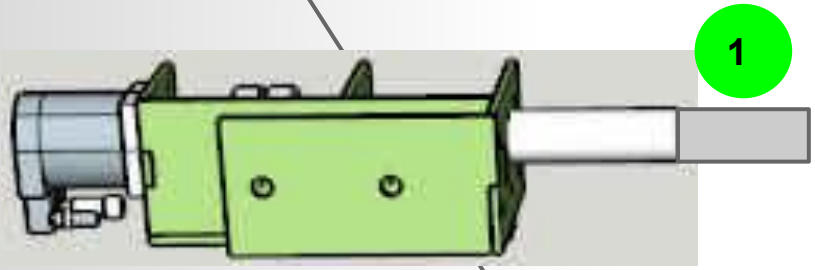
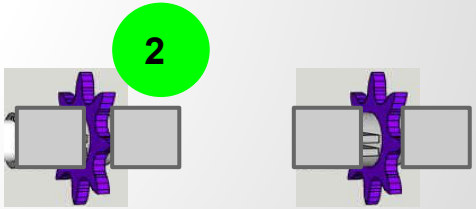


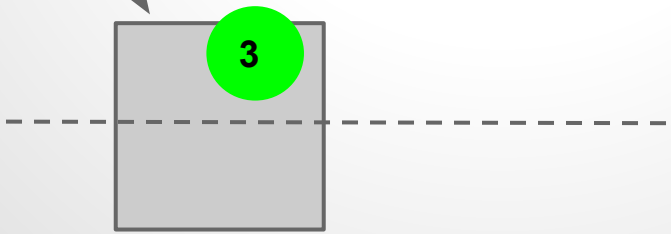
Universal Rotor 2

Build Instructions:

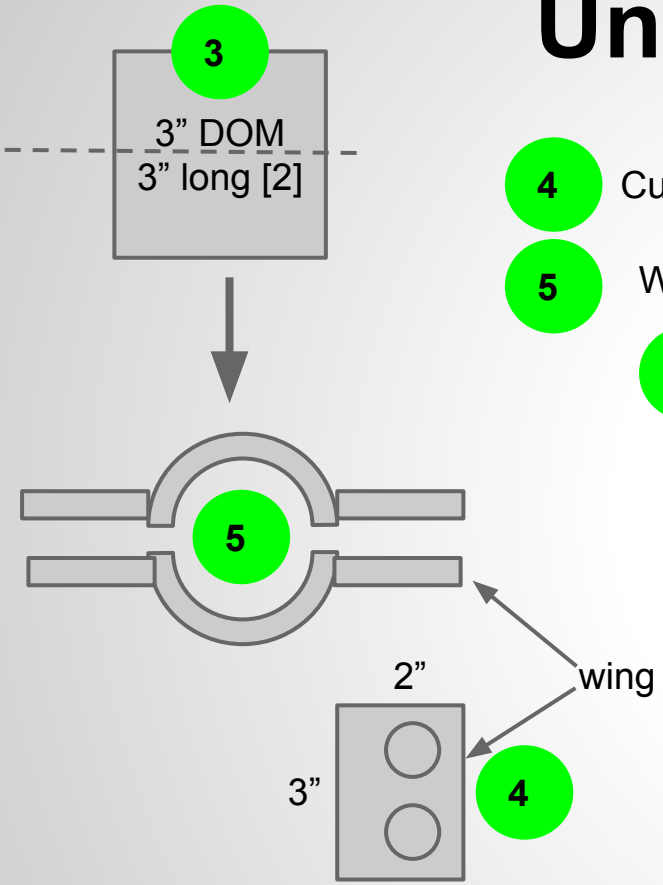
1. Cut [2] 6” section of a 3” shaft on bandsaw
2. Cut [4] 3” sections of 3” ID DOM Tubing
3. Cut DOM section in half lengthwise with #0 tip (½” Wall DOM)







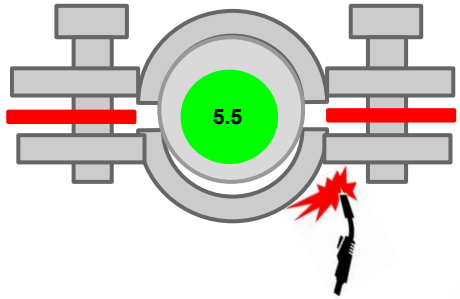
Universal Rotor 3

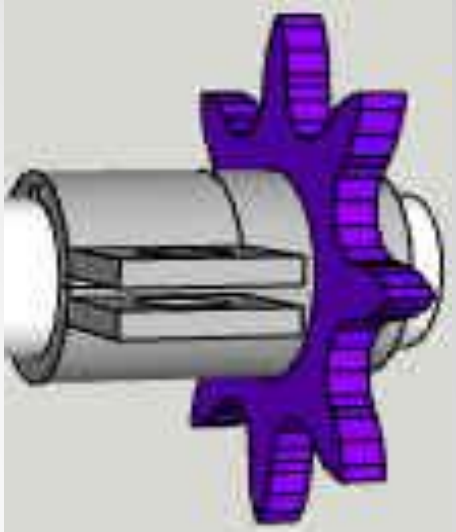


4 Cut wings from ½”x2” stock

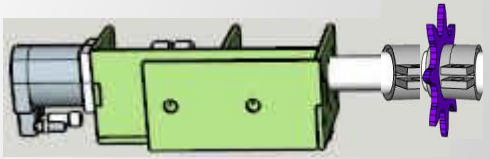
5 Weld wings to tubing halves

5.5 Use shaft as mold, and bolt these together using a 3/16” spacer

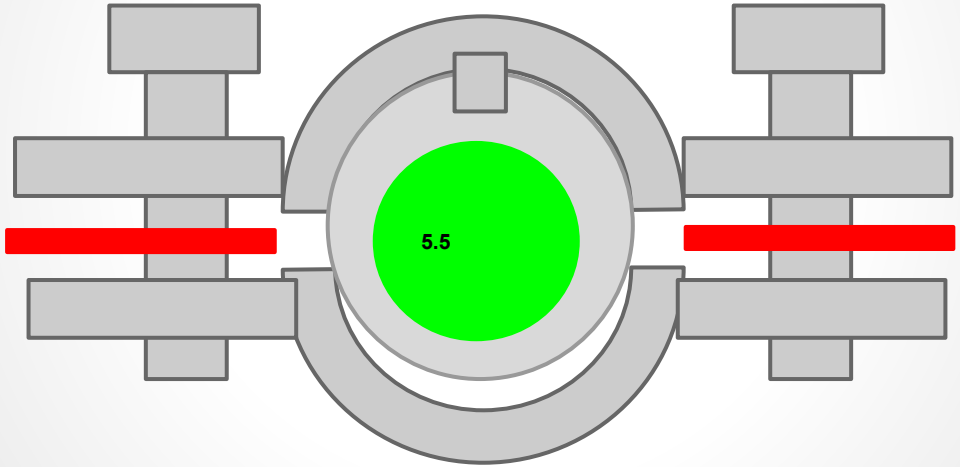




Concept - but with wing clamps on both sides

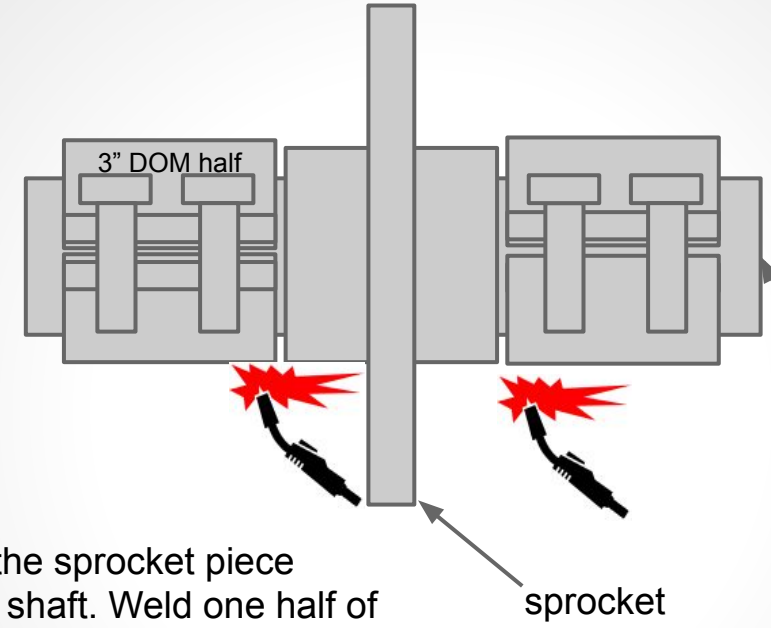


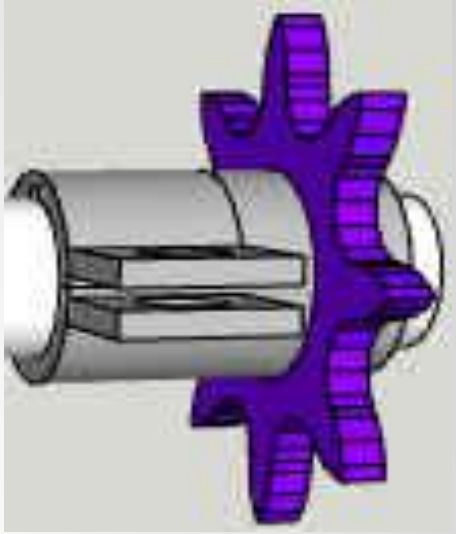
Keyway Clamp



Universal Rotor 3

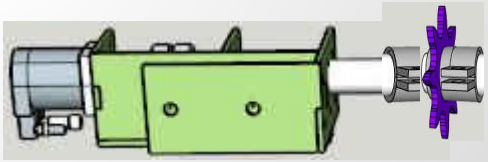
4000 lb of torque from this system. Bolts must hold 10,000 lb of torsion. Ok here, but not much more scalable.



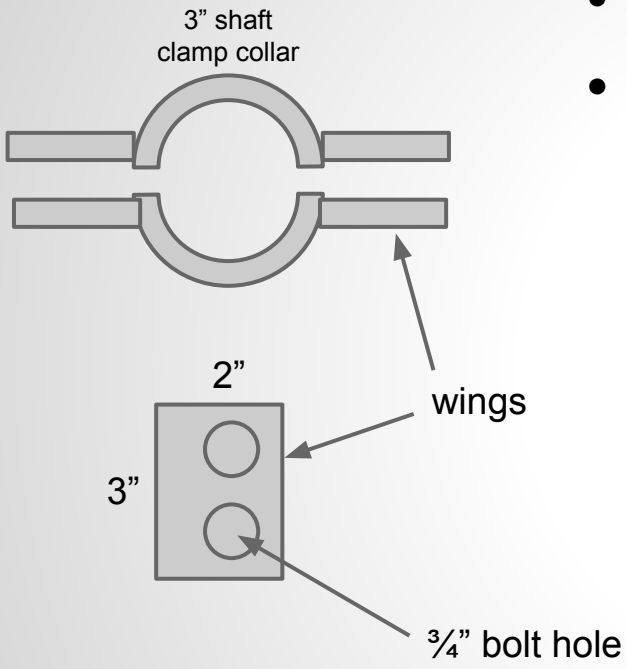


Concept - but with wing clamps on both sides

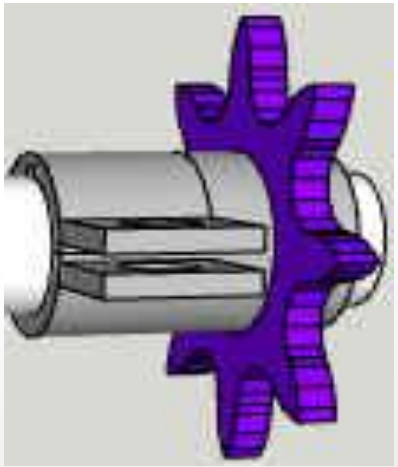
6 Weld winged halves to the sprocket piece while clamped down on shaft. Weld one half of the clamp so the top part of clamp can still be unbolted.



Clamping Calculations for 3” Clamp Collar

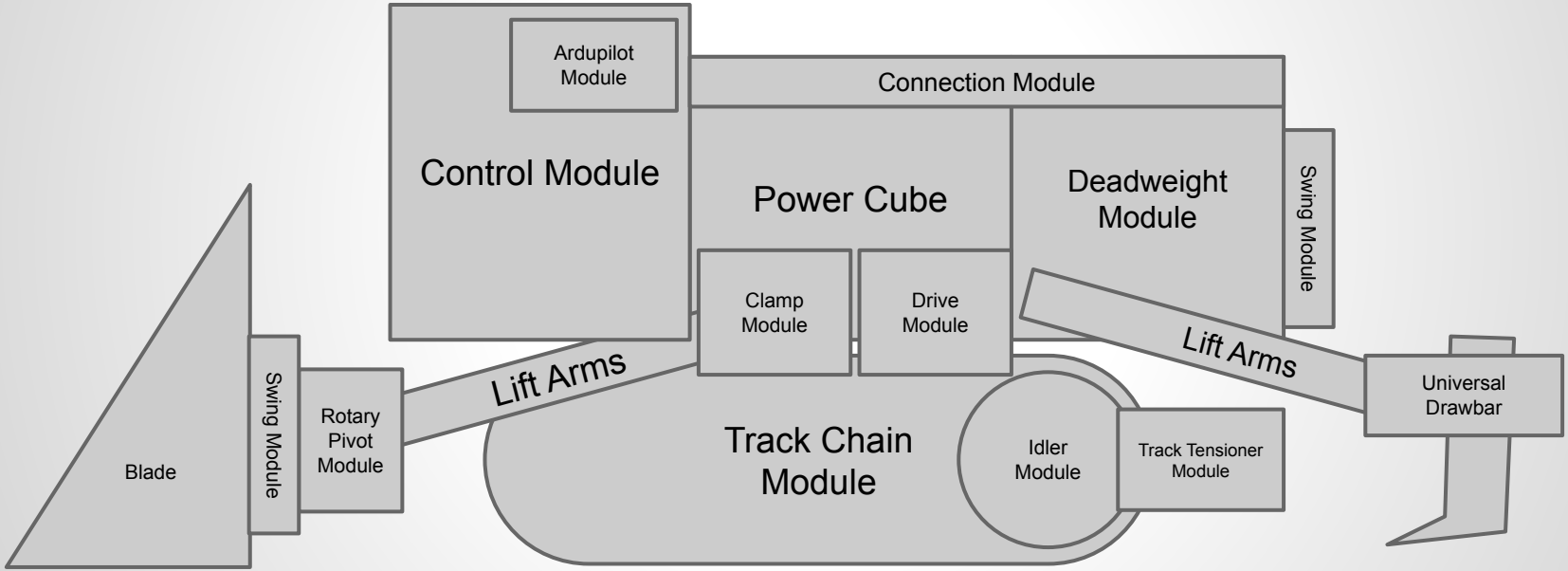


- Clamp strength of 1”-8 tpi bolt is 38k lb, with 53 ft-lb tightening torque
- Clamb strength of a ¾”-10 G8 bolts is 30k lb - so 4 of them per sprocket are 120k lb clamp force
  - This source indicates a coefficient of friction of .15 for cleaned mating surfaces, thus resulting in 18,000 lb of hold. We need 10,000 lb of hold.
  - This source says coefficient of friction for steel is .5-.8, **resulting in at least 60k lb of holding force**



Concept - but with wing clamps on both sides and two ¾” G8 bolts instead of a single 1” bolt

Bulldozer Proper



Modules Prior Art - OSE

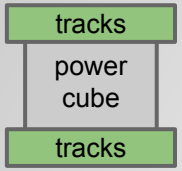
Builds upon Concepts:

- OSE Specifications
- Global Village Construction Set
- LifeTrac Construction Set
- Universal Rotor Construction Set
- Construction Set concept

Builds Upon the Proofs of Concept of Several Modules:

- Structural Power Cube - a Power Cube with a structural frame that allows the Power Cube to be used as a self-contained module
- Modular Wheel Units, which are an instance of the Universal Rotor
  - See 3 types of Wheel Mounts
  - See 3” Wheel Hub
- Structural Modular Tubing - 4”x4” square tubing for structures, either ½” or ¼” wall - and its scalability by using multiples
- Power Cube Scalability. To date, we have used up to three 28 hp Power Cubes, or as little as a single 1 hp Micro Power Cube to drive a 5000 lb tractor
- Scalable Pivot Joints and stock plates (bonding + pivot plates)

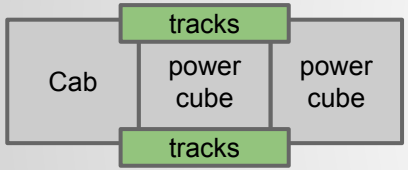
Configurations



Base Unit - 28 hp

- -slow speed -no cab
- +smallest unit
- +efficient shaft use
- +parallelizable
- +scalable to 2 wide + 2 deep
- 2000 lb base scalable to 8000 lb

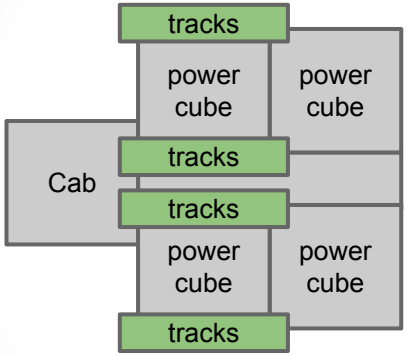
2,000 lb weight
8000 lb drive Torque



4,000 lb min + 6000 lb Torque

56 hp

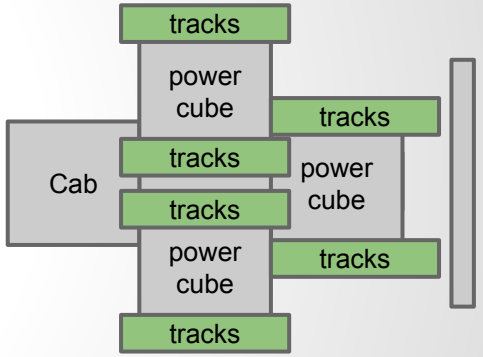
- +direct scaling of Base Unit
- +acceptable axial torque
- +fully scalable



7,000 lb min + 12,000 lb Torque

Fully Scalable Version - 112 hp+

- +direct scaling of Base Unit
- +acceptable axial torque reduction



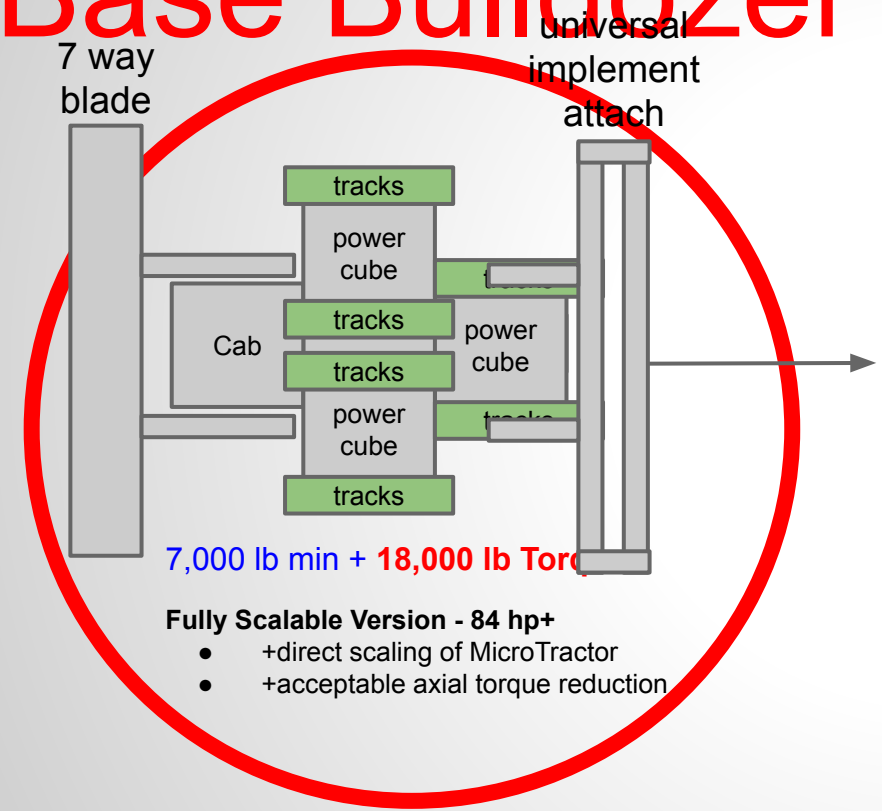
7,000 lb min + **18,000 lb Torque**

Fully Scalable Version - 84 hp+

- +direct scaling of Base Unit
- +acceptable axial torque reduction

Configurations 2

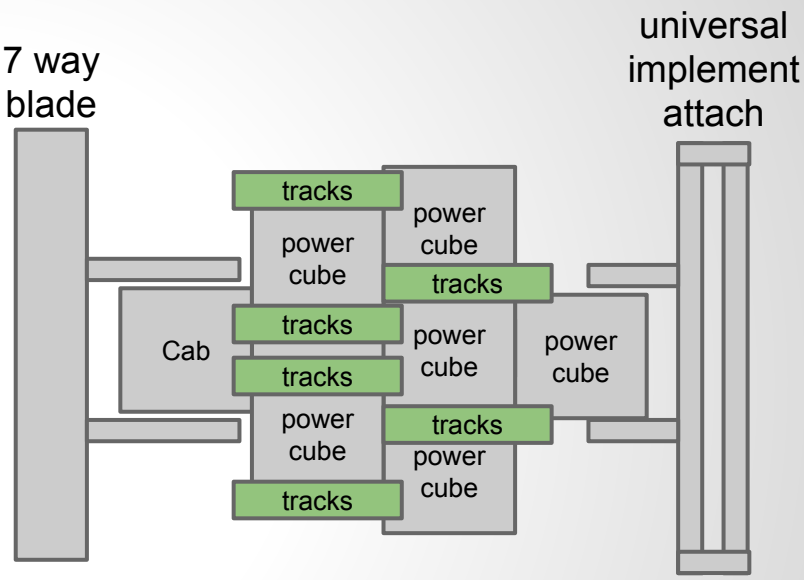
Base Bulldozer



7,000 lb min + **18,000 lb Tor**

Fully Scalable Version - 84 hp+

- +direct scaling of MicroTractor
- +acceptable axial torque reduction

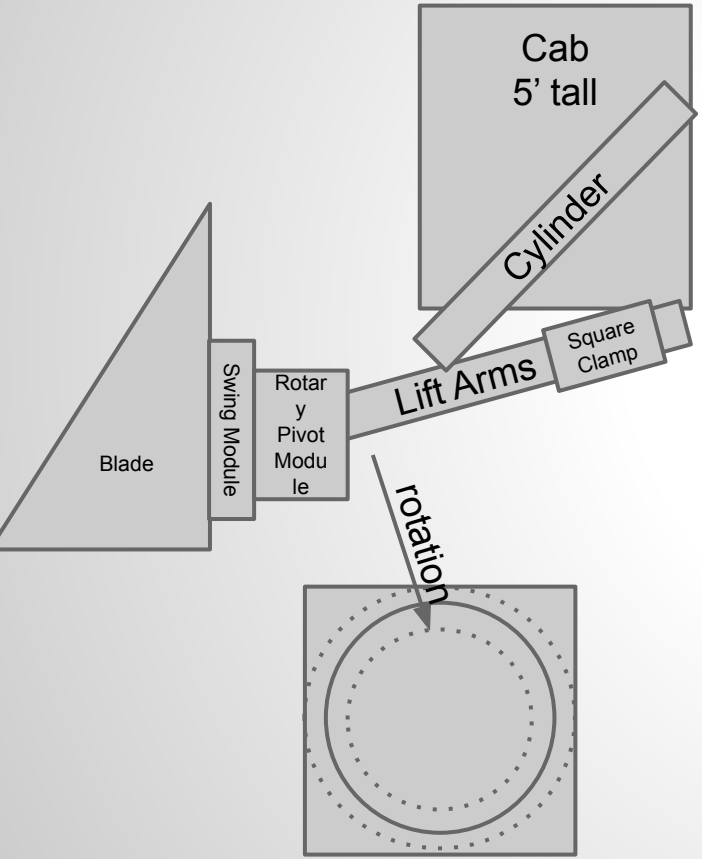


16,000 lb min + **18,000 lb Torque**

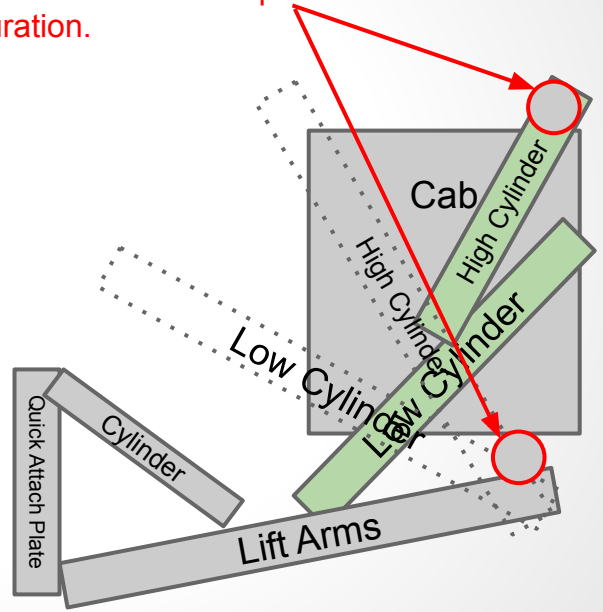
Fully Scalable Version - 168 hp+

- +direct scaling of Base Unit
- +Dead weight is removable
- Heavy structural cab is 2000 lb
- Blade is 3000 lb
- Keyline plow is 2000 lb

Cab and Dual Positions of Attaching Main Lift Cylinder for Low and High Reach

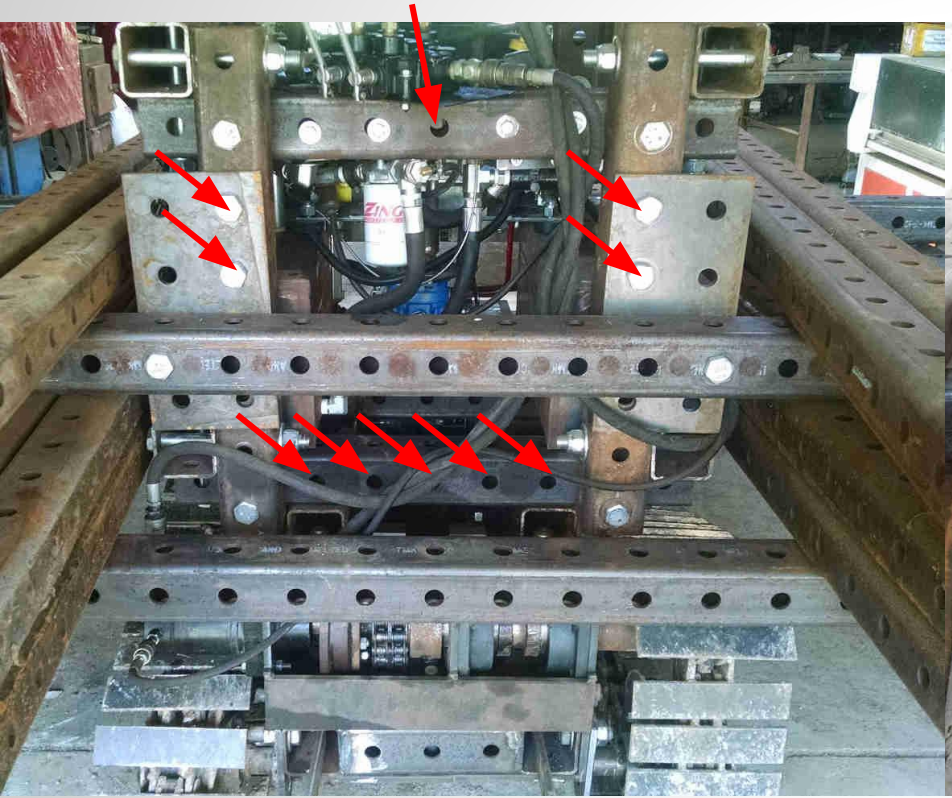


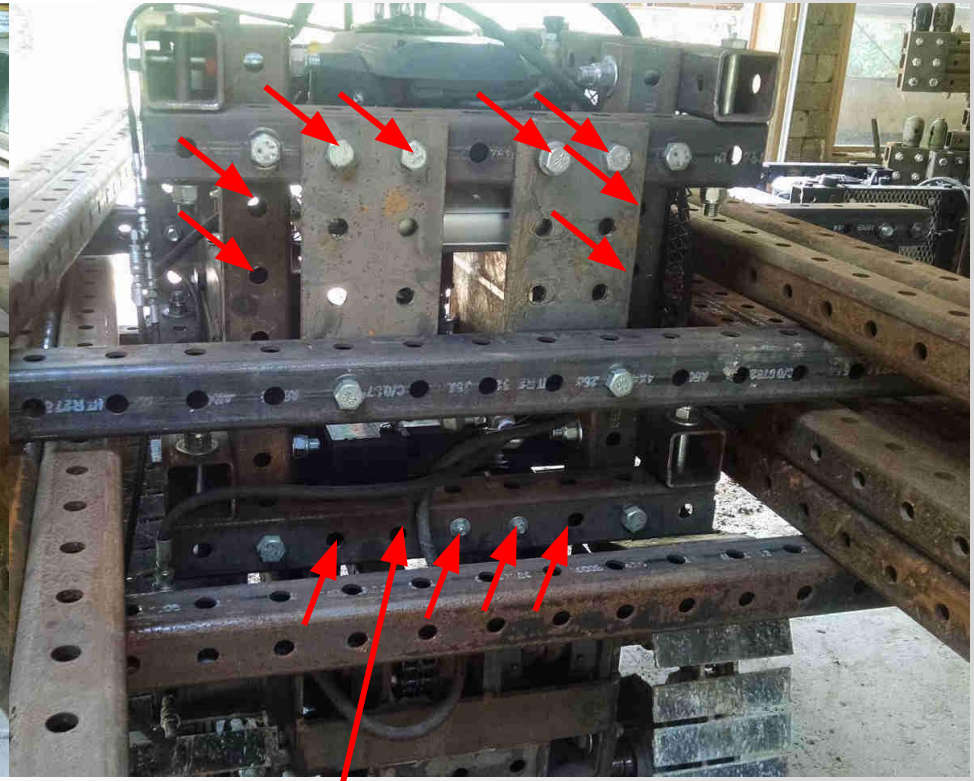
3" shaft u-bolted to top and bottom (or elsewhere) of frame so loader or cylinder can be attached to this 3" shaft. This way, the cylinder or loader can also be attached at the top or bottom as needed for high lift or low lift configuration.



MicroTrac Bolt Conflicts

Red arrows show available holes



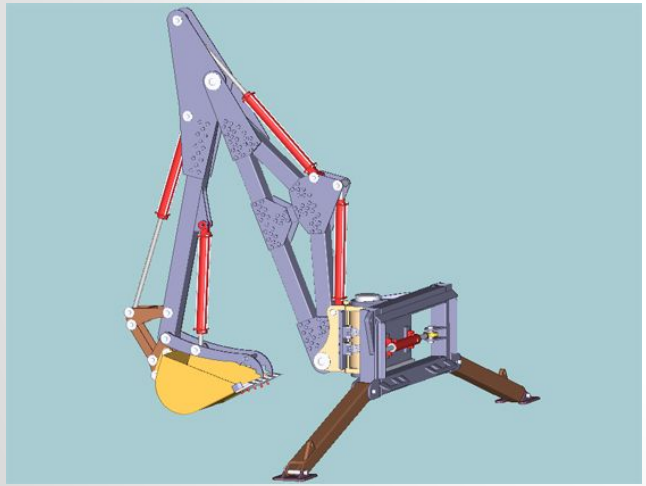


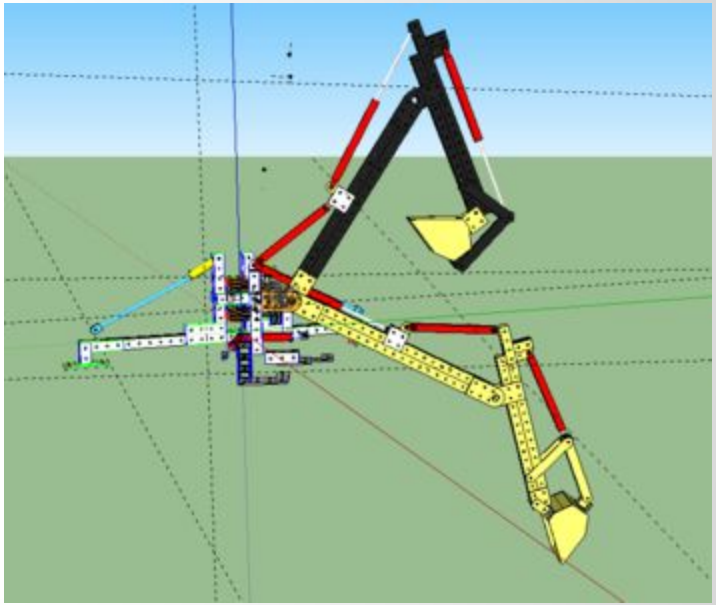
open if battery box is moved

Backhoe

Past work - link - this has been built, but side to side pivot does not work well. Too tight geometry.

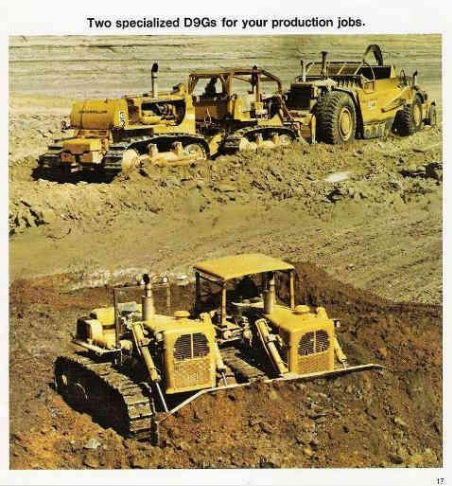
- Current improvement needed is side-to-side pivot like this using chain and cylinder (same chain as bulldozer tracks)





Cheap Fuel and Expensive Operator 101

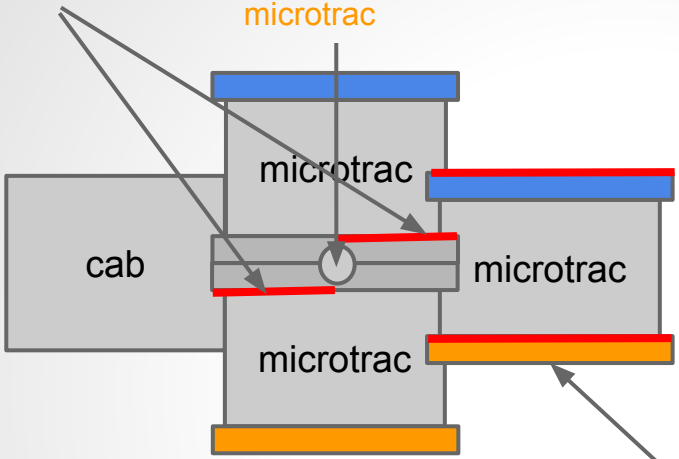
Any info on whether the middle tracks are free/idle? It has to be moving, as otherwise, they could use a single dozer with a 2x wide blade. It's about traction.



The part in red will be gliding sideways on dirt like a shovel.

pivot point, actually, i'm not even sure where the "pivot point" is considering the front microtrac

Exactly. That's what happens when a skid steering machine like this turns. There will be large forces. Force expected with a unity coefficient of friction is equal to the weight. That weight is 8k lb for each microtrac section. I'm not saying this is ideal or even good. But it's an acceptable price to pay for 100% modularity. It's a tradeoff for modularity. Nobody does this primarily becuase they are not building 100% modular devices, AFAIK.

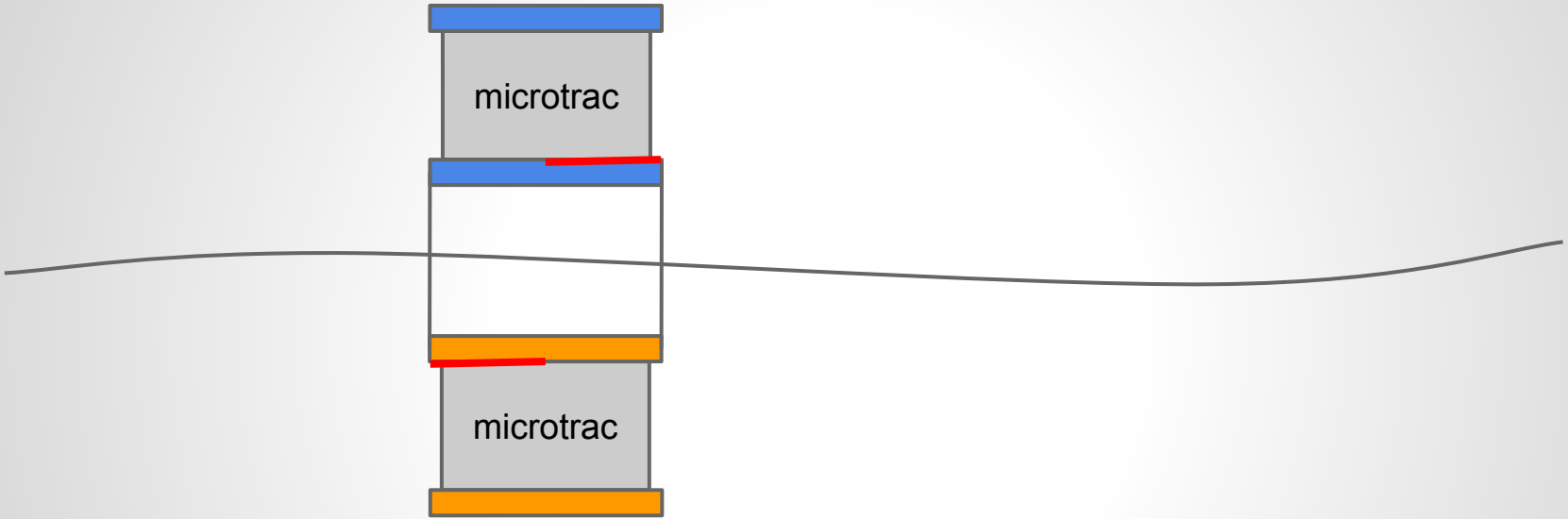


front cube also will get dragged.

Want to stay at 8 for road legal and manaeuverability reasons.

Motion Considerations: inner tracks slide on ground when turning. This is where their axial thrust resistance allows them to do so. Axial thrust rating of bearings is 36,000 lb using the 3" bearings.

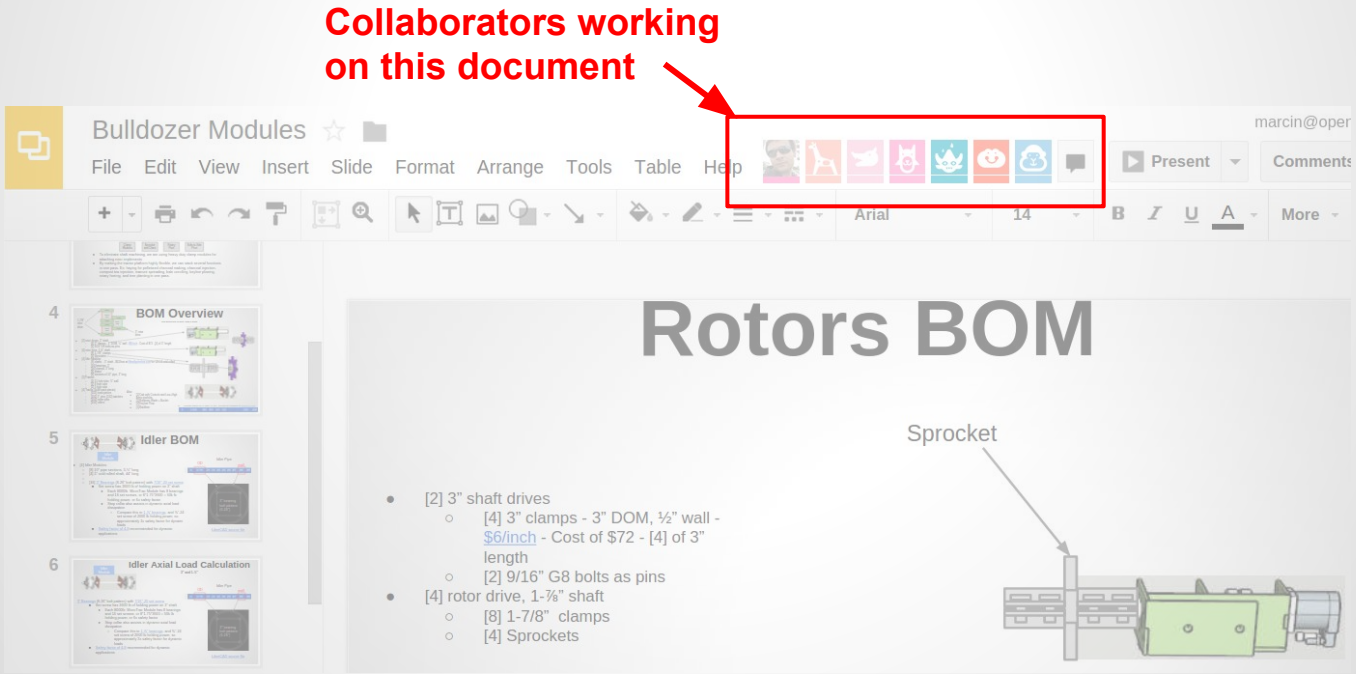
Row Straddling Considerations



Modularity of drive units allows row-straddling machines when a space is opened between the front microtracs so you can straddle rows, for example to make this into a hazelnut picker or blueberry picker or a dual-sided bale unroller.

Collaboration Goals

Imagine when at any time - there is a crew of people working collaboratively on a document 24/7. The potential of online mass collaboration has hardly been tapped. What does it take for OSE to achieve this?



Series Operation of Motors

In series operation - ports P1 and P2 of the selector valve are used. Fluid at point 1 goes to port A of Motor 1. Fluid cannot skip Motor 1 and flow through point 2 and 2' because of check valve C1. Therefore, fluid enters motor at port A, spins the motor, and exits out at port B. From there, the fluid cannot bypass Motor 2 and flow through 4 because port P4 is closed on the selector valve, nor point 4' because of check valve C2. Fluid from 3 cannot go through 2' because 2' is at higher pressure ('uphill' from C). Thus, the only way that the fluid can flow is through Motor 2 to D and then to P2. The path 4' cannot be taken because 4' is 'uphill' from D.

This Series pathway is reversible - pending use of additional check valves C3 and C4 according to an extension of the reasoning above. This is all good...but… the parallel route does not work as is...