Design, Development and Construction of a

Magnetohydrodynamic Cocktail Stirrer

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Problem

- Density- and temperature-driven separation in cocktails

Existing Solutions

Spoon, Swizzle Stick

- Boring

Lab Stir Plate

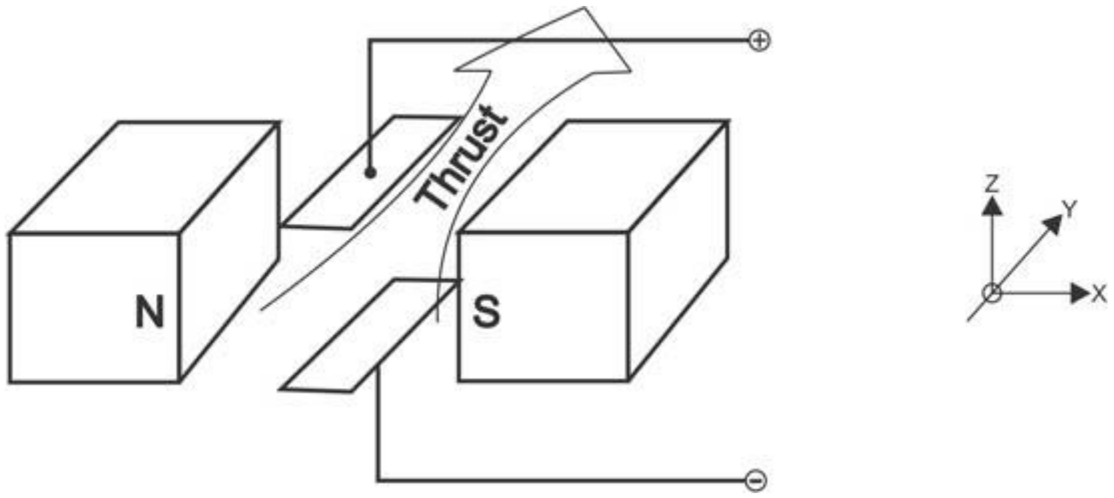
- Uses magnetic “pill”
  - Possibility of cross-contamination
  - Pill must be retrieved
- Still pretty boring

Proposal: Contactless Cocktail Stirrer

- Truly contactless (no magnetic “pill”)
- Uses magnetohydrodynamics
  - Electrical and magnetic interactions with conductive fluid

Magnetohydrodynamics

- Well studied in marine propulsion
- Simplest applications is Lorentz-force drive



Early Efforts: 2013

- Used direct insertion of current (electrodes in drink)
- NdFeB permanent magnet
- Advantages:
  - Simple
  - Provides good pumping
- Disadvantages:
  - Electrolysis of drink
  - Electrically-driven erosion of electrodes

Current effort: Magnetodynamic Coupling

- Changing magnetic field induces currents (Faraday's Law)
- Eddy currents interact with original magnetic field (Lorentz force)
- Commonly used in contactless braking systems

Challenges

- Root problem: cocktails are **much** less conductive than copper
  - Requires large dB/dt to create significant force
  - Increase field strength, rate of change, or both
- Must meet budget and space constraints
  - No superconductors, custom magnets, etc.
  - Must fit in my living room

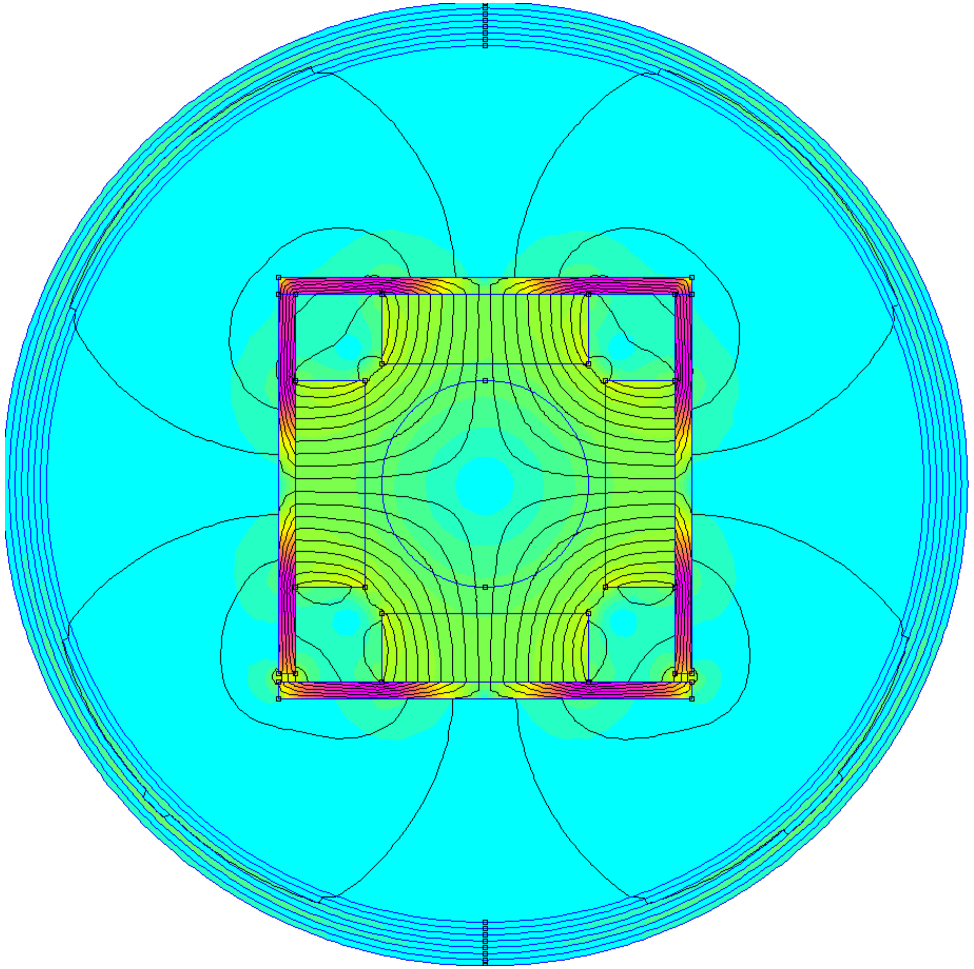
Magnet Selection

- Supermagnet from United Nuclear
- 3” dia., 1” thick
- NdFeB 45

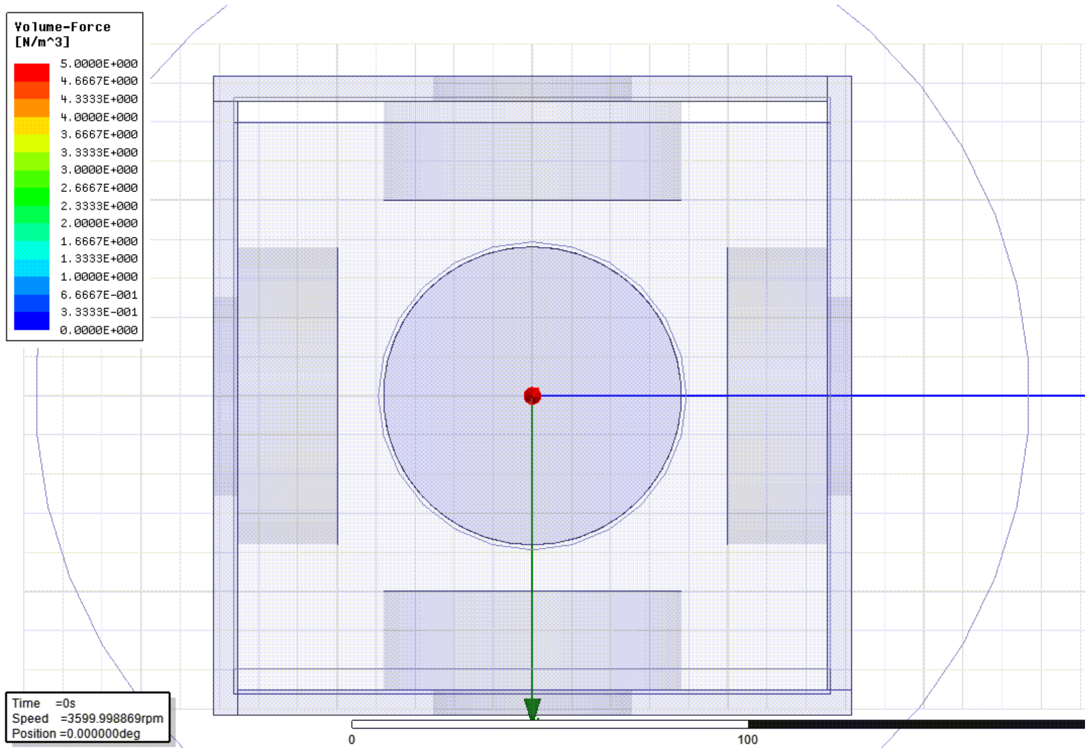
Supermagnet # 31

Magnetostatic Analysis: FEMM

- Used to characterize static field
- Quadrupole arrangement provides stronger (maximum) field than dipole
- 1018 steel shunts to provide good return path
- Maximum of 0.418 T in glass



Magnetodynamic Analysis: Ansys Maxwell



- Quadrupole assembly spun at 3600 RPM
- Seawater used as conductivity baseline
- Generates force vector field result
- Maximum of 3.3 N/m^3

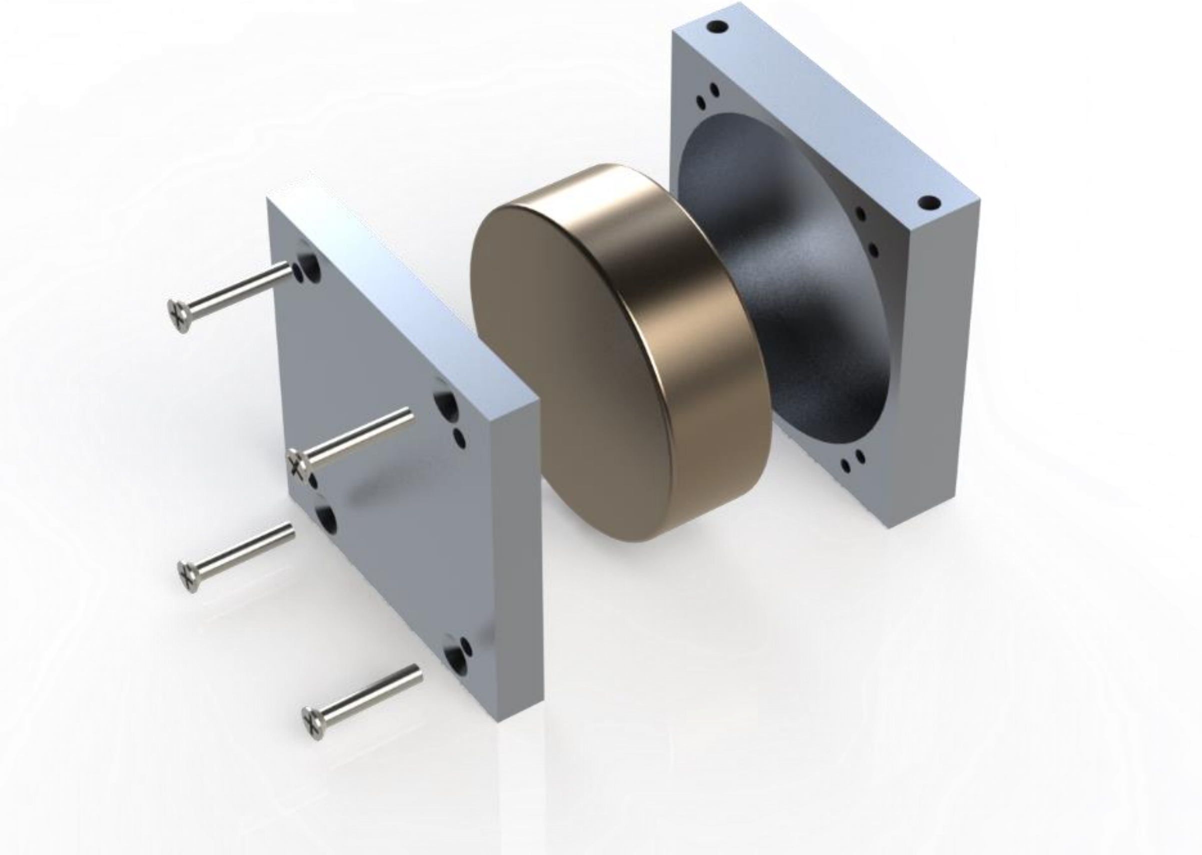
Computational Fluid Dynamics: OpenFOAM

Conductivity Characterization

- Experimental apparatus:
  - ½” x ½” x 24” UHMW trough
  - Capacitively-coupled plates at ends
  - 50 kHz sinusoidal excitation
- Stages:
  - Measure conductivity of precursors (liquor, mixers, etc.)
  - Measure conductivity of common cocktails
  - Optimize for conductivity

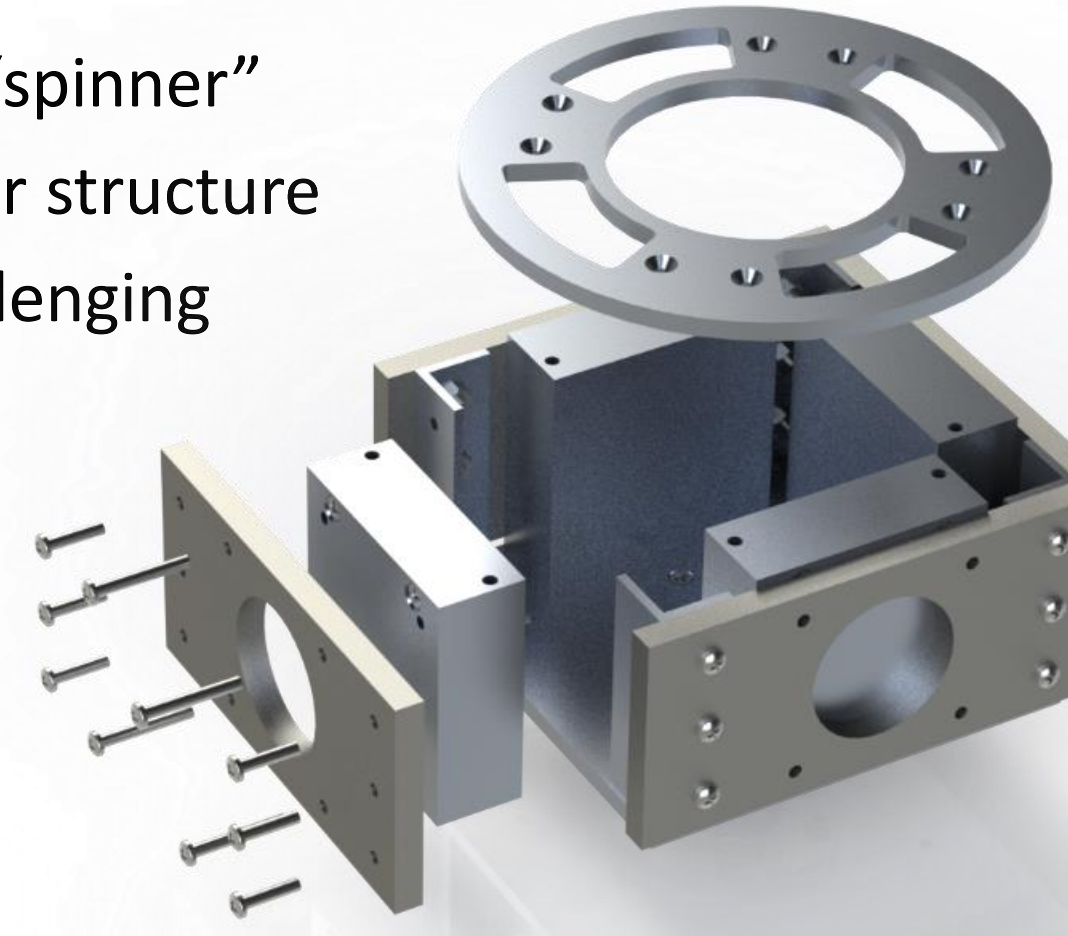
Mechanical Design: Magnet Holders

- Magnets contained in aluminum housings for mounting & protection
- 316 stainless steel (nonmagnetic) screws used



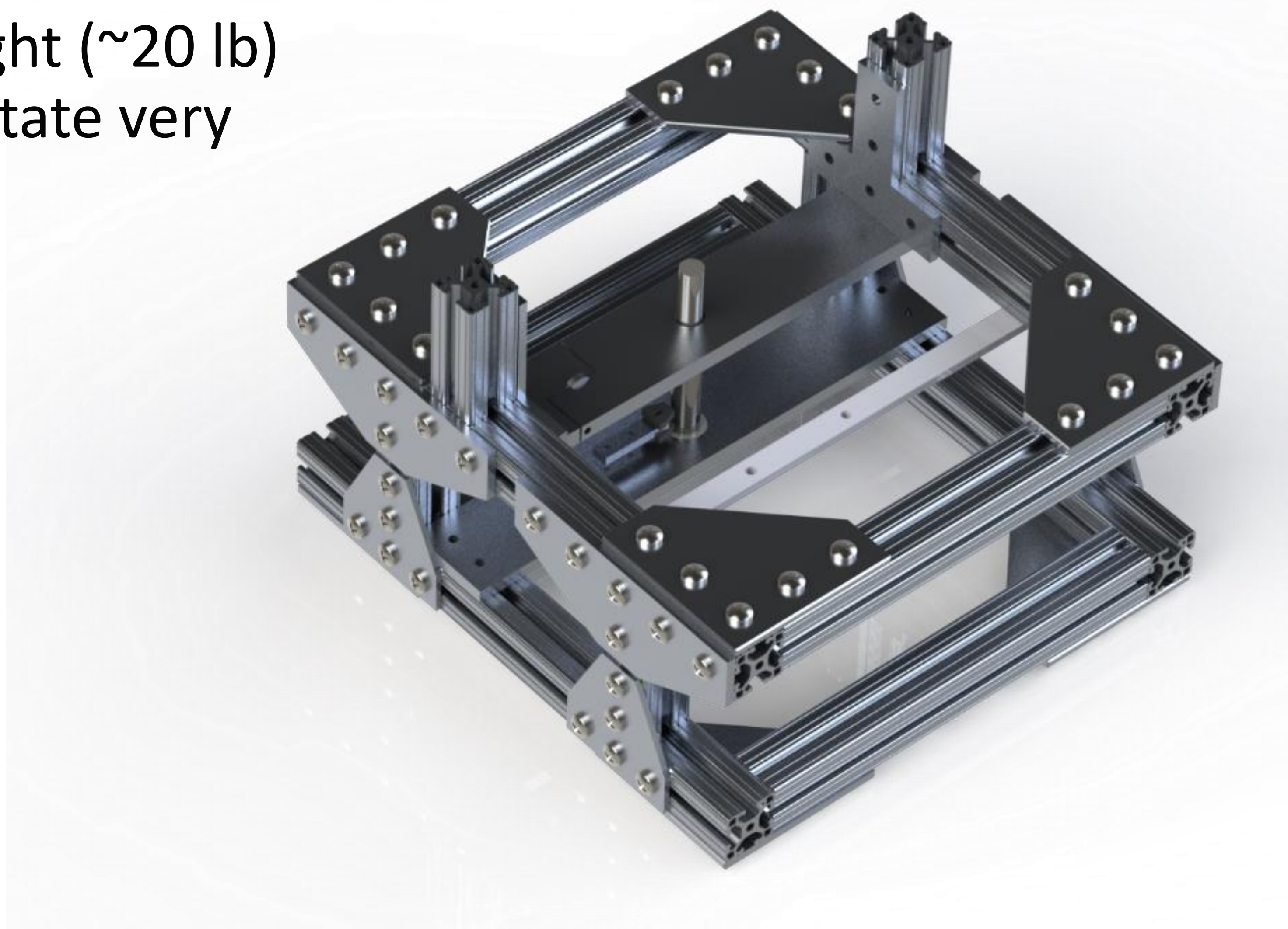
Mechanical Design: Spinner Assembly

- Assembly of four magnets into “spinner”
- Steel shunts form part of spinner structure
- Assembly anticipated to be challenging



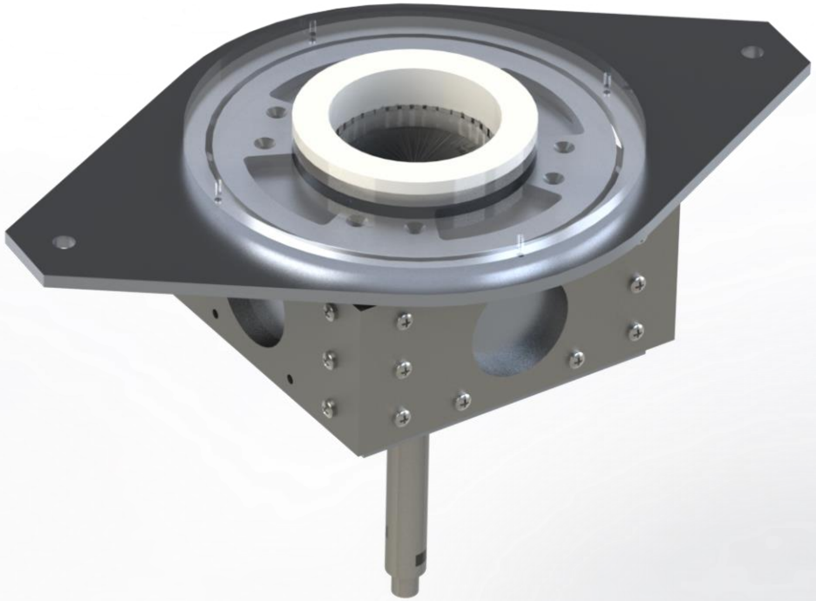
Mechanical Design: Frame

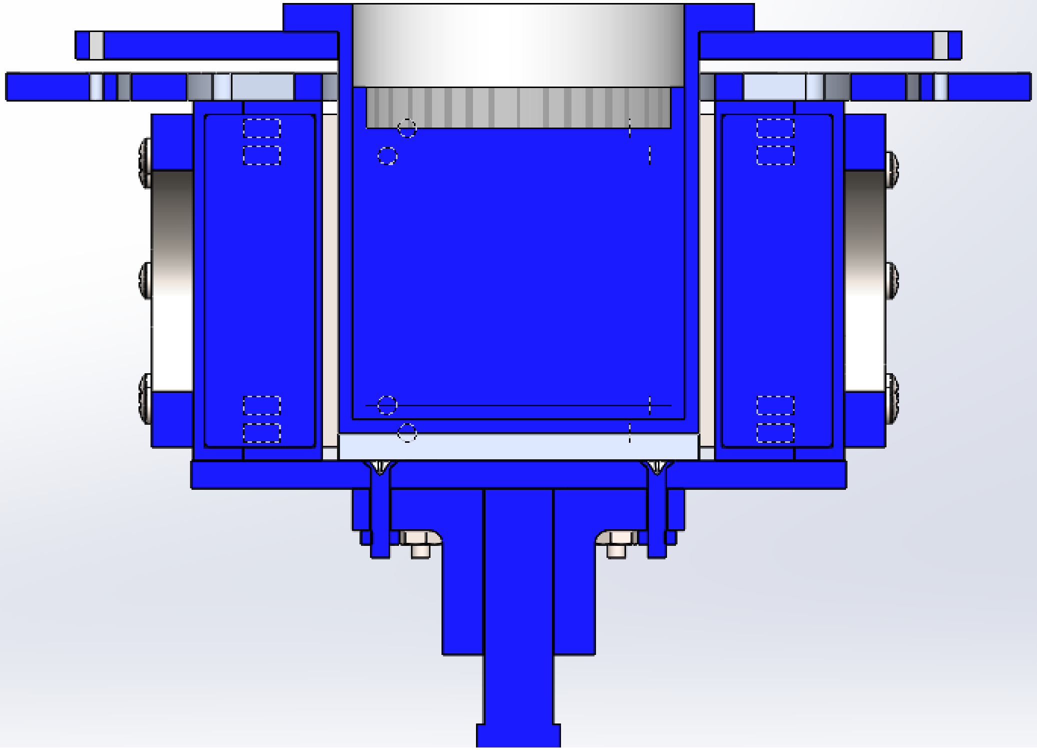
- Speed (3600 RPM) and weight (~20 lb) of spinner assembly necessitate very robust structure
- 1.5” 80/20 extrusion frame



Mechanical Design: Glass Support

- Cocktail glass must be suspended in spinner assembly
- Materials must be nonmagnetic and nonconductive
- Delrin cup in Lexan ring





Mechanical Design: Balancing

- Spinner must be carefully balanced
- Load cell on crossbar monitors centrifugal force
- By correlating with shaft encoder, angular location of mass overburden can be found
- Balance mass added on opposite side to balance spinner

Mechanical Design: Power

- 12 VDC CIM motor drives spinner
- Coupled to spinner shaft by #25 roller chain

Control System

- MDL-BDC24 PWM motor controller (40 A continuous)
  - Internal PID loop for velocity control
  - Controlled via CAN
- National Instruments cRIO-9022 controller
  - Realtime OS
  - FPGA backplane
- 12 VDC, 50 A power supply

Control System

- cRIO monitors:
  - Centrifugal force sensor
  - Shaft encoder
  - Motor voltage & current (via MDL-BDC24)
  - User interface
- And controls:
  - MDL-BDC24
  - Main power contactor

Safety

- cRIO shuts down motor if monitored parameters exceed safe limits
- MDL-BDC24 can “brake” motor (short across armature)
- “Emergency bushing” designed to limit maximum wobble of spinner
- User behind barrier, at least for initial tests