Motivation: Minimize downtime due to unequal filling intervals by matching the capacity of the planter with the capacity of the chemical stored by the system. A self-contained and flexible mobile agricultural chemical storage and metering system allows for several applications on the farm. The final design of this project will be a feasible product for commercial production.

Project Goals:
- 1000 gallon storage capacity
- Self-contained unit to allow for single point hookup to implement
- Allow for flexibility in pumping and metering devices to allow for application of several differing solutions without having to change components
- Utilize existing equipment to make project more feasible on a commercial level
- Compatible with variable rate technology (VRT)

Benchmark:
- The Agri-Products System
  - Up to 800 gallon storage capacity
  - $2585 MSRP
  - Approx. 17.5 ft width (limits mobility)
  - No loader attachment

Design Parameters:
- John Deere 4960 Tractor Specifications:
  - Engine Speed (rpm): 1800
  - PTO Speed (rpm): 800
  - PTO Size (in): 3.75
  - Ground Speed (mph): 5.6

- Tractor Loading:
<table>
<thead>
<tr>
<th>Applied Load (lbs)</th>
<th>Available Tire Load (lbs)</th>
<th>Allowable Added Weight (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planted Unfolded</td>
<td>Planted Folded</td>
<td>Planted Unfolded</td>
</tr>
<tr>
<td>Front Axle</td>
<td>Back Axle</td>
<td>Front Axle</td>
</tr>
<tr>
<td>7720</td>
<td>20500</td>
<td>25500</td>
</tr>
<tr>
<td>14480</td>
<td>23650</td>
<td>26200</td>
</tr>
</tbody>
</table>

- Design for operator comfort and safety
  - Operator station panel can operate valves electronically
  - Additional lights for greater night visibility

- Compatibility with existing VRT monitors
- Multiple fill points for convenience
- Use existing saddle tanks to hold additional chemical
- Maximum desired width of 16 ft
- Loader Specifications:
  - Standard John Deere 840 loader assembly
  - Maximum load of 9200 lbs
Design Process:

- Limiting design factor is flow rate, due to high application rates with low pressure delivery
- Assumed line losses were minimal
- Application rate

<table>
<thead>
<tr>
<th>Number of Rows</th>
<th>Row Spacing (in)</th>
<th>Application Width (ft)</th>
<th>Min Application Rate (gal/acre)</th>
<th>Min Flow Rate (gpm)</th>
<th>Max Flow Rate (gpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>30</td>
<td>60</td>
<td>15</td>
<td>10.2</td>
<td>48.2</td>
</tr>
</tbody>
</table>

- Pump Selection:
  - PTO mounted, belt driven centrifugal pump
  - Stainless steel components

- Flow Meter:
  - Operating range = 1-60 gpm
  - Power supply and signal compatible with modern VRT monitor

- Regulating Valve:
  - 2” solenoid actuated butterfly, open loop control
  - Power supply wiring compatible with modern VRT monitor
  - Maximum operating pressure = 300 psi

- Frame Design:
  - Saddle tanks supports located in existing mounting holes in the bottom of the loader mast
  - Loading assumed to be 3g at saddle tank support end
  - Deflection of saddle tank supports
    \[ \delta = -\frac{PL^3}{3EI} \]
  - Maximum deflection = 0.157 in
  - Stress in saddle tank mounts
    \[ \sigma = \frac{M}{S} \]
  - Maximum stress = 25,030 psi

- Weld calculations
  \[ f_s = \frac{p}{L_m} \quad f_a = \frac{p}{L_m} \quad b = \frac{\sqrt{f_a^2 + f_s^2}}{0.707f_{allow}} \]
<table>
<thead>
<tr>
<th>f_a (lbs/in)</th>
<th>f_s (lbs/in)</th>
<th>fallow (psi)</th>
<th>b (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>111.5</td>
<td>1092.2</td>
<td>13000</td>
<td>0.12</td>
</tr>
</tbody>
</table>

- Factors of Safety
  \[ FS = \frac{x_{actual}}{x_{allow}} \]
  - FS = 1.44
  - FS weld = 3.75

Build Process:

- Modified loader frame mounts by fabricating and welding saddle tank supports
- Re-worked and moved battery box assembly
- Built new steps for alternate location
- Installed saddle tanks with appropriate mounting hardware
- Wired new components into operator station controls and monitor
- Fabricated the quick disconnect front tank support and installed front tank
- Routed new plumbing components, including pump and metering valves
- Attached loader to purchased mounting brackets with mast
- Paint and finish work, including hose clamps and new lighting mounts

- Issues
  - Clearances between new and old components
  - Accounting for quantity and sizing of all fittings
  - Part shipping and delivery dates
Final Product:

- Project Limitations
- Front visibility issues
- Unable to transport system more than 50% full due to dynamic loading concerns
- Tight entrance and egress from tractor cab

Verification of Design

- Perform electrical check by operating system valves and lights from operator station (Completed)
- Verify metering system by calibrating closed loop system of the flow meter and regulating valve
- Check and record nominal system pressures at minimum and maximum flow rates

Parts List

- Approx. 40 components with 145 separate parts

Total System Cost = $20,800

Conclusions:

- The goal of designing a self contained and flexible mobile ag chemical storage and metering system that would mount to existing equipment was achieved in the given time frame. The final product met the capacity target and significantly improved on the width as compared to the benchmark system.
- This system will be used on a working grain farm not only to test the usefulness and longevity of the design, but also to increase the overall capacity of the farm.
- Further refinement of the design is desired, especially in the areas of improved front visibility and operator access.
- Lessons Learned:
  - Every large assembly can be broken into manageable sub-systems where detailed hardware selection early in the design process make final assembly more streamlined and easier to manage.
  - Project management with contributors is a more involved process than originally anticipated.

Acknowledgements:

- Advisors: Dr. Joseph Irudayaraj and Dr. Gary Krutz
- Sponsors: Agri-Products INC, Agro Chem, Banjo Corporation, Brooks Farms, Castongia's Incorporated, and Harvest Land CO-OP, and John Deere
- Special thanks to others in the department: James Bartlett, Scott Brand, Clay Mothershead, Zita Holland, and Carol Sikler