1640 Pivot Drive

Value Engineering

26 November, 2011

1640 Pivot Drive – 2011 version

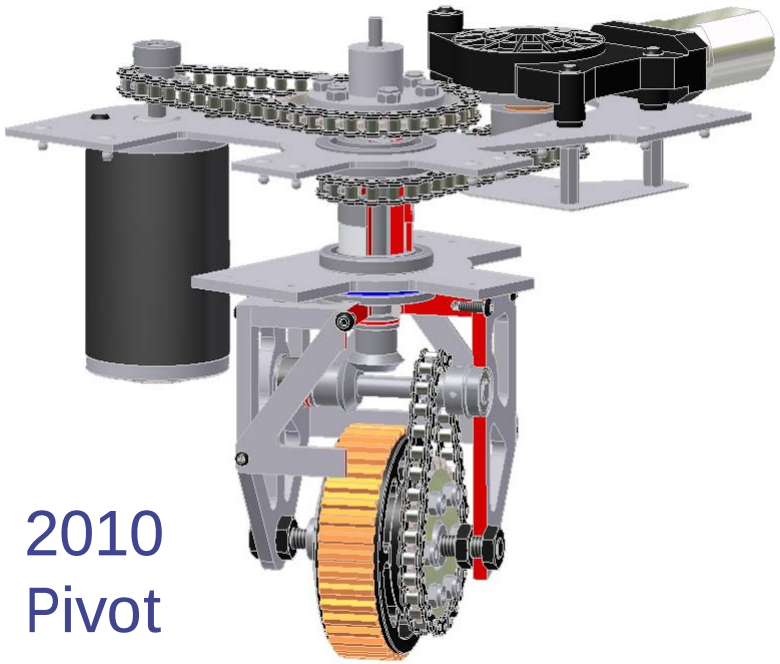
- Our 2nd year with Pivot Drive
- Combines agility with force
- Provides competitive advantage
- Enables game-specific drive modes
- Comes at a price:
  - Mass (36 lb) – down 3.6 from 2010
  - 8 Motors & motor controllers
  - $s for materials
  - Requires highly-skilled drivers (whom we now train)
  - Programming is formidable (but in our pocket)
  - High-level machining & assembly capabilities
- *1640 is known as a team which does Pivot well*

Value Engineering

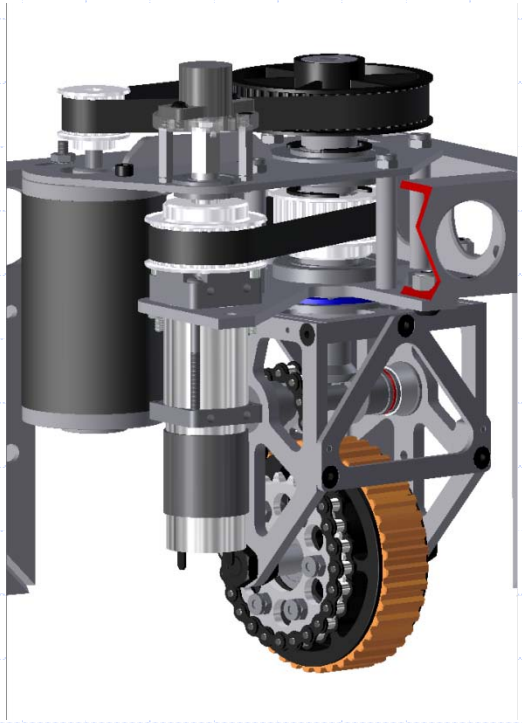
- Value Engineering seeks to widen the gap between a device's value (to the user/customer) and its cost by:
  - Increasing the value (performance);
  - Reducing the cost (traditionally $s, but mass, motors, driver skill,... apply as well); or
  - both

Previous Value Engineering

- We did this a year ago
- Results were an extensive redesign
- Expect less radical changes this year



2010
Pivot



2011
Pivot

Observed Performance Deficiencies

- Driving a straight line is difficult
- It would be good to expand our policy of not relying on set screws
- Further mass reduction would be good
- Heads of BHCSs used to attach pivot modules to chassis are easily stripped – use SHCSs
- Better access to nuts used for pivot module attachment needed
- Also easier manufacturing
  - The thermal interference assembly between Pivot Tube & Pivot Top was the very devil (even though it performed well in service)

Cost

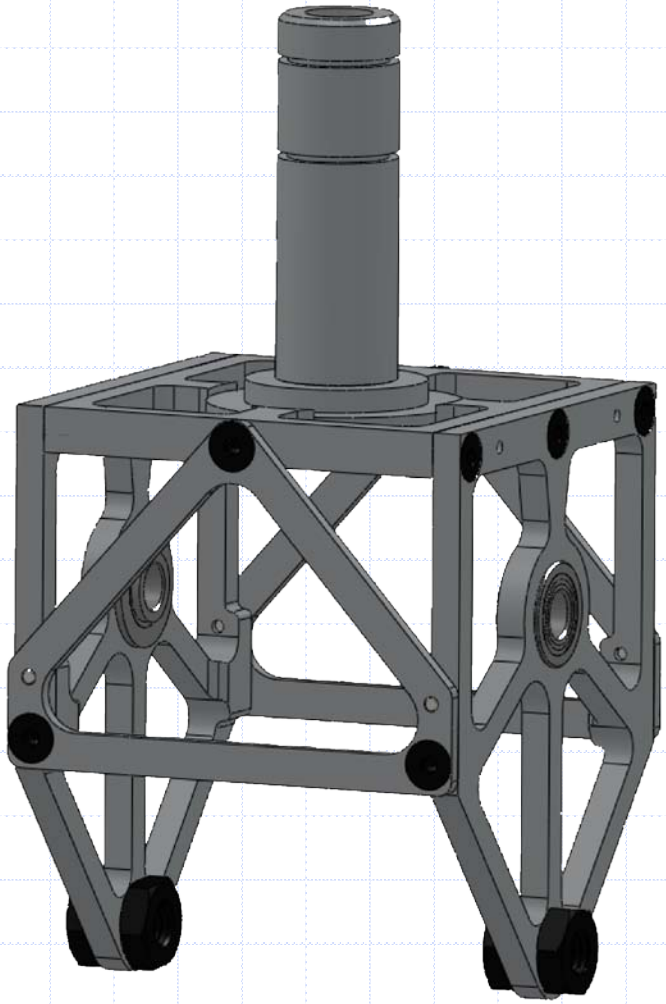
- It is more difficult to drive in a straight line with Pivot vis-à-vis Tank
- 8 motors
- Mass - Pivot mass 36.4 lb
- $s – drive-train materials cost $1,503 (versus $3,500 limit)
- Needs a lot of CNC machine time
- Driver Skills – Driver training is now a part of our culture

Benefits

- Pivot drive does provide real competitive advantage (agility + traction)
- In 2011 1640 built a **machine** for the 1st time
  - part of this change was driven by pivot drive (but not all)
- Driver training **is** now a part of our culture
- We win competitions now (not all due to pivot drive)
  - Half of all awards received by the team in its 7-year existence were received in 2011 (8/16)

Pivot 8

- Evolution, not revolution
- A lighter cage (0.6 lb savings for robot)
- 7075 transfer axle (0.4 lb savings for robot)
- Drill access holes in chassis for nutdrivers
- Other ideas?



Maybe...

- Machine Pivot Tube and Pivot Top for one piece
- Encoders to monitor drive speed
- Replace (8) 1” ball bearing races with bushings (cost & mass reduction)
- Linking front & rear drives

This is intended to be the start of a dialogue

What we did

- Made modules ambidextrous – separate L&R modules eliminated – fewer competition spares needed
- Used the lighter cage
- Used the 7075 Al transfer axle
- Designed lighter module plates
- Re-specified the steering motor & gearbox – cheaper & lighter
- Used unhardened miter gears – cheaper
- Identified better, less expensive angle sensors – cheaper & better
- Used flex couplings to couple angle sensors to steering shaft – lower maintenance & easier calibration
- Moved steering motors to top – less risk of damage
- Replaced Al steering drive pulley with Nylon – lighter & cheaper
- Repositioned stand-offs – stronger
- Replaced BHCSs with SHCSs for module mounting – easier maintenance
- Chassis design allows unrestricted access to mounting nuts
- Up-front planning of CAM/CNC operations – easier manufacture & better utilization of materials

Key results

- Module mass reduced from 9.3 to 8.6 lb_m – 0.7 lb_m reduction per module (7.5%)
- Module cost reduced from $375.^{72}$ to $340.^{67}$ - $35.^{05}$ savings per module (9.3%)
- Competition spare parts requirements halved by elimination of separate L & R modules
- Maintenance simplified
- Steering is spot-on (improved performance)
- CNC Milling performed with student involvement

Executive Summary

- While the 2012 and 2011 pivot modules are visibly closer in appearance than the 2011 and 2010 versions, the improvements achieved in this 2nd round of value engineering were on-par with the first round, with a focus shift from reliability in round 1 to cost reduction, mass reduction and ease of maintenance in round 2.

	2010	2011	2012
Module Cost ($):	$364.85	$375.72	$340.68
Savings ($):		($10.87)	$35.05
Savings (%):		-3.0%	9.3%
Module Mass (lb_m):	10.0	9.3	8.6
Reduction (lb_m):		0.7	0.7
Reduction (%):		7.0%	7.5%
Reliability	☹☹	☺☺☺☺	☺☺☺☺
Ease of Maintenance	☹☹	☺☺	☺☺☺