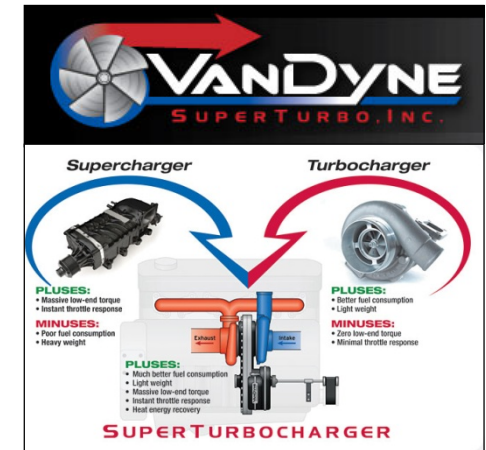
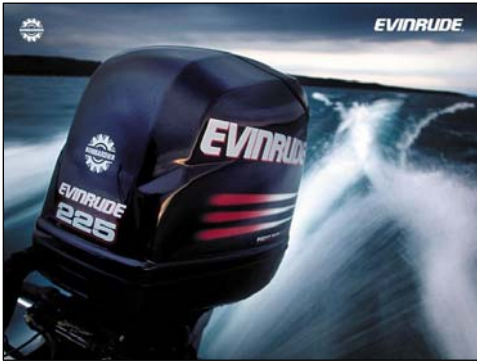




*Engineering Services
&
Hydraulic Hybrid Retrofits*

**Guy Babbitt Ph.D.
Czero, Inc.**

Engineering Consulting:



& other automotive & clean energy firms

Products:

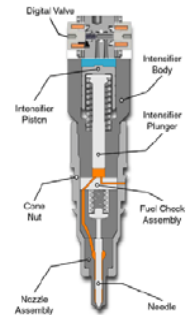
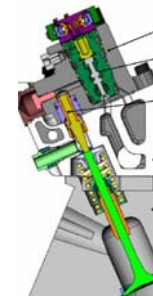
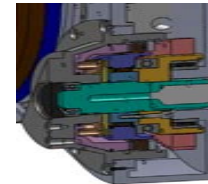
- Hydraulic Hybrid Retrofits
- Hydraulic Work Cycle Efficiency Upgrades



Automotive Engineering Experience:

Czero engineers have 20+ years experience developing innovative automotive and hydraulic power systems for car and truck OEMs all over the world:

- **Engines and transmissions**
- **Fuel systems**
- **Valve systems**

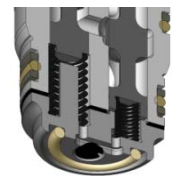
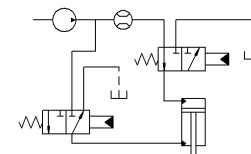
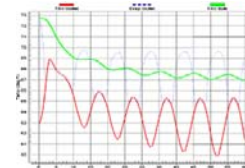
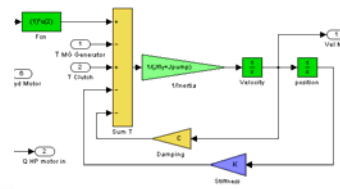
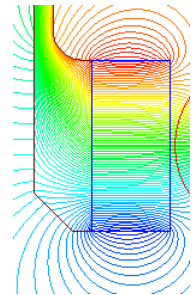
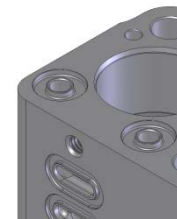
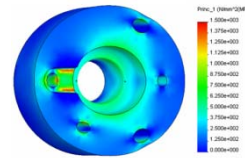


Involved in the installation of over 20 prototype engines in North America, Europe and Asia

- *Multiple products to production*
- *Inventors on multiple patents*

Expertise:

- Mechanical design, solid modeling, GD&T
- High bandwidth hydraulic system analysis and design
- FEA, CFD, Magnetic modeling
- Dynamic modeling
- Electronic controls
- Testing and development



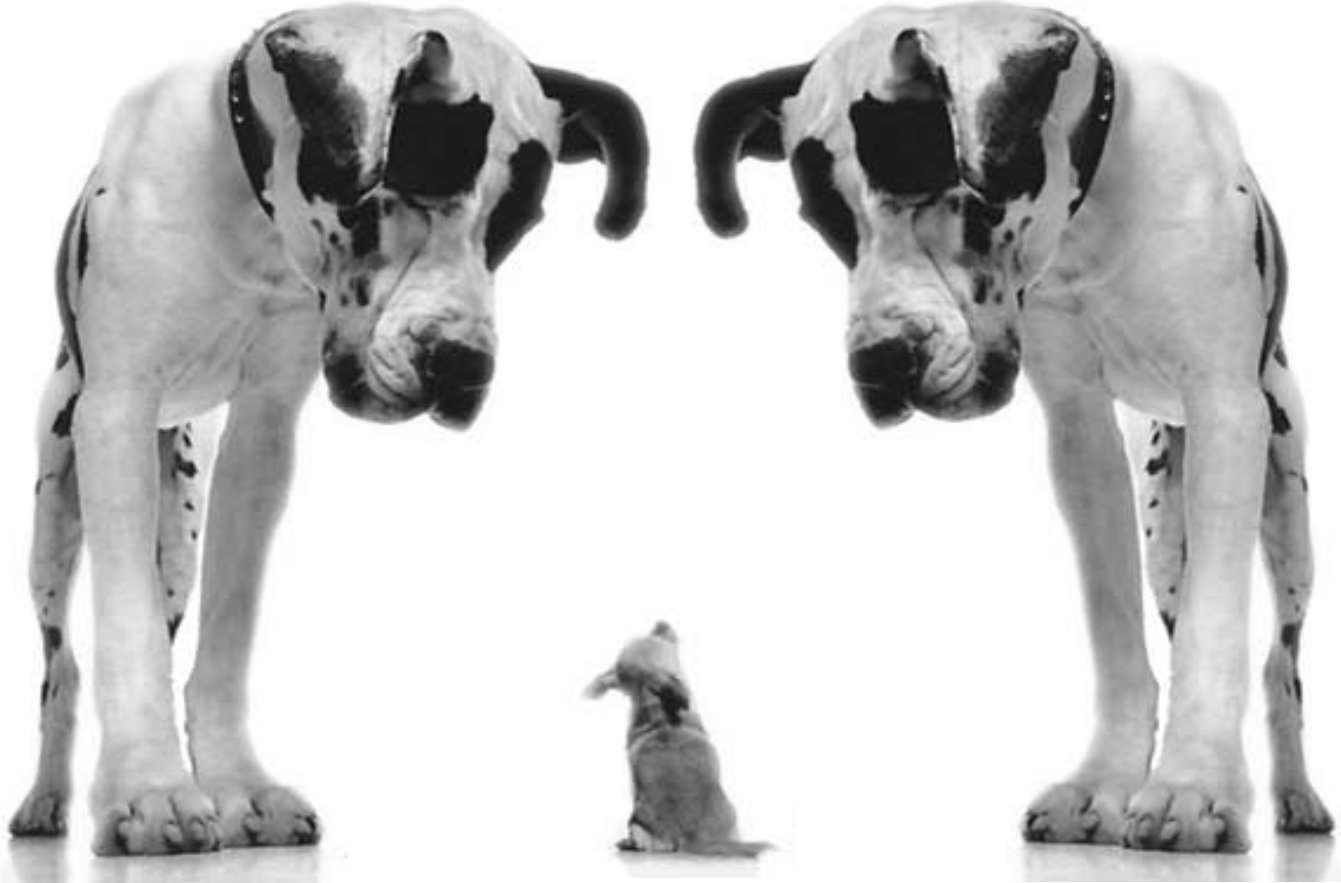
Hydraulic hybrids are not new to us....

- *Czero engineers have been involved with hydraulic hybrids on and off since early 1990's*
 - *Ph.D. Research*
 - *Corporate work*

Czero started working on hydraulic hybrids in 2007

- *Work up to recently has been more research and academic related*
- *Now we are looking at commercializing retrofit kits*

We know that there are a few established players in the field



***We know that there are a few
established players in the field ...***

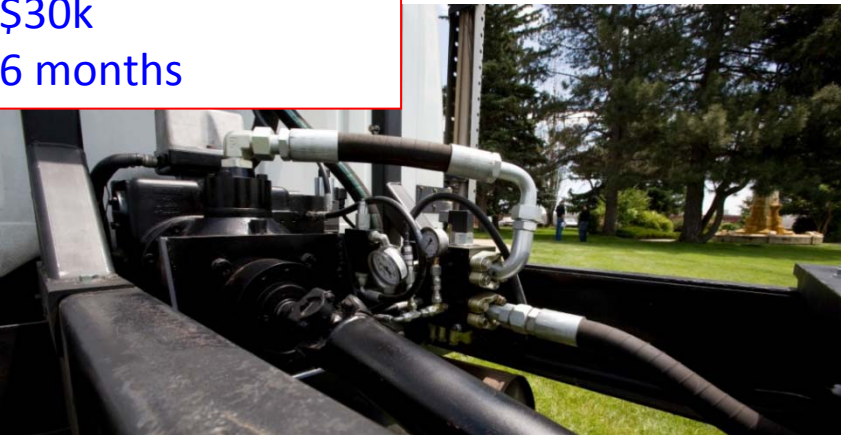
Test Mule for Controls Development



**Approximate project
cost and timing:**

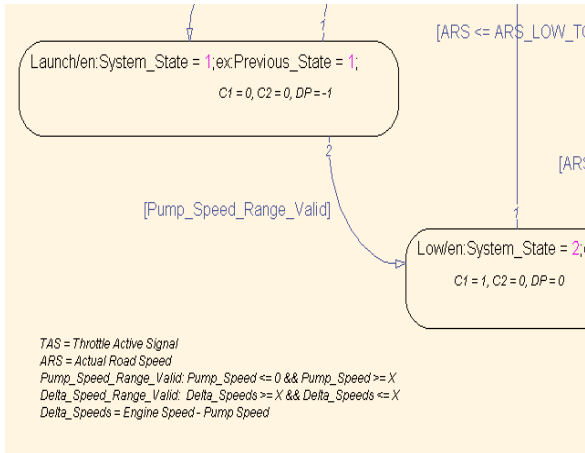
~ \$30k

~ 6 months



Controls:

- Using Mototron (Woodward)
- Serial communication w/engine
- Includes fault diagnostics



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MotoHawk
MotoTron Corporation
 505 Newton Road, Carlisle, MA, 01801
 www.mototron.com/0391-022-7700

Description:
 HHV
 Top-level root of model: HHV.mdl

Pch: HHV REV: 075

HHV
 HHV.mdl
 Copyright 2005, All Rights Reserved

SCIL4 MotoHawk (RTM)
 Code Coverage & Test IBI System
 ALWAYS GENERATE CODE COVERAGE CODE

MotoHawk

Target: ECU565-128 (DEV)
 Floating Point: single (32 bits)
 Stacks - FGND: 3072 BGND: 2048
 IDLE: 1024 IRQ: 1536
 Heap Size: 4096
 DLL Filename: HHV_v001
 SRZ Filename: HHV_v001

Total FLASH:	303760
Total EEPROM:	284
Total RAM:	112800
App FLASH:	52399
App EEPROM:	112
App RAM:	99931

The existence of a Target Definition block somewhere in the model is not up to a MotoHawk protect, capable of being built to a

1 Main Power Relay
 On Delay: 100 ms
 Off Delay: 250 ms

2 MotoHawk (RTM) Fault Manager Definition
 Storage: FLASH
 XY Data Type: UInt8
 Read Access: 1
 Write Access: 1
 Clear Access: 1

Build Constants

3 MotoHawk Function Trigger
 FOMD_RTL_PERIODIC
 Priority Order: 0

MotoHawk Function Trigger
 FOMD_ZK_RTL_PERIODIC
 Priority Order: 1

Fault Detection/Routing

Fault Detection				Fault Routing		
Signal	Definition	ID	Fault Trigger	Detection Mode	Action	Action Condition
Displacement Pump	Displacement_Stuck_AlarmFault	1	No signal variance for 20 counts	Enabled	Displacement_Stuck_AlarmAction	Active
	Displacement_RangeHigh_AlarmFault	2	[cc/rev]	Enabled	Displacement_OutOfRange_AlarmAction	Active
	Displacement_RangeLow_AlarmFault	3	[...][cc/rev]	Enabled	Displacement_OutOfRange_AlarmAction	Active
	Throttle_Stuck_AlarmFault	4	No signal variance for 20 counts	Enabled	Throttle_Stuck_AlarmAction	Active

What are the Challenges for Retrofits?

Technical Challenges:

Less controls integration possible

- Also potential benefit as the installation is less complex

System has to fit in wide variety of designs and models

- System mounting must be flexible
- Calibration must be easily adaptable, possibly use learning algorithms
- Buying behavior of fleets is often consistent with this need

Installation costs can be significant

- Need to build economies of scale and develop appropriate partnerships

What are the Challenges for Retrofits?

Commercial Challenges:

Reaching the large number of end users across a broad area

- Literally thousands of fleets

Making the economics work

- Target the low hanging fruit initially and expand to other vocations as economies of scale (and market recognition) grow

Quality control is distributed

- Simple, robust designs are the key
- Also makes developing the correct partnerships important

What are the Benefits for Retrofits?

Volume

- The number of vehicles available for rapid deployment of the technology is many times larger than the annual number of new vehicles sold.

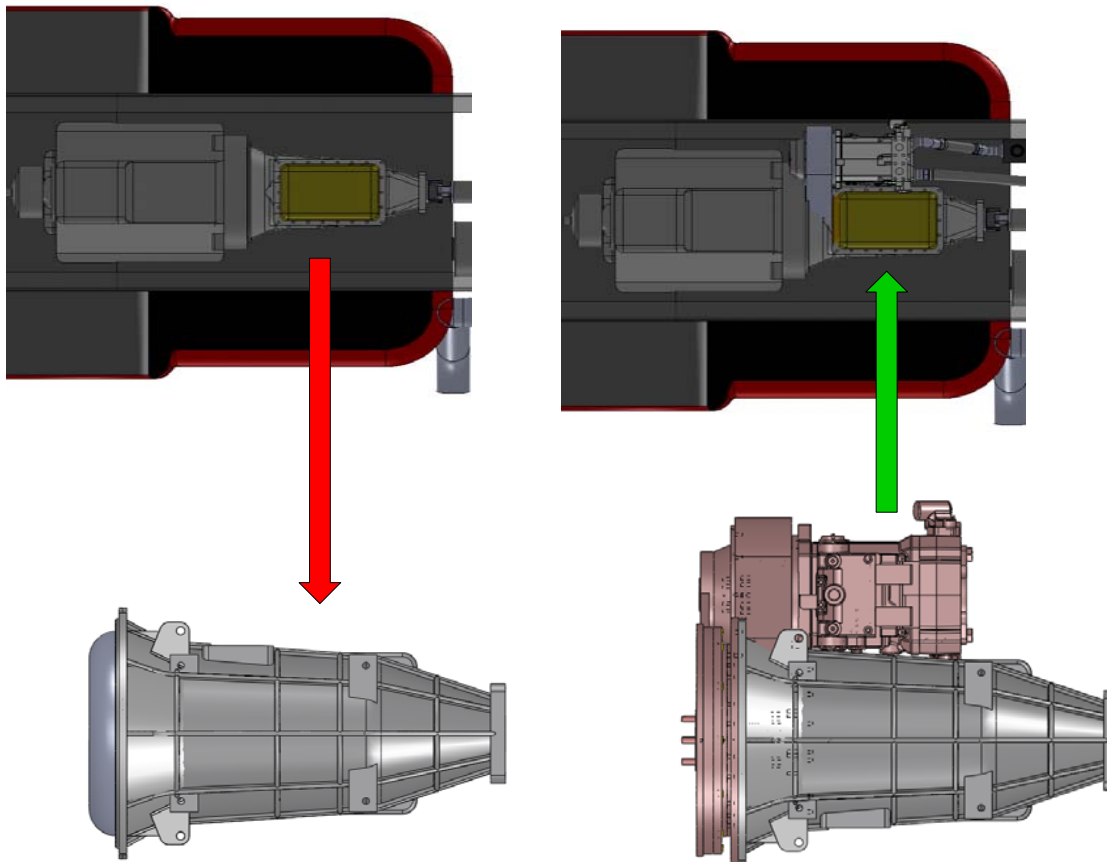
Timing

- Significant fleet turnover to hybrids with only new vehicles would take many years. Timing is much shorter by combining OE and retrofit solutions.

Cost

- Several vehicles can be retrofit with a hybrid system for the same cost as buying one new hybrid vehicle.

Design studies on integrating hybrids with automatic transmission

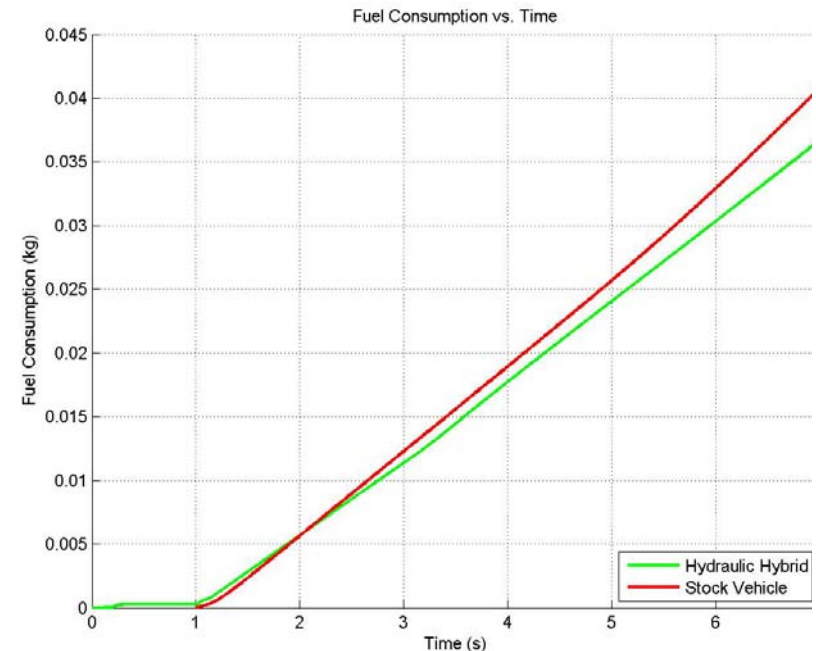
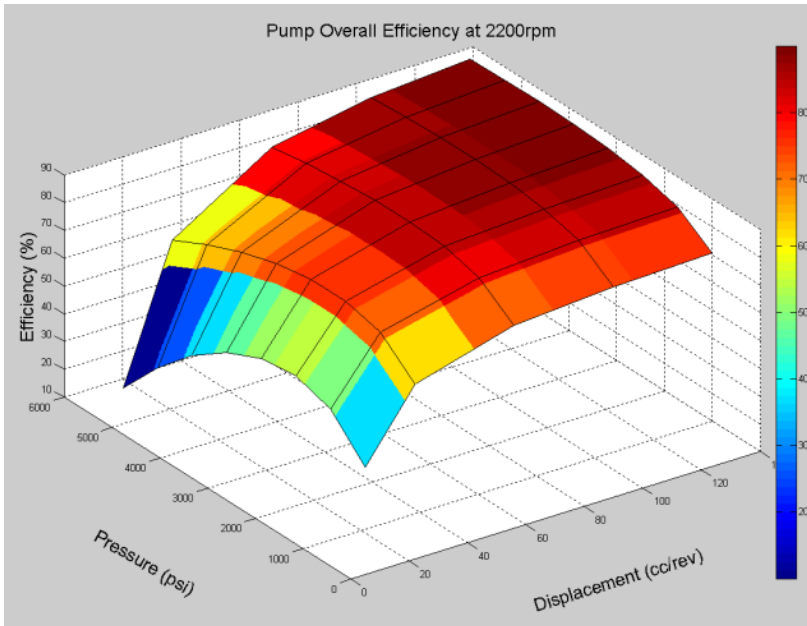
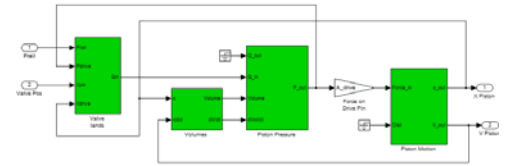


Goals:

- Make drop in replacement
- Maintain same axial length to eliminate modifications to the driveline
- Make the installation simple enough that the end user can do installation if desired in short amount of time

Detailed Dynamic Simulations:

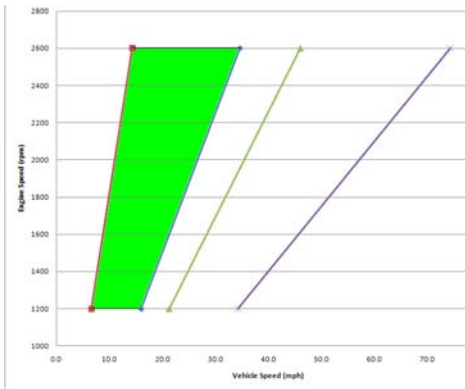
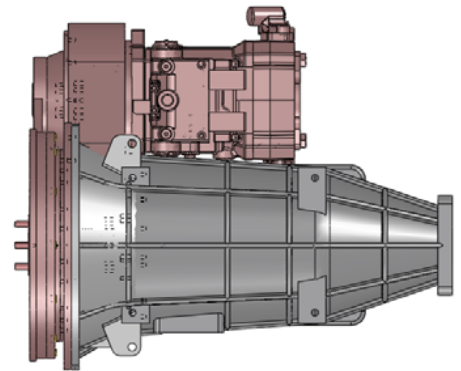
- Use MATLAB/Simulink – Allows software models of the system to be used to design the system, predict performance, and for controls development
- Includes pump, accumulator, engine efficiency, mass of individual gears, etc



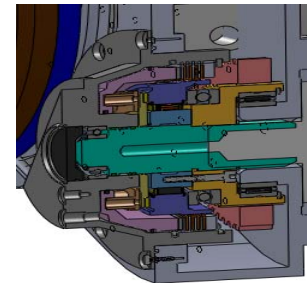
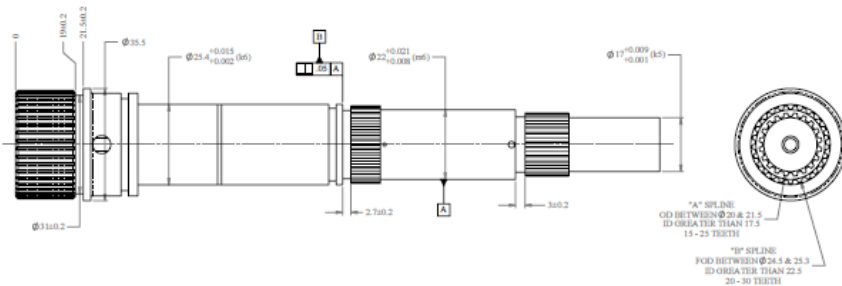


Design:

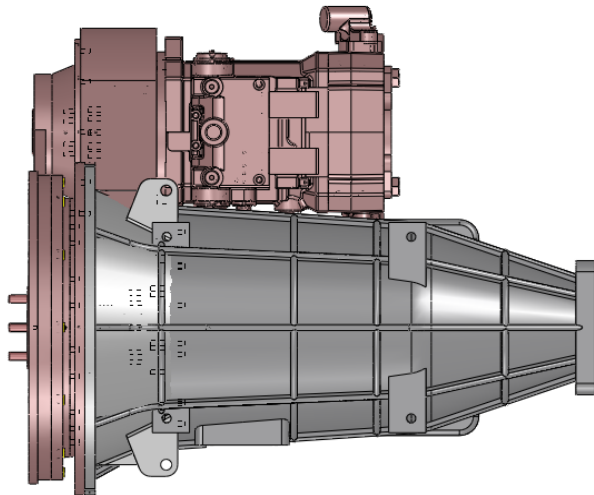
- Extensive analysis & simulation used to select configuration
- Design utilized numerous components currently in production
- Remaining parts designed for low cost manufacturability
- Utilize finite element analysis
- Use GD&T to reduce manufacturing costs



B	kW					Engine Speed After Lar
P	psi					GR
B prime						
T max Eng (ft-lbs)						
HR	0.55	0.60	0.65	0.70	0.75	0
HR'	0.36	0.39	0.42	0.46	0.49	0
GR w/ HR' w/o C	0.48	0.50	0.51	0.53	0.55	0
GR w/ HR' w/C	0.30	0.31	0.32	0.33	0.34	0
ω eng max (rpm)	2600	2600	2600	2600	2600	26
ω drive shaft max (rpm)	773	801	829	857	885	9
Vehicle Speed max (mph)	22.1	22.9	23.7	24.5	25.3	26
Speeds (rpm)						
1	2600	2600	2600	2600	2600	26



Integrated Automatic Transmission & Hybrid



Status:

- Extensive simulations performed
- Design done, prints complete
- Has not been built
- 3 Provisional patents applied for

Operates Much like a Parallel System

- Drop in transmission replacement
- Pump moves to accommodate different vehicles
- Possible to retrofit existing transmissions
- Lighter than other parallel designs
- Provides equal or better launch torque to stock vehicle

Challenges:

- Controls need to be integrated with transmission
- Longer development cycle
- Substantial development costs

- ***On hold until right partners found***

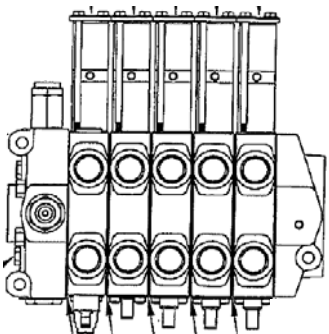
Generation III Hydraulic Hybrid Retrofit system:

- ***What it is*** - Parallel hybrid system designed specifically for retrofitting.
- ***Partnerships*** – We are working with two different large pump suppliers and a heavy-duty truck component suppliers to put the program together. Work in process.
- ***Team*** - We are building the management team within Czero and recently added seasoned executive level leaders from the vehicle industry.
- ***Funding*** - We are looking to continue development with grant based funding. (have received 2 grants to date)
- ***Demonstration program*** – *Targeting 2010*

Low Cost Retrofits Kits to Reduce Power Consumption in Work Circuits

15% or more of the fuel used in solid waste compaction (refuse) vehicles can be attributed to the work circuit

Czero is working on a low cost system that can dramatically reduce this energy consumption



Benefits:

- Can reduce fuel consumption
- Can reduce high idle at work stops
- Can decrease work cycle time and increase productivity in some cases

Status:

- Project relatively new for Czero
- Detailed analysis and design ongoing
- Looks very promising both technically and financially
- Provisional patent applied for
- Testing to begin this year

Summary

- Fleets have stated that there would be strong demand for hydraulic hybrid retrofit products if a robust, well tested and cost effective product were available.
- It has been unclear if retrofit solutions are going to be made available by manufacturers of OEM solutions.
- Czero feels that retrofits are an important hybrid market and we are focusing on them.
- Czero is in the process of putting partnerships together with larger firms to develop and market high quality systems.
- Czero is working on a demonstration program scheduled for mid 2010 (work circuit demonstration projects before that)

We have received tremendous support:



Governor's
Energy Office



Accelerating the Success of Entrepreneurs in Northern Colorado

Northern Colorado Clean Energy Cluster:



A Tomkins Company



HYSAN
by
Hydra-Soft



Thank You!



For more information please contact:

Guy Babbitt, Ph.D. - Czero, Inc.

200 W Mountain St., Suite A, Fort Collins, CO 80521

guy.babbitt@czero-solutions.com - (719) 331-9662