



# Transmission potential to contribute to CO2 reduction

## 2020 and beyond line haul perspective

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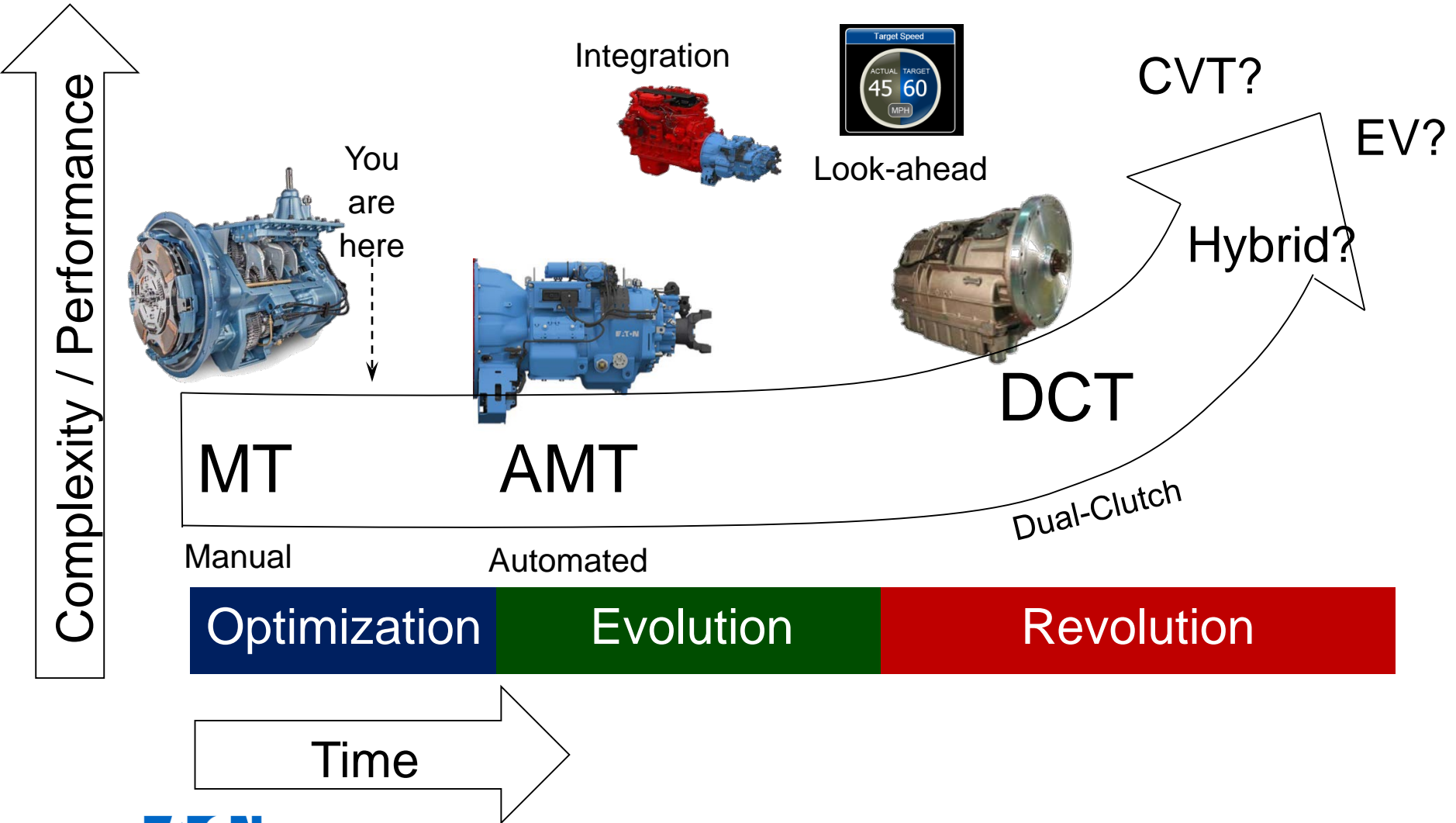
July 22, 2014



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# HD Transmission Technology Trends

Higher performance and complexity and deep integration



# Transmission Optimization

*Still opportunity to improve component efficiency*

- In-Gear efficiency [0.5%-1%]
- Dry sump & lubricants [1%]
- Bearing losses [.25%]
  
- Light weighting is important:  
Potential to eliminate 300-500 lbs  
drives **0.3-0.5%** fuel and **1% – 1.5%** freight efficiency
  - Architecture
  - Materials (shafts and gears 60% of gearbox weight)



Steel torque carrying elements

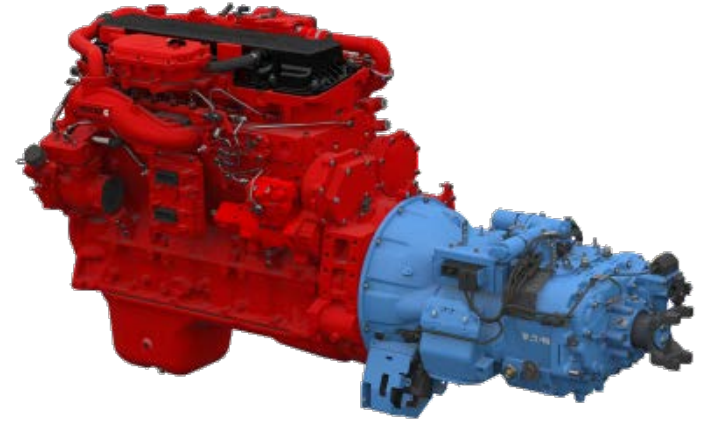
Lightweight filling (polymer/C-fiber or Al)

# Automation

Transition from Manual to AMT driven by fuel economy, shift to regional haul and driver demographics

## Automated Mechanical Transmissions

- **2-4%** fleet average improvement based on average driver skill
- Allows small ratios in high gears **[1-2%]**
- Effortless shifts allow higher shift density: key enabler to downspeeding
- Rapid adoption in market: SmartAdvantage, Volvo XE, DT-12. 8% in 2010, 15% in 2013, +20% in 2014.
- Expecting 55-60% market penetration of AMT by 2018



## Example: Eaton-Cummins SmartAdvantage

- Fully integrated engine & transmission
- 3-6% improvement over base engine (ISX 15L) and base transmission (UltraShiftPLUS LAS)

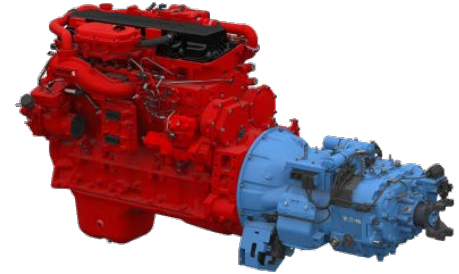
# Powertrain integration

## Automated Mechanical Transmissions

- AMT and mild engine downspeeding will be baseline line haul powertrain by 2020
- 3-6% improvement is shared between engine and transmission

## Dual Clutch Technology

- reducing the power excursions in engine, eliminating 0-torque condition at shifts **[1%-3%]**
- Significantly better drivability
- Enable further engine optimization by narrowing operating band (eg turbo optimization)
- Enable aggressive downspeeding due to drivability, eg 900-1000 rpm at cruise, additional 2%
- Lower cruise speed or higher productivity **[.5-2%]**



## Eaton-Cummins SmartAdvantage

- 3-6% improvement
- 1.5-3%: engine downspeeding from 1350 rpm to 1100 rpm at cruise
- **1.5-3%:** special ratios, shift logic and integrated controls



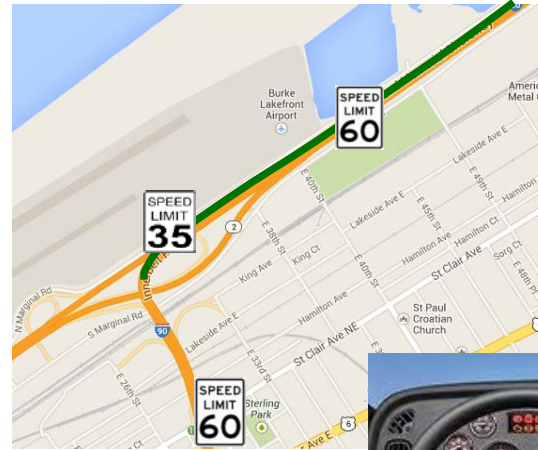
## Eaton DCT proof-of-concept transmission

- 11 ratios, progressive gearing
- Eliminate torque interrupt
- Maintains engine at full load during shifts
- 20% faster acceleration

# Look-Ahead technologies

Improve driver performance for fuel economy: **3-4%** fleet average improvement

- Unique features: accounts for
  - Driver behavior
  - Real time traffic conditions
  - Non-intrusive in cabin, shaves unnecessary acceleration peaks
- Seamless integration
  - With and without cruise control
  - Terrain and route (GPS, grade)
  - Route specifics (speed limits)
- Compatible with eco-roll type features



# Long-term: Low-CD increases HD hybrid potential

Competing trends: eco-roll, platooning, base engine efficiency



Cd	0.8	0.65	0.55	0.35
2% grade power	522	479	450	391
MPG (65mph)	6.5	7.6	8.6	11.4
-2% grade power	-29	-72	-102	-160
HD hybrid (50% brake regen)	507	442	399	311

Downsize potential

Fuel burn [gals]	13158	8772
Hybrid benefit	2.6%	9.9%
Hybrid fuel save [gals]	336	867
Hybrid fuel save \$	\$ 1,343	\$ 3,468

20kWh battery pack  
 Today \$10-20k, future = \$5-8k??

**Simplifying Assumptions**

- 50% BTE engine
- Mild grades
- Constant speed 65mph
- 80,000 lbs truck

# Key points

Line haul entitlement: 4.5– 8% from advanced transmission, 1.5-5% from engine, 2-4% from driver improvement and 2-10% hybrid

- **NRC 2010 study attributed 2% improvement entitlement to driveline, focused on mechanical efficiency of gears in transmissions and axles.**
  - SuperTruck and other developments relevant to 2020 timeframe go well beyond that number.
  - Preliminary 2014 NRC report recognizes potential of transmission and engine-transmission integration but does not quantify it.
- **Four sources of CO2 reduction associated with transmissions**
  - More efficient transmissions, minimizing mechanical losses and light weighting. [2%-3%]
  - Optimized gear ratios and automation that reduces driver variability and misuse [1.5%-3%]
  - Transmission integrated with engine: enabling downsizing, downsizing, reduced engine transients, excursions [1.5%-5%]
  - Transmission integrated with the vehicle: reducing power loss [1%-2%], hybrids [2%-10%], shifting based on driving environment (aka making average drivers better) [2%-4%]
- **Key transmission technologies**
  - Gearbox enhancements
  - Transition from manual to automation to dual clutch
  - Deep integration with engine enabling powertrain optimization: downspeeding and narrow-banding engine operations
  - Integration with the driving environment: Look-Ahead
  - Hybridization and related technologies



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