Final Update

Automotive Components White Paper

Prepared for:

April 6, 2017

MARTEC

Relentless. Research.

Project Background & Objectives

Project Background & Objectives

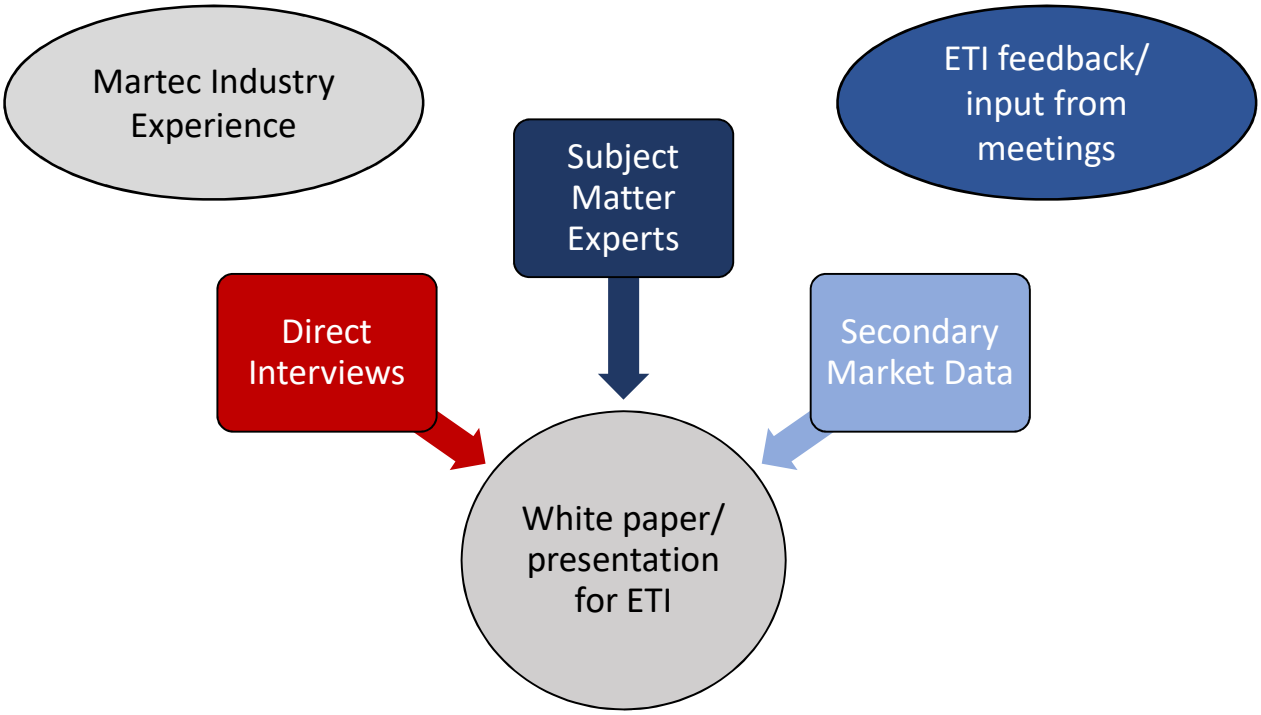
ETI has commissioned the development of an industry white paper, addressing how the increasing complexity of vehicles will impact the automotive aftermarket. Specifically, management is interested in developing a thought-leader position on this topic, that will impress upon its members the value of ETI as an organization, and encourage further involvement by equipment suppliers.

Issues explored through the course of this research include:

- Evaluation of various vehicle systems/components to better understand the long-term impact on service and repair, and specifically equipment.
  - *Which technologies are on the rise?*
  - *What components/technologies are in decline, are being phased out, and/or are becoming obsolete?*

- Beyond increasingly stringent fuel economy/emissions standards *(via light weighting)*, ICE enhancing technologies, etc., what other factors are impacting the way vehicles will be engineered in the future?
  - *Focus on primary systems – valve train, engine, exhaust, brakes, fuels supply, transmission/suspension/steering*
  - *Focus on specific equipment impact – scan tools, mechanical systems, shop management, etc.*

Project Methodology



Telephone and personal interviews were executed within the automotive industry.

- *Direct interviews with 3rd party sources*
- *Equipment suppliers*
- *Shops*
- *Research partners*
- *Key customers*

Martec also conducted extensive secondary research.

- *Technical reports/articles*
- *Patents, Research data*
- *Company reports*
- *Government data*
- *Other (newspapers, etc.)*

Project Timeline

1/23
- Kick-off Meeting

1/30-2/13
- Develop working outline
- Acquire/aggregate/analyze published reports

January

February

2/20
- Progress meeting

2/27
- Interview key subject matter experts and suppliers
- Analyze published reports

3/6-3/13
- Continue interviewing and analyzing information

3/20
- Final analysis and reporting

March

April

4/6
- Final presentation

Informal updates as needed

Next-Generation Systems

Executive Summary

1. **Martec explored future components across 12 automotive systems, coming up with a list of nearly 45 new components *"on the rise"* in the short (3-6 years) and long term (6+ years).**
    - After discussions with ETI, the list was narrowed down to a list of 13 components

2. **Three common themes surrounding these 13 components were:**
    1. Safety innovation (ADAS)
    2. Fuel economy/CAFÉ *(engine downsizing, turbos, hybrids, 10-speed, fuel tank and exhaust EVAP control)*
    3. Technology/electronic solutions *(software/telematics, driveability, sound, technology)*
    4. 48-volt systems often appear to be the common denominator to make advancements a reality

3. **Impact from these new complex components on independent repair shops and equipment manufacturers are typically viewed as long term problems, with a couple exceptions:**
    - Short term – ADAS *(already happening, particularly among collision repair shops)*
    - Long term – the big issue, autonomous vehicles disrupting the aftermarket *(both for independent shops and equipment manufacturers)*

Timeframe for key future technologies.

Component Description	Current (1-3 years)	Short-term (3-6 years)	Long-term (6+ years)
Software/ telematics*	✓	✓	✓
ADAS*	✓	✓	✓
Tier 3 exhaust (pollution)*	✓	✓	✓
Exhaust enhancing sound*	✓ *(premium vehicles only)*	✓ *(expanding)*	-
Active noise cancelling*	✓ *(premium vehicles only)*	✓ *(expanding)*	-
Turbo engines*	✓	-	-
P2 Hybrids*	*Preliminary exploration*	✓	-
48-volt systems*	✓ *(Expected within 12-18 months)*	✓ *(Continued advancement)*	-
Fuel tank advancements*	✓	-	-
Wiring – shrinking in size*	✓	-	-
10 speed transmissions*	✓	-	-
Advanced ignition systems*	-	-	✓
Sailing/ coasting technology	-	-	✓

** Covered in detail – body of report*

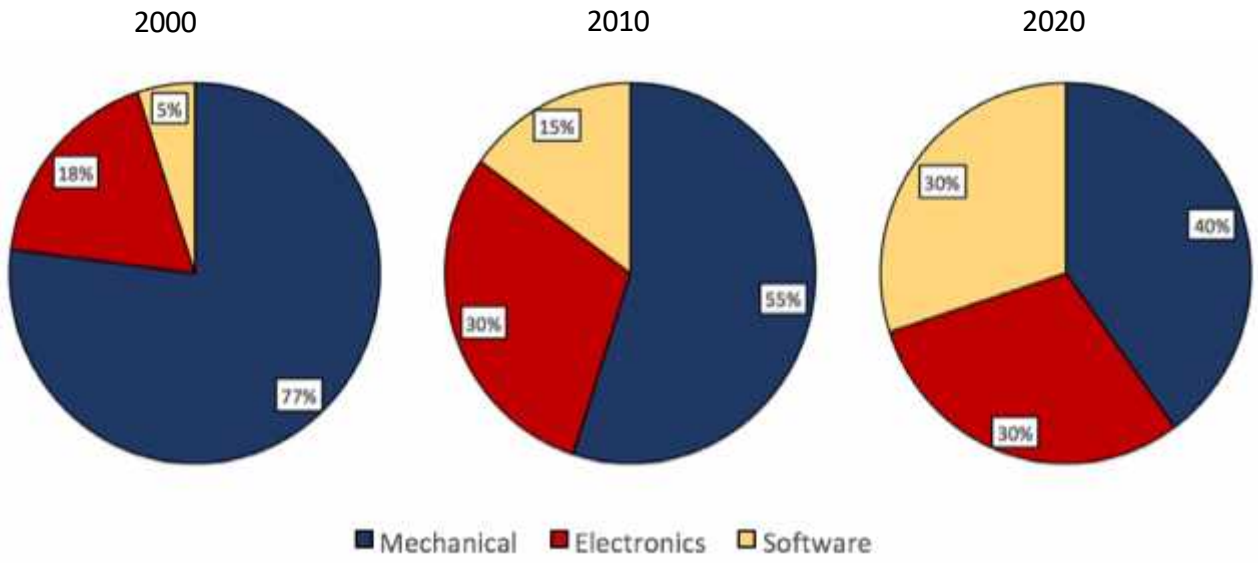
Based on team input and industry expert insights, Martec prioritized future automotive technologies by expected introduction.

- Martec has conducted further research on short-term component technologies and has been advised by automotive experts as it works to drill deeper into those segments

Software & Telematics

Software & Electronics will exceed the value of mechanical components by 2020.

The total value of software and electronics in automotive applications is expected to reach 60% of the total vehicle value by 2020…up from 23% in 2000.



The technology necessary to make connected and intelligent cars — specifically, Web networking, sensors, and software — is not in the traditional wheelhouse for most automobile makers.

- That shortcoming is an invitation to high-tech companies such as Apple and Google, which are making moves to develop the technology to "own" critical components of the networking, autonomous, and communications capabilities of automobiles

CarPlay and Android Auto integration

Integrating into the automotive world, Apple and Android are working with OEMs to introduce a dashboard that is easily compatible with both iPhones/ Androids and the vehicles dashboard buttons/ controls.

- These two systems are Apple CarPlay and Android Auto

Apple CarPlay is designed to be hands-free and is heavily reliant on Siri to help keep drivers focused on the road.

- Similar to the iPhone, Siri will place phone calls, get directions, send/ read text messages, play music, etc.
- The familiarity will come naturally to anyone who has used the iOS system in the past

Currently, the biggest issue is retrofitting older vehicles with this technology, as many of the features will not work as seamlessly as if it were installed when the car was manufactured.

CarPlay and Android Auto integration

Android Auto, on the other hand, has many of the same features as CarPlay, but goes beyond mirroring your smartphone.

- Automotive OEMs can purchase the Android system and customize it with desired appearance and features
- Google also has developed other automotive systems in the past that analyze vehicle information (vehicle sensors, diagnostic equipment, fuel level, tire pressure, etc.)

"This system could alert you that you are low on gas and use Google Maps to show you where the cheapest fuel is, within your range."

Center stack display future technologies

Touch screens:

- Bezel design technology (old)
  - *Screen display with buttons to control*
- Seamless touch design technology (current)
  - *Touchscreen mixed with button control option*
- Seamless curved center stack glass display technology (future)
  - *Featuring OLED technology*
  - *Difficulties forming complex glass shapes*
  - *Car designers working to eliminate "screens" and replace them with "LED dashboards with touchpad controls"*

Gesture/ Proximity Design:

- Hovering (short term trend)
  - *Single finger swiping – close proximity*
- Large object detection (long term trend)
  - *Large hand swiping – distant proximity*

Software and telematics could significantly impact the automotive aftermarket.

Of the different systems/components explored for this white paper, equipment manufacturers and shops believe that software and telematics could have the greatest long-term impact on the automotive aftermarket.

- Some positive *(for shops)*
- Some negative *(particularly for HHD manufacturers)*

Potential impacts include:

- Eliminate the need for handheld diagnostic equipment
  - *Display fault codes and vehicle data on the infotainment system*

  "At some point, with software and display sophistication increasing, handheld diagnostics become obsolete. The OEMs will have the ability to display vehicle data and fault codes on the infotainment system. This isn't a short-term concern, but 15 years from now…yeah, that could be an issue for us."

- Predictive/preventative maintenance

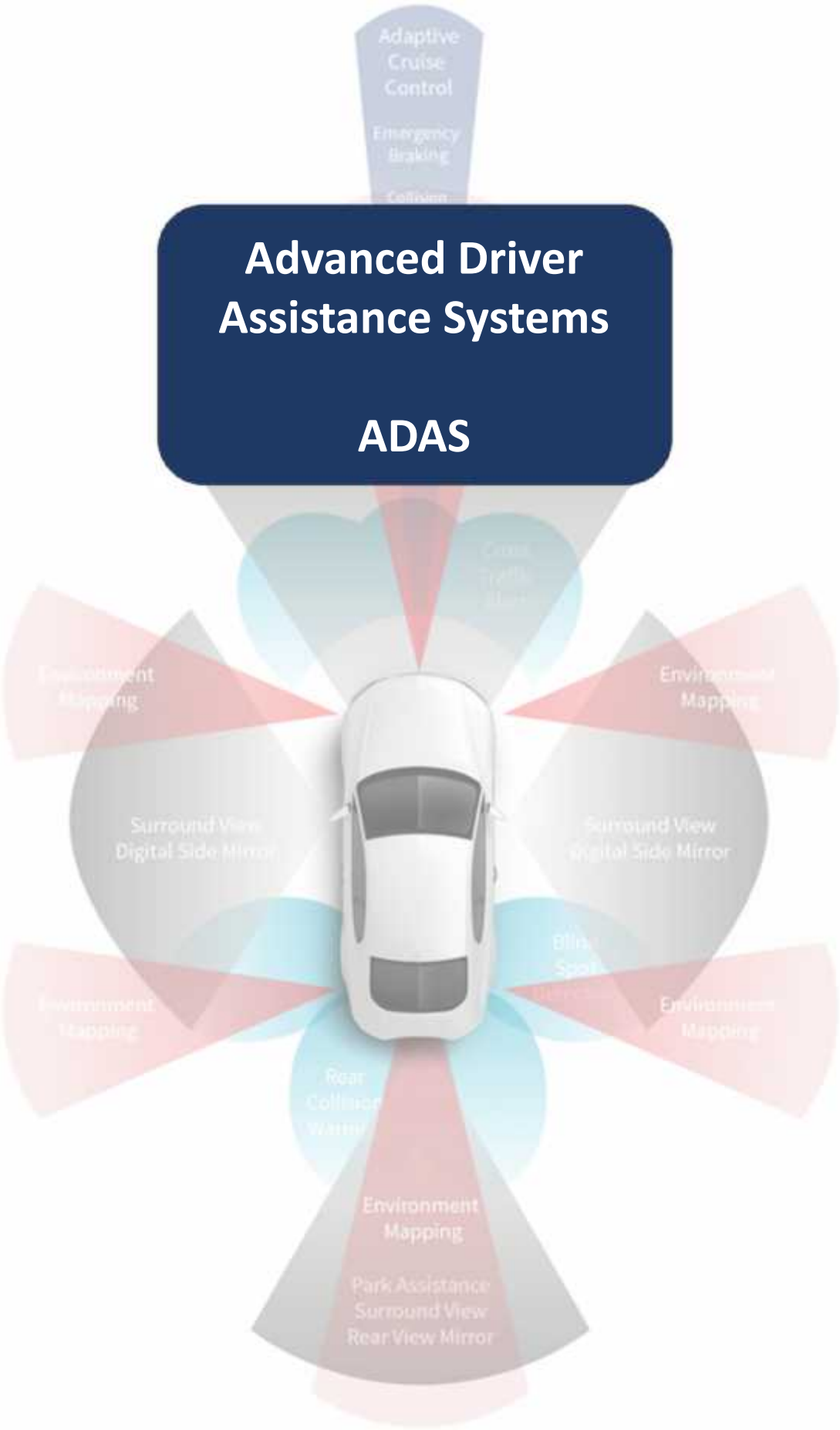
  "As cars get smarter and consumers get more trusting, the vehicle will tell them 'your O2 sensor is going bad, schedule service ASAP.' That should help us."

- Autonomous vehicles

  "Our biggest fear is for autonomous vehicles…could cars eventually just drive themselves to the nearest dealership for service? That's a nightmare scenario for independent shops."

Advanced Driver Assistance Systems

ADAS



Advanced Driving Assistance Systems (ADAS).

ADAS currently is being utilized by OEMs in premium vehicles, but is starting to be implemented into mid-level cars. While the full functionality of ADAS is still 3-6 years out, it will be rolled out in phases.

- The National Highway Traffic Safety Administration (NHTSA) has worked with all vehicle manufacturers to incorporate three established and proven technologies as "standard equipment" that will prevent or reduce deaths and injuries from automobiles crashes, these technologies collectively are known as Automatic Emergency Braking (AEB):
  - *Forward Collision Warning*
  - *Crash Imminent Braking*
  - *Dynamic Brake Support*

NHTSA has incorporated the AEB system into their 5-Star Safety Rating System, so automakers must include these crash avoidance technologies in order to receive the award for new vehicles.

On March 17, 2016, the NHTSA announced that it had secured a voluntary "commitment" in the form of a Memorandum of Understanding (MOU) from 20 automakers representing more than 99% of the U.S. auto market.

- The MOU indicates AEB must be a standard feature for 95% of light duty vehicles and trucks no later than 2023 model year for vehicles up to 8,500 pounds
  - *2026 model year for passenger vehicles 8,501-10,000 pounds*

ADAS will continue advancing through 2025, transitioning into fully autonomous vehicles.

ADAS Timeline

Safety/ Convenience
(1950-2000)

Cruise control	1958
Seatbelt reminders	1970's
Antilock braking system	1971
Airbags	1973
Electronic stability control	1987

ADAS
(2000-present)

Night Vision	2000
Forward Collision Warning	2000/08
Rear Camera/ Park Assist	2000
Lane Departure/ Keep Assist	2005/14
Adaptive Front Lights	2006
Auto Parking/ Blind Spot Detection	
Surround View Systems	2007
Drowsiness Alert	2010

Partially Autonomous
(2016-2025)

Single Lane Highway	2016
Autonomous Parking	2017
Traffic Jam Auto Pilot	2017
Highway Autopilot Lane Change	2018
Urban Autopilot	2022

Fully Autonomous
(2025+)

ADAS will challenge the capabilities of many repair shops.

"As OEMs continue to expand ADAS, the complexity is getting beyond the capabilities of most shops. In many cases it becomes a liability concern: 'I don't want to mess with any sensors...if something goes wrong I don't want the liability.'"

Particularly relevant for collision repair shops.

- Often not prepared to deal with ADAS sensors
- OEMs require post-repair scanning
  - *Shops often finding more fault codes post-repair than pre-repair*

"At this point, shops hook up a scanner after repairing a vehicles, they find fault codes and they send it down the road to the dealer."

- Repairs go beyond cosmetics

"The issue is that collision repair shops can't just make the car pretty again. They have the ability to replace ADAS sensors, but can they calibrate those sensors? Right now, no...not easily."

Further, scantool manufacturers are struggling to include sensors *(and calibrations)* in their equipment.

"Getting sensor calibration into scantools is difficult and slow. We're behind the curve right now."

Next Generation Exhaust Systems

Tier 3 exhaust (pollution standards)

Tier 3 emissions standards will phase in gradually from 2017-2025 and vary by vehicle class. These standards will be met by increasing technology within the catalytic converters and exhaust manifolds.

- The EPA estimates these changes will cost between $50 and $130 per vehicle for most OEMs (when Tier 3 standards are fully implemented).
- Oxides of nitrogen (NOx) are the main driver for more stringent Tier 3 standards
  - *In 2020, expect advancements in catalytic converter, specifically related to temperature:*
    - ✓ A vehicle produces most of its emissions at startup when it is cold
    - ✓ One way to raise the catalytic converter's temperature is to build an exhaust manifold that contains the converter – right now the converter is a separate part in the exhaust system (aka "Maniverter")
      - BMW i8 utilizes the maniverter
- Toyota is planning to meet all standards by offering a gasoline-electric hybrid powertrain across nearly its entire lineup.
- GM engineers are working on developing a technology that can improve the performance of catalytic converters and evaporative systems.

Tier 3 exhaust (pollution standards)

Another way OEMs are combating the strict Tier 3 standards is by turning wasted exhaust heat (energy) into electricity and then feeding the electricity into the vehicle's battery/charging system.

- P2 hybrids featuring a thermoelectric generator (TEG) component is one of the newer technologies to achieve this.
  - *OEMs; Ford, GM, BMW, and Chevy have recognized the benefits of TEGs and believe it can improve fuel efficiency by at least 5 percent*
    - ✓ This technology is 6+ years away

Exhaust Systems

As engine sizes shrink to meet new fuel economy standards, customers have expressed disappointment in the vehicle sound profile.

- In addition, some luxury vehicles have become so effective at insulating the cabin from road and engine noises, they lose the "roaring" engine characteristic.

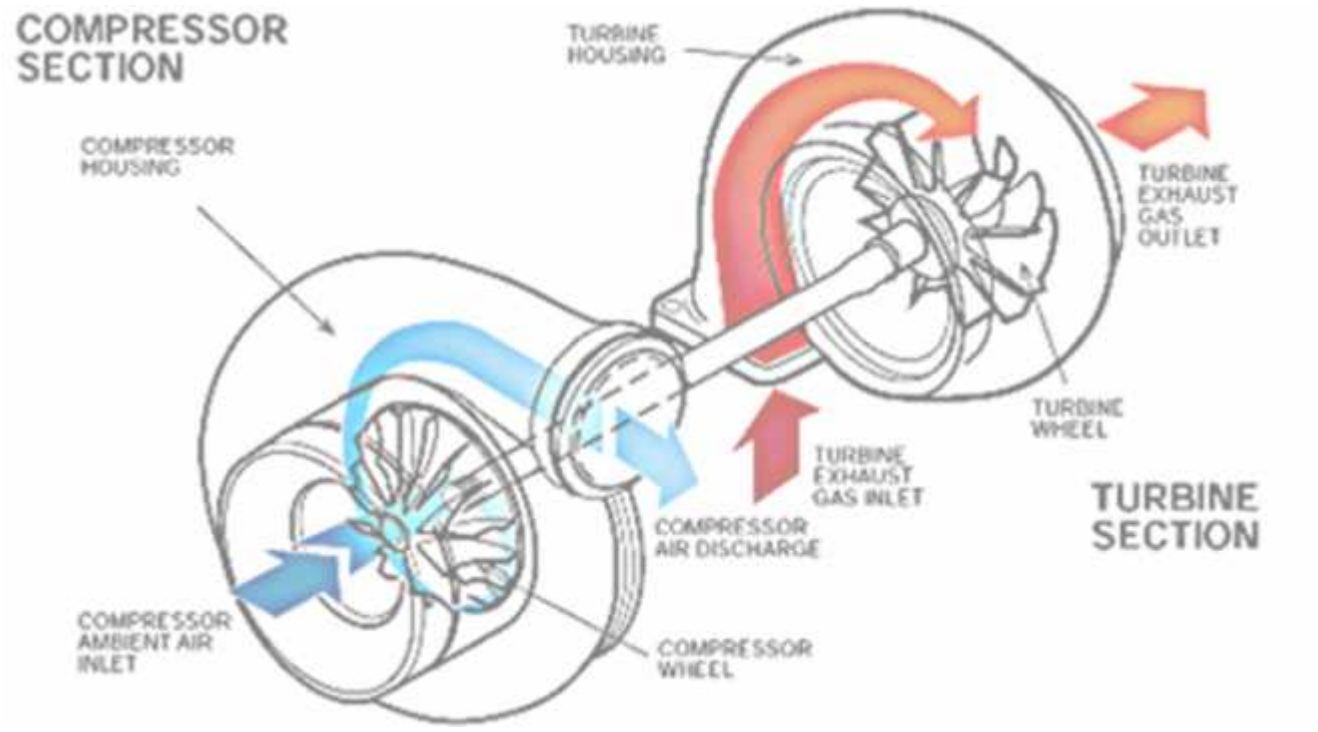
Engine sound enhancement is a future technology that can help solve this issue.

- Volume, tone, replication quality, range of operation, etc…
- Being explored both at the OEM and aftermarket levels:
  - *Ford – Mustang, F-150 V6*
  - *BMW – M5*
  - *Chevy - Camaro*
  - *VW – Beetle Turbo, GLI, GTI*

Further, many turbo-charged engines are actually converting sound vibration and heat into energy, as engine noise and heat loss through exhaust is considered lost energy.

- A 100% efficient engine would be completely silent, which is why older vehicle sound is more interesting and characterful

Turbo Engines



One-in-five North American engines were turbocharged in 2014; this is expected to increase to 39% in 2020.

In 2012, 2/3 cylinder engines made up ~8% of all light vehicle engines produced globally.

- This number is drastically increasing, growing 14% from 2012 to ~12.5 M 2/3 cylinder engines in 2017
- 4 cylinder engines grew 5% from 2012 to 2017, making up approximately 78% of all light vehicle engines produced globally

With smaller engines on the rise and EPA standards becoming more strict, turbochargers are becoming higher in demand.

- Rising in combustion engines from 42% in 2016 to 55% in 2026

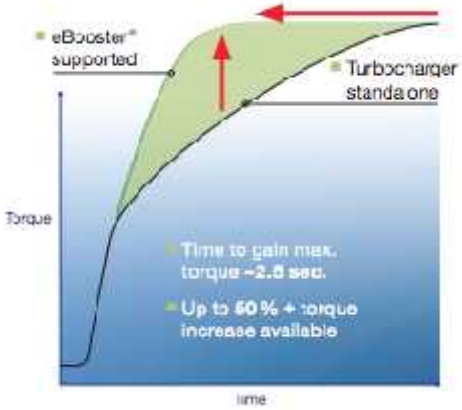
Technology Penetration % - Combustion Only – Gas & Diesel		
	2016	**2026**
Turbochargers	42%	55%
Exhaust Gas Recirculation	29%	47%
Variable Cam Timing	54%	70%
Dual Clutch Transmission	8%	10%
Stop/Start	35%	65%

eBooster Technology

BorgWarner's eBooster electrically driven compressor was designed to improve boost pressure and transient engine behavior at low engine speeds without increasing exhaust back pressure and negatively impacting on the engine gas exchange since no additional turbine is needed.

To meet the demand from customers the eBooster has been developed in order to accomplish different needs within the automotive industry:

- More efficient and clean engines
- Increased fuel efficiency
- Better driveability
  - *Less turbo lag*
- Meeting EPA standards



As a result, the eBooster is designed to work with the future 48-volt technology, allowing for enhanced low-end torque and transient response without any turbo lag.

- The eBooster is known to be an industry leading product, providing a clean, energy-efficient propulsion for the three types of clean/efficient automotive systems;
  - *Internal combustions engines*
  - *Hybrid engines*
  - *Electric vehicles*

eTurboCompound

In order to recover even more waste energy, BorgWarner's eTurboCompound will harvest any of the remaining exhaust gas energy to drive a generator to put electrical energy back into the vehicle.

- This technology is a turbine-driven, water-cooled generator installed downstream of the after-treatment system which uses the remaining waste heat to generate electrical energy

While the eBooster and eTurboCompound are options in the future, consumers will not start seeing them until 2025-2030.

Component	2025	2030
 eBooster™	~600,000 engines produced with eBooster technology	Will be grow at a fast pace, reaching nearly 2.3M engines equipped with eBooster technology by 2030
 eTurboCompound™	Exhaust recirculation for gasoline and diesel applications are expected to total ~18M units in 2025	Expected that the technology will grow to a total of ~23M units by 2030

Turbo Engines should have minimal impact on the aftermarket.

Shops and equipment manufacturers are familiar with turbo booster technology…

> *"Everything is turbo nowadays…and most of the turbos are modular and trouble-free."*

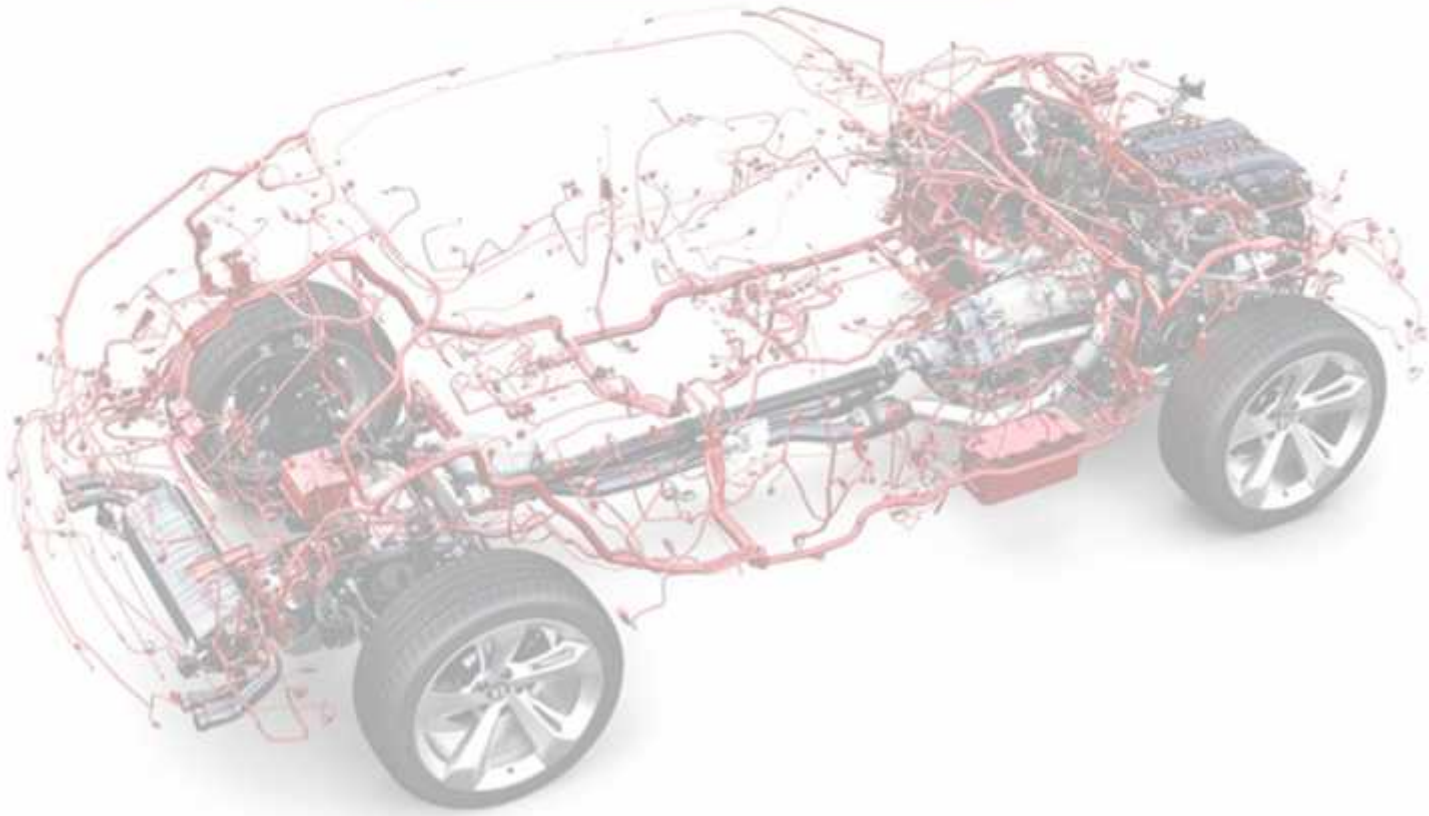
…Some expect next-generation turbo technology will be even easier to diagnose and repair.

> *"I don't anticipate that turbos will have any significant impact on either the equipment manufacturers or the shops. These are already fairly easy-to-repair and we believe they will become more plug-and-play as the technology advances."*

The smaller engines inherent with turbo technology also shouldn't have a significant impact on shops or equipment manufacturers.

> *"OEMs continue to explore smaller engines, that's why we've seen so many more turbos. I don't expect smaller engines will have any impact...it certainly doesn't complicate the technician's life in any way."*

48-Volt Electrical Systems



48-Volt Electrical Systems

Helping internal-combustion engines become more efficient

- More electrical power will be needed in order to run new electrical features, such as:
  - *Semi- or fully autonomous systems*
  - *Electronic engines and body controls*
  - *Infotainment features*

- Extremely complex cars like the Bentley Bentayga and Audi SQ7 TDI utilize the 48-volt system today, but it's expected that this will spread to the mainstream in the coming years.

- Engineers expect the advent of 48-volt electrical systems to enable new mild hybrids that achieve 70% improvement in efficiency at only 30% of the cost of current hybrids.
  - *Toyota's earlier style hybrids operated at 100-170-volts, requiring strict safety features. Any system over 60-volts requires these safety features.*
    - ✓ With the 48-volt electrical architecture, new mild hybrids can use thinner-gauge wiring and lower-cost connectors.

"Expect the technology [48-volt electrical systems] to make its way into one-fifth of all cars sold globally by 2025."

48-Volt Electrical Systems

48-Volt systems will be a critical component to many systems throughout vehicles today and in the future;

Current (12-volt):

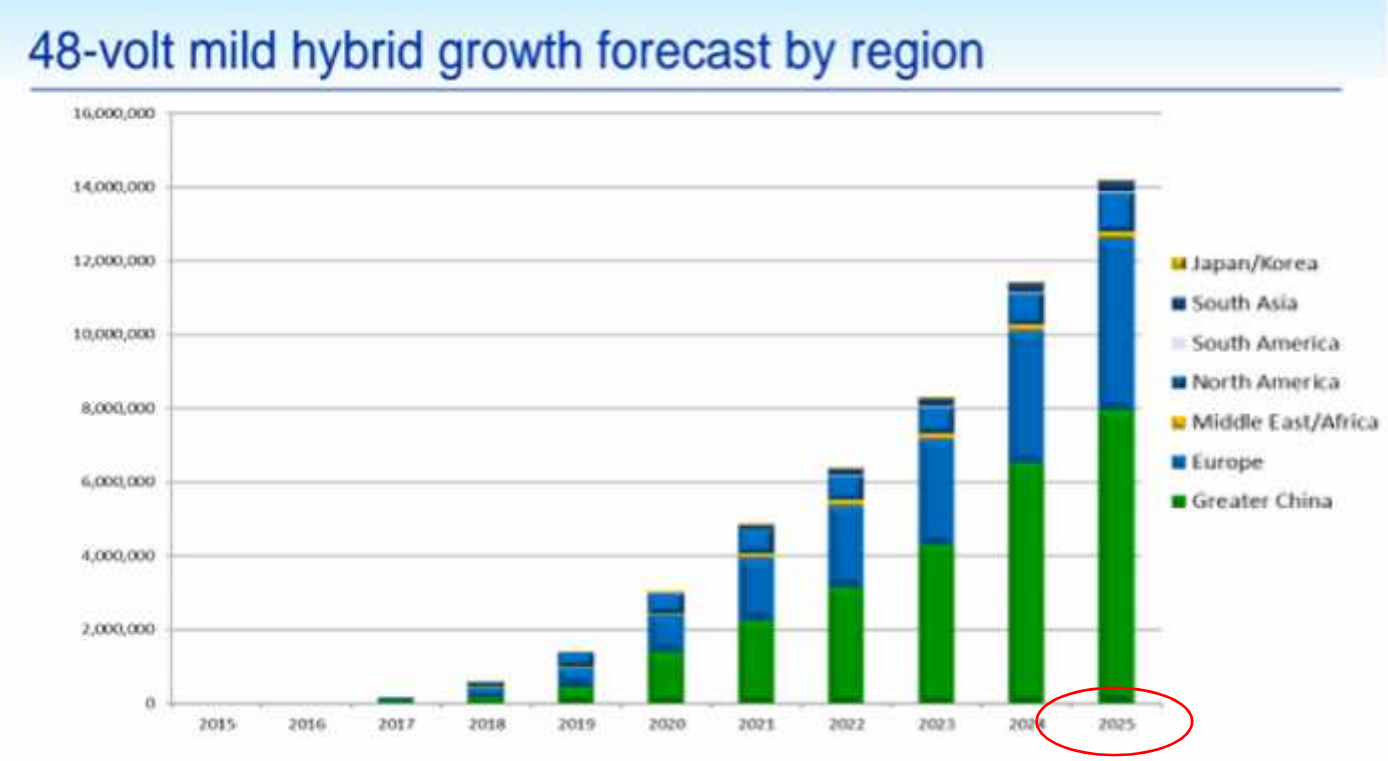
- ADAS features like; adaptive cruise control, lane keep assist, blind spot monitoring
- Technology packages like; heated seats, heated steering wheels, and heated windshields

Future (48-volt):

- New infotainment options
- Electric sway bar systems for better handling
- Fans, pumps, electric power steering racks, compressors all running more efficiently
- Benefits to wire-harness size and weight (smaller and lighter)
- Potential to drive a car under only electric power and run AC without the engine on can result in major fuel economy and comfort-related benefits
- Quickly heat up a catalyst in a diesel exhaust system to reduce emissions

48-Volt mild hybrid market penetration.

New concepts using 48-volt hybrid systems are in development and often include a small, electric motor integrated into the turbocharger to eliminate turbo lag and allow additional engine downsizing.



54.5 MPG Requirements

"The global market for 48 volt mild hybrids is expected to increase ninefold by 2025, with a total of 14 million vehicles expected to enter production."

48-volt systems may require new equipment at the shop level.

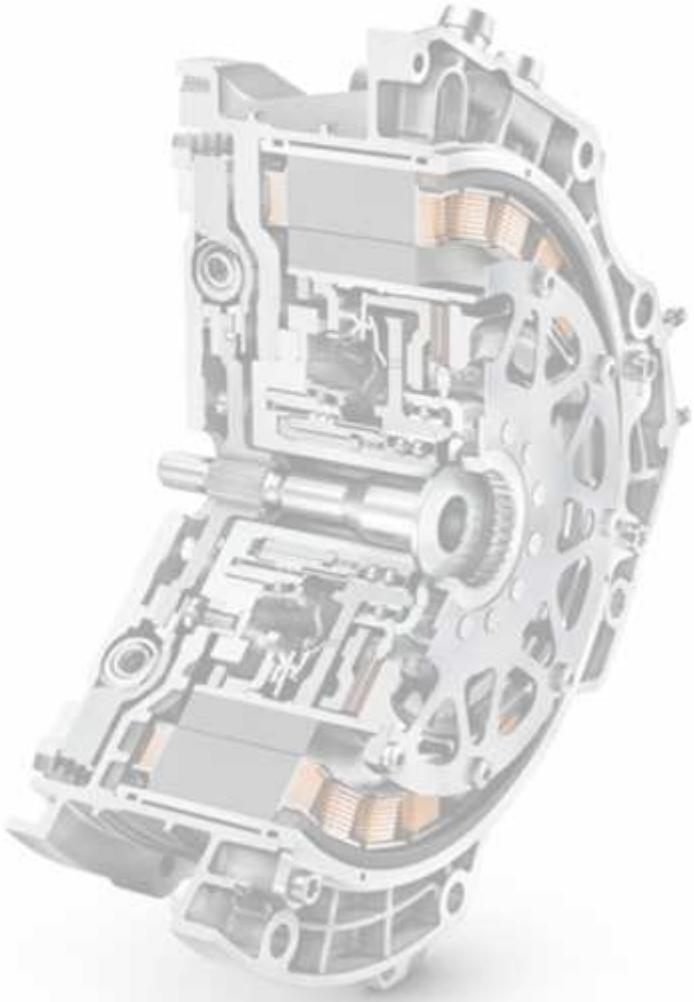
Scantools and testing/charging equipment may require upgrades.

> *"Today's scantools can't run on a 48-volt system. Plus testing and charging a 48-volt system will require new equipment. That's means another investment for the shop…which not every shop will make."*

The impact of 48-volt systems will take years to fully impact aftermarket repair shops.

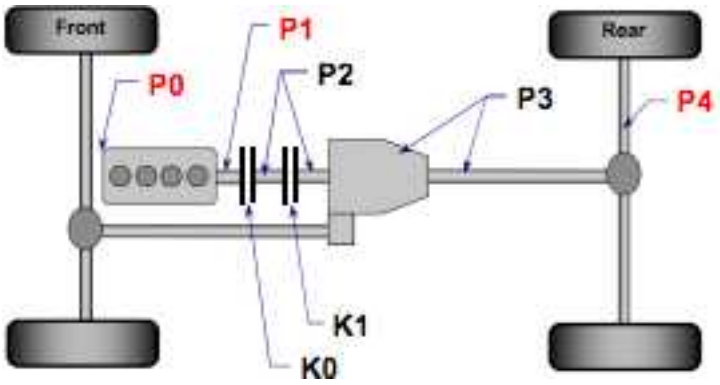
> *"It will take years before there are enough 48-volt vehicles on the road to dramatically shift the car PARC and force shops to retrench."*

P2 Hybrids



Hybrid vehicles breakout into multiple different arrangements; P0, P1, P2, P3, and P4.

Hybrid Architecture Positioning:



P0 = Belt driven Starter Generator (BSG)
P1 = Crankshaft mounted E-machine (CSG)
P2 = E-Machine on the gear input
P3 = E-Maschine on the gear output
P4 = Axle Drive

P1:

- Pros: Limited extra-weight
- Cons: No regenerative braking when clutch disengaged, Undergoes engine resistive torque when running Full Electric or regenerating during braking

P2:

- Pros: E-machine can be totally decoupled from engine
- Cons: Additional clutch (limited space for transverse engine)

P3/P4:

- Pros: Double shaft suitable with transverse engine, Regenerative braking with engine totally decoupled
- Cons: Additional transmission ratio

The twin-clutch hybrid system (P2 hybrids) works most efficiently with 48-Volt systems.

In comparison to P0/P1/P3/P4 hybrids today, the P2 system has the best outlook, however by 2025 experts believe P3 and P4 systems will operate more efficiently.

	P0 BSG	P1 BSG	P2 BSG	P4
Recuperation, electric torque assist, “change-of-mind”, engine-off coasting	X	X	X	X
Engine-off climate control	-	-	X	-
eCreeping	-	-	X	X

BSG: Belt Starter Generator – created by Continental and Schaeffler

Hybrid System Type	Time of solution	Estimated Fuel Savings
P0	Present day – in market	13%
P2	Rolling out platforms today	18%
P4	Future solution (2023-2025)	20%

P2 Hybrids have been in development and are appearing in new OEM platforms.

Todays 48V motor solution is in front of the engine (P0 configuration), although manufacturers like Toyota are pushing to implement new P2 hybrids within the next platform release.

- In the P2 arrangement the electric motor is located between the engine and the transmission.
- It can therefore be operated entirely independently of the combustion engine, which means that electric driving at temporary speeds of up to 31 mph is possible with a 48-volt drive as well.
- Such a solution, which enables fuel savings of up to 25 percent in concert with additional efficiency-boosting measures, was presented for the first time by Continental and Schaeffler at the 2016 Vienna Motor Symposium.
- Key OEMs using the P2 technology are the Hyundai Sonata Hybrid and the Infinity M35 Hybrid. Other OEMs who are already developing P2 hybrids include;
  - *Mercedes*
  - *Volkswagen*
  - *Toyota*
  - *BMW*

Fuel Tank Advancements

Fuel Systems

Future fuel system technologies are focused on several things:

- Integrating the controls inside the fuel tank to eliminate the need for breaching the tank itself and sealing those breaches
- Focus on fuel tank sensors/ measurement and improving the following measurement systems within fuel systems:
  - *Tank leakage detection*
  - *Pressure control*
  - *Fuel volume control*
  - *Fuel filler flap locking control*
  - *Mis-fueling protection*
  - *Fuel evaporation determination*
  - *Fuel quality determination*
  - *Tank level determination*

- Fuel pump control modules – DC control modules, BLDC control modules and integrated control modules

- Challenges include;
  - *Reducing system costs and complexity*
  - *Supplier management*
  - *Integration of sensor technologies for fuel type and quality measurement*

Comparison between todays fuel tank technology and future advancements.

Today's Technology – fuel measurement	*Future Technology – fuel measurement*
Fuel level measured by capsulated or non-capsulated potentiometer with float and other movable parts within the tank	*No movable parts; fuel level measured by sensor*
Limited technology, challenge to incorporate controls in tank environment	*Standardize package to fit into tank yielding higher level of accuracy, on-board self-diagnostic, fuel temperature measurement, others TBD*
	Modular approach for future functions o *Fuel quality* o *Evaporation pressure*

Vehicle Wiring Advancements

OEMs are testing new materials for wiring and exploring ways to lightweight.

Vehicle OEMs are down gauging wire and using/exploring alternative materials– especially for wire harnesses and battery cables

More specifically, the percentage of copper in vehicles is decreasing due to increased use of aluminum. However, the total volume of copper in vehicles is still increasing due to increasing use of electronics

- Substitution has been moving slowly due to risk-averse organizations
  - *Economic and weight savings are under investigation ultimately should drive substitution*
- High percentage of small-gauge copper wires in vehicles cannot be substituted by aluminum due to material advantages

Equipment manufacturers and aftermarket experts indicate that wiring advancements should have minimal impact on the aftermarket.

Asian, North American, and European OEMs are working to significantly decrease wire thickness.

OEMs are looking to reduce cost and complexity by decreasing the size of wire harnesses.

This downsizing is progressing across all three primary auto production regions

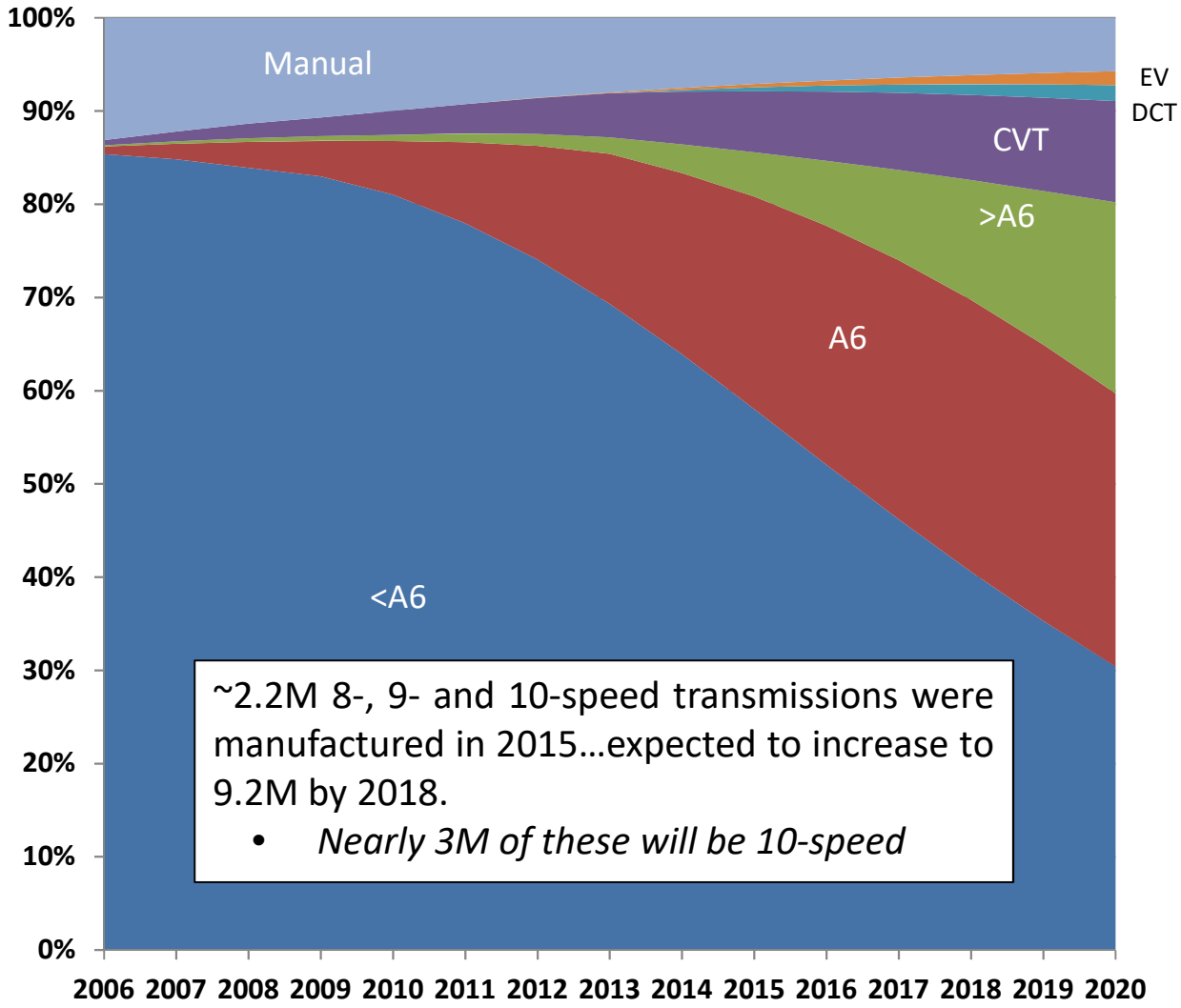
- Asian suppliers indicated extensive efforts to downsize and cut costs for wire systems, while a major German supplier discussed using advanced design software to optimize wiring designs
  - *Trend toward .13mm2 gauges on wires…up to 10% of wires*
- Asian suppliers and OEMs both indicated significant efforts to downsize wire harnesses
  - *Yazaki emphasized manufacturing capability of .13mm2 wire, a key part of downsizing the hundreds of small wires throughout a vehicle*
    - ✓ Honda is changing the box structure of its harnesses to allow for lower gauge wire, as well as changing to ISO standard wire
- North American downsizing efforts also continue at an aggressive pace
  - *Bundle size and assembly cost are very important to Ford, which favor a downsizing approach over aluminum substitution*
  - *GM also is pursuing gauge downsizing to reduce cost and mass*
- European suppliers and OEMs are seeking to optimize wire gauge
  - *Using advanced design software and distributed architecture allows these companies to use less wire overall and make it the minimum size possible*

10-Speed Transmission

Transmission Penetration

Through 2020, the majority of VIO will include traditional automatic transmissions.

Transmission Share of Vehicles in Operation



EV = Electric Vehicles
DCT = Dual Clutch Transmission
CVT = Continuously Variable Transmission

10 Speed Transmissions

Vehicle OEMs continue to explore options to replace six- and eight-speed transmissions with better performing alternatives.

- Driven by CAFÉ standards
- Often adding overdrive gears to help large engines improve fuel economy
- Peak introduction expected after 2021 when CAFÉ rules increase significantly

Ford and GM jointly developed a 10-speed transmission for use in large, rear-wheel drive cars and four-wheel-drive pickups.

- GM offered as an option on 2017 Camaro ZL1
  - *Expanding to 8-10 vehicles for 2018 model year*
- Ford made the 10-speed standard on it F-150 Raptor
  - *Optional on other 2017 F-150s*
  - *Standard on all F-150s within three years*

Honda, Toyota and Hyundai all exploring 10-speed transmissions for front-wheel drive applications

- Honda introducing on 2018 Odyssey
- Toyota introducing on 2017 Lexus LC 500

Service & Repair Implications

Several trends indicate reduced transmission repair and increased transmission replacement in the future:

- *"Sealed for life"* components
- Increased transmission complexity *(DCT, CVT, etc…)*

> *"We have struggled to understand how to reman a CVT transmission. The independent shops likely won't ever figure it out…they'll purchase a reman transmission and replace the whole unit instead of trying to fix it."*

- Large transmission reman operations have experienced significant growth over the past several years

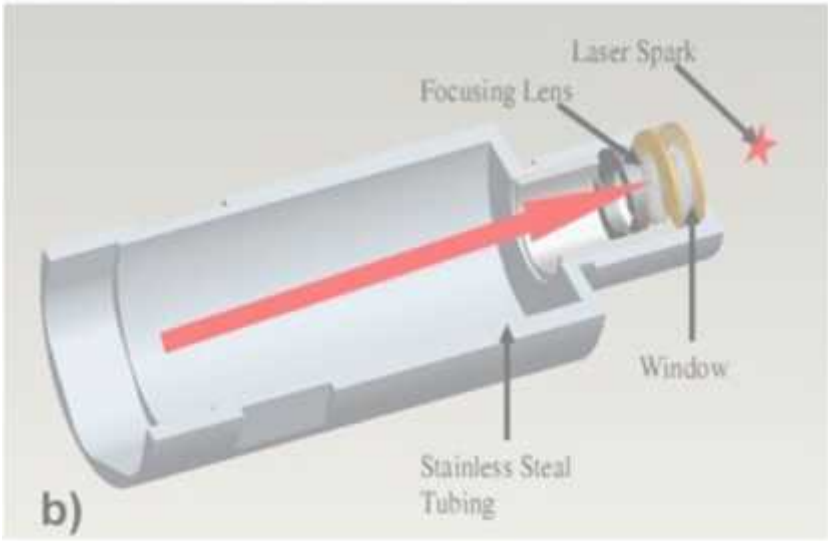
> *"The more complicated transmissions get, the better the long-term prospects for Jasper and other large reman operations."*

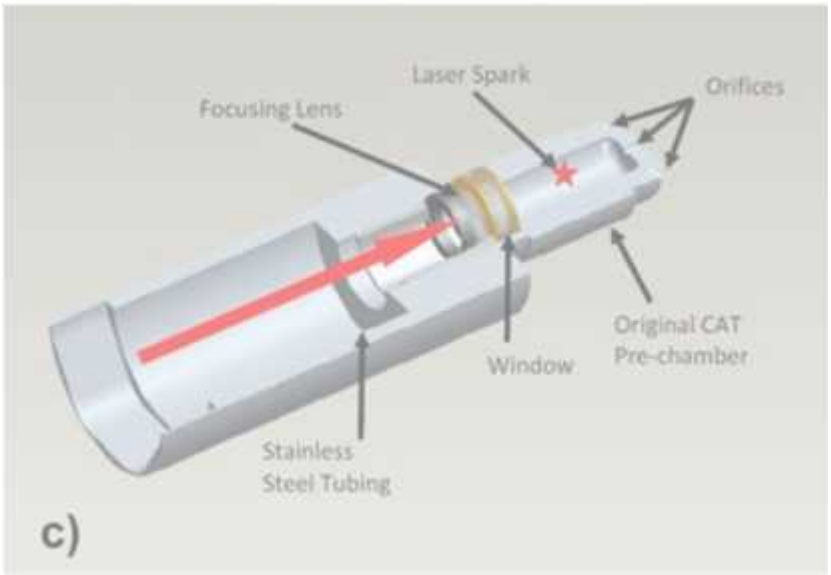
Replacement trend allows a higher percentage of independent shops to provide *"transmission service."*

- Demonstrated by significant reduction in specialty transmission repair shops
  - *Down 25-30% since 2004*
  - *Transmission shops often diversifying into other "general repair" arenas*

Equipment manufacturers report that advanced transmissions should have minimal impact on equipment *(both mechanical and diagnostic).*

Next-Generation Ignition Systems





Laser Plasma/ Compression Ignition Systems

As OEMs struggle to meet CAFÉ standards, traditional spark plugs/ignition systems are a significant barrier. Major problems with current spark-ignited systems include:

Poor fuel economy:

- The 54.5 mpg CAFE requirement has caused the auto industry to re-evaluate their current ignition systems.
  - *Experts believe that these new and future requirements can only be met by advanced ignition systems, and not by any current spark plugs.*
- Emissions:
  - *Complex, multi-stage catalysts are the norm for reducing greenhouse gases, hydrocarbons, and oxides of nitrogen (NOX) from emissions of typical internal combustion engines.*
  - *Most of these emissions are the result of ultra-hot ignition and incomplete combustion within the engine.*
- Lean burn:
  - *One way to increase fuel economy and decrease emissions simultaneously is to ignite mixtures with less fuel under partial engine load conditions.*
  - *Current spark-ignited systems struggle with this, especially near idling speeds.*
- Locating fuel/air molecules:
  - *Because fuel is only ignited near the arc gap in a standard spark plug, a suitable fuel/air mixture needs to be present to ignite.*
  - *As mixtures get leaner and leaner, this becomes a growing problem.*

Laser Plasma/ Compression Ignition Systems

These reasons listed on the last slide are why OEMs are evaluating and testing a variety of alternatives for traditional spark plugs.

- Laser ignition, plasma ignition, and compression ignition are the frontrunners for future ignition systems.

Laser ignition	Plasma ignition	Compression ignition
Burn fuel more efficiently. Cleaner and greener cars. Can be tuned more efficiently than spark plugs.	Completely burns all fuel inside the combustion chamber at a faster rate.	Has the benefits of a diesel engines, but runs on gasoline.
Extremely expensive. Have suffered from incomplete combustion.	A low-power solution is a long way off for plasma systems.	More difficult to control than other combustion engines.
6+ years (in progress)	6+ years (in progress)	6+ years (in progress)

Laser Plasma/ Compression Ignition Systems

Laser Ignition

- System will ignite fuel in the middle of the chamber instead of one end of the chamber.
  - *Other benefits of laser ignition;*
    - ✓ The more complete burn also emits fewer polluting by-products such as nitrogen oxide.
    - ✓ Firing at the optimal instant for ignition.

"Laser ignition can boost the fuel efficiency of a car from 40 miles per gallon to 50 miles per gallon"

"Some companies are interested in retrofitting their existing engines with laser ignitions"

Plasma Ignition

- A high voltage ignition spark with a very large ignition kernel with peak currents exceeding 20 to 30 amps.

Compression Ignition

- A new ignition that combines the best characteristics of both the Otto (gasoline engine) and diesel cycles – this is called Homogeneous Charge Compression Ignition (HCCI).
  - *Using the heat generated by compressing the incoming air to ignite the fuel without a spark plug, like a diesel, but would run on gasoline.*

Laser Plasma/ Compression Ignition Systems

Headwind:

While new ignition systems are necessary to meet requirements in the future, today's spark plug will remain dominant in the long-term outlook.

- Cost on the consumer side and OEM side are major barriers.
  - *OEMs cannot afford to implement these expensive technologies into their vehicle platforms. Testing and time will be necessary for the costs of these systems to drop.*
  - *Consumers can purchase today's spark plugs from an aftermarket supplier for $5-10. Having to replace any of the alternative systems would be costly to the consumer*

- In addition, engine technology today is not ready to support these new ignition systems.

Tailwind:

Using laser ignition over spark plugs will lead to more efficient engines, as high compression ratios can be used in the cylinder without the need for increased voltage.

- This high voltage used in high compression engines also leads to spark plugs wearing out much faster, an issue that won't affect a laser setup.

This concludes our presentation. Thank you for the opportunity to support ETI's market research initiatives.

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The Martec Group

Questions & Discussion