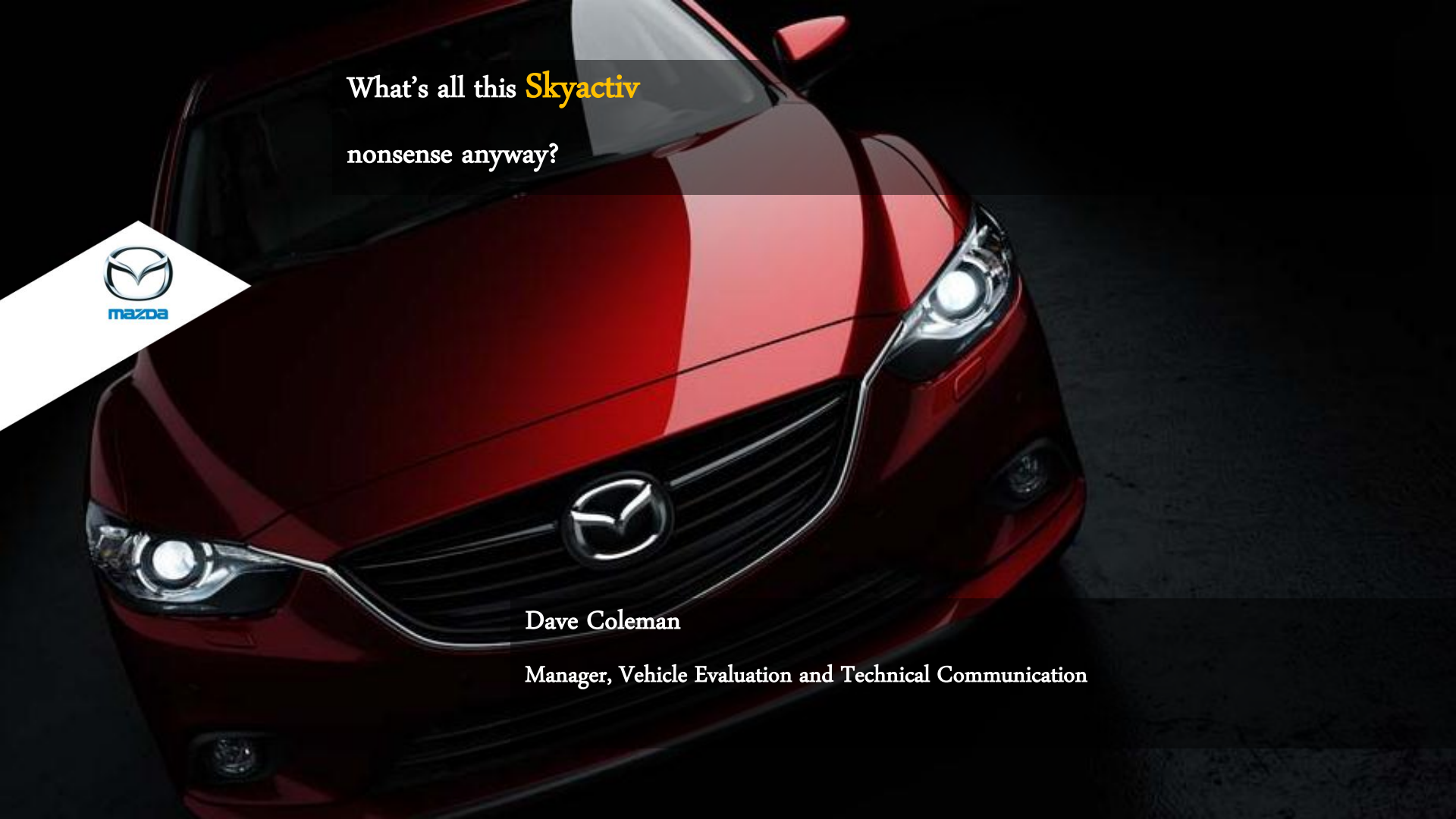
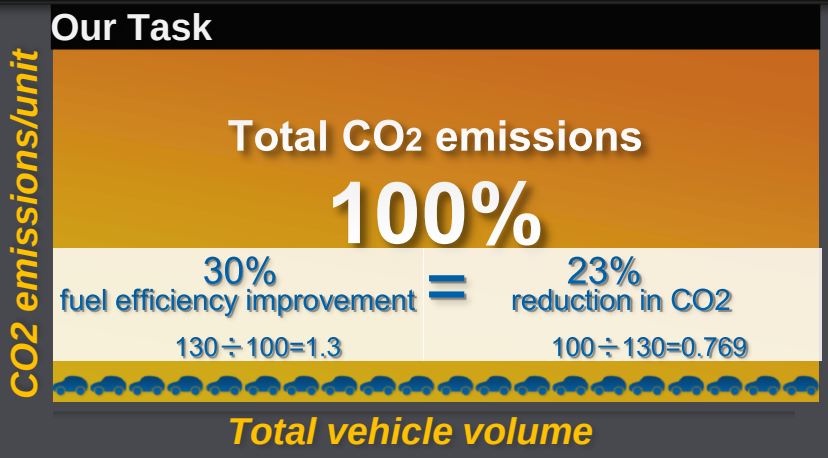
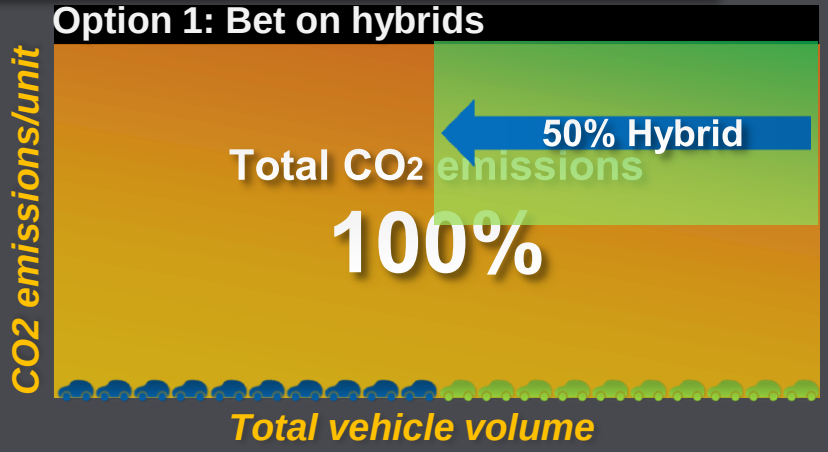
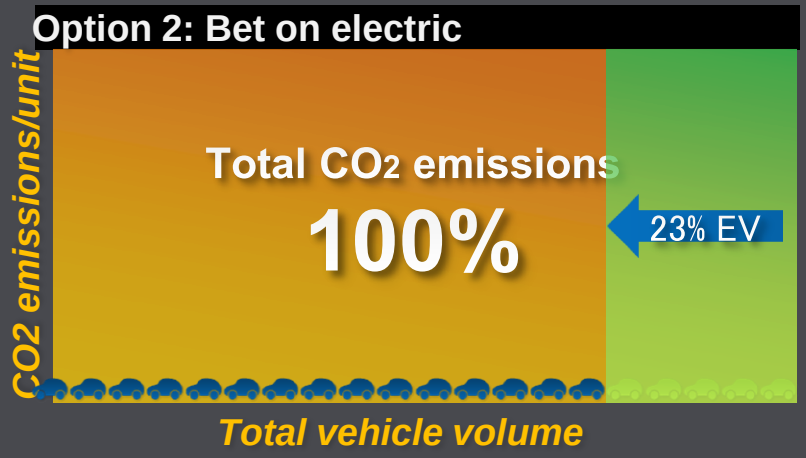
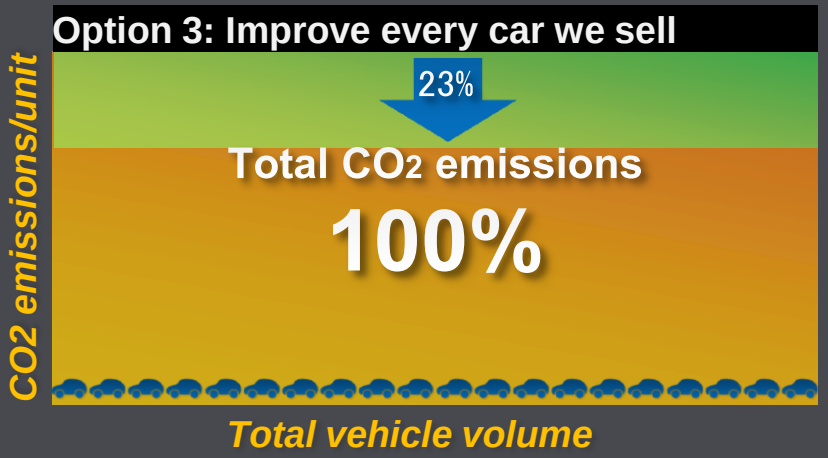

What's all this Skyactiv
nonsense anyway?
mazda
Dave Coleman
Manager, Vehicle Evaluation and Technical Communication

30% better fuel economy by 2015 (vs. 2008)









Development starts with a clean slate

B6 Engine

BP Engine

MZR Engine

FS Engine

KL V6 Engine

Cyclone V6 Engine

Skyactiv-g

Skyactiv-d

Skyactiv-chassis

Skyactiv-Body

Skyactiv-Drive

Skyactiv-mt

1983

FNR-series AT

G-series MT

1980

F-series MT

AA6 MT

Contributors to 30% improvement

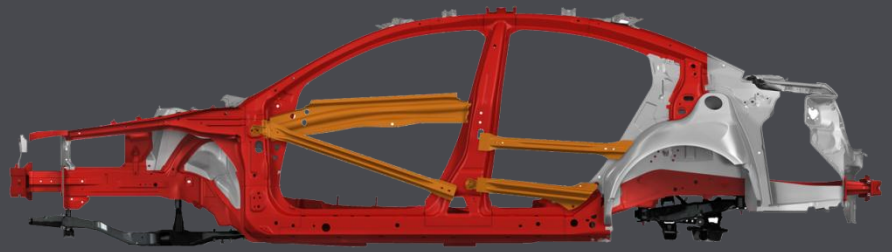
Engine	 	SKYACTIV-G SKYACTIV-D	15% 20%
Transmission	 	SKYACTIV-drive SKYACTIV-MT	4-7% 1%
Weight Reduction		SKYACTIV-Body & Chassis	3-5%
Synergies, model substitution and nit picking			Enough%

Total 30%

Each new model will be at least 100kg lighter than its predecessor

Development targets

- Increase rigidity 30%
- Reduce weight 8%
- Top crash safety performance

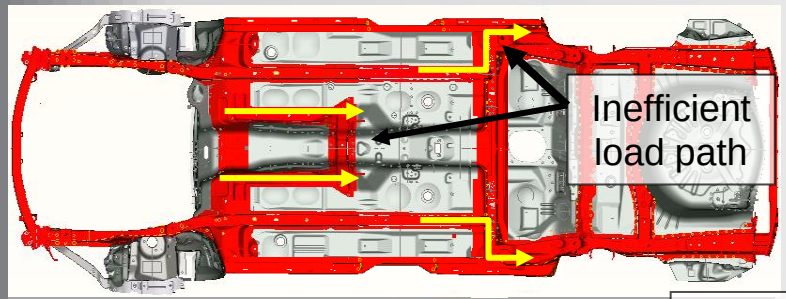


Weight loss strategy

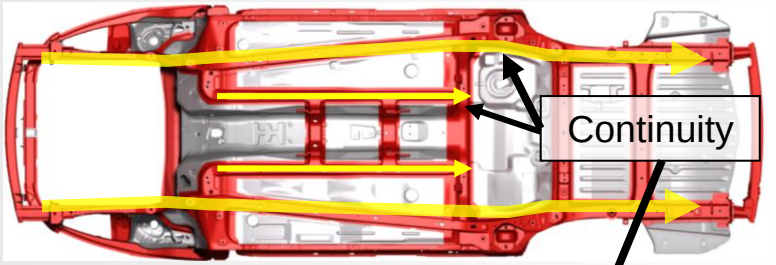
- Efficient structure
- High-tensile steel (no exotic materials yet)
- Common body structure concept across many models

Straighter frame and multiple load paths

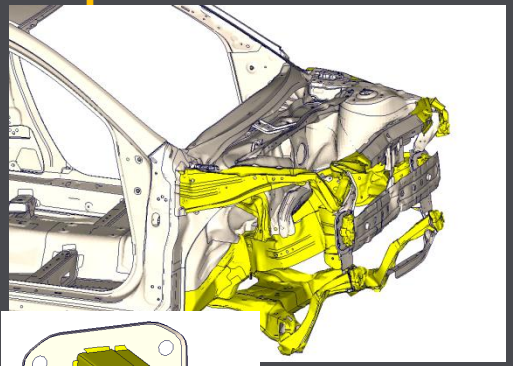
Previous

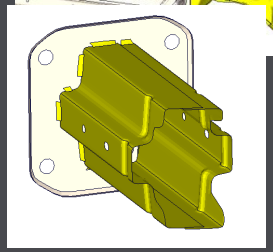


SKYACTIV-body

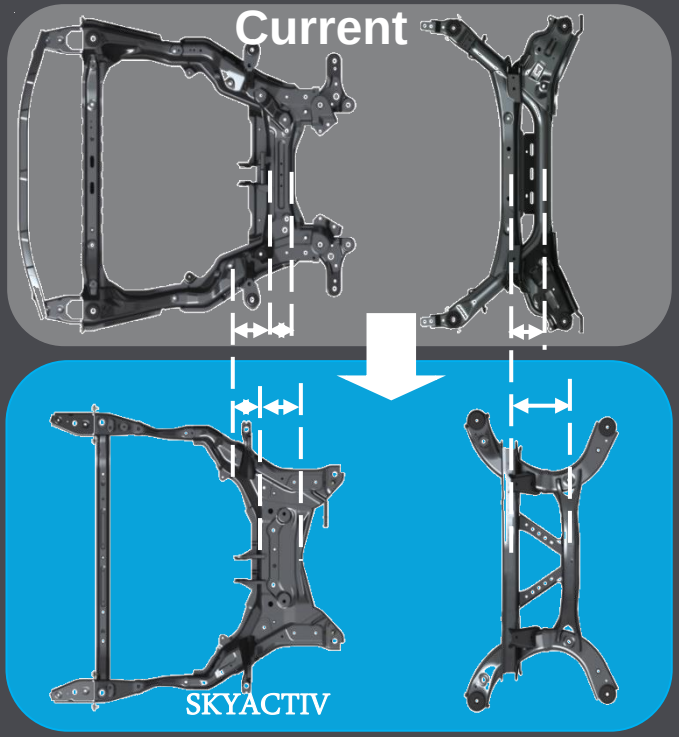


12-point box section



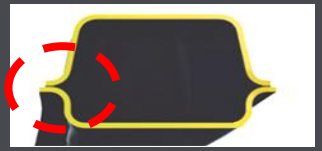


Corners of a box section are the strongest parts, so 12-point box shape offers “free” strength improvement.

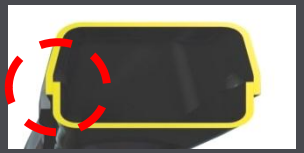


Spot welds replaced with MIG welds

Current



SKYACTIV

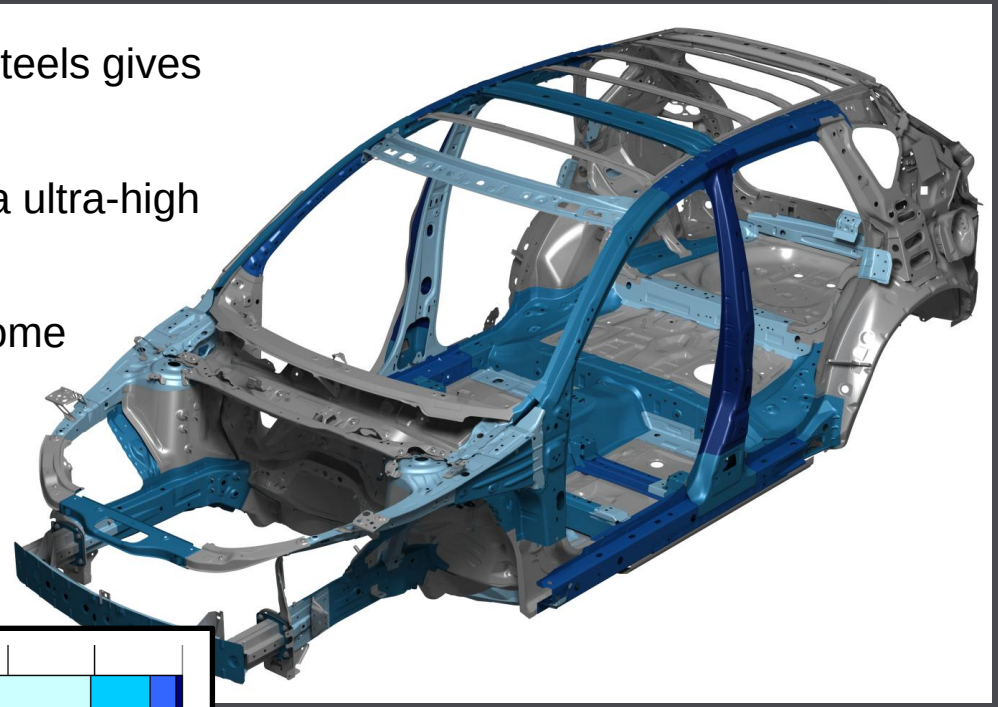


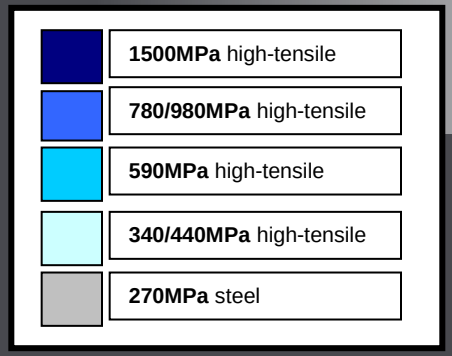
Rigidity enhanced by removing flange

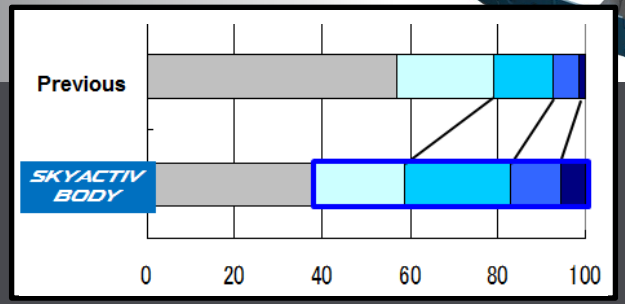
	Front Crossmember	Rear Crossmember
Weight:	**-6.4kg(14.1lb)**	**-4.5kg(9.9lb)**
Rigidity:	**140%**	**100%**

High-Tensile strength steel

- Targeted use of high-tensile steels gives high strength with low weight.
- Industry first use of 1800 MPa ultra-high tensile steel (in bumpers.)
- 61% of total body weight is some form of high-tensile steel.



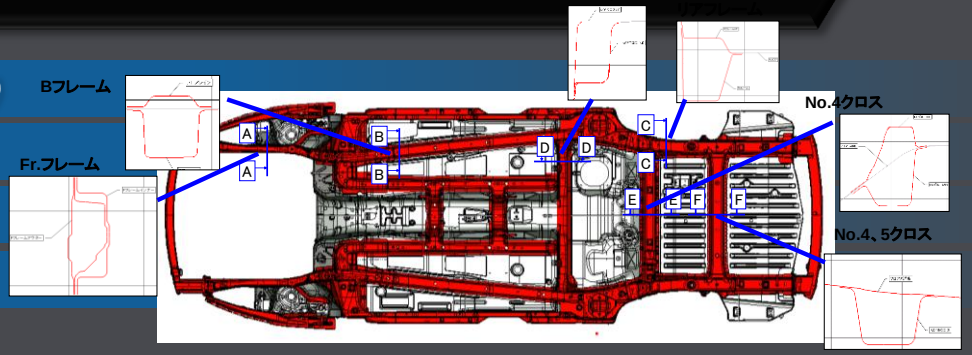




Redefining platform flexibility

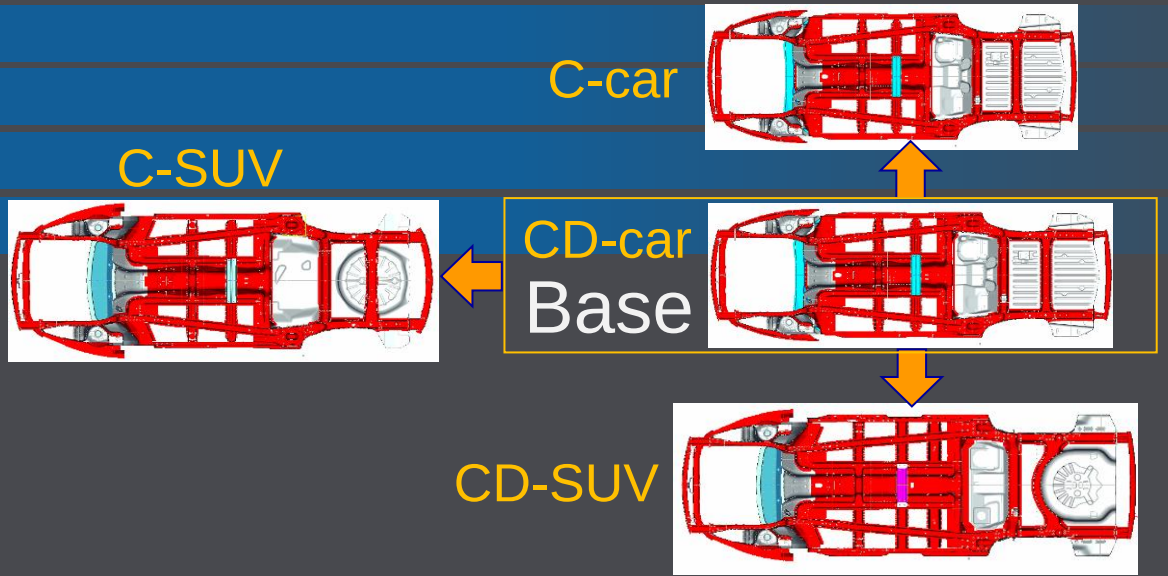
Fixed:

- *Structural concept (continuous load paths)*
- *Frame cross sections*
- *Joining structures and methods*
- *Fixturing method and assembly sequence*



Variable:

- *Floor Height*
- *Wheelbase*
- *Overhang*
- *Track width*



mazda

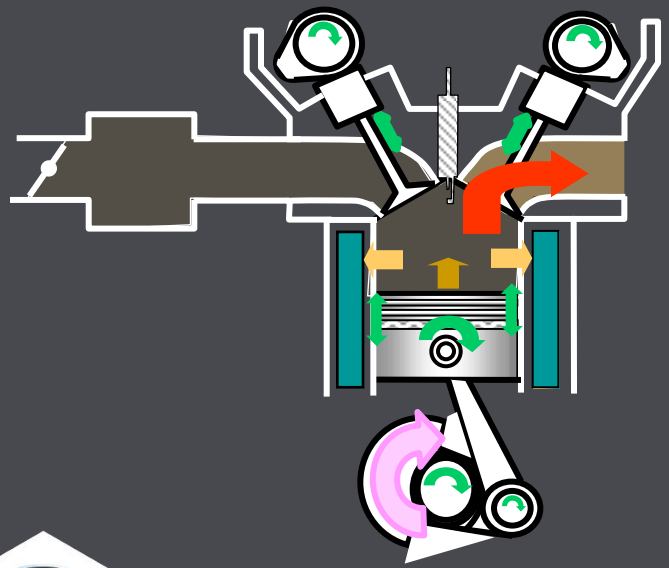
Skyactiv Weight loss record so far

- **Lightest CX-5 vs lightest CX-7:**

  -130 kg (-288 lbs)

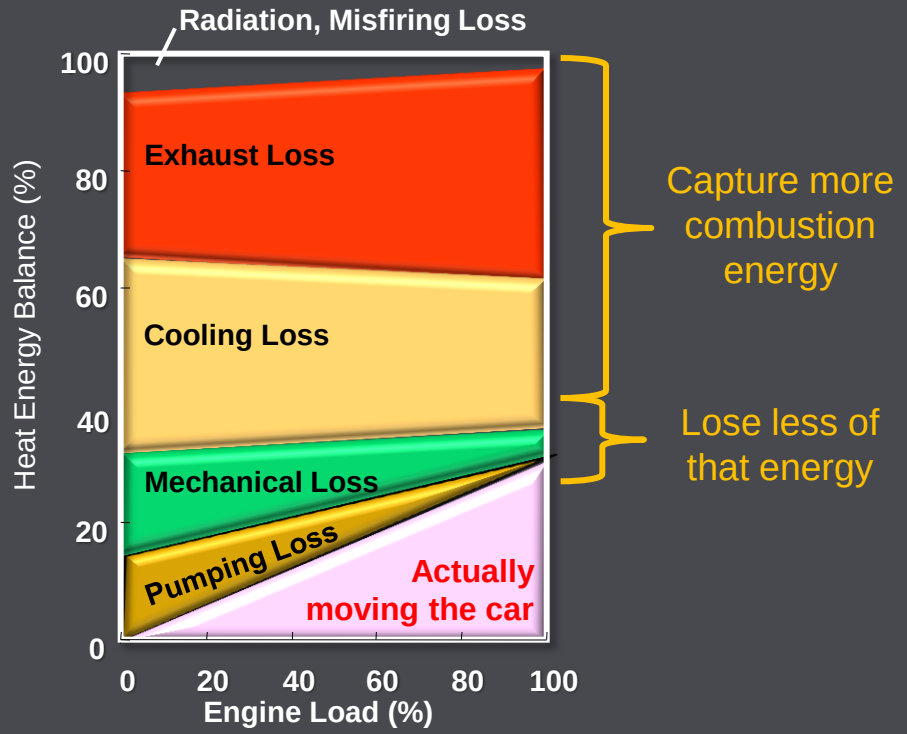
- **Heaviest CX-5 vs Heaviest CX-7:**

  -261 kg (-575 lbs)



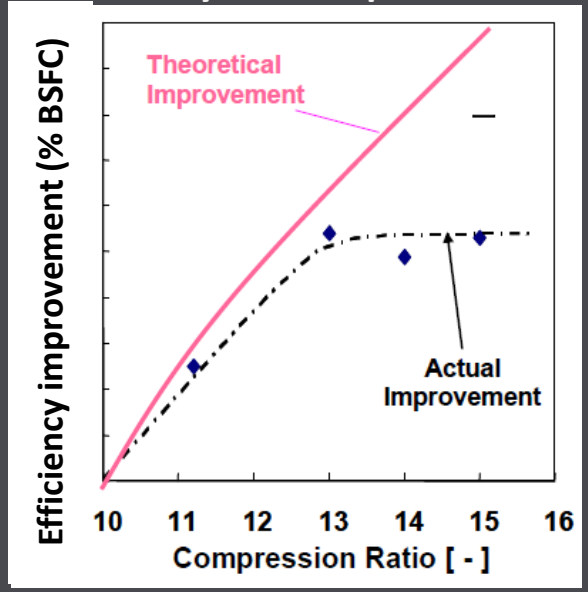
There are still huge opportunities for improved efficiency from gasoline engines.

Opportunities for improved efficiency

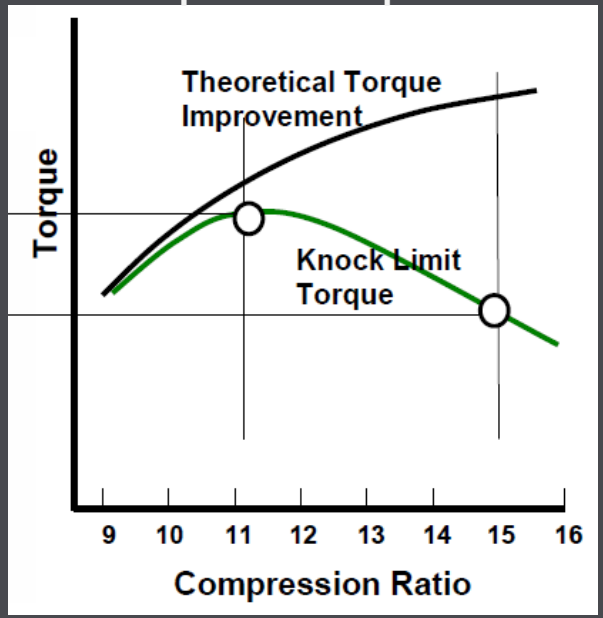


Higher expansion ratio (and compression ratio) is key factor in capturing combustion energy.

Efficiency vs. Compression

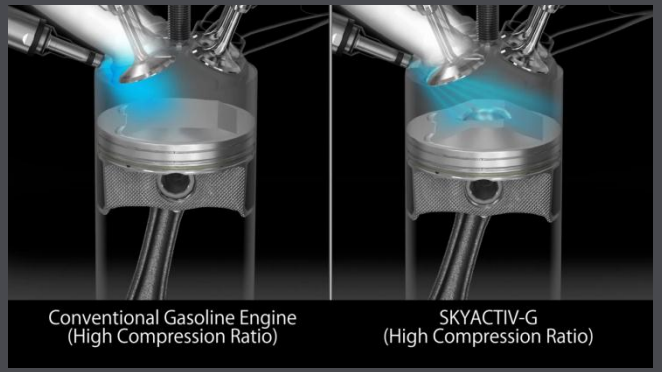


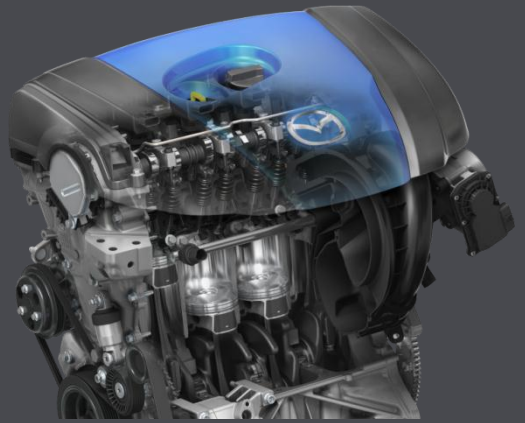
Torque vs. Compression



Achieving those theoretical gains requires deep study of combustion fundamentals

Knock is uncontrolled combustion self-ignited by the heat and pressure of high compression.





The Mazda Solutions

- Lower the temperature before combustion
- Faster combustion so there's less time for knock to develop

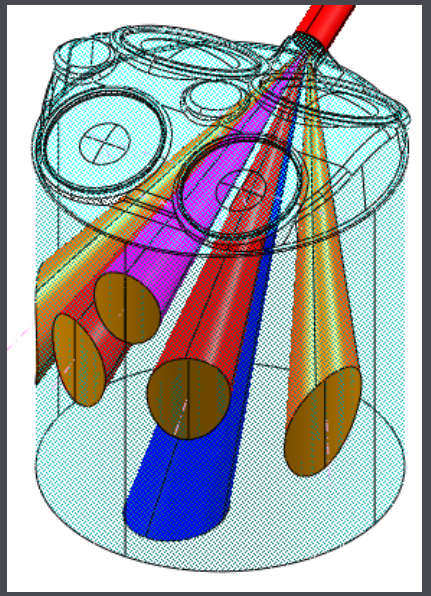
Advanced Direct Injection

Higher injection pressure (2,900 psi,) up from 1,600 on previous DISI engine, and 43 on port injected engines

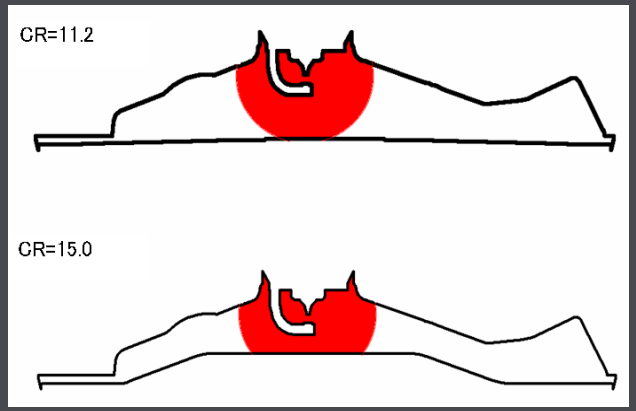
Multi-injection strategy

6-hole injection pattern for optimum fuel distribution

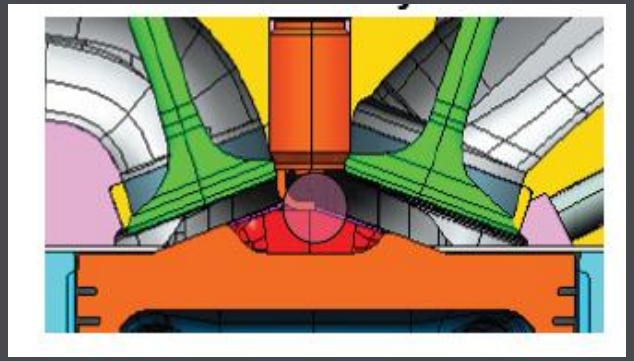
Spray-guided tumble flow of intake air

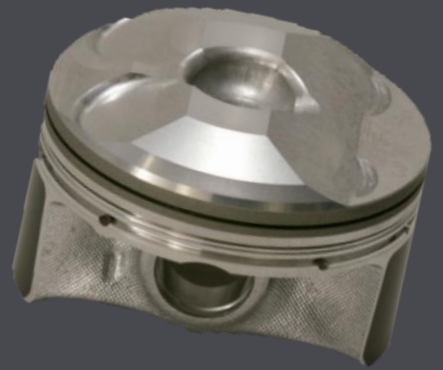


Problem: Flame kernel contacts the piston, causing cooling loss and slowing combustion (which increases chance of knock)



Solution: Combustion pocket





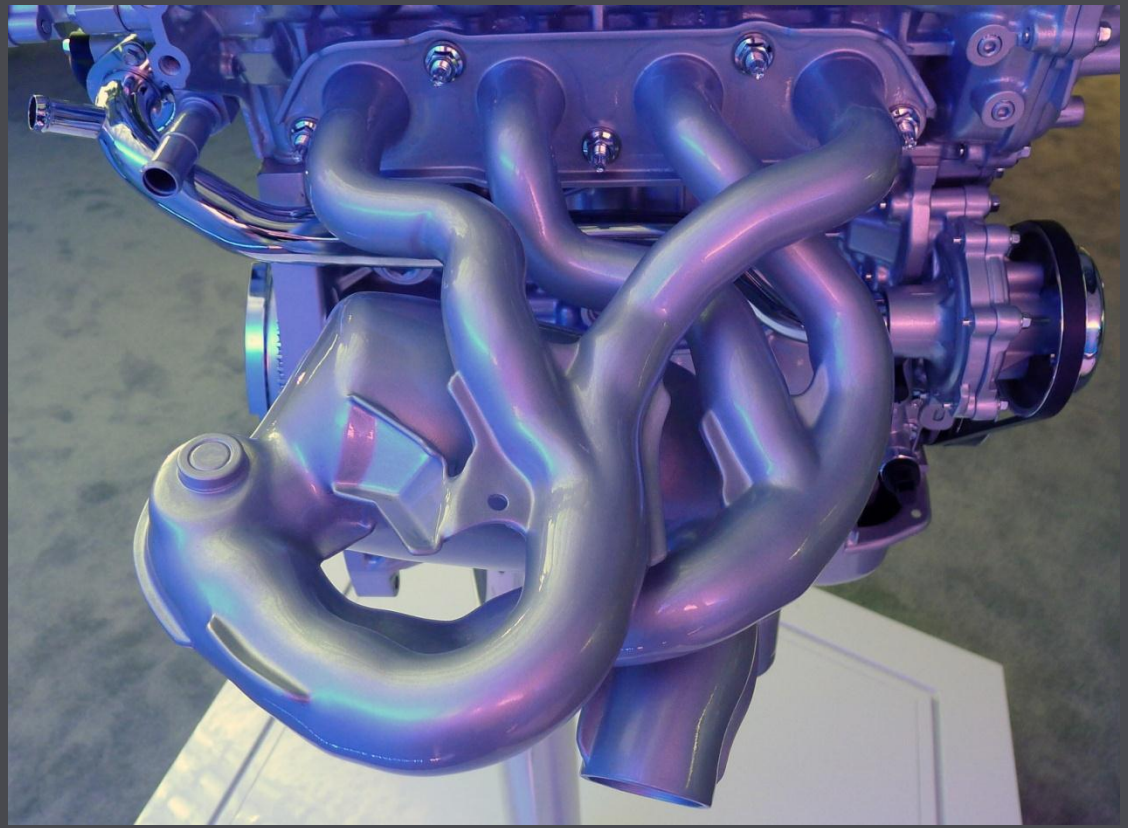
4-2-1 Exhaust Manifold:

Tuned exhaust manifold is as important as advanced direct injection and volcano-top piston combined.

Compression with 87 AKI fuel:

Conventional manifold	4-2-1 manifold
12:1	13:1
(Mazda3)	(CX-5)

Packaging requires coordination with SKYACTIV-BODY

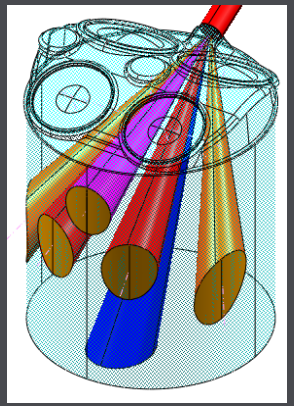


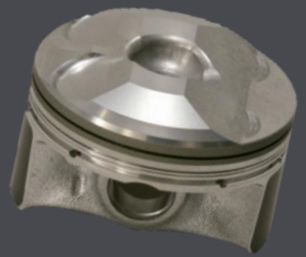
New idea? Not really...

All race engines use this idea.

But this manifold puts the catalyst too far away, so it takes too long to heat up.

But we did it...

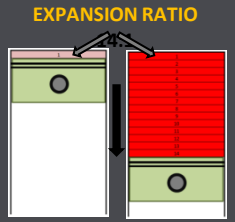


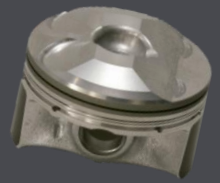


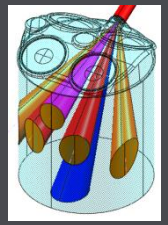
The Mazda Solutions

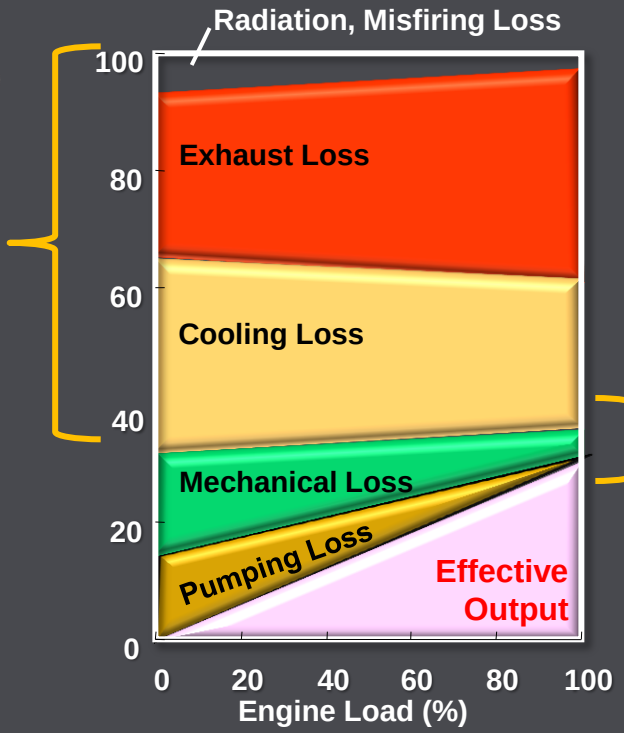
- Advanced DISI and combustion pocket create stable, stratified charge.
- Stable combustion allows retarded ignition that doubles exhaust temperature

Capture more energy from combustion



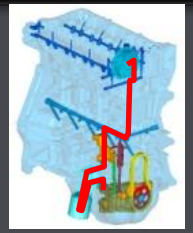




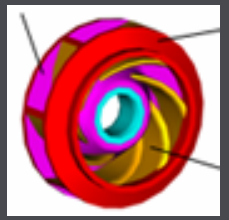


Lose less energy on the way to the wheels

Friction reduction through the “gram strategy” approach



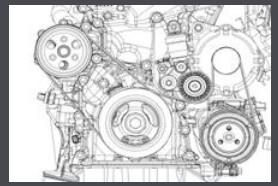
74% less oil pump drag



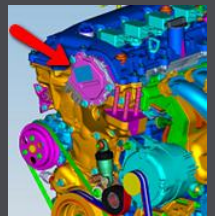
31% less water pump drag

25% less reciprocating drag

50% less valvetrain friction

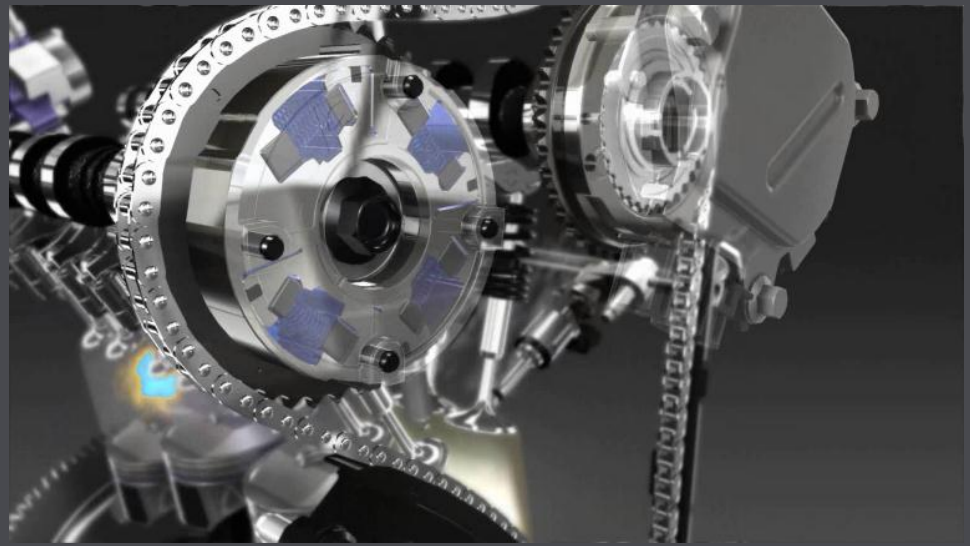


27% less belt drive drag



20% less pumping loss

Open-throttle, Miller Cycle cruise



Intake valve timing is controlled over a 70-degree range to allow seamless switching between conventional and open-throttle Miller Cycle operation.

Leaving the intake valve open late is more efficient than closing the throttle. Pumping loss reduced by 20%

Brake Specific Fuel Consumption matches conventional Diesels

SKYACTIV-G
91 AKI

* Figures vary a few percent in N. American spec (87AKI).

Skyactiv-G can scale from 1.3 to 2.5 liters

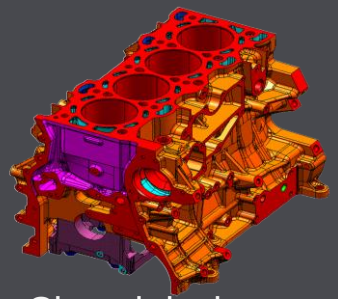
Fixed elements:

- *Combustion concept*
- *Interfaces (bellhousing, accessory mounts)*
- *Basic structure (open deck, split crankcase)*
- *Fixturing method and assembly sequence*

Variable elements:

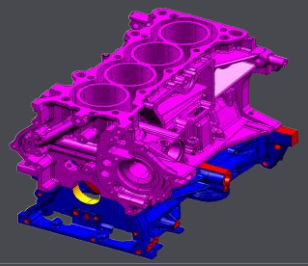
- *Bore x Stroke*
- *Bore Spacing*
- *Engine length and height*
- *Crank pin dimensions*

MZR L-series 2.0L



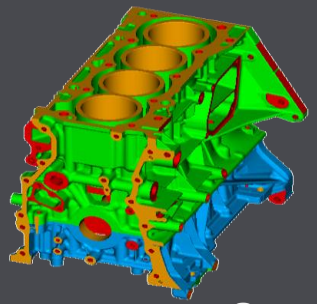
Closed deck
Bearing ladder

MZR Z-series 1.3L

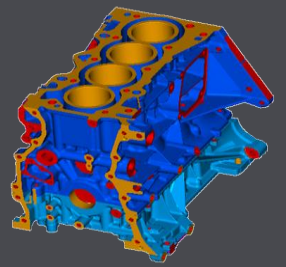


Open deck
Split Crankcase

Skyactiv-G 2.0L



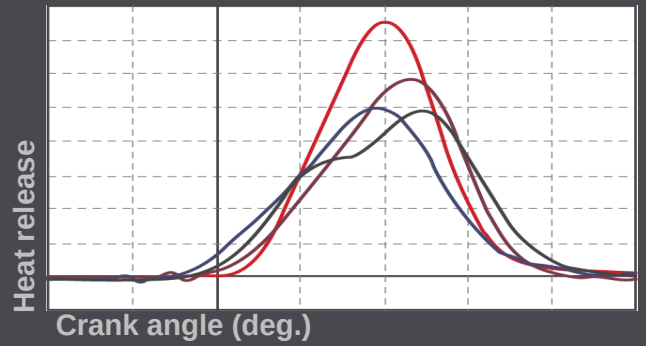
Skyactiv-G 1.3L



Same structure,
different size

Common combustion character simplifies calibration

Previous Engine Families

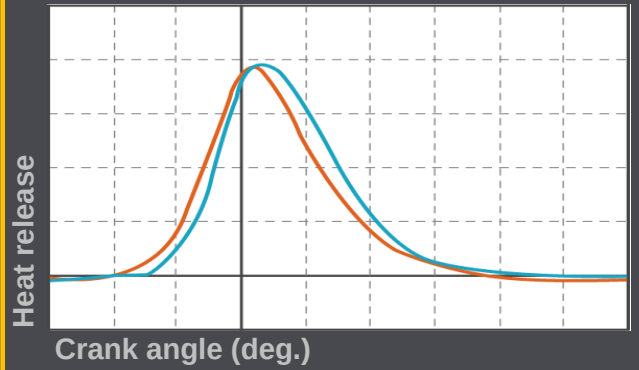


Different combustion characteristics for each engine family

Z-series MZR (1.3-1.5L)
L-series MZR (1.8-2.5L)
L-series MZR with DI
L-series MZR with DI + Turbo

Result: huge engineering commitment to maintain over 177 different engine calibrations

SKYACTIV-G engines

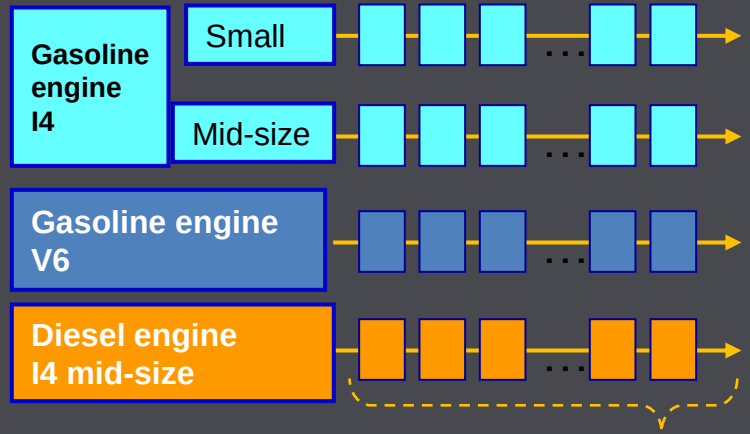


Similar combustion characteristics for all displacements

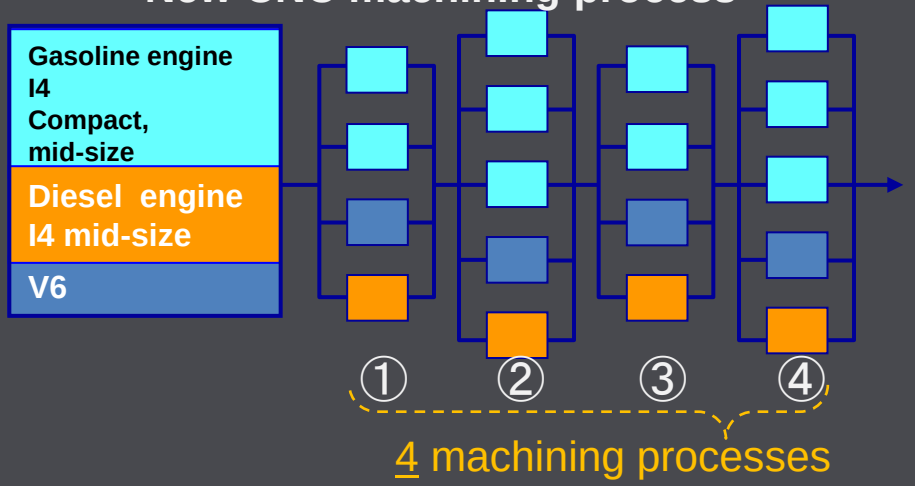
Scalable design from 1.3-2.5L

Result: dramatically reduced development and calibration expense

Old single-purpose machining process



New CNC machining process

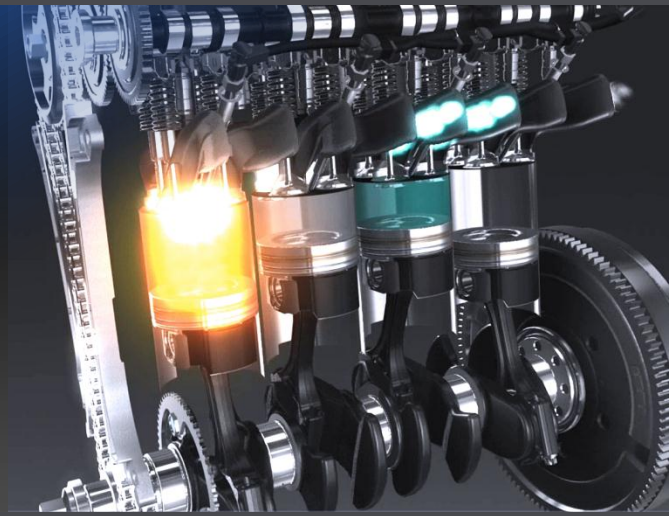


Capital investment reduced 70%

I4, V6 (current 3.7L), Gasoline and Diesel engines machined and assembled on one mixed line

Flexibility to respond to unexpected demand (eg: Diesel in Japan is 500% over plan)

SKYACTIV®-D



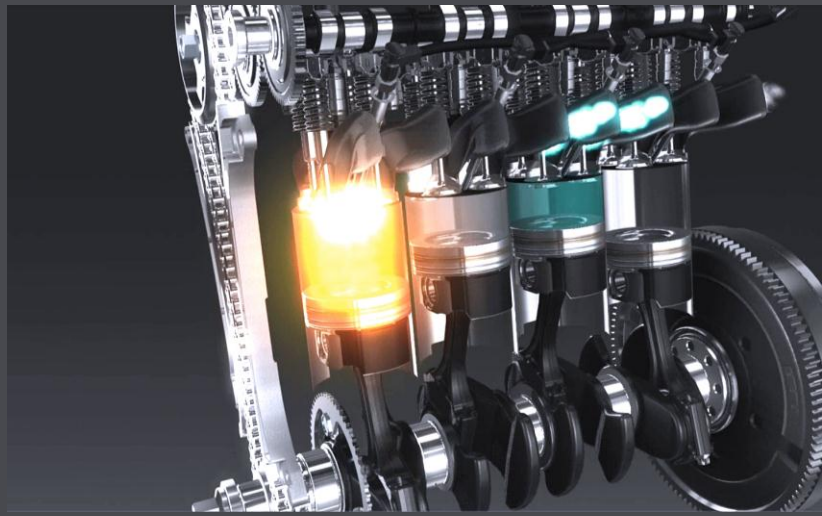
Development Targets:

- 20% better fuel economy (vs. current Diesel)
- More low-rpm torque *and* more high-rpm flexibility
- Meet emissions standards around the world without expensive urea injection
- Lower cost than Hybrids

The Emissions challenge

The Diesel emissions challenge

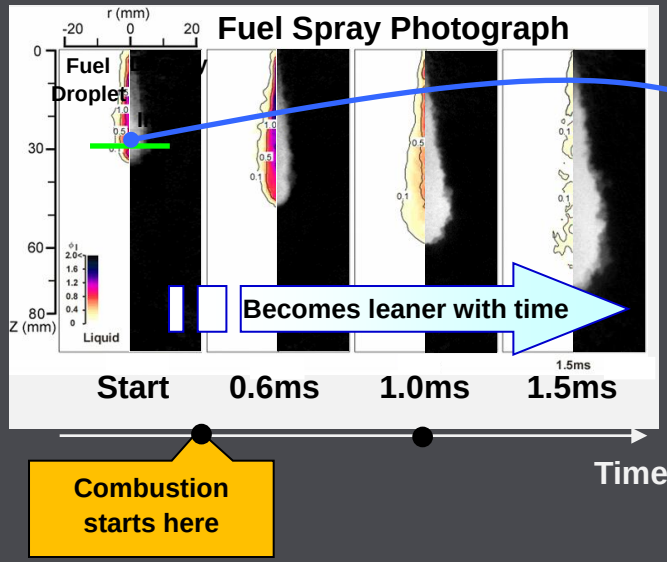
- Lean combustion causes NOx
- Most NOx countermeasures cause soot
- Urea injection fixes NOx, but is expensive, inconvenient



The Emissions challenge

Current Diesel (High Compression)

➡ High Compression Temperature



High temperature →NOx
Lack of oxygen → Soot

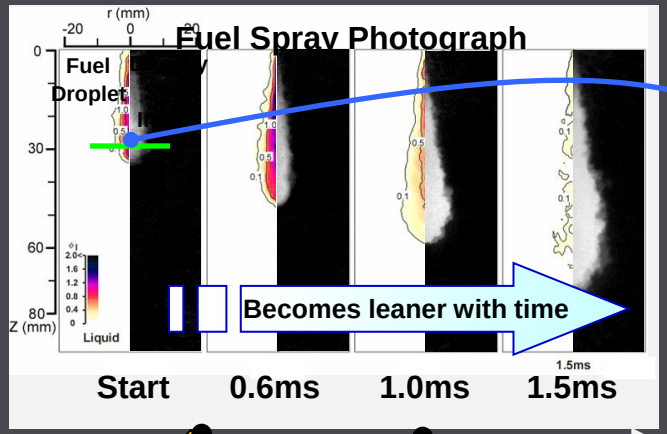
Diesel ignition occurs before the fuel is sufficiently mixed. Local hot spots cause NOx and over-rich spots cause soot.

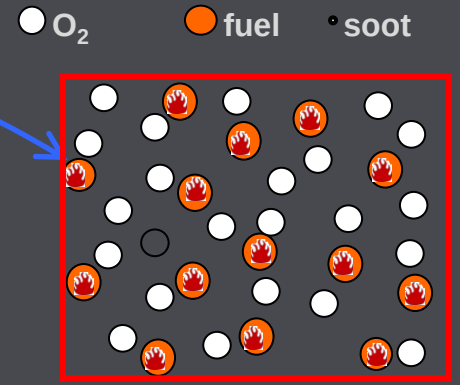
The Emissions challenge

Skyactiv-D

(Low Compression)

➡ Low Compression Temperature





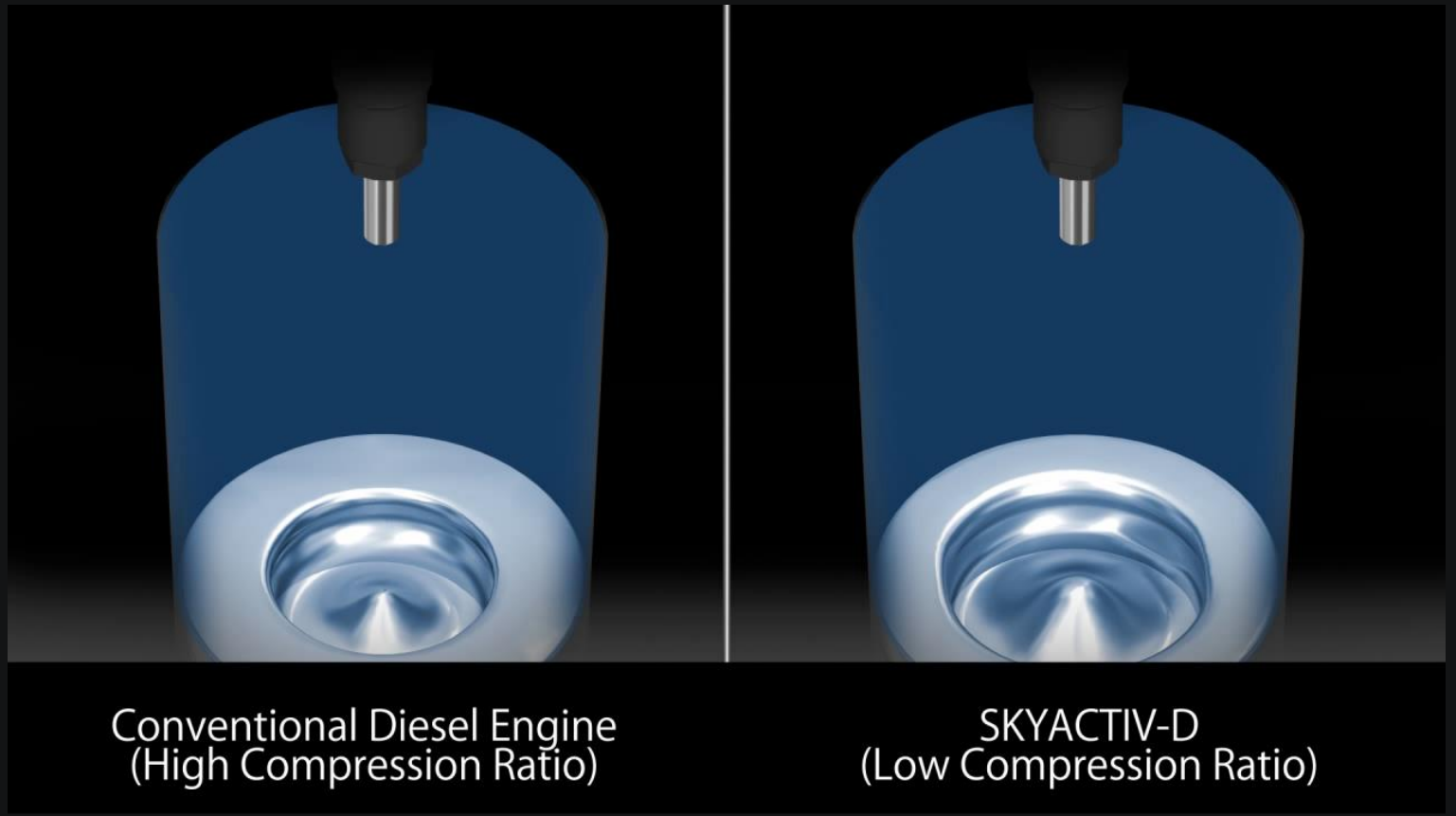
Better mixing = cleaner emissions

High-compression combustion

Skyactiv-D combustion

Lower compression gives more time to mix before ignition.
The result is clean combustion with low NOx and soot emissions

Low compression

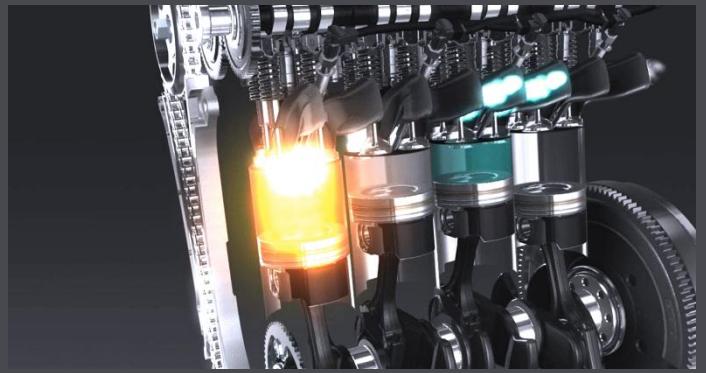


Low compression

Diesel engine breakthrough

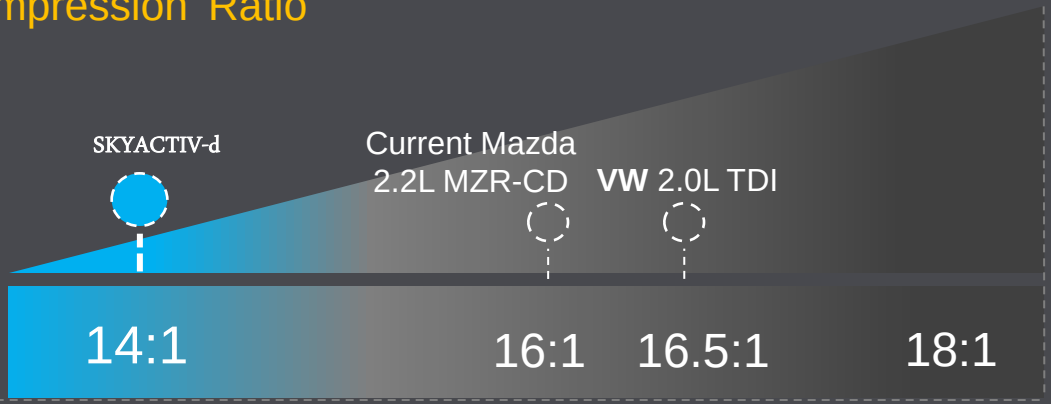
The lowest compression ratio available for a diesel engine in a passenger car!

Enables ideal combustion timing



Compression Ratio

SKYACTIV-D

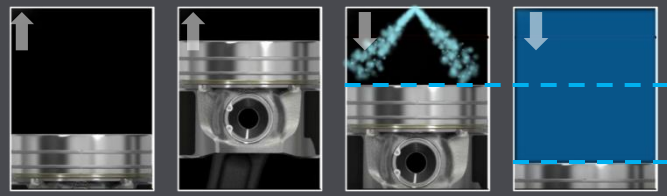


Ideal combustion timing

Low compression enables ideal combustion timing near the top of the piston stroke

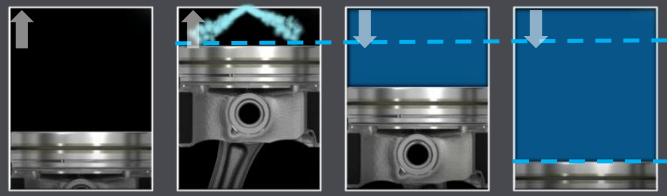
Higher expansion ratio improves power and fuel economy

Benefits of SKYACTIV-D:
20% less fuel consumption and CO_2 emissions compared to its predecessor!



Current Mazda MZR-CD 2.2L

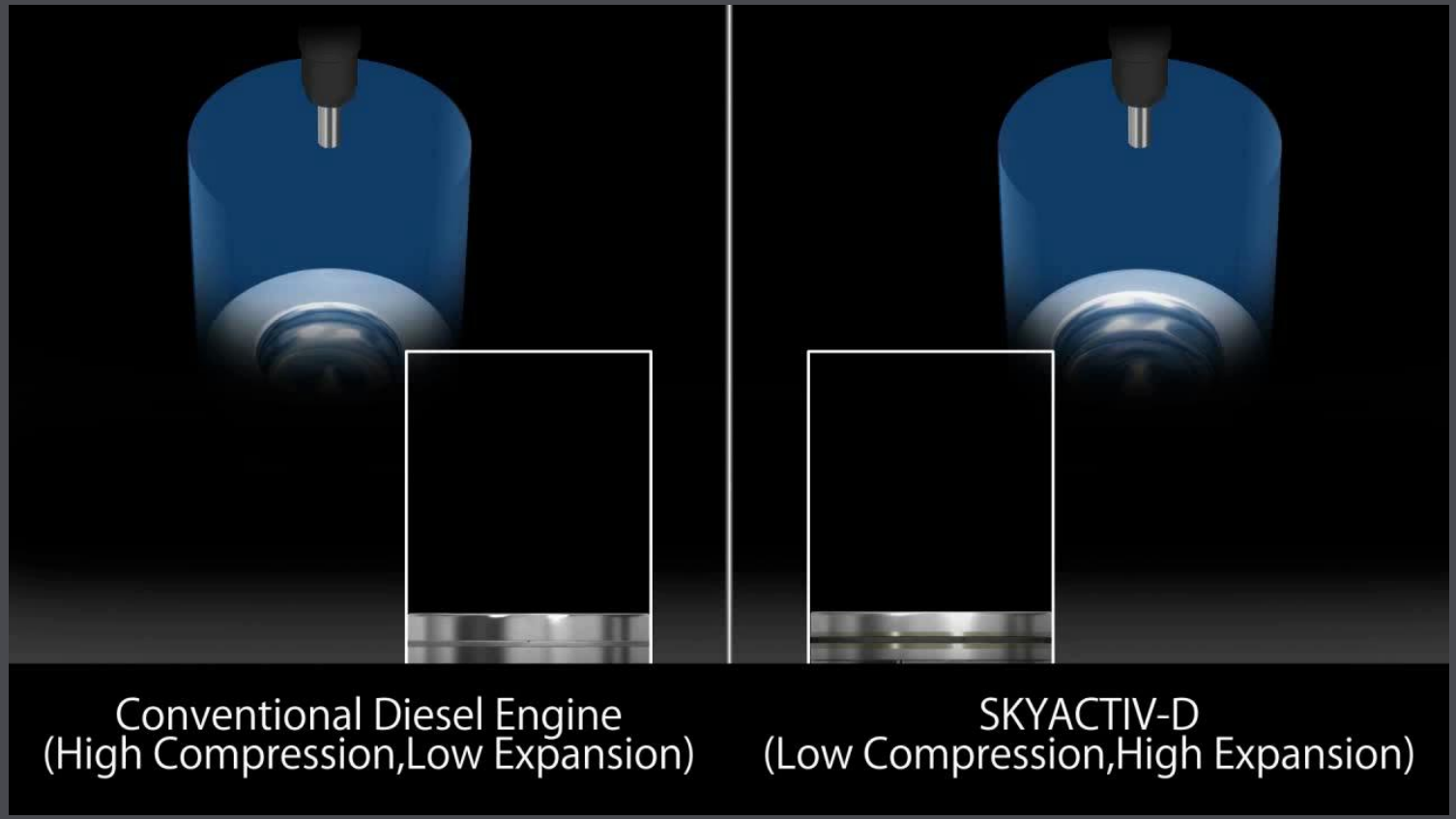
Small expansion ratio



SKYACTIV-D

High expansion ratio

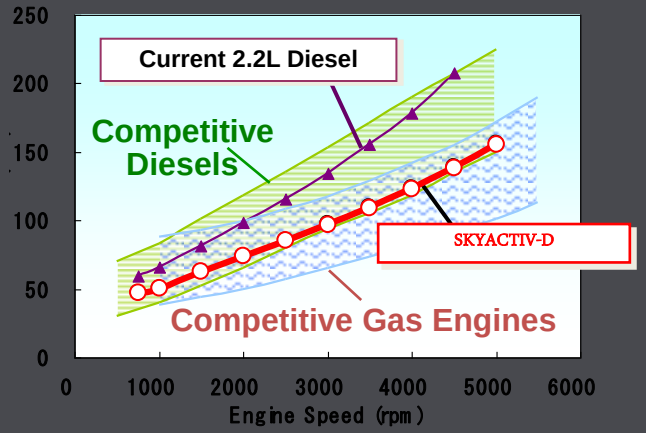
Ideal combustion timing



Low compression = low friction

Low compression = lighter construction

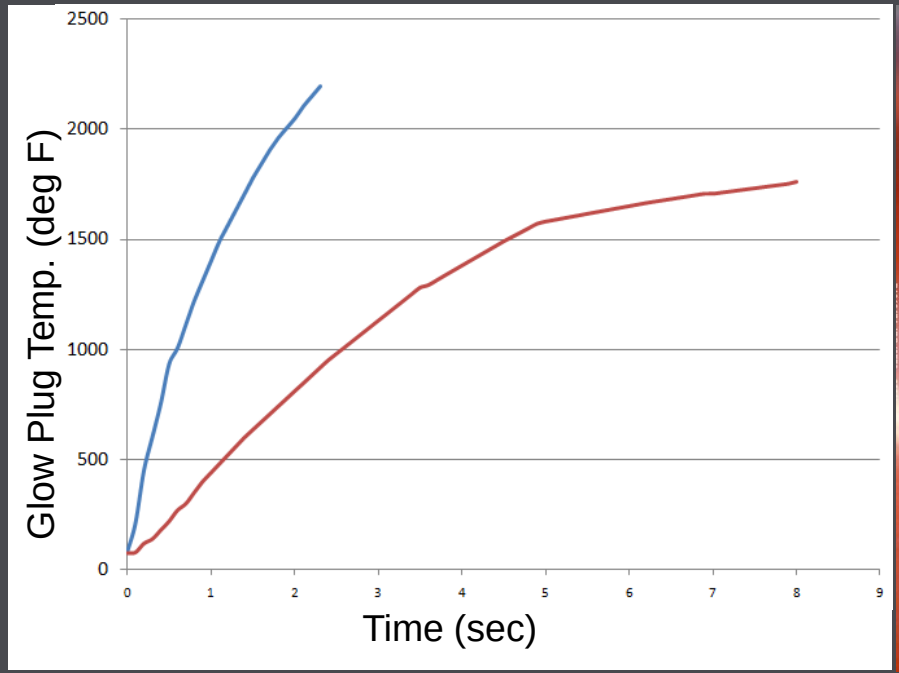
- New block, crank, rods and pistons reduce engine weight by 10%
- Better handling

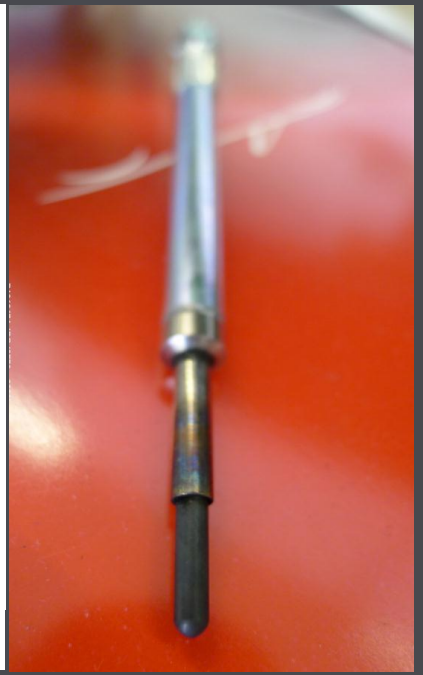


- Mechanical friction decreased to gasoline engine levels
- 5% Improvement in fuel economy
- Lively engine response and higher redline

Low compression makes cold starts difficult

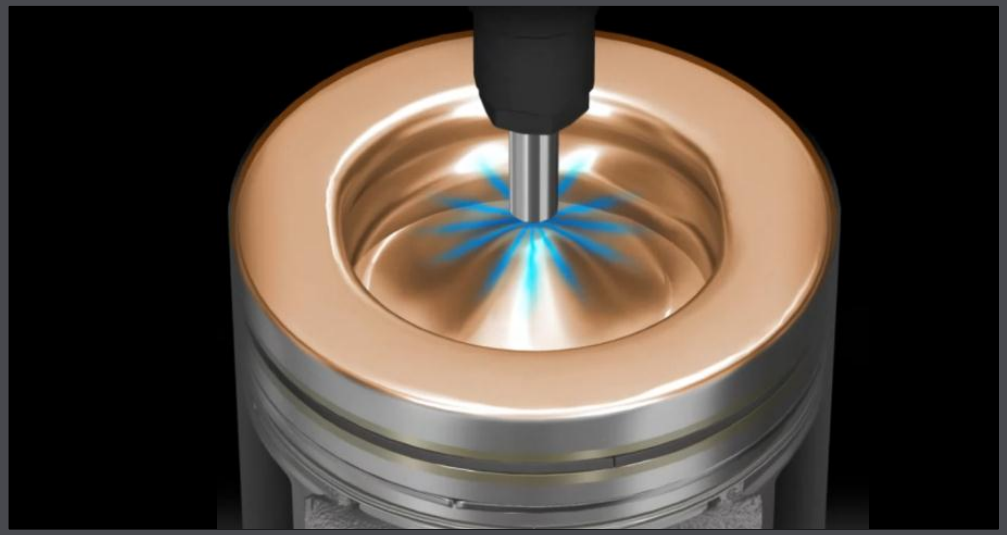
- Solution #1: Intelligent, fast-acting ceramic glow plugs





Low compression makes cold starts difficult

- Solution #2: super-fast 12-hole piezo injectors



Low compression makes cold starts difficult

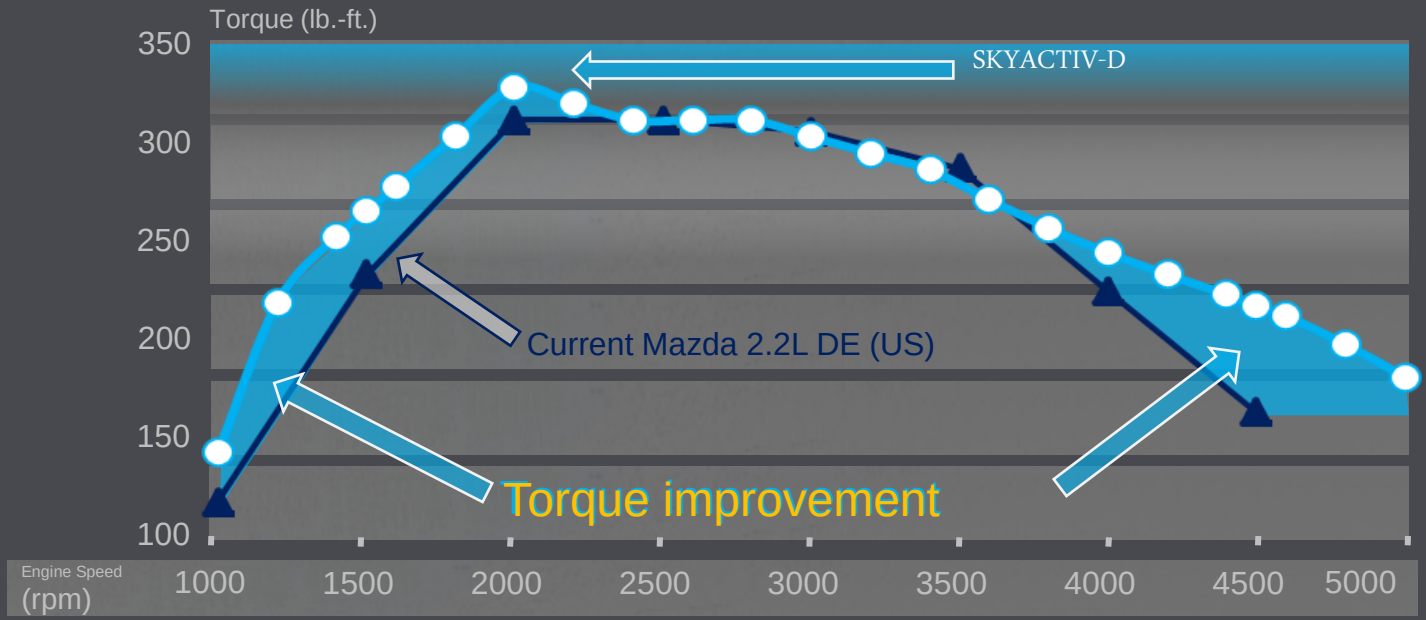
- Solution #3: Patented Variable Valve Lift strategy.

  - A special cold-start-only cam lobe briefly opens the exhaust valve *during the intake stroke.*
  - Hot exhaust gasses warm the intake charge for easier cold combustion.

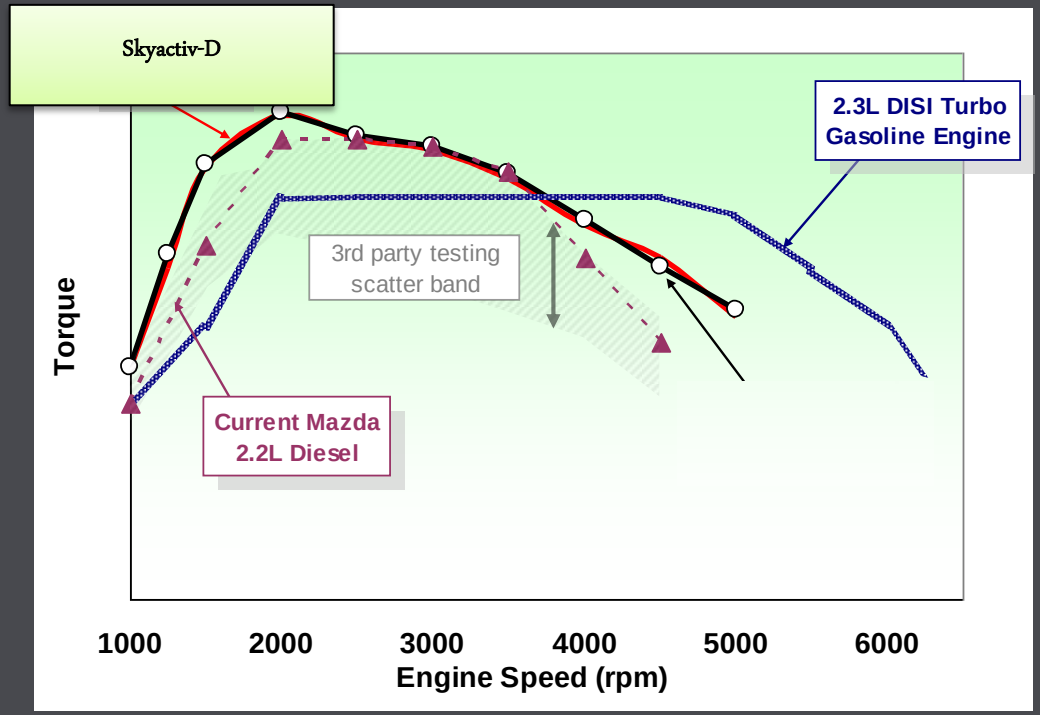
Series Sequential Twin Turbos

Wide, flexible powerband

More low-rpm torque, more high-rpm power, more flexible, more fun

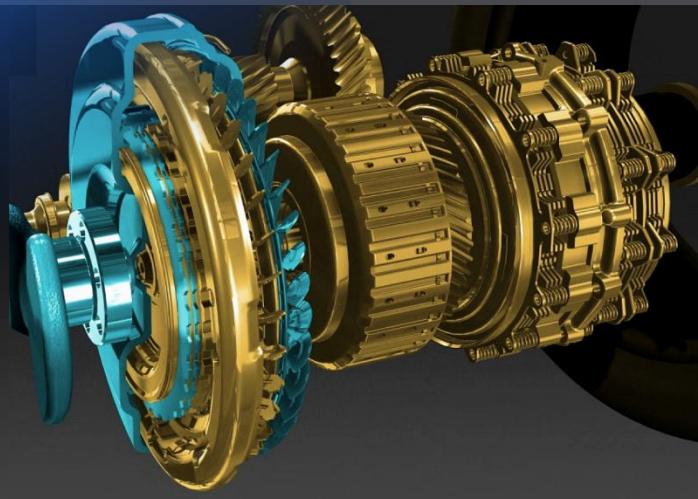


Wide, flexible powerband



Off-the-charts efficiency

SKYACTIV®-Drive



The SKYACTIV engineering philosophy starts with a blank slate and an open mind.

Ideal Automatic Transmission

- High efficiency
- Direct, connected feel, like a manual transmission
- Quick & responsive shifting
- Smooth shifting
- Easy, intuitive low-speed control
- Smooth & powerful launch

SKYACTIV-drive

Survey of Existing Technologies

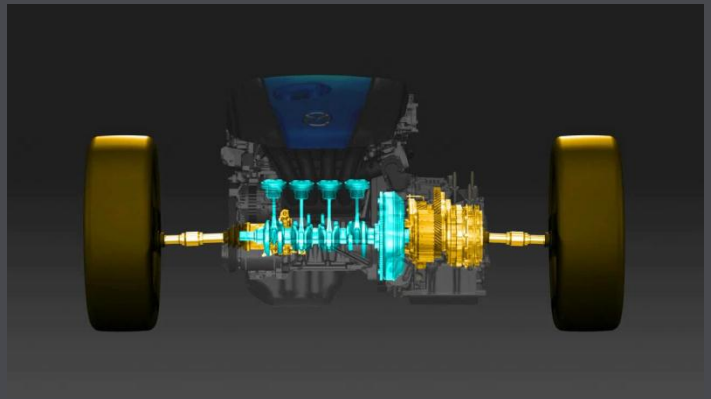
Nothing can achieve Mazda's needs

		Dual Clutch	CVT	Conventional Torque Converter	Mazda Ideal
Efficiency	Low-speed	✓	✓	✗	✓
	High-speed	✓	✗	✓	✓
Direct, connected feel		✓	✗	✗	✓
Quick, responsive shifting		✓	✗	✗	✓
Smooth shifting		✓	✓	✗	✓
Easy low-speed control		✗	✓	✓	✓
Smooth, powerful launch		✗	✓	✓	✓

Overcome transmission losses

Conventional automatic problems:

- Torque converter slip
- Indirect feel - no connection
- Slow shifting
- Rough downshifts



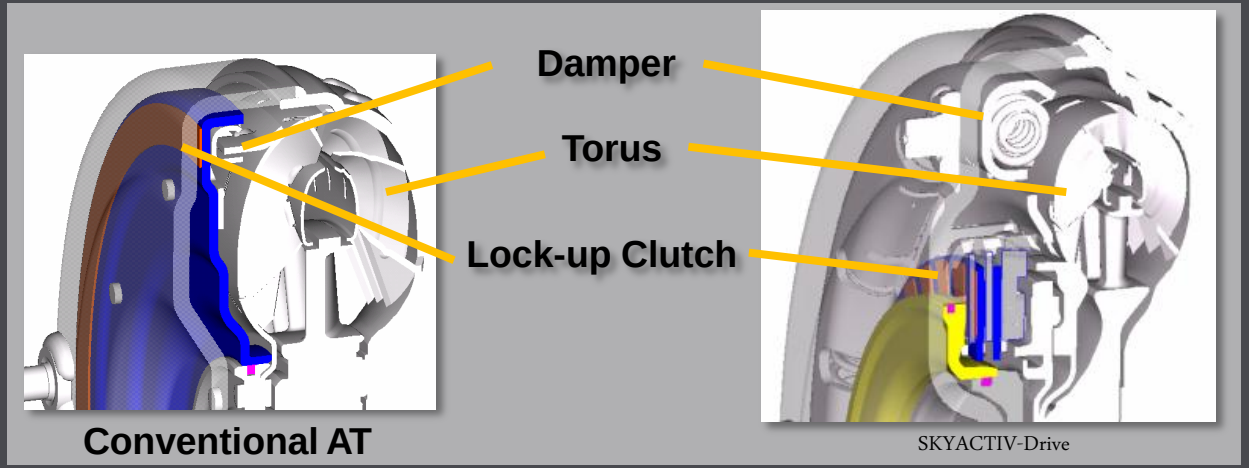
Mazda's solution:

- Use both torque converter and clutch, depending on the situation.
- Redesign Hydraulic Control for quick shifting

Multi-plate clutch + torque converter

Clutch and torque converter together

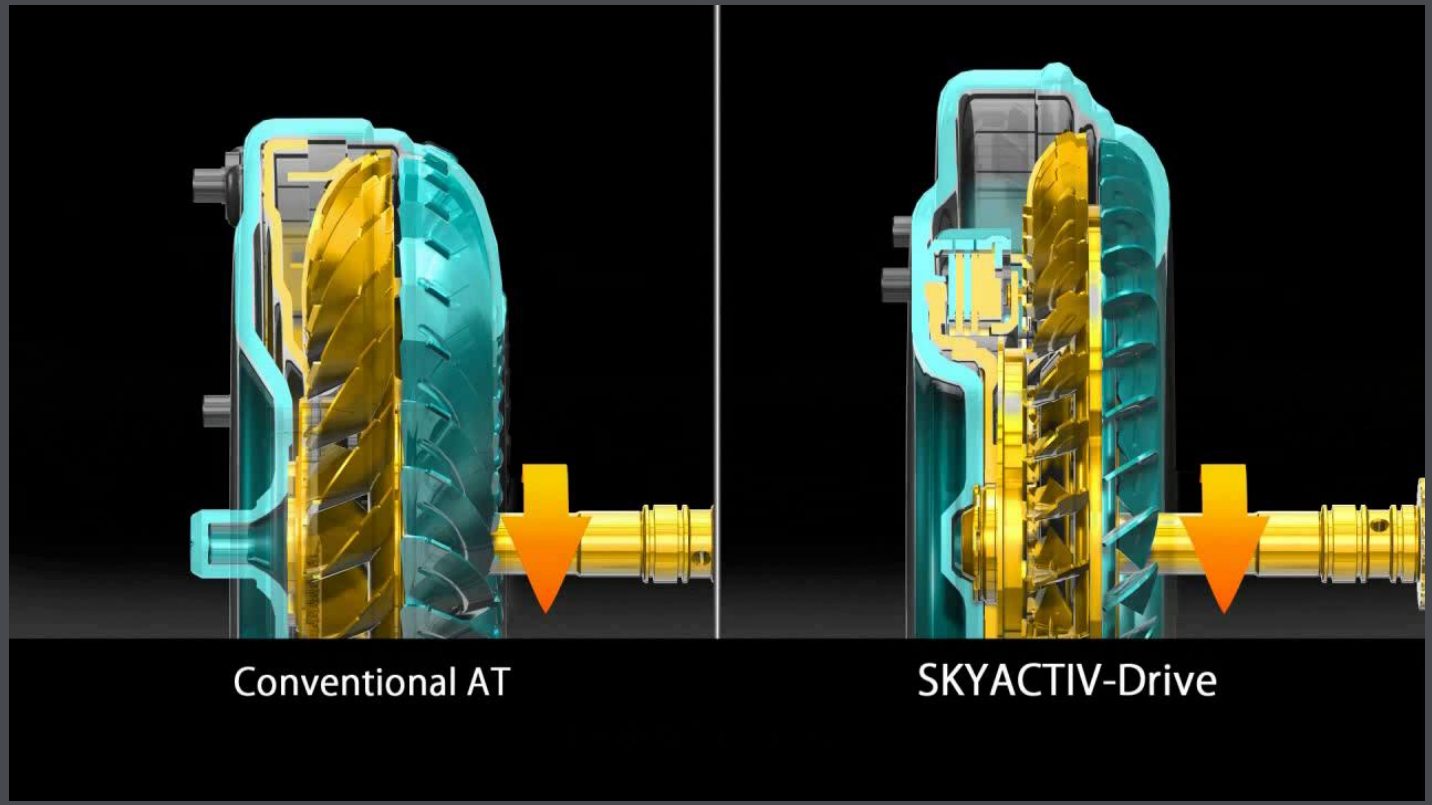
- Direct, connected feeling
- 7% better fuel economy
- Quiet and smooth



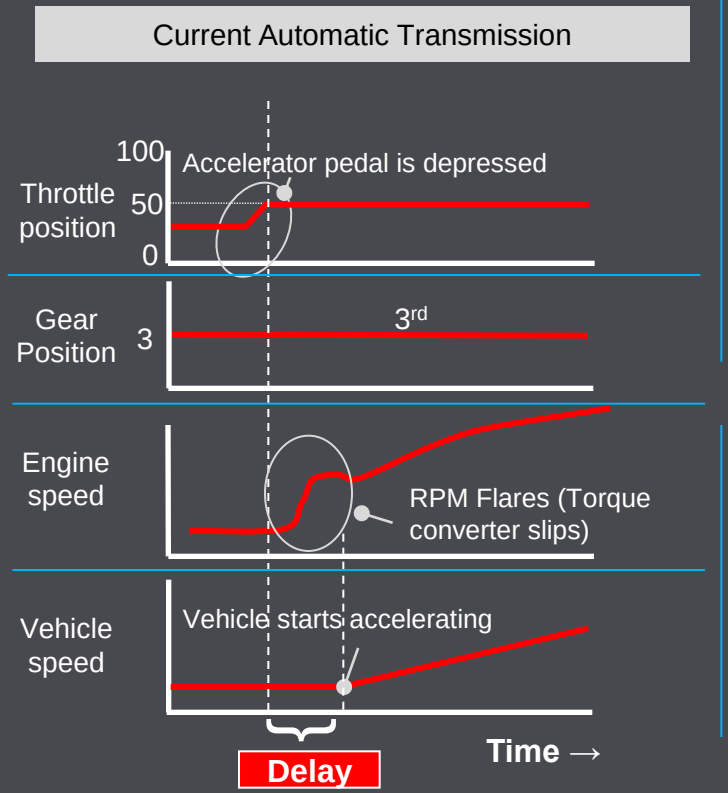
SKYACTIV-Drive torque converter/clutch assembly

- Smaller torus only operates under 5mph
- Larger, multi-plate clutch for more precise control
- Larger damper to cancel vibrations caused by new low rpm, high load conditions

Multi-plate clutch + torque converter

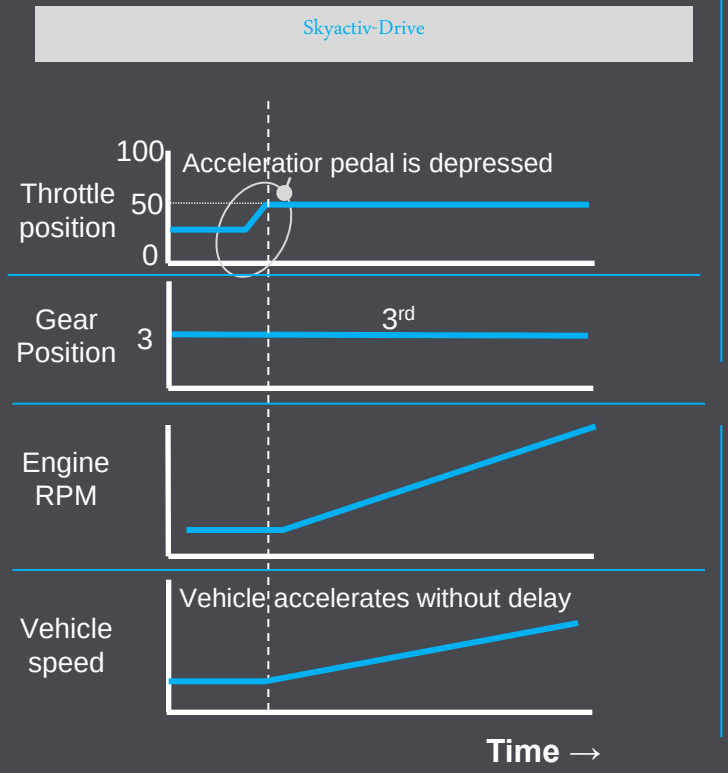


disconnected, slippy power delivery



Torque converter slippage delays acceleration response to driver's input.

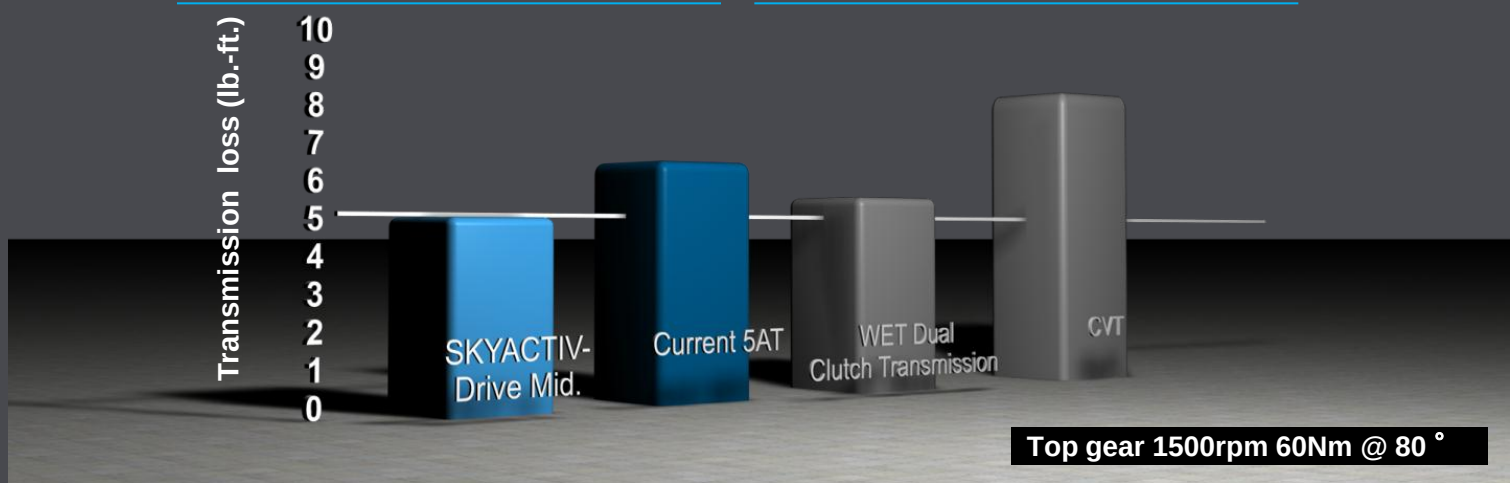
Direct, connected feel



Locked-up clutch provides direct, immediate response.

Benefits

- 7% better fuel economy
- More efficient than Dual Clutch or CVT



Smooth & quick shifting

The problem:

Tolerance stackup makes transmission response inconsistent.

The resulting shifts are slow and not smooth enough.

The solution:

Gram-strategy approach to eliminate delay and imprecision from every part.

Mechatronic module that's individually calibrated to compensate for production tolerances.

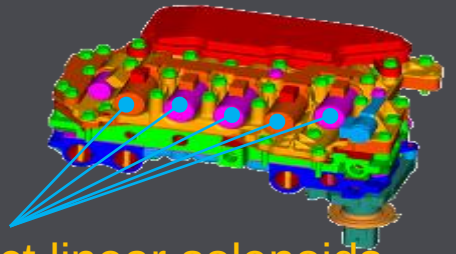
The Result

Perfectly rev-matched downshifts and smooth, seamless upshifts

. Faster downshift response to gas pedal input

A drivetrain that responds to the driver's needs almost telepathically

Integrated Mechatronic Module



Direct linear solenoids

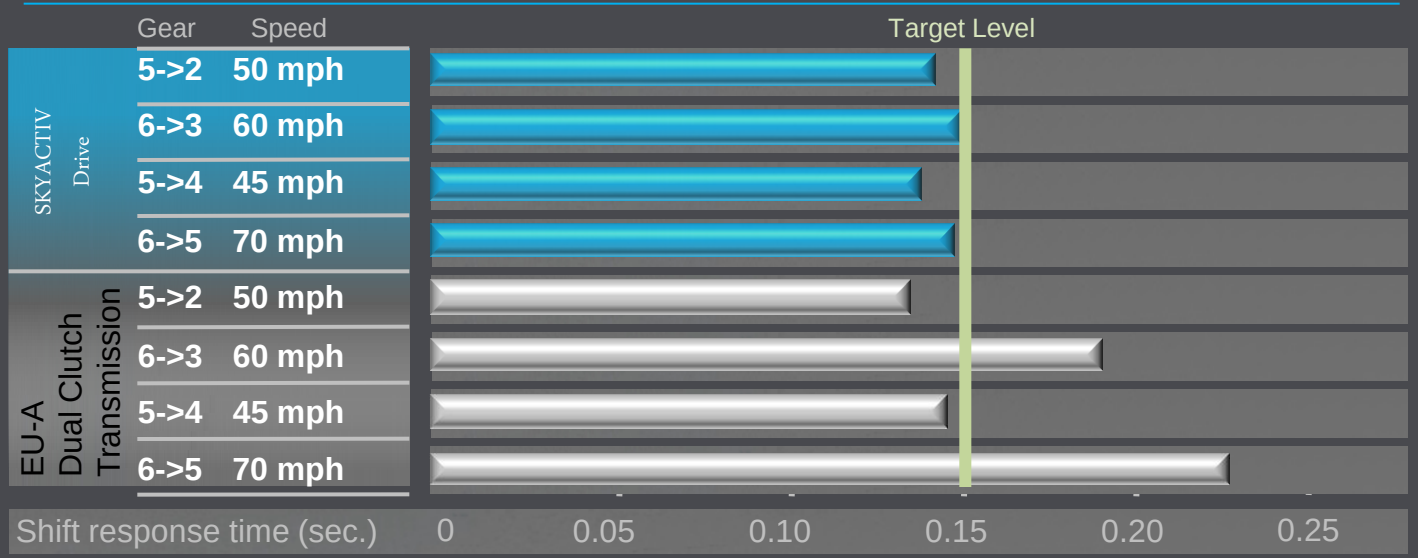
Smooth & quick shifting

Shorter shift response time

Faster downshifting than a dual clutch transmission

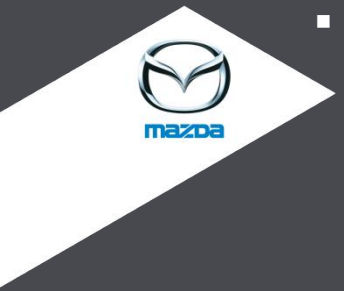
The Mazda solution

New mechatronic module controls the gear change process

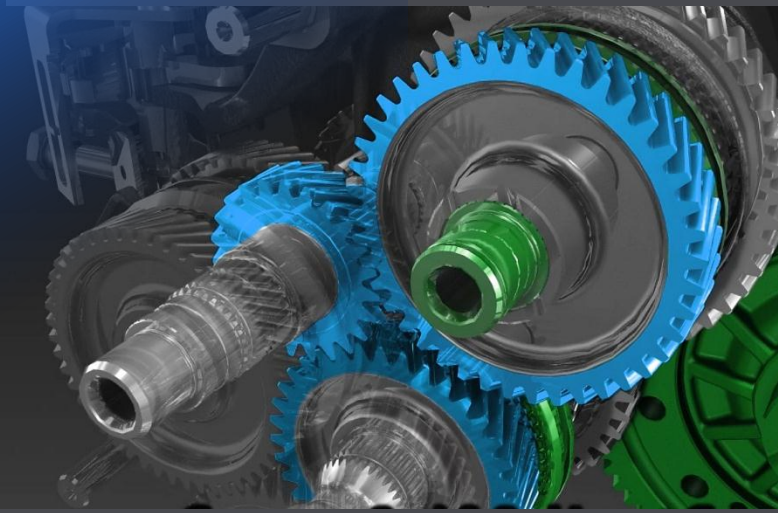


Recap: how we did it

Target	How SKYACTIV-DRIVE does it
▪ High efficiency ▪ Direct, connected feel, like a manual transmission	Eliminate torque converter slippage above 5 mph
▪ Quick & responsive shifting ▪ Smooth shifting	Mechatronic module and high-speed communication between engine and trans
▪ Easy, intuitive low-speed control ▪ Smooth & powerful launch	Still using the torque converter for what it does best.



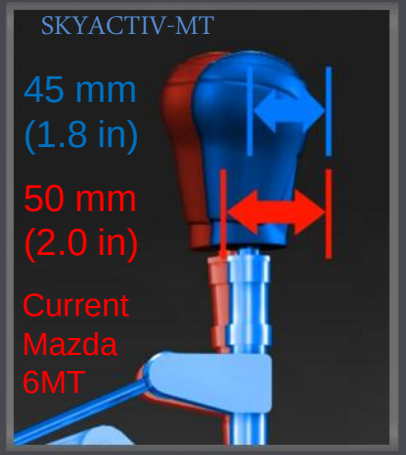
SKYACTIV®-MT



Development targets

- Light and direct shift feel,
  like the MX-5 Miata
- Light weight and compact size
- Better fuel economy

Light & crisp shift feel



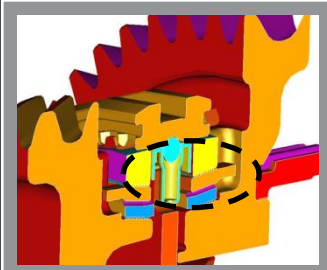
The Problem:

- Shorter shift throws = heavier shift throws. Its simple leverage

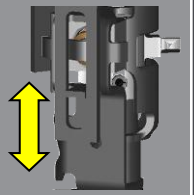
The Mazda solution:

Everything! Every part redesigned for light effort and short travel.

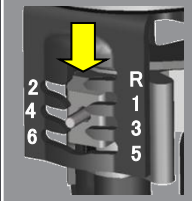
- Internal shift travel shortened 15%
- Low-effort locking ball synchro
- Linear ball bearings
- Gravity-assisted shift mechanism
- Low-friction detent mechanism



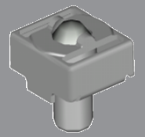
Short-travel shift spline (from 9mm to 7.6mm)



Low-friction detent mechanism



Gravity-assisted shift mechanism



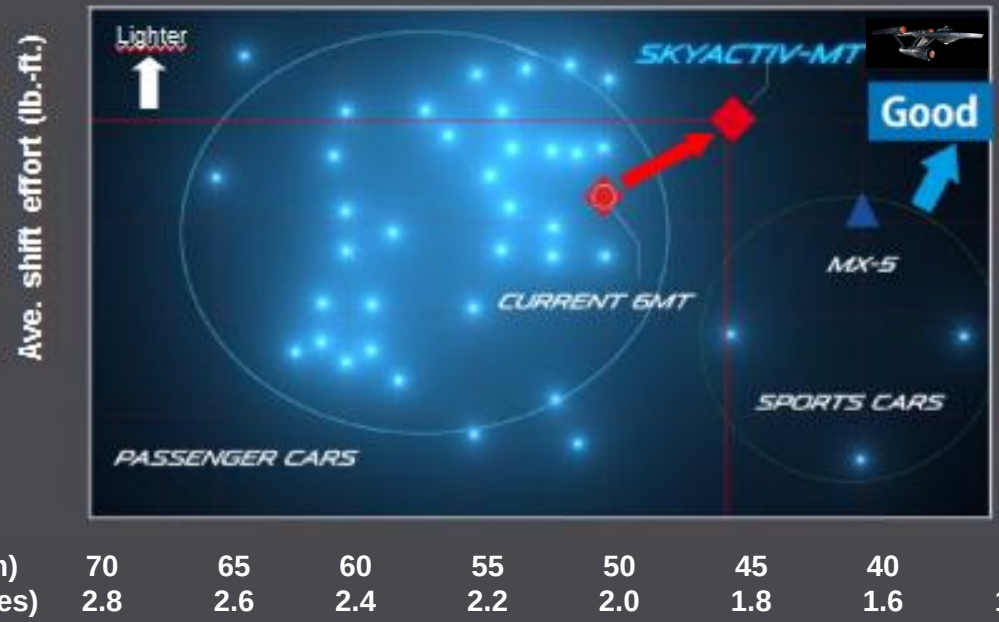
Locking ball synchro

Linear ball bearings

Crisp & lightweight

The Result

Shift stroke is the shortest of any competitive passenger car, and lighter than most.



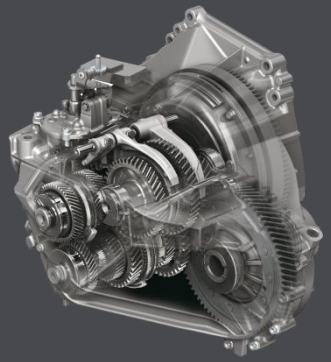
Light & compact layout

Torque capacity vs. weight

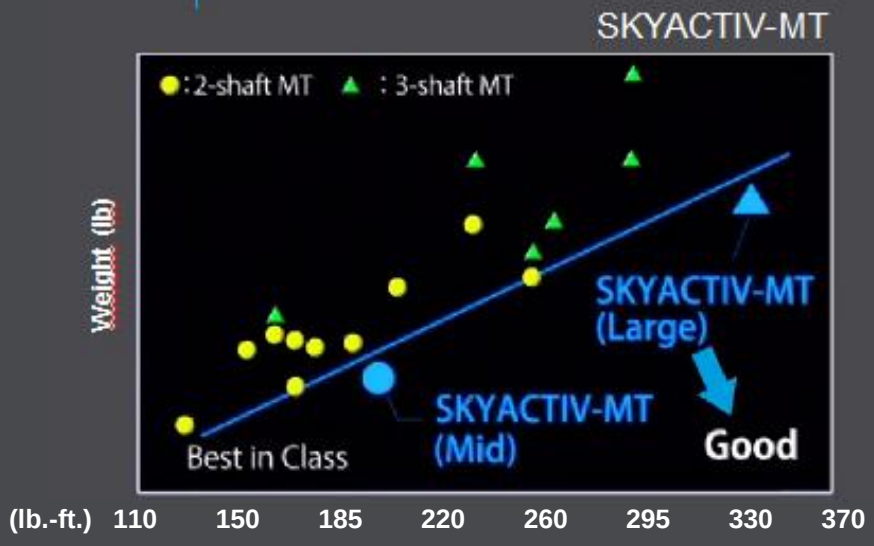
SKYACTIV-MT combines high torque capacity with minimized weight

Transmission efficiency

Both SKYACTIV-MT versions achieve best-in-class performance



SKYACTIV-MT



Reduced Friction

- Lower-viscosity oil (75W-90 to 75W-80)
- Ball bearings replace tapered roller bearings
- Oil distribution system reduces fluid stirring losses.