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Certification Procedures for Advanced Technology Heavy-Duty Vehicles

Evaluating Test Methods and Opportunities for Global Alignment

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Topics

- Background and motivation
- Summary of test procedure options for heavy-duty (HD) hybrids
- Current certification methods for criteria pollutants and fuel efficiency/GHGs and pathways towards better alignment of the two programs
  - Japan
  - European Union
  - North America
  - China
- Considerations for global harmonization
- Summary remarks

The International Council on Clean Transportation

- In 2001, a group of 18 leading air quality and transportation regulators and experts from around the world met in Bellagio, Italy to develop policy guidelines for the future regulation of motor vehicles and transportation fuels
- The ICCT has over 30 full time staff with offices in San Francisco, Washington DC, Berlin, and Beijing
- The mission of the ICCT is to dramatically improve the environmental performance and efficiency of onroad vehicles, aircraft, and marine vessels in order to protect public health, the environment, and quality of life

Background and Motivation

- The case for developing sound test procedures for HD hybrid systems and vehicles is very strong
  - More equitable testing of hybrid vehicles/systems
  - Opportunities for better alignment between criteria pollutant and fuel efficiency/GHG programs
  - Pathways to 'global' harmonization of test procedures
- Increased activity worldwide for fuel efficiency/GHG regulatory development
  - US and Japan: finalized programs
  - Canada, Mexico, the EU, China: programs to be finalized in the near-term
  - Other important HDV markets may be looking at policy development in the future
  - 2020 timeframe → opportunity for 'global' harmonization
- GTR No. 4 test procedure can be the first step towards harmonization of both criteria pollutant and GHG programs worldwide

Chassis Dynamometer-based Testing

- Full vehicle (or chassis) is exercised on a chassis dynamometer
- Key inputs, assumptions: coastdown test results are typically required for road-load inputs
- Regulatory programs using this method for hybrids: N. America (one of three options)

Advantages	Disadvantages
• Ability to test any vehicle configuration • All vehicle components are tested as a complete system • Uses actual control system algorithms (hybrid control unit, HCU) during testing	• Limited availability of chassis dynamometer testing laboratories due to high capital costs. Also, facilities for performing coastdowns may be limited as well. • Testing is resource and time intensive • Potential inconsistency with existing engine procedures (e.g. FTP currently does have an official *equivalent* vehicle cycle) • Internal rotating components ("extra inertia") and regeneration ("false drag") can be an issue • Track coastdown and dyno coastdown must be done in exactly the same configuration and with the same functions enabled (air conditioning, etc.) • Accuracy may be impacted when the front wheels don't rotate (falsely high regeneration efficiency)

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Engine Dynamometer-based Testing

- Engine and hybrid system are tested together on an engine dynamometer
- Key inputs, assumptions: defining the amount of potential (grade) or kinetic (braking) energy that can be captured during the motoring portions of the engine cycle
- Regulatory program using this method for hybrids: N. America (one of three options)

Advantages	Disadvantages
• High degree of familiarity with engine testing • Consistency with existing criteria pollutant standards, which are based on engine dynamometer testing • Uses actual control system algorithms (hybrid control unit, HCU) during testing	• Only applicable to pre-transmission parallel hybrid systems • No opportunity to test driveline systems (i.e. transmission) • May conflict with fuel efficiency/GHGs certification that is based on vehicle cycle (e.g. FTP currently does not have an official *equivalent* vehicle cycle) • Test cell provides all of the cooling – fan losses must be added separately

Powertrain Dynamometer-based Testing

- Entire driveline is exercised on a “powertrain” test cell. The power absorbers are connected to the transmission output shaft.
- Key inputs, assumptions: defining the amount of potential (grade) or kinetic (braking) energy that can be captured during the motoring portions of the engine cycle
- Regulatory program using this method for hybrids: N. America (one of three options)

Advantages	Disadvantages
• Ability to test any vehicle configuration • All driveline components are tested as a complete system • Uses actual control system algorithms (hybrid control unit, HCU) during testing	• Very few powertrain test cells in existence • Need to define entirely new “powertrain” test cycle based on speed/load at the transmission output shaft. This can be done using a vehicle or engine cycle.

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Hardware-in-the-Loop Simulation and Testing

- A virtual vehicle is designed and simulated over a speed vs. time cycle. During simulation, the physical HCU is "in the loop" and controls the interactions of the modeled driveline components. A "unique" cycle for the hybrid engine results from simulation, and this unique cycle can be used for further testing to determine pollutant and GHG levels
- Key inputs, assumptions: the modeled vehicle is based on measured component data (e.g. engine, battery, motor, transmission, inverter, etc.)
- Regulatory program using this method for hybrids: Japan

Advantages	Disadvantages
• May be less resource intensive than the other methods • The ability to capture "real-world" engine speed/load behavior based on a vehicle cycle • May allow for rapid development and optimization prior to certification/type approval	• Creating computational models for all possible hybrid architectures (e.g. plug-ins, start/start, hydraulic, etc.) could be data intensive and time consuming • Detailed data for creating models for each component is difficult to acquire • Simulation program is likely to be very complex and only verifiable by experts in the field • Requires track testing (coastdown or constant speed) and component testing for data inputs

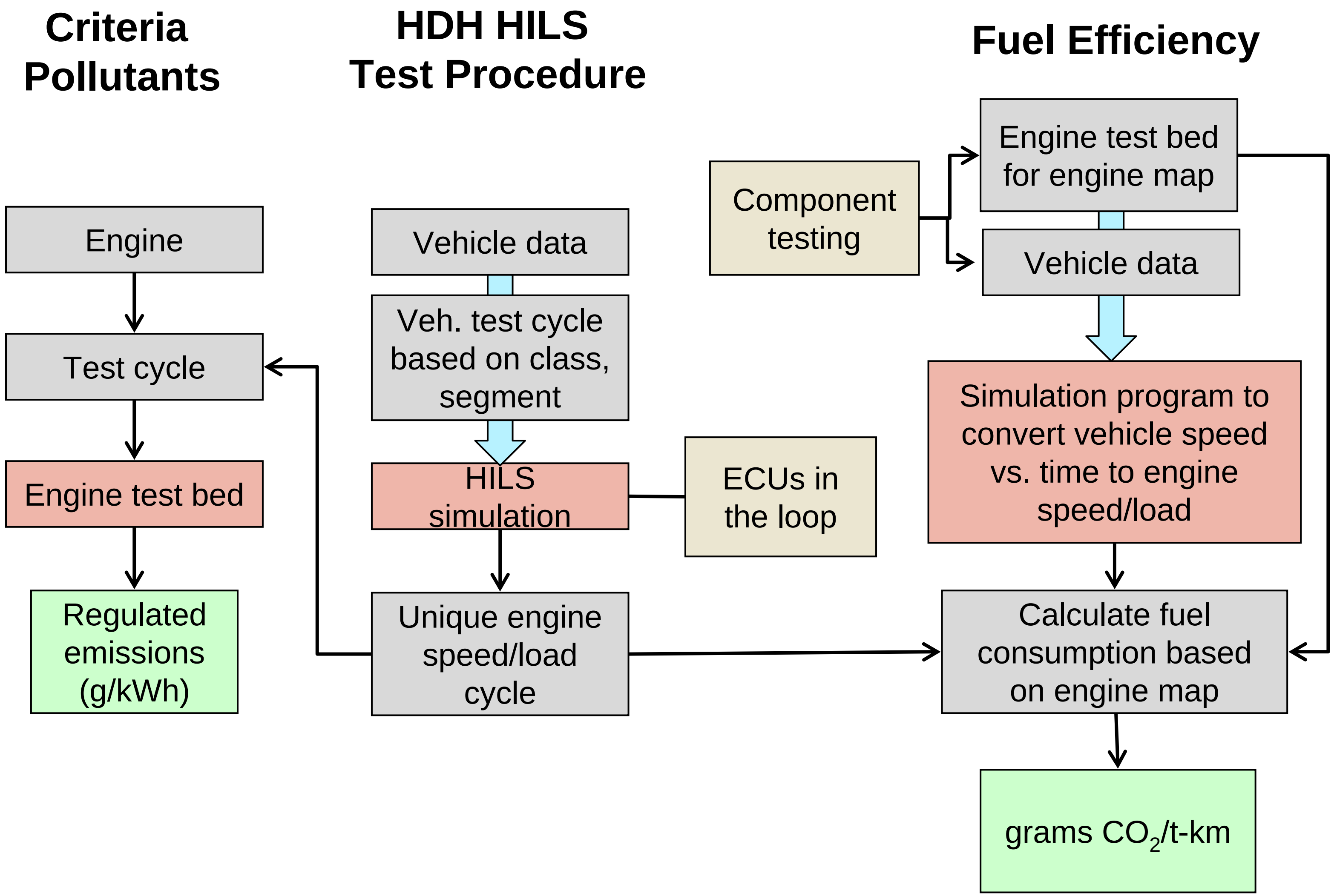
Test Method Comparison

	Consistency w/ existing engine test procedures	Applicable powertrain configurations	Robustness	Resource requirements
Chassis dynamometer	Moderate	Favorable	Moderate	Unfavorable
Engine dynamometer	Favorable	Unfavorable	Favorable	Favorable
Powertrain dynamometer	Moderate	Favorable	Moderate	Moderate
HIL simulation and testing	Moderate	Favorable	Moderate	Moderate

No one method is clearly superior across all relevant parameters!

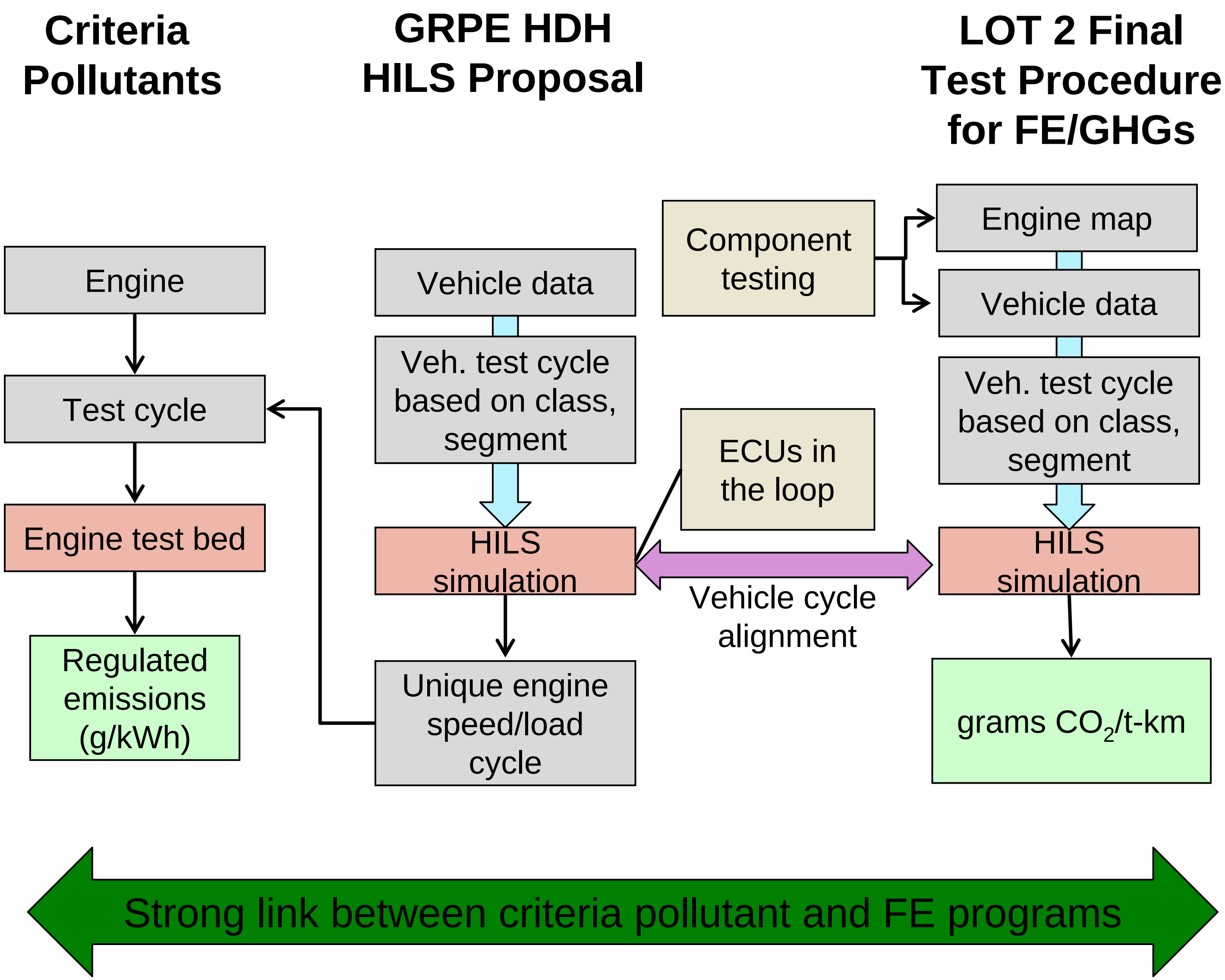
Favorable Moderate Unfavorable

Japan: HD Hybrid Certification



Strong link between criteria pollutant and FE programs

E.U. Proposal for HD Hybrid Certification



N. America: Current Certification Steps for HD Hybrids

Criteria Pollutants

Hybrid engine only

↓

Engine dyno testing using FTP and SET cycles

↓

Regulated emissions (g/bhp-hr)

Fuel Efficiency/GHGs: 3 Options

Chassis dyno testing vs. a conventional vehicle "A to B testing"

Engine dyno based testing vs. a conventional engine For pre-transmission systems only

Powertrain dyno based testing vs. a conventional vehicle "A to B testing"

Poor alignment between the two programs

- Criteria pollutant program: emission levels may be misrepresented because hybrid engine may not be operating as it would in the complete hybrid system
- FE/GHG program: testing a hybrid system using two (or three) of the certification options would likely provide different results for the benefit of the hybrid system

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N. America: Pathways for Hybrid Certification

Key issue #1: Establishing consistency for hybrid certification in Phase 2 of the FE/GHG program

Pathway	Key Considerations
• Adopt GTR test procedure as sole option for hybrid certification	• Strengthens opportunities for global alignment for conventional vehicles as well
• Choose either chassis testing or powertrain testing as the sole option for hybrid certification	• Resource constraints • Test setup complexity
• If all of the current options will be allowed in the Phase 2 program, establish functional equivalency between the options	• Developing a vehicle cycle based on the FTP and/or engine cycles based on the vehicle test cycles

Key issue #2: Allowing hybrid systems to be certified in the criteria pollutant program rather than separate testing for hybrid engines

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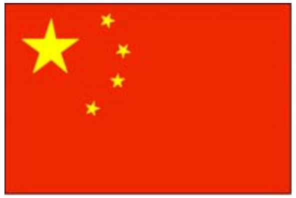
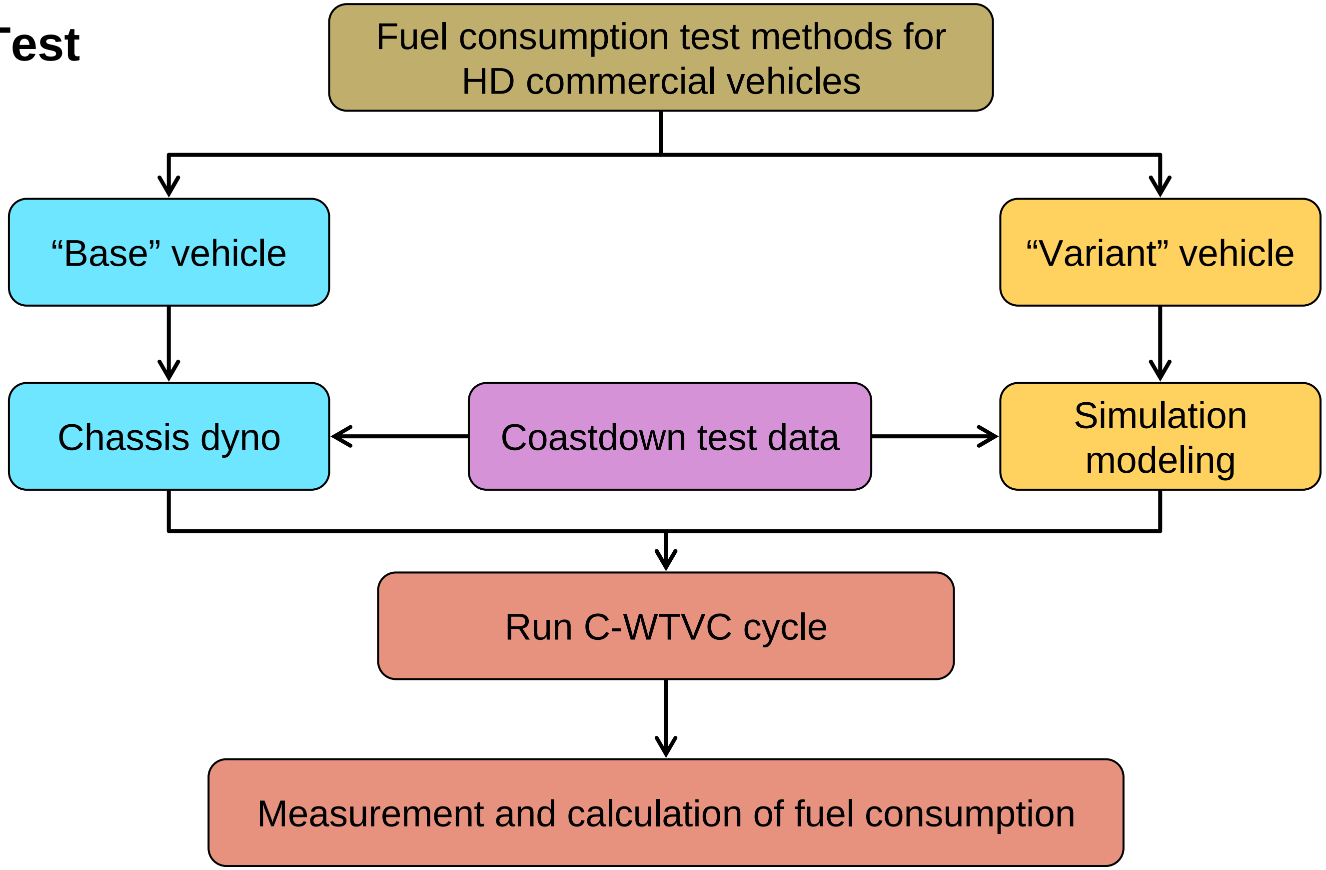
China: Fuel Consumption Program Summary



Finalized Test Procedure



Considerations for Global Alignment

- **Harmonization of criteria pollutant and fuel efficiency/GHG test procedures**
  - Decreases testing burden and the opportunities for gaming
  - WHTC (engine cycle) was developed to be functional equivalent to the WTVC (vehicle cycle)
    - Leveraging these cycles allows for consistency for both conventional and hybrid vehicles
    - Lot 2 (FE/GHG test procedure for the EU): proposes that all vehicles be simulated on a common, relatively short test cycle, regardless of class and segment → For maximum convergence with criteria pollutant regulations, this test cycle should be the WTVC, not the CST (Common Short Test) cycle
- **Accommodating a variety of advanced technologies**
  - Finalized amendments to GTR No. 4 will have a lasting influence
  - Test methods should be able to accommodate a wide range of current and future driveline configurations
- **Ensuring compliance over vehicle lifetime**
  - Especially salient issue for criteria pollutant emissions
  - Thought should be given to whether the test procedure can be used for both certification and in-use compliance testing

Summary Remarks

- This GRPE process is important for a number of reasons
  - Ensuring more equitable treatment of hybrid vehicles/systems in criteria pollutant testing
  - Creating a stronger link between criteria pollutant and FE/GHG programs in the respective countries/regions for both conventional and hybrid vehicles
  - Paving the way for ‘global’ harmonization of test procedures
- There is no test procedure option for hybrid vehicles/systems that is clearly superior across all of the evaluation parameters
- The functional equivalence of the WHTC and WTVC presents a clear opportunity for creating strong alignment between criteria pollutant and fuel efficiency/GHG programs

Thank you

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