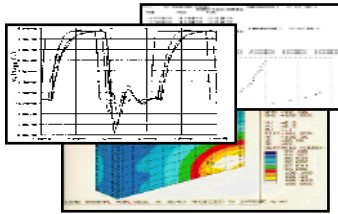# Efficient software techniques for OBD implementation

... don't underestimate the effort.

Pi Innovo

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Electronics – From Concept to Manufacture

Pi Innovo
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World Class
Engineering Consultancy

- Broad domain expertise
- System design
- Control design
- Electronics design
- Custom products

Field Proven
Standard ECU Products

- Large hardware family
- Royalty free RTOS
- Application software
- Rapid prototyping tools
- Industry tools integration
- Semicustom options

Manufacturing
Partners

- Tier 1 & 2
- Automotive
- Military/ITAR
- Contract Manufacture
- TS16949, ISO14001

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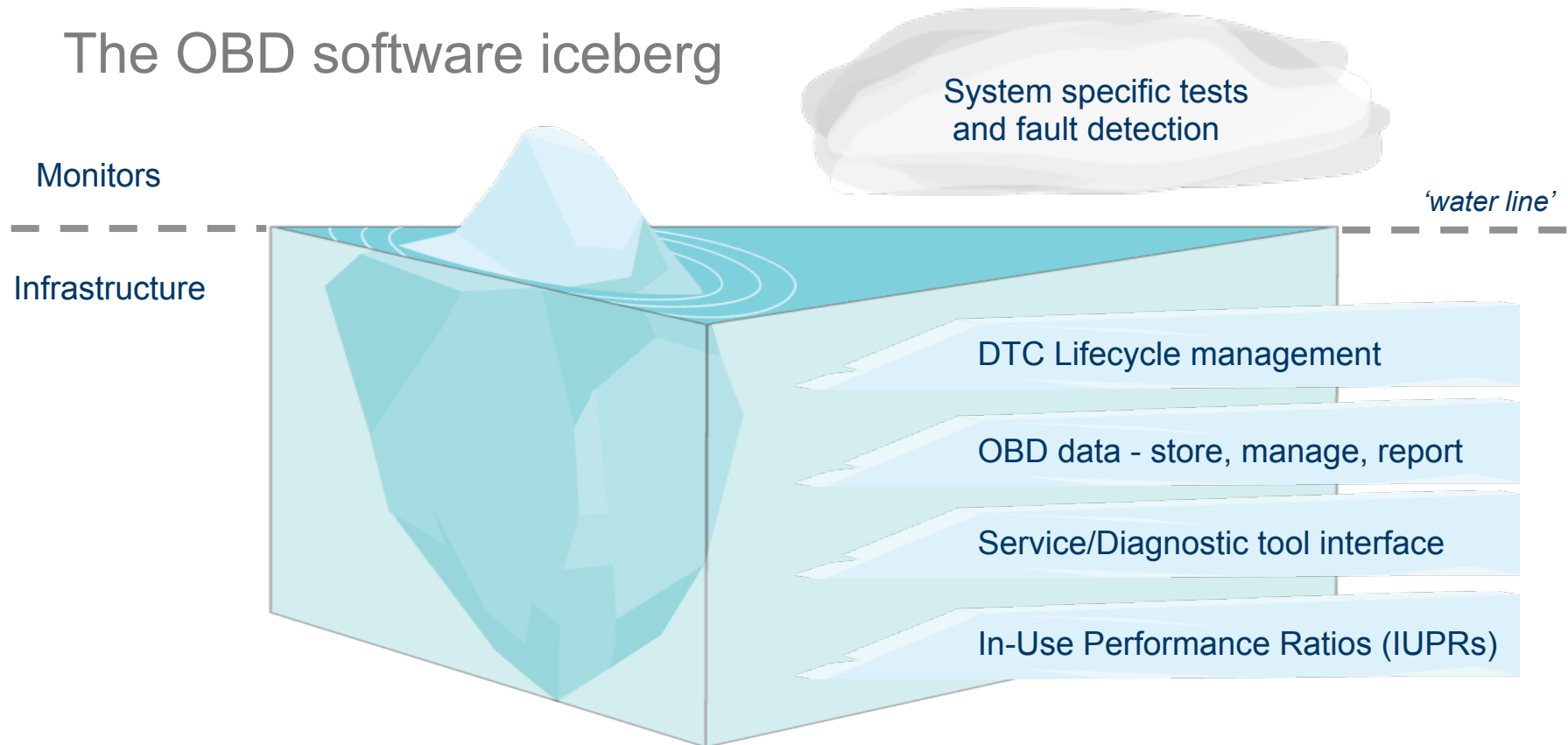
The OBD software iceberg

System specific tests
and fault detection

Monitors

'water line'

Infrastructure

DTC Lifecycle management

OBD data - store, manage, report

Service/Diagnostic tool interface

In-Use Performance Ratios (IUPRs)

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Monitors vs. Infrastructure

- **Monitors:**
  - Diagnostic monitors tend to be proprietary
  - Closely guarded intellectual property
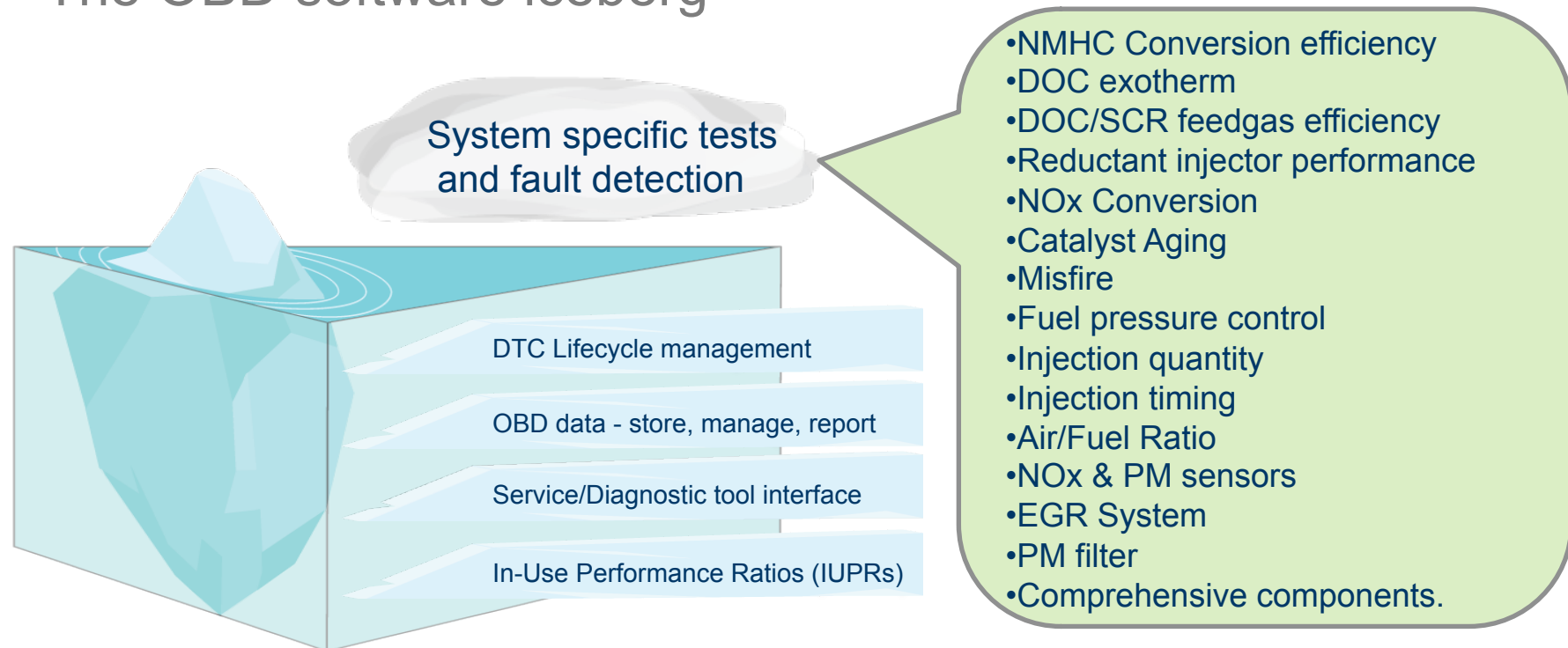 - System specific
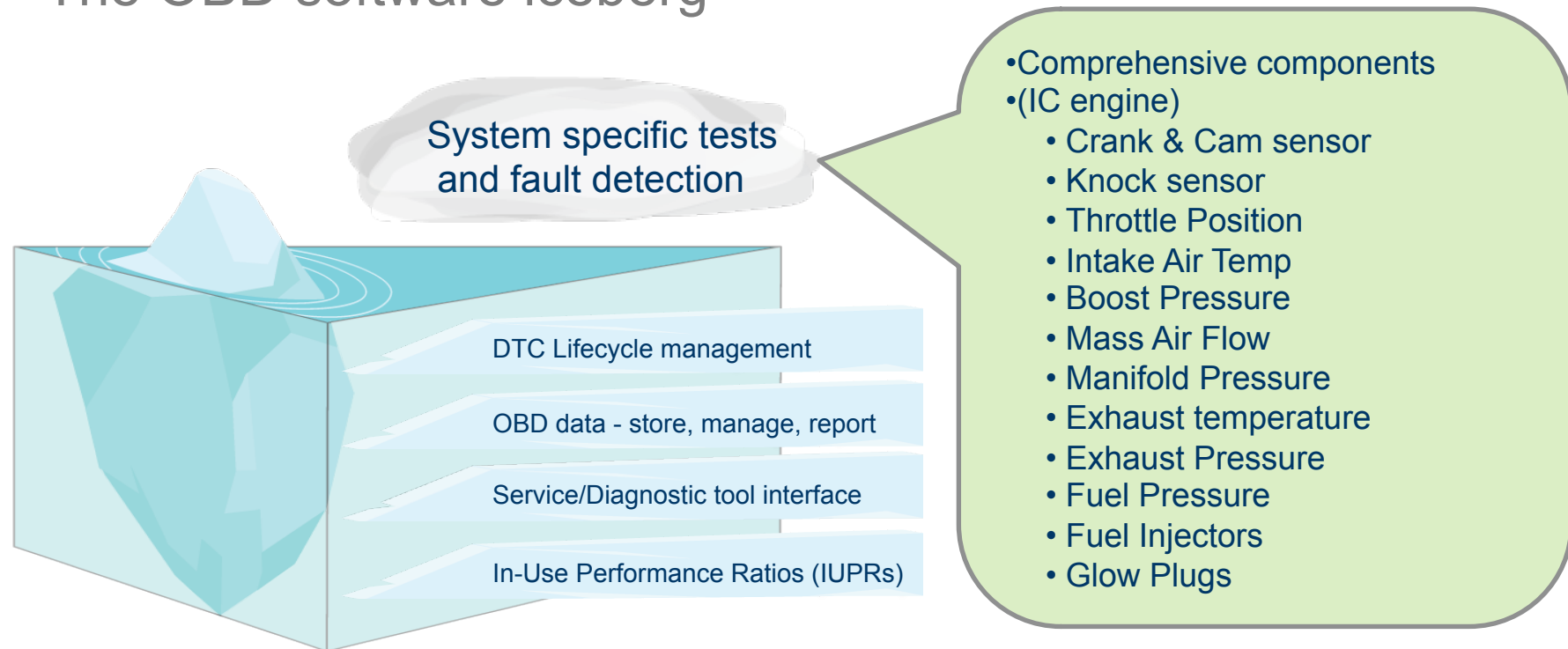
- **Infrastructure:**
  - All the items below the waterline of the ice burg
  - Standardized based on regulations
  - Many various regulating bodies
    - CARB, EPA, Euro, etc.

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The OBD software iceberg

System specific tests and fault detection

- DTC Lifecycle management
- OBD data - store, manage, report
- Service/Diagnostic tool interface
- In-Use Performance Ratios (IUPRs)

- NMHC Conversion efficiency
- DOC exotherm
- DOC/SCR feedgas efficiency
- Reductant injector performance
- NOx Conversion
- Catalyst Aging
- Misfire
- Fuel pressure control
- Injection quantity
- Injection timing
- Air/Fuel Ratio
- NOx & PM sensors
- EGR System
- PM filter
- Comprehensive components.

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The OBD software iceberg

System specific tests and fault detection

DTC Lifecycle management

OBD data - store, manage, report

Service/Diagnostic tool interface

In-Use Performance Ratios (IUPRs)

- •Comprehensive components
- •(IC engine)
  - • Crank & Cam sensor
  - • Knock sensor
  - • Throttle Position
  - • Intake Air Temp
  - • Boost Pressure
  - • Mass Air Flow
  - • Manifold Pressure
  - • Exhaust temperature
  - • Exhaust Pressure
  - • Fuel Pressure
  - • Fuel Injectors
  - • Glow Plugs

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The OBD software iceberg

System specific tests
and fault detection

DTC Lifecycle management

OBD data - store, manage, report

Service/Diagnostic tool interface

In-Use Performance Ratios (IUPRs)

- Comprehensive components
- (Hybrid)
  - Monitoring of all energy input devices
  - Battery
  - Charging System Performance
  - Electric Motor Performance
  - Regenerative Braking Performance

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The OBD software iceberg

DTC = Diagnostic Trouble Code

Note: Slightly different lifecycle between CARB and Euro.

System specific tests
and fault detection
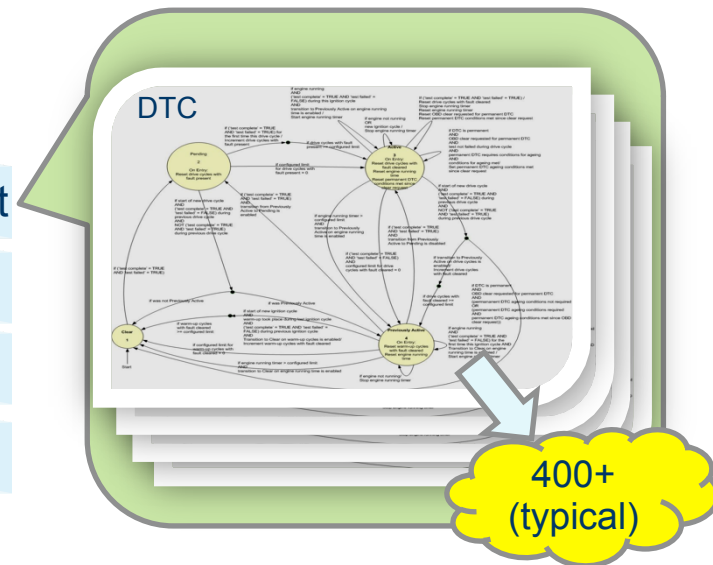
DTC Lifecycle management

OBD data - store, manage, report

Service/Diagnostic tool interface

In-Use Performance Ratios (IUPRs)

DTC

400+
(typical)

Pending

2

On Entry:
Reset drive cycles with
fault present

If ("test complete" = TRUE
AND "test failed" = TRUE) for
the first time this drive cycle /
Increment drive cycles with
fault present

If ("test complete" = TRUE
AND "test failed" = TRUE)
AND
transition from Previously
Active to Pending is
enabled

If start of new drive cycle
AND
("test complete" = TRUE AND
"test failed" = FALSE) during
previous drive cycle
AND
NOT ("test complete" = TRUE
AND "test failed" = TRUE)
during previous drive cycle

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Diagnostic Example

The regulations require that the sensor be diagnosed for specific faults.

- Short to power
- Short to ground
- Open circuit
- Intermittent
- In-range failure / rationality

Some companies have diagnostics, but not at the level required in the regulations.

DTC Activates

Monitor

Freeze Frame

Warm up cycles
Drive cycles
Occurrence counts
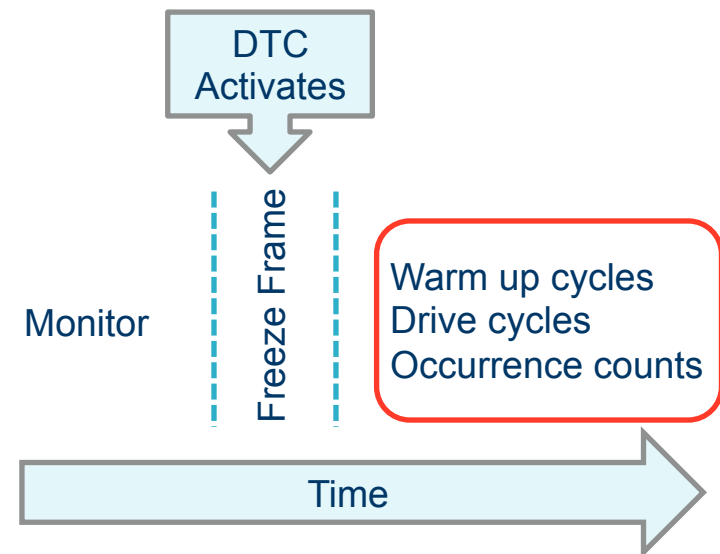
Time
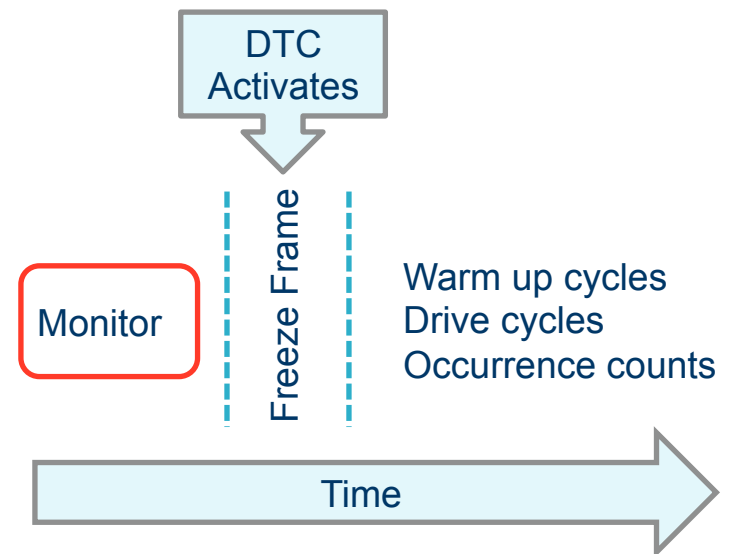
Diagnostic Example

Once the diagnostic monitor has triggered a chain of events is kicked off that is unique to each diagnostic in the system

- DTC is logged for the specific fault
- Freeze frame data is saved
  - Conditions under which the fault occurred

DTC Activates

Monitor

Freeze Frame

Warm up cycles
Drive cycles
Occurrence counts

Time

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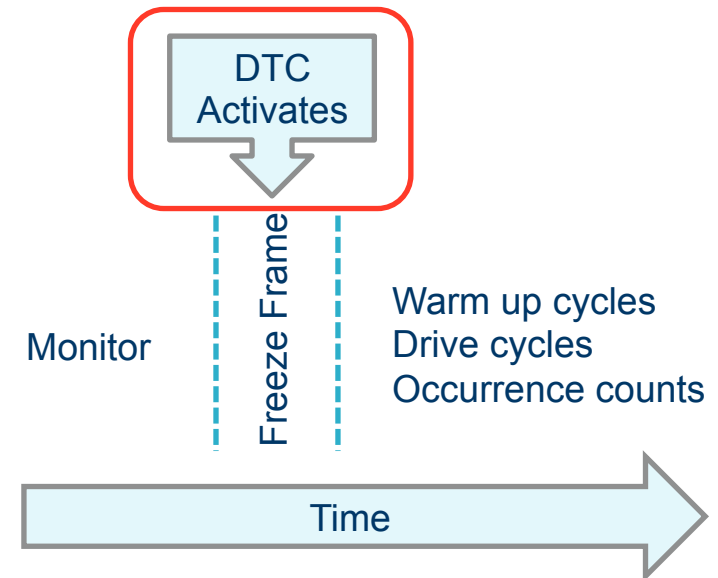
Diagnostic Example

- When a monitor sets a DTC the lifecycle must be followed exactly for <u>each</u> DTC

    - How many drive cycles since the fault was set?
    - How many warm up cycles since the fault was set?
    - How many engine hours?

- All this must be saved in non-volatile memory
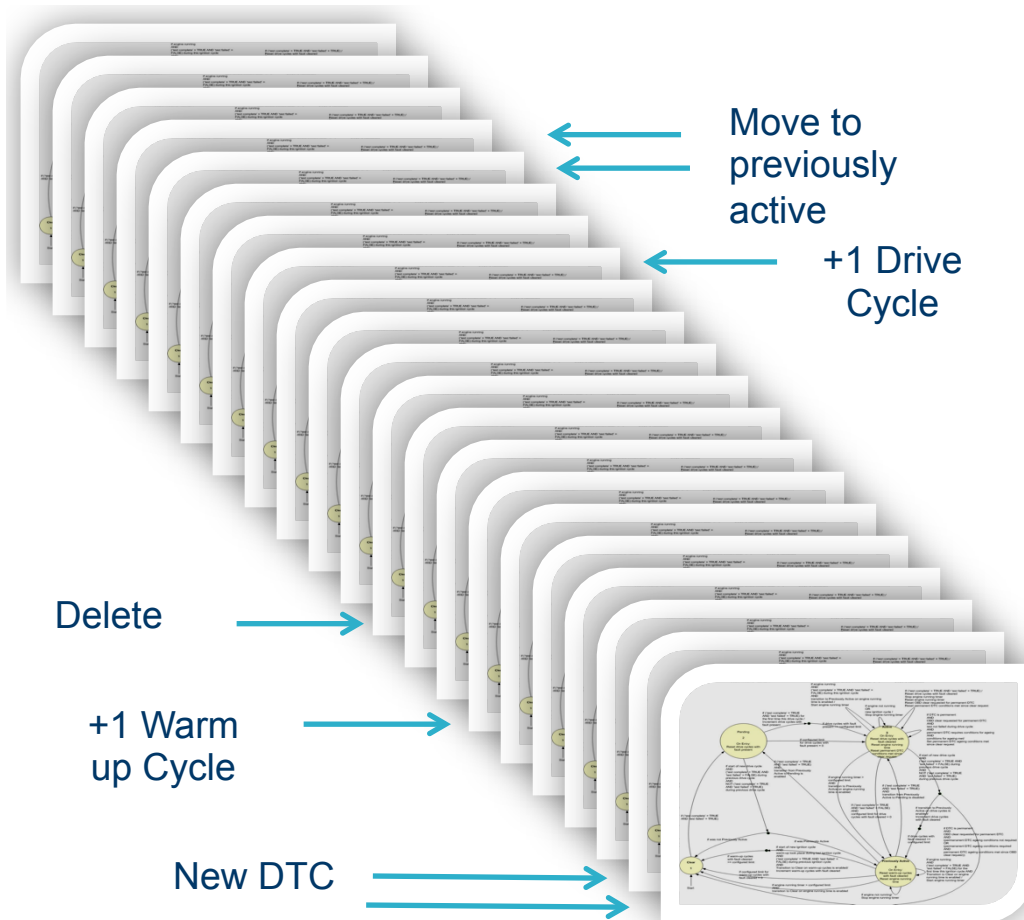- All this must be broadcast to the service tool

DTC Activates

Monitor

Freeze Frame

Warm up cycles
Drive cycles
Occurrence counts

Time

Move to previously active

+1 Drive Cycle

Delete

+1 Warm up Cycle

New DTC

All of this book keeping must be done for each and every DTC that is registered.

Typical pre 2007 HD Diesel
- 30-60 diagnoseable components
- 60-150 individual faults

Expected 2014 HD Hybrid
- 80-100 diagnoseable components
- 400-1000 individual faults
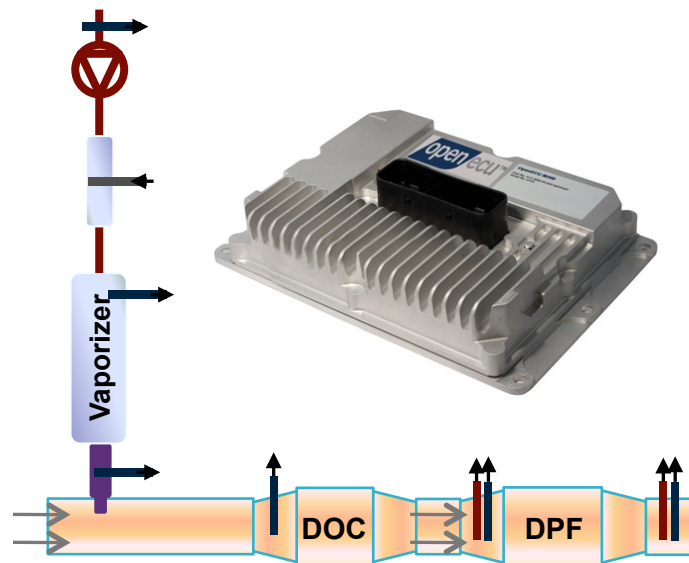
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Past OBD project example
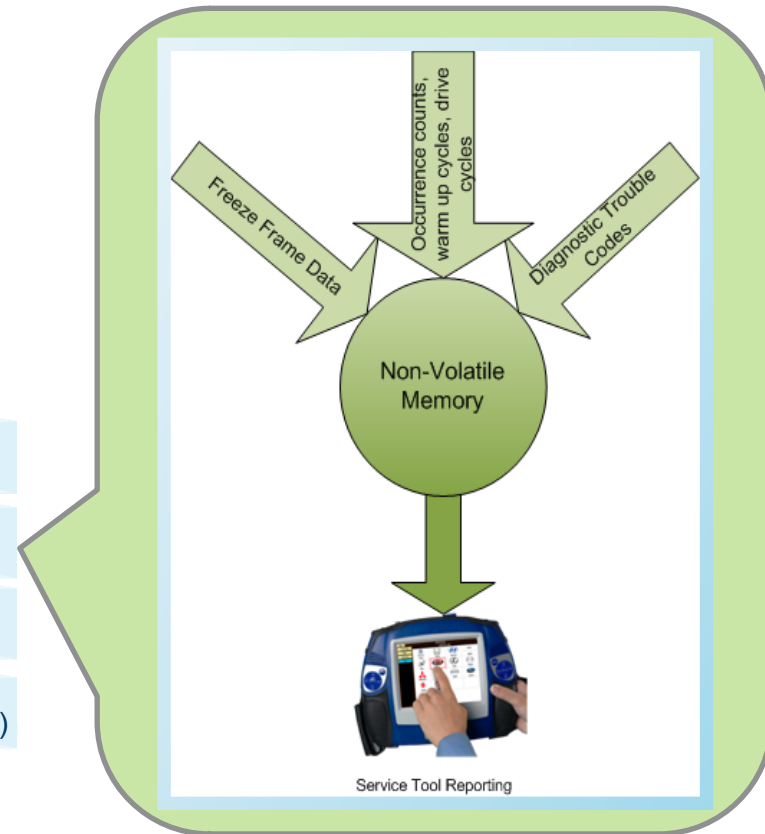

- 7   Subsystem monitors
- 114   Diagnostic tests
- 416   DTCs (trouble codes)
- 3   freeze frames for every active DTC

This results in significant data volumes that must be managed thru a lifecycle and reported accurately to the scan tool.

.... and this was 'just' the aftertreatment system.

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OBD Memory Requirements

System specific tests
and fault detection

DTC Lifecycle management

OBD data - store, manage, report

Service/Diagnostic tool interface

In-Use Performance Ratios (IUPRs)

Freeze Frame Data

Occurrence counts, warm up cycles, drive cycles

Diagnostic Trouble Codes

Non-Volatile Memory

Service Tool Reporting
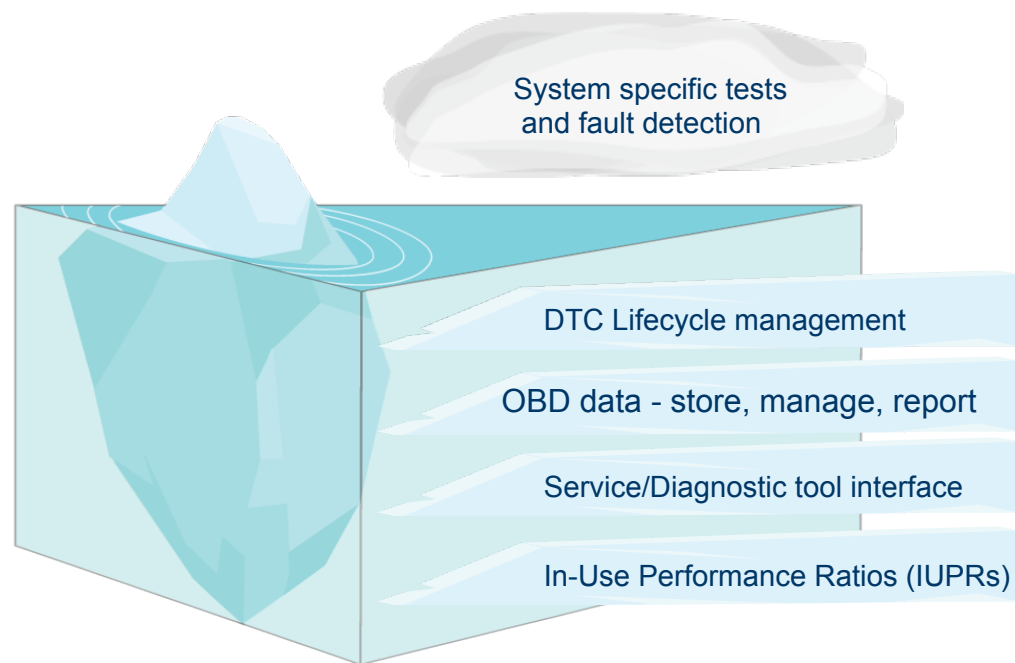
OBD Impact on ECU

- Rule of thumb: Diagnostic software size will roughly equal the control software.
  - How much effort went into your controls development?
- OBD can drive changes to the microprocessor if insufficient resources are available.
  - NVM, RAM & program memory most greatly impacted
  - CPU throughput not greatly impacted
- Testing and validation efforts should not be overlooked either

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Heavy Duty – J1939

ID	Description
DM1	Active Diagnostic Trouble Codes
DM2	Previously Active Diagnostic Trouble Codes
DM3	Diagnostic Data Clear/Reset for Previously Active DTCs
DM4	Freeze Frame Parameters
DM5	Diagnostic Readiness 1
DM6	Emission Related Pending DTCs
DM7	Command Non-continuously Monitored Test
DM8	Test Results for Non-continuously Monitored Systems
DM10	Non-continuously Monitored Systems Test Identifiers
DM11	Diagnostic Data Clear/Reset for Active DTCs
DM12	Emissions Related Active DTCs
DM14	Memory Access Request
DM15	Memory Access Response
DM16	Binary Data Transfer
DM19	Calibration Information
DM20	Monitor Performance Ratio
DM21	Diagnostic Readiness 2
DM23	Previously Active Emission Related Faults
DM24	SPN Support
DM25	Expanded Freeze Frame

ID	Description
DM26	Diagnostic Readiness 3
DM27	All Pending DTCs
DM28	Permanent DTCs
DM29	Regulated DTC Counts
DM30	Scaled Test Results
DM31	DTC to Lamp Association
DM32	Regulated Exhaust Emission Level Exceedance
DM33	Emission Control Device Active Time
DM34	NTE Status
DM35	Immediate Fault Status
DM36	Harmonized Roadworthiness - Vehicle (HRWV)
DM37	Harmonized Roadworthiness - System (HRWS)
DM38	Harmonized Global Regulation Description (HGRD)
DM39	Cumulative Continuous MI - System (HCMI)
DM40	Harmonized B1 Failure Counts (HB1C)
DM41	DTCs- A, Pending
DM42	DTCs- A Confirmed and Active
DM43	DTCs- A, Previously Active
DM44	DTCs- B1, Pending
DM45	DTCs- B1, Confirmed and Active
DM46	DTCs- B1, Previously Active
DM47	DTCs- B2, Pending
DM48	DTCs- B2, Confirmed and Active
DM49	DTCs- B2, Previously Active
DM50	DTCs- C, Pending
DM51	DTCs- C, Confirmed and Active
DM52	DTCs- C, Previously Active

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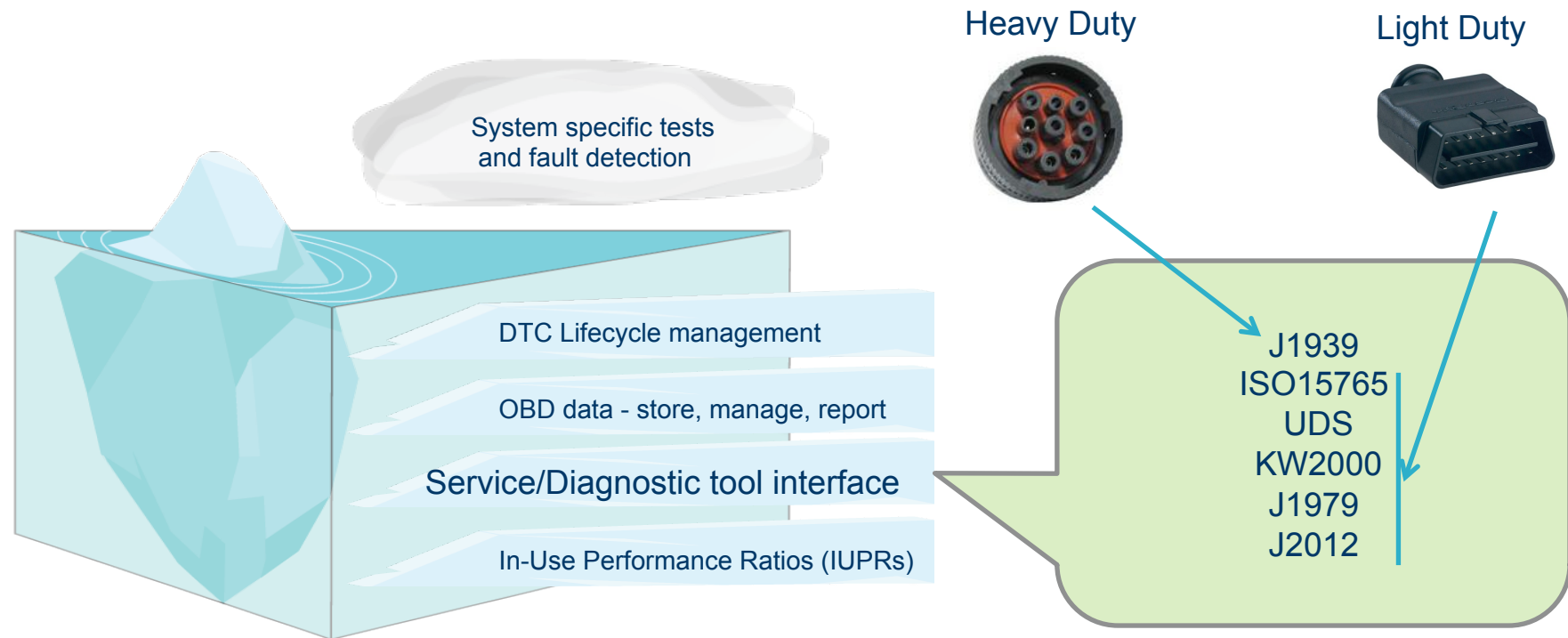
OBD Service Interface

Heavy Duty

Light Duty

System specific tests
and fault detection

DTC Lifecycle management

OBD data - store, manage, report

Service/Diagnostic tool interface

In-Use Performance Ratios (IUPRs)

J1939
ISO15765
UDS
KW2000
J1979
J2012

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The OBD software iceberg

System specific tests
and fault detection

'water line'

DTC Lifecycle management

OBD data - store, manage, report

Service/Diagnostic tool interface

In-Use Performance Ratios (IUPRs)

There is a ton of work
to do here.

Both above and below
the water line.

Service Tool Reporting
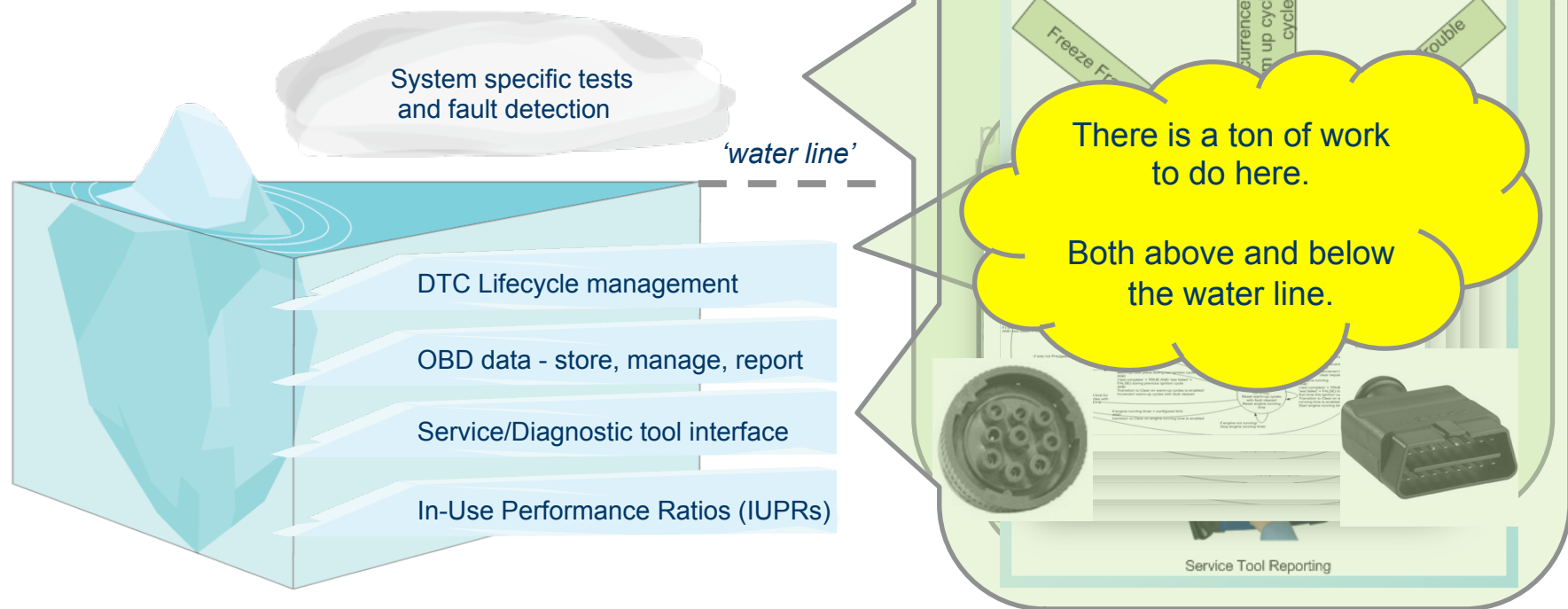
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OBD Infrastructure Software

Effort to implement just the infrastructure software is significant

- Review and understand regulations (CARB, EPA, Euro, etc)
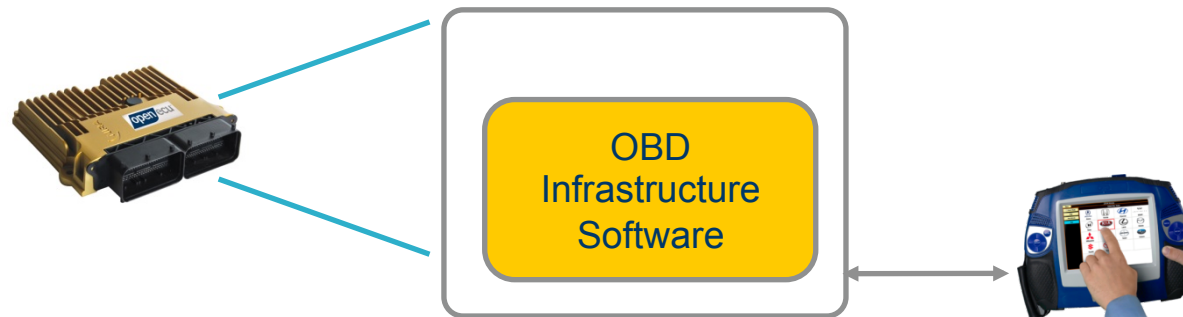- Develop software requirements and test cases
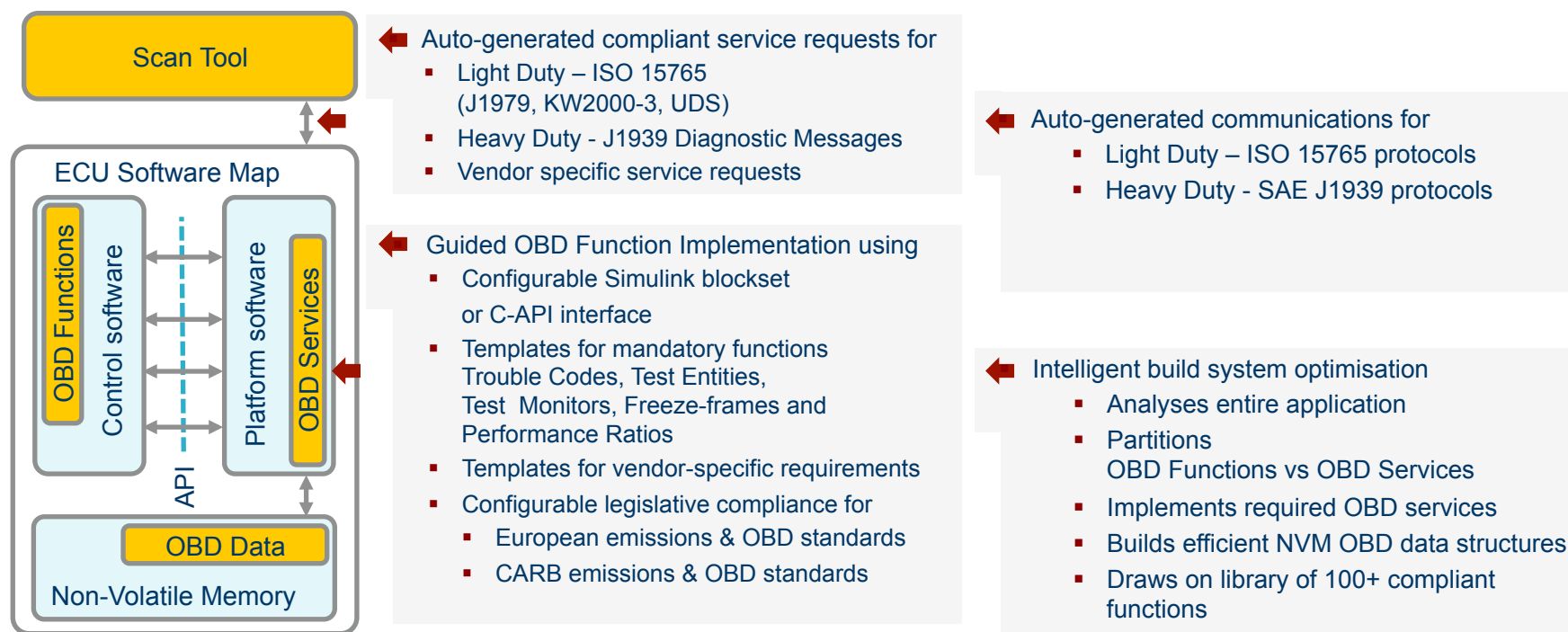- Implement software, validate, and verify
- ~10 man-years

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What does this all mean?

- OBD data burden multiplies with system complexity
- Watch out for ECU resource constraints when planning your projects.
- Infrastructure software effort should not be underestimated.

- Focus your efforts on the diagnostic monitors and certification efforts, not the infrastructure software.

Pi Innovo OBD Infrastructure Software

open/ecu™

Scan Tool

Auto-generated compliant service requests for
- Light Duty – ISO 15765 (J1979, KW2000-3, UDS)
- Heavy Duty - J1939 Diagnostic Messages
- Vendor specific service requests

Auto-generated communications for
- Light Duty – ISO 15765 protocols
- Heavy Duty - SAE J1939 protocols

ECU Software Map

OBD Functions
Control software
API
Platform software
OBD Services

OBD Data
Non-Volatile Memory

Guided OBD Function Implementation using
- Configurable Simulink blockset or C-API interface
- Templates for mandatory functions Trouble Codes, Test Entities, Test Monitors, Freeze-frames and Performance Ratios
- Templates for vendor-specific requirements
- Configurable legislative compliance for
  - European emissions & OBD standards
  - CARB emissions & OBD standards

Intelligent build system optimisation
- Analyses entire application
- Partitions OBD Functions vs OBD Services
- Implements required OBD services
- Builds efficient NVM OBD data structures
- Draws on library of 100+ compliant functions

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Thank You!

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