Managing Software Interfaces of On-Board Automotive Controllers

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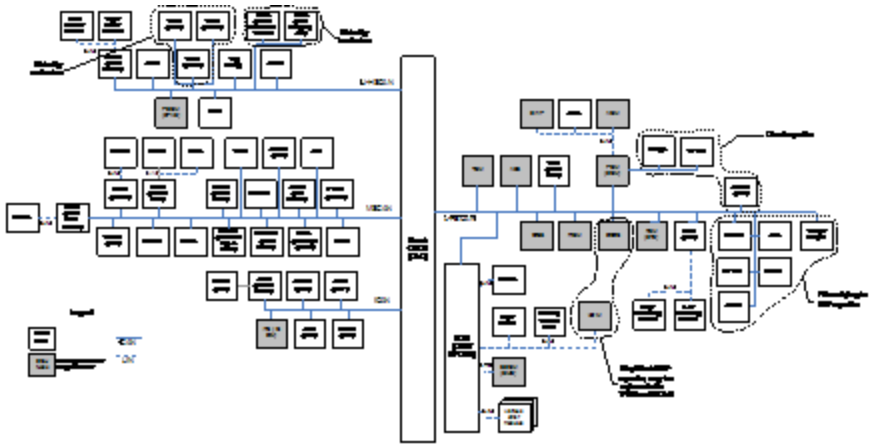
Introduction

Today's cars rely heavily on software-intensive electronic controllers that share information.

A typical Ford vehicle has 20 controllers. Our high-end vehicles have about 40 controllers.



Vehicle Network

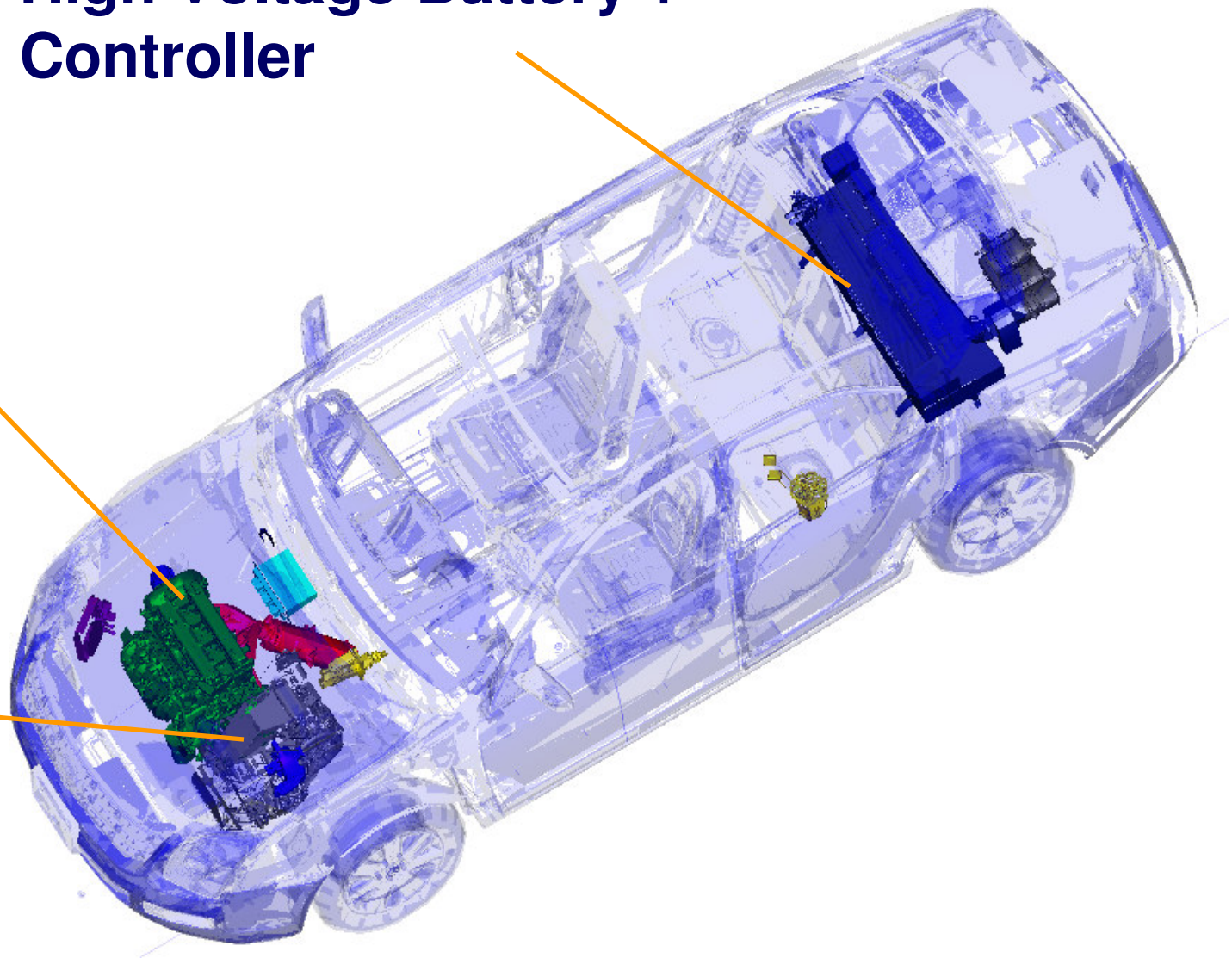
Increasingly, controllers must cooperate to deliver functions none can provide alone.

Hybrid Electric Power Pack

High Voltage Battery + Controller

Engine + Controller

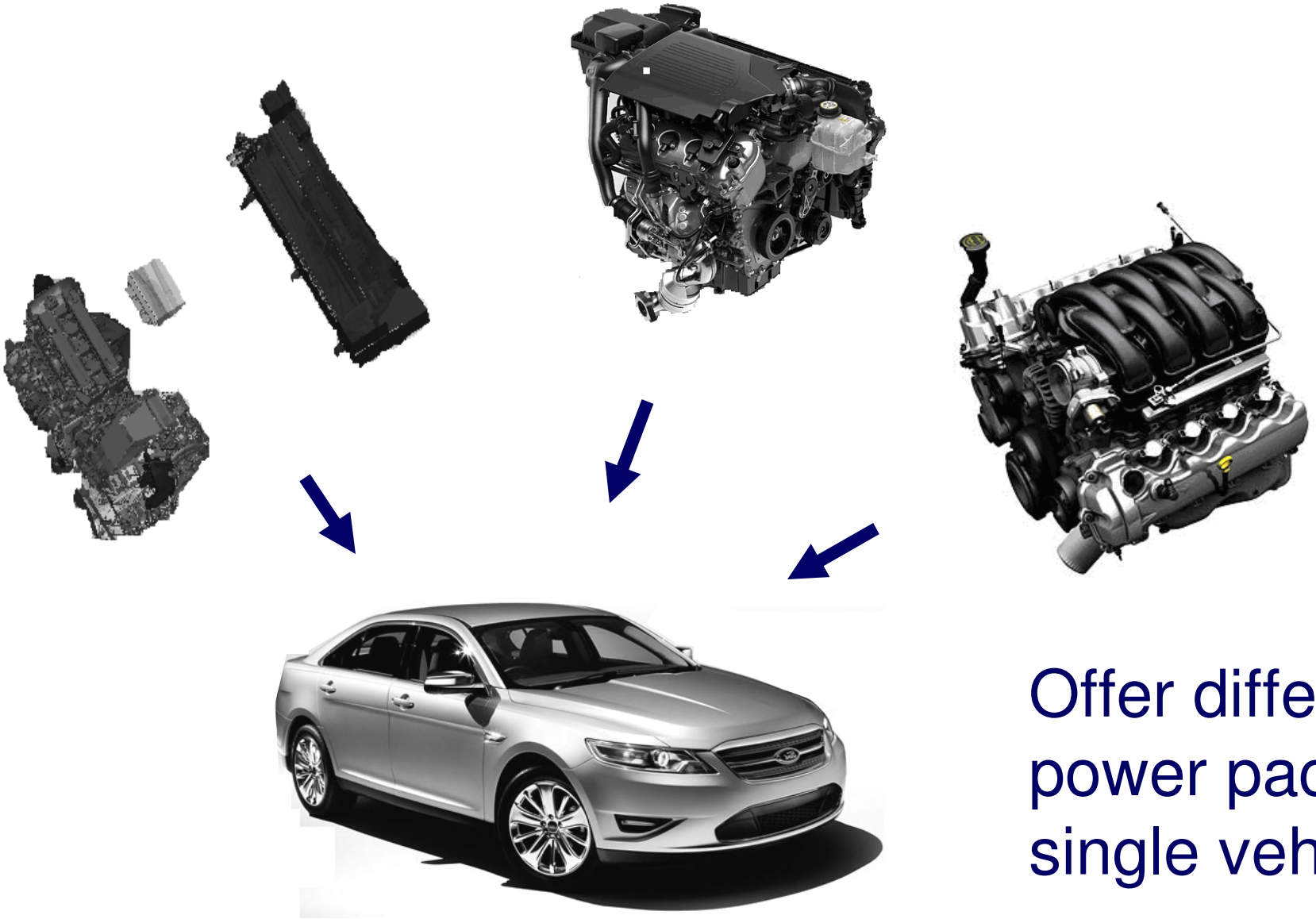
Motor + Generator + Gear Set + Controller



Business Goals

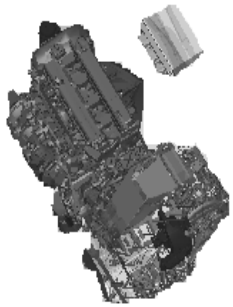
- Avoid duplication of engineering work
- Easily deploy new features and technologies
- Be quicker to market
- Reduce product and development cost

Scenario 1



Offer different power packs in a single vehicle

Scenario 2



Reuse a power pack in different vehicles

The Problem

We tried to reuse the hybrid electric power pack of a North American SUV in a European sedan that original had a conventional power pack. (scenario 2)

- Many unanticipated interface mismatches
- Lots of re-engineering
- Slow progress
- Project eventually cancelled

Two big causes:
- Interface variations
- Organizational constraints

Cause 1 - Variation

Optional features across large product line

Legacy designs from many brands

Ford Mercury Lincoln Mazda Volvo Jaguar Land Rover

Cause 2 - Organizational Constraints

We were not architecturally driven.

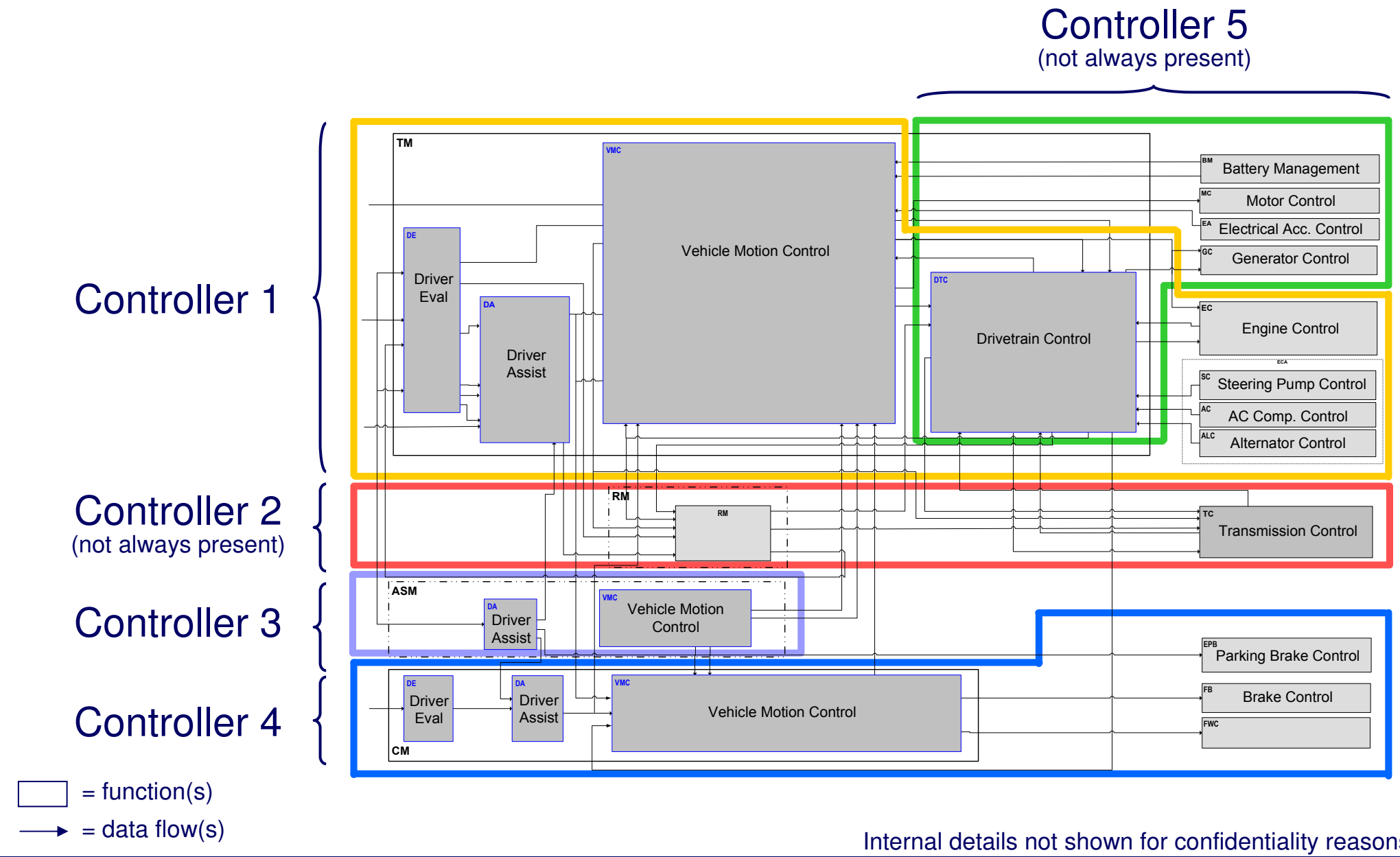
- Non-functional requirements have low priority
- Decisions often driven by immediate needs of an individual project
- Incremental change favored to reduce risk
- Collective mental model of system overwhelmingly focused on hardware view
- Different brands have different business models

The Solution

A new project ... to eliminate the problems that caused the first project's failure ...

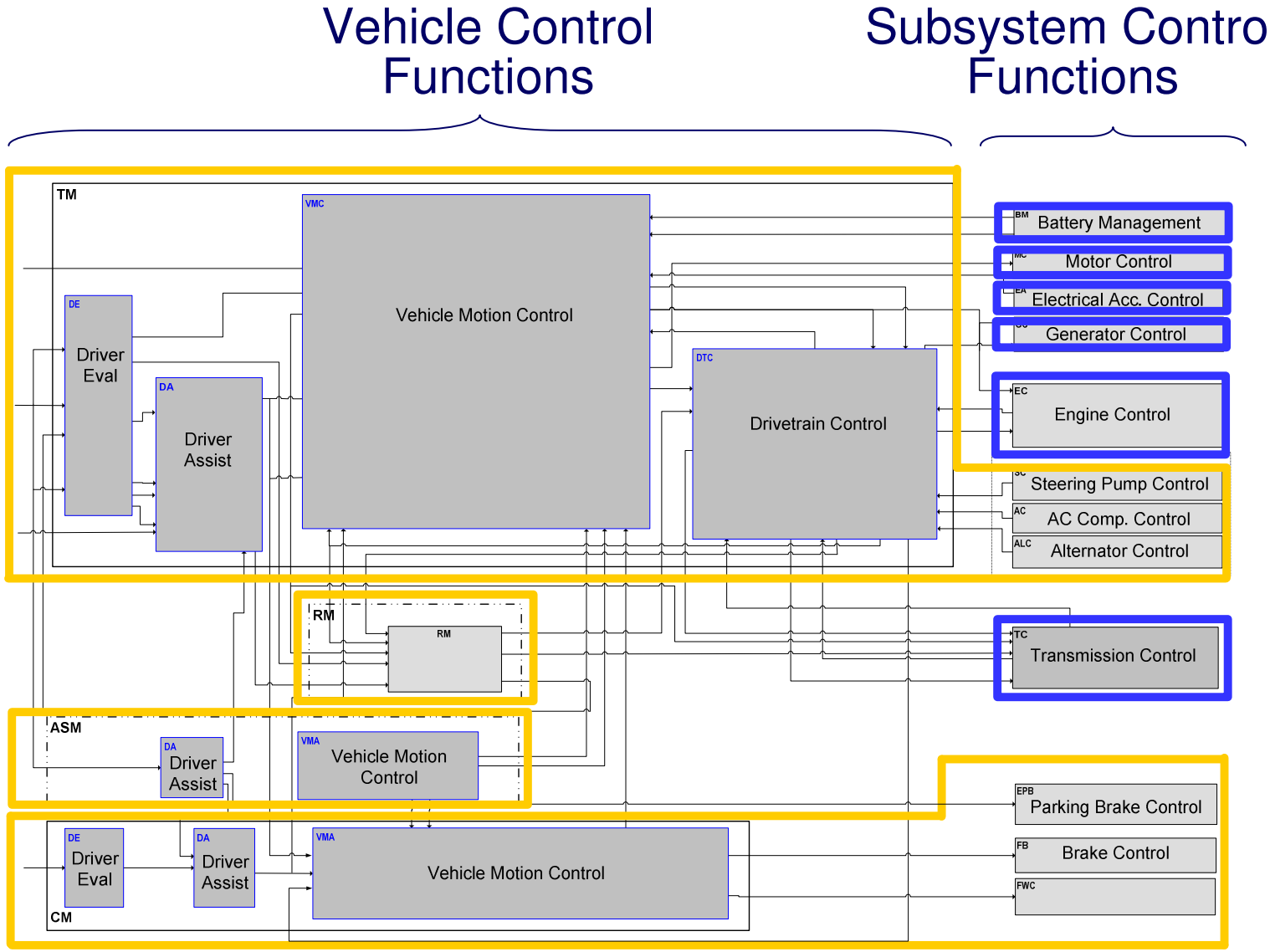
- Six workstreams, one devoted to control architecture and interfaces
- A committed team of subject matter experts who can make change happen
- A new framework to guide our thinking
- Commonized control architecture and signal interfaces

Solution - A New Framework - Hardware



Internal details not shown for confidentiality reasons.

Solution - A New Framework - Function



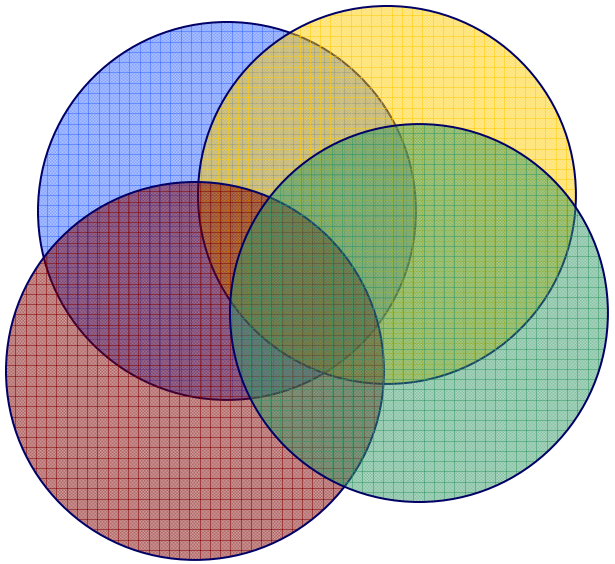
= function(s)

= data flow(s)

Internal details not shown for confidentiality reasons.

Solution - Interface Commonization

1160 interface signals collected from legacy designs



- id
- name
- description
- range
- resolution
- enumerated values
- update rate
- initial value
- aliases
- transmitters
- receivers
- etc.

We created three categories:

standardized for common, long-term use
restricted for short-term use only
prohibited to eliminate variation

Results

393 redundant or undesirable signals eliminated

Signal Category	Number of Signals	Fraction of All Signals
Standardized	392	34%
Restricted	99	8%
Prohibited	393	34%
TBD*	276	24%
Total	1160	100%

* Note: We have since addressed the TBD signals.

Results

Established corporate data dictionary for all network interface signals, not just those affecting the power pack

That means about 800 more signals

Signal Category	Number of Signals	Fraction of All Signals
Standardized	1200	60%
Restricted	311	15%
Prohibited	506	25%
Total	2017	100%

The Lessons Learned

#1 Illuminate the entire product line constantly.
Establish a framework for thinking about the system that covers the entire product line. Make it the basis for integrating new features. This helps balance new features and old features.

#2 Keep the team.
A permanent cross-functional team can provide continuous attention to non-functional quality attributes. Do not disband the team unless other mechanisms are established to take its place.

The Lessons Learned

3 Evolution works too.

Many organizational habits are deeply rooted. It is far more effective to evolve existing work products and processes instead of trying to revolutionize them.

#4 Do not wait for a complete architecture description.

A multi-view architecture description makes great sense but is difficult to establish in an organization that is not architecture-driven. Add value incrementally by working from implementation to architecture.

The Lessons Learned

#5 Educate.

Plan time and resources for education about architecture. Most of the engineering community does not think in terms of quality attributes, stakeholder concerns, architectural strategies, and multiple views.

#6 Be persistent; have patience.

Some changes take a very long time. Keep at it. Light pressure is better than no pressure.