CAR Breakfast Briefing

TRW Systems Engineering - Slip Control Systems

Deron Littlejohn

25Mar14

ADVANCED THINKING / SMART THINKING / GREEN THINKING

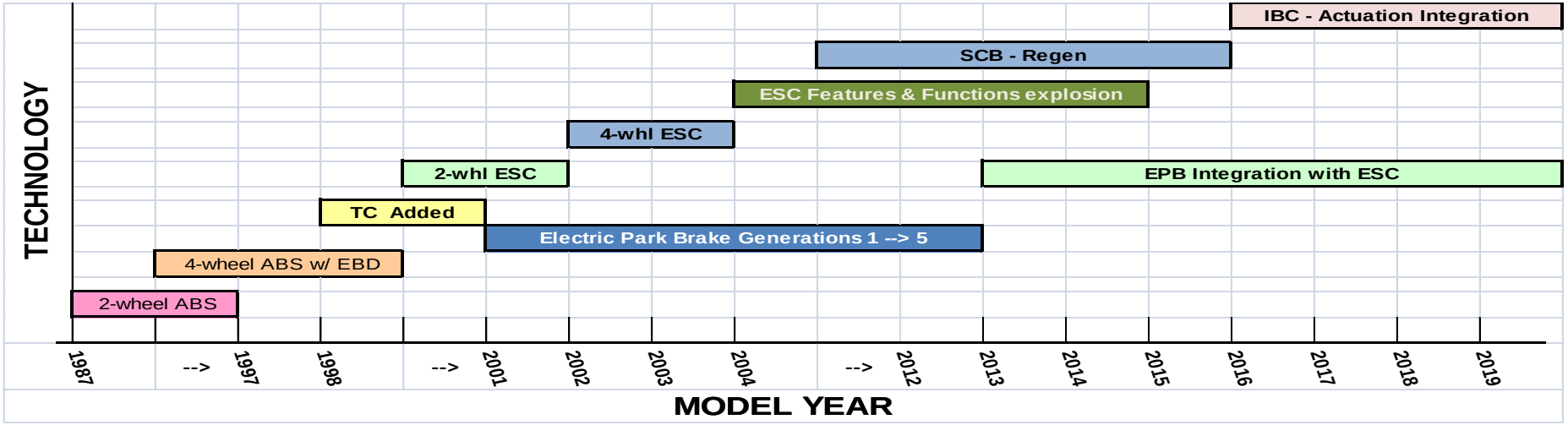
TRW – Slip Control Systems Background

What are “Slip Control Systems”

- Electronically controlled elements of today’s automotive brake systems that provide safety and convenience features such as:
  - Anti-Lock Braking (ABS)
  - Electronic Stability Control (ESC)
  - Traction Control (TC)
  - Adaptive Cruise Control (ACC)
  - Regenerative Brake Blending Systems (RBS) {EVs & Hybrids}
  - Hill Descent Control (HDC)
  - Etc……
- As all of these systems control the pressure being applied to each of the vehicle wheels, they dynamically control the ‘Slip’ of each wheel.

© TRW Automotive 2014

TRW – Slip Control Systems
Brief History



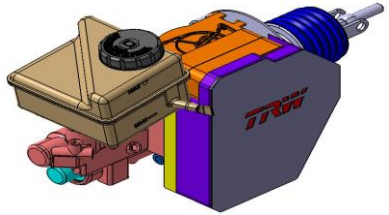
Early ABS

Present ESC

SCB - Regen

Present EPB

Integrated Brake Control



© TRW Automotive 2014

TRW – Slip Control Systems
Trends

- **From Humble Beginnings**
  - Rear Wheel Anti-Lock (RWAL)

➢ **To Standard Equipment**
  - Electronic Stability Control

- **To Complex Feature Additions**
  - TSC, ACC, Disc-Brake Cleaning, iTPM, Hill Assist, etc.

✓ **To Integration Hub**
  - EPBi, Chassis Domain Control, Steer Torque Overlay, etc.

» **To Next Generation ‘Green’ Technology**
  - Regen Braking support for EVs and Hybrids
  - ‘0’ vacuum brake systems:
    - Reduce engine parasitic / increase Fuel Economy

© TRW Automotive 2014

What are the Challenges Today?

1. Growing levels of functionality
   - ❑ NCAP / Collision Mitigation expectations
   - ❑ Hosting of OEM / 3rd party software
     - ➢ Processing power and memory continue exponential trend
       - !! **Multi-core uP with 8Mbytes of ROM by 2019**
   - ❑ Support of fault tolerant ‘Semi or Fully’ Autonomous Driving

2. Increasing Standardizations and Safety Requirements
   - ❑ Growth in AUTOSAR adoption – standard software modules
   - ❑ Process adherence – Automotive SPICE
   - ❑ ISO 26262 ASIL-D system compliance

© TRW Automotive 2014

What are the Challenges Today?

3. Requirements Capturing / Decomposition
   - ❑ Multiple formats from Customer base
   - ❑ Various levels of detail / completeness
   - ❑ Insufficient internal requirements captured to ‘link’ to.

4. Bi-lateral Traceability
   - ❑ Present systems not compatible with the concept
   - ❑ Lack of original decomposition – difficult to now insert ‘back’
   - ❑ Not enough experience yet to determine the right fidelity of detail
     - ➢ Ex: every line of code?

© TRW Automotive 2014

What are the Challenges Today?

5. Lessons Learned Feedback / Incorporation
   - ❑ Back into the Requirements / Design documents
   - ❑ Across to other similar projects
   - ❑ Forward to new projects

6. Employee Training / Knowledge / Experience
   - ❑ Present culture of career rotation
     - ➢ The Next Generation Transition:

The ‘Old Guard / Tribal Knowledge’
vs.
The ‘Transitionals / Mobile Connected’

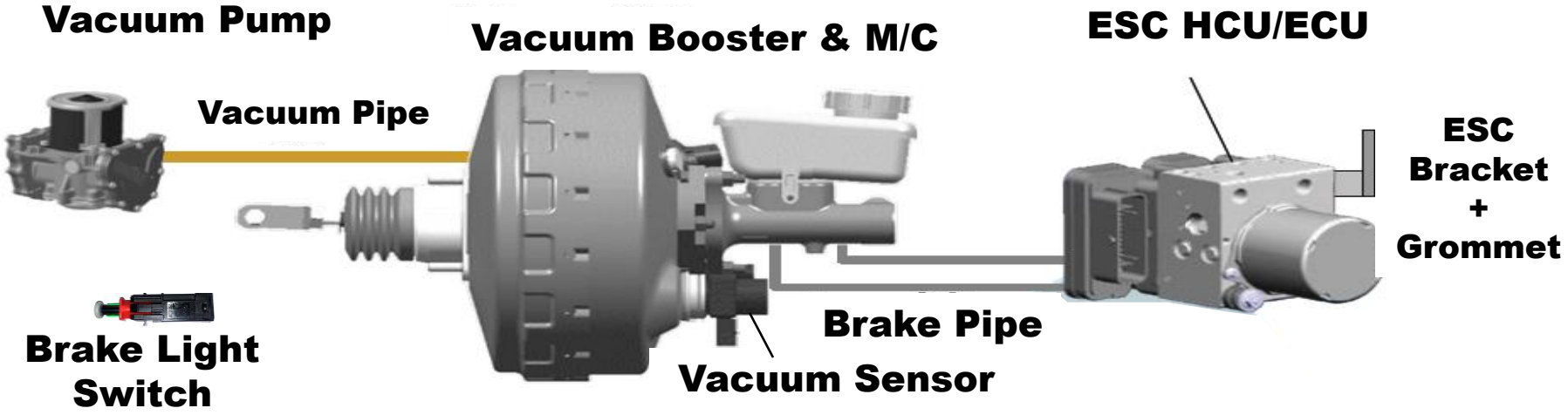
© TRW Automotive 2014

What is coming next?

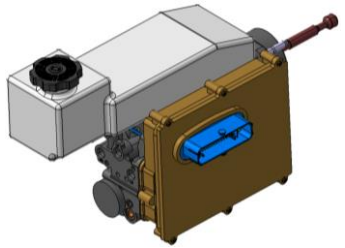
- Industry desires a system that is
  - Vacuum independent
  - Fast Pressure Apply Dynamics {NCAP / Collision Mitigation}
  - Seamless pressure control {Stop-N-Go ACC, etc.}
  - World class pedal feel
  - Support for EVs & Hybrids
  - Fully Fault Tolerant / High Quality / No issues
  - Scalable for all known functions
  - Ability to host ‘black box’ OEM software
  - Etc.

© TRW Automotive 2014

TRW – Slip Control Systems
Integrated Brake Controls (IBC)



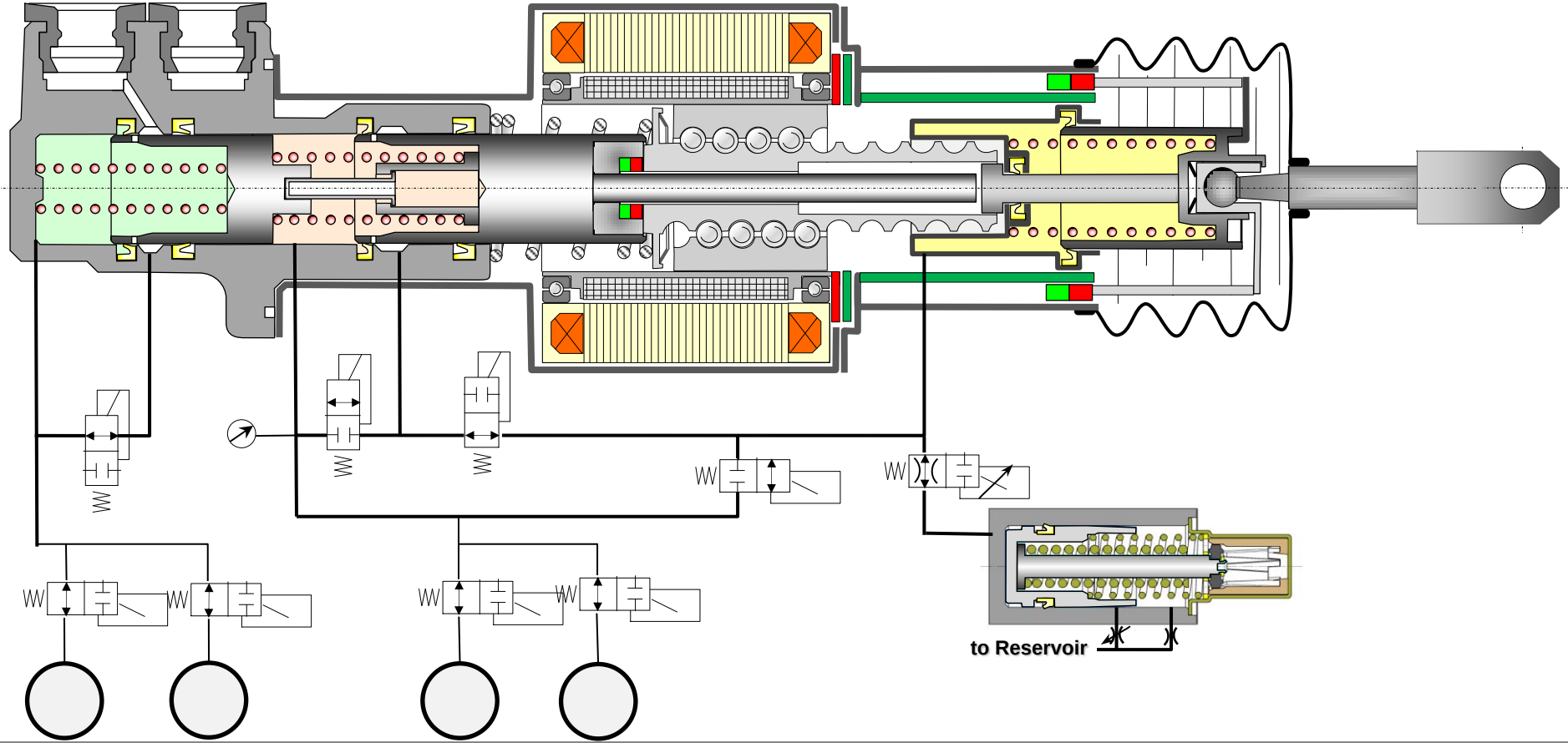
Weight - Number of Parts - Installation - Logistics - Wiring Harness - etc.



IBC

© TRW Automotive 2014

TRW – Slip Control Systems
Integrated Brake Control (IBC)



© TRW Automotive 2014

How Does TRW Design / Develop such Systems?

1. Strong Systems Engineering Organization and Culture
2. Cross Discipline Engineer Development
3. High use of analysis tools in the process
4. Tight communications between Component Engineering and Systems Design
5. Global Operation

© TRW Automotive 2014

Cross Discipline Engineer Development

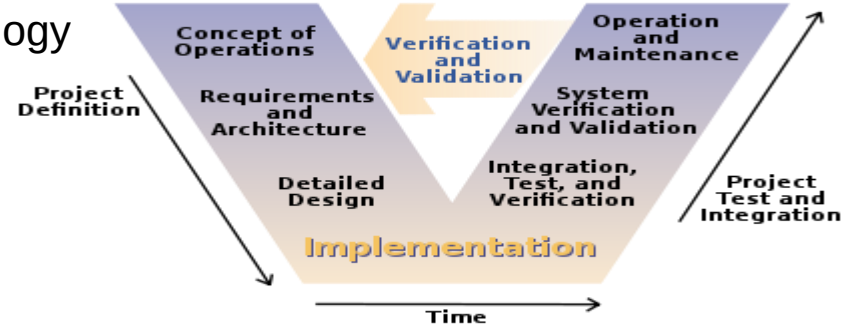
- Systems Design Staff comprised of engineers from various educational backgrounds:
  - Mechanical Engineers
  - Electrical Engineers
  - Control Systems Engineers
  - Software Engineers

- Cross Discipline work assignments are encouraged:
  - Mechanical Engineers writing software
  - Electrical Engineers designing motors / valves
  - System Analysis Engineers – from all disciplines

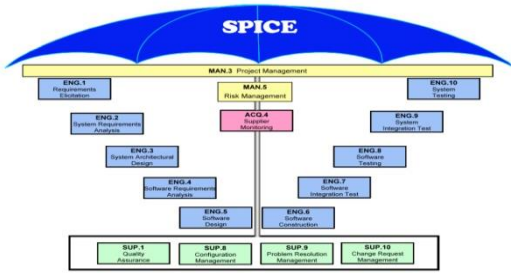
© TRW Automotive 2014

What is the TRW Design / Development Process?

1. Utilizes the traditional ‘V’-cycle methodology



2. Today’s emphasis is to comply with the industry process standards:
   1. Automotive Spice
   2. ISO 26262 {Safety products}
   3. AUTOSAR interfaces



© TRW Automotive 2014

TRW – Slip Control Systems
Analysis Tools / Process

– Simulation / Software-In-the-Loop, Hardware-In-the-Loop Verification tools

HIL Rigs

SLC (Left/Right Max Roll Angle)

Speed (KPH)	WB_3400 NM_370 ESP ON	WB_3400 NM_370 ESP OFF	WB_2800 NM_370 ESP ON	WB_2800 NM_370 ESP OFF	WB_3850 NM_370 ESP ON	WB_3850 NM_370 ESP OFF	WB_3400 NM_430 ESP ON	WB_3400 NM_430 ESP OFF	WB_3400 NM_370 ESP ON	WB_3400 NM_370 ESP OFF	
85	1.3/1.2	1.3/1.3	1.3/1.3	1.3/1.3	1.2/1.2	1.3/1.3	1.2/1.2	1.3/1.3	1.2/1.2	1.3/1.3	LLVW
90	1.3/1.3	1.4/1.4	1.3/1.3	1.3/1.3	1.2/1.2	1.4/1.4	1.3/1.3	1.4/1.4	1.3/1.3	1.4/1.4	
95	1.3/1.3	1.4/1.4	1.4/1.4	1.4/1.4	1.3/1.3	1.4/1.4	1.3/1.3	1.4/1.4	1.3/1.3	1.4/1.4	
100	1.3/1.4	1.4/1.4	1.4/1.4	1.4/1.4	1.3/1.4	1.4/1.4	1.3/1.4	1.4/1.4	1.3/1.3	1.4/1.4	
105	1.4/1.4	1.5/1.5	1.4/1.4	1.5/1.5	1.4/1.4	1.5/1.5	1.3/1.4	1.5/1.5	1.4/1.5	1.5/1.5	
80	4.8/4.8	4.9/4.9	4.9/4.9	5.2/5.2	4.7/4.7	4.8/4.8	4.9/4.8	4.9/4.9	4.9/4.8	4.9/4.9	LGVW
85	5/5	5/5	5.1/5.1	5.1/5.1	4.9/4.9	5/5	5/5	5/5	5/5	5/5	
90	5.1/5.2	5.5/5.5	5.2/5.2	7.5/6.4	5.1/5	5.4/5.5	5.1/5.1	5.5/5.5	5.1/5.1	5.5/5.5	
95	5.2/5.2	9.4/8.7	5.3/5.3	R/16.1	5.1/5.2	6.4/6.4	5.2/5.2	9.4/8.7	5.2/5.2	9.4/8.7	
100	5.3/5.3	15.3/11.2	5.3/5.4	R/R	5.2/5.2	9.7/9	5.3/5.3	15.8/11.1	5.3/5.3	15.3/11.2	
60	6.1/6.2	6.4/6.4	5.8/5.8	6.3/6.3	6.2/6.2	6.5/6.5	6.1/6.1	6.4/6.4	6.1/6.1	6.4/6.4	HGVW
65	6.5/6.3	8.6/8.6	6.8/6.8	8.7/8.7	6.3/6.3	8.4/8.4	6.5/6.4	8.7/8.6	6.4/6.4	8.7/8.6	
70	7/7.4	15.2/14.4	7.3/7.2	20.6/20.1	7.4/7.4	12/11.7	7.2/7.2	15/14.2	7.4/7.3	15.2/14.4	
75	7.9/7.8	19.1/18	7.9/8.6	R/R	8.5/8.5	15/13.9	7.9/7.8	19/17.9	8/7.8	19.1/17.9	
	6AMT								5MT		

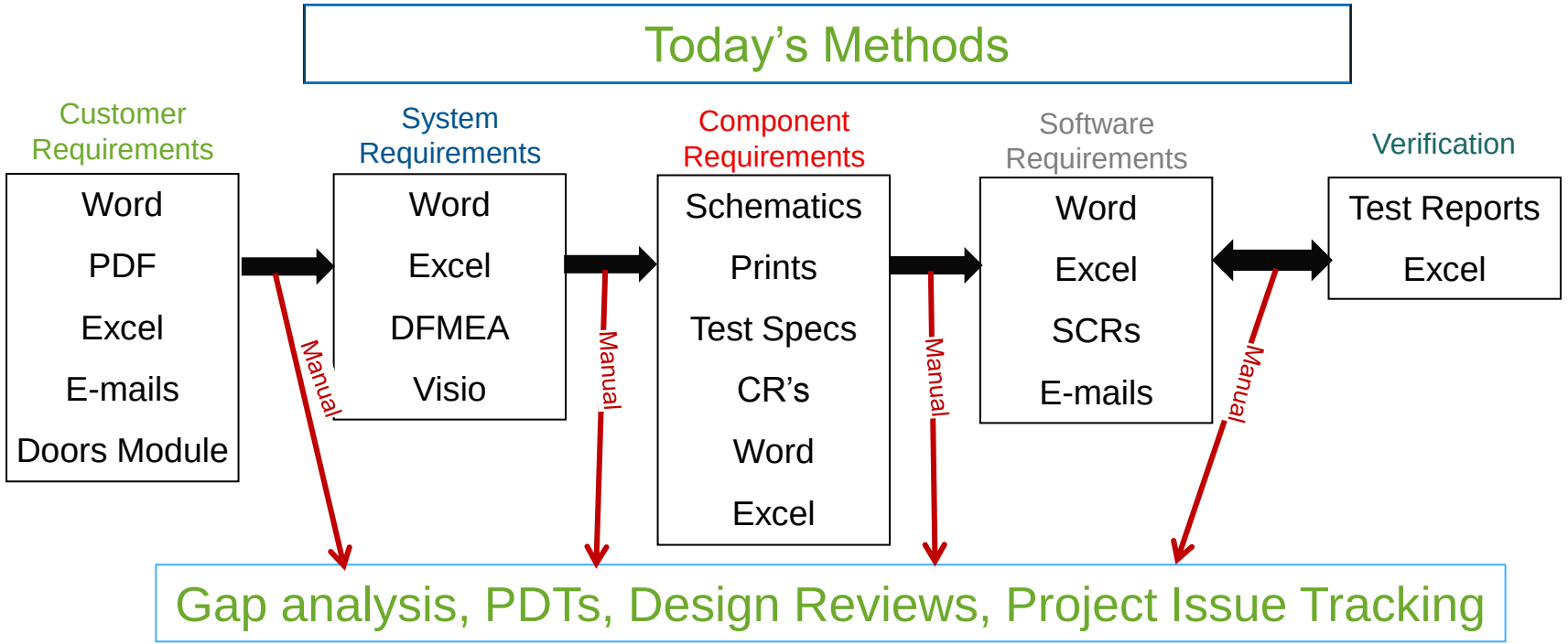
Predicting ESC performance

For Unique vehicles with complex variant configurations

© TRW Automotive 2014

The Biggest Challenges:

1) Requirements Capture 2) Requirements Decomposition 3) Bi-lateral Traceability

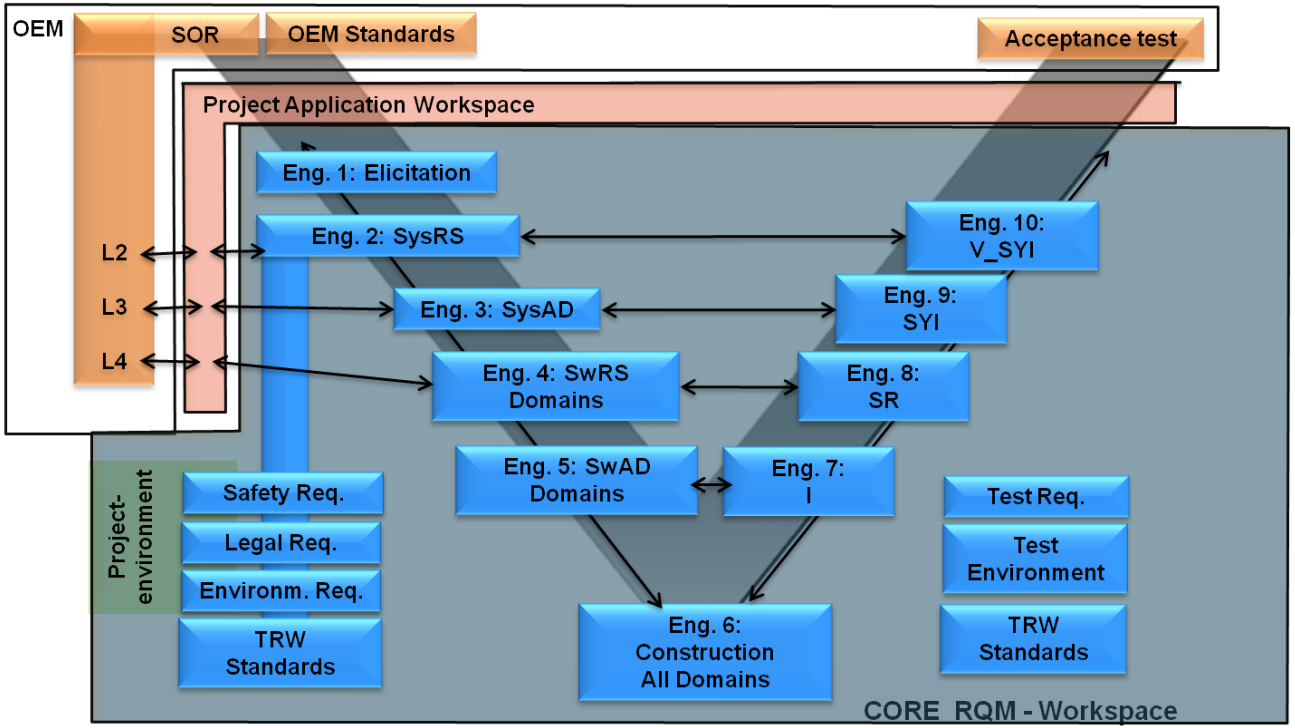


© TRW Automotive 2014

TRW – Slip Control Systems
Systems Engineering Process – Requirements Management

Tomorrow's Methods?

A Fully Integrated Database?



© TRW Automotive 2014

What are TRW Expectations of the Tool Chain?

Not practical that the OEM's / Tier 1's will commonize to a single tool chain

Tools must remain flexible and maintain ability to work with data / databases already developed

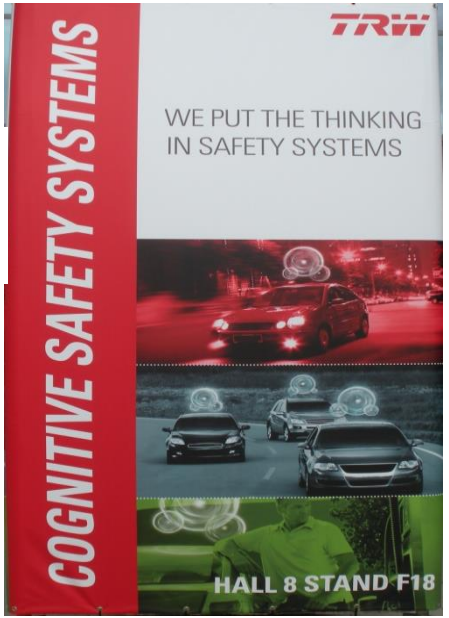
- ✓ Mimic the Instrumentation / CAD tools progression
  - ➢ Concentrate on the information structures
  - ➢ Maintain 'Open' architectures
  - ➢ Develop common interfaces

Converting / Linking between tool chains will be a must!

© TRW Automotive 2014

TRW Systems Engineering

- **Efficient use of cross-discipline engineering analysis, design & verification processes to deliver increasingly robust safety systems to the Global Automotive environment.**



© TRW Automotive 2014