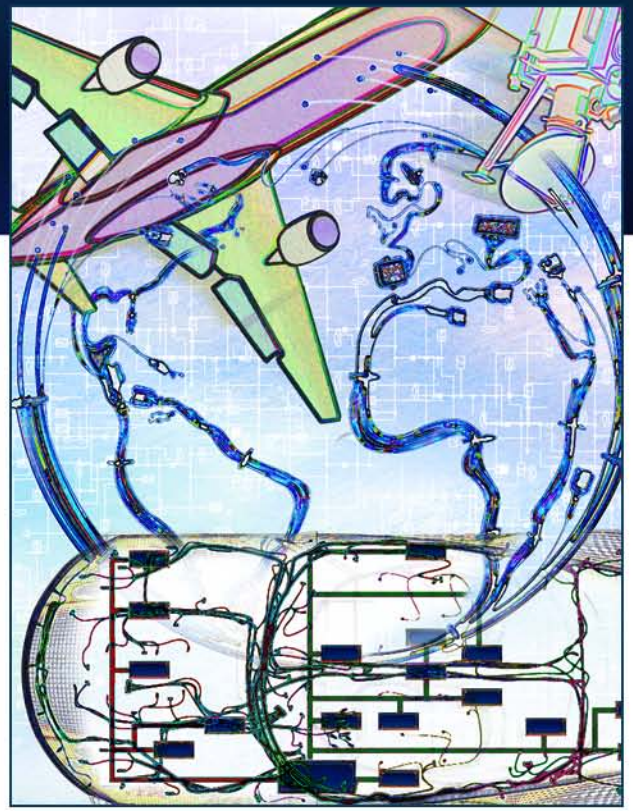


Applying EDA techniques to optimization to in-vehicle distributed systems

Serge Leef

Vice President and General Manager

System-Level Engineering Division

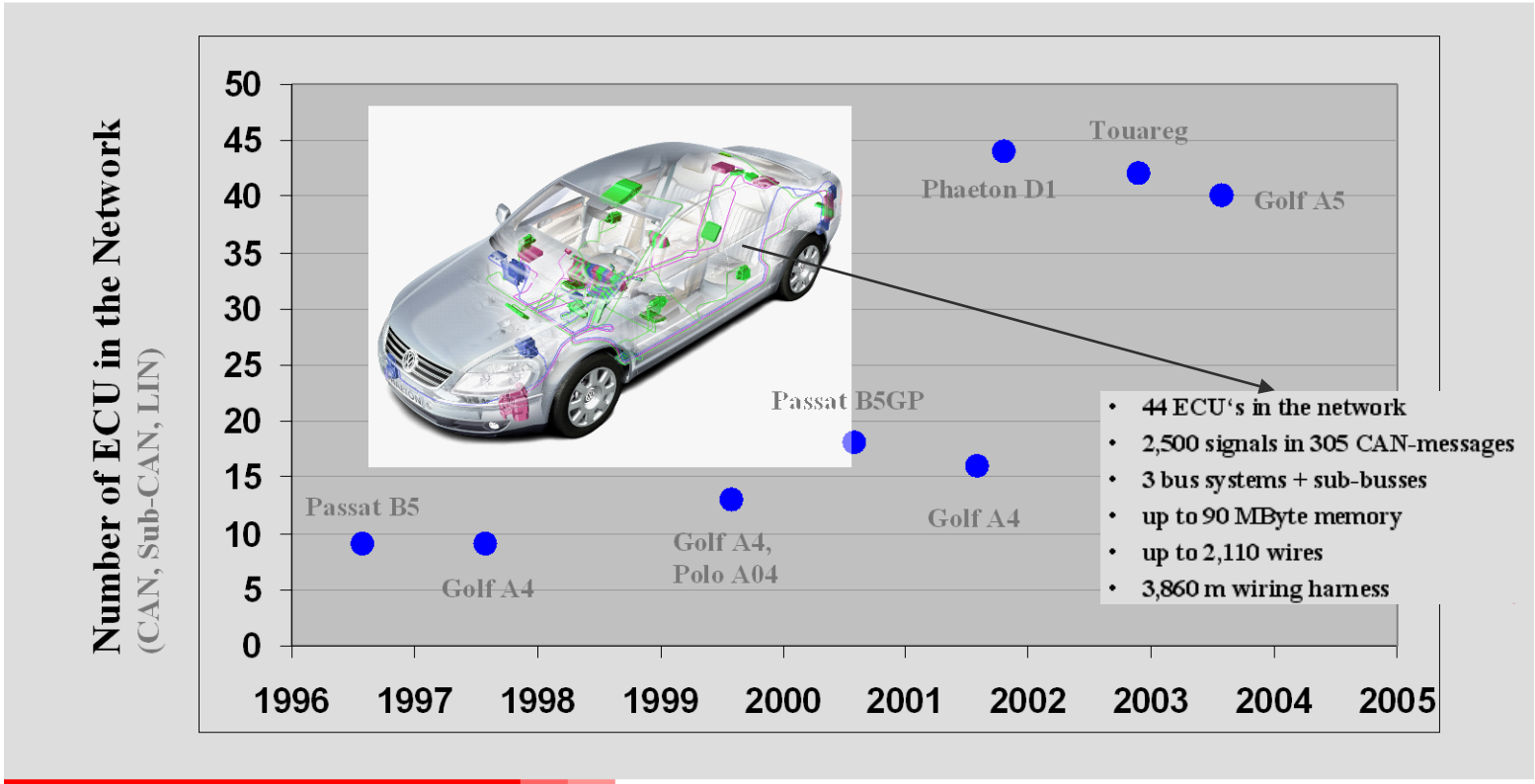
March 2010

Mentor Graphics®

Automotive: the new frontier for EDA?

Automotive electronics

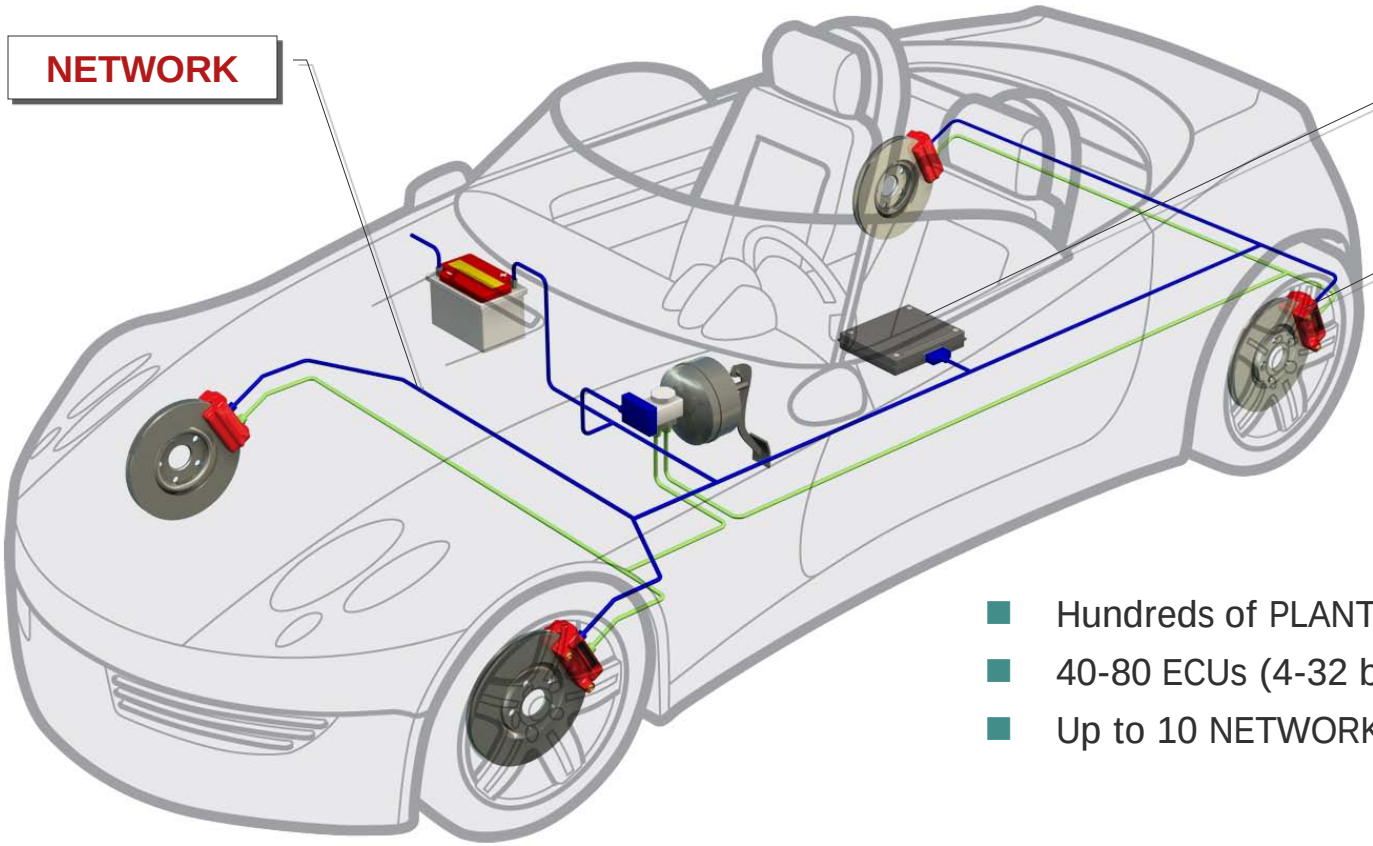
From a mechanical industry to an industry driven by electronics



Elektrik-/Elektronik-Entwicklung
Elektronikstrategie

Seite 3

Examining Automotive Electronics



- Hundreds of PLANTs
- 40-80 ECUs (4-32 bit CPUs)
- Up to 10 NETWORKS of 4+ distinct types

Modern vehicle is a complex, distributed compute and control system

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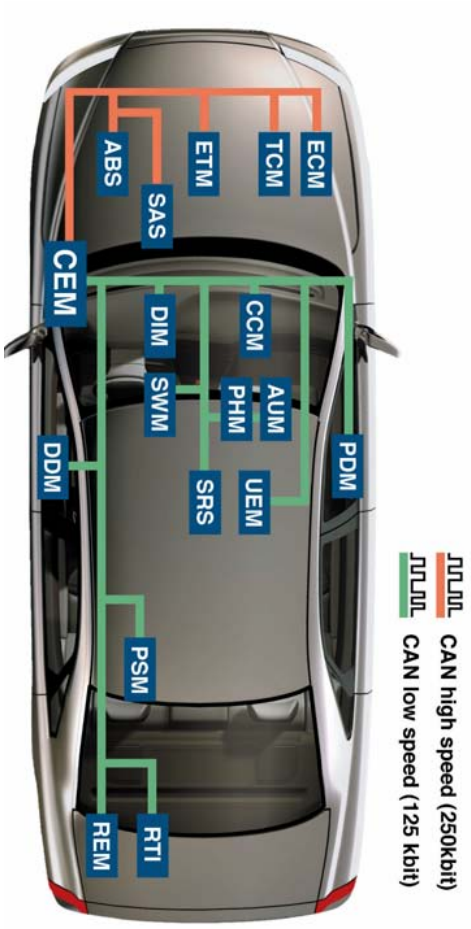
Why are Automotive Electronics an exciting *automation* opportunity NOW?



- Disruption in vehicle electronics design
  - From isolated control units to a highly complex, distributed control network that is supplied by a multi-tiered vendor network
  - Rising SW content and network complexity
  - Example: server-anchored network in new 7 class
- Growing recognition of the need to reduce number of test cars and move analysis and optimization to the front end of development process
  - Huge effort & costs currently at project end
  - Integration, validation and testing
  - Drive to reduce development costs and shorten design cycle
- Getting the system right first time becomes critical
  - Warranty costs == development costs

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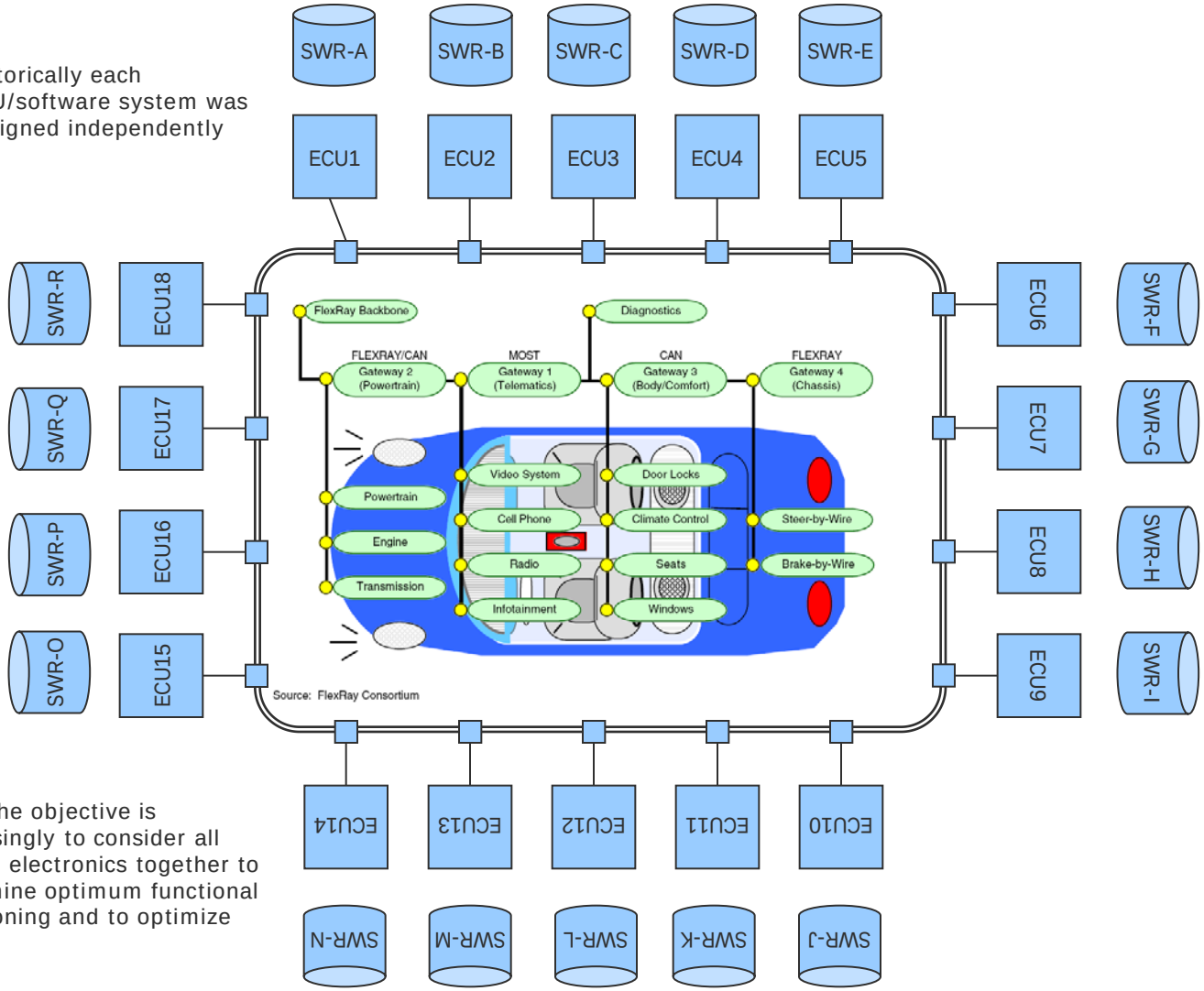
Optimizing Vehicle Architectures

Historically each ECU/software system was designed independently



...But the objective is increasingly to consider all vehicle electronics together to determine optimum functional partitioning and to optimize costs

- What software should run on which ECU?
- Can cable lengths be minimized
- Is use of older & cheaper networking protocols possible?
- Is it possible to reduce the number of ECUs?
- Is it possible to trade-off component cost against performance and features?
- Can an optimum partitioning be automatically determined if I supply a library of possible ECUs from my likely suppliers along with cost, feature, and performance goals?

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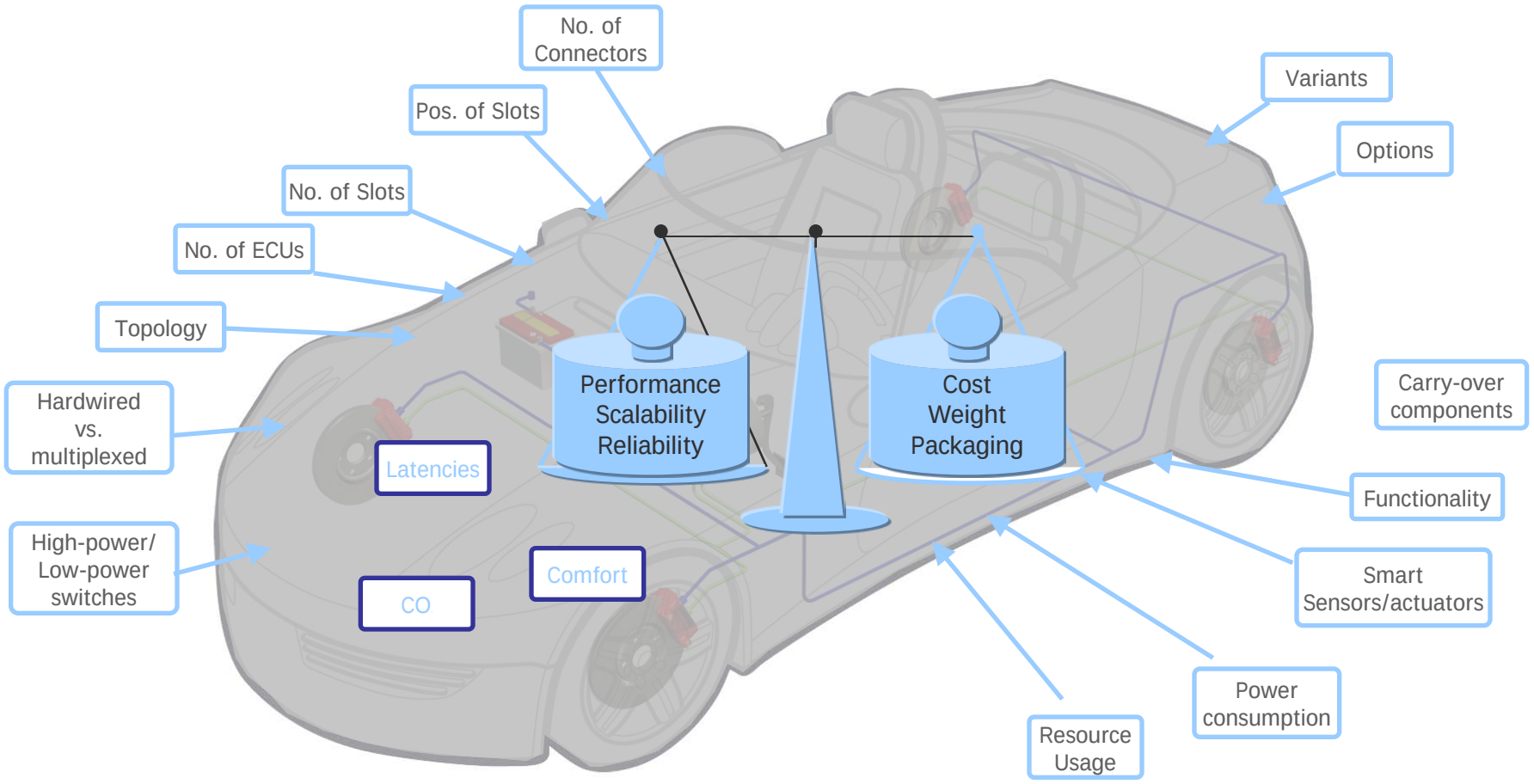
Additional Optimization Dimensions



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Why not manual optimization?

- Multiple, conflicting criteria must be simultaneously optimized
  - Distribution adds network design, wiring complexity, fault-tolerance issues, bus load issues, network startup issues etc
- Today's vehicle functions are highly inter-connected
  - Function-by-function design yields globally-sub-optimal solution
  - Silicon-copper tradeoffs not always obvious
- Size of design problem dramatically increasing
- AUTOSAR standardizes the ECU/SWC interface
  - Tools have a standard to target

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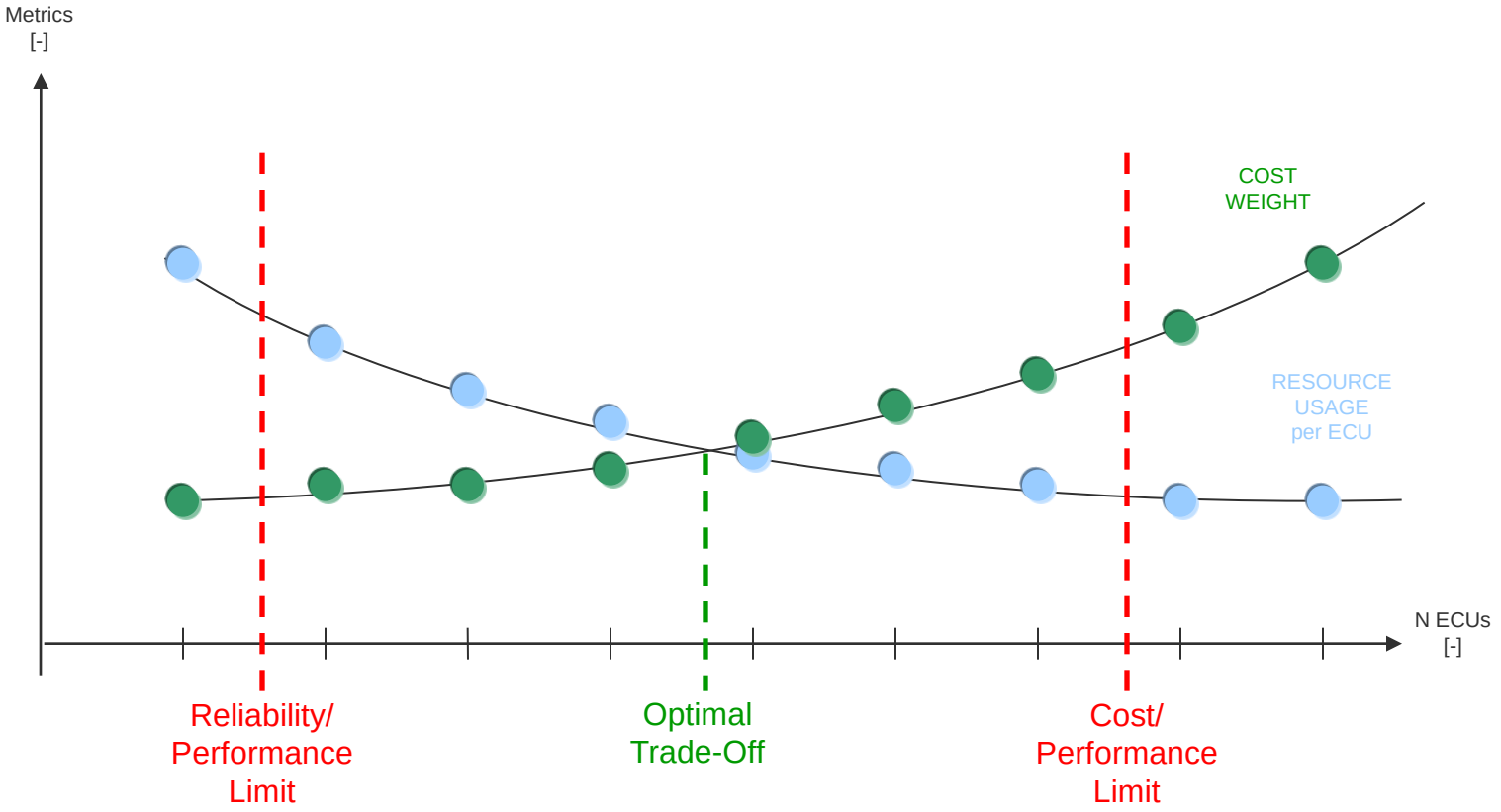
Why not manual optimization?

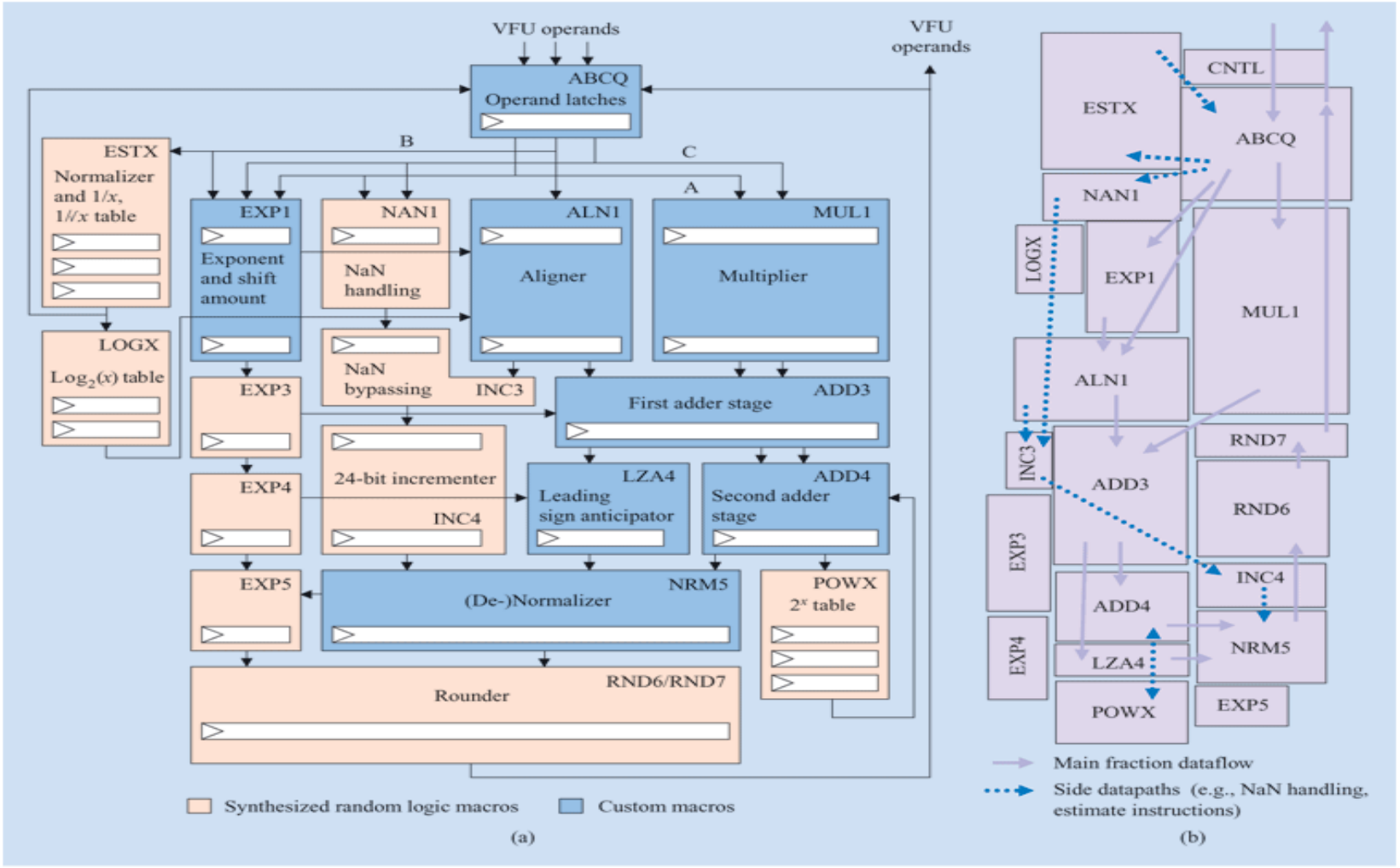
- Today, humans can generate and grade only a few points on these curves
- With tool support, many more possibilities can be examined
- AUTOSAR standardizes the inputs needed



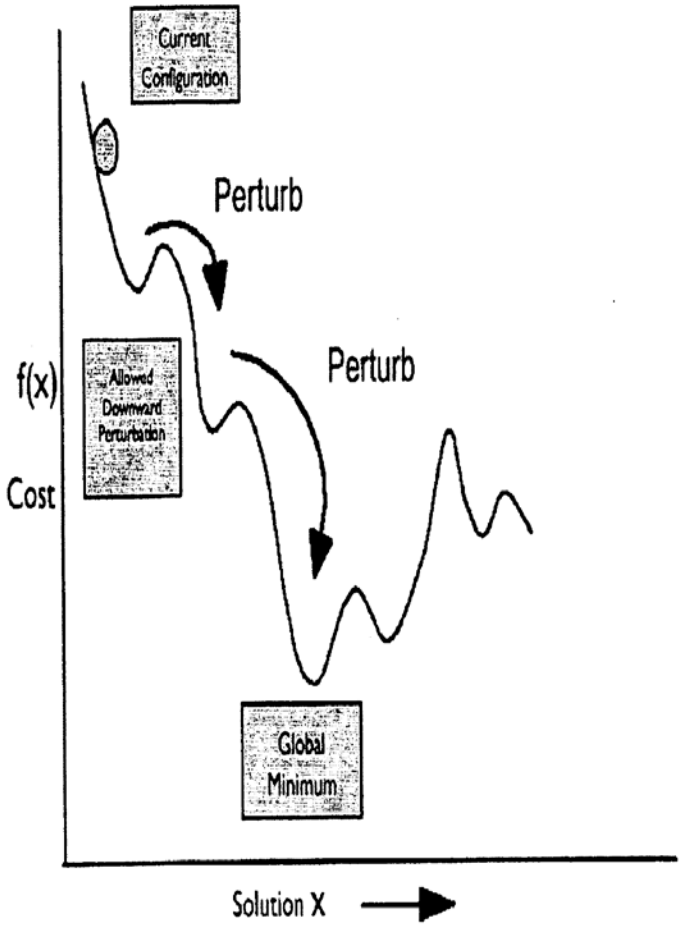
Similar EDA problem: Floor-planning

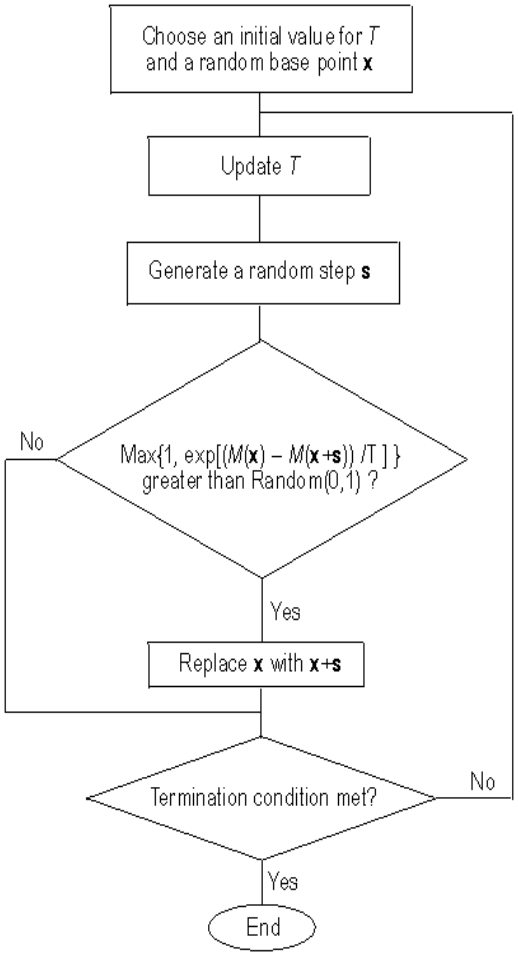
- SWCs are like VLSI macros/standard cells
- ECUs are like physical areas on the layout onto which IC blocks are mapped
- Signal-to-frame mapping is like wire routing
- Physical synthesis simultaneously modifies design logic, its on-chip placement and routing to simultaneously optimize area, power, performance, manufacturability etc...

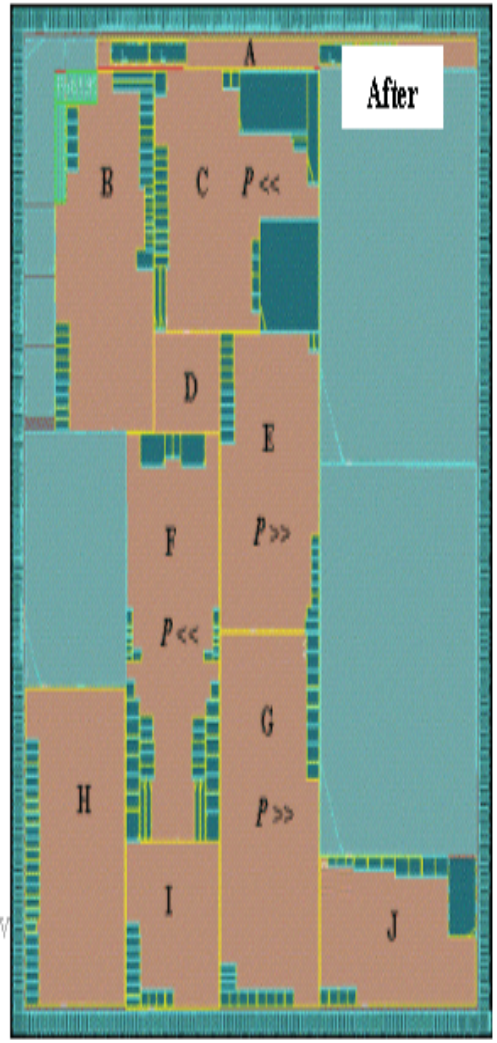
IC Floor-planning problem



Optimization via “Simulated Annealing”







Specifics of Automotive Distributed Systems

- Smaller number of components than VLSI designs → only 1000s of SWCs, 10s of ECUs but...
  - Individual components very dissimilar: differing memory usage, CPU consumption, location constraints, I/O resources required etc
- Options and variant handling – simultaneously optimize across several sets of designs
- Components not independent
  - Regulatory/safety-related constraints (some components must be together, some must not be)
  - Environmental constraints (some possible physical sites excluded for certain ECUs (Electromagnetic/Thermal reasons)
- Bus bandwidth much lower than is assumed on-chip
- Physical wiring adds significant dollar cost, weight
- *Smaller, more highly dimensioned solution space to explore*

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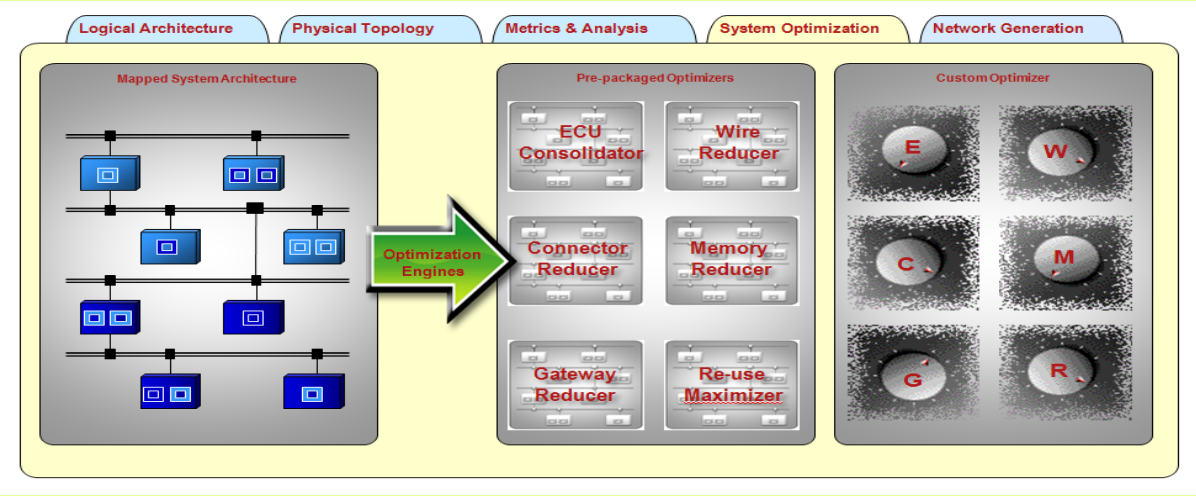
What would an automatic optimizer look like?



- Support user-chosen weightings for different components of cost function
- Support user-chosen constraints on valid solutions
- Optimizer must handle legacy/carryover designs
- Optimizer should rank different alternatives to allow designer to choose

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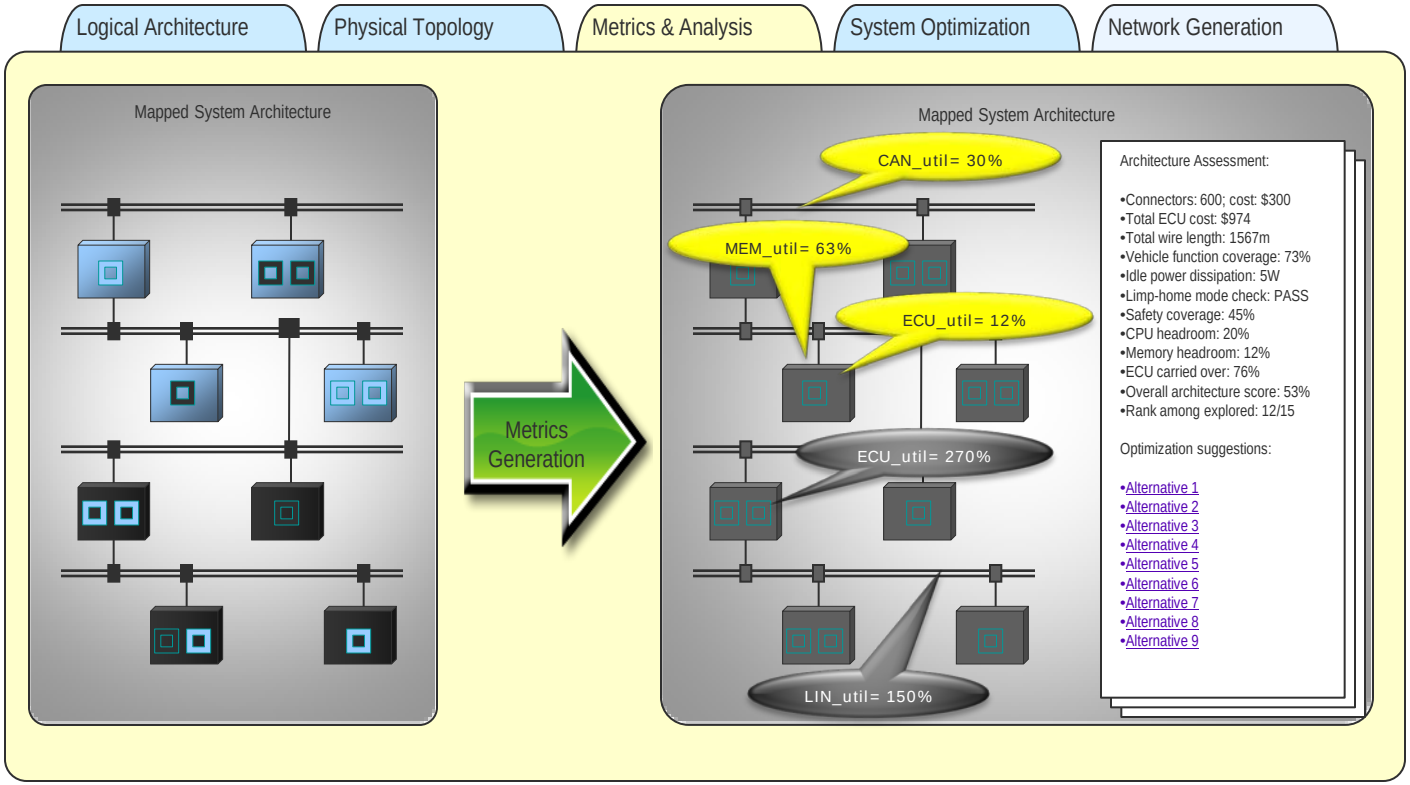
Inputs and Outputs

- Input:
  - Software components (SWCs) with declared memory/CPU/input-output requirements
  - Logical connectivity among software components
  - ECUs with declared memory/CPU/input-output capabilities
  - Pre-existing fixed SWC-ECU mappings (to handle carryover)
  - User-chosen weightings for different cost function metrics
    - Total ECU cost, total wire length etc
- Tool automatically explores much larger set of SWC-ECU mappings than humans can
- Output: Optimized SWC/ECU mapping
- *Could go further and suggest architectural modifications*
  - *Network topology, bus types for specific segments, etc…*

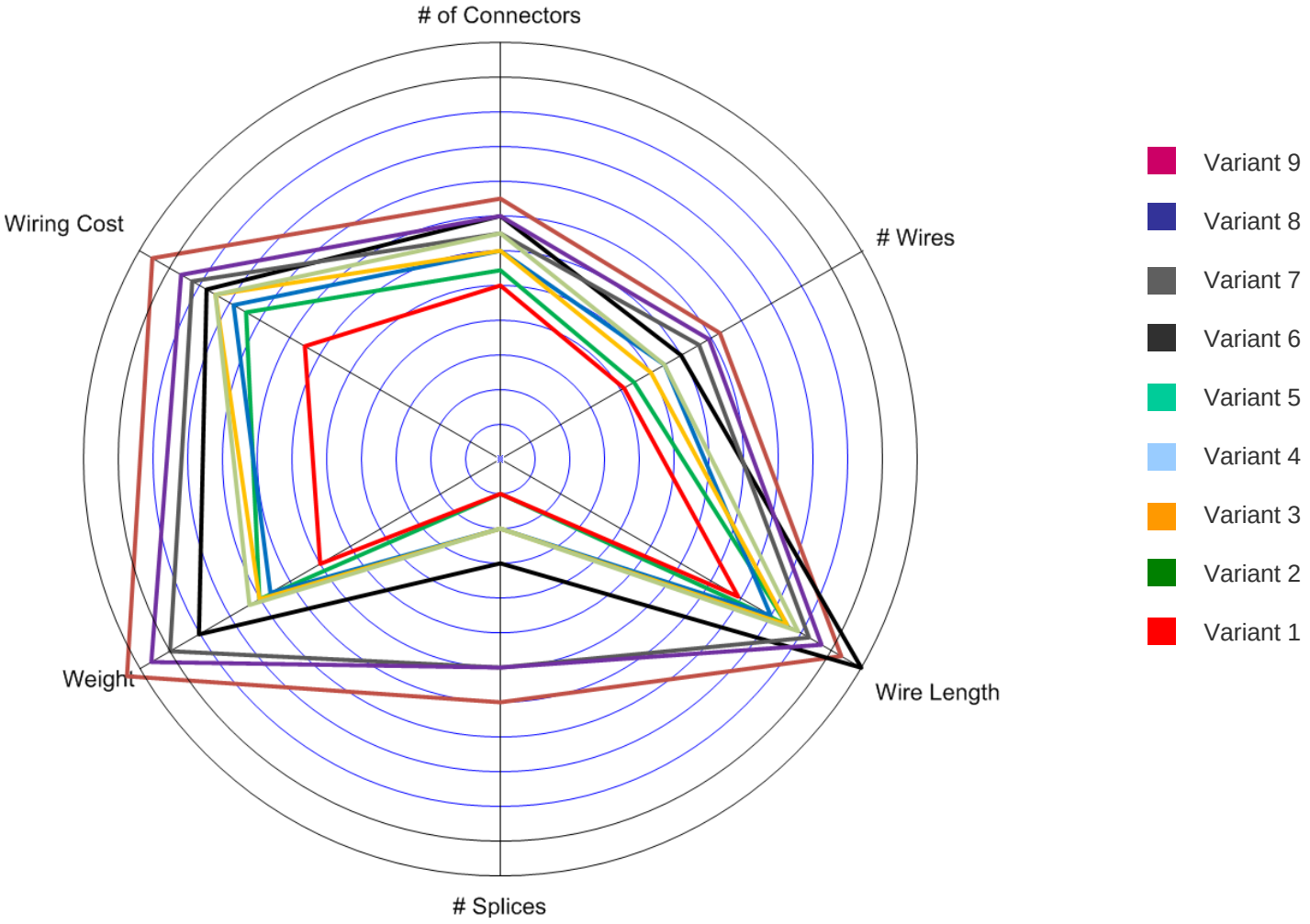
Adaption / acceptance challenges and barriers

- Acceptance of a standardize way of representing ECUs and SWCs → AUTOSAR
- Required input data must be generated:
  - Resources available on ECUs
  - Resources required by SWCs
  - Cost data for ECUs, physical wiring ...
- Ability to incorporate legacy portions of the architecture
- Difficult for engineers to accept automatically generated solutions that appear counter-intuitive to the humans
- Organizational challenges – benefits require system rather than ECU focus

Would “assisted“ rather than automatic approach be more readily acceptable?



Metrics Generation: Physical Metrics



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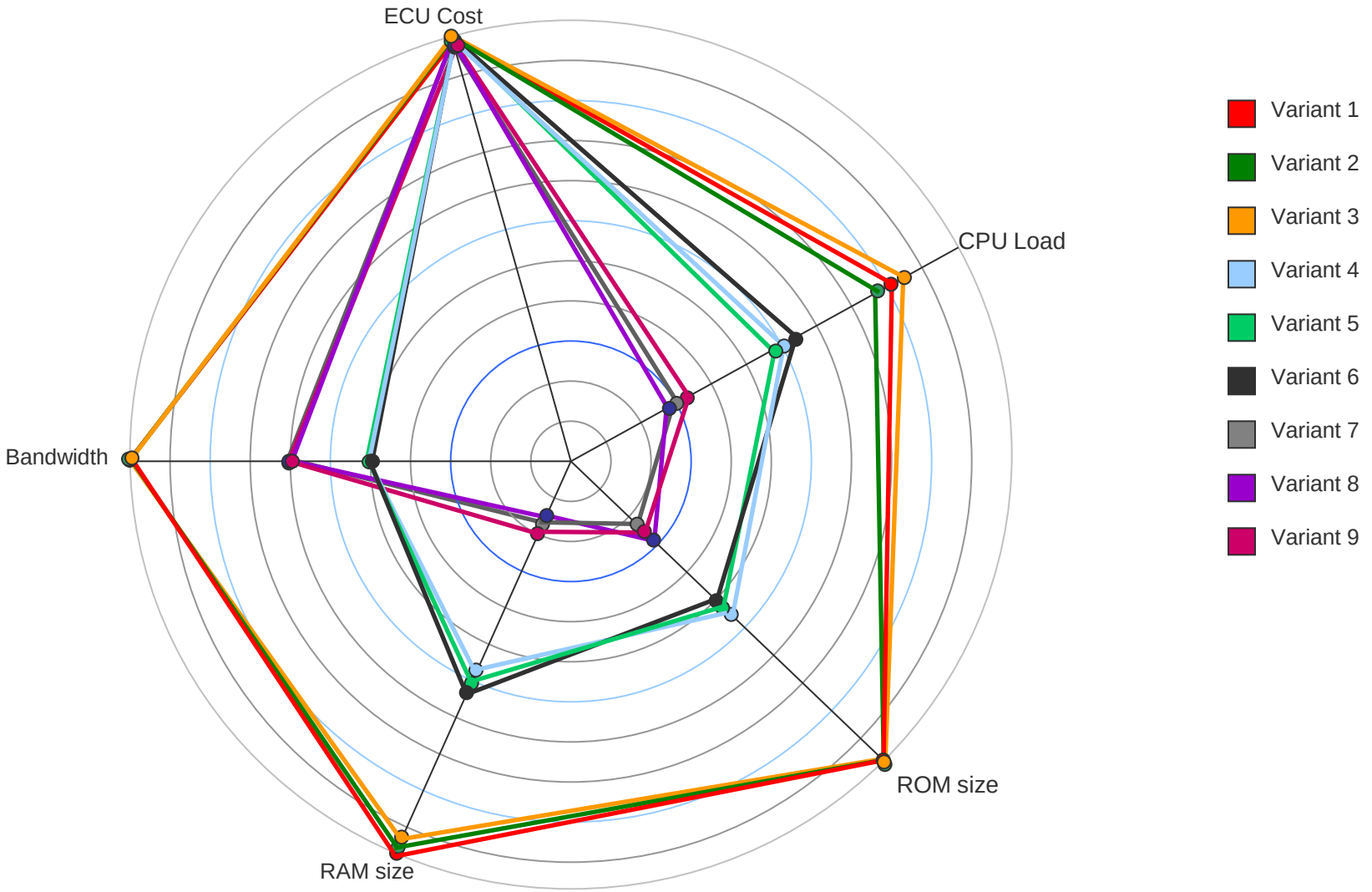
Metrics Generation: Logical Metrics



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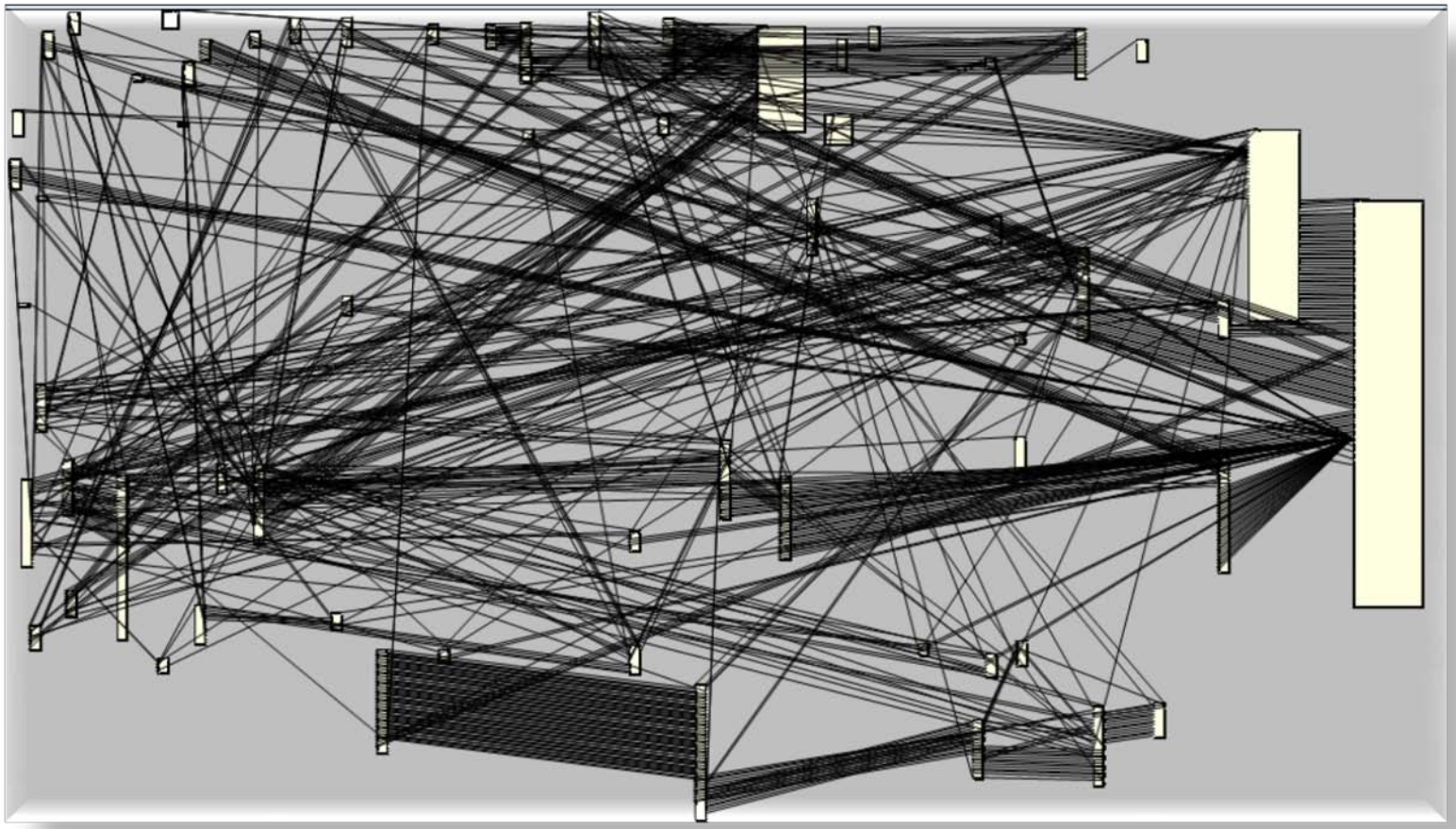
Benefits of an “assisted” approach

- Off-load manual entry of SWC/ECU mappings
- Design choices generated are correct-by-construction
- Automatically consider a large number of design possibilities
  - Generate sorted list of alternatives
  - Quantitative basis for human decisions
- Enables quicker response to changing feature set, cost inputs
- Note: Architect is assisted, not replaced
  - Human judgment is still paramount
  - Tool just generates more choices faster

Optimization makes sense at system and sub-system levels – even simple sub-systems use multiple ECUs

(ex: climate control system from a medium complexity vehicle)



67 Functions/SWCs, 1400 Tasks, 1300 Signals, 3 ECUs

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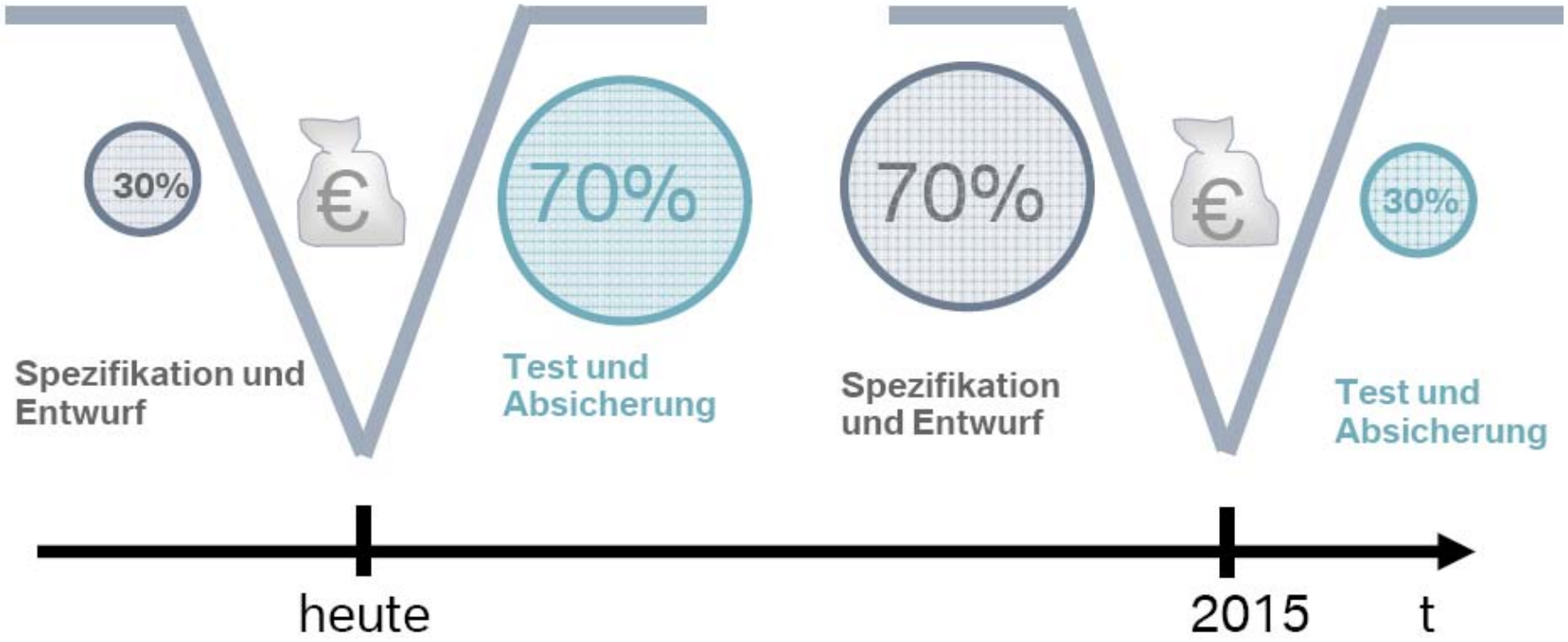
Customers want to shift analysis and optimization to the front end of design



Source: BMW - 2008

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Summary

- Applying automatic optimization techniques to automotive distributed systems has potential for profound improvements
- Barriers to adaption are substantial
  - Organizational, legacy, OEM/T1 divisions, etc...
- Semi-automatic approaches are more appealing
- Immediate term opportunities for in-depth system analysis should enable higher quality manual optimization

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