Looking at Transportation in New Ways

Burkhard Huhnke  VWGoA Electronics Research Lab, Palo Alto CA

Hot Chips August 2010
Global research and development program
Global research and development program

- Worldwide collaboration
  - Knowledge network
  - Teamwork of experts worldwide
  - Driving innovations
  - Comparison of concepts
  - Best solutions in car
The ERL is a Bridge
The ERL is a Bridge

Silicon Valley Engineering

- Out-of-the-box thinking
- Rapid evolution of ideas
- Make do with minimal resources
- Borrow technology from other fields
- “How can we make this work?”
The ERL is a Bridge

Silicon Valley Engineering
- Out-of-the-box thinking
- Rapid evolution of ideas
- Make do with minimal resources
- Borrow technology from other fields
- “How can we make this work?”

Automotive Engineering
- Focus on safety and manufacturability
- A century of in-vehicle experience
- Vast test and validation resources
- Trusted automotive technology
- “Prove that it works in all situations”
The ERL is a Bridge

Silicon Valley Engineering
- Out-of-the-box thinking
- Rapid evolution of ideas
- Make do with minimal resources
- Borrow technology from other fields
- “How can we make this work?”

ERL Engineering
- New, bold ideas and technology
- Meeting rigorous automotive requirements

Automotive Engineering
- Focus on safety and manufacturability
- A century of in-vehicle experience
- Vast test and validation resources
- Trusted automotive technology
- “Prove that it works in all situations”
The Electronics Research Lab – Driving The Future
Driver assistance systems
The Electronics Research Lab – Driving The Future

Driver assistance systems

Connected Car
The Electronics Research Lab – Driving The Future

Driver assistance systems

Connected Car

Human Machine Interface

Copyright © 2010  VWGoA Electronics Research Lab
The Electronics Research Lab – Driving The Future

Driver assistance systems

Human Machine Interface

Connected Car

eMobility development
Global Challenges
Lack of space

... in Los Angeles

poor or rich
- both have to wait -

... in Dhaka
Challenges for Society

Decreasing energy resources at a rising cost
Increasingly complex traffic situations
Increasing need for safety
Challenges of the future

- Individual customer requirements
- Income polarisation
- Demographic change

Society

- Urbanisation
- Increasing traffic load
- Seamless mobility

Safety

- Increasing vehicle number
- Legal requirements
- New markets

Energy

- Climate change
- CO₂
- Peak of oil
Increasing vehicle segments and different customer requirements

1992 (15 segments)

Driving pleasure

Price

Prestige

Use/variety

2008 (40 segments)

Driving pleasure

Price

Prestige

Use/variety
Electronics enables new functions but requires a novel interpretation of usability

Driving in the thirties: 30'
- Gas valve
- Fuel
- Outside temperature-> - ignition
  - fuel injection
  - Choke
  - decompress
  - search OT
  - crank
- Control all engine data (watertemp, oiltemp, oil level, oilpressure,...)
- Control all engine parameters
- Dose cooling air

Driving in the eighties: 80'
- Unlock
- Switch on ignition
- Turn on radio
- Put on safety belt
- Start engine
- Drive
- No warning = no need to act

Driving in the 21st century:
- Enter
- Input destination
- Select entertainment
- Put on safety belt
- Start engine
- Select and configure assistance
- Drive
- Monitor assistance functions
- Follow infotainment suggestions – travel guide, traffic info etc.
- Use mobile devices?
VW Beetle in 1949: a historical E/E architecture
Soft- and hardware evolution

Example: gearbox CPU
The automobile of the future

..... learns to see
vision technology

..... is connected
wireless, mobile communication

..... interfaces to you
speech and graphics
The automobile of the future
Driver assistance systems
Safety: The Driver as Uncertainty Factor
Causes of Fatal Accidents (84% misjudgement)

- Mental factors: 38%
- Incorrect decisions: 46%
- Unexpected behaviour: 11%
- Technology: 5%

Causes of Fatal Accidents (84% misjudgement): Sleep, Distraction, Car in front, Vechicle dynamics, Bet, Lane-Keeping, Parked car, Pedestrians/animals, Accident, Other, Technology.
Vehicle Safety
Fatal accidents over time (Germany)

Daten: Statistisches Bundesamt
Road safety

Fatal accidents over time in Germany

Quelle: Volkswagen AG - Forschung, Umwelt und Verkehr
Vehicle Safety - Potential for Protection

Communicate

See

Feel

Crush zone

Seat belt

Rigid passenger compartment

Airbags

adaptive passenger protection

Today

Time

Active safety

Passive safety

See

Communicate

Crush zone

Seat belt

Rigid passenger compartment

Airbags

adaptive passenger protection

Today

Time

Active safety

Passive safety
Effectivity of current assistance and safety features

50% EU-target

Beyond our control

Emergency medical response*

0% 2000 2010 2020

100% (year 2000)

Fatal accident

Beyond our control

Emergency medical response*

0% 2000 2010 2020

100% (year 2000)

Fatal accident

*Quelle: VW Unfallforschung
Effectivity of current assistance and safety features

With a consequent market distribution of available passive safety technology (Golf platform)
Effectivity of current assistance and safety features

- Effectivity of current assistance and safety features:
  - 100% (year 2000)
  - 50% EU-target
  - Beyond control

Special effects through incentive programs

Quelle: VW Unfallforschung
Effectivity of current assistance and safety features

Additional theoretical potential by 20% - with a consequent market distribution of advanced driver assistance systems
Increasing need for safety

Supporting the driver when he/she is in need of assistance

**Under-challenging the driver**
- Simple, monotonous driving tasks
- E.g. long distance trips, traffic jams

**Over-challenging the driver**
- Complex driving tasks
- E.g. entering a motorway, turning at intersections etc.

- Complexity of driving task
- Need for support
- How good/flawless is the driver?
In critical situations the driver needs assistance:

**Safety Angel**

- information
- warning
- assistance
- up to automatic accident avoidance

In annoying situations the driver wants assistance:

**Autopilot**

- under defined conditions
- specific situations
- selected road sections only
Sensors: Seeing like an Alert Person

- Short-range radar
- Rear camera
- Interior sensor
- Multibeam Laser
- Supersonic
- Video camera
- Infrared camera
- Long-range radar
Timeline of Driver Assistance

- Speed
  - Adaptive Cruise Control
  - Traffic Jam Assistant
- Steering
  - Lanekeeping Assistance
  - Automatic Parking
- Parking
  - Parking Assistance
  - Collision Avoidance
- Sight
  - Adaptive Lighting
  - 2020?
Building Block of Technologies

Driving at the limits of physics
- Vehicle dynamics
- Track coordination
- Drifting algorithm
- High speed

Driving in unknown terrain
- Recognition of environment
- Locating
- Trajectory

Driving according to traffic regulations
- Driving strategy
- Complex environment
- Expanding the horizon
- Predict danger
Where is this project located

The pikes peak TTS is a key project at the Volkswagen Automotive Innovation Lab (VAIL) located at Stanford University, an initiative dedicated to promote innovation into automotive technologies.
Driving at the limits of physics (2010)

- Drifting algorithm
- High speed
Driving according to traffic regulations

- Driving strategy
- Complex environment
Car to car communication in the past
Potentials of car to car communications

- Higher efficiency due to up-to-date, precise information
- Better safety due to early perception of critical situations
- Lively experience by vehicle specific portal services and internet-communities
Improving traffic safety

Information from an ambulance

Bad visibility

In-car warning from traffic signs

Road works
The intersection assistant

- Detecting opposing traffic
- Pedestrian detection
- Traffic light phase information
- Detecting crossing traffic
Car to x – expanding the horizon
Market penetration is a key factor for car2x - technologies

- High quality safety effects
- Minimal traffic flow

- 50% of vehicle sales (i.e. all Audi, BMW, MB, VW – or all midsize vehicles or bigger)
- 25% of vehicle sales (all vehicles equipped with OEM navigation systems)
- 8% of vehicle sales (luxury- and premium segment)
Find your parking lot fast

- Parking monitors transmit real-time parking lot use
- Vehicles transmit information on actual parking lot use
- 5% car2X equipment rate provides sufficient service quality
The vision – heterogeneous networks
The Connected Car in a Connected World
Human Machine Interface
Human Machine Interface – texting while driving
Human Machine Interface – distracted driving
# The Future of Human Machine Interfaces

<table>
<thead>
<tr>
<th>Customer</th>
<th>Basis</th>
<th>Challenge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic driving functions:</td>
<td>standard</td>
<td>automatic driving</td>
</tr>
<tr>
<td>- well known for decades</td>
<td></td>
<td>reliable assistance</td>
</tr>
<tr>
<td>- learnt in school</td>
<td></td>
<td>differentiation via HMI</td>
</tr>
<tr>
<td>New systems z.B. DAS, hybrid:</td>
<td>safety relevant</td>
<td>combination of DAS and DIS</td>
</tr>
<tr>
<td>- unfamiliar to customers</td>
<td></td>
<td>new dialog models</td>
</tr>
<tr>
<td>Infotainment, navigation, audio, telephone, etc.:</td>
<td>High expectations: function, look&amp;feel, interaction</td>
<td>software/responsibility</td>
</tr>
<tr>
<td>- well known</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Infotainment Evolution

openstreetmap.org  plazes.com  facebook.com

location based services  social networks
Who is the competition?

new technologies
Integration of online internet services

Traffic information
Fuel prices
Time tables
Restaurants and hotels
Tourist information
Current events
Driver information with backend services

- hazard notes/intersection assistance/parking assistance
- up-to-date traffic information
- navigation systems
- environment information (XFCD)
- web-services/communities
- internet radio/multi media
- Apps from Audi/VW-Appstore
Harmonization of world wide ITS standards is mandatory

- C2C-CC working documents
- ISO CALM standards
- IEEE 802.11p + 1609.X standards

ITS Station Reference Architecture:
- Applications
- Facilities
- Networking & Transport
- Access Technologies
- Security
Only integrated systems will provide an acceptable solution
Somebody sent me a text ...

What did he write?

Drive, you fool!
Signal is green!
eMobility
EVs and HEVs

1970: Typ2 City Taxi
1980: Golf I Hybrid, T2 Electric, Golf II Electric
1990: Chico Hybrid, Golf II Hybrid, Jetta CitySTROMer, Golf III Hybrid, Golf Electric
2000: Bora SUVA Hybrid, ECO.Power, Bora Electric, Golf III CitySTROMer
2010: Touran TSI Hybrid, Audi Duo, Skoda Hybrid, Space up! blue
eMobility

1973  VW electrical bus
- BEV
- Electric power 17 kW

1991  Study VW Chico
- Hybrid
- Electric power 25 kW + 7 kW

1993  VW Golf City Stromer
- BEV
- Electric power 25 kW

2007  Study VW Space Up! blue
- Fuel cell
- Electric power 45 kW

1993 VW electrical bus
- BEV
- Electric power 25 kW

1993 VW Golf City Stromer
- BEV
- Electric power 25 kW

2007 Study VW Space Up! blue
- Fuel cell
- Electric power 45 kW

1993 VW Golf City Stromer
- BEV
- Electric power 25 kW

2007 Study VW Space Up! blue
- Fuel cell
- Electric power 45 kW

1993 VW Golf City Stromer
- BEV
- Electric power 25 kW

2007 Study VW Space Up! blue
- Fuel cell
- Electric power 45 kW

1993 VW Golf City Stromer
- BEV
- Electric power 25 kW

2007 Study VW Space Up! blue
- Fuel cell
- Electric power 45 kW

1993 VW Golf City Stromer
- BEV
- Electric power 25 kW

2007 Study VW Space Up! blue
- Fuel cell
- Electric power 45 kW

1993 VW Golf City Stromer
- BEV
- Electric power 25 kW

2007 Study VW Space Up! blue
- Fuel cell
- Electric power 45 kW
Drive train and fuel strategy

- Renewable energy
- Natural gas
- Crude oil
- Electricity
- SunFuel®
- Synthetic diesel
- Gasoline
- Blue-e-motion
- e-tron
- TwinDRIVE
- BlueMotion
- DSG
- TSI/ TFSI
- TDI
- TwinDRIVE
- BlueMotion
CO₂- and energy efficiency (power train) (until 2020)

Electrical vehicles - highest potential concerning CO₂- & energy efficiency depending on the energy generation process
Energy Cost

Energy cost fossil / renewable 2007/2020

- Natural gas
- Coil
- Nuclear
- Bio
- Wind onshore
- Wind offshore
- Water
- Photovoltaic

Cost [€/cent/kWh]

State of the art 2007 max
State of the art 2007 min
Forecast 2020 max
Forecast 2020 min

Quelle: Joint Research Centre (EU-Kommission) 2008
# Electrification

<table>
<thead>
<tr>
<th>Combustion engine</th>
<th>Mild hybrid</th>
<th>Full hybrid</th>
<th>Plug-in hybrid</th>
<th>Electrical vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2 l 77 kW TSI</td>
<td>start/stop system, recuperation</td>
<td>Touareg Hybrid</td>
<td>Golf twinDRIVE</td>
<td>Up! blue-e-motion</td>
</tr>
</tbody>
</table>

- Start/stop system
- Recuperation
- 1.2 l 77 kW TSI
- Touareg Hybrid
- 1.2 l 77 kW TSI
- Golf twinDRIVE
- Up! blue-e-motion
## Energy storage: technologies and requirements

<table>
<thead>
<tr>
<th>Energy storage</th>
<th>Combustion engine</th>
<th>Mild Hybrid</th>
<th>Full Hybrid</th>
<th>Plug-in Hybrid</th>
<th>Electrical vehicle</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Technology</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lead acid</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nickel metal hydride</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lithium-Ion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Electric power</strong></td>
<td>~ 2 kW</td>
<td>~ 6 kW</td>
<td>~ 15 kW</td>
<td>~ 30 kW</td>
<td>~ 80 kW</td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td>&lt; 1 kWh</td>
<td>1 – 2 kWh</td>
<td>10 – 15 kWh</td>
<td>&gt;25 kWh</td>
<td></td>
</tr>
<tr>
<td><strong>Voltage</strong></td>
<td>12 V</td>
<td>&lt; 60 V</td>
<td>&gt; 60 V</td>
<td>&gt;&gt; 60 V</td>
<td></td>
</tr>
<tr>
<td><strong>Durability</strong></td>
<td>5 years</td>
<td>8 - 10 years</td>
<td>&gt;10 years</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Cell format

**Hybrid**
- High specific power
- Low specific energy
- Small cells, thin, porous electrode

<table>
<thead>
<tr>
<th>Capacity</th>
<th>Mass/vol</th>
<th>Energy</th>
<th>Spec. power</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Ah</td>
<td>0.25 kg</td>
<td>18 Wh (80 Wh/kg)</td>
<td>500 W (&gt; 2.000 W/kg)</td>
</tr>
</tbody>
</table>

**Plug-In Hybrid, electrical vehicles**
- High specific energy
- Low specific power
- Big cells, thick, dense electrode

<table>
<thead>
<tr>
<th>Capacity</th>
<th>Mass/vol</th>
<th>Energy</th>
<th>Spec. power</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 Ah</td>
<td>1.2 kg / 750 cm³</td>
<td>180 Wh (150 Wh/kg)</td>
<td>800 W (700 W/kg)</td>
</tr>
</tbody>
</table>
Battery system

- CPU
- EV200
- AC-charging
- Liquid cooling
- Battery housing
- DC-charging
- e-box
- Mounting
- Service plug-in
Volkswagen Group is evaluating several battery concepts

- 18650 Cells
- Large Cylindrical Cells
- Large Prismatic Cells
- Large Pouch Cells

Performance Vehicles

High-volume Production Vehicles

New City Vehicles
market and cost – Li Ion cells

status
consumer cell
today mass production
2007: 2.6 Mrd. cells ≈ 13 GWh

forecast
automotive cells
series production 2010,
mass production 2015

Cost: €/kWh

0 250 500 750 1000
1999 2000 2001 2002 2003 2004 2005 2006

NiMH
Li-Ion
NiCd

Exchange rate
1,50 USD = 1 €

300 $/kWh / 190 €/kWh for consumer 18650-cells

Quellen: METI-Roadmap, AABC,
Challenge: charging time

Gasoline

Pump nozzle: 27,000 kW
(~ 50 l/min)

→ 1 minute = 1000 km
driving range

VS.

electricity

Three-phase: 10 kW

→ 1 minute charging = 1 km
driving range
concept Golf! blue-e-motion

Vehicle data

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle weight</td>
<td>1545 kg*</td>
</tr>
<tr>
<td>* 205 kg more than Golf Blue Motion TDI with DSG</td>
<td></td>
</tr>
<tr>
<td>Dimensions L/ B/ H</td>
<td>4199/ 1786/ 1480 mm</td>
</tr>
<tr>
<td>Gearbox</td>
<td>EQ 210 (1-Gang-Getriebe)</td>
</tr>
<tr>
<td>Maximum speed</td>
<td>135 km/h</td>
</tr>
<tr>
<td>Acceleration (0-100)</td>
<td>11,8 s</td>
</tr>
<tr>
<td>elektr. Driving range</td>
<td>up to 150 kilometer</td>
</tr>
</tbody>
</table>

Power train

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>E-motor</td>
<td>85 kW / 115 PS</td>
</tr>
<tr>
<td>battery</td>
<td>26,5 kWh (Li-Ion)</td>
</tr>
<tr>
<td>voltage</td>
<td>324 V</td>
</tr>
<tr>
<td>torque</td>
<td>270 Nm</td>
</tr>
</tbody>
</table>
Thank you for your attention!

Pikes Peak TTS: „Autonomous Hill Climbing“