Next Generation Automobiles
in Miyagi

http://www.miyagicar.com/

Strategic Regional Innovation Support Program by MEXT (For recovery from Tohoku Disaster)　Next-Generation Automobiles / Miyagi Area　Published October, 2014

Strategic Regional Innovation Support Program by MEXT
(For recovery from Tohoku Disaster)

Next-Generation Automobiles / Miyagi Area

Global/Local Innovations for Next Generation Automobiles

Program and presenting materials for

- International Conference "Global/Local Innovations for Next Generation Automobiles" on October 8 -10, 2014
- Joint Session of Eleventh International Conference on Fluid Dynamics (ICFD2014) CS3: "Global/Local Innovations for Next Generation Automobiles" on October 9, 2014

Published October, 2014

Tohoku Economic Federation
Tohoku University
Miyagi Prefecture
The 77 Bank
Intelligent Cosmos Research Institute

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Next Generation Automobiles" on October 9, 2014

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Tohoku Economic Federation
Tohoku University
Miyagi Prefecture
The 77 Bank
Intelligent Cosmos Research Institute

To All People around the World,

We thank you very much for your enormous support for our recovery and reconstruction in the areas devastated by the 2011 Tohoku Earthquake and Tsunami. Although we still experience many difficult days, going through this hardship has allowed us to discover new ways to strengthen bonds that invigorate our attitude toward reconstruction and revival.

In this situation, the automotive industry has largely been considered a major center of economic opportunity because of its economic impact. All over the Tohoku region but especially in Miyagi prefecture, the expectation for the automotive industry is enormous. Emblematic of this expectation is the recent startup of the Toyota Motor East Corporation.

Our project the "Strategic Regional Innovation Support Program" supported by MEXT (Ministry of Education, Culture, Sports, Science and Technology) kicked off in July 2012 in order to realize the reconstruction and revival of Tohoku, through the development of new products and system by the collaborative efforts of industry, academia and government. This collaboration is primarily based on the strong and diverse R&D at Tohoku University, a leader in domestic and international education.

As a research-oriented university, Tohoku University has been involved in a number of collaborative efforts with big business but less so with smaller, local businesses. As one might assume, the importance of developing local businesses is of the highest order. Since June 2012, we have held a wide variety of events: Research information session for local business people, over thirty lectures for manpower training, more than forty laboratory tours for local business people, our researchers were invited to tour local companies, and poster presentations by all laboratories which joined in this project. These events broke down the borders separating the university from local businesses and as a result a number of new collaborations have begun to bloom.

We also understand that there are many leaders who are trying a variety of challenges to realize both global and local innovations in next generation automobiles. We are very happy to organize an international symposium on global/local innovations for next generation automobiles by inviting such worldwide leaders and design a variety of ways to realize global/local innovations in next generation automobiles. We have to emphasize that many local companies greatly contribute to this symposium in addition to leading laboratories in Tohoku University. We sincerely hope that this symposium provides opportunities to deepen our friendship and promote reconstruction and revival of Tohoku Area through a variety of challenges for the innovations in next generation automobiles.

Katsuto Nakatsuka, Project Director

Akira Miyamoto, Chairman of Research Promotion Committee

Contact

Project Office

Intelligent Cosmos Research Institute Corporation
Next Generation Automobiles Division

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Research Promotion Committee

Miyamoto Laboratory
New Industry Creation Hatchery Center, Tohoku University

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Phone: +81-22-795-7233　　FAX: +81-22-795-7235
E-mail: c_innovation@aki.niche.tohoku.ac.jp

Please visit our official website for details of the project;
www.miyagicar.com

If you have any inquiry, please contact the laboratories and companies directly. And please don't hesitate to contact the Research Promotion Committee to refer which of them may help you.

International Conference "Global/Local Innovations for Next Generation Automobiles"

Organizers: A. Miyamoto (Tohoku University), P. Kapsa (Ecole Central de Lyon),
M.C. Williams (URS Corporation), and K. Nakatsuka (Intelligent Cosmos Research Institute)

Joint Session of Eleventh International Conference on Fluid Dynamics (ICFD2014)
CS3: "Global/Local Innovations for Next Generation Automobiles"

Date: October 8(Wed) – 10(Fri), 2014
Conference Site: Sendai International Center, Sendai, Japan
Website: http://www.miyagicar.com/
http://www.ifs.tohoku.ac.jp/icfd2014/sessions/index.html

October 8 (Wed)

12:00-12:50 Lunch Meeting / Sakura 1

13:00-13:10 **Opening**
Akira Miyamoto, Philipe Kapsa, Mark C. Williams, and Katsuto Nakatsuka

14:50-15:00 Break

October 9 (Thu)

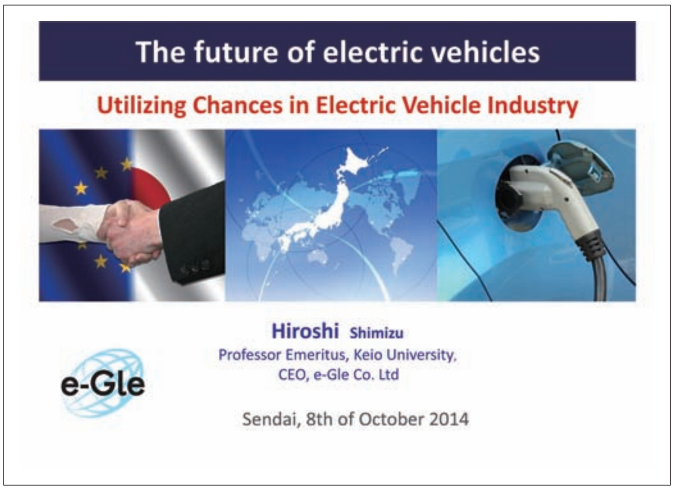
ICFD Joint Session CS3

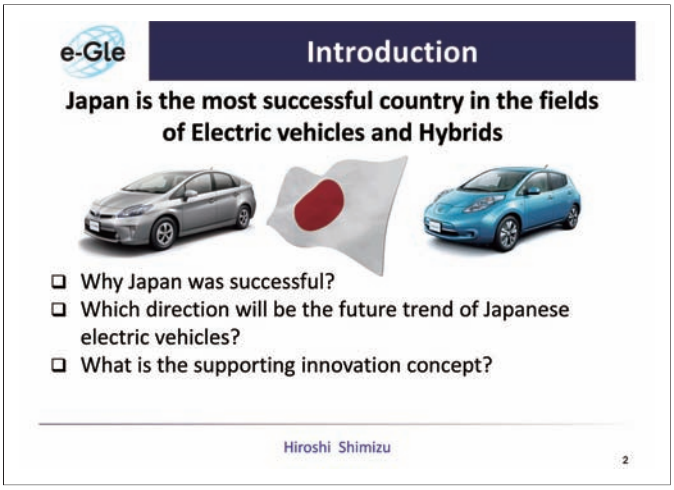
October 10 (Fri)

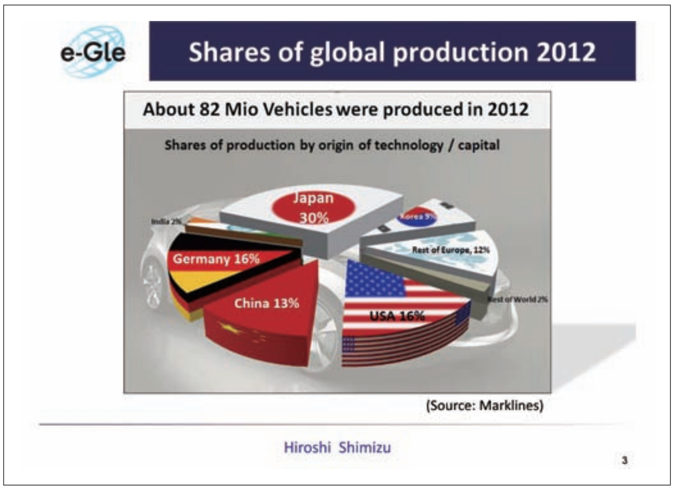
Concluding Remarks: Akira Miyamoto, Philipe Kapsa, Mark C. Williams, and Katsuto Nakatsuka

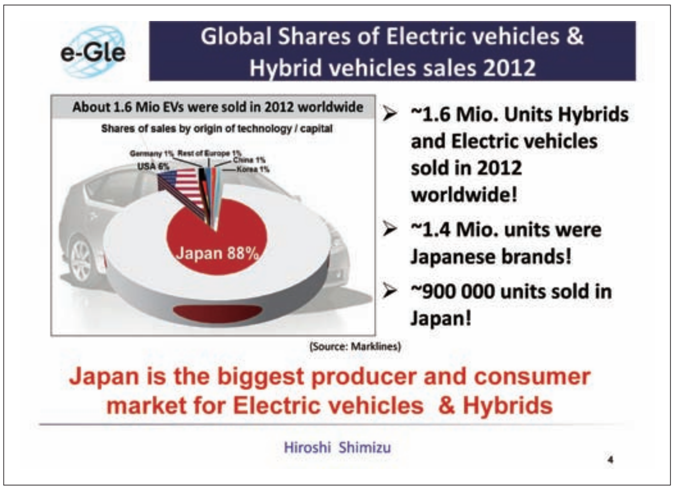
The future of electric vehicles

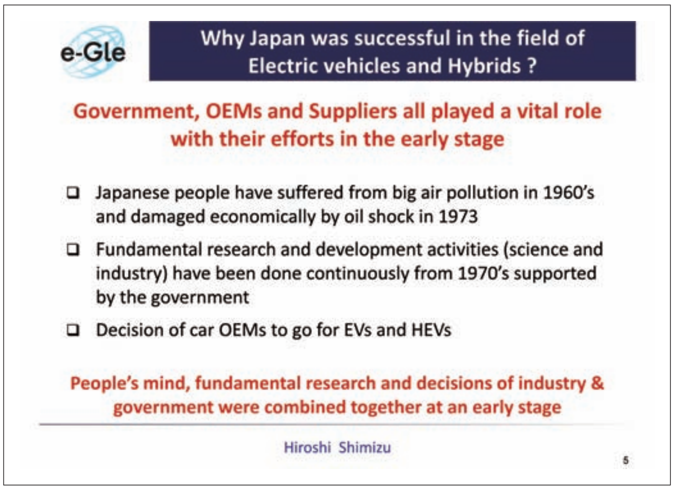
Hiroshi Shimizu
CEO, e-Gle Ltd. & Professor, Keio University, Japan

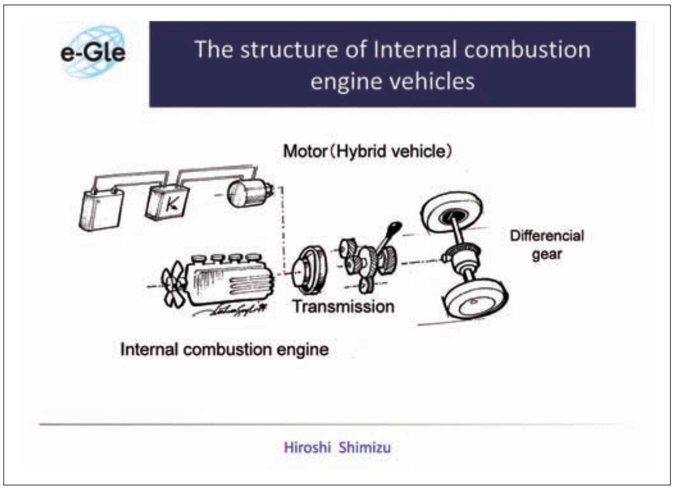




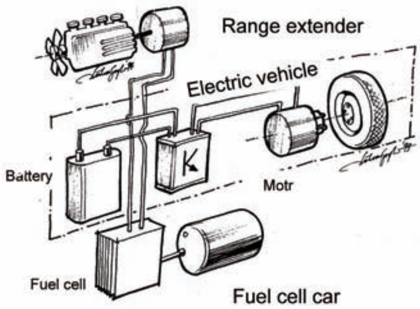






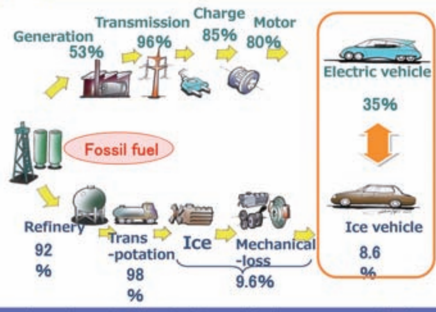


The structure of Electric vehicles



Hiroshi Shimizu

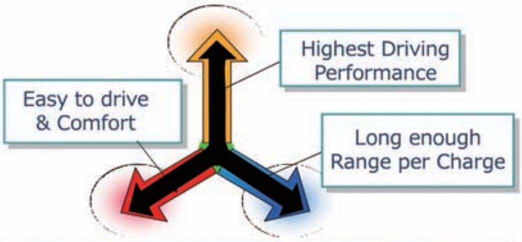
Efficiency of ICE and Electric vehicles



Why electric vehicles? Very high energy efficiency.

Hiroshi Shimizu

The value of outstanding electric vehicles everyone want to buy



Realize by the performance of components and the structure of the vehicle.

Hiroshi Shimizu

Which technology will survive ?

Not necessarily the "best" technical solution survives!

Other Key Success Factors have to be met

- **Consumer orientated** - usability, service etc.
- **Production orientated** - low production costs, easy to make etc.
- **High efficiency** - running costs, energy consumption etc.

Technologies succeeded as a combination of these factors: LCD display (against plasma), ICE & TGV against Linear Magnet

Hiroshi Shimizu

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Evaluation of technology

	HEV	EV		
		Pure battery	Range Extender	Fuel cell
Usability	+++	++	+++	+
Efficiency	++	+++	+++	++
Simplicity	++	+++	+++	+

Hiroshi Shimizu

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Future trend of Electric vehicles.

- The evaluation of technology shows that currently EVs with range extender seems to be most promising.

BMW i3

- In-wheel motor has a 30 % higher efficiency than the conventional drive system.
- Only considering optimization of total drive system will create the best electric vehicle

Li-Ion Battery, Ne-Fe Magnet, IGBT invented and developed so far are enough to realize the high-performing EV

Hiroshi Shimizu

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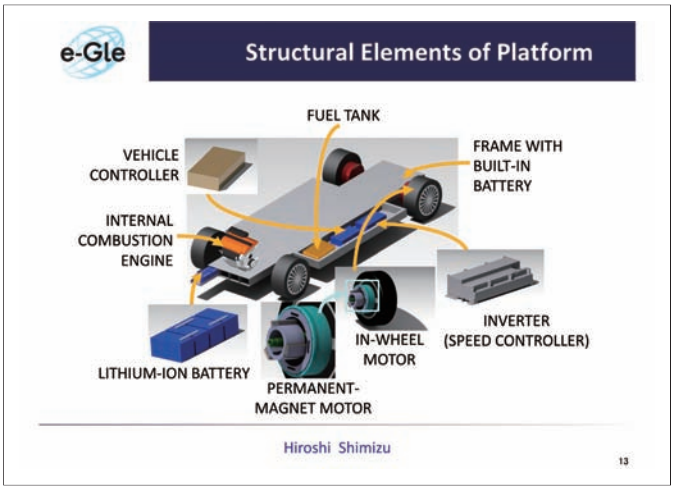
e-Gle
Structural Elements of Platform
FUEL TANK
VEHICLE CONTROLLER
FRAME WITH BUILT-IN BATTERY
INTERNAL COMBUSTION ENGINE
INVERTER (SPEED CONTROLLER)
IN-WHEEL MOTOR
LITHIUM-ION BATTERY
PERMANENT-MAGNET MOTOR
Hiroshi Shimizu
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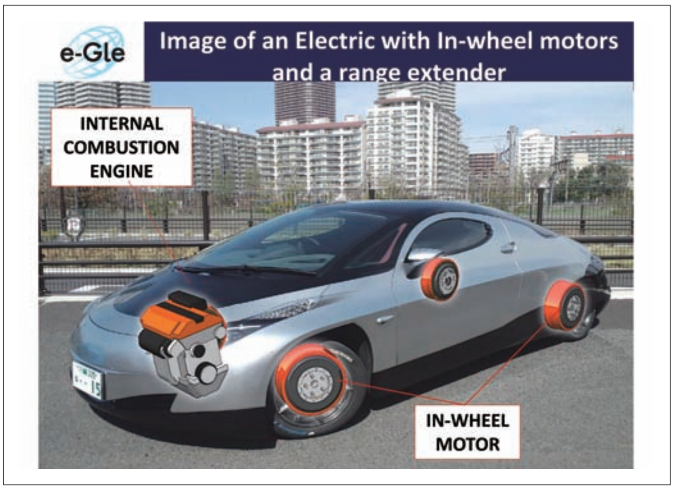
e-Gle
Image of an Electric with In-wheel motors and a range extender
INTERNAL COMBUSTION ENGINE
IN-WHEEL MOTOR


e-Gle
What is the next step of electric vehicles ?
The automated driving.
Electric vehicles should be driven without drivers.
❑ Avoid accidents and traffic jam.
❑ Save the time for traffics.
❑ Everyone can go anytime and anywhere.
Hiroshi Shimizu
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e-Gle
Final Target
❑ Developing the next generation vehicle
– High performing and environmental friendly
– Capability have to enough to be accepted in the society
❑ Distribute the vehicle to all over the world
❑ People in the world should have comfortable mobility and sustainable environment
Collaboration among all the people in the world
are the key of developing mobility for the global future
Hiroshi Shimizu
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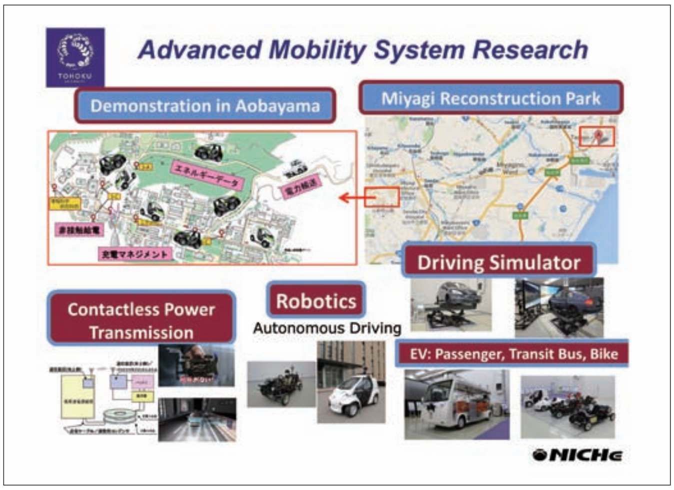
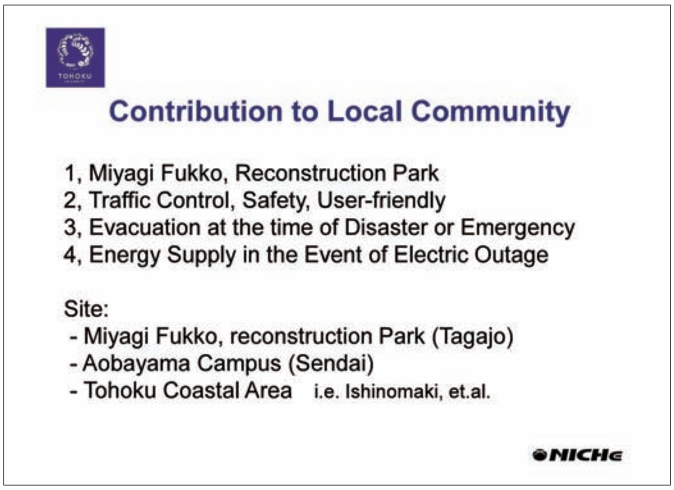
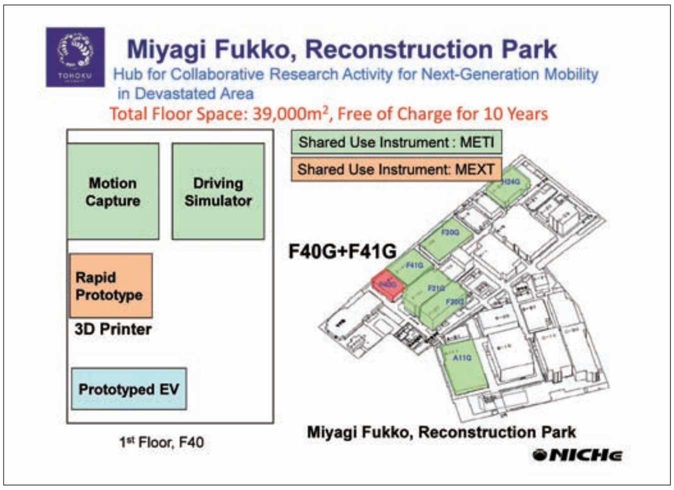
Next-Generation Advanced Mobility System
- Promotional activities supporting local industries -

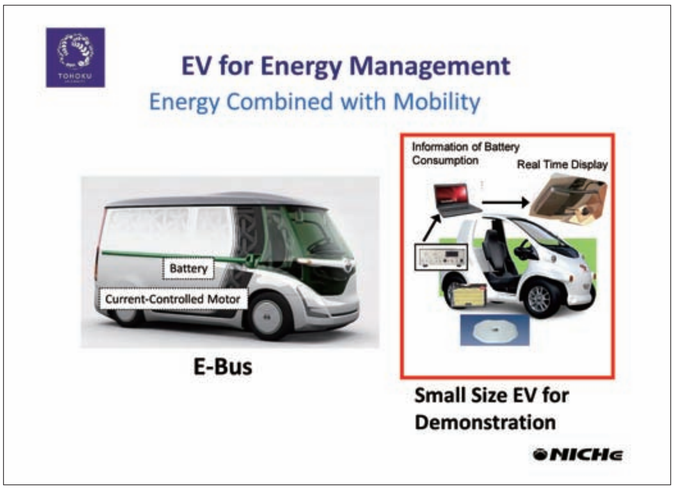
Fumihiko Hasegawa

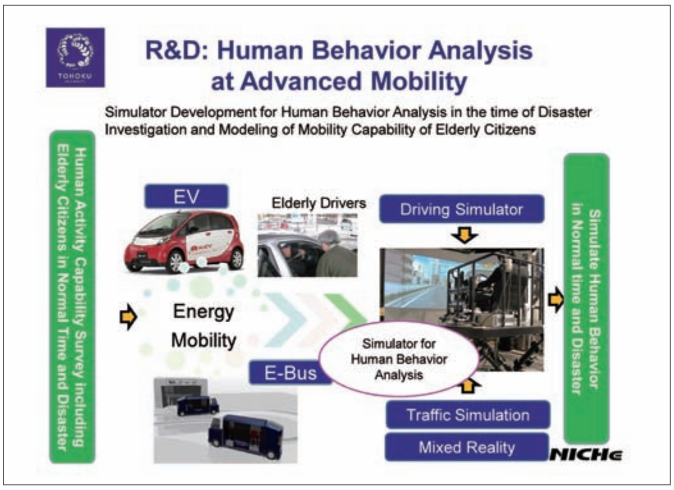
Professor, Deputy Director, New Industry Creation Hatchery Center, Tohoku University, Japan

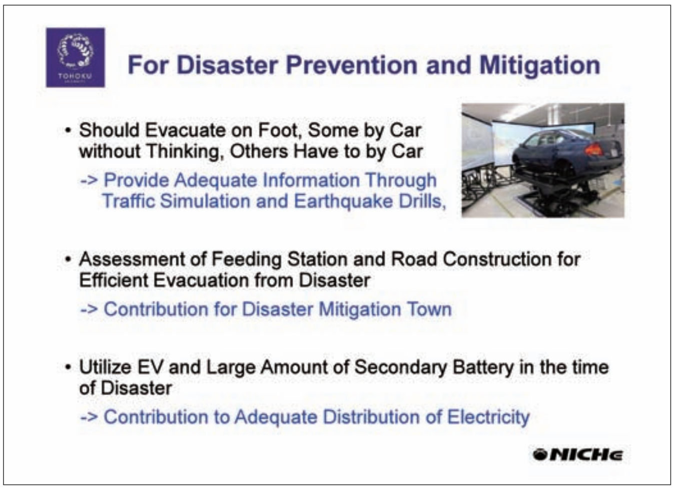






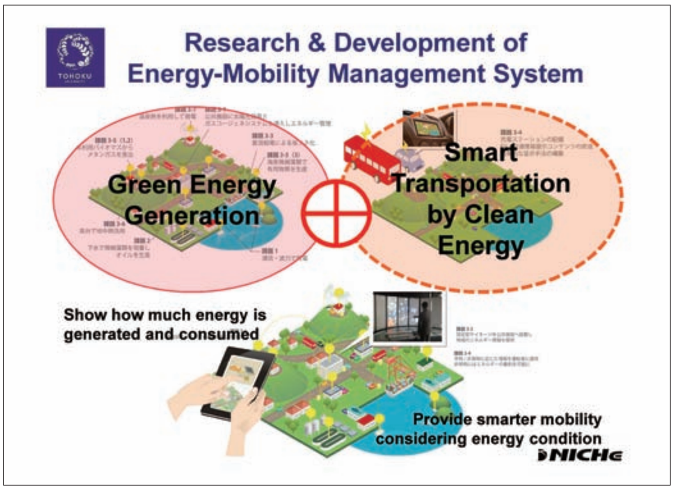

EV for Energy Management
Energy Combined with Mobility
Battery
Current-Controlled Motor
E-Bus
Information of Battery Consumption
Real Time Display
Small Size EV for Demonstration
NICHe

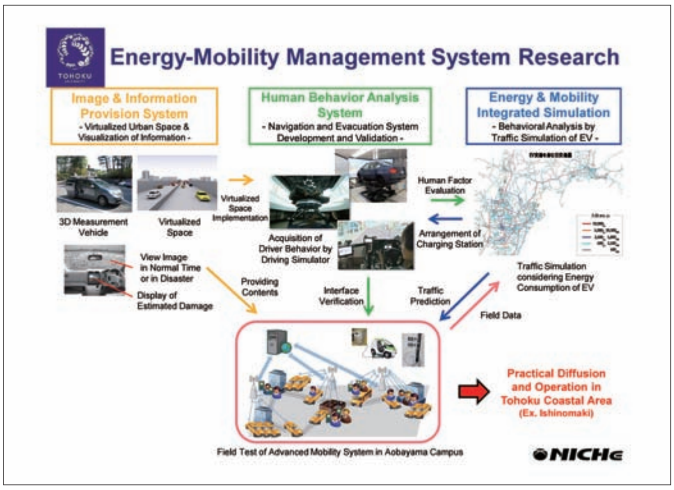

R&D: Human Behavior Analysis at Advanced Mobility
Simulator Development for Human Behavior Analysis in the time of Disaster
Investigation and Modeling of Mobility Capability of Elderly Citizens
Human Activity Capability Survey including Elderly Citizens in Normal Time and Disaster
EV
Elderly Drivers
Driving Simulator
Energy
Mobility
Simulator for Human Behavior Analysis
E-Bus
Traffic Simulation
Mixed Reality
Simulate Human Behavior in Normal time and Disaster
NICHe


For Disaster Prevention and Mitigation
• Should Evacuate on Foot, Some by Car without Thinking, Others Have to by Car
-> Provide Adequate Information Through Traffic Simulation and Earthquake Drills,
• Assessment of Feeding Station and Road Construction for Efficient Evacuation from Disaster
-> Contribution for Disaster Mitigation Town
• Utilize EV and Large Amount of Secondary Battery in the time of Disaster
-> Contribution to Adequate Distribution of Electricity
NICHe

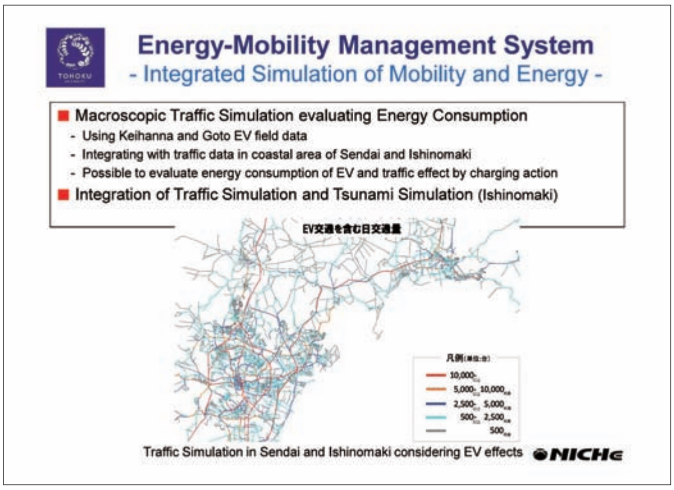

Visits for Restoration Model within and outside of the country
• Receiving inspection groups from countries in reconstruction by JICA
2013: Somali Democratic Republic (Africa)
2014: Republic of Mali (Africa)
Somali Democratic Republic (Africa)
Republic of Mali (Africa)
NICHe

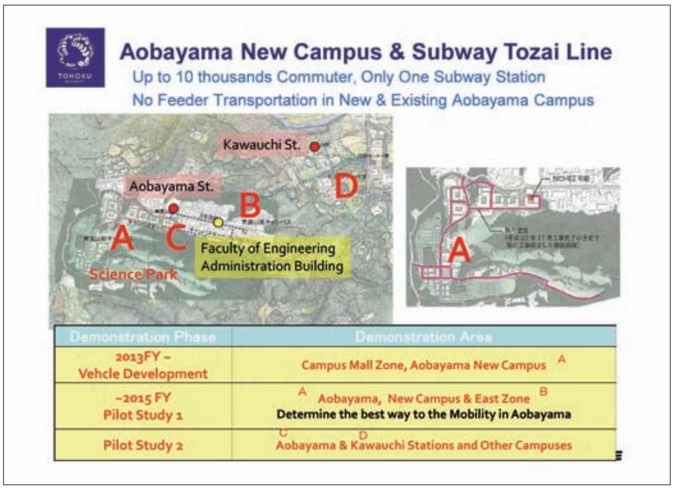

Advanced Mobility Research Integration
R&D with Local Industries
Traffic Simulation and Management
Human Behavior Analysis
ITS
Miyagi Fukko, Reconstruction Park
Demonstration of Traffic System
Personal Information
Driving Simulator
Next-Generation Mobility
Road Information
Vehicle Information
Energy Mobility Management System
Aobayama Campus
Energy Information
Traffic Information
EV, E-Bus
Mode Change in Disaster (Energy Supply from EV)
Ishinomaki City
Total Energy Management in Urban Area
Wireless Charging Station

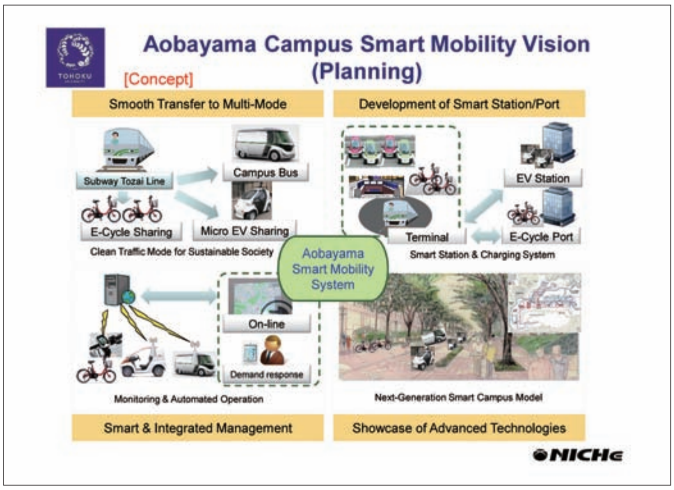

Research & Development of Energy-Mobility Management System
Green Energy Generation
Smart Transportation by Clean Energy
Show how much energy is generated and consumed
Provide smarter mobility considering energy condition
NICHe


Energy-Mobility Management System Research
Image & Information Provision System
- Virtualized Urban Space & Visualization of Information -
Human Behavior Analysis System
- Navigation and Evacuation System Development and Validation -
Energy & Mobility Integrated Simulation
- Behavioral Analysis by Traffic Simulation of EV -
3D Measurement Vehicle
Virtualized Space
Virtualized Space Implementation
Human Factor Evaluation
View Image in Normal Time or in Disaster
Display of Estimated Damage
Acquisition of Driver Behavior by Driving Simulator
Arrangement of Charging Station
Traffic Simulation considering Energy Consumption of EV
Providing Contents
Interface Verification
Traffic Prediction
Field Data
Practical Diffusion and Operation in Tohoku Coastal Area
(Ex. Ishinomaki)
Field Test of Advanced Mobility System in Aobayama Campus
NICHe

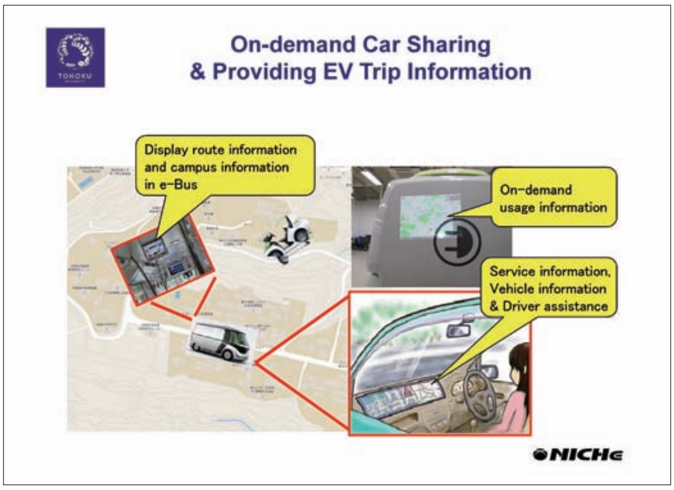

Research & Development of
Energy-Mobility Management System
Field Experiments in Aobayama Campus
Develop to Coastal Area (Ishinomaki, etc.)
Autonomous Driving of Efficient Micro EV
3D environmental sensing
Development of Mode-Changeable EV
Supply Energy from EV in Emergency
Wireless Charging Station
NICHe

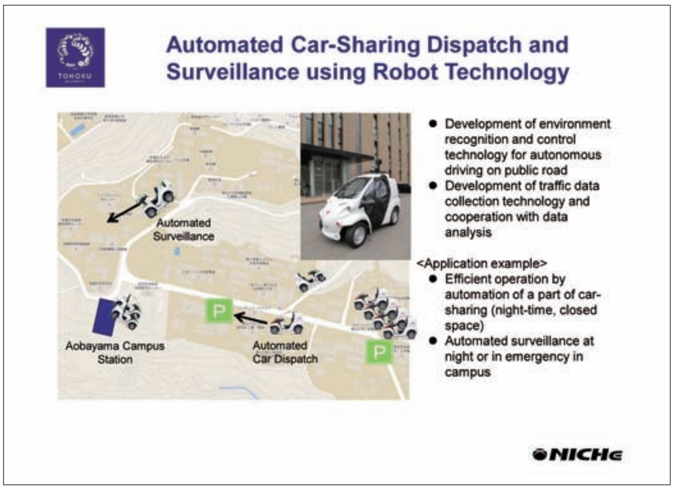

Energy-Mobility Management System
- Integrated Simulation of Mobility and Energy -
Macroscopic Traffic Simulation evaluating Energy Consumption
- Using Keihanna and Goto EV field data
- Integrating with traffic data in coastal area of Sendai and Ishinomaki
- Possible to evaluate energy consumption of EV and traffic effect by charging action
Integration of Traffic Simulation and Tsunami Simulation (Ishinomaki)
Traffic Simulation in Sendai and Ishinomaki considering EV effects
NICHe

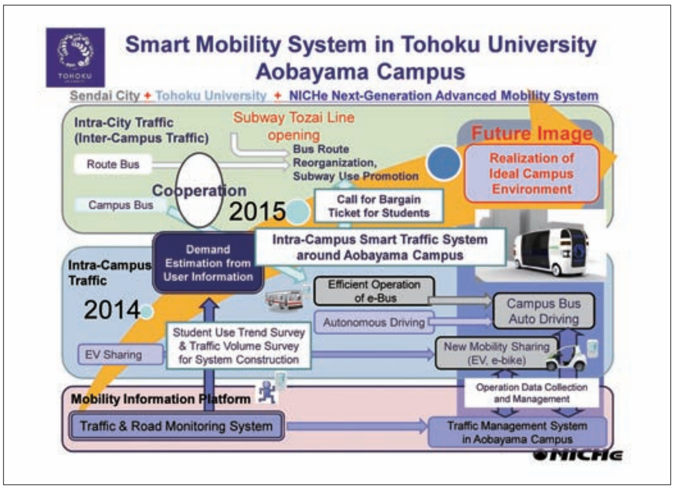

Aobayama New Campus & Subway Tozai Line
Up to 10 thousands Commuter, Only One Subway Station
No Feeder Transportation in New & Existing Aobayama Campus
Kawauchi St.
Aobayama St.
Faculty of Engineering Administration Building
Science Park
A
B
C
D
Demonstration Phase
Demonstration Area
2013FY ~ Vehcle Development
Campus Mall Zone, Aobayama New Campus
~2015 FY Pilot Study 1
Aobayama, New Campus & East Zone
Determine the best way to the Mobility in Aobayama
Pilot Study 2
Aobayama & Kawauchi Stations and Other Campuses


Aobayama Campus Smart Mobility Vision
[Concept] (Planning)
Smooth Transfer to Multi-Mode
Development of Smart Station/Port
Subway Tozai Line
Campus Bus
E-Cycle Sharing
Micro EV Sharing
Clean Traffic Mode for Sustainable Society
EV Station
Terminal
E-Cycle Port
Smart Station & Charging System
Aobayama Smart Mobility System
On-line
Demand response
Monitoring & Automated Operation
Next-Generation Smart Campus Model
Smart & Integrated Management
Showcase of Advanced Technologies
NICHe


NICHe
Subway Station:
As a Hub for Next Generation Mobility
E-Bus, EV Sharing and Management
Bike Sharing
Co-creating Optimum Mobility with Community
Experience of Advanced Mobility
NICHe


On-demand Car Sharing
& Providing EV Trip Information
Display route information and campus information in e-Bus
On-demand usage information
Service information, Vehicle information & Driver assistance
NICHe

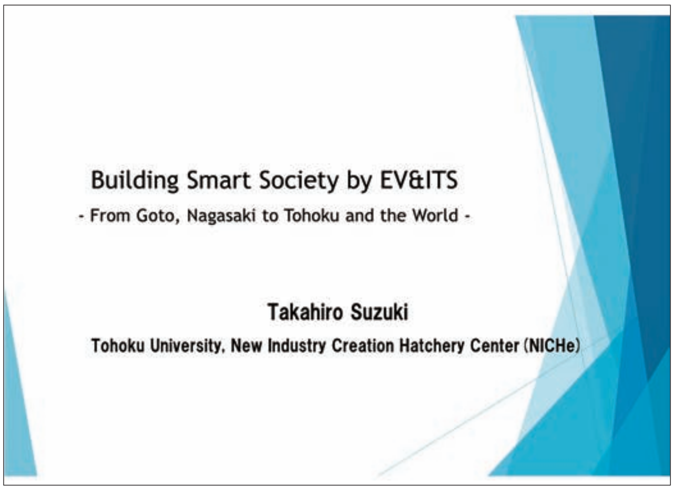

Automated Car-Sharing Dispatch and Surveillance using Robot Technology
Automated Surveillance
Aobayama Campus Station
Automated Car Dispatch
● Development of environment recognition and control technology for autonomous driving on public road
● Development of traffic data collection technology and cooperation with data analysis
<Application example>
● Efficient operation by automation of a part of car-sharing (night-time, closed space)
● Automated surveillance at night or in emergency in campus
NICHe

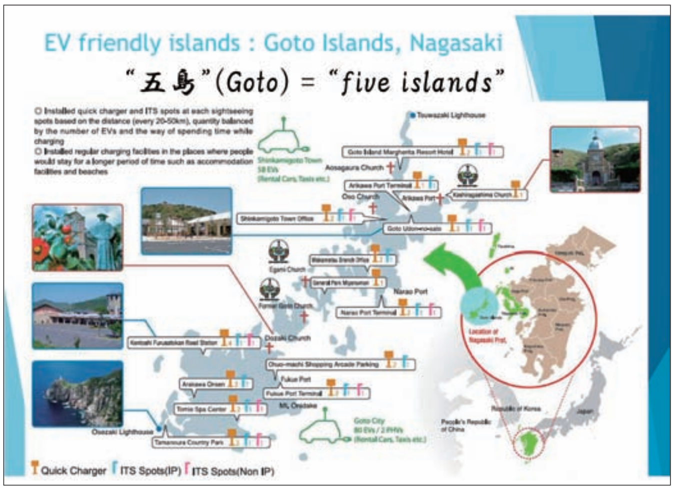

Smart Mobility System in Tohoku University Aobayama Campus
Sendai City + Tohoku University + NICHe Next-Generation Advanced Mobility System
Intra-City Traffic (Inter-Campus Traffic)
Subway Tozai Line opening
Bus Route Reorganization, Subway Use Promotion
Route Bus
Campus Bus
Cooperation
2015
Call for Bargain Ticket for Students
Future Image
Realization of Ideal Campus Environment
Intra-Campus Traffic
Demand Estimation from User Information
Intra-Campus Smart Traffic System around Aobayama Campus
2014
Efficient Operation of e-Bus
Autonomous Driving
Campus Bus Auto Driving
EV Sharing
Student Use Trend Survey & Traffic Volume Survey for System Construction
New Mobility Sharing (EV, e-bike)
Operation Data Collection and Management
Mobility Information Platform
Traffic & Road Monitoring System
Traffic Management System in Aobayama Campus
NICHe

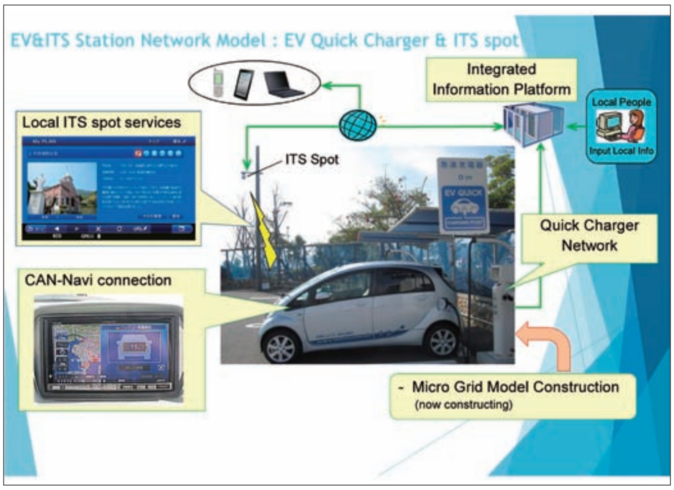
Building Smart Society by EV&ITS
- From Goto, Nagasaki to Tohoku and the World -

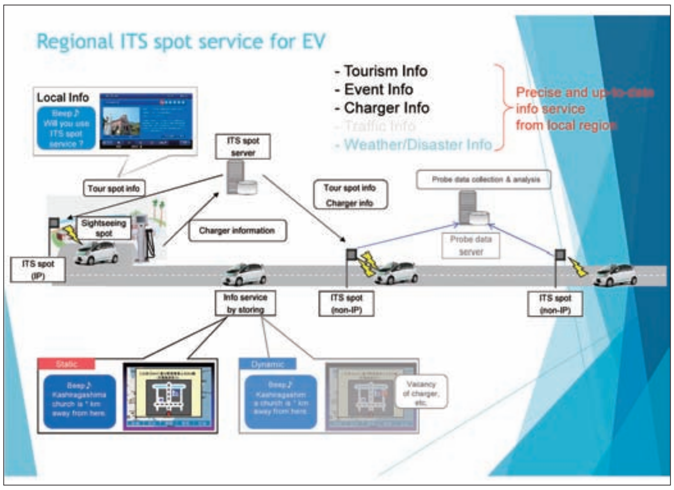
Takahiro Suzuki

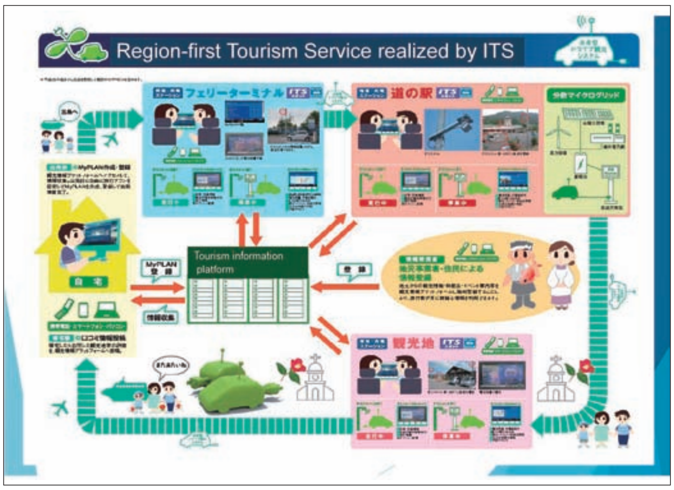
Professor, Deputy Director, New Industry Creation Hatchery Center, Tohoku University, Japan

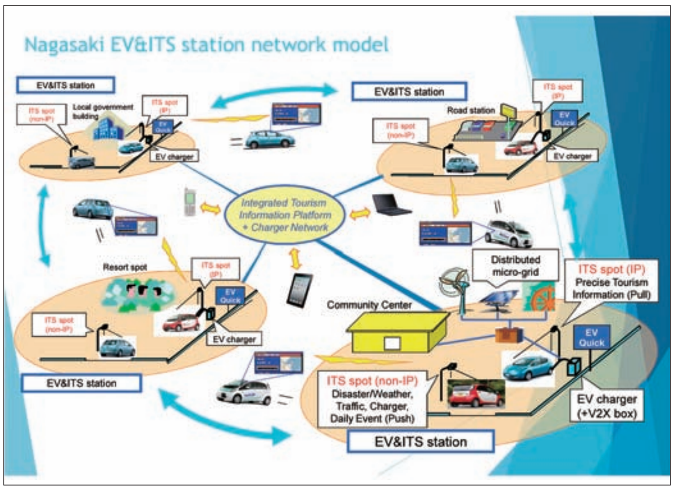


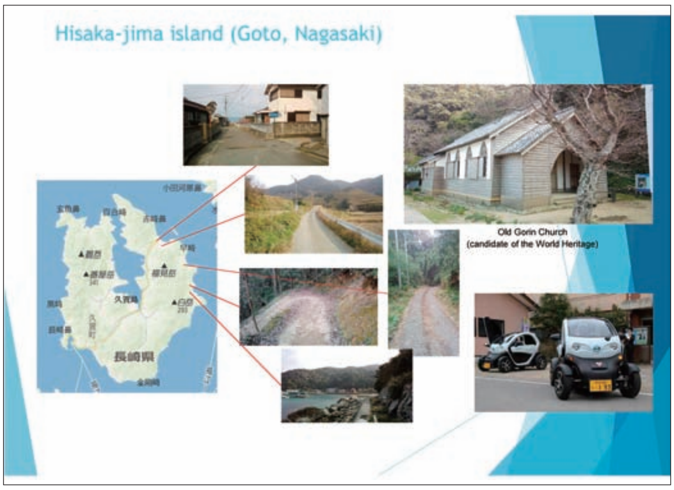


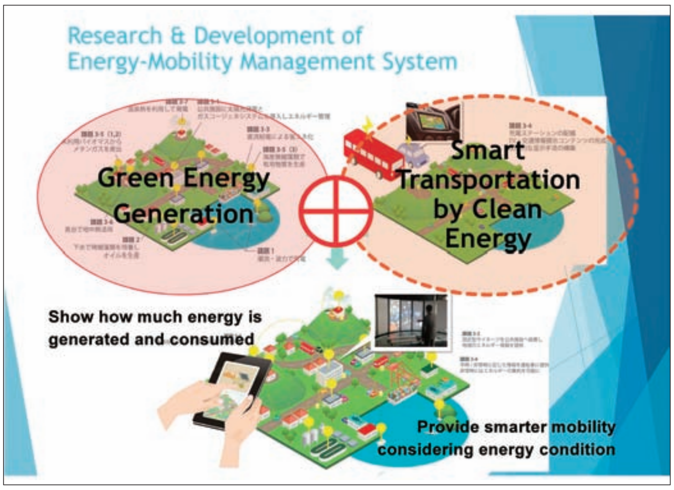


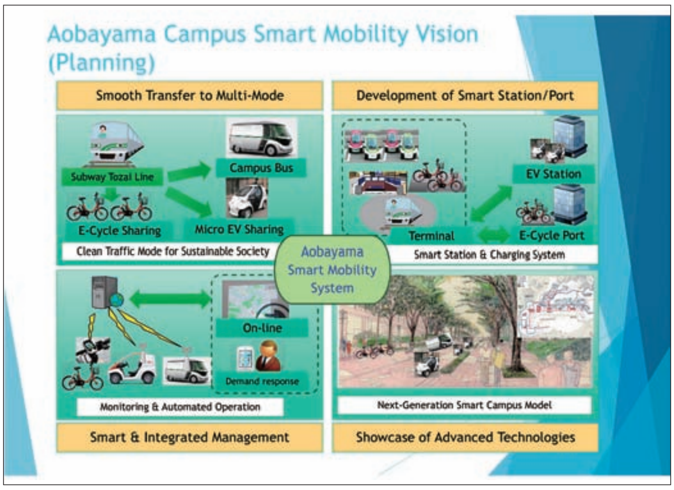







Hisaka-jima island (Goto, Nagasaki)
長崎県
Old Gorin Church
(candidate of the World Heritage)


Research & Development of
Energy-Mobility Management System
Green Energy
Generation
Smart
Transportation
by Clean
Energy
Show how much energy is
generated and consumed
Provide smarter mobility
considering energy condition


Aobayama Campus Smart Mobility Vision
(Planning)
Smooth Transfer to Multi-Mode
Development of Smart Station/Port
Subway Tozai Line
Campus Bus
E-Cycle Sharing
Micro EV Sharing
Clean Traffic Mode for Sustainable Society
EV Station
Terminal
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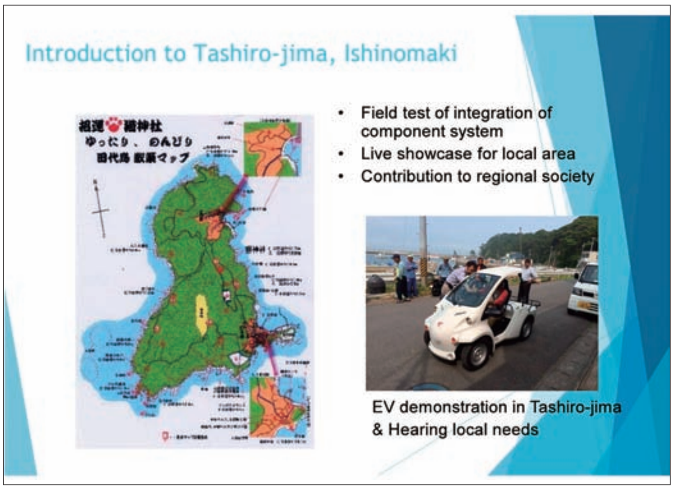
Smart Station & Charging System
Aobayama
Smart Mobility
System
On-line
Demand response
Monitoring & Automated Operation
Next-Generation Smart Campus Model
Smart & Integrated Management
Showcase of Advanced Technologies

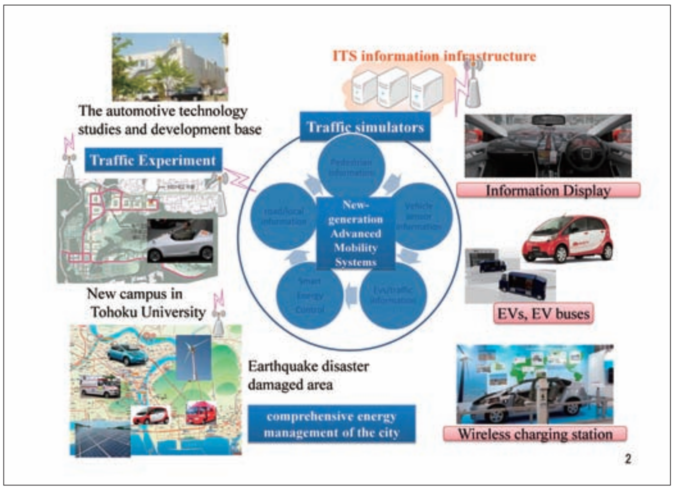

Introduction to Tashiro-jima, Ishinomaki
• Field test of integration of component system
• Live showcase for local area
• Contribution to regional society
EV demonstration in Tashiro-jima
& Hearing local needs

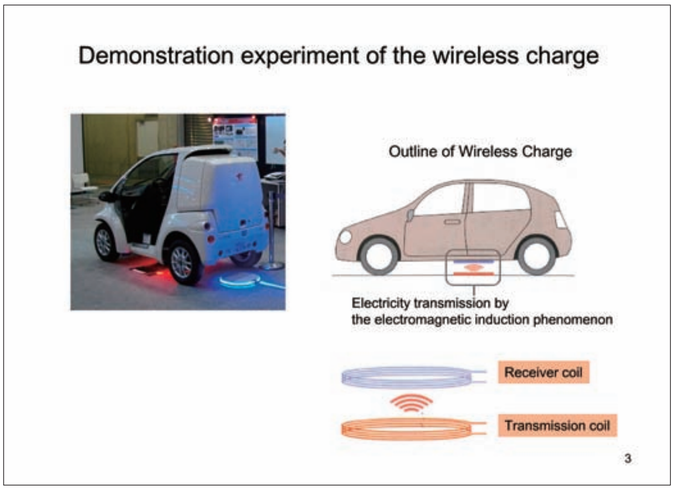

EV car-sharing in Tohoku area

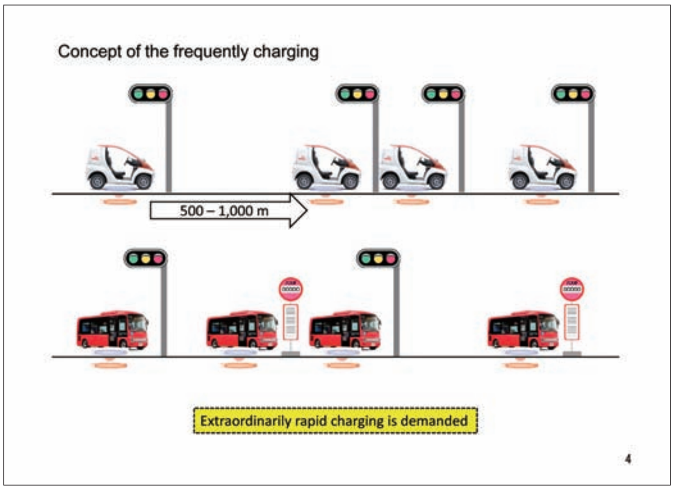

Goto Eco-Island Image
World Heritage
Candidate Churches
Eco-Island of the Future:
Energies are Locally
Produced and Consumed
Electric Farming Machines
and Solar Chargers
Mt.Oni
Goto Cattle & Goto Pig
Offshore Wind Tower
Flower Blooming Road
by Zero Emission
EV
Wind Farm
Place in connection
with "Ryoma"
Osezaki
Lighthouse
Thank you for your kind attentions.
Beautiful Seashore
Parking with EV Chargers
EVs are charged
at sightseeing spots
Solar Electric Ship
Tuna Farm
Mega Solar Park
Information Acquiring
from ITS spots
LED Squad Fishing Boat
(Electrified)

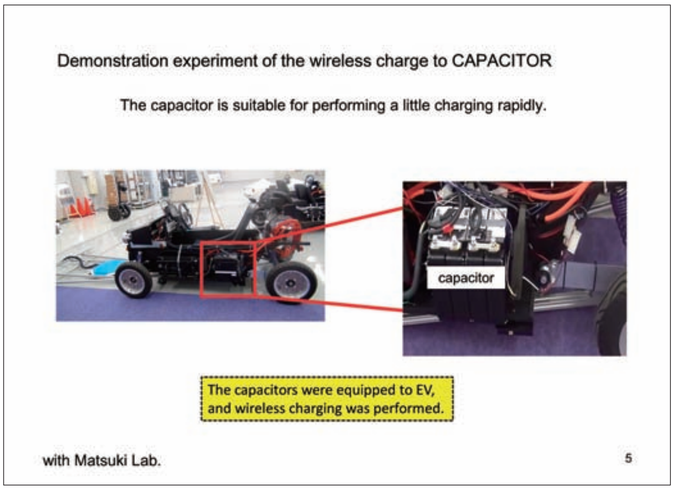
Application to Next-Generation Advanced Mobility of Wireless Charging and Information Display

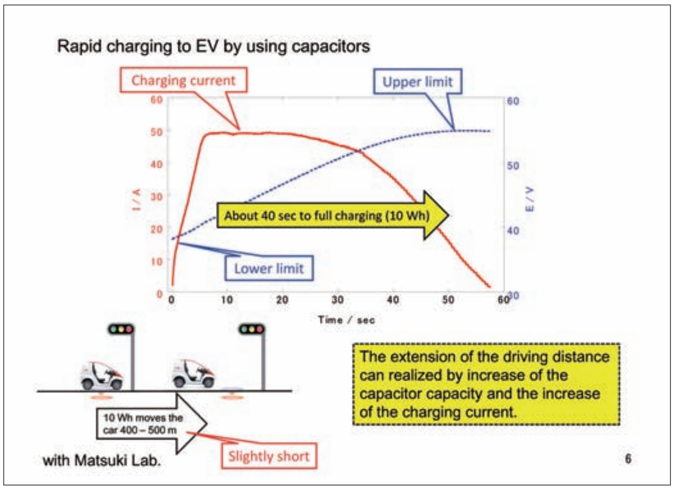
Masahiro NISHIZAWA
Associate Professor, New Industry Creation Hatchery Center, Tohoku University, Japan











Challenge to advanced information display to EV

Curved surface display on the dashboard

Display as information station

Real-time monitoring of the vehicle information

with Fujikake Lab.

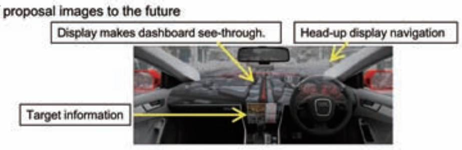
7

The actual situation and approach of the information display for cars

Head-Up display for drivers

Information display for passengers

One of proposal images to the future



8

Latent problem of the display for the car

At the time of a crash

Apparatus moves around the inside of car

Head of crew hits the apparatus on the dashboard

The display apparatus should be soft

9

Application image of the flexible display

The soft flexible display is installed on the dashboard.

The display is installed in any place in the car.
Because the softness is not spoiled,
the protection of the crew will be kept at the time of the crash.

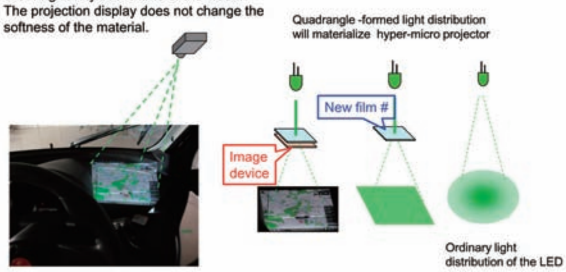
with Fujikake Lab.

10

Challenge concept of projection display

Dashboard is made of soft material, for the ensuring safety at the time of the crash.
The projection display does not change the softness of the material.

Quadrangle -formed light distribution will materialize hyper-micro projector



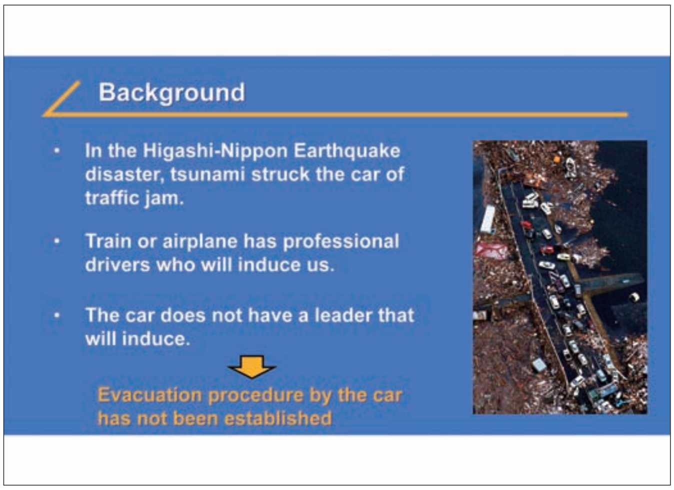
M. Nishizawa et al., *Proceedings of the 18th International Display Workshops*, (2011), 1385-1388.

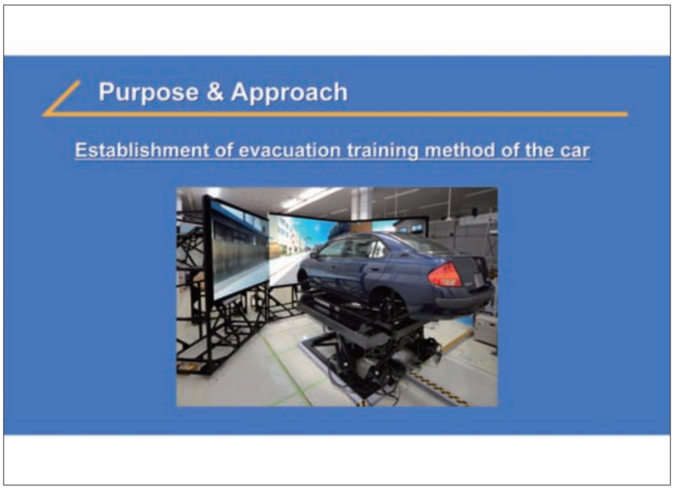
11

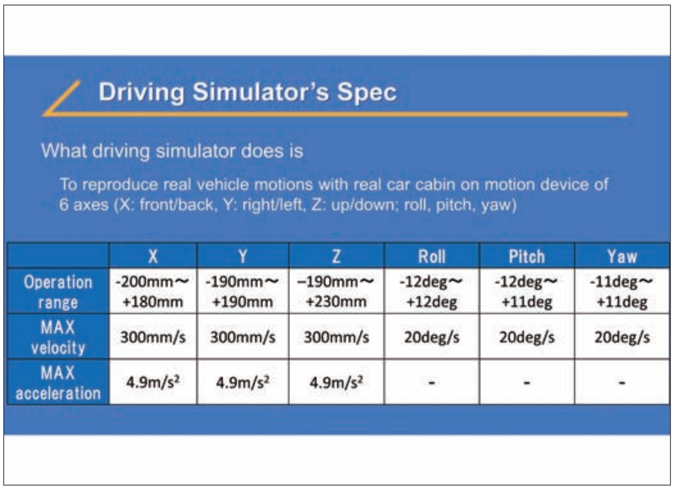
Utilizing of driving simulator for the earthquake disaster reconstruction

Shigeyuki YAMABE

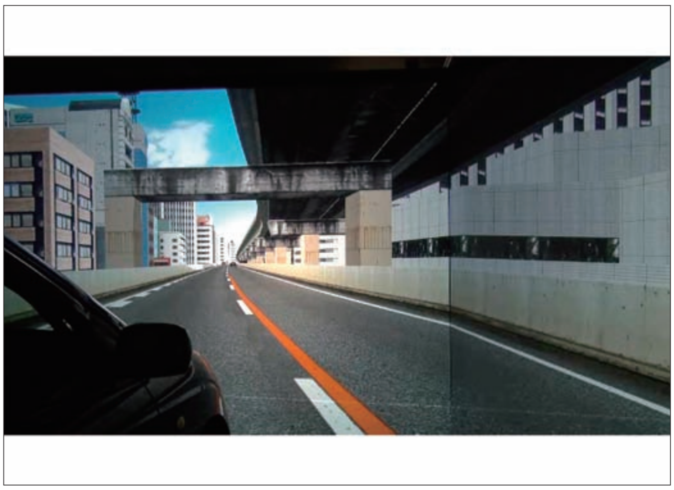
Associate Professor, New Industry Creation Hatchery Center, Tohoku University, Japan

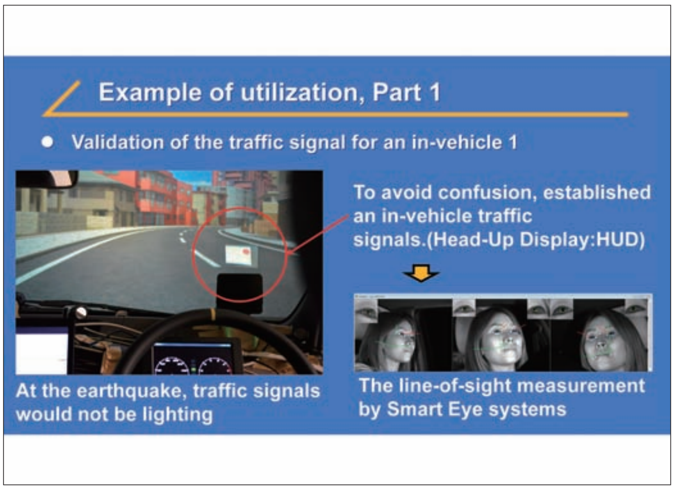


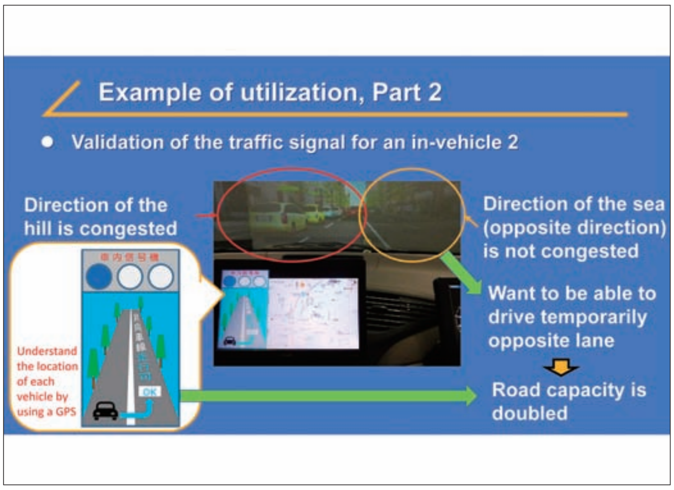


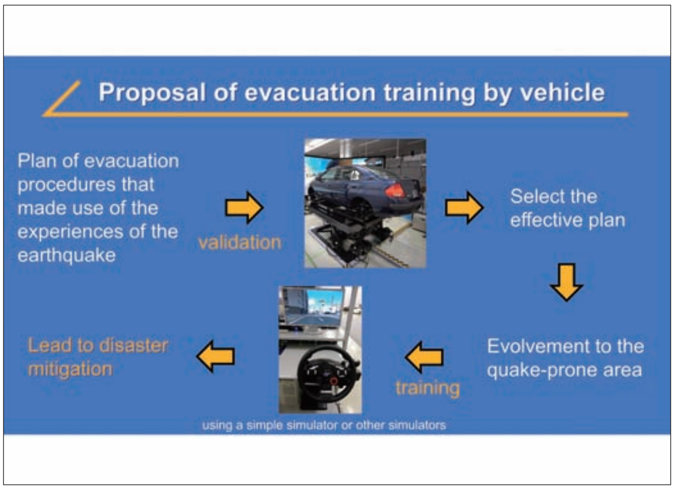


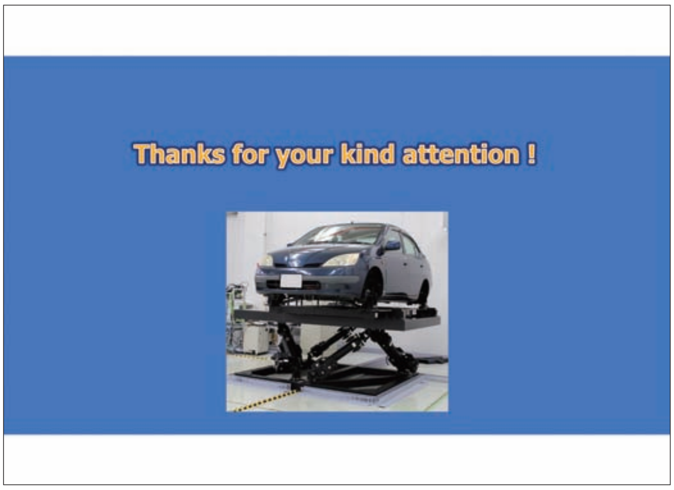
	X	Y	Z	Roll	Pitch	Yaw
Operation range	-200mm～+180mm	-190mm～+190mm	−190mm～+230mm	-12deg～+12deg	-12deg～+11deg	-11deg～+11deg
MAX velocity	300mm/s	300mm/s	300mm/s	20deg/s	20deg/s	20deg/s
MAX acceleration	4.9m/s²	4.9m/s²	4.9m/s²	-	-	-




Example of utilization, Part 1
Validation of the traffic signal for an in-vehicle 1
To avoid confusion, established an in-vehicle traffic signals.(Head-Up Display:HUD)
At the earthquake, traffic signals would not be lighting
The line-of-sight measurement by Smart Eye systems


Example of utilization, Part 2
Validation of the traffic signal for an in-vehicle 2
Direction of the hill is congested
Direction of the sea (opposite direction) is not congested
Want to be able to drive temporarily opposite lane
Understand the location of each vehicle by using a GPS
OK
Road capacity is doubled


Proposal of evacuation training by vehicle
Plan of evacuation procedures that made use of the experiences of the earthquake
validation
Select the effective plan
Evolvement to the quake-prone area
training
Lead to disaster mitigation
using a simple simulator or other simulators

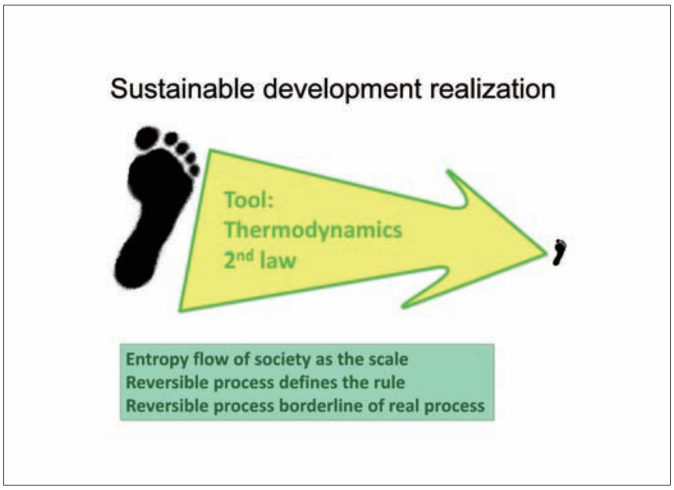

Thanks for your kind attention !

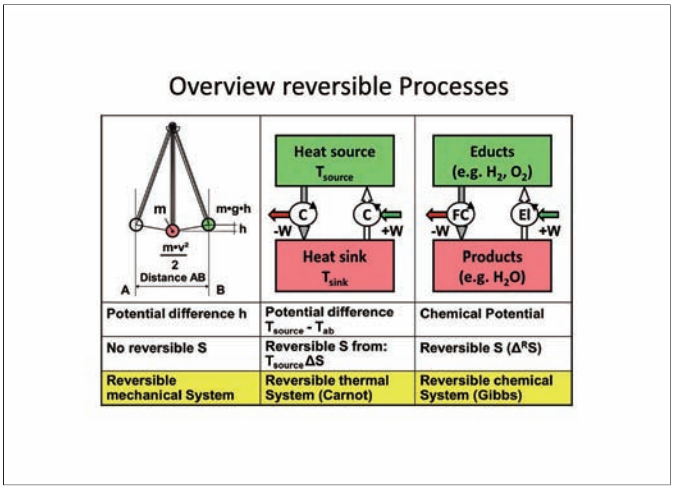
Green transportation - a challenge for European automotive industry

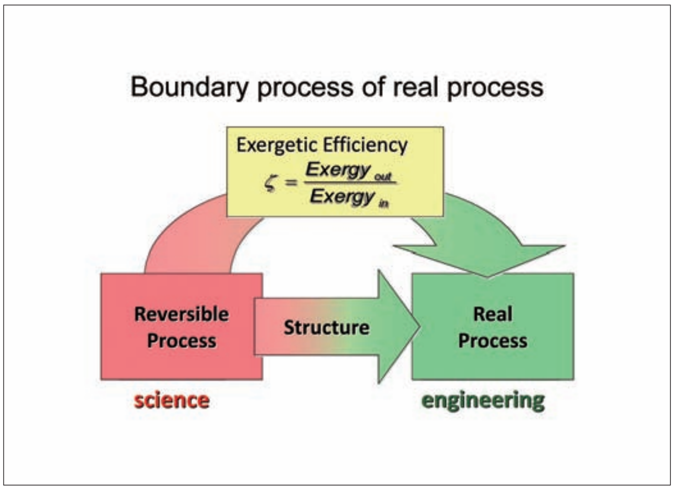
Wolfgang G. Winkler

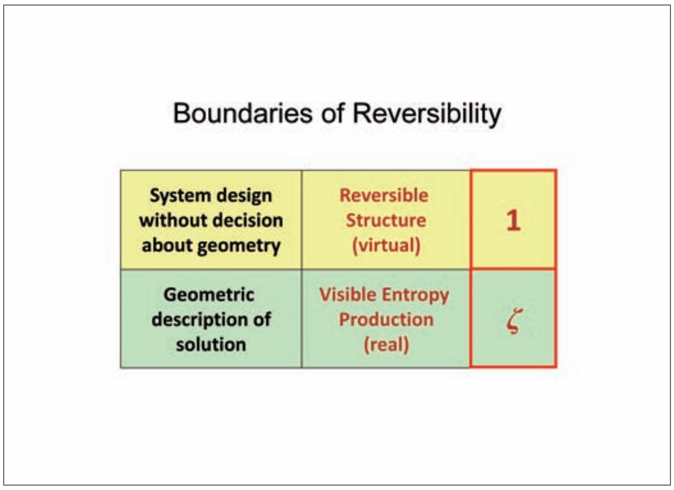
Professor, em. Director of Institute of Energy Systems and Fuel Cell Technology

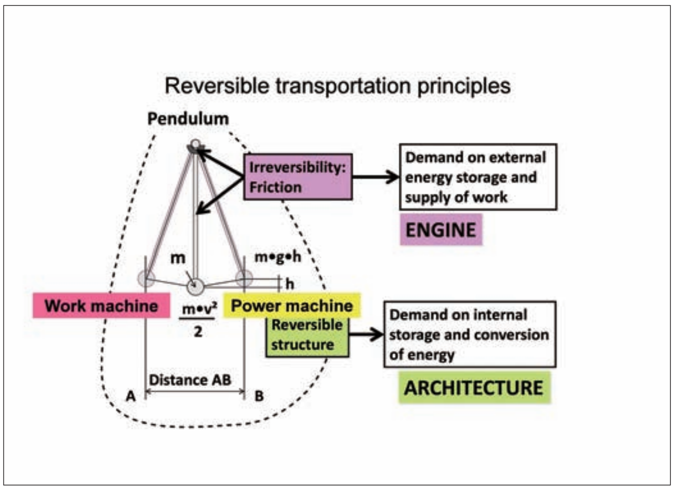
Hamburg University of Applied Sciences

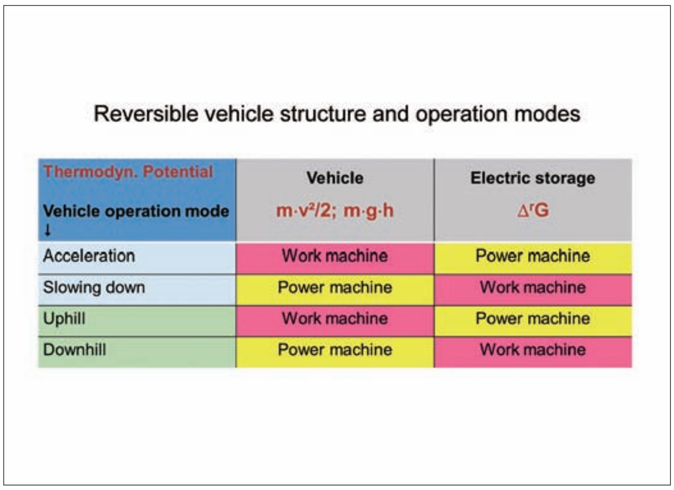


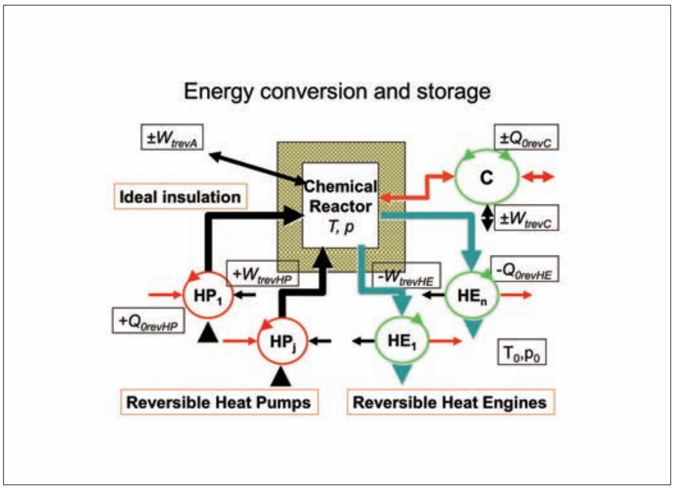


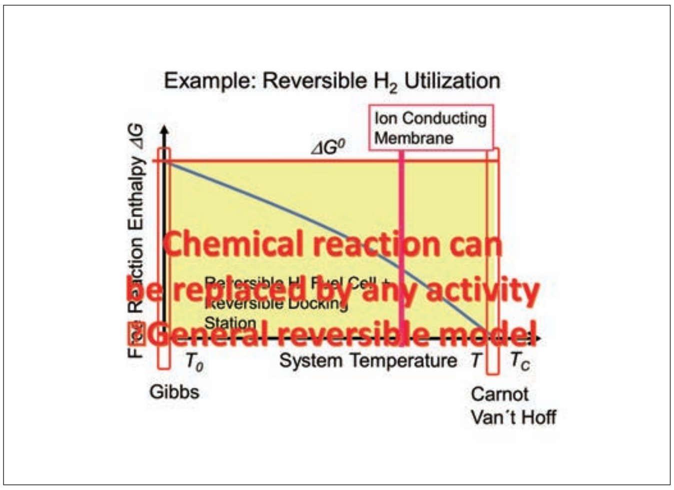


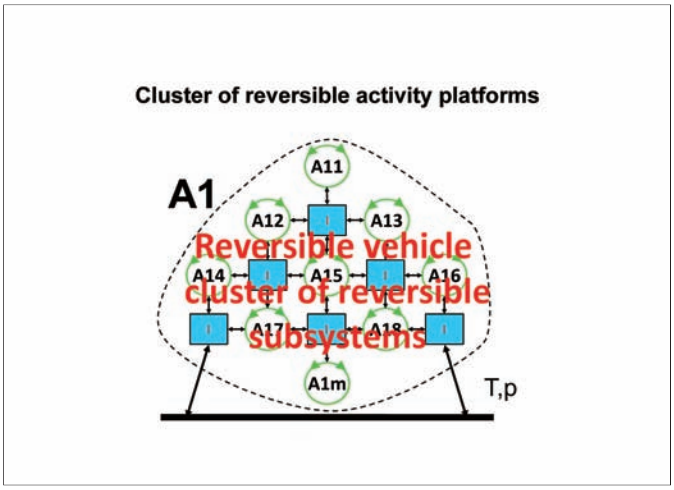


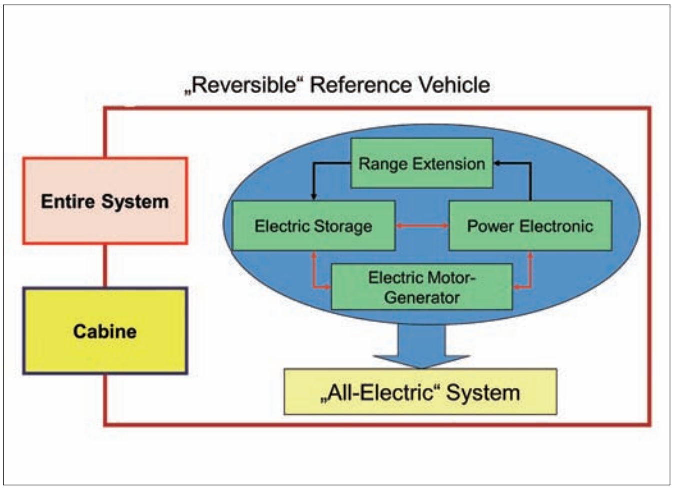


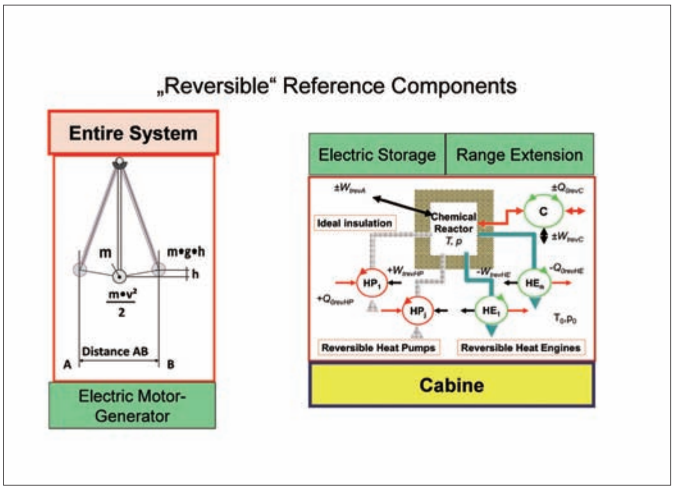


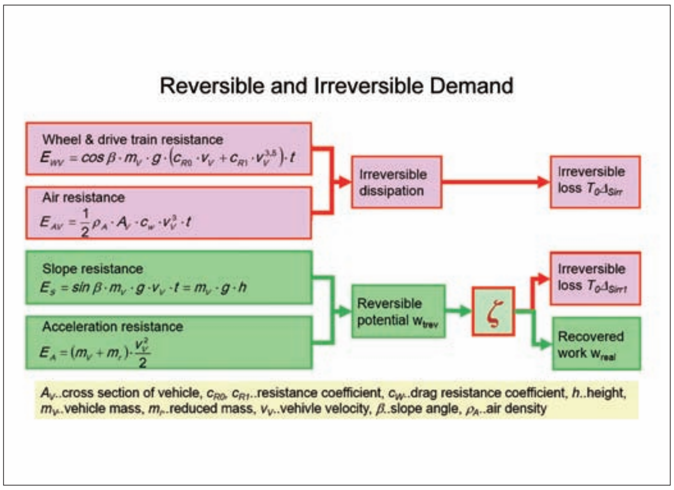

Energy conversion and storage
$\pm W_{trevA}$
$\pm Q_{0revC}$
Ideal insulation
Chemical Reactor T, p
C
$\pm W_{trevC}$
$+W_{trevHP}$
$-W_{trevHE}$
$-Q_{0revHE}$
HP_1
HE_n
$+Q_{0revHP}$
HP_j
HE_1
T_0, p_0
Reversible Heat Pumps
Reversible Heat Engines

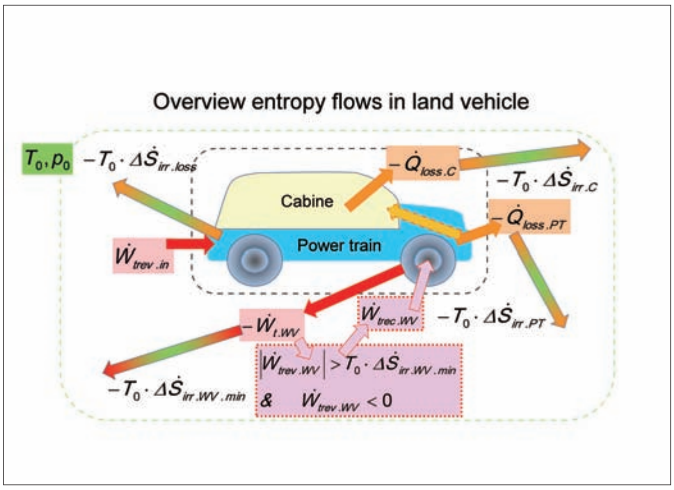

Example: Reversible H_2 Utilization
Free Reaction Enthalpy ΔG
ΔG^0
Ion Conducting Membrane
Chemical reaction can be replaced by any activity
General reversible model
Reversible H_2 Fuel Cell + Reversible Docking Station
T_0
System Temperature T
T_C
Gibbs
Carnot
Van´t Hoff


Cluster of reversible activity platforms
A1
A11
A12
A13
A14
A15
A16
A17
A18
A1m
Reversible vehicle cluster of reversible subsystems
T,p


„Reversible" Reference Vehicle
Entire System
Cabine
Range Extension
Electric Storage
Power Electronic
Electric Motor-Generator
„All-Electric" System

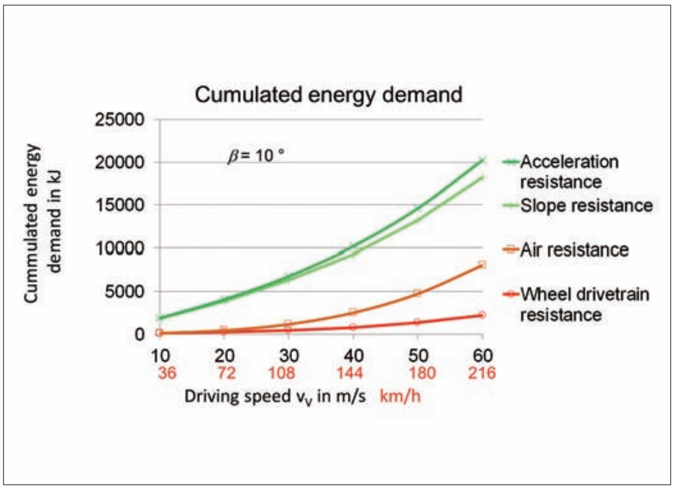

„Reversible" Reference Components
Entire System
m
m•g•h
h
m•v²/2
Distance AB
A
B
Electric Motor-Generator
Electric Storage
Range Extension
Chemical Reactor
Ideal insulation
Reversible Heat Pumps
Reversible Heat Engines
Cabine

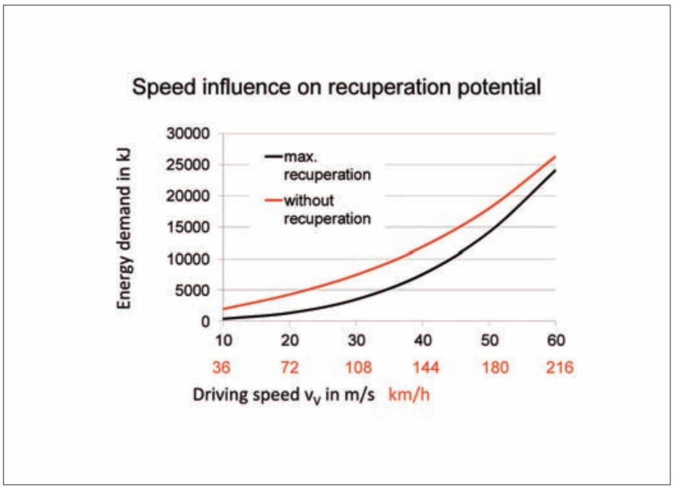

Reversible and Irreversible Demand
Wheel & drive train resistance
$E_{WV} = \cos\beta \cdot m_V \cdot g \cdot (c_{R0} \cdot v_V + c_{R1} \cdot v_V^{3,5}) \cdot t$
Air resistance
$E_{AV} = \frac{1}{2} \rho_A \cdot A_V \cdot c_w \cdot v_V^3 \cdot t$
Irreversible dissipation
Irreversible loss $T_0 \Delta_{Sirr}$
Slope resistance
$E_S = \sin\beta \cdot m_V \cdot g \cdot v_V \cdot t = m_V \cdot g \cdot h$
Acceleration resistance
$E_A = (m_V + m_r) \cdot \frac{v_V^2}{2}$
Reversible potential W_{trev}
ζ
Irreversible loss $T_0 \Delta_{Sirr1}$
Recovered work W_{real}
A_V..cross section of vehicle, c_{R0}, c_{R1}..resistance coefficient, c_W..drag resistance coefficient, h..height, m_V..vehicle mass, m_r..reduced mass, v_V..vehivle velocity, β..slope angle, ρ_A..air density

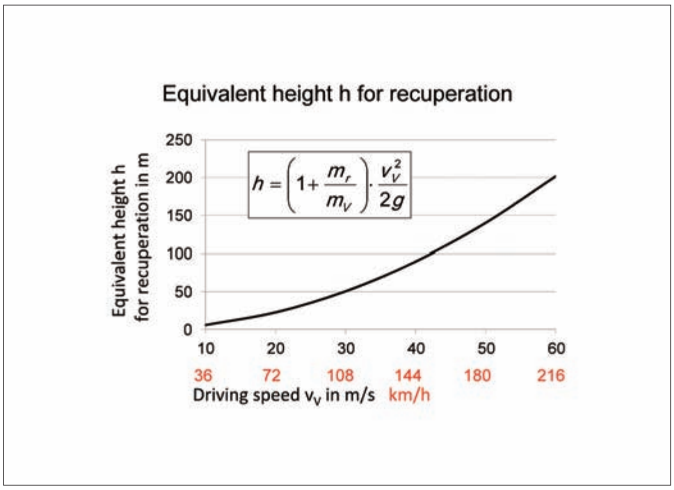


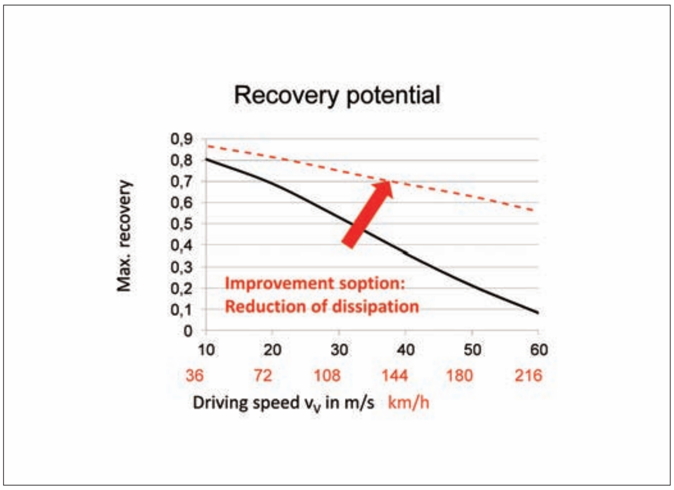
Study reference data

• Vehicle mass	m_V	1000 kg
• Reduced mass	m_r	100 kg
• Drag resistance coefficient	c_W	0,25
• Cross section	A_V	1,8 m²
• Resistance coefficient	c_{R0}	0,01
• Resistence coefficient	c_{R1}	0,000001
• Mission term	t	100 s
• Slope angle	□	10°

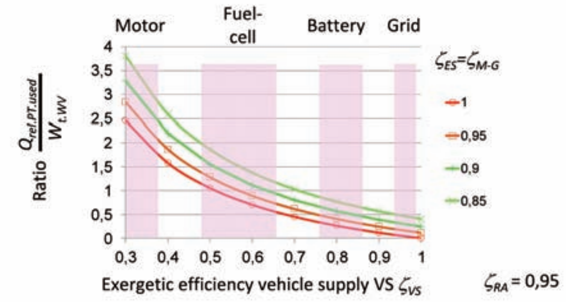




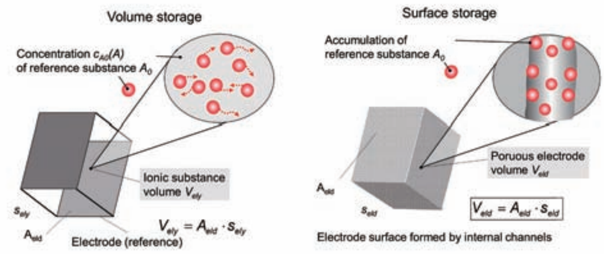




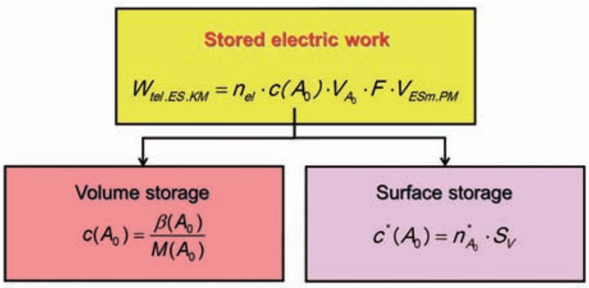
Heat supply for cabine



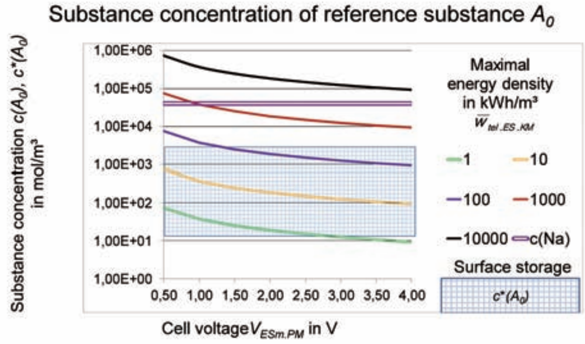
Storage structures



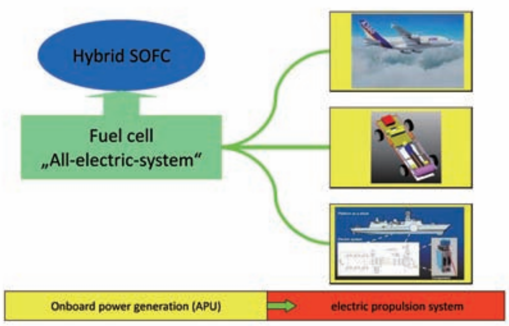
Principal electrical storage processes



Substance concentration of reference substance A_0

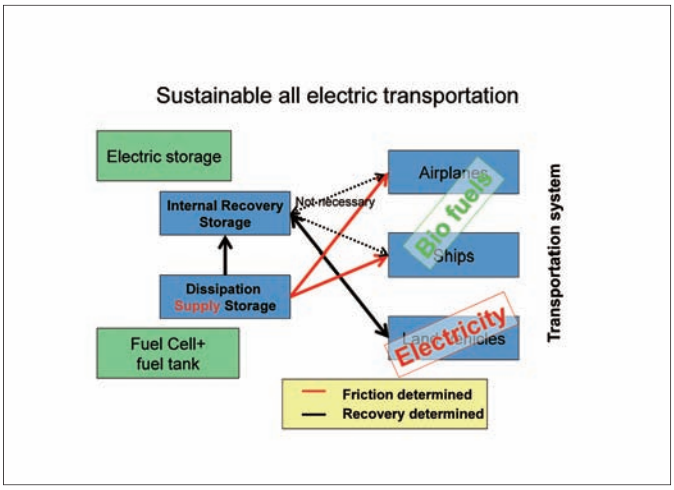


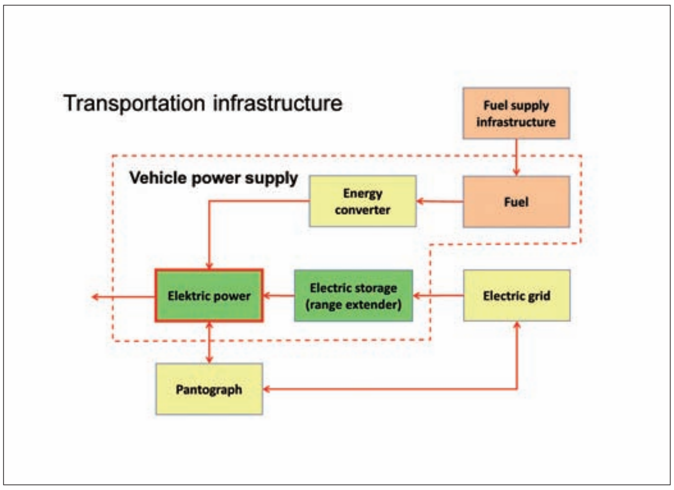
„All-electric" transportation systems

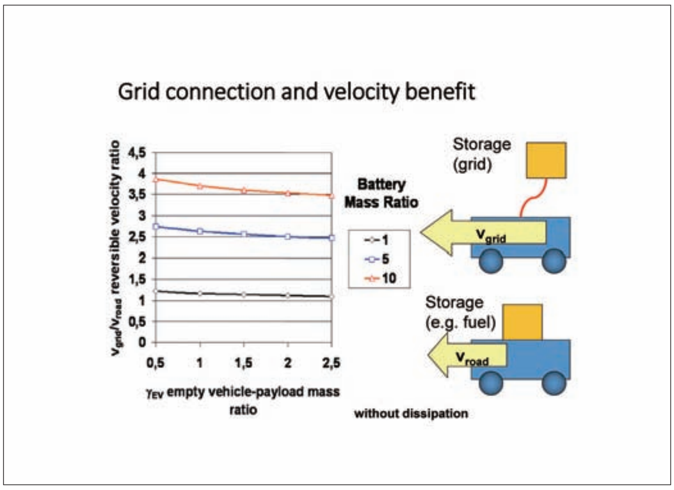


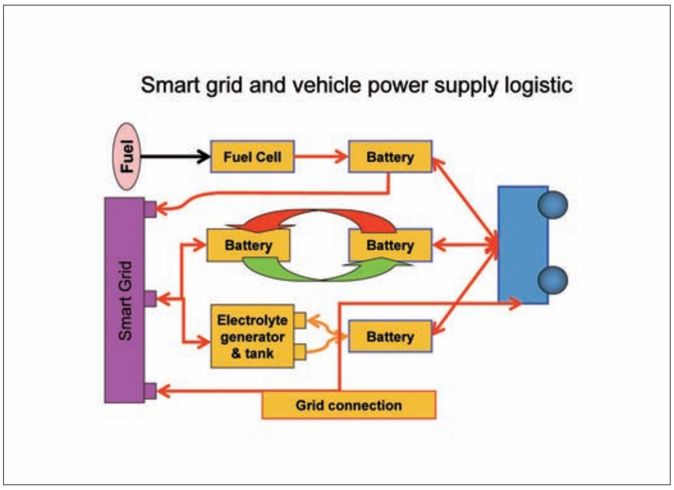
Typical mission parameters

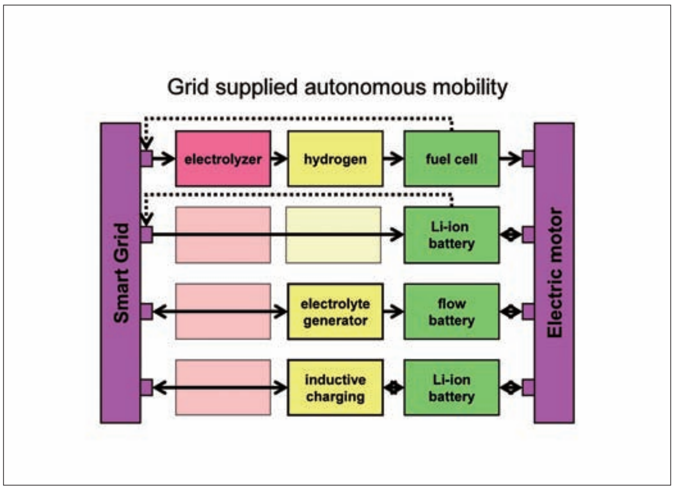
	Velocity km/h	Rel.mass kg/person	Height m	Cycles / mission
Ship	40	20000	0	1
Airplane	850	600	10000	1
Land vehicle	100	400	0 - 1000	High number

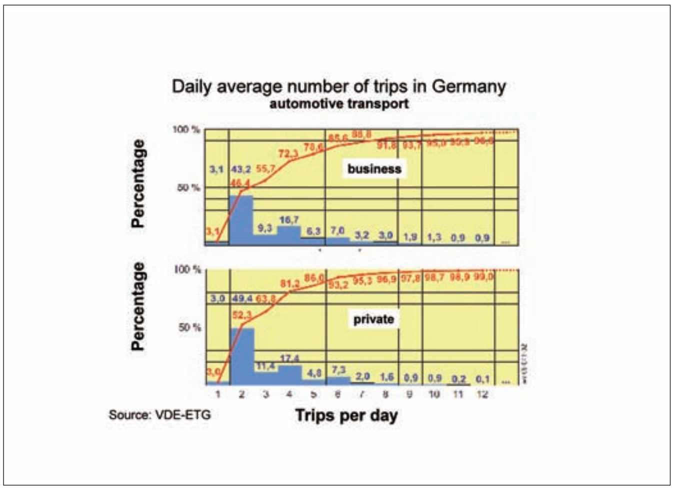

Sustainable all electric transportation
Electric storage
Internal Recovery Storage
Dissipation Supply Storage
Fuel Cell+ fuel tank
Not necessary
Airplanes
Ships
Land vehicles
Bio fuels
Electricity
Transportation system
Friction determined
Recovery determined

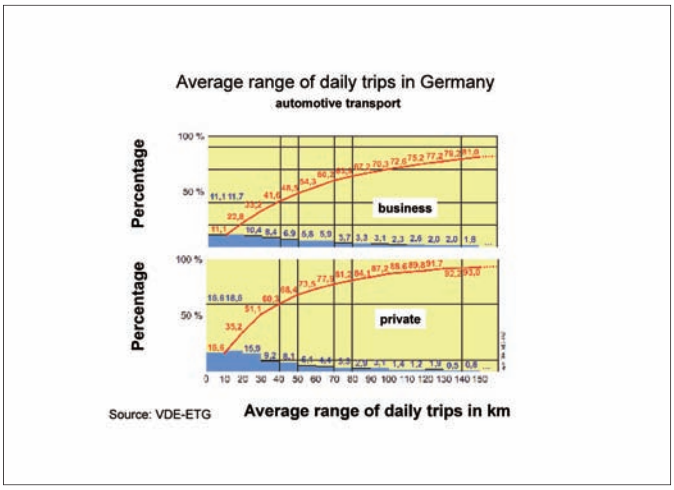

Transportation infrastructure
Fuel supply infrastructure
Vehicle power supply
Energy converter
Fuel
Elektric power
Electric storage (range extender)
Electric grid
Pantograph

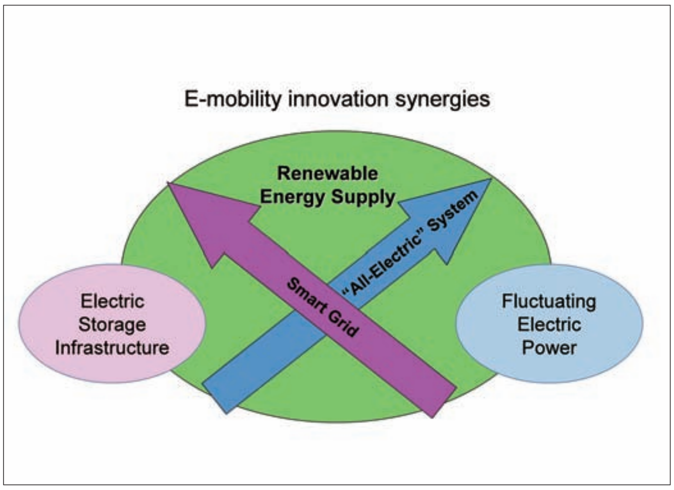

Grid connection and velocity benefit
vgrid/vroad reversible velocity ratio
γEV empty vehicle-payload mass ratio
Battery Mass Ratio
1
5
10
Storage (grid)
vgrid
Storage (e.g. fuel)
vroad
without dissipation

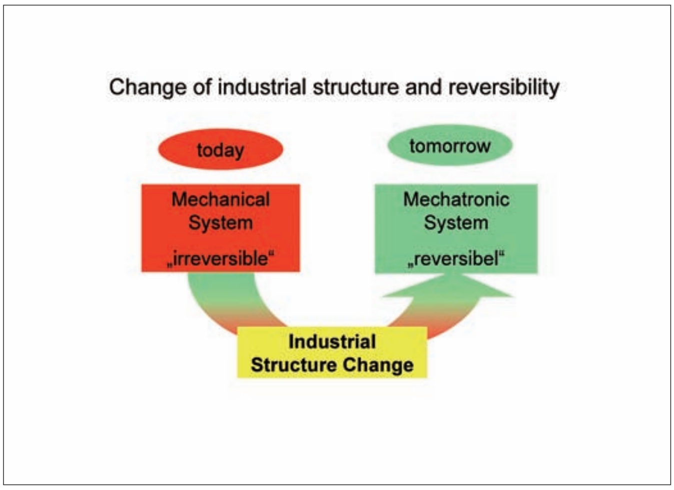

Smart grid and vehicle power supply logistic
Fuel
Fuel Cell
Battery
Battery
Battery
Smart Grid
Electrolyte generator & tank
Battery
Grid connection

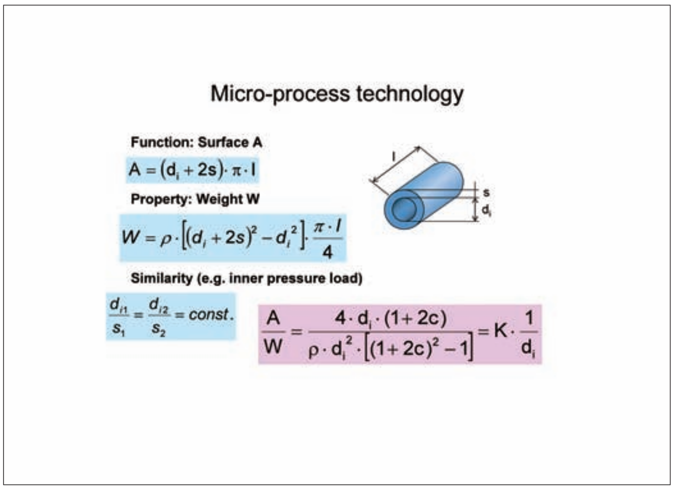

Grid supplied autonomous mobility
Smart Grid
electrolyzer
hydrogen
fuel cell
Li-ion battery
electrolyte generator
flow battery
inductive charging
Li-ion battery
Electric motor

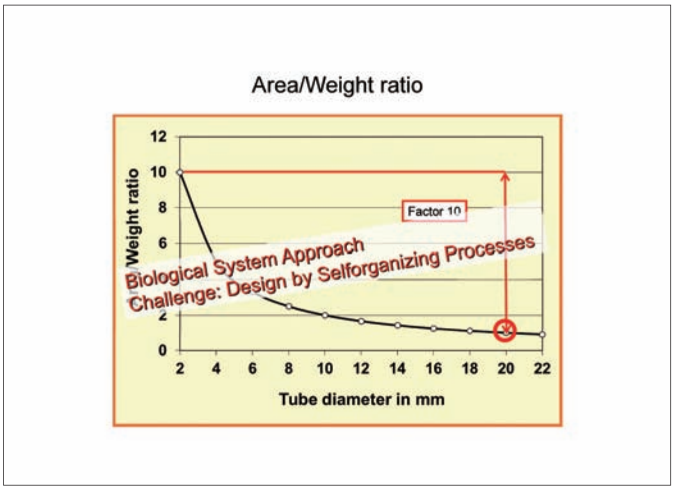

Daily average number of trips in Germany
automotive transport
Percentage
business
Percentage
private
Trips per day
Source: VDE-ETG

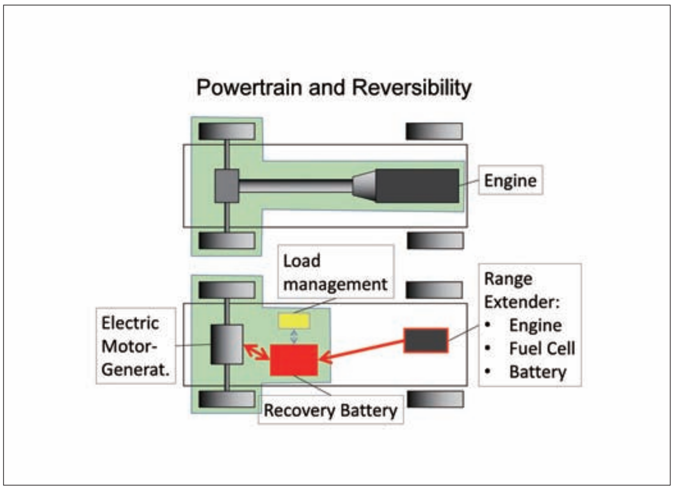

Average range of daily trips in Germany
automotive transport
Percentage
business
private
Source: VDE-ETG
Average range of daily trips in km

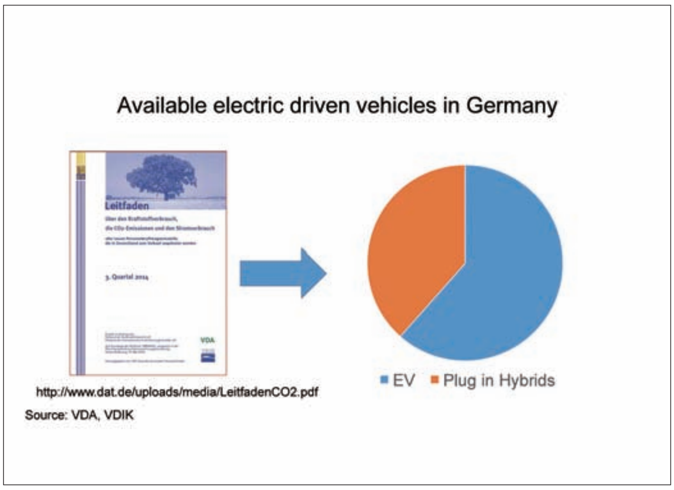

E-mobility innovation synergies
Renewable Energy Supply
"All-Electric" System
Smart Grid
Electric Storage Infrastructure
Fluctuating Electric Power

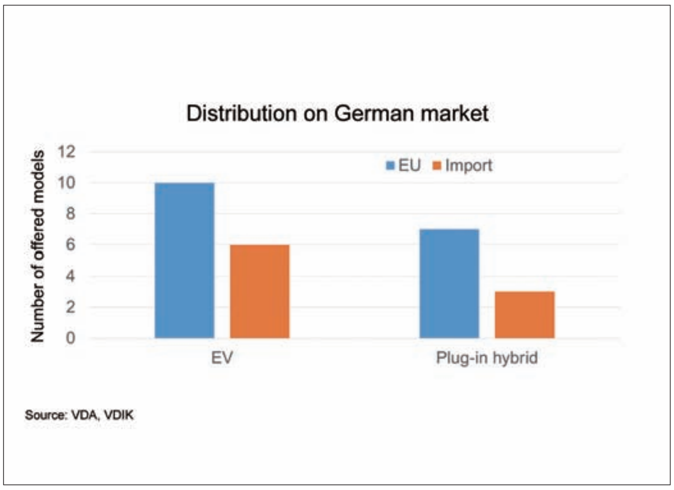

Change of industrial structure and reversibility
today
tomorrow
Mechanical System „irreversible"
Mechatronic System „reversibel"
Industrial Structure Change

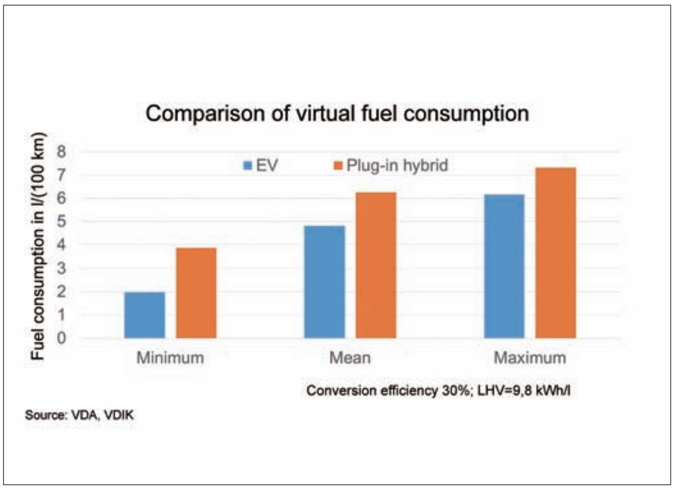

Micro-process technology
Function: Surface A
$A = (d_i + 2s) \cdot \pi \cdot l$
Property: Weight W
$W = \rho \cdot \left[(d_i + 2s)^2 - d_i^2\right] \cdot \frac{\pi \cdot l}{4}$
Similarity (e.g. inner pressure load)
$\frac{d_{i1}}{s_1} = \frac{d_{i2}}{s_2} = const.$
$\frac{A}{W} = \frac{4 \cdot d_i \cdot (1+2c)}{\rho \cdot d_i^2 \cdot \left[(1+2c)^2 - 1\right]} = K \cdot \frac{1}{d_i}$

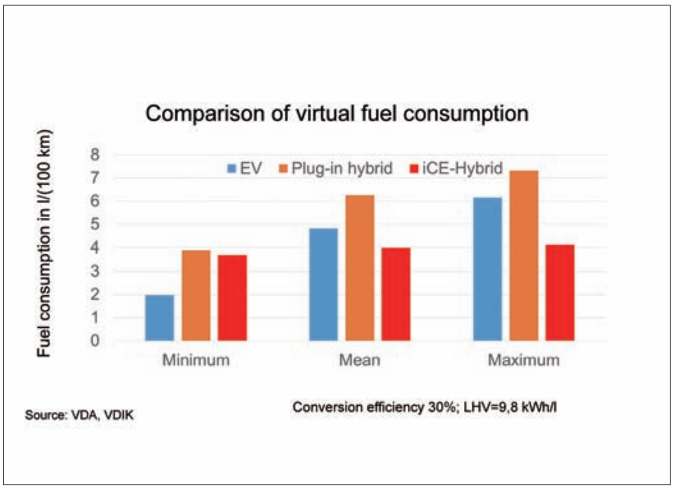

Area/Weight ratio
Weight ratio
Factor 10
Biological System Approach
Challenge: Design by Selforganizing Processes
Tube diameter in mm

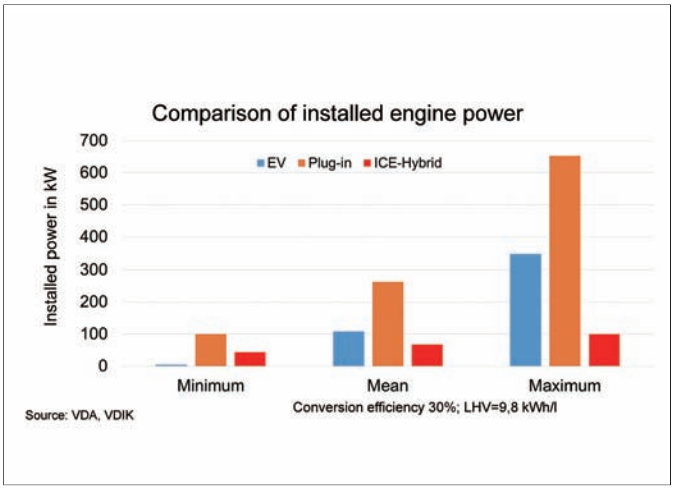

Powertrain and Reversibility
Engine
Load management
Range Extender:
• Engine
• Fuel Cell
• Battery
Electric Motor-Generat.
Recovery Battery

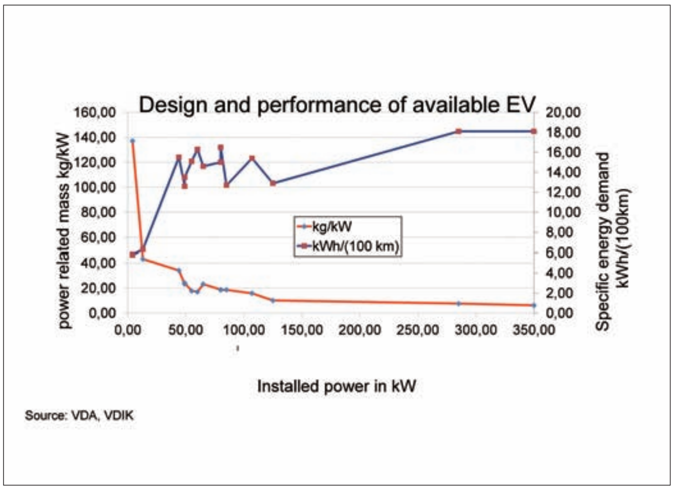

Available electric driven vehicles in Germany
Leitfaden
3. Quartal 2014
VDA
EV
Plug in Hybrids
http://www.dat.de/uploads/media/LeitfadenCO2.pdf
Source: VDA, VDIK


Distribution on German market
Number of offered models
12
10
8
6
4
2
0
EU
Import
EV
Plug-in hybrid
Source: VDA, VDIK

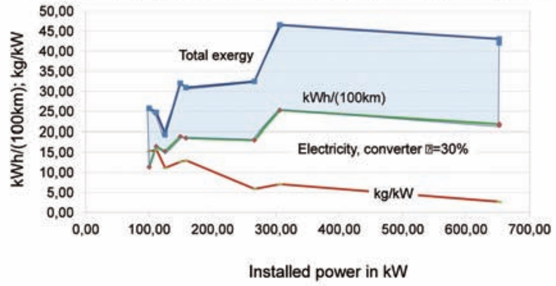

Comparison of virtual fuel consumption
Fuel consumption in l/(100 km)
8
7
6
5
4
3
2
1
0
EV
Plug-in hybrid
Minimum
Mean
Maximum
Conversion efficiency 30%; LHV=9,8 kWh/l
Source: VDA, VDIK


Comparison of virtual fuel consumption
Fuel consumption in l/(100 km)
8
7
6
5
4
3
2
1
0
EV
Plug-in hybrid
iCE-Hybrid
Minimum
Mean
Maximum
Conversion efficiency 30%; LHV=9,8 kWh/l
Source: VDA, VDIK


Comparison of installed engine power
Installed power in kW
700
600
500
400
300
200
100
0
EV
Plug-in
ICE-Hybrid
Minimum
Mean
Maximum
Conversion efficiency 30%; LHV=9,8 kWh/l
Source: VDA, VDIK


Design and performance of available EV
power related mass kg/kW
160,00
140,00
120,00
100,00
80,00
60,00
40,00
20,00
0,00
kg/kW
kWh/(100 km)
0,00
50,00
100,00
150,00
200,00
250,00
300,00
350,00
Installed power in kW
20,00
18,00
16,00
14,00
12,00
10,00
8,00
6,00
4,00
2,00
0,00
Specific energy demand kWh/(100km)
Source: VDA, VDIK

Design and performance of available Plug-in hybrids



Source: VDA, VDIK

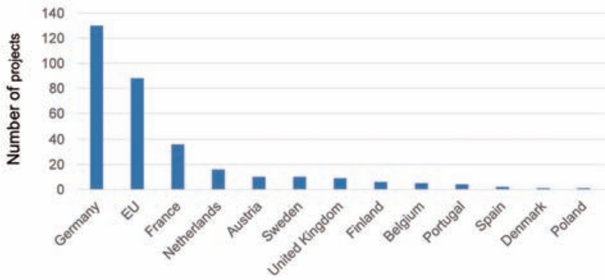
"Needed" electrical vehicle specification

➤ **Max. Range** →93% of daily trips of private vehicles →81% of daily trips of business vehicles	**150 km**
➤ **Mass power train/Vehicle mass**	**20-30 %**
➤ **Max. Operation time** →86% of daily operation time →> 95% of total operation time	**120 min**
➤ **Maximum speed**	**130-150 km/h**
➤ **Recharging periode**	**individually**
➤ **Life time/Load cycles** →more than 9 years at 3 load cycles a day	**> 10.000**
➤ **Total price**	**< 15.000 €**

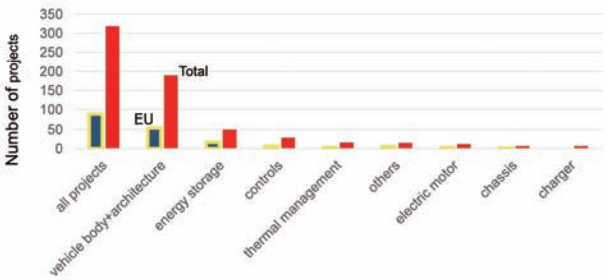
Overview automotive research projects in EU

http://iet.jrc.ec.europa.eu/ev-radar/

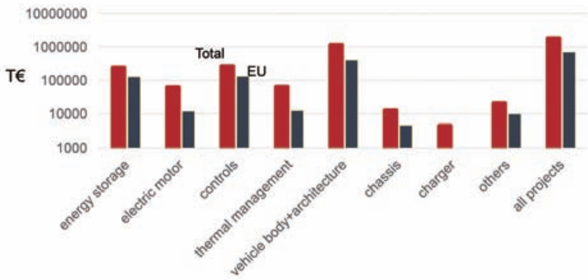
Research project funding per country

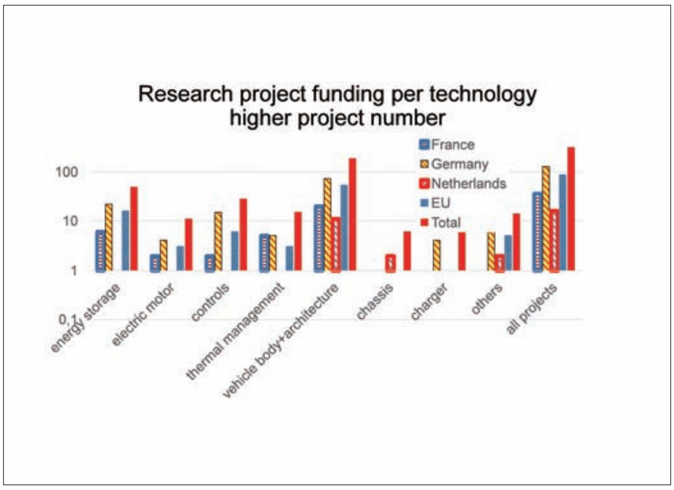


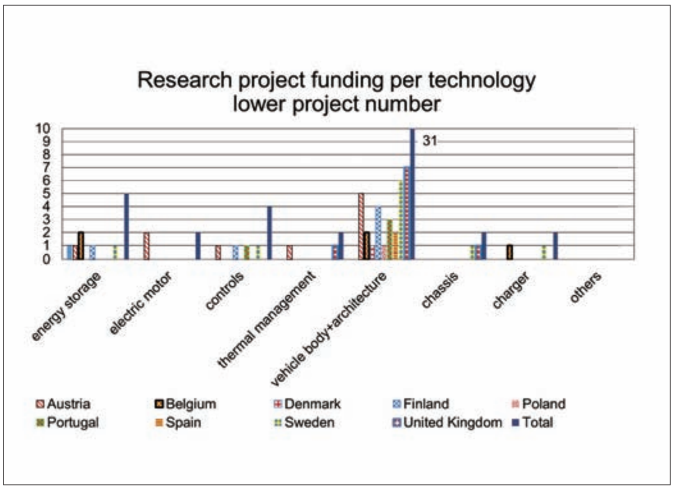
Research project funding number per technology



Research project funding volume per technology







[1] W. Winkler: Sustainable product development based on second law of thermodynamics. Applied Energy 88 (2011). p 3248–3256.

[2] W. Winkler: Process engineering considerations of electrochemical storage. Journal of Energy and Power Engineering. in print.

[3] W. Winkler, M. C. Williams:Fuel cell opportunities in transportation systems - Identification and future market introduction. EFC 09 Piero Lunghi Conference. Rome, 15 – 18 December 2009. Conference Proceedings p 205 - 206

[4] J. Viebranz: Aufnahme und Bewertung der verschiedenen Lösungsansatze zu „All-Electric"-Fahrzeugen. Diploma thesis. Hamburg University of Applied Sciences. 10. March 2010.

[5] Leitfaden über den Kraftstoffverbrauch, die CO2-Emissionen und den Stromverbrauch.

Neufahrzeug-Vergleichsdaten für Endverbraucher. 3. Quartal 2014

http://www.dat.de/uploads/media/LeitfadenCO2.pdf

[6] http://ec.europa.eu/clima/policies/transport/vehicles/cars/index_en.htm

[7] http://iet.jrc.ec.europa.eu/ev-radar/

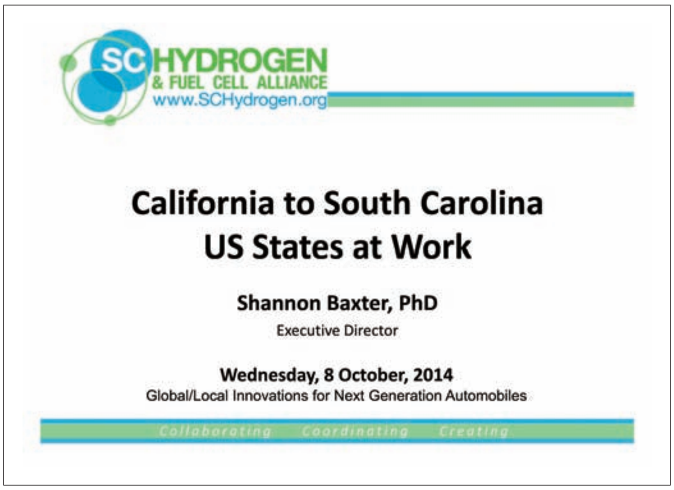
[8] G. Pasaoglu, D. Fiorello, L. Zani, A. Martino, A. Zubaryeva, C. Thiel: Projections for Electric Vehicle Load Profiles in Europe Based on Travel. Survey DataEuropean Commission, DG JRC, Institute for Energy and Transport, Petten, the Netherlands, TRT Trasporti e Territorio srl, Milan, Italy.

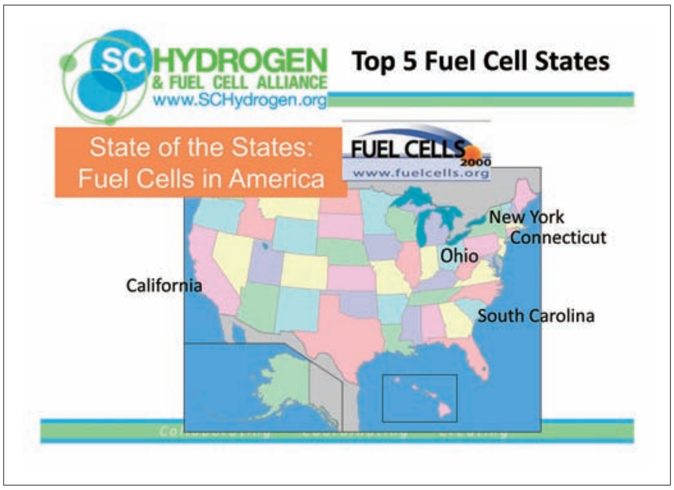
http://setis.ec.europa.eu/system/files/Projections_for_Electric_Vehicle_Load_Profiles_in_Europe_Based_on_Travel_Survey_Data.pdf

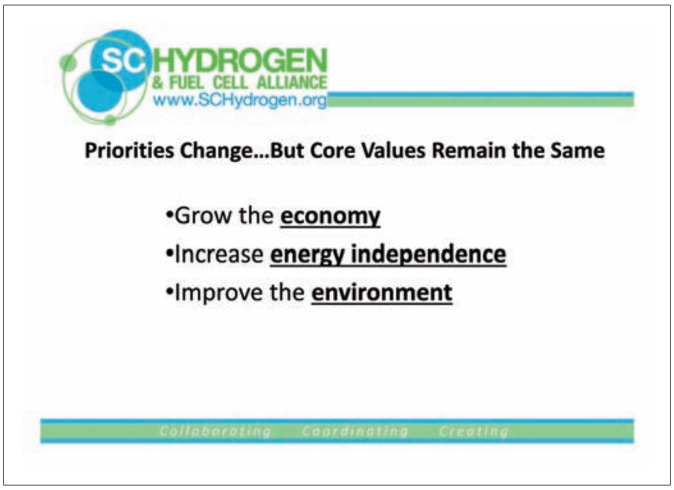
California to South Carolina: US States at Work

Shannon Baxter

Executive Director, South Carolina Hydrogen and Fuel Cell Alliance, USA

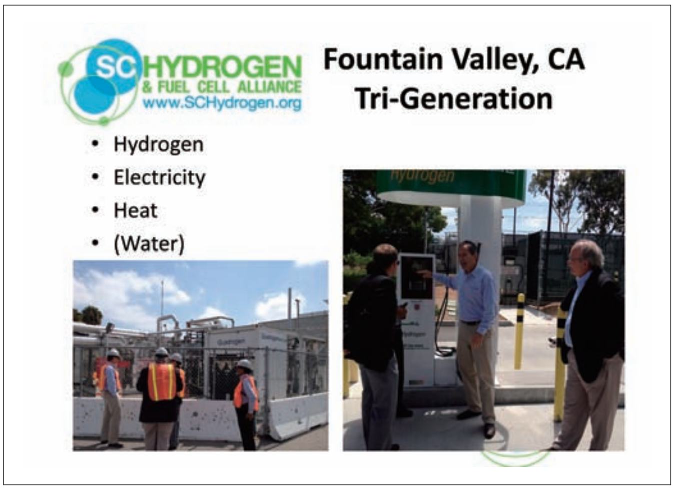


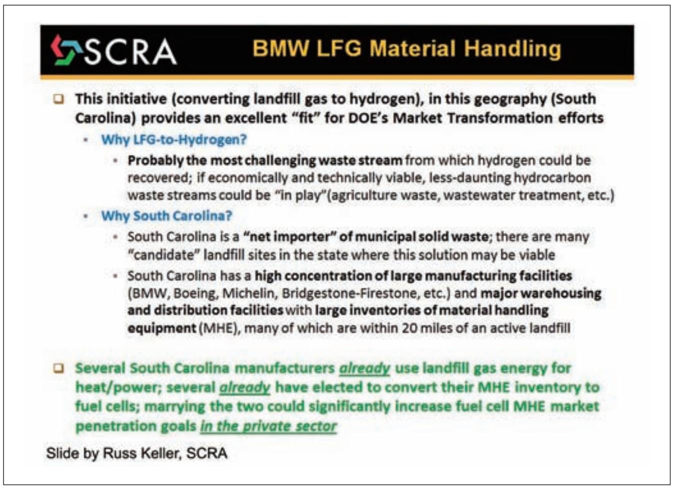




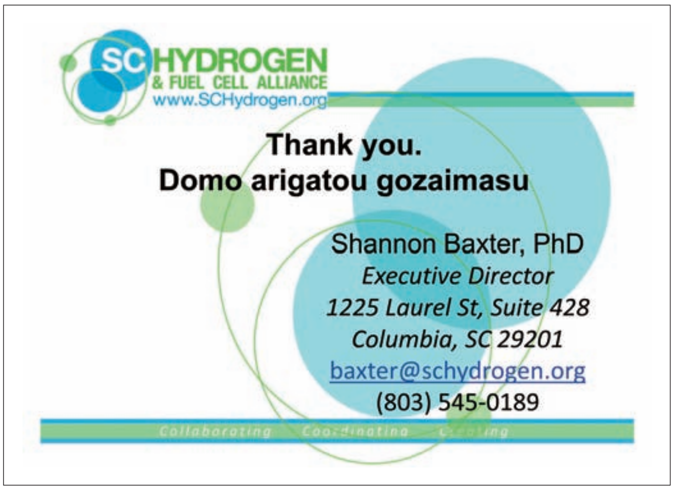

SC HYDROGEN & FUEL CELL ALLIANCE
www.SCHydrogen.org
Infrastructure
Only 2 "Public" Stations outside of California (in the US) are in Connecticut and South Carolina
Nevada
California
Fresno
Bakersfield
Las Vegas
Long Beach
San Diego
Collaborat


SC HYDROGEN & FUEL CELL ALLIANCE
www.SCHydrogen.org
Multi-purpose Hydrogen Stations
Reducing Stranded Investment Though Cooperation
Collab


SC HYDROGEN & FUEL CELL ALLIANCE
www.SCHydrogen.org
Fountain Valley, CA
Tri-Generation
• Hydrogen
• Electricity
• Heat
• (Water)
Hydrogen


SCRA
BMW LFG Material Handling
This initiative (converting landfill gas to hydrogen), in this geography (South Carolina) provides an excellent "fit" for DOE's Market Transformation efforts
Why LFG-to-Hydrogen?
Probably the most challenging waste stream from which hydrogen could be recovered; if economically and technically viable, less-daunting hydrocarbon waste streams could be "in play"(agriculture waste, wastewater treatment, etc.)
Why South Carolina?
South Carolina is a "net importer" of municipal solid waste; there are many "candidate" landfill sites in the state where this solution may be viable
South Carolina has a high concentration of large manufacturing facilities (BMW, Boeing, Michelin, Bridgestone-Firestone, etc.) and major warehousing and distribution facilities with large inventories of material handling equipment (MHE), many of which are within 20 miles of an active landfill
Several South Carolina manufacturers already use landfill gas energy for heat/power; several already have elected to convert their MHE inventory to fuel cells; marrying the two could significantly increase fuel cell MHE market penetration goals in the private sector
Slide by Russ Keller, SCRA

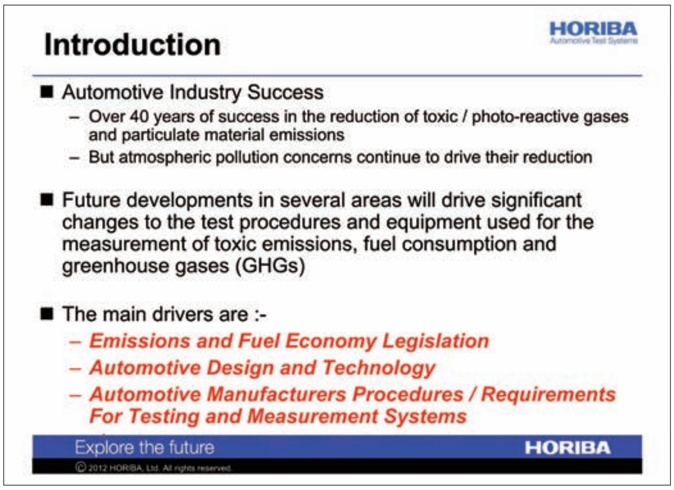

SC HYDROGEN & FUEL CELL ALLIANCE
www.SCHydrogen.org
Successful Actions in South Carolina
• Legislative Champions
• Hydrogen and Fuel Cell Permitting Law
• Material Handling Equipment Installations
• Supply Chain Mapping and defining the NAISC codes for the supply chain
• State and local collaborations
• National Laboratory and University Research

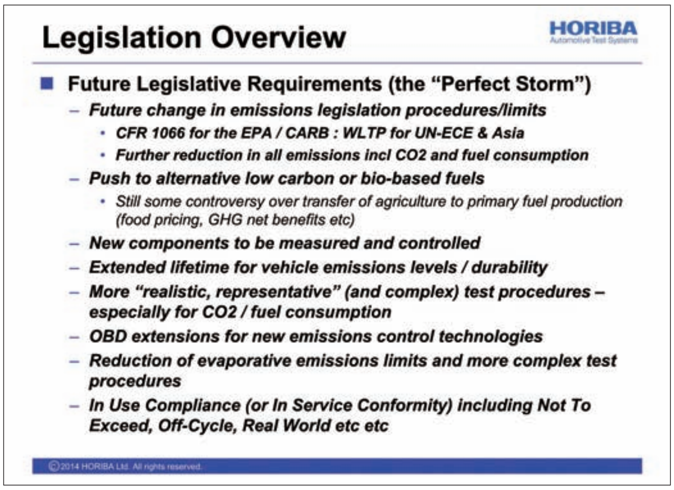

SC HYDROGEN & FUEL CELL ALLIANCE
www.SCHydrogen.org
Thank you.
Domo arigatou gozaimasu
Shannon Baxter, PhD
Executive Director
1225 Laurel St, Suite 428
Columbia, SC 29201
baxter@schydrogen.org
(803) 545-0189
Collaborating Coordinating

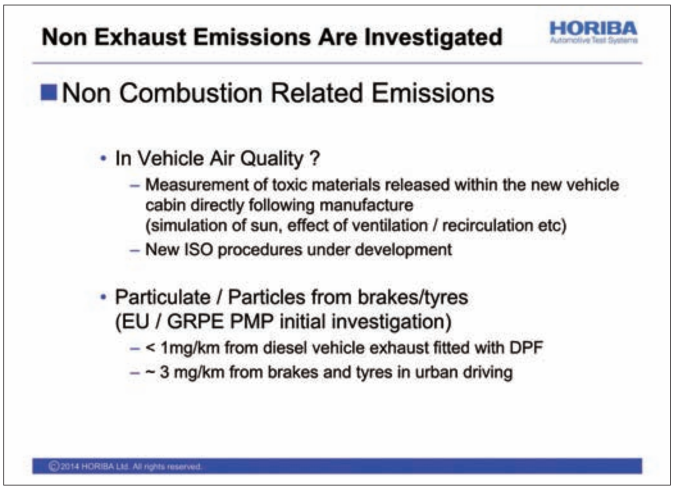
Future USA and Global Vehicle Emissions Legislation and Real World Emission Monitoring

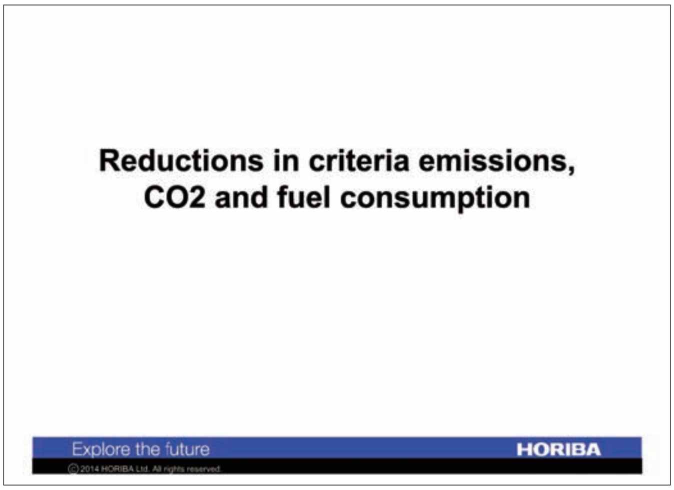
Leslie Hill

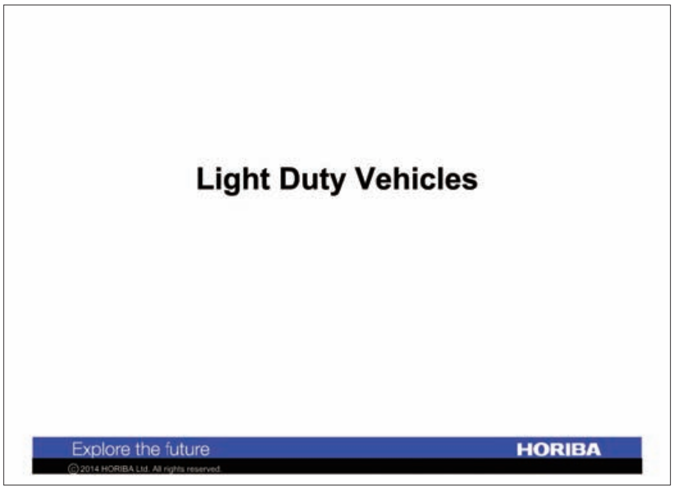
Exhaust Emissions Measurement, HORIBA Ltd., UK











USA : California LEV-III Limits

HORIBA Automotive Test Systems

LEV III Exhaust Mass Emission Standards for New 2015 and Subsequent Model Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles						
Vehicle Type	Durability Vehicle Basis (mi)	Vehicle Emission Category	NMOG + Oxides of Nitrogen (g/mi)	Carbon Monoxide (g/mi)	Formaldehyde (mg/mi)	Particulate (g/mi)
All PCs; LDTs 8500 lbs. GVWR or less; MDPVs. Vehicles in this category are tested at their loaded vehicle weight	150,000	LEV160	0.160	4.2	4	0.06
		ULEV125	0.125	2.1	4	0.06
		ULEV70	0.070	1.7	4	0.06
		ULEV50	0.050	1.7	4	0.06
		SULEV30	0.030	1.0	4	0.06
		SULEV20	0.020	1.0	4	0.06
MDVs 8501 - 10,000 lbs. GVWR. Vehicles in this category are tested at their adjusted loaded vehicle weight	150,000	LEV395	0.395	6.4	6	0.12
		ULEV340	0.340	3.2	6	0.06
		ULEV250	0.250	2.6	6	0.06
		ULEV200	0.200	2.6	6	0.06
		SULEV170	0.170	1.5	6	0.06
		SULEV150	0.150	1.5	6	0.06
MDVs 10,001-14,000 lbs. GVWR. Vehicles in this category are tested at their adjusted loaded vehicle weight	150,000	LEV630	0.630	7.3	6	0.12
		ULEV570	0.570	3.7	6	0.06
		ULEV400	0.400	3.0	6	0.06
		ULEV270	0.270	3.0	6	0.06
		SULEV230	0.230	1.7	6	0.06
		SULEV200	0.200	1.7	6	0.06

These standards shall apply only to vehicles not included in the phase-in of the particulate standards set forth in subsection (a)(2).
† The numeric portion of the category name is the NMOG+NOx value in thousandths of grams per mile.

*Interim "In Use" PM emissions at 2 * limits below*

LEV III Particulate Emission Standard Values and Phase-In for Passenger Cars, Light-Duty Trucks, and Medium-Duty Passenger Vehicles		
Model Year	% of vehicles certified to a 3 mg/mi standard	% of vehicles certified to a 1 mg/mi standard
2017	10	0
2018	20	0
2019	40	0
2020	70	0
2021	100	0
2022	100	0
2023	100	0
2024	100	0
2025	75	25
2026	50	50
2027	25	75
2028 and subsequent	0	100

(B) *Particulate Standards for Medium-Duty Vehicles Other than Medium-Duty Passenger Vehicles.*

USA : EPA Tier 3

HORIBA Automotive Test Systems

- Harmonized EPA Tier 3 with CARB LEV-III

Table 1
Tier 3 Certification Bin Standards (FTP; 150,000 miles)

Bin	NMOG+NOx	PM*	CO	HCHO
	mg/mi	mg/mi	g/mi	mg/mi
Bin 160	160	3	4.2	4
Bin 125	125	3	2.1	4
Bin 70	70	3	1.7	4
Bin 50	50	3	1.7	4
Bin 30	30	3	1.0	4
Bin 20	20	3	1.0	4
Bin 0	0	0	0	0

* In MYs 2017–20, the PM standard applies only to that segment of a manufacturer's vehicles covered by the percent of sales phase-in for that model year, Table 3.

Greenhouse Gas Emissions

HORIBA Automotive Test Systems

- Passenger automobile, light-duty trucks, and medium-duty passenger vehicles must comply with N2O and CH4 standards using one of the following provisions:
  1. N2O and CH4 Standards
     - 0.010 g/mi N_2O based on FTP test cycle
     - 0.030 g/mi CH_4 based on FTP test cycle
  2. Add N2O and CH4 to CO2 Fleet Average measured from FTP + HWFET
     - CO2 equivalent= N_2O x 298, CH_4 x 25

EPA LD Vehicle GHG Emissions 2017 - 2025

HORIBA Automotive Test Systems

- Final Rule published 15th October 2012
- **CO2 and Fuel Economy Fleet Targets**
  - EPA is establishing standards that are projected to require, on an average industry fleet wide basis, ***163 grams/mile of carbon dioxide (CO2) in model year 2025***, which is equivalent to 54.5 mpg if the entire fleet were to meet this CO2 level through tailpipe CO2 and fuel economy improvements. The EPA and NHTSA expect that a portion of these improvements will be made through improvements in air conditioning leakage and through use of alternative refrigerants, which would not contribute to fuel economy.
  - NHTSA has developed two phases of passenger car and light truck standards in this rulemaking. The first phase, from ***MYs 2017–2021, includes final standards that are projected to require, on an average industry fleet wide basis, a range from 40.3–41.0 mpUSg in MY 2021***.
    The second phase of the CAFE program, from ***MYs 2022–2025***, includes standards that are not final, but NHTSA projects that those standards could require, on an average industry fleet wide basis, a range from ***48.7– 49.7 mpUSg in model year 2025.***

EU Passenger Car Emissions

HORIBA Automotive Test Systems

European emission standards for passenger cars (Category M1*), g/km								
Tier	Date	CO	THC	NMHC	NOx	HC+NOx	PM	PN
Diesel (CI)								
Euro 1†	Jul-92	2.72 (3.16)	-		-	0.97 (1.13)	0.14 (0.18)	
Euro 2	Jan-96	1	-		-	0.7	0.08	
Euro 3	Jan-00	0.64	-		0.5	0.56	0.05	
Euro 4	Jan-05	0.5	-		0.25	0.3	0.025	
Euro 5 Phase 1	Sep-09	0.5	-		0.18	0.23	0.005	
Euro 5 Phase 2	Sep-11	0.5	-		0.18	0.23	0.0045	6*10e11
Euro 6	Sep-14	0.5	-		0.08	0.17	0.0045	6*10e11
Gasoline (PI)								
Euro 1†	Jul-92	2.72 (3.16)	-		-	0.97 (1.13)	-	
Euro 2	Jan-96	2.2	-		-	0.5	-	
Euro 3	Jan-00	2.3	0.2		0.15	-	-	
Euro 4	Jan-05	1	0.1		0.08	-	-	
Euro 5 Phase 1	Sep-09	1	0.1		0.06	-	0.005	
Euro 5 Phase 2	Sep-11	1	0.1	0.068	0.06	-	0.0045	
Euro 6	Sep-14	1	0.1	0.068	0.06	-	0.0045	6*10e12 6*10e11 in 2017

* Before Euro 5, passenger vehicles > 2500 kg were type approved as light commercial vehicle N1 - I
† Values in brackets are conformity of production (COP) limits

Main EURO 6 Issues

HORIBA Automotive Test Systems

- EURO 6 PN for LD DI PI Vehicles
  - GDI PN limit
    - 6 * 10^{12} p / km from 2014 to 2017
    - 6 * 10^{11} p / km from 2017
    - Most vehicles will meet the limit w/o particle traps for initial phase ?
      - Gasoline Particle Filters thereafter ?
      - Periodic regen may not be necessary due to higher temperature conditions allowing continuous regen capability
    - Implications of the RDE-LDV for PN emissions in the Real World and Off Cycle
  - EURO 6 CI NOx Limit at 80 mg/km
    - Only achievable for smallest LD vehicles without after-treatment ?
    - Medium LD vehicles will require NOx traps, SCR for the largest vehicles
    - Concern about the implications of the RDE-LDV for emissions in the Real World / Off Cycle
    - EU Commission : Timing for introduction of an NO2 standard or % of NOx ?
    - Discussions of a NOx standard for a – 7 deg C test for diesels
    - Voluntary RDE validation for new homologations from 1st Sept 2014 (EU request) for NOx and CO
    - Mandatory RDE validation from 1st September 2017, with Not To Exceed limits, for NOx, CO and PN

European Mandatory Fleet CO2 limits

HORIBA Automotive Test Systems

- EURO Directive Issued For CO2 Limits : 130 g/km
  - The new regulation makes these objectives binding for the average fleet of a given car manufacturer in successive stages
  - In 2012, 65% of their car fleet must meet the target
  - In 2013 75%
  - In 2014 80%.
  - From 2015, the whole fleet needs to comply with the CO2 emissions objective.
- Warning to Auto-Industry For Future Planning
  - Council and European Parliament introduced an objective of 95 g CO2/km for 2020. – *Germany proposes delay to 2024*
  - By 2013, the Commission has to review the modalities for reaching this target.
  - *New ! Proposed target for 2025 of 68 – 78 g/km*
- ***1 gram CO2 / km = 95 euro per vehicle penalty in 2015 !!! Equivalent to ~ 200m euro per gram CO2 for FORD EU Group sales numbers in 2008***
- **Entire process of CO2 mass measurement with respect to accuracy, repeatability, reproducibility is critical to manufacturer's operations**

European Mandatory Fleet CO2 limits

HORIBA Automotive Test Systems

- EURO Directive Issued For CO2 Limits : 130 g/km

All limits based on current NEDC and EURO 5/6 Test procedures

Change to WLTP will increase the vehicle CO2 emissions

Will the limits be increased accordingly ?

target.
- *New ! Proposed target for 2025 of 68 – 78 g/km*
- ***1 gram CO2 / km = 95 euro per vehicle penalty in 2015 !!! Equivalent to ~ 200m euro per gram CO2 for FORD EU Group sales numbers in 2008***
- **Entire process of CO2 mass measurement with respect to accuracy, repeatability, reproducibility is critical to manufacturer's operations**

European Mandatory Fleet CO2 limits

HORIBA Automotive Test Systems

- EURO Directive Issued For CO2 Limits : 130 g/km

EU Commission announced that Light Duty Commercial Vehicles will now also be included in CO2 emission reduction targets

Fleet Average
- 175 g/km by 2017
- 147 g/km by 2020
ref 2007 average = 203 g/km

- ***1 gram CO2 / km = 95 euro per vehicle penalty in 2015 !!! Equivalent to ~ 200m euro per gram CO2 for FORD EU Group sales numbers in 2008***
- **Entire process of CO2 mass measurement with respect to accuracy, repeatability, reproducibility is critical to manufacturer's operations**

New USA Emissions Testing Protocols

The New CFR

Explore the future HORIBA

Derivation of Part 1065 and Part 1066

HORIBA Automotive Test Systems

Emission Limits Drastically Reduced

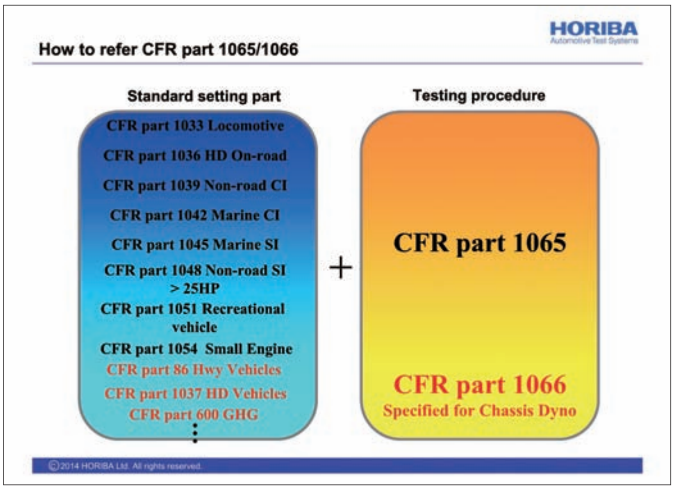
2007/2010 Heavy Duty Diesel Changes	▪ CFR Part 86 ▪ Improve repeatability ▪ Better accuracy at low range 　▪ Particulate Matter and NOx
CFR Part 1065	▪ Unified testing procedure for many different engine types ▪ Easier to read ▪ Central location
CFR Part 1066	▪ Chassis Test Procedure 　▪ Heavy Duty and Light Duty ▪ Many references to CFR Part 1065 ▪ References 40 Part 86 subpart B

- 40CFR Part 1066
  - Testing procedure, not emission standards
    - 40CFR Part 86 and 40 CFR Part 600 are the standard setting parts for Light Duty Vehicle
  - Heavy Duty Vehicle for MY2014 and later
  - Light Duty Vehicle for MY2022 and later (2017 for PM mass)
  - Latest: 40-CFR-Part1066 vehicle test procedures Final LD Tier 3 FRM Mar-3,2014

CFR part 1000 – 1099

HORIBA Automotive Test Systems

1033	CONTROL OF EMISSIONS FROM LOCOMOTIVES
1039	CONTROL OF EMISSIONS FROM NEW AND IN-USE NONROAD COMPRESSION IGNITION ENGINES
1042	CONTROL OF EMISSIONS FROM NEW AND IN-USE MARINE COMPRESSION-IGNITION ENGINES AND VESSELS
1043	CONTROL OF NOX, SOX, AND PM EMISSIONS FROM MARINE ENGINES AND VESSELS SUBJECT TO THE MARPOL PROTOCOL
1045	CONTROL OF EMISSIONS FROM SPARK-IGNITION PROPULSION MARINE ENGINES AND VESSELS
1048	CONTROL OF EMISSIONS FROM NEW, LARGE NONROAD SPARK-IGNITION ENGINE
1051	CONTROL OF EMISSIONS FROM RECREATIONAL ENGINES AND VEHICLES
1054	CONTROL OF EMISSIONS FROM NEW, SMALL NONROAD SPARK-IGNITION ENGINES AND EQUIPMENT
1060	CONTROL OF EVAPORATIVE EMISSIONS FROM NEW AND INUSE NONROAD AND STATIONARY EQUIPMENT
1065	**ENGINE-TESTING PROCEDURES**
1066	**VEHICLE-TESTING PROCEDURES**
1068	GENERAL COMPLIANCE PROVISIONS FOR ENGINE PROGRAMS
1074	PREEMPTION OF STATE STANDARDS AND PROCEDURES FOR WAIVER OF FEDERAL PREEMPTION FOR NONROAD ENGINES AND NONROAD VEHICLES


How to refer CFR part 1065/1066
HORIBA
Automotive Test Systems
Standard setting part
CFR part 1033 Locomotive
CFR part 1036 HD On-road
CFR part 1039 Non-road CI
CFR part 1042 Marine CI
CFR part 1045 Marine SI
CFR part 1048 Non-road SI > 25HP
CFR part 1051 Recreational vehicle
CFR part 1054 Small Engine
CFR part 86 Hwy Vehicles
CFR part 1037 HD Vehicles
CFR part 600 GHG
+
Testing procedure
CFR part 1065
CFR part 1066
Specified for Chassis Dyno
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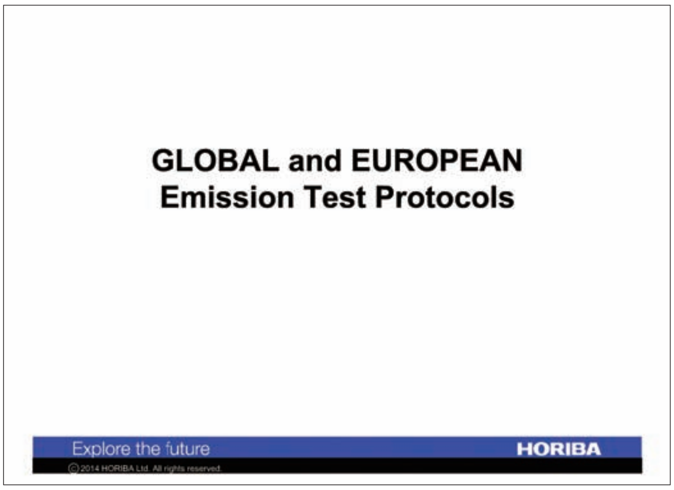
GLOBAL and EUROPEAN
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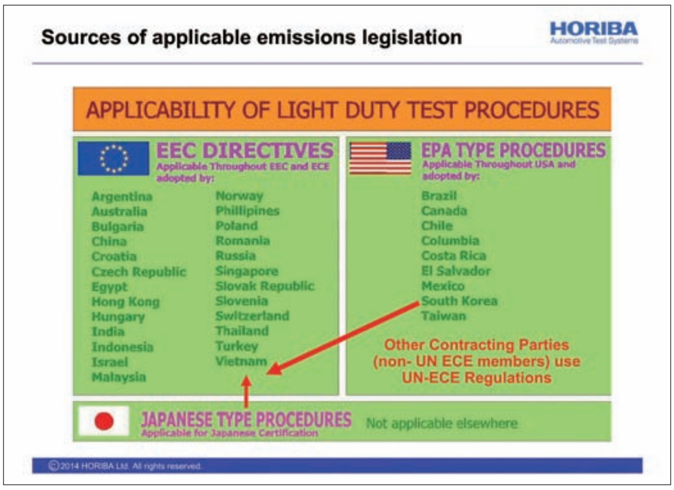
Sources of applicable emissions legislation
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Automotive Test Systems
APPLICABILITY OF LIGHT DUTY TEST PROCEDURES
EEC DIRECTIVES
Applicable Throughout EEC and ECE adopted by:
Argentina
Australia
Bulgaria
China
Croatia
Czech Republic
Egypt
Hong Kong
Hungary
India
Indonesia
Israel
Malaysia
Norway
Phillipines
Poland
Romania
Russia
Singapore
Slovak Republic
Slovenia
Switzerland
Thailand
Turkey
Vietnam
EPA TYPE PROCEDURES
Applicable Throughout USA and adopted by:
Brazil
Canada
Chile
Columbia
Costa Rica
El Salvador
Mexico
South Korea
Taiwan
Other Contracting Parties (non- UN ECE members) use UN-ECE Regulations
JAPANESE TYPE PROCEDURES
Applicable for Japanese Certification
Not applicable elsewhere
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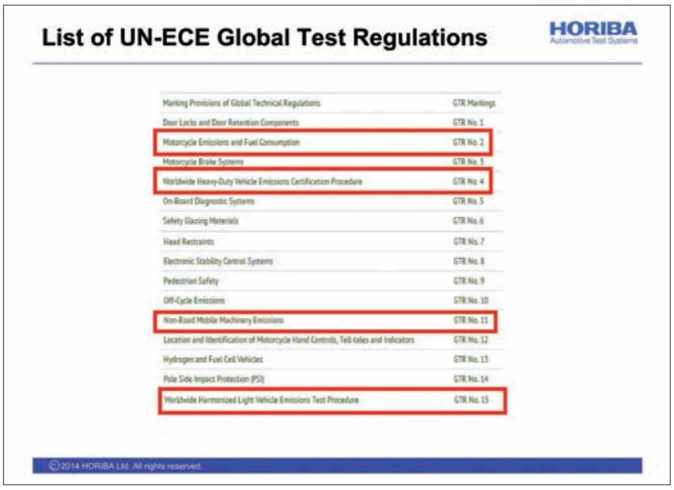
List of UN-ECE Global Test Regulations
HORIBA
Automotive Test Systems
Marking Provisions of Global Technical Regulations GTR Markings
Door Locks and Door Retention Components GTR No. 1
Motorcycle Emissions and Fuel Consumption GTR No. 2
Motorcycle Brake Systems GTR No. 3
Worldwide Heavy-Duty Vehicle Emissions Certification Procedure GTR No. 4
On-Board Diagnostic Systems GTR No. 5
Safety Glazing Materials GTR No. 6
Head Restraints GTR No. 7
Electronic Stability Control Systems GTR No. 8
Pedestrian Safety GTR No. 9
Off-Cycle Emissions GTR No. 10
Non-Road Mobile Machinery Emissions GTR No. 11
Location and Identification of Motorcycle Hand Controls, Tell-tales and Indicators GTR No. 12
Hydrogen and Fuel Cell Vehicles GTR No. 13
Pole Side Impact Protection (PSI) GTR No. 14
Worldwide Harmonized Light Vehicle Emissions Test Procedure GTR No. 15
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World Light Duty Vehicle Test Procedure
(WLTP)
Explore the future
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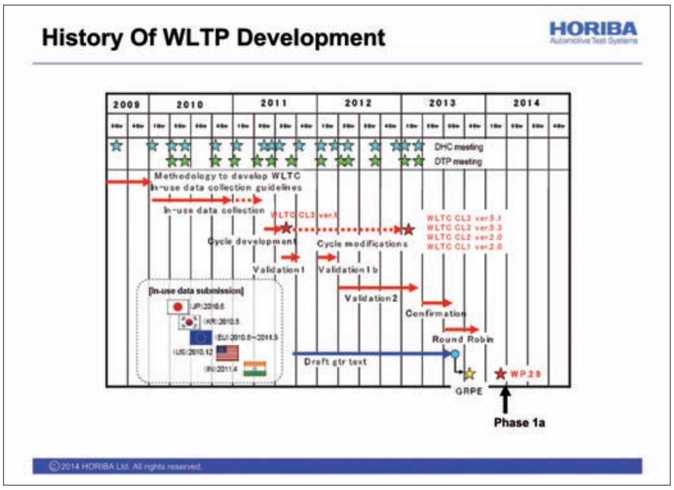
History Of WLTP Development
HORIBA
Automotive Test Systems
2009
2010
2011
2012
2013
2014
DHC meeting
DTP meeting
Methodology to develop WLTC
In-use data collection guidelines
In-use data collection
WLTC CL3 ver.1
Cycle development
Cycle modifications
WLTC CL3 ver.5.1
WLTC CL3 ver.5.3
WLTC CL2 ver.2.0
WLTC CL1 ver.2.0
Validation 1
Validation 1 b
[In-use data submission]
Validation 2
Confirmation
Round Robin
Draft gtr text
GRPE
WP.29
Phase 1a
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EU Commission / Technical Authorities

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- Major Issues
  - EU Commission Key Opening Words : Realistic, Representative, Avoidance of manufacturer "Gaming" *(fuel economy data must reflect "real world")*
  - New more realistic settings must be applied for
    - Vehicle Inertia setting (now stepless as electric C/Ds are used)
    - Use of multi-mode gearbox : testing under multiple settings (worst/best)
    - Specifications for vehicle mass / tyres / aerodynamic vehicle options – worse case and best case then interpolate for intermediate variants
  - Test Cell and Soak Area Temperatures
    - Originally 25 +/- 5 deg C : same as other GTR procedures (m/cycle and trucks, NRMM)
    - EU Commission wants it to be "more realistic" = lower EU average daily temperature is 10 deg C
      - WG has raised several valid objections and identified compromise solutions
      - EU Commission has proposed a correction factor to 10 deg C emissions *for CO2 only*
    - 23 +/- 3 deg C current proposal
      - Has implications on test cell and soak area temperature control and monitoring
      - Not all test cells can maintain this tolerance, especially during the test
        - » Tolerance will be extended for after vehicle start to +/- 5K

BMW proposed 14 deg C to set vehicle family adjustment factor

2. Cycle Allocation for Different Vehicle Classes

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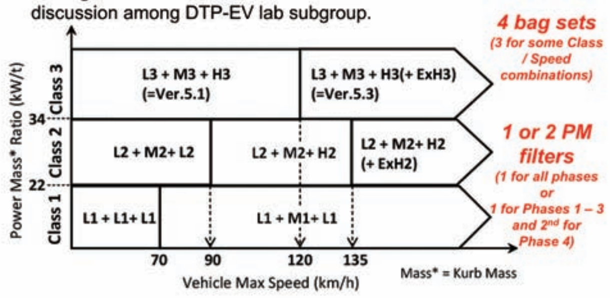
During 15th DHC meeting (Dec 2012), the following cycle allocation was agreed. Threshold for electrified vehicles is under the discussion among DTP-EV lab subgroup.



4 bag sets (3 for some Class / Speed combinations)

1 or 2 PM filters (1 for all phases or 1 for Phases 1 – 3 and 2nd for Phase 4)

*1) exempted as per Contracting Parties need

*2) capped speed according to vehicle maximum speed

 33

World Light Duty Vehicle Drive Cycles

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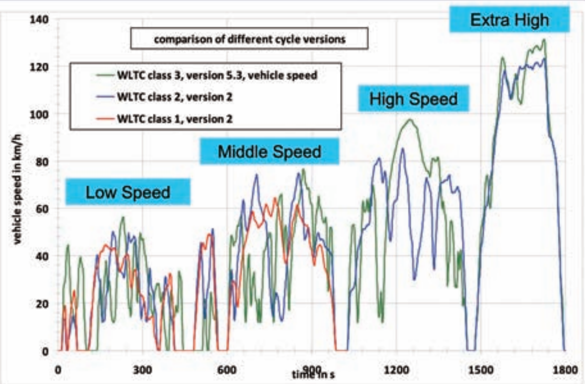

Additional Pollutants to be addressed in WLTP

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NO2 – Nitrogen Dioxide
NO becomes NO2 in the atmosphere so why measure NO2 specifically ?
NO2 concentrations increasing at roadside (diesel oxidation cats create NO2)
NO2 is used to react with soot on continuously regenerating particle filters
NO2 is the more toxic component of NOx
At present time, no confirmation of an NO2 standard as a specific mass limit or as a % of NOx mass (or may be both combined ?)

NH3 – Ammonia
specifically from vehicle NOx controlled by SCR with urea only or for other vehicles ?

N2O – Nitrous Oxide
specified as a GreenHouse Gas

Ethanol
for fuels with ethanol content > 20%

Aldehydes : Formaldehyde, Acetaldehyde
for fuels with ethanol content > 20%
(above compounds typically represent ~ 90% of oxygenated HCs from ethanol fuelled vehicles)

Will the ethanol volume threshold be aligned with EPA/CARB at E25 ? And will factors for NMOG from NMHC be applied ?

Will factors for NMOG from NMHC also be generated for ethanol volumes to E85 ? (thus removing the need to measure these compounds ?)

WLTP Implementation Date ?

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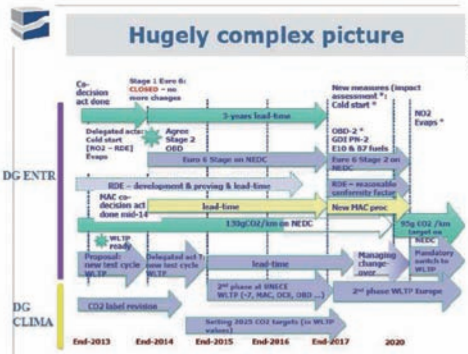

Major issue is the target date for introduction of WLTP.

EU Commission requests 2017/18 at latest.

Industry (ACEA) considers after 2020 as being realistic considering the implications and other legislative changes as outlined here

WLTP Implementation in EU Type Approval

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- Scenarios of WLTC implementation are:

Scenario	Application of WLTC for CO_2 emission measurement	Application of WLTC for criteria pollutant emissions measurements
Flexi	1 September 2014/15[3] or the earliest dates possible due to the duration of the regulatory procedure + necessary time for adapting laboratory infrastructure.	Until 2019/20: choice of the manufacturer between NEDC and WLTC; after that dates WLTC mandatory.
One shot	1 September 2017/18[4]	
Better late than never	1 January 2019/20	

(3) Mandatory Euro 6 dates.
(4) These dates correspond to the dates already introduced into Euro 6 for the application of more severe Euro 6 OBD threshold limits and particle number limits for positive ignition direct injection vehicles, i.e. they define a natural separation of two Euro 6 steps.

Probably the most plausible scenario as Industry has expressed their concerns about the Flexi option (2 different type approval processes running in parallel)

Conflict between the future fleet average (95 g/km) and the change from EURO 6 to WLTP. Could delay WLTP for CO2 till after 2021 ?

Trend of increasingly complex Automotive Technology

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Implications of Engine/Vehicle Technologies

HORIBA Automotive Test Systems

- ***New vehicle technologies, driven by emissions and fuel economy, and their impact on vehicle testing***

Research, Engine design, Modelling, Develop, Testing

- – Improved combustion and ICE design for low CO2 and fuel consumption and lower toxic emissions
  - *Fundamental fuel efficiency increase including low engine friction*
    - *– Small capacity, highly turbo-charged, fewer cylinders*
    - *– Improvement in PI (positive ignition) engines to come closer to CI engines*
  - *Calibrated for alternative and multiple fuels*
- – Low parasitic loss auxiliary engine components (A/C, power steering, water pump etc)

Impact on vehicle settings simulation

- – Efficient, low loss transmissions, drivelines and tyres etc
- – Lightweight vehicles with improved aerodynamics

Impact on test cell design, equipment procedures and automation

- – Complex multiple stage after-treatment devices
  - Including periodically regenerating devices
- – Higher fuel efficiency powertrains including kinetic energy recovery (electrical, mechanical, hydraulic, pneumatic)
- – Thermal energy management / recovery
- – Plug-in electrical vehicles incl range extended EVs

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Correlation between Laboratory Process and Real World is now key

The Trend To Real World Vehicle Emissions Testing

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Field Testing

In Service Conformity

In Use Compliance

Off Cycle Emissions

Real World Emissions

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In Use Measurement is nothing new !

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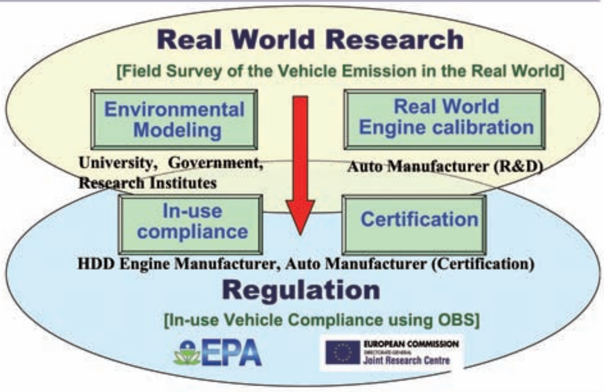

"In Use Compliance"

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- Modern Concept of Vehicle On Board Measurement for "Field Testing" or "In Use Compliance" was introduced by EPA
  - Certification Requirement as consequence of the 1998 Consent Decree against the HDD Engine Manufacturers
    - Caterpillar, Cummins, Detroit Diesel, Volvo, Mack/Renault, Navistar
  - One of the provisions was the acceptance of SET (Supplemental Emissions Test : steady state) and NTE (Not To Exceed) limits of 1.25 times the FTP applicable mass emissions limits
  - Equipment for vehicles testing generically known as PEMS (Portable Emissions Measurement Systems)
  - NTE testing to be measured as "Field Testing" under test procedures and equipment defined under 1065 regulations : subpart J
    - Gaseous systems specified and systems comply
    - Real Time PM mass systems : original "real time" PM mass measurement principles were impractical – alternative methods available and accepted
      - Methods now defined into Subpart J

EU PEMS Drivers

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Legislative framework of in-service conformity

Directives 2005/55/EC, 2005/78/EC (Euro IV-V):

- correct operation of the emission control devices during the normal life of the vehicle under normal conditions of use is confirmed
- conformity of properly maintained and used in-service vehicles/engines is ensured

Euro VI proposal (COM(2007) 851 final):

- In order to better control actual in-use emissions including OCE and to facilitate the in-service conformity process, a testing methodology and performance requirements based on the use of portable emission measuring systems (PEMS) should be adopted.

PEMS Application for EU On Road HD Vehicles

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- Originally PEMS was to be applied in the EU, as in the USA, for In Service Conformity (EC 582/2011)
  - confirming at a time period after the official Type Approval engine test that the emissions of HD vehicles using the engine complied with the emissions limits
- Now specified (EC 64/2012) as part of the Type Approval process
  - No Type Approval certificate without the PEMS confirmation of CO, THC, NOx and (soon) PM mass

Real Driving Emissions for Light Duty Vehicles

RDE-LDV

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You will have seen this type of report

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Home News World Sport Finance Comment Culture Travel Life Women Fashion

Women Men Motoring Health Property Gardening Food History Relationships

News | First Drives | Manufacturers | Festival of Motoring | Goodwood | Top Gear

HOME » MOTORING » MOTORING NEWS

Emission tests 'substantially underestimate' pollution pumped out by diesels

The amount of pollution generated by diesel cars on congested roads may be much higher than previously thought.

Diesels may actually be emitting three times the pollution allowed under current emissions tests Photo: Alamy

Increasing EU Interest in Real World Emissions

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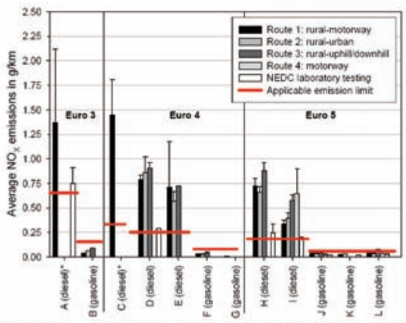
- The continuing issue of atmospheric pollution within EU cities remains a priority for the EU Commission
  - Mainly NOx and PM levels are of concern
  - Reductions in the levels of atmospheric pollution are not being achieved despite reductions in the vehicle's emissions according to the legislated limits and procedures
- LD vehicle emissions based on the the equipment and procedures from HD Vehicle On Road testing
  - USA "Not To Exceed"
  - EU "In Service Conformity"
- Measurements were performed on LD Vehicles by the EU JRC (Joint Research Centre) in Ispra
  - Issued a report (hyperlink) - ISBN 978-92-79-19072-8

NOx Emissions



All gaseous components comply with relevant standard in the Laboratory emissions test.

NOx emissions were considerably above standard in real-world

Figure 11: Average NO_X emissions on the PEMS test routes and during NEDC testing in the laboratory; uncertainty intervals indicate the maximum average emissions for each test and vehicle; * Route 1: rural-motorway for Vehicles A and C (see Table 3) includes a combination of the two test routes Ispra-Milan-Ispra and Milan-urban

RDE-LDV

- Real Driving Emissions for Light Duty Vehicles
  - As a result of the JRC report, a new working group was initiated to study the implications of the report on LDV emissions testing and how legislative testing procedures may be modified
- Working Group Activities / Plan
  - Two approaches on how to measure the emissions outside of the normal laboratory test conditions, drive cycle and test procedure were proposed
    - A Laboratory based test under different ambient conditions and modified drive cycles of differing severity (Random Cycle method)
    - An On-Road based vehicle test procedure using PEMS
  - Working Group Members reviewing both methods until end of 2011 and reporting data
  - Decision on final method was to be confirmed by March 2012
- Conclusion (at end of 2012)
  - PEMS to be applied for all gaseous components
  - Random Cycle concept would be retained and reserved in the case that a PEMS for PN was not achievable – TNO to develop (Sept 2014)

RDE-LDV Current Scope / Timing

- 2015 : "Monitoring Phase" of RDE-LDV
  - NOx and CO will be measured for all LD vehicles
  - No limits will be applied
  - All data will be available to Member States and Technical Authorities
  - Limited data will be published
- 1st September 2017 "Regulatory Phase" of RDE-LDV
  - NOx, CO and PN will be measured for all LD vehicles
  - "Not To Exceed" limits will be applied
- The above remain to be confirmed formally in legislation

Summary

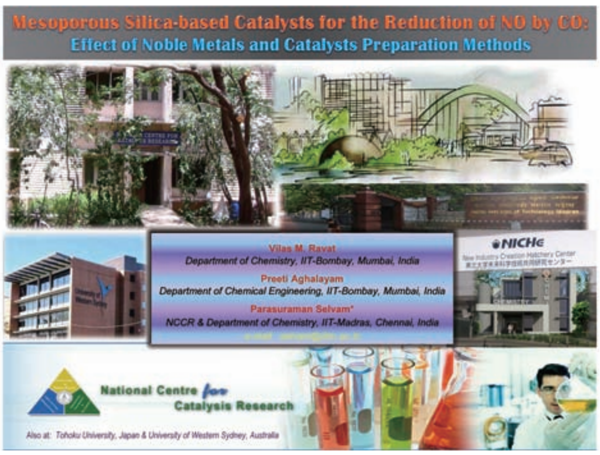
- New emissions legislation in all territories continues to drive reductions for all automotive applications in criteria and GHG emissions as well as introducing new components to be measured and controlled
  - *Driving development of new sampling and analytical systems as well as improvements to existing techniques*
- New test procedures and regulations for emissions testing systems have been introduced for the USA : new GTRs via the UN-ECE have been developed and are being applied for the rest of the world.
  - *Harmonisation of the two regulatory streams continues to be a target*
  - *The complexity of the new procedures requires significant development of test automation systems in order to simplify their application*
- The use of Field Testing / In Use Compliance / In Service Conformity / Off-Cycle / Real World Emissions measurement is expanding and will be applied to more categories of vehicle as a supplement to existing Type Approval procedures
  - *Has a major impact on the emissions and fuel economy research, development, calibration and certification process*

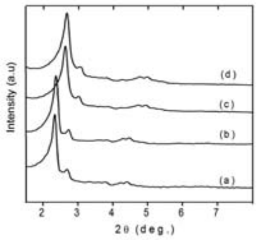
NH_3-$DeNO_x$ Activity of Composite Catalysts [Meso-$Ce_xZr_{1-x}O_2$ + Micro-Fe-Beta]

Parasuraman Selvam

Professor, National Centre for Catalysis Research and Department of Chemistry

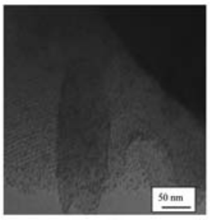
Indian Institute of Technology-Madras, India



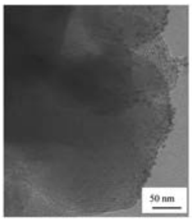


XRD of MCM-48 and PdMCM-48

Catalyst	Surface area (m²/g)	Metal content (%)	Metal Size (nm)
PdMCM-48	1007	3.90	2.80
PdMCM-48	986	3.85	8.30
PdMCM-48	950	3.75	15.9
RhMCM-48	1021	3.98	----
RuMCM-48	924	3.95	15.7
PtMCM-48	950	3.90	13.0
PdMCM-41	870	4.00	3.10
PdSBA-3	805	3.90	4.30

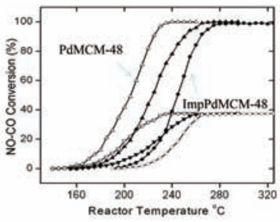


RhMCM-48 with a pore diameter of 2.5 nm



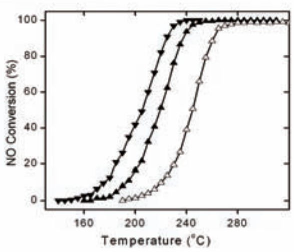
PdMCM-48 with a pore diameter of 3.3 nm

Effect of catalyst preparation method



Catalyst	Pd size (nm)	Pd content (wt %)	NO conversion 25%	100%
PdMCM-48	2.8	3.90	190 °C	235 °C
PdMCM-48 (DP)	8.3	3.85	210 °C	265 °C
PdMCM-48 (IMP)	15.9	3.75	235 °C	280 °C

Effect of Supports



Effect of reaction temperature on the reduction of NO by CO reaction over different mesoporous supports :

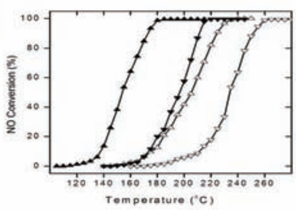
[-▼-] PdMCM-48
[-▲-] PdMCM-41
[-Δ-] PdSBA-3 .

- PdMCM-48 in effective among the mesoporous supports.
- All Pd containing MFI structure shows near about same performance.

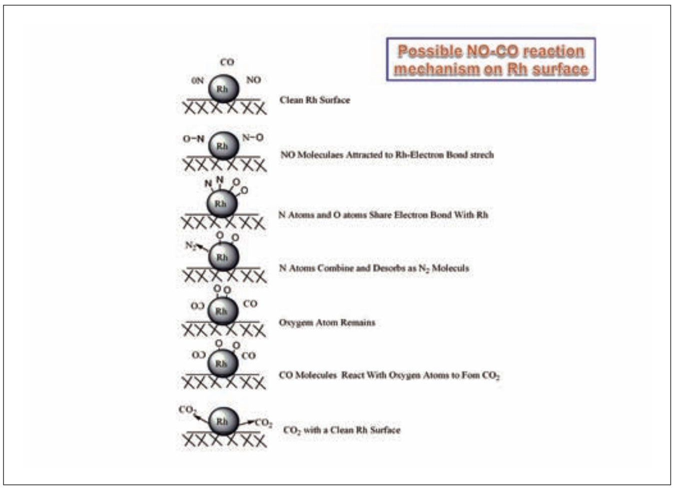
Comparisons of Noble Metal Effect on MCM-48

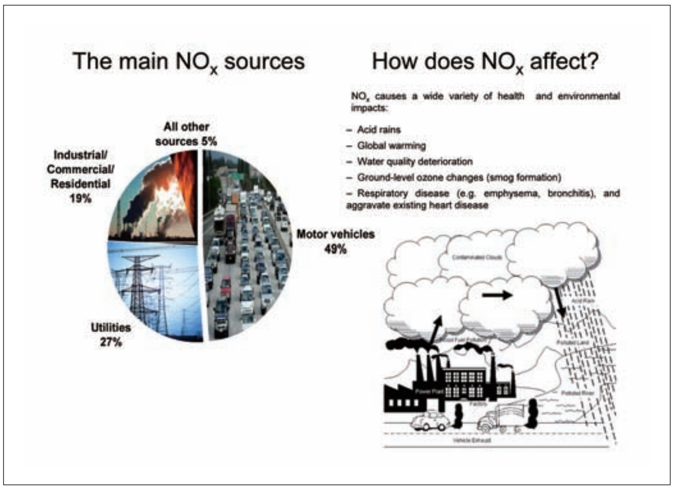
RhMCM-48 is active at low temp. PdMCM-48 and RuMCM-48 show better activity than PtMCM-41

Catalysts	Size nm	NO conversion 25%	100%
PdMCM-48	2.8	190 °C	235 °C
RhMCM-48	1.9	145 °C	185 °C
RuMCM-48	15.7	185 °C	220 °C
PtMCM-48	13.0	225 °C	260 °C



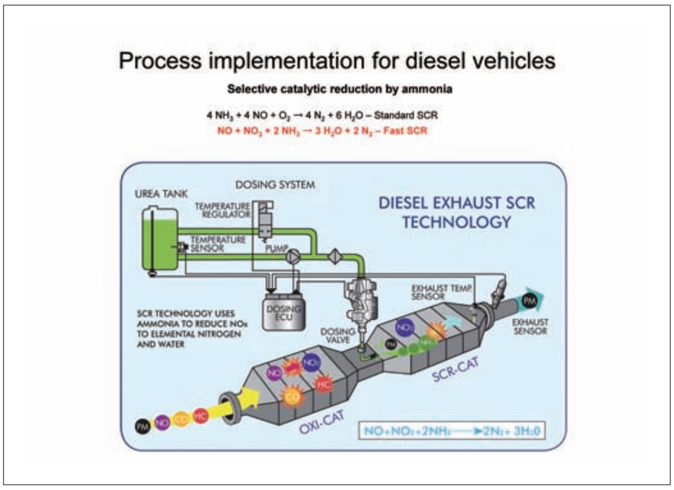
Catalytic performances of different noble metal supported [-▲-] RhMCM-48, [-▼-] RuMCM-48, [-Δ-] PdMCM-48, and [-∇-] PtMCM-48 catalysts.

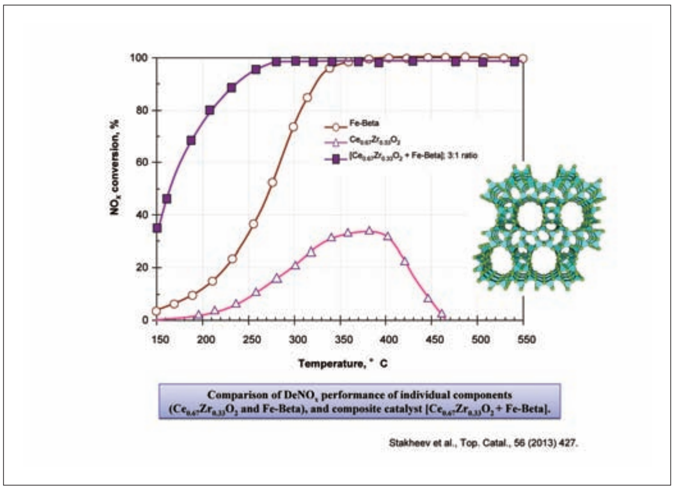


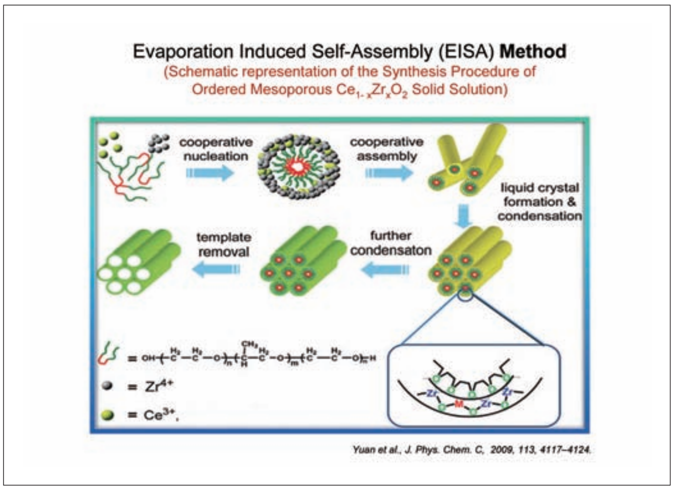


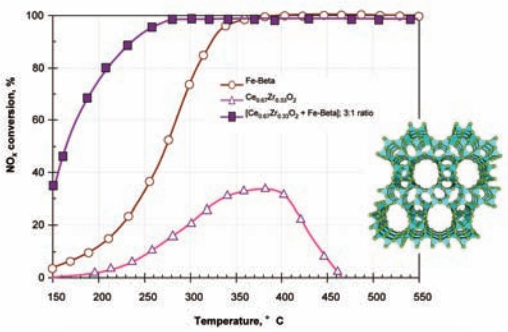
Worldwide emission standards

	REGULATION											
	EURO III TO EURO IV				EURO IV TO EURO V				EURO V TO EURO VI			
Reg. pollutants	NOx	PM	HC	CO	NOx	PM	HC	CO	NOx	PM	HC	CO
Emissions target (g/kWh*)	3.5	0.02	0.40	1.5	2.0	0.02	0.40	1.5	0.4	0.01	0.13	1.5
Emission reduction* (%)	30%	80%	30%	25%	43%	0%	0%	0%	80%	50%	72%	0%
After-treatment system*	• NOx controlb: SCR systems (open loop) • PM control: DOC + PFF				• NOx controlb: SCR systems (closed loop) • PM control: DOC + PFF				• NOx control: SCR systems (closed loop) • PM control: DOC + DPFs			







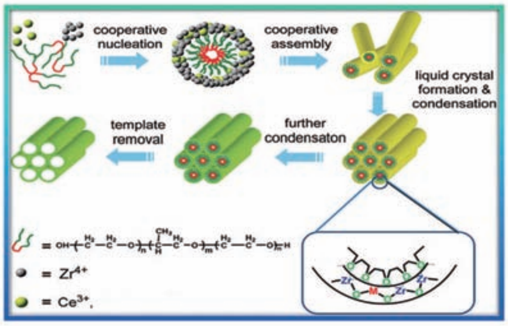


Comparison of DeNO$_x$ performance of individual components ($Ce_{0.67}Zr_{0.33}O_2$ and Fe-Beta), and composite catalyst [$Ce_{0.67}Zr_{0.33}O_2$ + Fe-Beta].

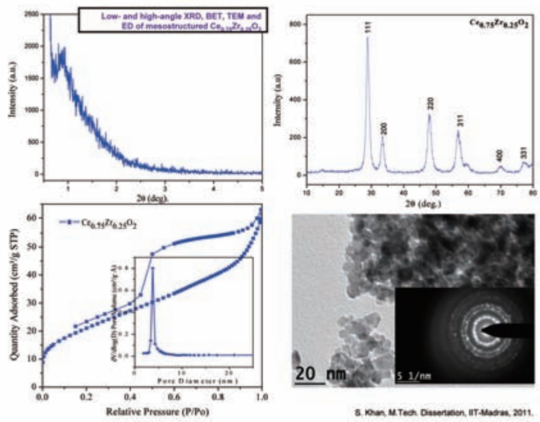
Stakheev et al., Top. Catal., 56 (2013) 427.

Evaporation Induced Self-Assembly (EISA) **Method**

(Schematic representation of the Synthesis Procedure of Ordered Mesoporous $Ce_{1-x}Zr_xO_2$ Solid Solution)



Yuan et al., J. Phys. Chem. C, 2009, 113, 4117–4124.

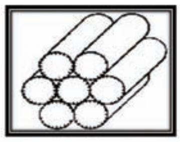


S. Khan, M.Tech. Dissertation, IIT-Madras, 2011.

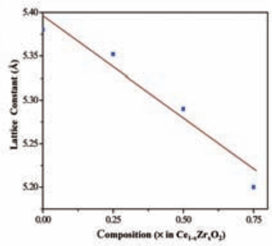
Structural and textural properties of mesostructured CeO_2 and $Ce_{1-x}Zr_xO_2$

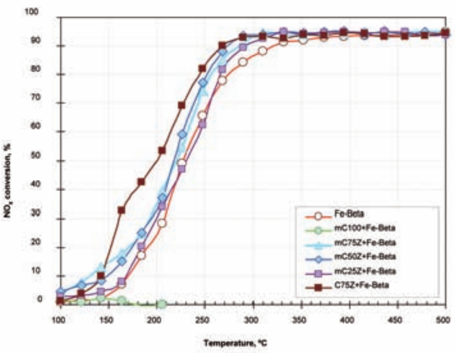
S. Khan, M.Tech. Dissertation, IIT-Madras, 2011.

Materials	a_0 (Å)	d_{100} (nm)	t (nm)	S_{BET} ($m^2 g^{-1}$)	D (nm)	V_P ($cm^3 g^{-1}$)
CeO_2	5.38	7.94	7.2	100.1	3.1	0.29
$Ce_{0.75}Zr_{0.25}O_2$	5.36	10.96	7.5	76.7	4.1	0.09
$Ce_{0.50}Zr_{0.50}O_2$	5.29	9.09	7.6	70.6	3.7	0.08
$Ce_{0.25}Zr_{0.75}O_2$	5.19	5.39	7.8	58.2	3.6	0.08

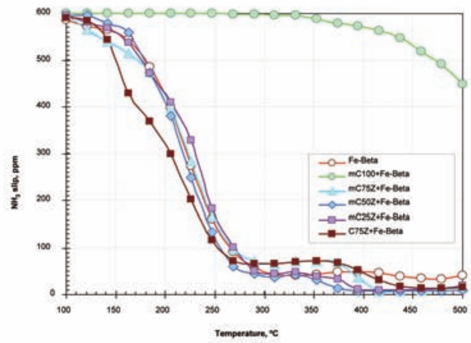


Lattice constant of mesoporous $Ce_{1-x}Zr_xO_2$ as a function of Zr content 'x'.

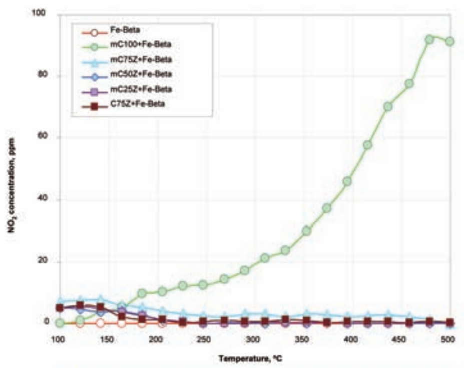




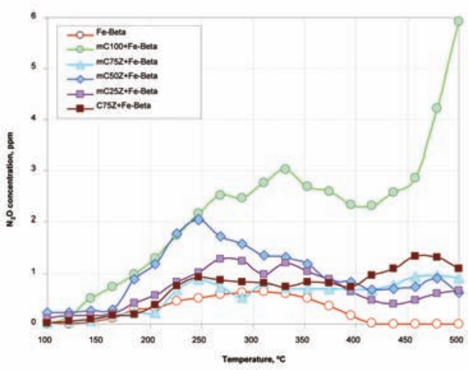
NH_3-DeNO$_x$ performance of Fe-Beta zeolite and the composite [$Ce_xZr_{(1-x)}O_2$ + Fe-Beta]. NO$_x$ conversion. Overall flow rate: 300 ml/min. Catalyst load: 0.160 g (Fe-Beta load: 0.04 g).



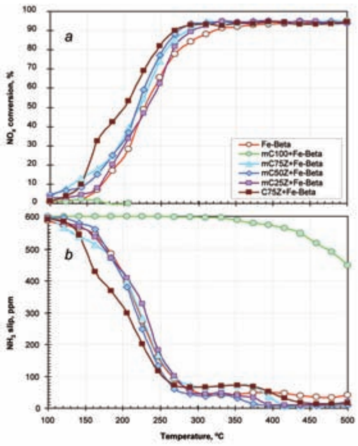
NH_3-DeNO$_x$ performance of Fe-Beta zeolite and the composite [$Ce_xZr_{(1-x)}O_2$ + Fe-Beta]. Outlet NH_3 concentration. Overall flow rate: 300 ml/min. Catalyst load: 0.160 g (Fe-Beta load: 0.04 g).



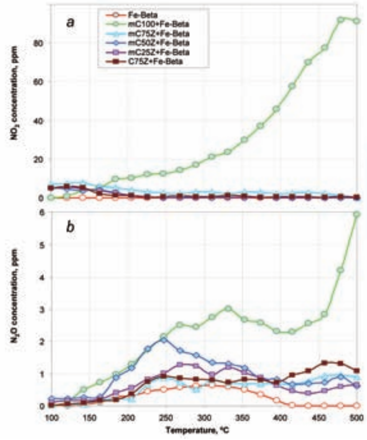
Reaction product (NO_2 concentration, ppm) distribution for Fe-Beta and $[Ce_xZr_{(1-x)}O_2$ + Fe-Beta] composite catalysts.



Reaction product (N_2O concentration, ppm) distribution for Fe-Beta and $[Ce_xZr_{(1-x)}O_2$ + Fe-Beta] composite catalysts.



NH_3-DeNO$_x$ performance of Fe-Beta and the composite $[Ce_xZr_{(1-x)}O_2$ + Fe-Beta].
a)NO_x conversion.
b)Outlet NH_3 concentration.
Overall flow rate: 300 ml/min.
Catalyst load: 0.160 g
(Fe-Beta load: 0.04 g).



Reaction product distribution for Fe-Beta and $[Ce_xZr_{(1-x)}O_2$+Fe-Beta] composite catalysts.
(a)NO_2 concentration, ppm
(b)N_2O concentration, ppm

The Age of Big Competition Next Generation Automobile Business

Tokuta Inoue

Senior Research Fellow, New Industry Creation Hatchery Center, Tohoku University, Japan

The Age of Big Competition
Next Generation Automobile
Business

Tokuta Inoue
Senior Research Fellow, Tohoku University
(Toyota Genesis Research Institute)

Big Competition
in 10 Areas

1. Products Lineup
2. Module, Architecture Design
3. Parts Supply
4. Production Method
5. Production & Sales Network
6. R&D
7. Regulation
8. Business Model
9. Alliance
10. Invader

Key

Local Innovation

Key

Bench Marking

Key

Leader

Key

Insight & Imagination

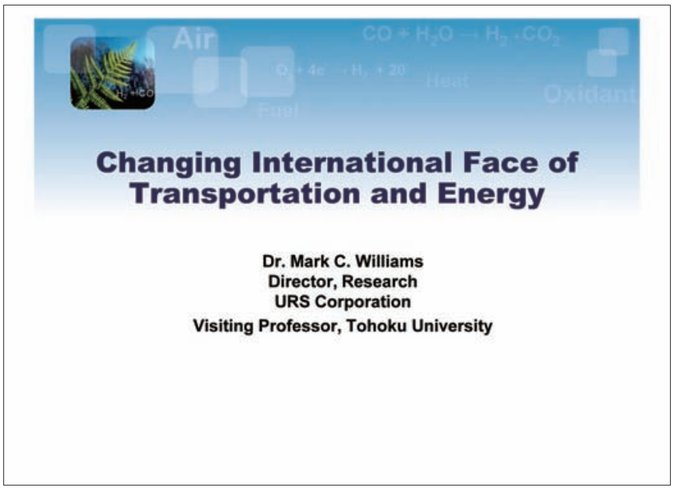

PARADIGM SHIFT
?
Who knows?

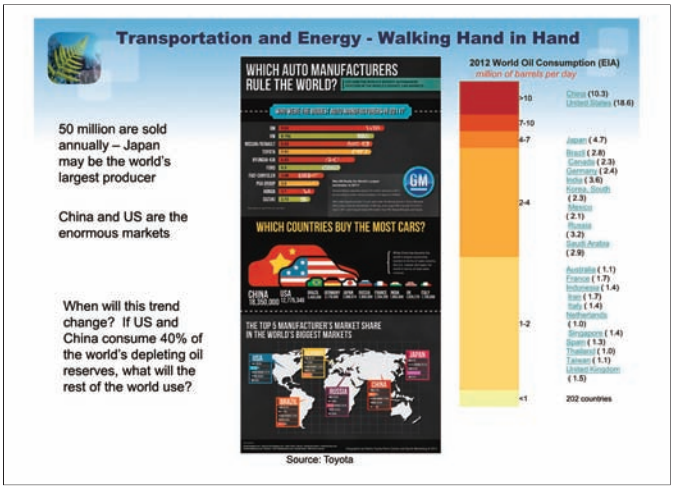

Thank you for your attention

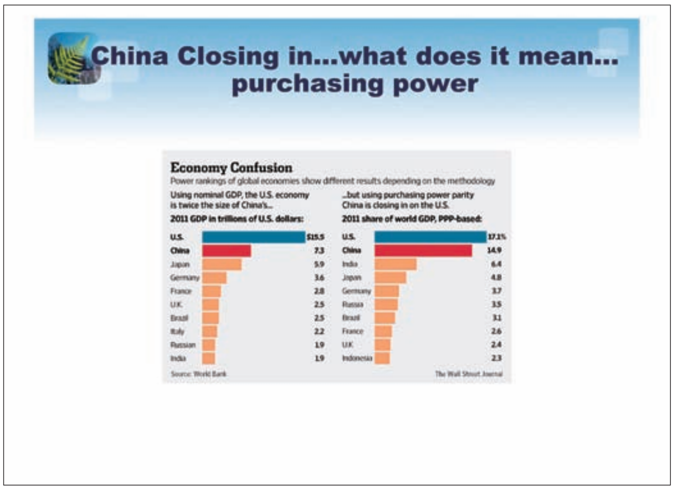
Changing International Face of Transportation and Energy

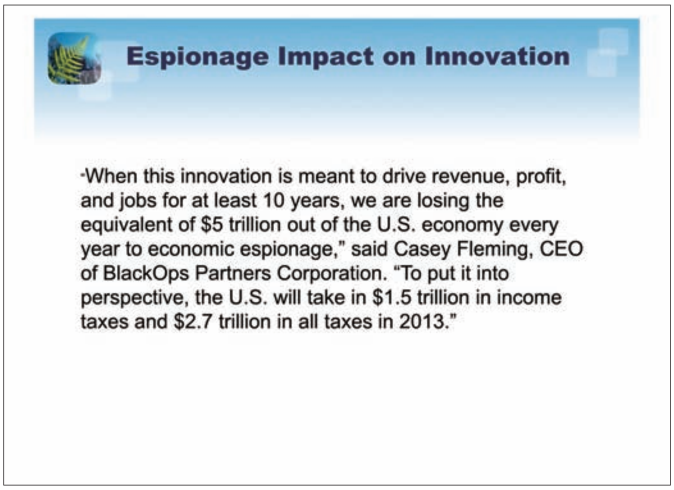
Mark C. Williams

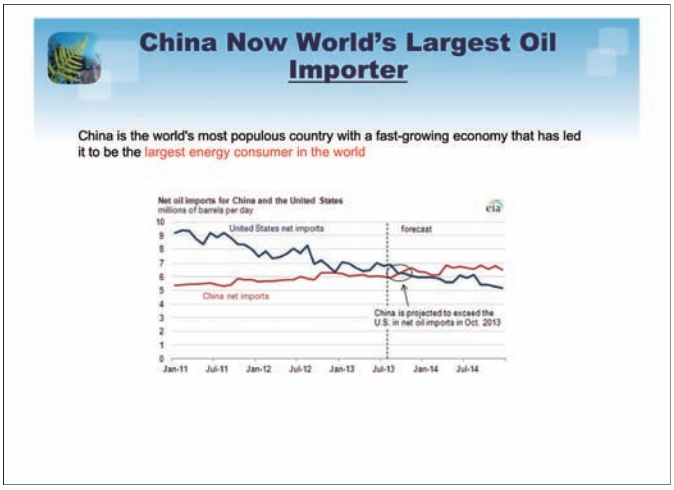
Director, Research, URS Corporation, USA

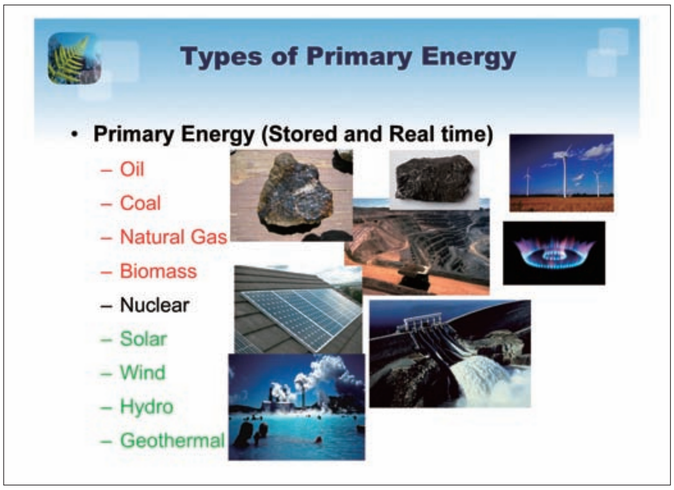












USA Petroleum Transportation Facts

- The world produces/consumes 80 million BBL/day petroleum products
- USA consumes 20 million BBL/day (7 billion BBL/year) petroleum products
- In USA around 2/3 is used for transportation
- Oil is currently $90-100/BBL
- USA imports 8 MM BBL/day
- $300-500 billion/year trade deficit

7

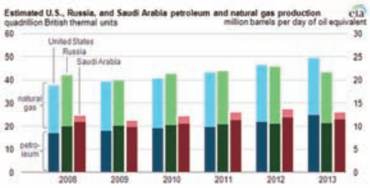
Geography

Ft McMurray

- 225 miles to Edmonton
- 400 miles to Calgary
- 1300 miles to Denver

Image courtesy of: Norman Einstein

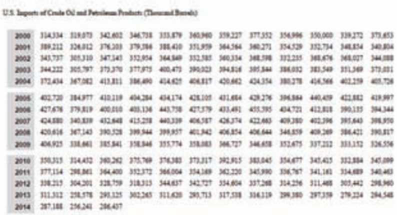
USA is Now World's Largest Oil and Natural Gas Producer



Oil: where do imports come from for USA?

- The world is rapidly consuming the finite amounts of stored energy, especially petroleum.
- Canada (2-3 million BBL/day - half from tar sands) and Middle East (Saudia Arabia/Kuwait) (1.5 million BBL/day) help supply USA petroleum. Rest are Mexico, Venezuela, Columbia, and Russia.
- Canada tar sands contain 300 BBL, one of the world's largest resources ever known, would supply USA for only 40 years. The relentless hunt for oil will continue to the limit of economic viability.
- Major expansion in Canadian production expected in near future. North America expected to become world's largest producer.
- Canada's largest single source of income and CO2 emissions.

USA Imports Dropping



U.S. Imports of Crude Oil and Petroleum Products (Thousand Barrels)

2000	314,334	319,073	342,602	346,738	333,879	360,960	359,227	377,352	356,996	350,000	339,272	373,653
2001	389,212	326,012	376,203	379,386	388,410	351,959	364,564	360,271	354,529	352,734	348,854	340,804
2002	343,737	305,310	347,343	352,954	364,849	352,585	360,334	348,598	332,235	365,676	368,027	344,088
2003	344,222	305,797	373,370	377,975	400,473	390,023	394,816	395,844	386,032	383,549	351,369	373,031
2004	372,434	367,082	413,811	386,490	414,625	406,817	420,662	424,354	380,278	416,566	402,259	405,726
2005	402,720	384,977	410,119	404,284	434,174	428,105	431,684	429,276	396,864	440,459	422,882	419,997
2006	427,676	379,819	400,010	403,136	443,758	427,579	433,491	455,395	434,721	412,818	390,135	394,344
2007	424,880	340,839	432,648	415,258	440,339	406,587	426,374	422,463	409,380	402,396	395,640	398,950
2008	420,616	367,143	390,528	399,944	399,957	401,942	406,854	406,644	346,859	409,269	384,421	390,817
2009	406,925	338,661	385,841	358,846	355,774	358,083	366,727	346,658	352,675	337,212	333,152	326,556
2010	350,315	314,432	360,262	375,769	376,383	373,317	392,915	383,045	354,677	345,415	332,884	345,099
2011	377,134	298,861	364,400	352,372	366,004	354,169	362,220	345,990	336,767	341,161	334,689	340,463
2012	338,215	304,201	328,759	318,313	344,637	342,727	334,604	337,268	314,256	311,468	303,442	298,960
2013	311,312	258,578	293,125	302,265	311,620	293,713	317,538	316,119	299,380	297,359	279,224	294,548
2014	287,188	256,241	286,437									

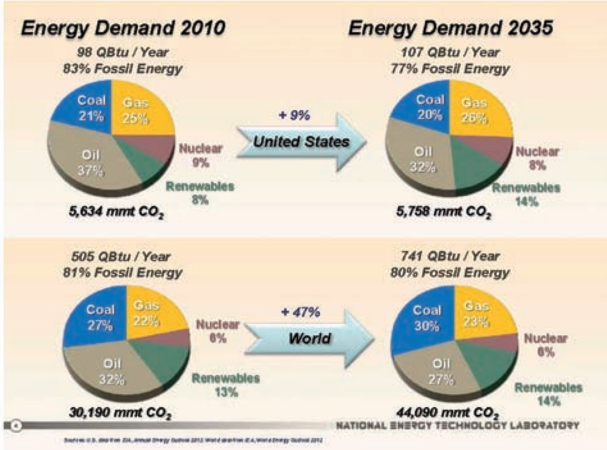
USA Energy Independence Now Possible with Conservation

- USA World's Largest Oil Producer
- USA Largest NG Producer
- Still imports 300,000,000 BBL/month
- Cost $1 billion/day
- Opportunity with demand side management to lower consumption through higher automobile fleet efficiency
- 2/3 oil used for transportation
- Opportunity for improvement in stationary power generation with fuel cells
- Opportunity to be energy independent…which means not funding terrorism?

Coal: Transitioning to a Sustainable Energy Future

- In 2012 40% of the world's electricity needs were provided by coal. Coal is the second source of primary energy after oil. (IEA)
- China produces 4.0 billion tons of coal per year (EIA)
  - China is consuming its coal resources faster than any nation
- USA produces 1.0 billion tons of coal per year (EIA)
- Coal use in North America is being discouraged by environmentalists
- Coal may still be mined in NA and exported to countries giving them a low-cost energy advantage
- Coal's use world-wide is accelerating.
- Coal may last only 150 years

13



Nuclear Power Plant Efficiency

- The fuel rods will spend about 3 operational cycles (typically 6 years total now) inside the reactor
- Generally when about 3% of their uranium has been fissioned, they will be moved to a spent fuel pool where the short lived isotopes generated by fission can decay away.
- After about 5 years in a spent fuel pool the spent fuel is radioactively and thermally cool enough to handle, and it can be moved to dry storage casks or reprocessed.
- There is no storage facility for nuclear waste in USA.
- In USA all nuclear waste belongs to the Department of Energy and hence to the American people.

The Future

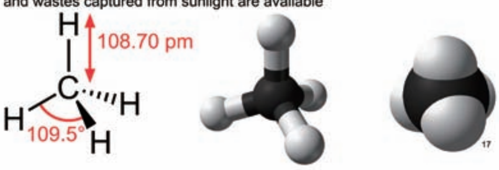
- Oil, Coal and nuclear are finite stored energy
- These will be going away in the future
- These leaves solar, natural gas, biomass, wind, geothermal and hydro

Natural Gas

We will always have natural gas (methane) on this planet

We benefit from the chemical energy extracted from sunlight on this planet
- Coal, petroleum and natural gas are stored chemical energy from the past

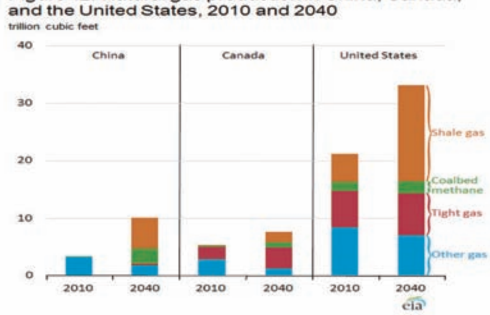
As long as there is life and sunlight, we will always have natural gas on this planet in the future
- Methane from human (ADG) and plant and animal and plant residues and wastes captured from sunlight are available



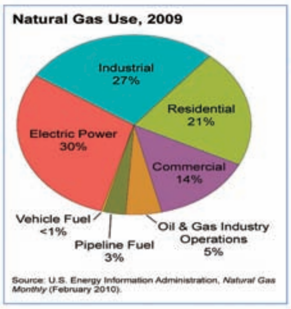
17

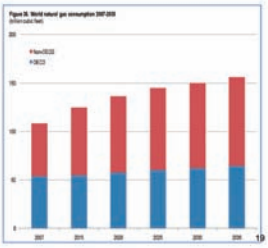
US surpasses Russia as world's top natural gas producer – larger than China and Canada

Figure 42. Natural gas production in China, Canada, and the United States, 2010 and 2040



United States uses 23 trillion cubic feet/year (Tcf/yr) of NG





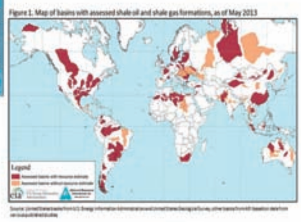
19

Energy

The Global Natural Gas Resource

(The result of new science, technology, engineering, math and research)

The areal extent of global shale gas basins would cover almost all of the western hemisphere.



The areal extent of US shale gas basins would cover more than half the country.

Methane Hydrates

Energy's Next Frontier

- **Resource widespread and bountiful**
  - 50,000 Tcf offshore the U.S. Lower 48
  - 5,000 Tcf or more likely recoverable
- **Better characterization is needed**
  - Sampling and testing of deepwater deposits
  - Role in the natural environment
- **New technology is needed**
  - For safe, efficient extraction
  - Industry expenditure is negligible
- **International Collaboration**
  - Leveraging international funds to expand and accelerate research

Natural gas released from gas hydrate is flared during cooperative DOE-ConocoPhillips-Japanese scientific production test on the Alaska North Slope, March 2012

NATIONAL ENERGY TECHNOLOGY LABORATORY

NETL

Stored NG and Transportation Facts

- **US consumes 20 million BBL/day petroleum products**
- **This is the energy equivalent of 27 Tcf/year NG**
- **At the PSU estimate, the Marcellus Shale, if only 1/3 was recovered, could replace US petroleum for transportation for only around 50 years**
- **NG at $5/MMBTU is the energy equivalent of $28 /BBL oil**
- **Oil is currently $105/BBL**

22

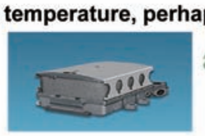
CNG Vehicles

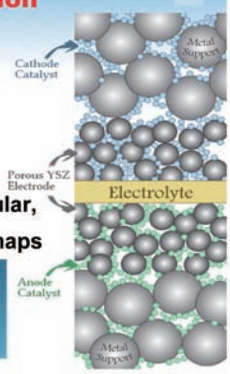
- **Currently, the only natural gas light-duty vehicle manufactured in the U.S. is the Honda Civic ($26,000 list price; 24 city/36 hwy/28 combined gasoline equivalent mpg).**
- **Only roughly 110,000 of the 12 million CNG vehicles worldwide are in the U.S., including aftermarket conversions.**
- **There are roughly 250 million registered passenger vehicles in the US (EIA)**
- **Cost to convert vehicles to NG is estimated $12,500 to $22,500 depending on the vehicle, engine, size of CNG tanks needed, and who does the converting (Green Car Journal, 2011)**
- **Inadequate NG Infrastructure in USA**

23

Natural Gas Fuel Cells for Transportation

- **Natural gas fuel cells**
  - Direct methane
  - Internal reforming
- **Complete re-look**
- **Metal-supported planar or tubular, intermediate temperature, perhaps SOFC-type**
  - Durability
  - Efficiency

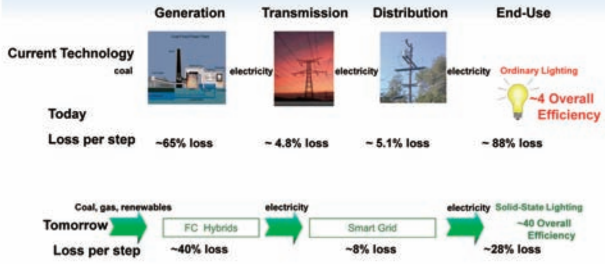




Powering the Electric Grid from Natural Gas, Biomass, Wind, Hydro, Geothermal and Solar

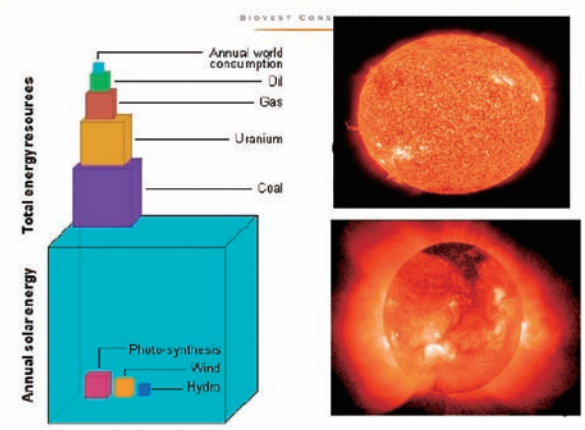
- **These fuels primarily support the electric electrical grids of the future**
  - Already beginning to happen in USA and Germany
  - First time in US history more electricity is being made from NG than coal
- **The use of this electrical energy for transportation and especially battery vehicles and plug-in hybrids is increasing.**
- **Electrification of local transportation through the electric grid will be key feature once oil is depleted**

Transitioning from Energy Waste to Wise Energy Use



We can increase efficiency by more than **10x**!

26



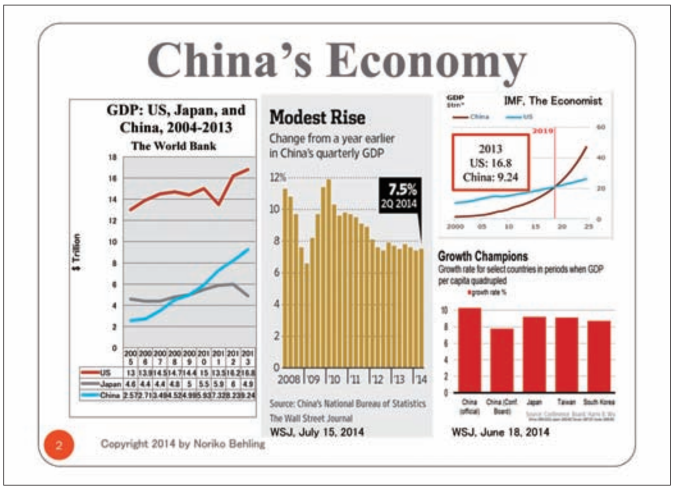
Priority Research

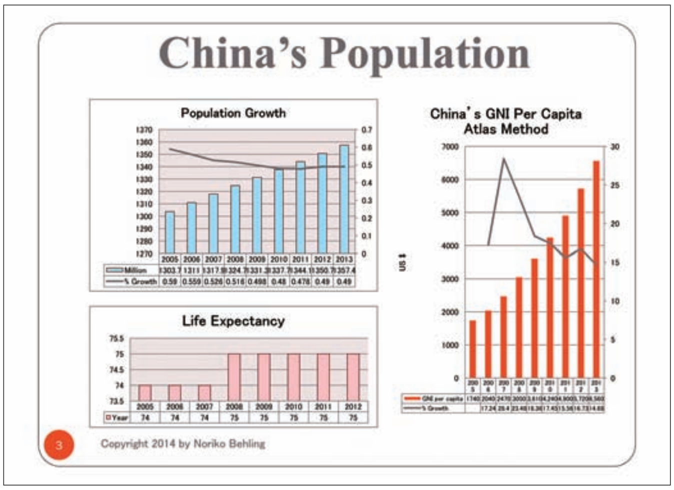
- Light (solar performance and cost) - transportation and stationary
- Energy Storage
  - Natural gas on-board storage
  - Battery (performance and cost)
- Waste heat recovery
- H2 fuel cells for transportation for long distance
- Natural gas fuel cells for transportation
- H2 and fuel production directly from water, CO2 and light
- H2 and liquid fuels indirectly from water, NG and energy (light, thermal)

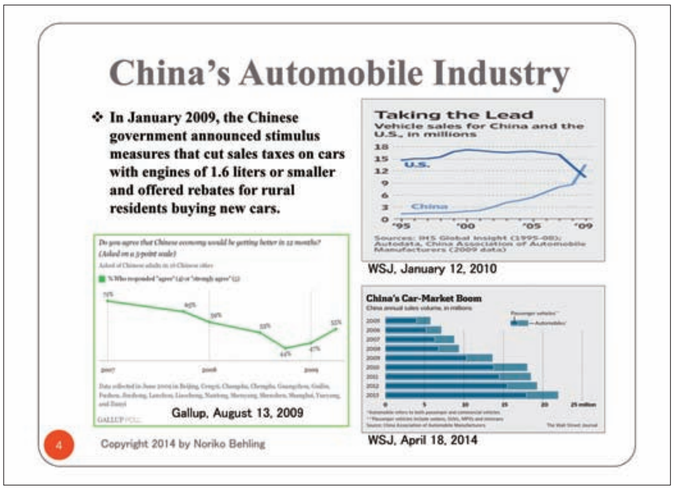
Overview of the Automobile Industry in China

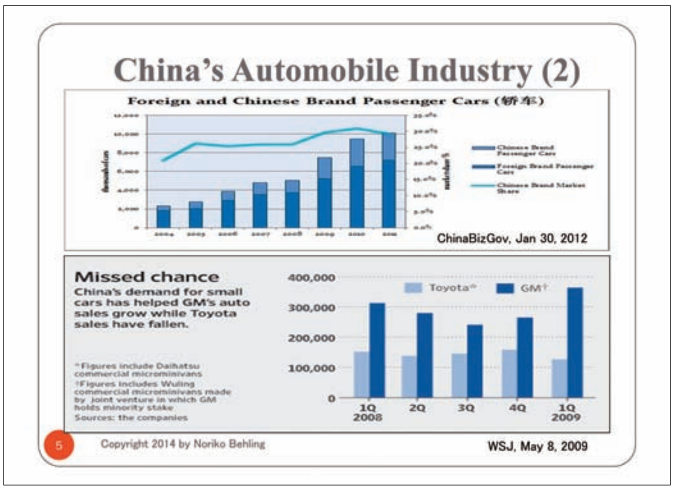
Noriko Hikosaka Behling

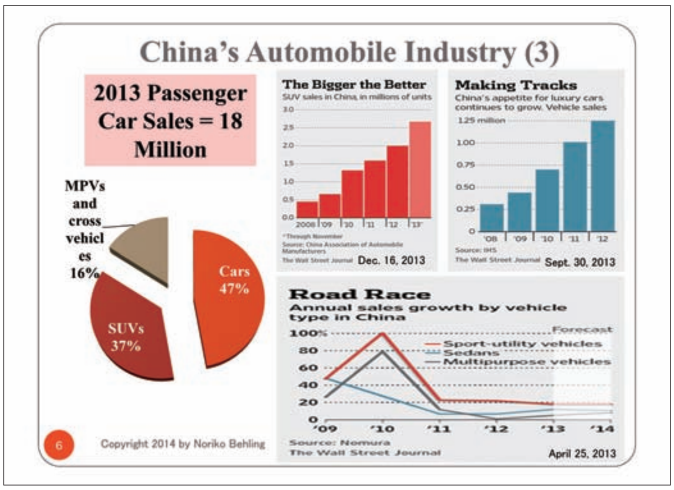
Author, Virginia, USA



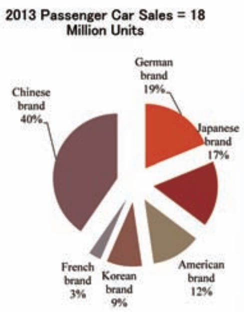




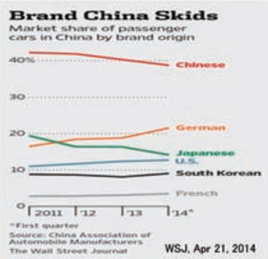




China's Automobile Industry (4)



- Declining Ratio of China Domestic Car Sales
- Poor Quality, Uninspiring Marketing and Inefficient Industry Structure



WSJ, Apr 21, 2014

7 Copyright 2014 by Noriko Behling

China's Automobile Industry (5)

WSJ, June 11, 2014

- Volkswagen remains on top. One of the earliest entrants in the market, VW consolidated its grip with a 14.4% market share so far in 2014, from 13.4% last year. It offers everything from low-end sedans to sporty not including its Skoda or Audi units.
- VW brand and pricing are so compelling that dealers barely offer discounts and still sell to a higher proportion of visitors than other brands.
- The clearest losers are domestic car makers. They sold 38% of all locally made cars this year through May, down from nearly 42% in the same period last year.

8

China's Automobile Industry (6)

- After nationalist protests in late 2012, Toyota, Honda and Nissan regained some market share partly by launching new models. But Toyota's market share at 4.9% in June 2014 is still below the 2011 level of 5.5%.
- Other foreign brands lagged behind are General Motors main passenger-car brands. The 8.2% market share its Buick and Chevrolet brands command this year has slumped from 8.6% last year. GM's latest SUVs haven't sold as well as hoped.
- In contrast, Ford, a relative newcomer to China, has made inroads with SUVs and sedans. Ford sold 4.1% of the cars made in the country between January and May, compared to 3.8% last year and just 2.2% in 2011.

--WSJ, June 11, 2014

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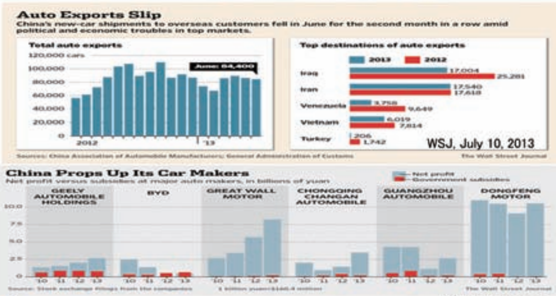
China's Automobile Industry (7)

- China has more than 170 domestic car makers.
- Local government incentives keep small companies expanding even as Beijing encourages consolidation. Some $700 million in incentives given to local brands in 2013.



WSJ, July 10, 2013

10 Copyright 2014 by Noriko Behling

WSJ, May 23, 2014

China's Automobile Industry (8)

- After three years of seizing market share from Chinese rivals, foreign auto makers are starting to compete with each other.

WSJ, Dec. 10, 2013

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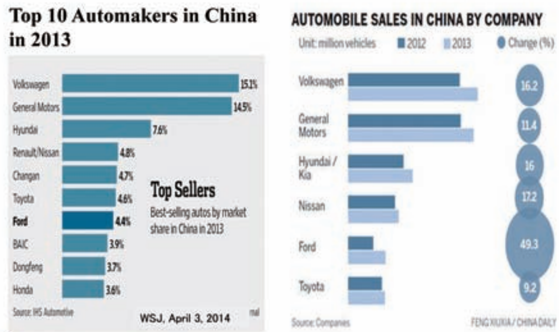
China's Automobile Industry (9)



WSJ, April 3, 2014

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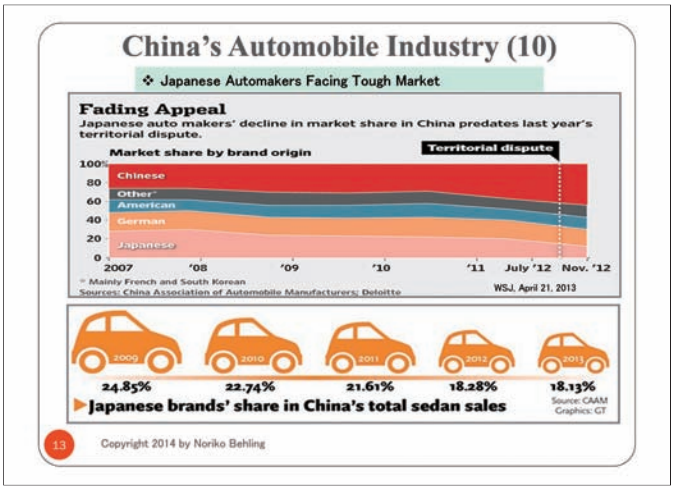
China's Automobile Industry (10)
❖ Japanese Automakers Facing Tough Market
Fading Appeal
Japanese auto makers' decline in market share in China predates last year's territorial dispute.
Market share by brand origin
Territorial dispute
Chinese
Other*
American
German
Japanese
2007 '08 '09 '10 '11 July '12 Nov. '12
* Mainly French and South Korean
Sources: China Association of Automobile Manufacturers; Deloitte
WSJ, April 21, 2013
24.85%
22.74%
21.61%
18.28%
18.13%
Japanese brands' share in China's total sedan sales
Source: CAAM
Graphics: GT
13
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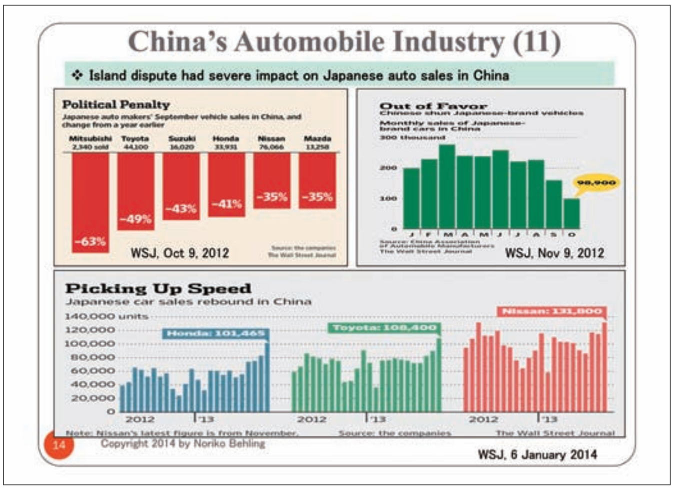
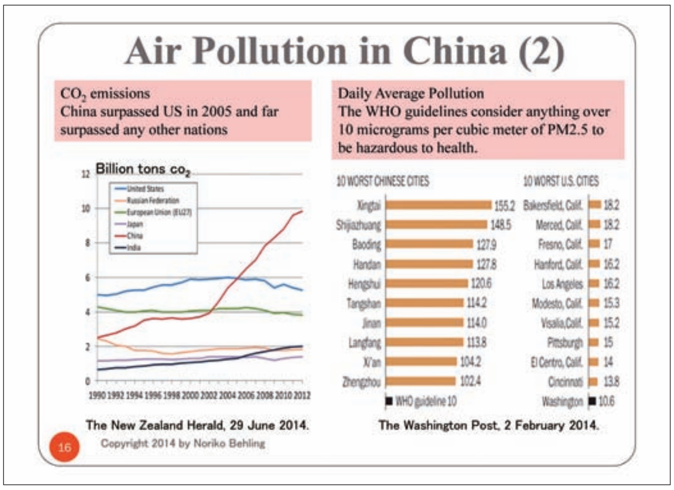

China's Automobile Industry (11)
❖ Island dispute had severe impact on Japanese auto sales in China
Political Penalty
Japanese auto makers' September vehicle sales in China, and change from a year earlier
Mitsubishi Toyota Suzuki Honda Nissan Mazda
-63% -49% -43% -41% -35% -35%
WSJ, Oct 9, 2012
Out of Favor
Chinese shun Japanese-brand vehicles
Monthly sales of Japanese-brand cars in China
300 thousand
98,900
WSJ, Nov 9, 2012
Picking Up Speed
Japanese car sales rebound in China
140,000 units
Honda: 101,465
Toyota: 108,400
Nissan: 131,800
2012 '13 2012 '13 2012 '13
Note: Nissan's latest figure is from November.
Source: the companies
The Wall Street Journal
14
Copyright 2014 by Noriko Behling
WSJ, 6 January 2014


Air Pollution in China:
A Critical Problem
A photo of the skyline of Shanghai's Lujiazui Financial District covered with heavy smog, Associated Press, 9 December 2013
15
Copyright 2014 by Noriko Behling


Air Pollution in China (2)
CO2 emissions
China surpassed US in 2005 and far surpassed any other nations
Daily Average Pollution
The WHO guidelines consider anything over 10 micrograms per cubic meter of PM2.5 to be hazardous to health.
Billion tons co2
United States
Russian Federation
European Union (EU27)
Japan
China
India
10 WORST CHINESE CITIES
Xingtai 155.2
Shijiazhuang 148.5
Baoding 127.9
Handan 127.8
Hengshui 120.6
Tangshan 114.2
Jinan 114.0
Langfang 113.8
Xi'an 104.2
Zhengzhou 102.4
WHO guideline 10
10 WORST U.S. CITIES
Bakersfield, Calif. 18.2
Merced, Calif. 18.2
Fresno, Calif. 17
Hanford, Calif. 16.2
Los Angeles 16.2
Modesto, Calif. 15.3
Visalia, Calif. 15.2
Pittsburgh 15
El Centro, Calif. 14
Cincinnati 13.8
Washington 10.6
The New Zealand Herald, 29 June 2014.
The Washington Post, 2 February 2014.
16
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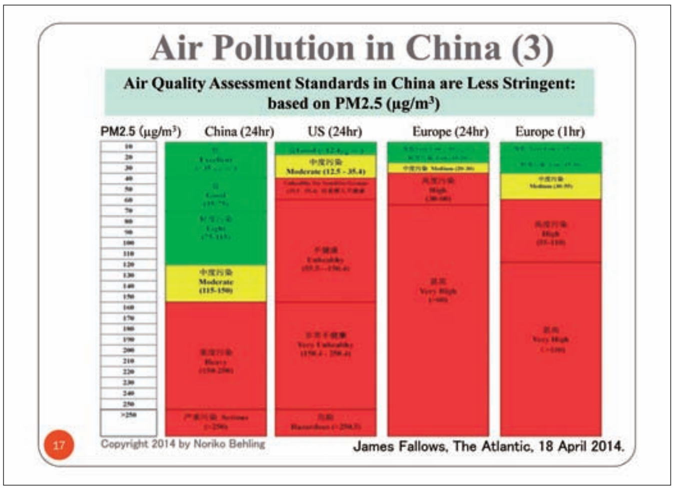
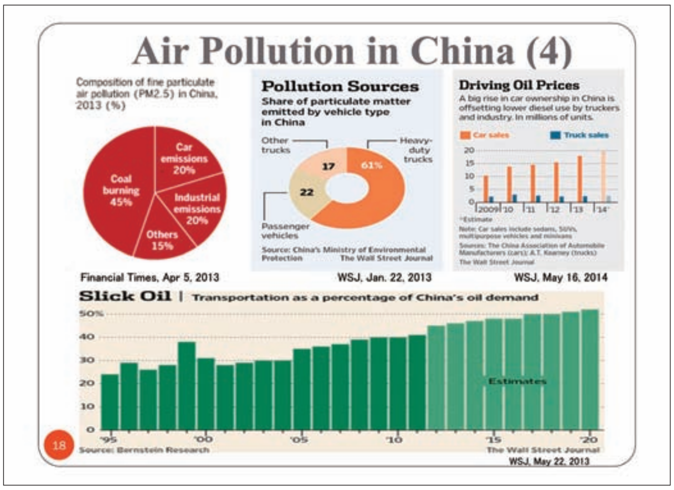

Air Pollution in China (3)
Air Quality Assessment Standards in China are Less Stringent: based on PM2.5 (μg/m³)
PM2.5 (μg/m³)
China (24hr)
US (24hr)
Europe (24hr)
Europe (1hr)
17
Copyright 2014 by Noriko Behling
James Fallows, The Atlantic, 18 April 2014.


Air Pollution in China (4)
Composition of fine particulate air pollution (PM2.5) in China, 2013 (%)
Car emissions 20%
Coal burning 45%
Industrial emissions 20%
Others 15%
Financial Times, Apr 5, 2013
Pollution Sources
Share of particulate matter emitted by vehicle type in China
Other trucks
Heavy-duty trucks
Passenger vehicles
61%
Source: China's Ministry of Environmental Protection
The Wall Street Journal
WSJ, Jan. 22, 2013
Driving Oil Prices
Car sales
Truck sales
WSJ, May 16, 2014
Slick Oil | Transportation as a percentage of China's oil demand
Estimates
Source: Bernstein Research
The Wall Street Journal
WSJ, May 22, 2013
18

Air Pollution in China (5)

China's Anti-Pollution Protests Grow Increasingly Violent

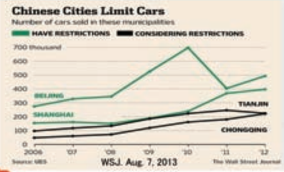
- **A damaged police after residents clashed with police during a protest in Hangzhou, east China's Zhejiang province, on May 11.**
- **Dozens hurt in eastern China protesting construction of a waste incinerator, the latest example of public willingness to fight government plans viewed as polluting--WSJ, May 12, 2014**

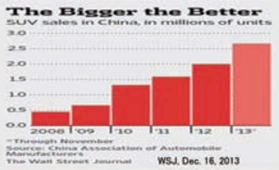
Agence France-Presse/Getty Images

19

China's Air Pollution Control Policy (1)

- In January 2011, Beijing started to renew vehicle license plates via a vehicle license lottery. Many cities followed this example.
- Hangzhou restricted the number of new car licenses it issues and will only issue new plates via an auction and lottery.
- Shanghai, Guangzhou, Guiyang, and Tianjin also limit the number of new vehicles registered each year.
- Consumers responded by buying more expensive SUVs with bigger engines.
- Consumers see SUVs as both a powerful status symbol and a safer option on China's often dangerous roads.
- Great Wall Motors had 70% year-over-year growth in SUV sales—twice that of its total sales in April.
- This could have significant implications for global oil demand.





20

China's Air Pollution Control Policy (2)

- As of October 2013 China limited permissible running age of a vehicle, scrapping up to 6 million vehicles that don't meet emission standards. Hebei province, where seven of China's smoggiest cities, has been ordered to scrap 660,000 cars that do not meet emission standards.
- Up to 333,000 will be taken off the roads in Beijing and 160,000 in Shanghai. Up to 5 million are being removed in highly developed regions including the Yangtze River Delta, the Pearl River Delta and the smog-choked region of Beijing-Tianjin-Hebei.
- Elimination of old cars has prompted less affluent to buy more Minivans in 2014.

WSJ, June 10, 2014

21

China's Air Pollution Control Policy (3)

- In September 2013, China began a subsidy program for new energy vehicles. China wants 500,000 hybrid and electric vehicles on its roads by next year and five million by 2020. Buyers of electric cars can receive subsidies up to 60,000 yuan ($9,800); buyers of gasoline-electric hybrids can get as much as 35,000 yuan. Subsidies will drop 10% next year and another 20% in 2015.
- In July 2014, China announced individual car buyers will be exempt from a 10% vehicle tax when they purchase new energy vehicles or fuel-efficient automobiles.
- Also China revealed a mandate with subsidies requiring 30 percent of all automobiles purchased by public agencies to be electric or "new energy" vehicles by 2016. The new rules will be phased in over the next two years
- Subsidies will be offered for purchases of vehicles that cost less than 180,000 yuan ($29,186), subsidies included.
- Local governments would be asked to build charging stations and other infrastructure.
- In early 2014, Shanghai announced plans to give 3,000 free license plates to buyers of imported electric cars, exempting them from a bidding system that drives up license plate prices to more than 70,000 yuan.

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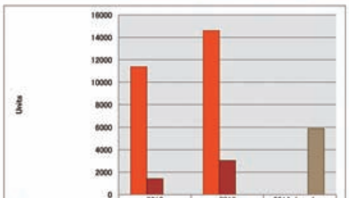
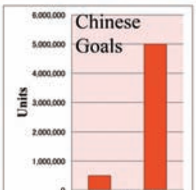
China's Air Pollution Control Policy (4)

- Only around 17,600 new energy vehicles were purchased in China in 2013, including hybrid and pure-electric cars and buses.



	2012	2013	2014 Jan–June
BEVs (Battery Electric Vehicle)	11375	14,604	
PHEVs (Plug-in Hybrid Electric Vehicle)	1416	3,038	
Total New Energy Vehicle Sales			5889
Total	12,791	17,642	5889

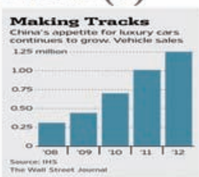


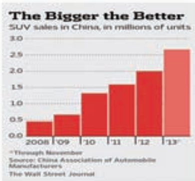
	2015	2,020
China's New Energy Vehicle Goals	500,000	5,000,000

23

Future Opportunities (1)

- Luxury Cars. Consulting firm McKinsey in 2013 estimated that by 2022 China's urban population will grow by an additional 100 million to 357 million. Upper middle class, households with disposable income between 106,000 and 229,000 yuan will expand to 54% of all households from 14% in 2012. These consumers would be prime targets for luxury car marketers, especially if they embraced monthly payments. (WSJ, April 28, 2014)
- SUVs. According to the Market China SUV Industry Report, 2014, the SUV market is expected to grow rapidly over the next five years, and sales volume will reach 7.9 million in 2018. (PRWEB, February 12, 2014). Many foreign automakers are planning to produce SUVs in China. GM China introduced the Cadillac SRX, which melds the characteristics of a car and a sport-utility vehicle, in 2009. Sales of the car rose 23% in China to 14,496 vehicles in the first half of 2014 from the year before, accounting for more than 40% of Cadillac sales in the country.





24

Future Opportunities (2)

Lower-Tier Buyers are Next Frontier in China

❖ Compact Cars, including Minivans, and Low Cost Cars.

Consumers living in smaller cities, known as tier-three and tier-four cities, will drive future demand for cars in China, as the world's largest market for new autos undergoes structural shifts, according to a survey by the semiofficial China Association of Automobile Manufacturers and market-research firm Nielsen Holdings. These cities are less affluent but faster-growing. About 60% of would-be buyers in these cities are looking at cars priced at below 120,000 yuan (around $19,400), according to the survey. (WSJ, July 10, 2013)

25

Future Opportunities (3)

❖ Huge Potential in China's Auto Loan Business

❖ Auto makers introduce China to the car loan, where young car buyers are open to financing where cash has traditionally ruled

WSJ, July 9, 2014

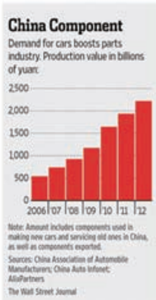
26

Future Opportunities (4)

❖ Used Cars. In the last five years, 60 million new cars were sold in China. Now, some are starting to come back on the market as used vehicles. In addition, many cities are reducing the number of new car registrations. Through trade-ins, used car dealers get the license plates. The city isn't retiring old license plates, so they can continue to use them. Last year, the number of used cars in China increased by 8.6% to 5.2 million units, while the turnover grew 10.6% to yuan 291 billion, according to the China Automotive Distribution Industry and Aftermarket Report.

❖ Leased Cars. Tesla said it created a new finance arm and is offering a business leasing program for small and medium-size businesses, providing another financing option for its electric cars.

❖ Automobile Parts. Delphi, an auto parts maker, expect its China revenue to double to nearly $5.5 billion by 2016 as Chinese car makers boost quality for discerning local customers. Delphi China President said Chinese brands could become global players if the government relaxed joint-venture restrictions on foreign auto companies.



27

Future Opportunities (5)

❖ Luxury Trucks. After dropping the past couple of years, the commercial truck market is about to take off again, fueled by increasing demand for higher-quality vehicles. China's truckers are increasingly moving up the price scale away from the low-cost, no-frills trucks that have traditionally dominated the market. Rising fuel costs, shippers' need for bigger loads and better roads that permit trucks to travel at higher speeds are driving demand for bigger and better trucks (WSJ, 18 Oct 2013).

28

Foreign Automakers' Strategies (1)

- Audi, BMW, and Daimler are focusing on smaller made-in-China luxury cars. They are are speeding up plans to offer a wider selection of small cars and sport-utility vehicles in China (WSJ, Sept. 30, 2013).
- Volkswagen plans to invest $24.7 billion in China from 2014 to 2018 to open new factories and introduce new models. It aims to sell more than 3.5 million vehicles in China in 2014. It also focuses on new energy cars.

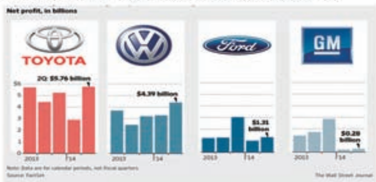
29 WSJ, Sept. 30, 2013

Foreign Automakers' Strategy (2)

❖ Toyota, the world's largest car maker by sales, plans to bring 15 new car models to China by 2017 as part of its efforts to double its sales to plans to reach more than one million in 2014 and two million cars over the long run. (WSJ, April 19, 2014)

❖ Toyota is becoming more ambitious about its China business, with an aim to take the third spot in the world's largest market for cars in terms of market share.

❖ Toyota will focus on low-cost cars and hybrid vehicles.

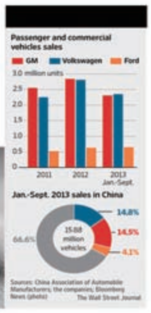


30 WSJ, August 5, 2014

Foreign Automakers' Strategies (3)

- GM plans to introduce nine new or refreshed SUVs in China within the next five years and to release a new Cadillac every year through 2016. The new Cadillac SRX melds the characteristics of a car and a sport-utility vehicle.
- Ford said that it will have introduced 15 new models in China between 2011 including the luxury brand

Lincoln and the classic Mustang muscle car. It plans to market a new version of Mustang in China and Europe in late 2014.



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Foreign Automakers' Strategy (4)

❖Hyundai Motor Plans New China Factory

- ❖ Hyundai plans to build a fourth plant by late 2014 in Chongqin. It has 3 plants, each 300,000 unit capacity in Beijing.
- ❖ Hyundai plans to launch its first battery-powered electric vehicle (EV) in 2016.
- ❖ Hyundai faces rising competition in China, from Japanese rivals and from GM and Volkswagan. GM plans to add four plants by 2015; Volkswagen opened a new factory in Xinjiang last August. (WSJ, March 26, 2014)

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Foreign Automakers' Strategies (5)

- ❖ After years of lost ground, Fiat and Chrysler plan to produce Jeep in China aiming at China's booming SUV market starting in late 2015 (WSJ, April 19, 2014).
- ❖ China's Donfeng injected at least €3 billion ($4.09 billion) into France's Peugeot and became one of largest shareholders (WSJ, Feb. 18, 2014).

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Thank You Very Much for Your Attention

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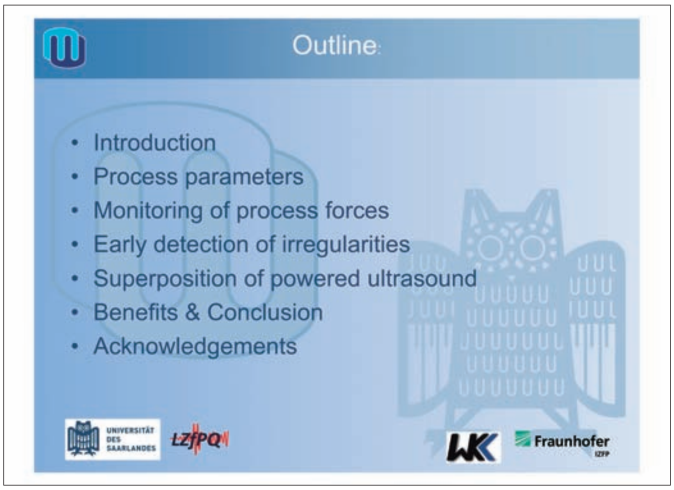
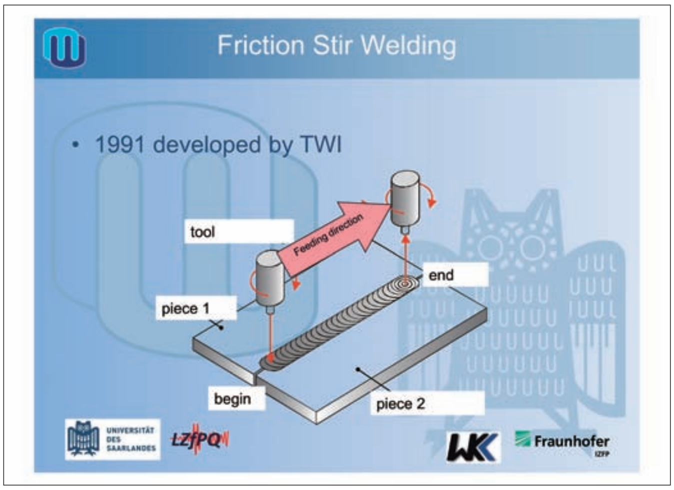
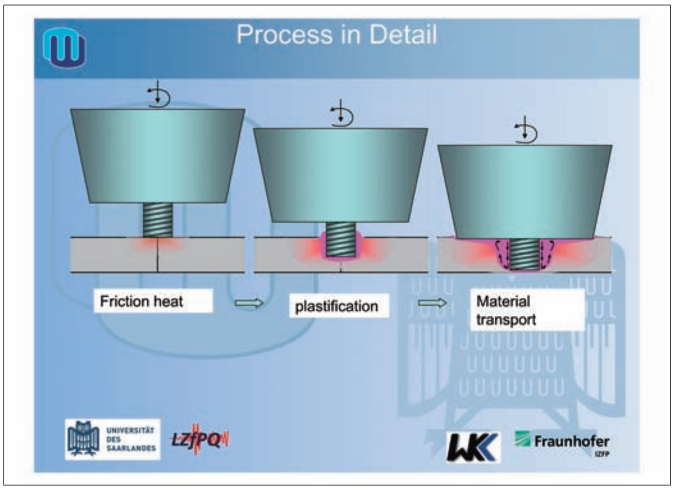
Advanced NDT to Monitor Friction StirWelding

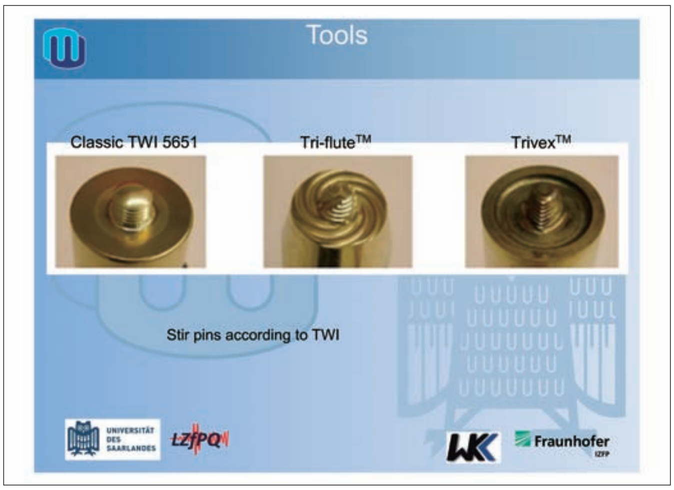
Gerd Dobmann

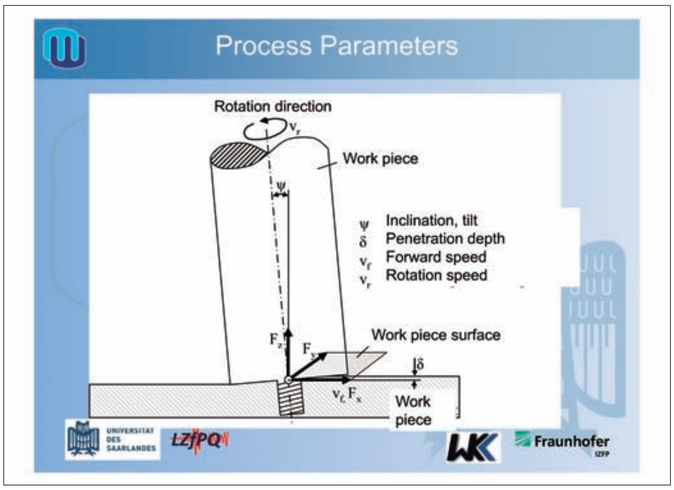
Chair for NDT and Quality Assurance, Saar University, Germany

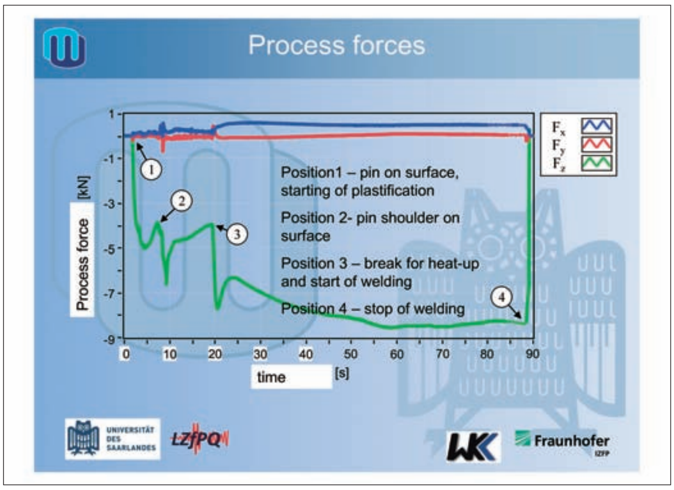


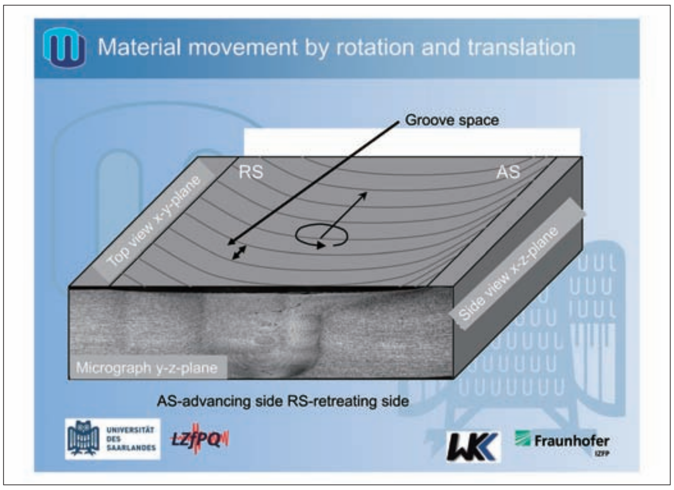


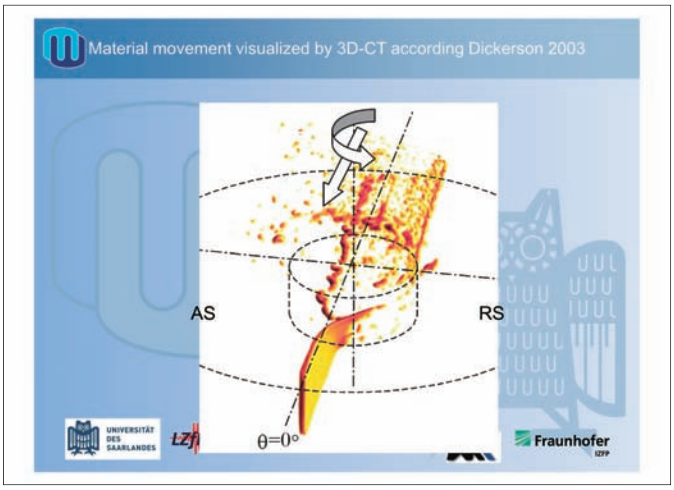




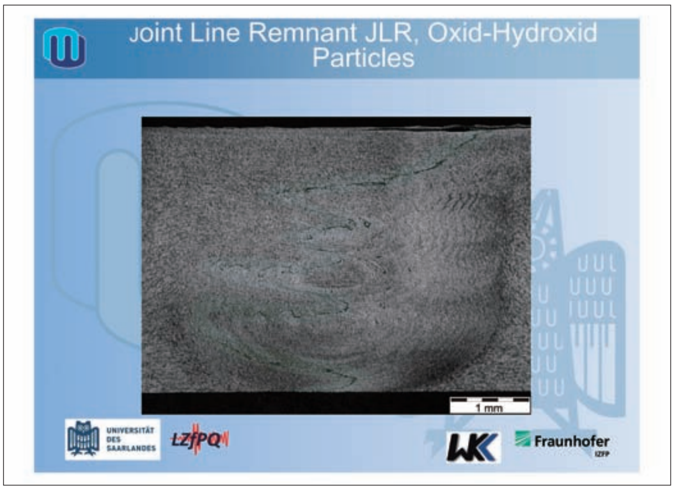


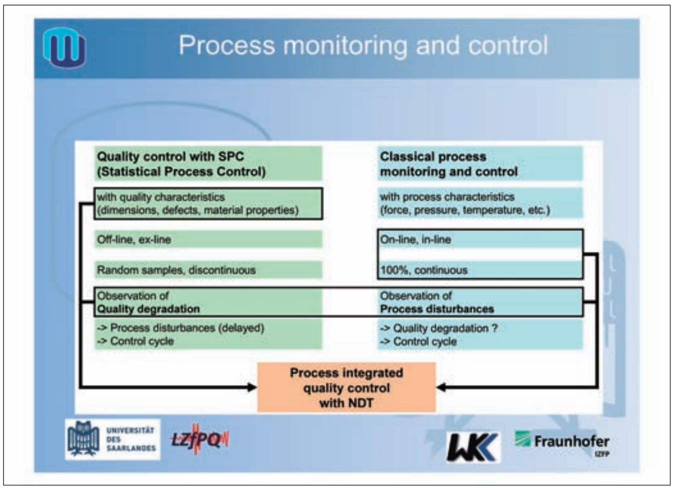

Process forces
Position1 – pin on surface, starting of plastification
Position 2- pin shoulder on surface
Position 3 – break for heat-up and start of welding
Position 4 – stop of welding
Process force [kN]
time [s]
Fx
Fy
Fz

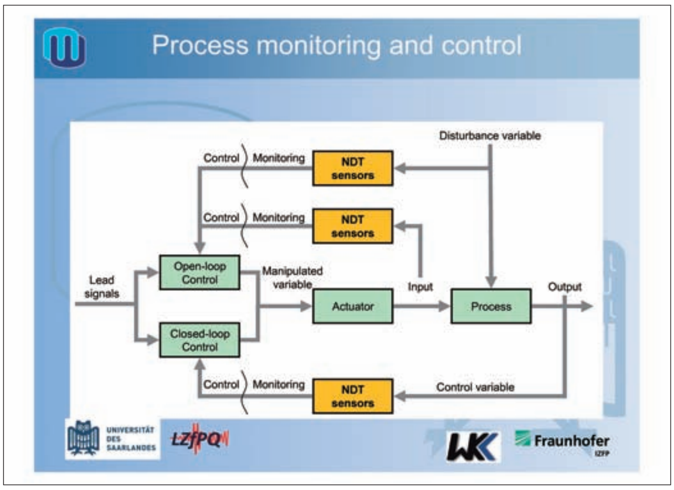

Material movement by rotation and translation
Groove space
RS
AS
Top view x-y-plane
Side view x-z-plane
Micrograph y-z-plane
AS-advancing side RS-retreating side


Material movement visualized by 3D-CT according Dickerson 2003
AS
RS
θ=0°


AlMg3Mn-AlMg3Mn FSW with nugget, TMAZ, HAZ and BM at RS and AS
RS
AS
Nugget
TMAZ
HAZ
BM
2 mm


Joint Line Remnant JLR, Oxid-Hydroxid Particles
1 mm


Process monitoring and control
Quality control with SPC (Statistical Process Control)
with quality characteristics (dimensions, defects, material properties)
Off-line, ex-line
Random samples, discontinuous
Observation of Quality degradation
-> Process disturbances (delayed)
-> Control cycle
Classical process monitoring and control
with process characteristics (force, pressure, temperature, etc.)
On-line, in-line
100%, continuous
Observation of Process disturbances
-> Quality degradation ?
-> Control cycle
Process integrated quality control with NDT


Process monitoring and control
Disturbance variable
Control
Monitoring
NDT sensors
Control
Monitoring
NDT sensors
Lead signals
Open-loop Control
Manipulated variable
Input
Output
Actuator
Process
Closed-loop Control
Control
Monitoring
NDT sensors
Control variable
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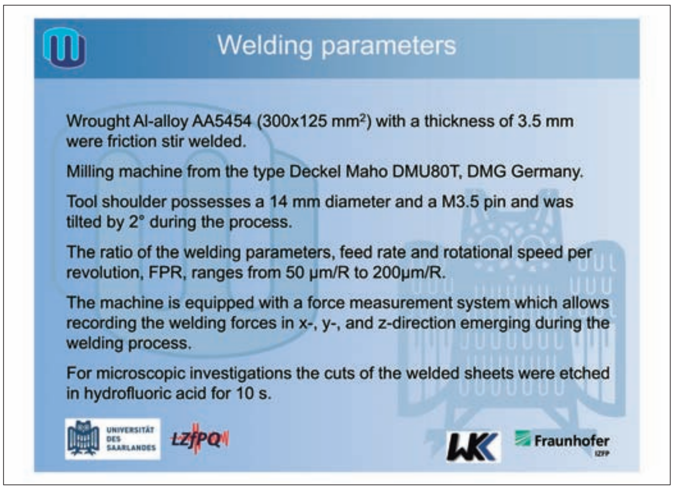
LZfPQ
Fraunhofer IZFP


Welding parameters
Wrought Al-alloy AA5454 (300x125 mm²) with a thickness of 3.5 mm were friction stir welded.
Milling machine from the type Deckel Maho DMU80T, DMG Germany.
Tool shoulder possesses a 14 mm diameter and a M3.5 pin and was tilted by 2° during the process.
The ratio of the welding parameters, feed rate and rotational speed per revolution, FPR, ranges from 50 µm/R to 200µm/R.
The machine is equipped with a force measurement system which allows recording the welding forces in x-, y-, and z-direction emerging during the welding process.
For microscopic investigations the cuts of the welded sheets were etched in hydrofluoric acid for 10 s.
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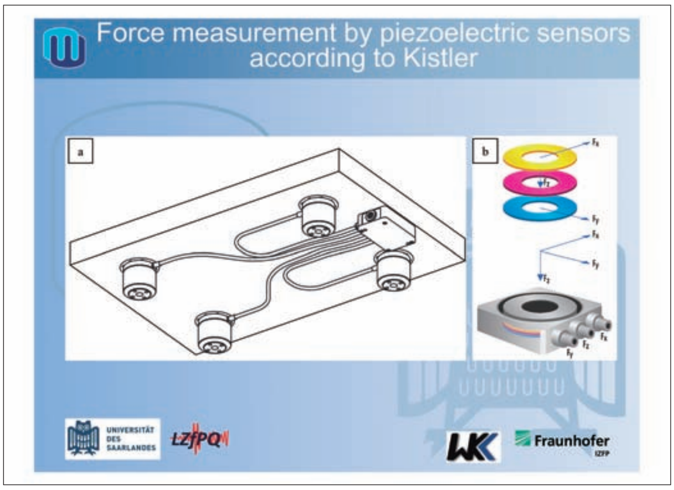
Fraunhofer IZFP


Force measurement by piezoelectric sensors according to Kistler
a
b
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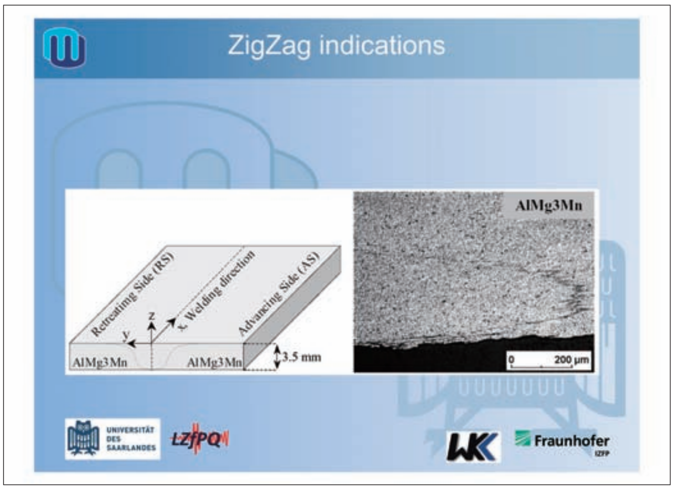
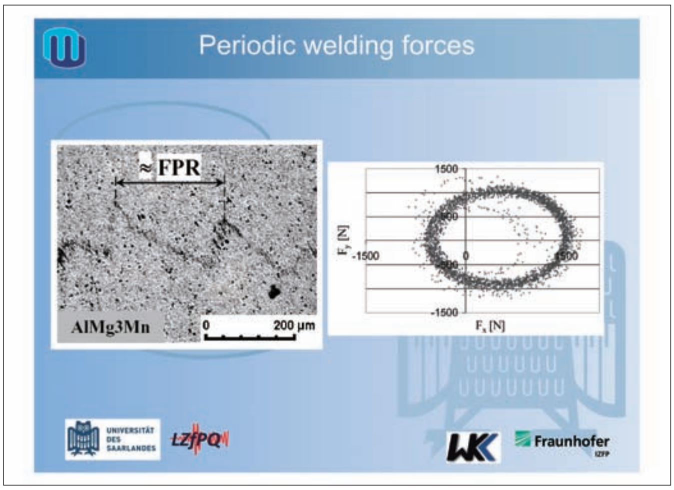
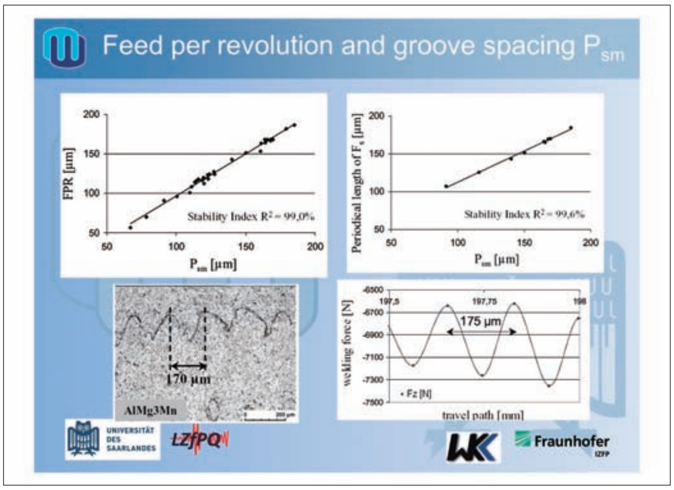
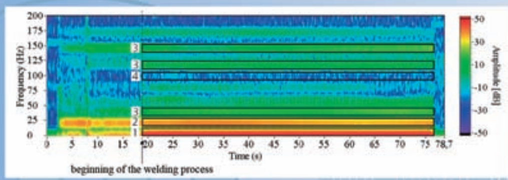
LZfPQ
Fraunhofer IZFP


ZigZag indications
Retreating Side (RS)
x, Welding direction
Advancing Side (AS)
AlMg3Mn
AlMg3Mn
3.5 mm
AlMg3Mn
0
200 µm
UNIVERSITÄT DES SAARLANDES
LZfPQ
Fraunhofer IZFP

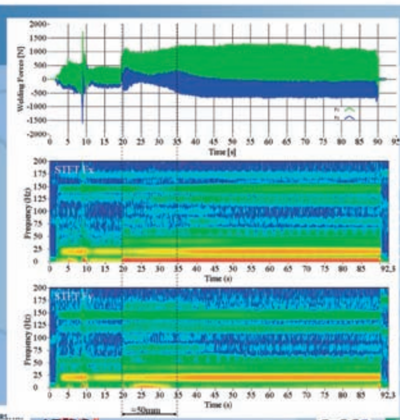

Periodic welding forces
≈ FPR
AlMg3Mn
0
200 µm
1500
-1500
-1500
1500
0
Fy [N]
Fx [N]
UNIVERSITÄT DES SAARLANDES
LZfPQ
Fraunhofer IZFP


Feed per revolution and groove spacing Psm
FPR [µm]
Stability Index R² = 99,0%
Psm [µm]
Periodical length of Fz [µm]
Stability Index R² = 99,6%
Psm [µm]
170 µm
AlMg3Mn
welding force [N]
175 µm
Fz [N]
travel path [mm]
UNIVERSITÄT DES SAARLANDES
LZfPQ
Fraunhofer IZFP

Pattern recognition in the spectrogram of a sound weld

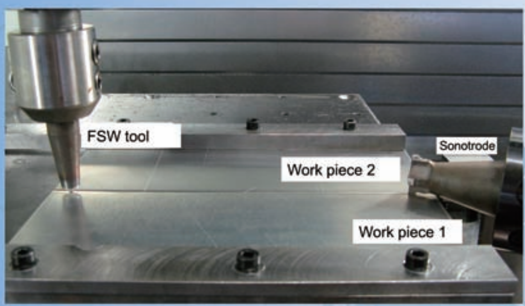


Continuously high amplitudes in the F x -frequency range lower than that of tool rotation (contrary to the STFT of F y).
Continuously high amplitudes in the frequency range of the tool rotation frequency.
Continuously high amplitudes in the frequency range of the harmonics.
Continuously low amplitudes at 100 Hz, independent of tool rotation frequency.

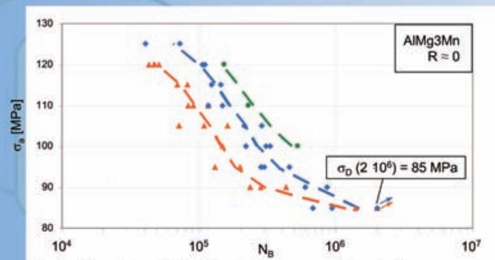


Development of a worm hole

Superposition of high powered (20 kHz, 25-40µm, 3kW) ultrasound, 500N



Benefit & conclusion – more than a factor 2 in lifetime



Red=with oxide particles, blue=oxide removed by grinding, green=powered ultrasound

Conclusions

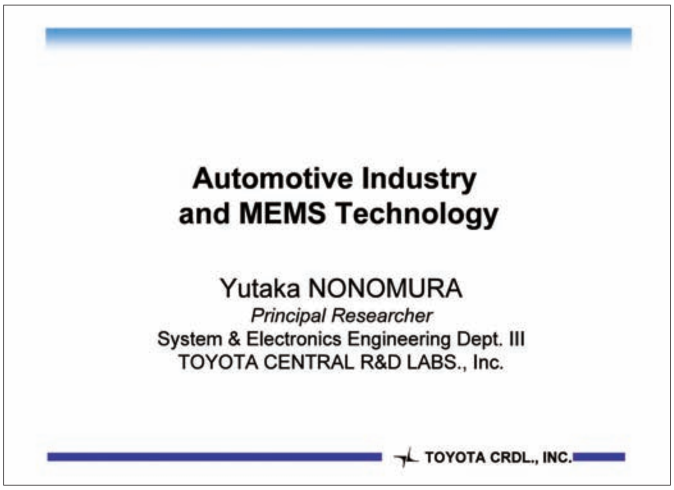
- The FSW-Process can be online monitored due to Force-Measurement and –Analysis
- The early development of welding irregularities can be detected
- The Process can be controlled
- The superposition of High-Powered Ultrasound is enhancing the welding quality in terms of fatigue life time with at least a factor two.

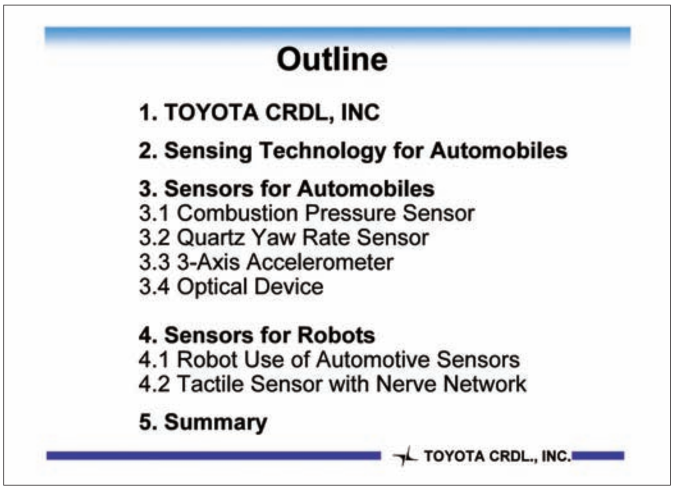
Acknowledgements

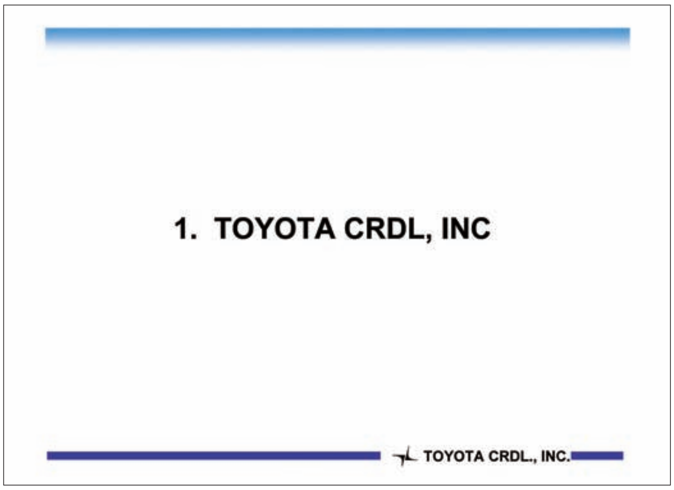
- I have to acknowledge the PhD-thesis of Tobias JENE
- The fruitful and longtime cooperation with the Institute of Materials Science and Engineering, WKK, Technical University Kaiserslautern, Prof. Dietmar EIFLER and Prof. Guntram WAGNER

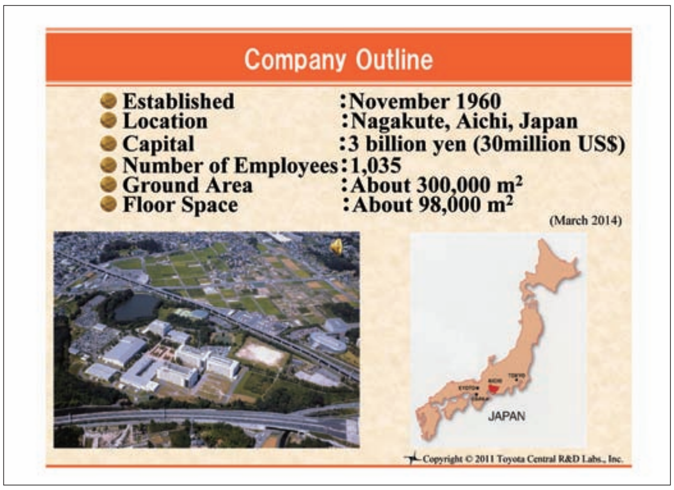
Automotive Industry and MEMS Technology

Yutaka NONOMURA
Principal Researcher, TOYOTA CENTRAL R&D Labs., Inc., Japan









Technological History 1

- 1960: Toyota CRDL, Inc. established in Nagoya City
- 1972: Thermo-Reactive Deposition and Diffusion Process (TRD Process)
- 1975: Exhaust Gas Purification System, Oxygen Sensor
- 1980: Expanded and Transferred to Nagakute
- 1982: T-10 Robot
- 1987: Sound Quality of Car Interior Engine Noise
- 1990: Nylon-Clay Hybrid (NCH)
- 1997: Reaction Control Technology under Shear Flow (Rubber Recycling), Insulated Gate Bipolar Transistor (IGBT) and Diode for Hybrid Vehicles

Technological History 2

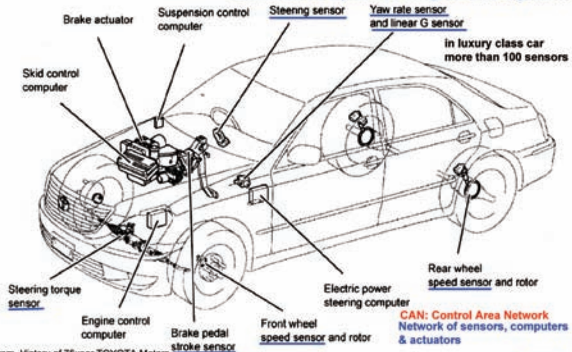
- 2000: Toyota Unveils Cyber Humanoid Body for Research of Accident Injuries (THUMS®), GUM METAL (Published in Science 2003)
- 2001: Visible-Light Active Photocatalyst (Published in Science 2001)
- 2002: An Ordered Mesoporous Organosilica Hybrid Material with a Crystal-Like Wall Structure (Published in Nature 2002)
- 2004: Ultrahigh-Quality Silicon Carbide Single Crystals (Published in Nature 2004), High Performance Lead-free Piezoelectric Materials (Published in Nature 2004), DLC-Si Coating Process
- 2005: Inertial Force Sensing System for Mobility Robots
- 2009: Pedestrian Detection for Night View System
- 2010: Noble Metal Sintering Suppression Technology in Exhaust Catalyst
- 2011: Solar Fuels - CO_2 Photoconversion into Organic Compounds

2. Sensing Technology for Automobiles

TOYOTA CRDL., INC.

Configuration of VDIM

VDIM: Vehicle Dynamics Integrated Management



from History of 75year TOYOTA Motors

TOYOTA CRDL., INC.

Sensor Application Comparison

	Automobile	Home Electronics	Industry	Airplane
Accuracy	1 to 5%	5 to 20%	0.1 to 1%	0.1 to 1%
Temperature Range	-40 to 120 ℃	-10 to 50 ℃	0 to 60 ℃	-55 to 70 ℃
Vibration	2 to 25 G	1 to 5 G	0 to 5 G	0.5 to 10 G
Power Fluctuation	+/- 50%	+/- 10%	+/- 10%	+/- 10%
EMC	Large	Small	Medium	Small
Ambient	Water, Salt, Dirt, Erosion	Water	Water, Oil, Erosion	Water, Salt
Sensor Cost	1 to 10 $	1 to 10 $	10 to 100 $	100 to 1000 $
Whole Cost	0.01 to 0.1 M$	0.001 to 0.01 M$	0.001 to 1 M$	0.1 to 100 M$
Cost Ratio	10^2 to 10^5	10^1 to 10^4	10^1 to 10^5	10^2 to 10^5
Mass Production	Good	Good	Poor	Poor
Maintenance	Public, Professional	Public, Professional	Professional	Professional

EMC: electromagnetic compatibility

Accuracy: Middle
Working range: Wide
Life: Long

High stability
High reliability
Low cost by mass production

TOYOTA CRDL., INC.

Kind of Automotive Sensor

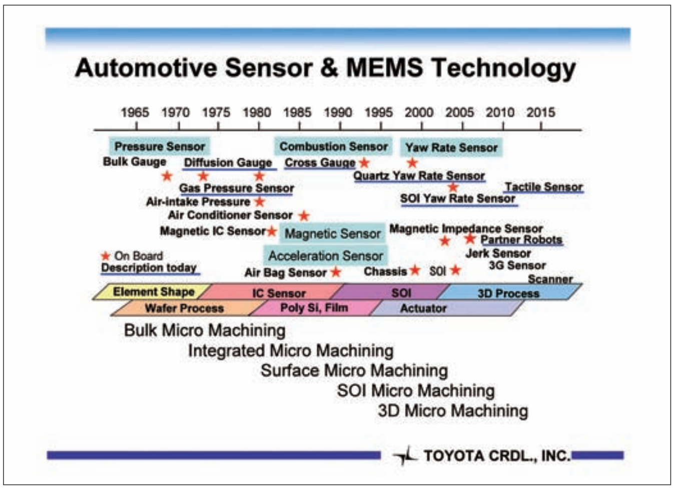
Temperature	Water, Oil, Intake, Exhaust air, Fuel, Cabin
Gas	Oxygen, Lean, NO_x, HC, H_2
Pressure	Intake air, Air flow, Combustion, Supercharging, Brake, Tire, Compressor
Position	Fuel level, Cam, Vehicle height, Seat
Angle	Crankshaft, rotation, Throttle, Steering, Direction
Speed	Engine, Vehicle, Transmission, Wheel
Angular rate	Yaw rate, Rollover
Acceleration	Airbag, Chassis, Suspension
Force, Load	Brake pedal, Steering torque, Loading
Vibration	Knocking
Light, Electric wave, Sound	Laser, Microwave, Visible light, IR light, Solar irradiation, Headlight, Voice, Ultrasound
Others	Glow plug, Particle, Rain drop, Humidity, Antenna, Fingerprint, Current

Inner sensor: Pressure, Acceleration, Angular rate (very important to control vehicle)
Outer sensor: Sonar, Rader, Vision (expecting advanced safety)

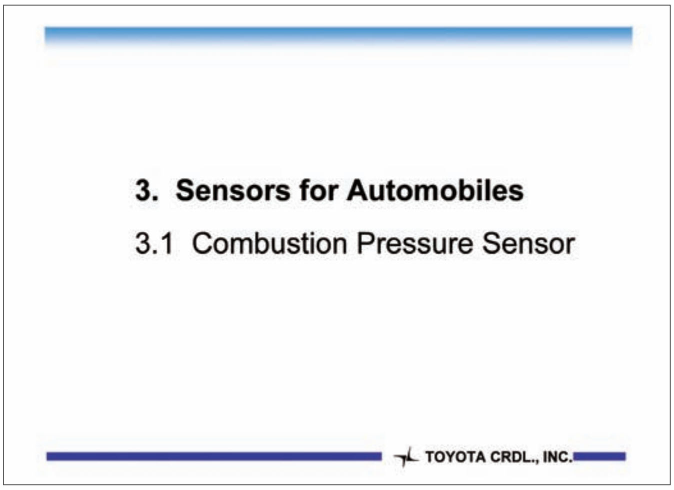
TOYOTA CRDL., INC.

Prize of "One Step on Electro-Technology"
from IEE Japan in 2013 (電気の礎)
The Institute of Electrical Engineers of Japan
Piezoresistive Semiconductor Pressure Sensor
Toyota Central R&D Labs., Inc.
- Si Diaphragm with Semiconductor Strain Gauge with MEMS Technology (1970s)
- Gas Pressure Monitoring Sensor (Toyota Machine Works 1980)
- Intake Pressure Sensor for Automobile (Denso 1981)
Si Diaphragm
Strain Gauge
Si Diaphragm by MEMS
Gas Pressure Monitoring Sensor
Cross-sectional View
Top View
Pressure Sensor
from Prize of "One Step on Electro-Technology" of IEE Japan
TOYOTA CRDL., INC.

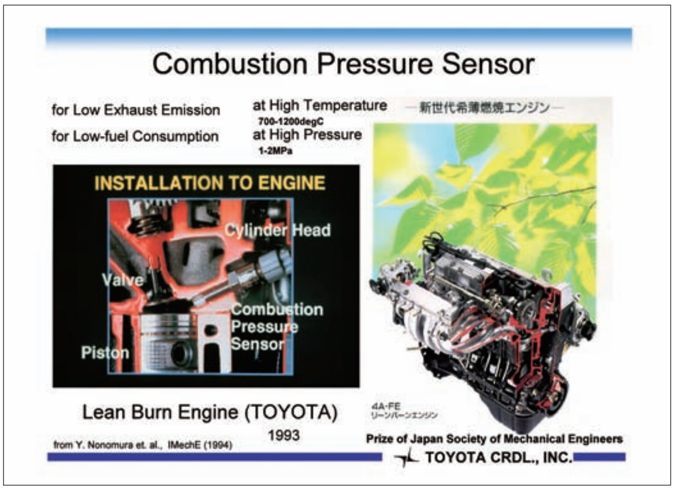
Dr. Isemi Igarashi
(Late vice center president)
Matchmaker for my marriage
Award certificate
Samples
Trophy
PRIZE
Entrance of Toyota Central R&D Labs. Inc.



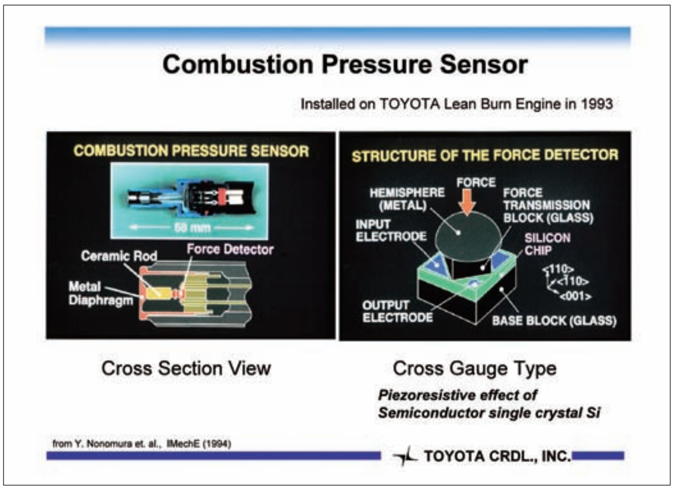
Automotive Sensor & MEMS Technology
1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Pressure Sensor
Combustion Sensor
Yaw Rate Sensor
Bulk Gauge
Diffusion Gauge
Cross Gauge
Quartz Yaw Rate Sensor
Tactile Sensor
Gas Pressure Sensor
Air-intake Pressure
SOI Yaw Rate Sensor
Air Conditioner Sensor
Magnetic IC Sensor
Magnetic Sensor
Magnetic Impedance Sensor
Partner Robots
On Board Description today
Acceleration Sensor
Jerk Sensor
3G Sensor
Air Bag Sensor
Chassis
SOI
Scanner
Element Shape
IC Sensor
SOI
3D Process
Wafer Process
Poly Si, Film
Actuator
Bulk Micro Machining
Integrated Micro Machining
Surface Micro Machining
SOI Micro Machining
3D Micro Machining
TOYOTA CRDL., INC.



3. Sensors for Automobiles
3.1 Combustion Pressure Sensor
TOYOTA CRDL., INC.

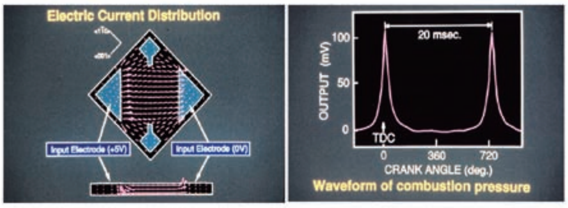


Combustion Pressure Sensor
for Low Exhaust Emission
for Low-fuel Consumption
at High Temperature
700-1200degC
at High Pressure
1-2MPa
新世代希薄燃焼エンジン
INSTALLATION TO ENGINE
Cylinder Head
Valve
Combustion Pressure Sensor
Piston
Lean Burn Engine (TOYOTA)
1993
4A-FE
Prize of Japan Society of Mechanical Engineers
from Y. Nonomura et. al., IMechE (1994)
TOYOTA CRDL., INC.



Combustion Pressure Sensor
Installed on TOYOTA Lean Burn Engine in 1993
COMBUSTION PRESSURE SENSOR
58 mm
Ceramic Rod
Force Detector
Metal Diaphragm
STRUCTURE OF THE FORCE DETECTOR
HEMISPHERE (METAL)
FORCE
FORCE TRANSMISSION BLOCK (GLASS)
INPUT ELECTRODE
SILICON CHIP
<110>
<110>
<001>
OUTPUT ELECTRODE
BASE BLOCK (GLASS)
Cross Section View
Cross Gauge Type
Piezoresistive effect of Semiconductor single crystal Si
from Y. Nonomura et. al., IMechE (1994)
TOYOTA CRDL., INC.

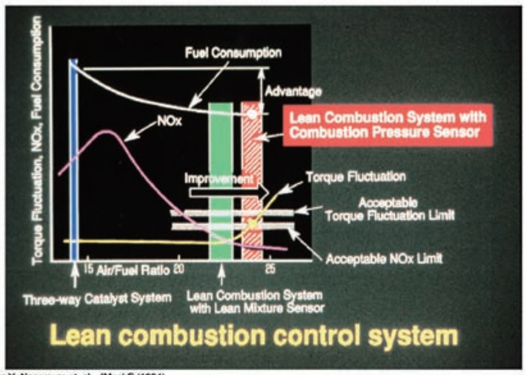
Combustion Pressure Sensor



from Y. Nonomura et. al., IMechE (1994)

TOYOTA CRDL., INC.

Combustion Pressure Sensor



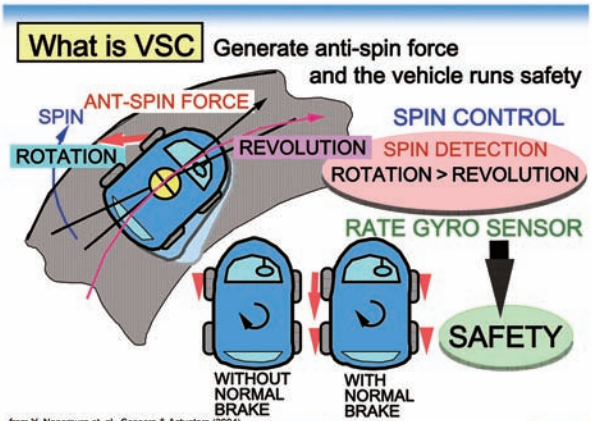
from Y. Nonomura et. al., IMechE (1994)

TOYOTA CRDL., INC.

3. Sensors for Automobiles

3.2 Quartz Yaw Rate Sensor

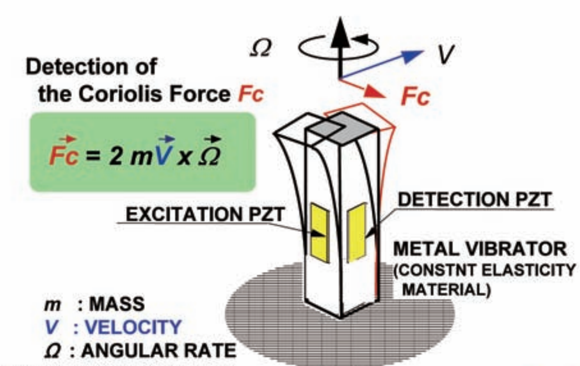
TOYOTA CRDL., INC.



from Y. Nonomura et. al., Sensors & Actuators (2004)

TOYOTA CRDL., INC.

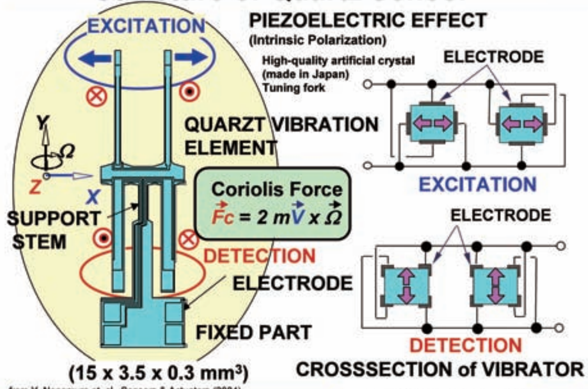
Principle of the Vibration Sensor



from Y. Nonomura et. al., Sensors & Actuators (2004)

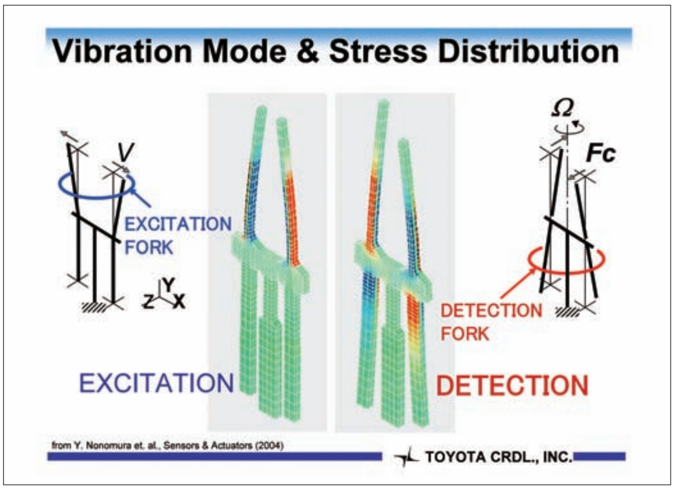
TOYOTA CRDL., INC.

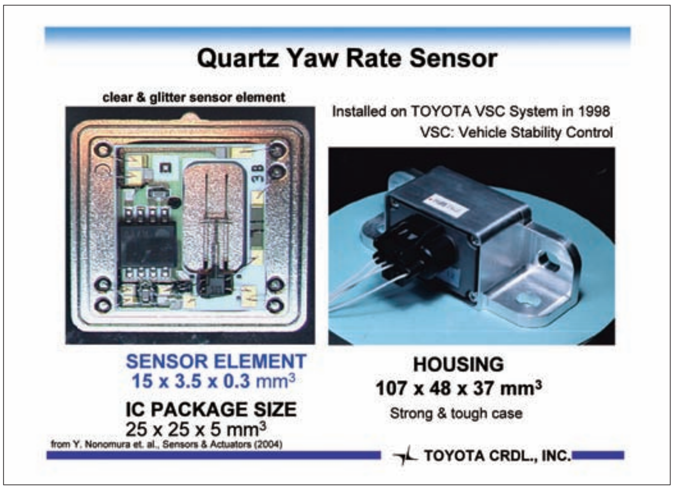
Structure of Quartz Sensor

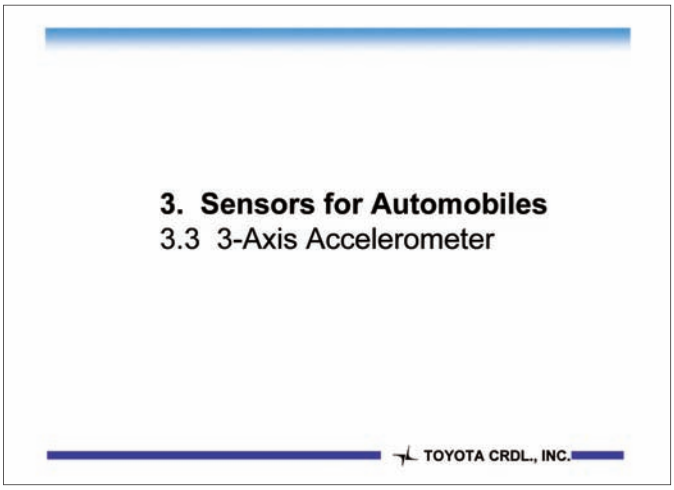


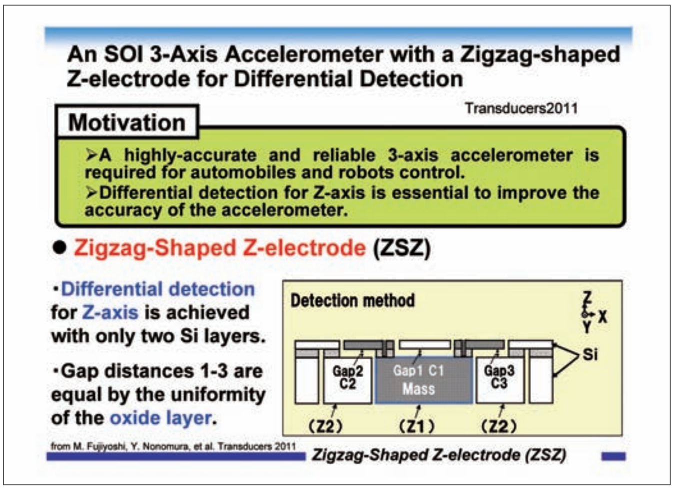
from Y. Nonomura et. al., Sensors & Actuators (2004)

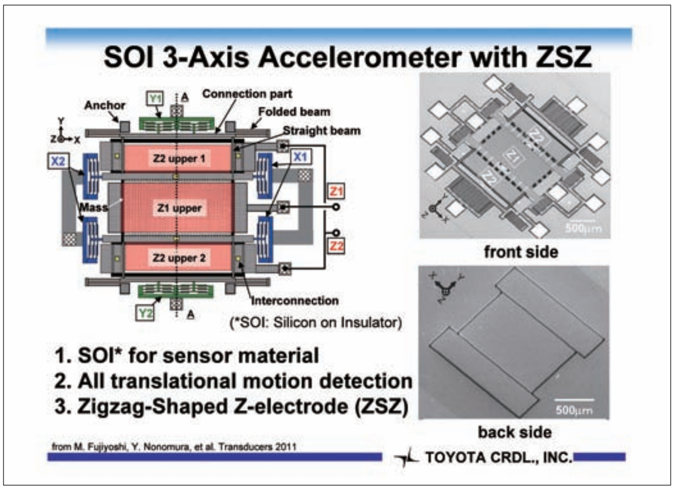
TOYOTA CRDL., INC.

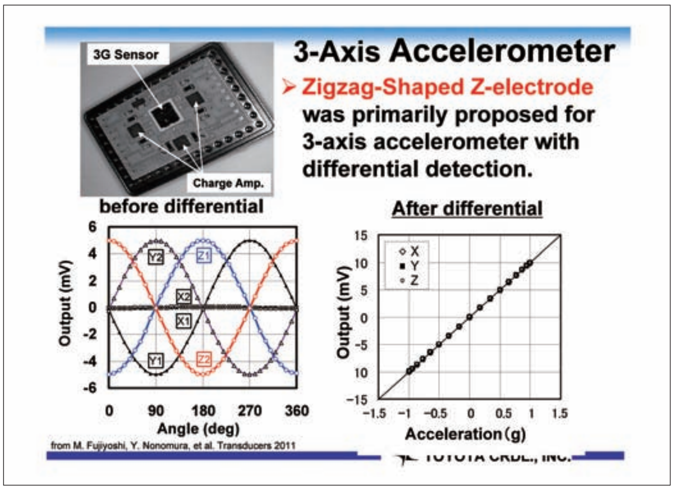

Vibration Mode & Stress Distribution
V
EXCITATION FORK
Z Y X
Ω
Fc
DETECTION FORK
EXCITATION
DETECTION
from Y. Nonomura et. al., Sensors & Actuators (2004)
TOYOTA CRDL., INC.


Quartz Yaw Rate Sensor
clear & glitter sensor element
Installed on TOYOTA VSC System in 1998
VSC: Vehicle Stability Control
SENSOR ELEMENT
15 x 3.5 x 0.3 mm3
IC PACKAGE SIZE
25 x 25 x 5 mm3
HOUSING
107 x 48 x 37 mm3
Strong & tough case
from Y. Nonomura et. al., Sensors & Actuators (2004)
TOYOTA CRDL., INC.


3. Sensors for Automobiles
3.3 3-Axis Accelerometer
TOYOTA CRDL., INC.


An SOI 3-Axis Accelerometer with a Zigzag-shaped Z-electrode for Differential Detection
Transducers2011
Motivation
➢A highly-accurate and reliable 3-axis accelerometer is required for automobiles and robots control.
➢Differential detection for Z-axis is essential to improve the accuracy of the accelerometer.
● Zigzag-Shaped Z-electrode (ZSZ)
・Differential detection for Z-axis is achieved with only two Si layers.
・Gap distances 1-3 are equal by the uniformity of the oxide layer.
Detection method
Z X Y
Si
Gap2 C2
Gap1 C1
Mass
Gap3 C3
(Z2)
(Z1)
(Z2)
from M. Fujiyoshi, Y. Nonomura, et al. Transducers 2011
Zigzag-Shaped Z-electrode (ZSZ)


SOI 3-Axis Accelerometer with ZSZ
Anchor
Connection part
Folded beam
Straight beam
Y1
Y2
X1
X2
Z1
Z2
Z2 upper 1
Z1 upper
Z2 upper 2
Mass
Interconnection
(*SOI: Silicon on Insulator)
front side
back side
500μm
1. SOI* for sensor material
2. All translational motion detection
3. Zigzag-Shaped Z-electrode (ZSZ)
from M. Fujiyoshi, Y. Nonomura, et al. Transducers 2011
TOYOTA CRDL., INC.


3G Sensor
Charge Amp.
3-Axis Accelerometer
➢ Zigzag-Shaped Z-electrode was primarily proposed for 3-axis accelerometer with differential detection.
before differential
After differential
Output (mV)
Angle (deg)
Acceleration (g)
from M. Fujiyoshi, Y. Nonomura, et al. Transducers 2011

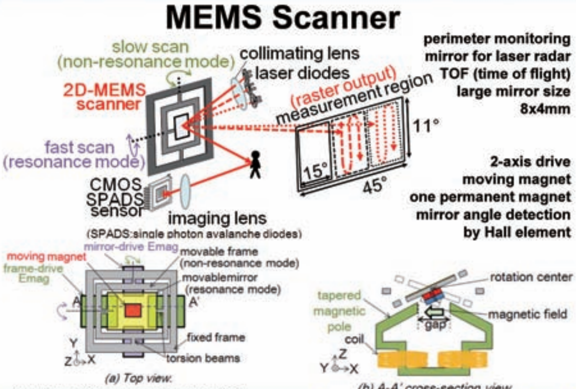
VSC (Vehicle Stability Control)
VDIM (Vehicle Dynamics Integrated Management)

TOYOTA Motor The car with the VSC or VDIM runs safety and smoothly on a slippery road of low μ such as wet, snow, and frozen.

3. Sensors for Automobiles

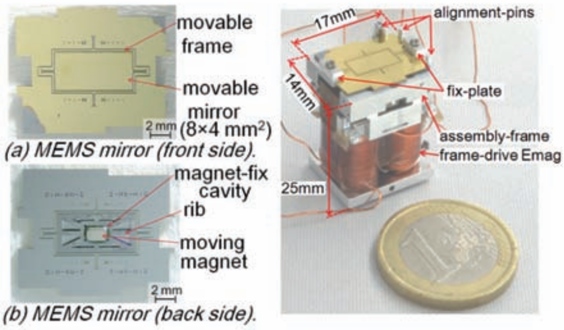
3.4 Optical MEMS

MEMS Scanner



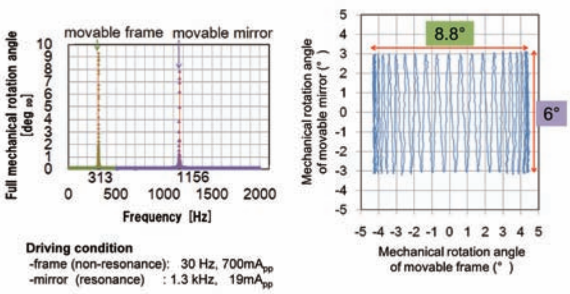
from I.Aoyagi, Y.Nonomura, et al.Transducers 2013

Structure of MEMS Scanner



from I.Aoyagi, Y.Nonomura, et al.Transducers 2013

Characteristics of MEMS Scanner



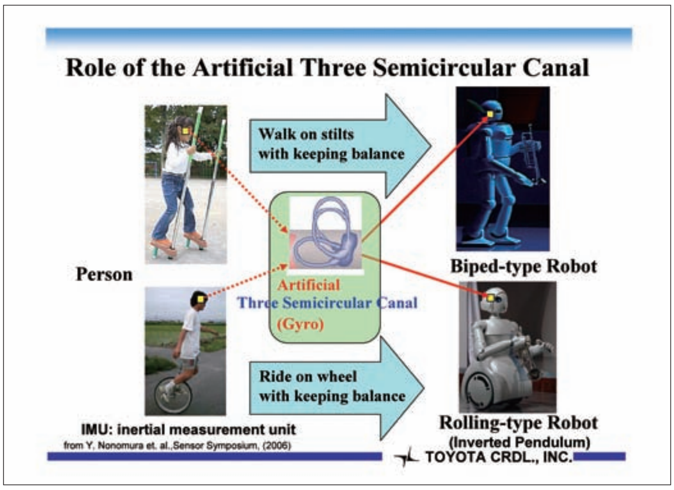
Driving condition
- -frame (non-resonance): 30 Hz, 700mA$_{pp}$
- -mirror (resonance) : 1.3 kHz, 19mA$_{pp}$

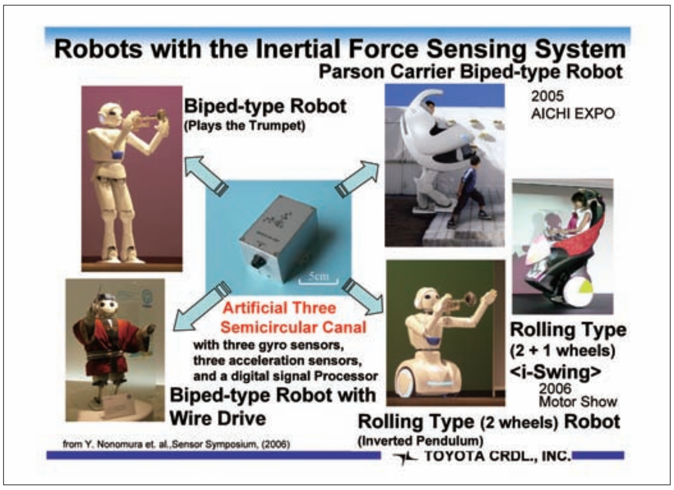
from I.Aoyagi, Y.Nonomura, et al.Transducers 2013

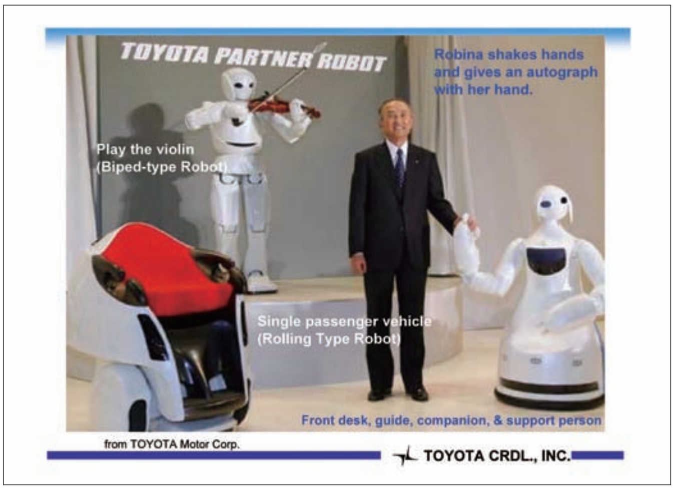
4. Sensors for Robots

4.1 Robot Use of Automotive Sensors

Toyota Group has a dream
to create a new world and style of life with robots as partners.



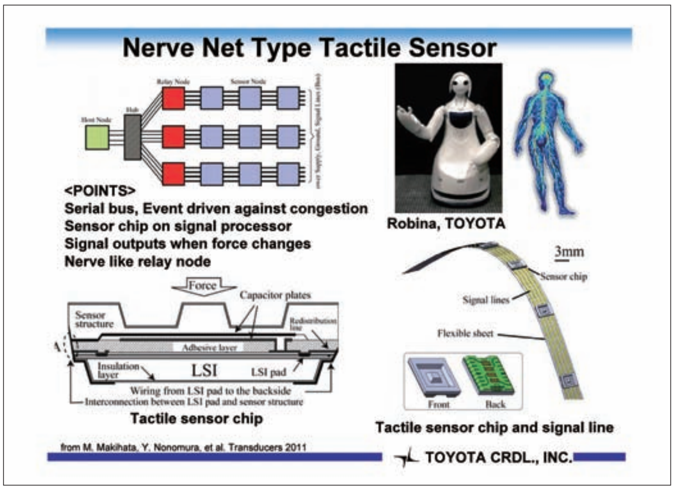


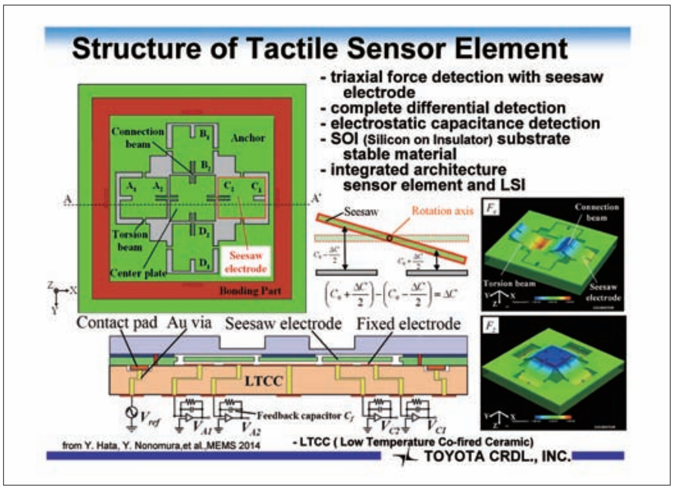


4. Sensors for Robots

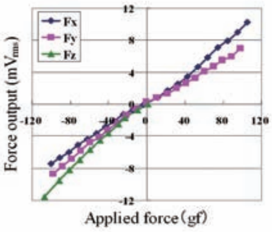
4.2 Tactile Sensor with Nerve Network

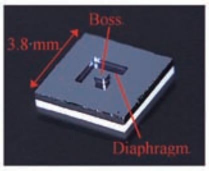
TOYOTA CRDL., INC.

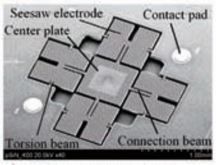




Characteristic of Sensor Element







$$\begin{pmatrix} F_x \\ F_y \\ F_z \\ 0 \end{pmatrix} = \frac{1}{4} \cdot \begin{pmatrix} 2 & 0 & -2 & 0 \\ 0 & 2 & 0 & -2 \\ 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 0 \end{pmatrix} \cdot \begin{pmatrix} \Delta V_A \\ \Delta V_B \\ \Delta V_C \\ \Delta V_D \end{pmatrix}$$

from Y. Hata, Y. Nonomura,et al.,MEMS 2014

TOYOTA CRDL., INC.

5. Summary

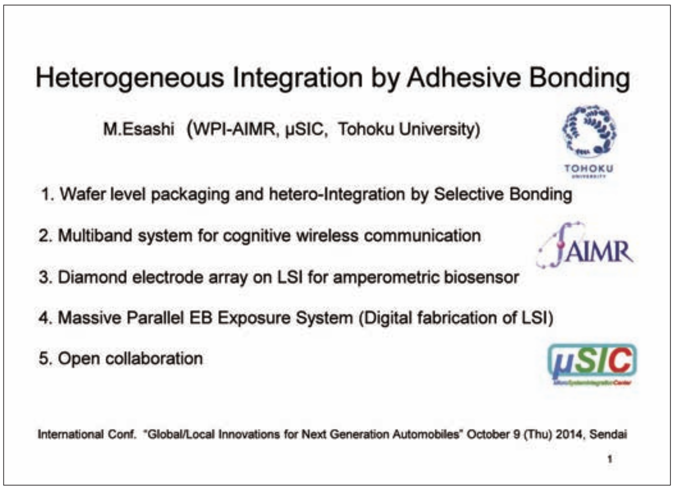
- The sensors for the automobiles have been advanced with the MEMS technology.
- New sensors and devices are created with new MEMS technology, and that will continue to grow.
- The needs and applications of the sensors and devices are expanding.
- The sensors and devices of the automobiles should be integrated with LSI for high performance and communication systems.

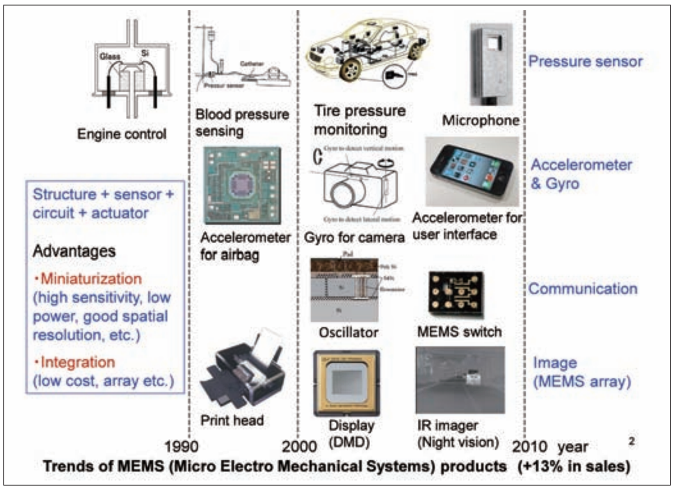
TOYOTA CRDL., INC.

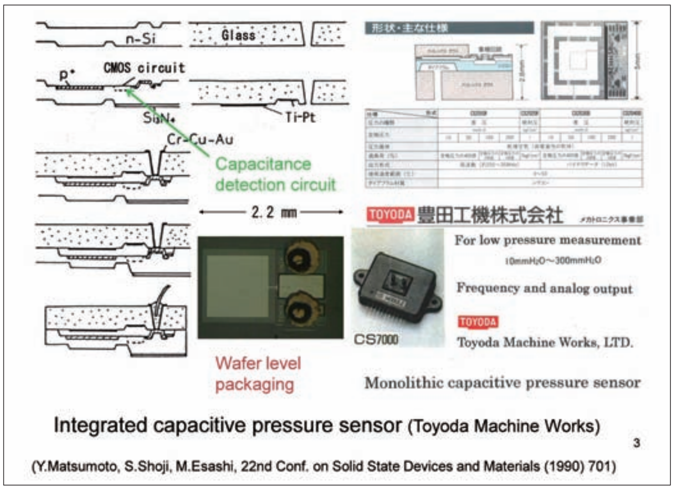
Heterogeneous Integration by Adhesive Bonding

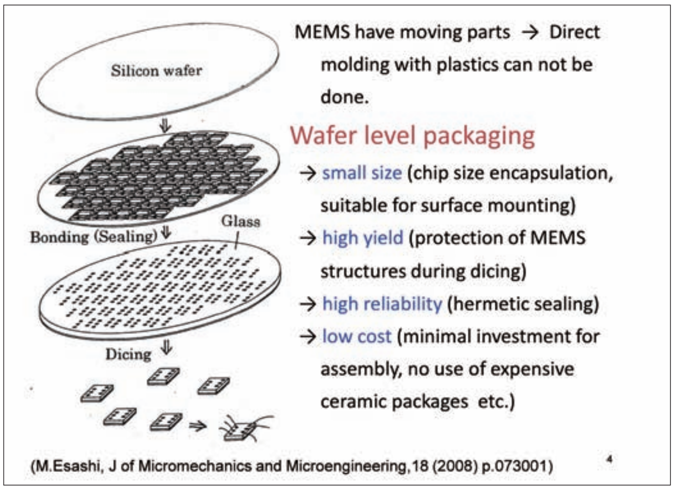
Masayoshi Esashi

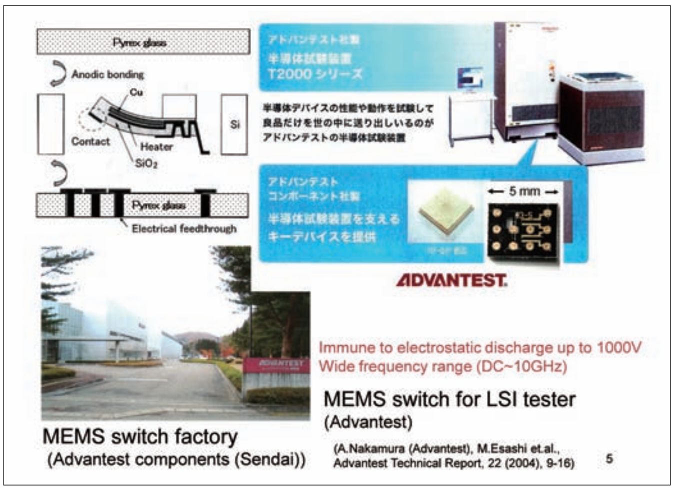
Professor, Advanced Institute for Materials Research, Tohoku University, Japan

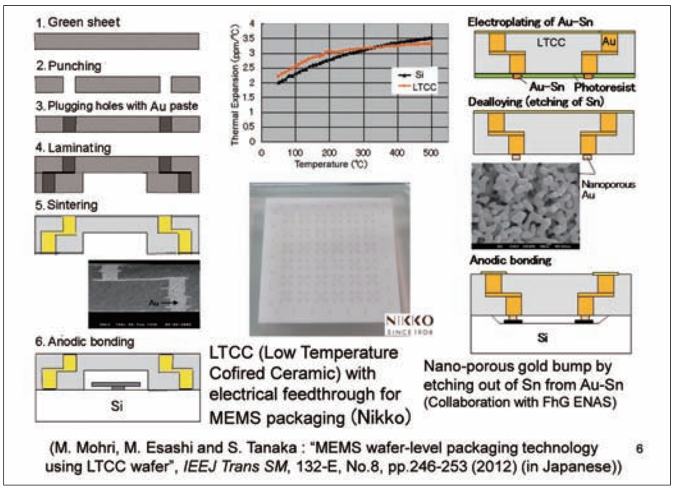


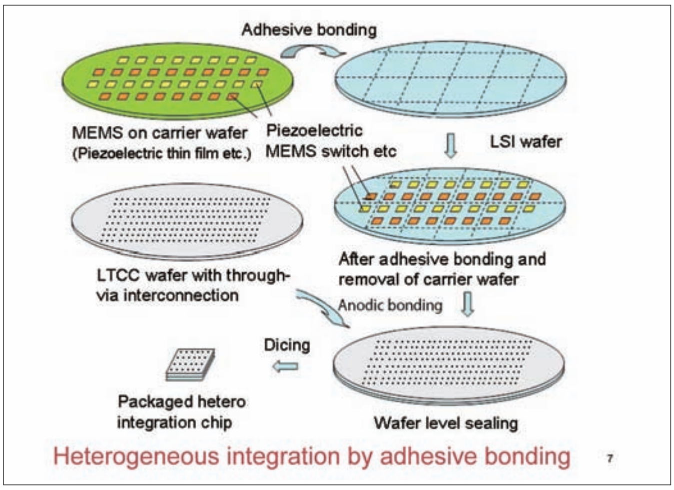






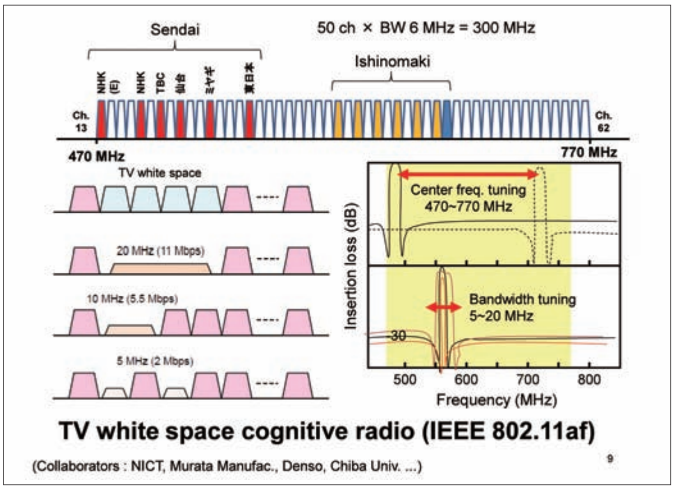


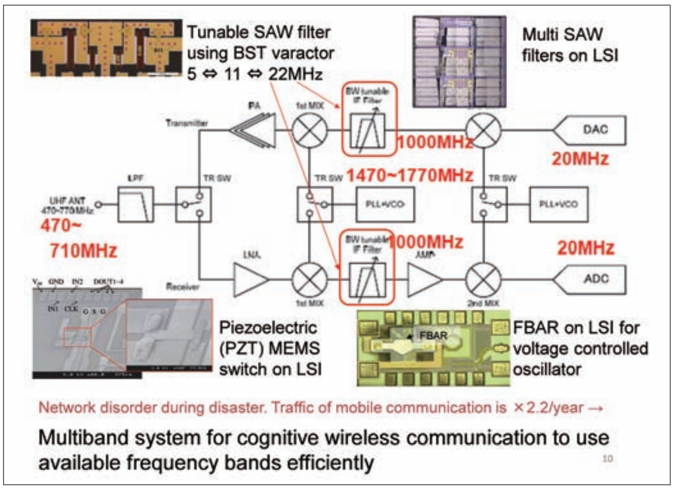


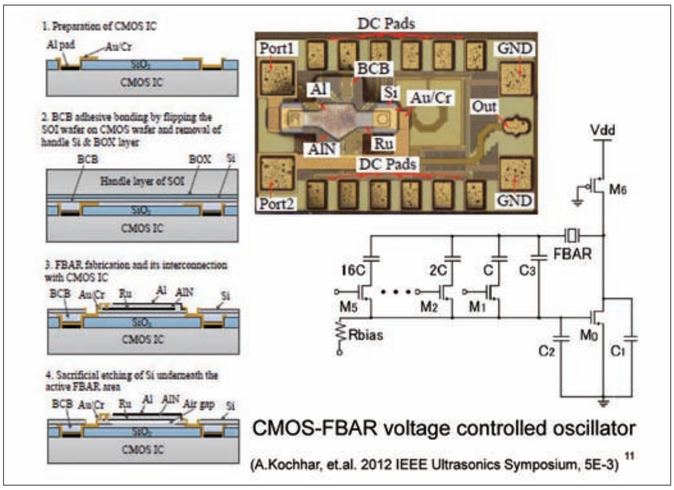


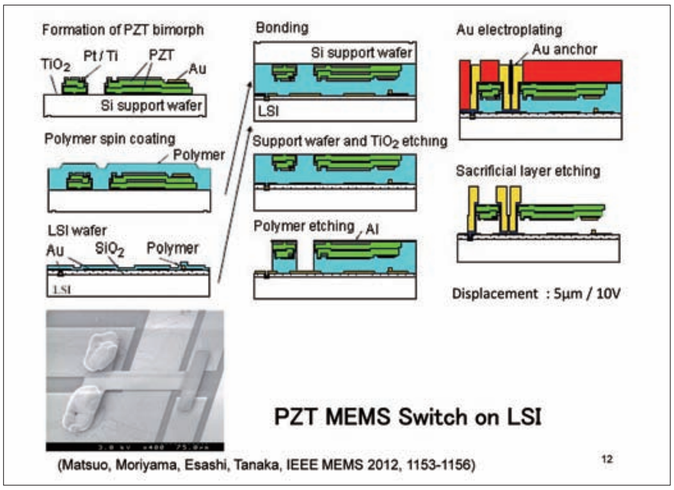
1. Wafer level packaging and hetero-Integration by Selective Bonding
2. Multiband system for cognitive wireless communication
3. Diamond electrode array on LSI for amperometric biosensor
4. Massive Parallel EB Exposure System(Digital fabrication of LSI)
5. Open collaboration

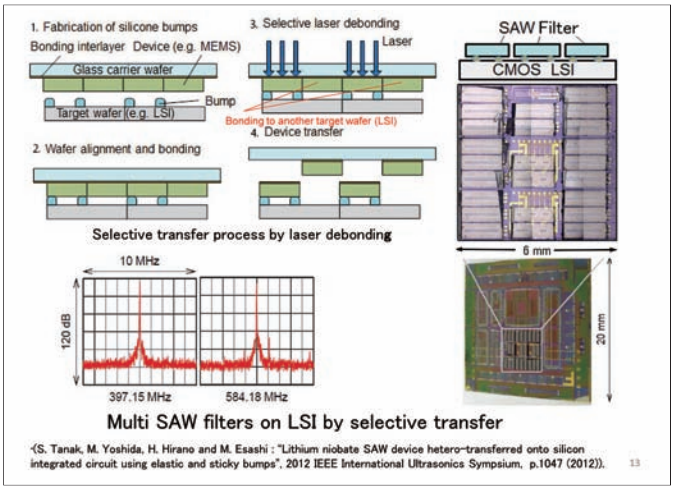
8

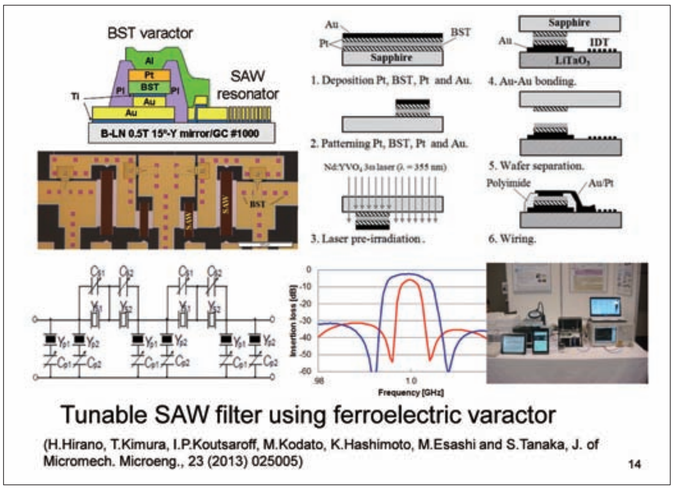












1. Wafer level packaging and hetero-Integration by Selective Bonding
2. Multiband system for cognitive wireless communication
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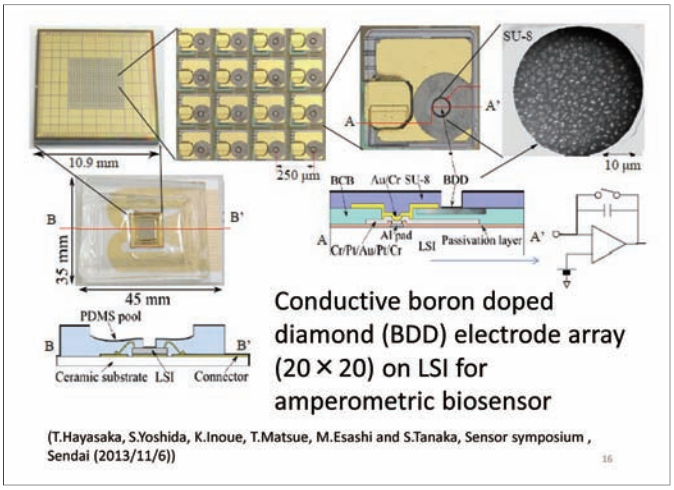
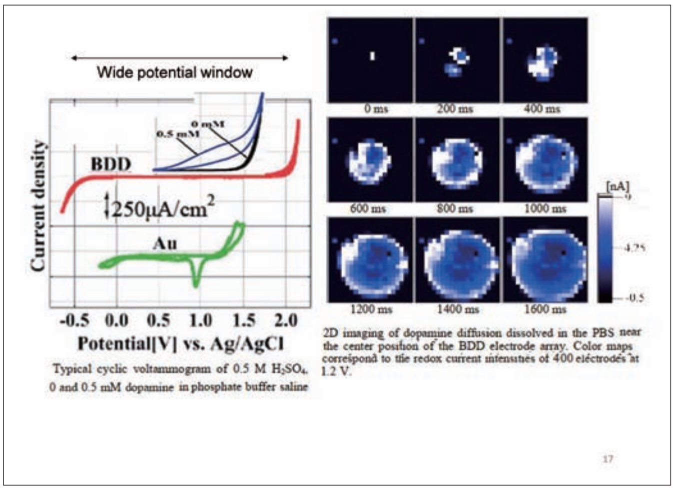
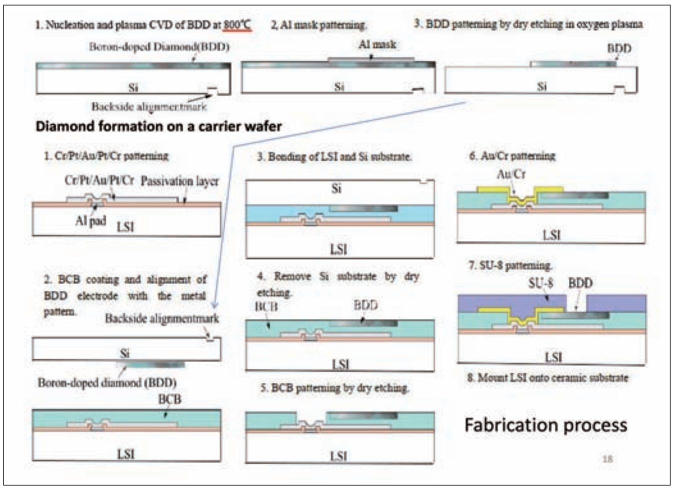
15







1. Wafer level packaging and hetero-Integration by Selective Bonding

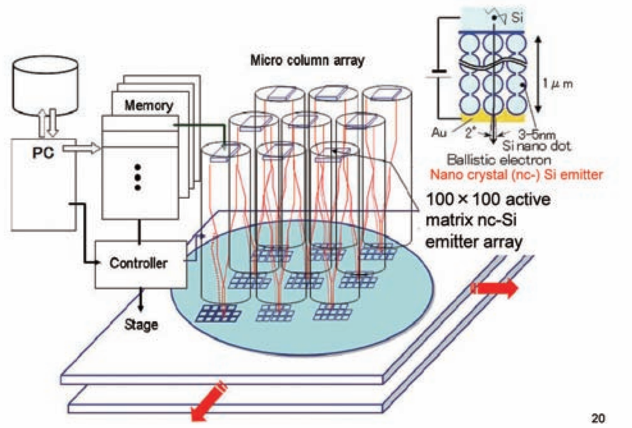
2. Multiband system for cognitive wireless communication

3. Diamond electrode array on LSI for amperometric biosensor

4. Massive Parallel EB Exposure System(Digital fabrication of LSI)

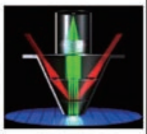
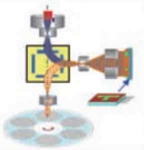
5. Open collaboration

19



20

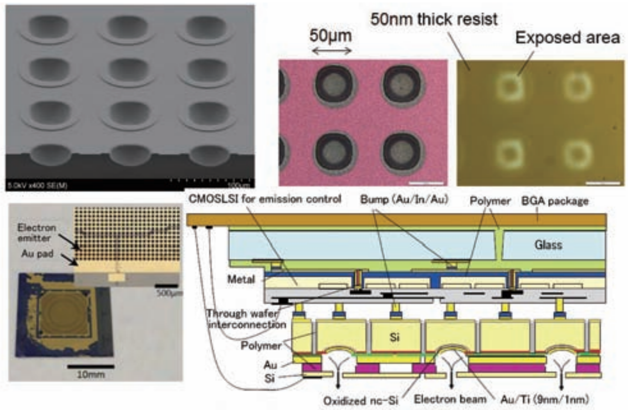
Concept of massive parallel electron beam exposure system using nc-Si emitter

	IMS Nanofabrication	MAPPER Lithography	KLA-Tencor
Name	PML2	MAPPER	REBL
Spec.			
	Massive parallel		
	50kV	5kV	50kV
	Point beam/Gray scale		
	～10M beams	13k beams	Reflective (REBL) >1M pixels
TPT	5wph (50wph by 10 tools)	10wph (100wph by 10 tools)	40wph (Via) 2wph (Metal)
Verify	2012	2011	2013
Others	EU FP7 MAGIC project		DRAPA/KLA-Tencor

Parallel EB exposure systems under development

21

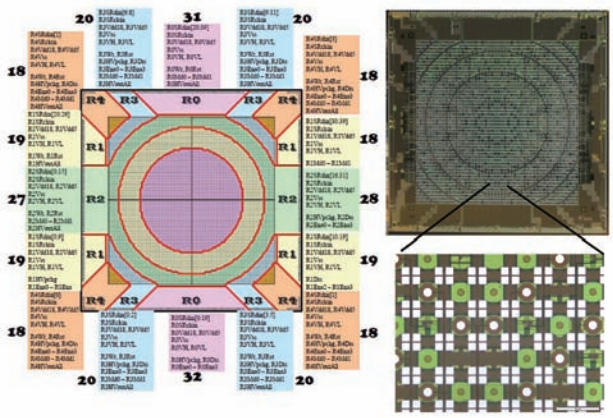
(SEAJ2012 Road map p.25 http://www.seaj.or.jp/rdmp/2012roadmap/2012litho.pdf)



Structure of 100 × 100 active matrix nc-Si emitter

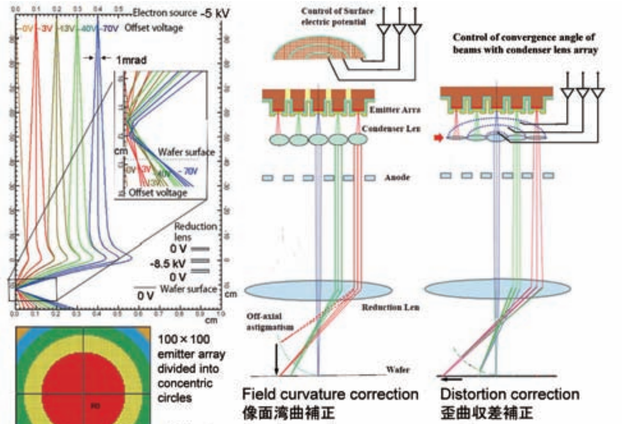
(H.Nishino, S.Yoshida, A.Kojima, N.Ikegami, N.Koshida, S.Tanaka and M.Esashi, Technical Digest IEEE MEMS 2014 (2014) 467-470)

22



100 × 100 active matrix electron source LSI and pad layout in 430 pin package

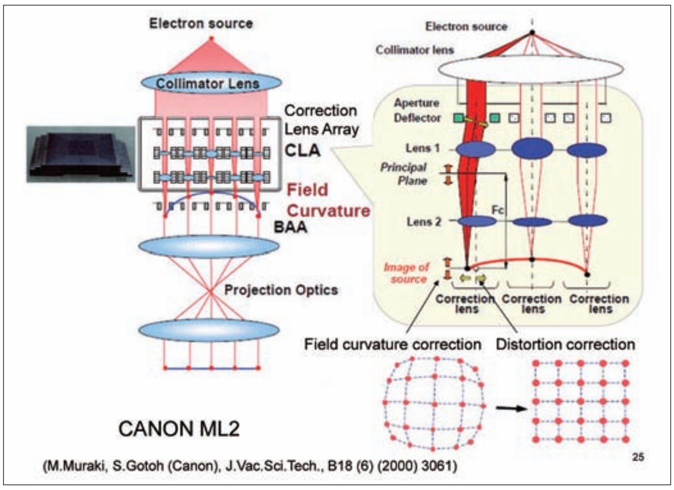
23

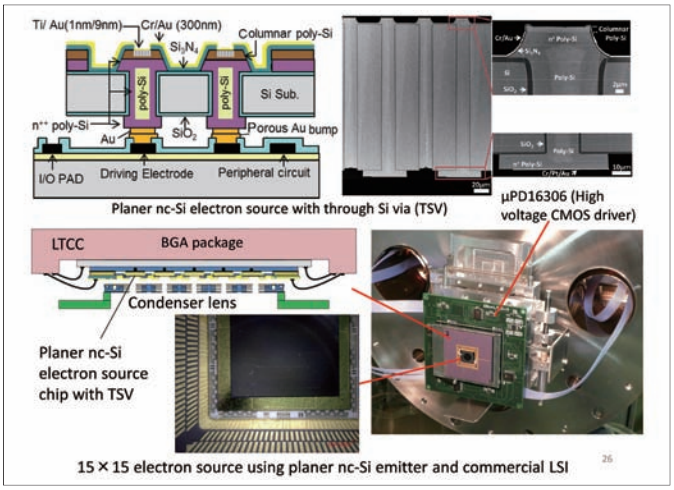


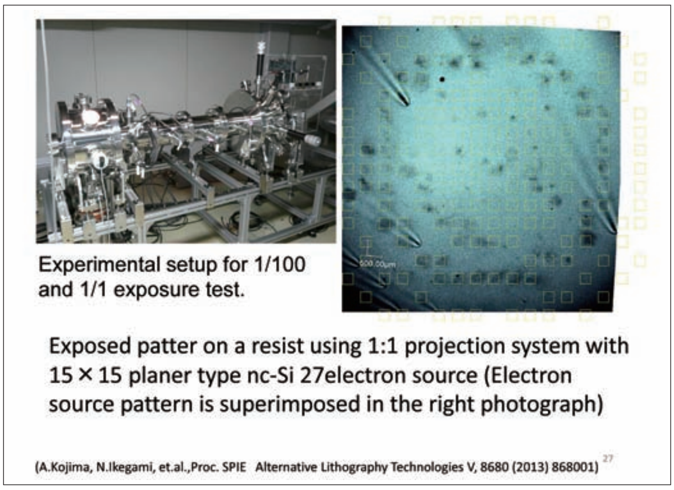
Electronic aberration compensation

(N.Ikegami, N.Koshida, A.Kojima, M.Esashi et.al, J. Vac. Sci. Technol., B31 (2013) 06F703)

24

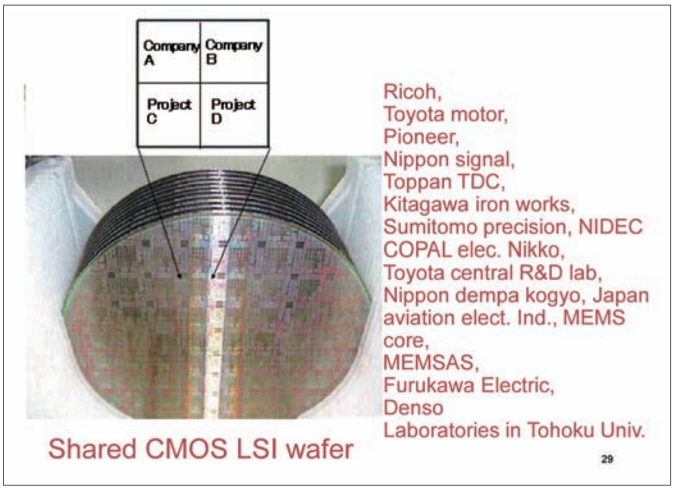


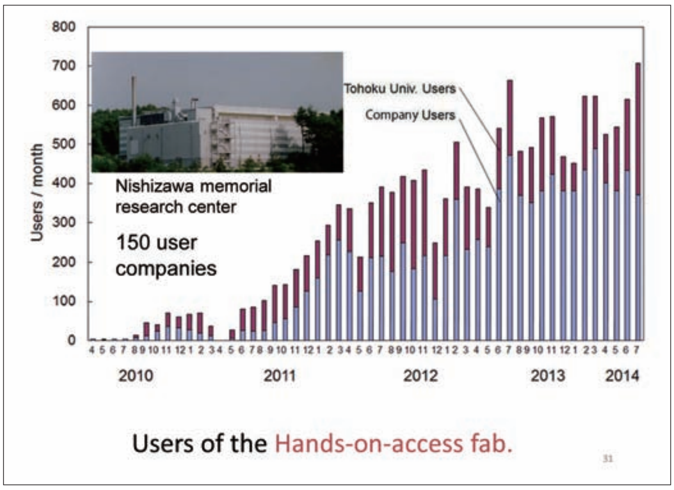


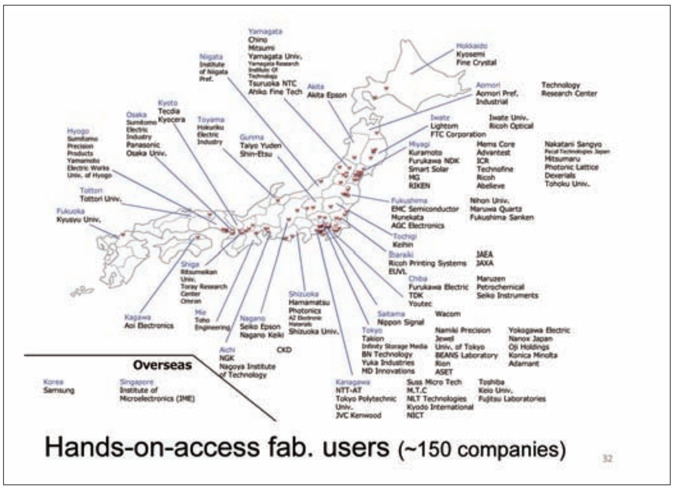


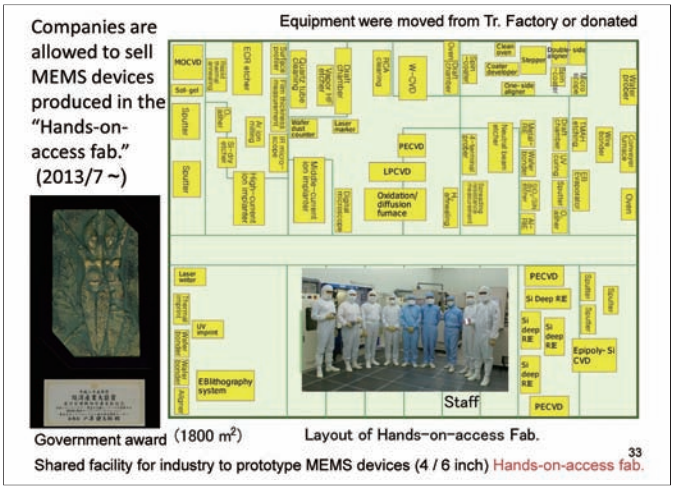
1. Wafer level packaging and hetero-Integration by Selective Bonding
2. Multiband system for cognitive wireless communication
3. Diamond electrode array on LSI for amperometric biosensor
4. Massive Parallel EB Exposure System(Digital fabrication of LSI)
5. Open collaboration

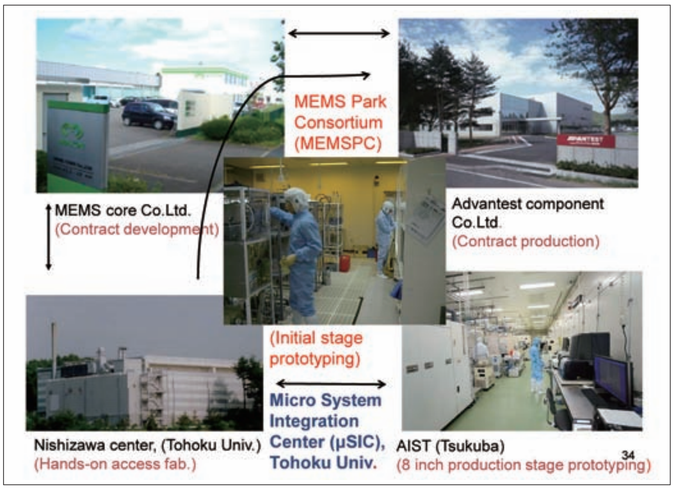
28



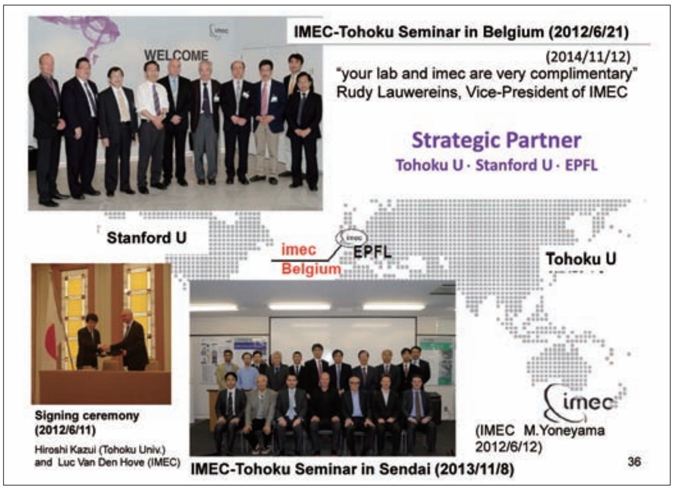

800
700
600
500
400
300
200
100
0
Users / month
Tohoku Univ. Users
Company Users
Nishizawa memorial research center
150 user companies
2010
2011
2012
2013
2014
Users of the Hands-on-access fab.
31

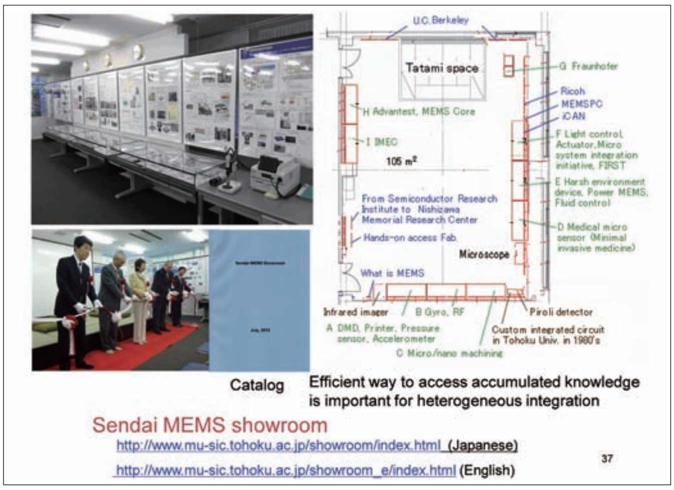

Overseas
Korea
Samsung
Singapore
Institute of Microelectronics (IME)
Hands-on-access fab. users (~150 companies)
32

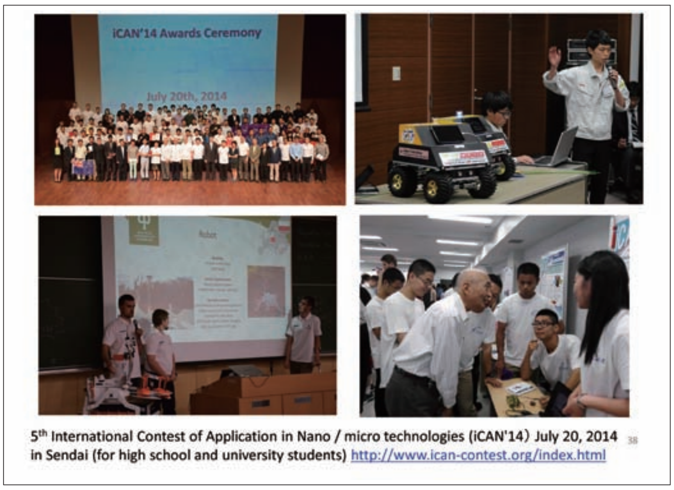

Companies are allowed to sell MEMS devices produced in the "Hands-on-access fab." (2013/7 ~)
Equipment were moved from Tr. Factory or donated
MOCVD
EOR etcher
W-CVD
PECVD
LPCVD
Oxidation/ diffusion furnace
Sputter
Stepper
Staff
EBlithography system
Epipoly-Si CVD
Government award (1800 m²)
Layout of Hands-on-access Fab.
Shared facility for industry to prototype MEMS devices (4 / 6 inch) Hands-on-access fab.
33

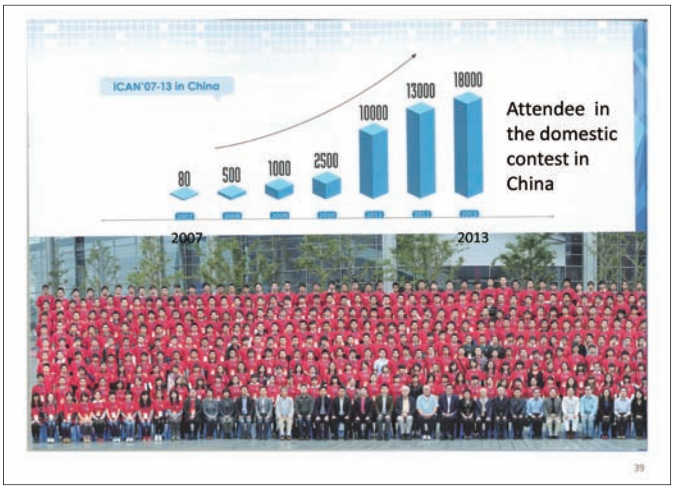

MEMS Park Consortium (MEMSPC)
MEMS core Co.Ltd.
(Contract development)
Advantest component Co.Ltd.
(Contract production)
(Initial stage prototyping)
Micro System Integration Center (μSIC), Tohoku Univ.
Nishizawa center, (Tohoku Univ.)
(Hands-on access fab.)
AIST (Tsukuba)
(8 inch production stage prototyping)
34

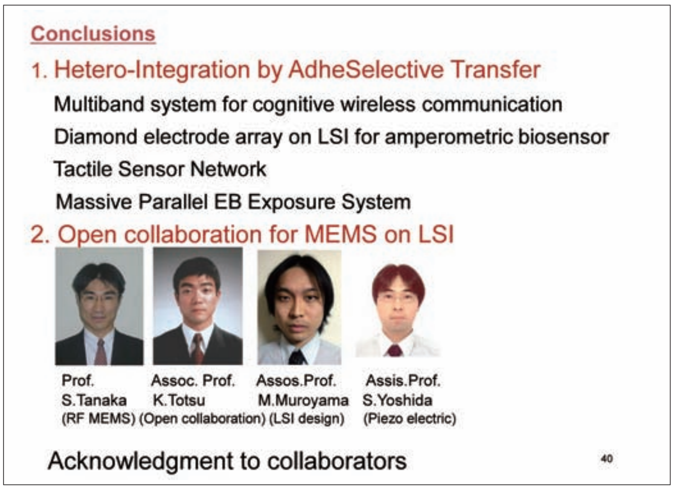

FhG Germany – Sendai city partnership signing ceremony in Munich (July15,2005)
1st Fraunhofer Symposium in Sendai "Doing Worldwide Business via MEMS technology" (Oct.19, 2005)
FhG Project center in WPI-AIMR, Tohoku Univ. (April 1, 2012)
FhG Germany – WPI-AIMR Tohoku Univ. partnership signing ceremony in Sendai (Nov. 8, 2011)
Collaboration with FhG (Fraunhofer Institute) in Germany
35


IMEC-Tohoku Seminar in Belgium (2012/6/21)
WELCOME
(2014/11/12)
"your lab and imec are very complimentary"
Rudy Lauwereins, Vice-President of IMEC
Strategic Partner
Tohoku U · Stanford U · EPFL
Stanford U
imec
Belgium
EPFL
Tohoku U
Signing ceremony (2012/6/11)
Hiroshi Kazui (Tohoku Univ.) and Luc Van Den Hove (IMEC)
(IMEC M.Yoneyama 2012/6/12)
IMEC-Tohoku Seminar in Sendai (2013/11/8)
36


U.C.Berkeley
Tatami space
G Fraunhofer
Ricoh
MEMSPC
iCAN
H Advantest, MEMS Core
I IMEC
105 m²
F Light control, Actuator, Micro system integration initiative, FIRST
E Harsh environment device, Power MEMS, Fluid control
From Semiconductor Research Institute to Nishizawa Memorial Research Center
Hands-on access Fab.
D Medical micro sensor (Minimal invasive medicine)
Microscope
What is MEMS
Infrared imager
B Gyro, RF
Piroli detector
A DMD, Printer, Pressure sensor, Accelerometer
Custom integrated circuit in Tohoku Univ. in 1980's
C Micro/nano machining
Catalog
Efficient way to access accumulated knowledge is important for heterogeneous integration
Sendai MEMS showroom
http://www.mu-sic.tohoku.ac.jp/showroom/index.html (Japanese)
http://www.mu-sic.tohoku.ac.jp/showroom_e/index.html (English)
37


iCAN'14 Awards Ceremony
July 20th, 2014
5th International Contest of Application in Nano / micro technologies (iCAN'14) July 20, 2014
in Sendai (for high school and university students) http://www.ican-contest.org/index.html
38

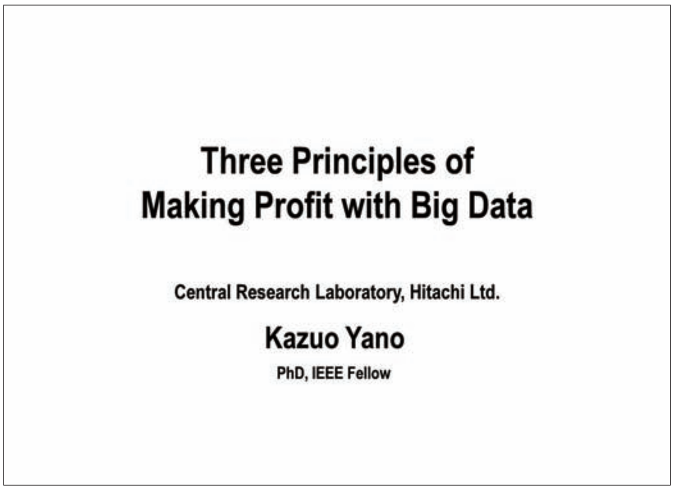

iCAN'07-13 in China
80
500
1000
2500
10000
13000
18000
Attendee in the domestic contest in China
2007
2013
39

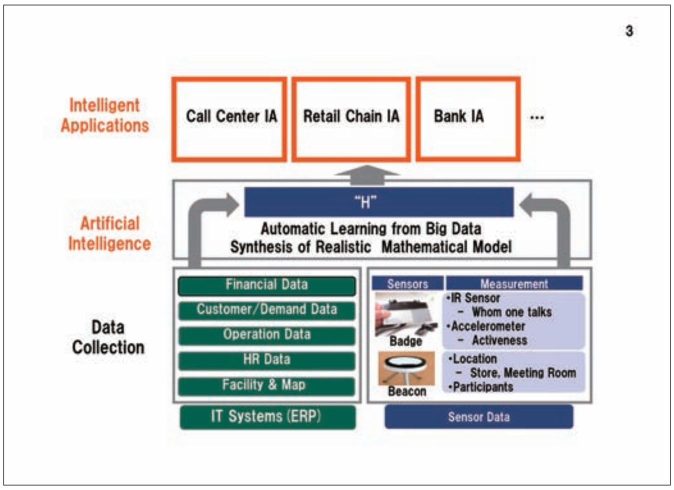

Conclusions
1. Hetero-Integration by AdheSelective Transfer
Multiband system for cognitive wireless communication
Diamond electrode array on LSI for amperometric biosensor
Tactile Sensor Network
Massive Parallel EB Exposure System
2. Open collaboration for MEMS on LSI
Prof. S.Tanaka (RF MEMS)
Assoc. Prof. K.Totsu (Open collaboration)
Assos.Prof. M.Muroyama (LSI design)
Assis.Prof. S.Yoshida (Piezo electric)
Acknowledgment to collaborators
40

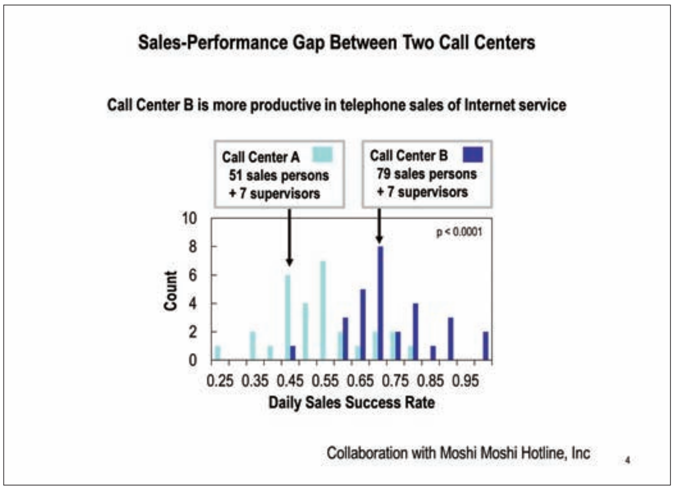
Three Principles of Making Profit with Big Data

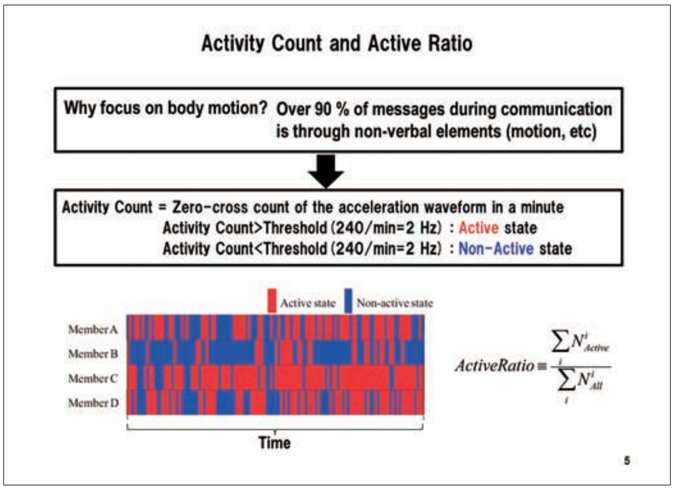
Kazuo Yano

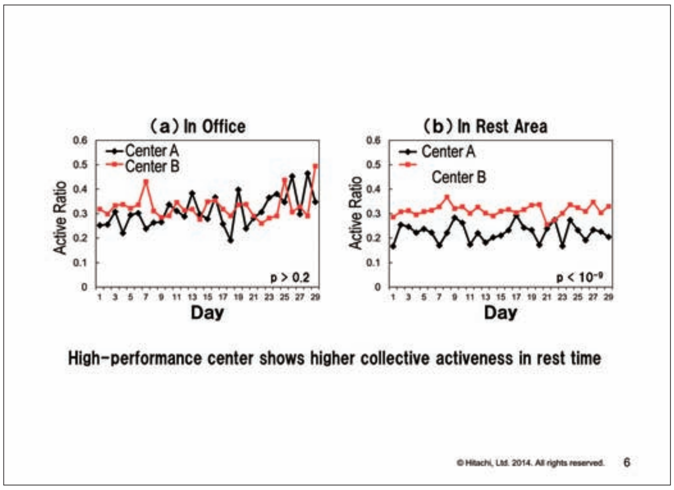
Senior Chief Researcher, Central Research Laboratory, Hitachi, Ltd., Japan

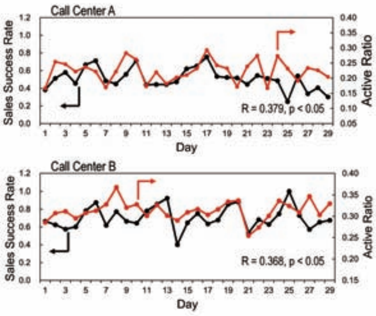










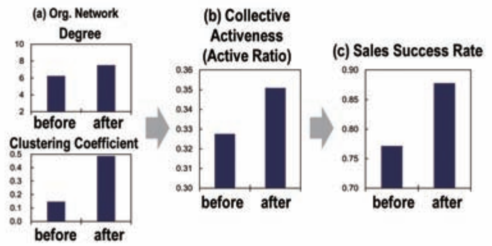


Sales Success Rate Correlated to Active Ratio during Rest Time

7

Optimization

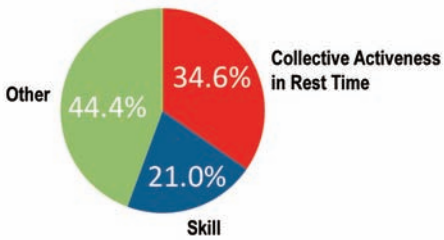
- Call Center B (Last one week)
- 4 people with similar age are assigned to share the team for resting
- 3 weeks before intervention is compared to 1 week after intervention



8

Contribution to Sales Success Rate

Contribution of Activeness in Rest Time is Greater than that of Sales Skill.



9

Retail Store Experiment

10

Time Frame　20days（6/18～30、7/22～8/1）

	Layer	Data	Source	Detail
Fi-nance	Outcome (Cost・Return)	・Revenue ・Sales Item ・Sales Count	・POS Data (CSV)	・Revenue 60 M Yen ・Customer 30,000 People ・Sales Count 99,000 Items
Cus-tomer	Demand Behavior (Customer)	・Flow Line ・Stopping ・Inquiry	Sensor ・IR ・Accelerometer	・Random Sample Study (Request wearing sensor at gate) 608 persons (2%)
Work	Operation (O&M)	・Placing ・Guest Service ・Resting	Sensor ・IR ・Accelerometer	・All Employee 80 Persons (about 8B data points)
Facil-ity	Infrastructure (Product)	・Facility Layout ・Item Shelf Assign	・Floor Plan ・Shelf Table	・Shelf & Area Codes Sensor Locations

Can Computer Provide Effective Solution Beyond Human? YES

11

Experiment　Contest between a Consultant in Retail Domain and a computer

Problem　Enhance the Sales per Customer in a Month based on 10-day data

	Human	Computer
Contestants	Consultant 2 Person Team with Experience in Retail	Operated by a Researcher without Retail Knowledge
Approach	・Interview with Executive etc ・Utilize Domain Knowledge ・Use Data to Hypothesize	・Computer used only data ・No Domain Knowledge Used ・Action Selected from Results by Human
Action	POP Ads for Focus Items (LED Bulb etc.) & Item Rearrangement	Highly Sensitive Spot of Employee presence on Sales Identified
Result	No Sales Increase Confirmed	Sales per Customer for Total Store was Increased by 15%(Victory)

Conclusion: Computers with big data are to help enhance business performance

2014年7月19日発行　草思社

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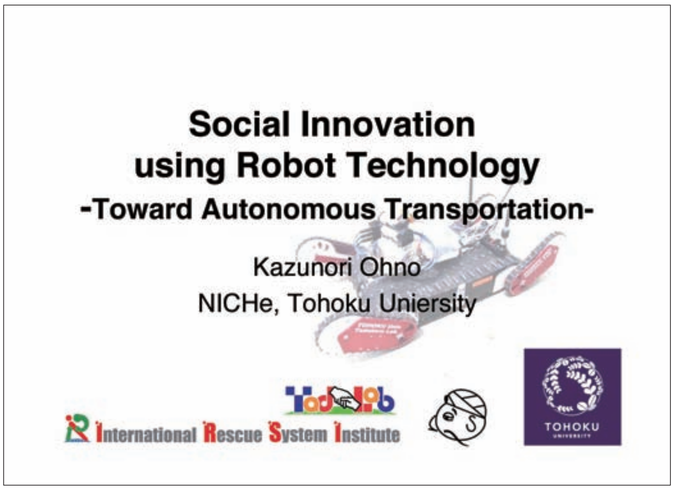
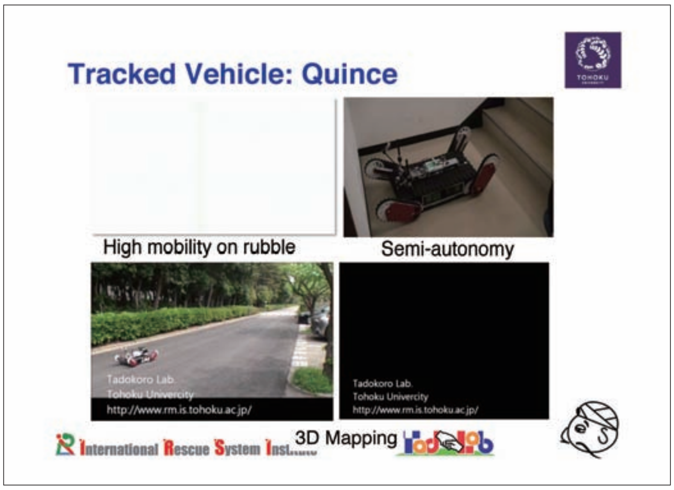
Social Innovation using Robot Technology
-Toward Autonomous Transportation-

Kazunori Ohno
Associate Professor, New Industry Creation Hatchery Center, Tohoku University, Japan





Spider-copter

It can observe target with few energy.

Expectation to Social Innovation using Robot Technology

- Automation of Physical Distribution in a factory and the industrial area
- Automation of transportation of medicine, medical records, and meals in the hospital
- Autonomous driving car for elderly persons and patients

- Market size of the robot at 2020.(2012.5) (Fuji economy inv.2012.5)
  - Global market of industrial robots: $6.6 billion
  - Domestic market of service robots: More than $1.3 billion
- Japanese Gov. Japan revival strategy (2013.6)
  - Autonomous & Safe Driving: $200billion at 2030

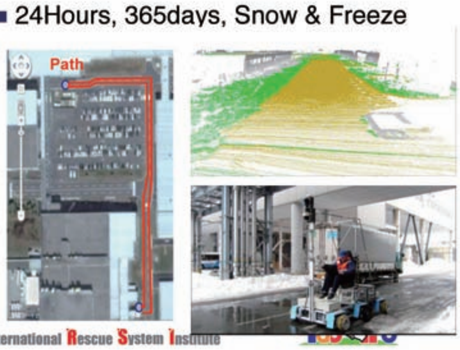
Intelligence for Personal Vehicle

Development of obstacle avoidance, planning, localization, navigation functions.

International Rescue System Institute

Autonomous Outdoor Carrier

- 24Hours, 365days, Snow & Freeze



Automation of Public Transportation

Development of Autonomous Driving Car

International Rescue System Institute

Thank you!

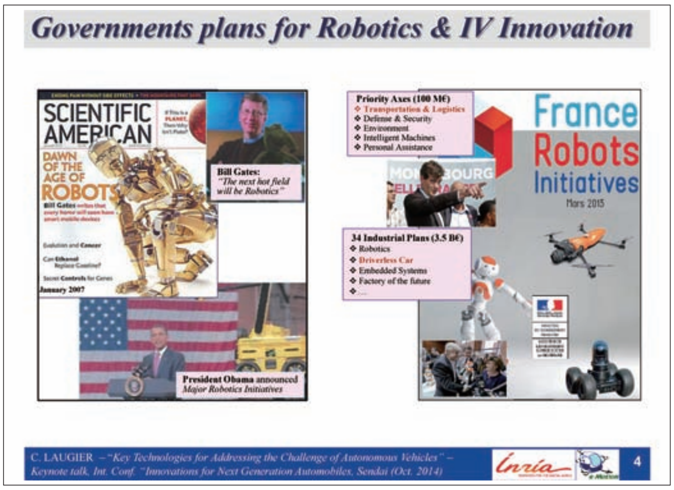
http://www.rm.is.tohoku.ac.jp/

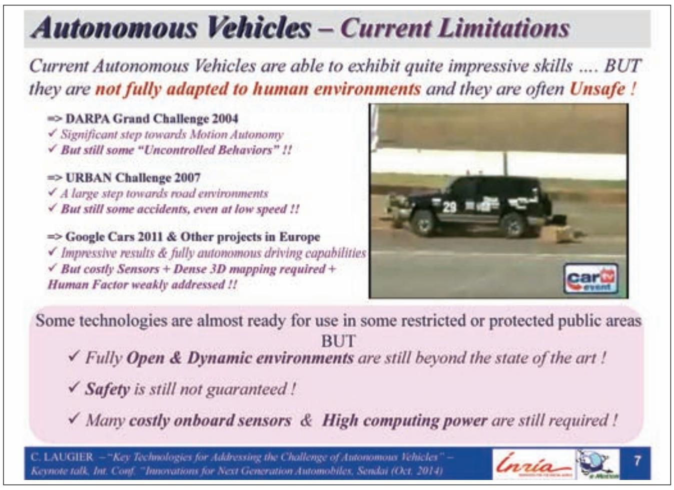
International Rescue System Institute

TOHOKU

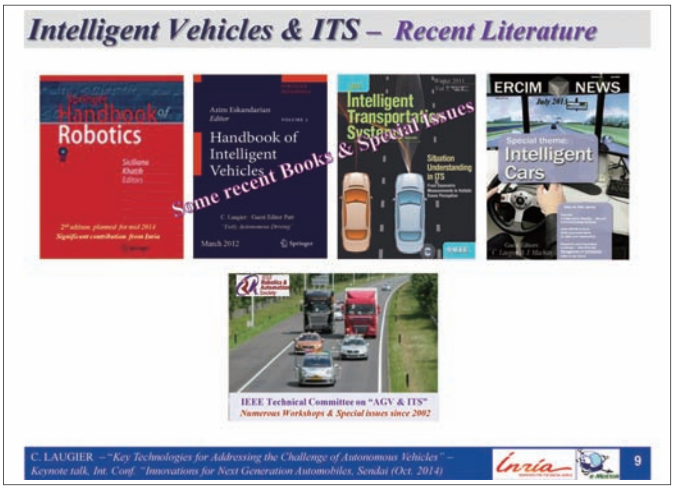
Key Technologies for Addressing the Challenge of Autonomous Vehicles

Christian LAUGIER
First class Research Director, INRIA Grenoble Rhône-Alpes, France




Autonomous Vehicles – Current Limitations
Current Autonomous Vehicles are able to exhibit quite impressive skills .... BUT they are not fully adapted to human environments and they are often Unsafe !
=> DARPA Grand Challenge 2004
✓ Significant step towards Motion Autonomy
✓ But still some "Uncontrolled Behaviors" !!
=> URBAN Challenge 2007
✓ A large step towards road environments
✓ But still some accidents, even at low speed !!
=> Google Cars 2011 & Other projects in Europe
✓ Impressive results & fully autonomous driving capabilities
✓ But costly Sensors + Dense 3D mapping required + Human Factor weakly addressed !!
Some technologies are almost ready for use in some restricted or protected public areas
BUT
✓ Fully Open & Dynamic environments are still beyond the state of the art !
✓ Safety is still not guaranteed !
✓ Many costly onboard sensors & High computing power are still required !
C. LAUGIER – "Key Technologies for Addressing the Challenge of Autonomous Vehicles" – Keynote talk, Int. Conf. "Innovations for Next Generation Automobiles, Sendai (Oct. 2014)
7


Intelligent Vehicles – Innovation & Products
❑ Cybercars : Some start-ups & first products
Cycab (Inria /Robosoft)
Cybergo (Induct)
Amsterdam Schiphol Airport (2Get There, 1997-2004)
Cybus, La Rochelle 2012 (CityMobil & Inria)
❑ ADAS : Increasing number of products & equipped cars
Adaptive Cruise Control (ACC)
Lane Guidance System (PCB and Camera sensor from Hundai)
Night / Bad Weather Vision
Collision Warning with Brake support (Lincoln MKS, 2009)
Radar based Pre-Collision System (Toyota Lexus, 2003)
Parallel Parking System (V1: Toyota Prius 2003 ; V2: Toyota Lexus 2006 & 2010)
=> Inspired by Inria approach 1996
8


Intelligent Vehicles & ITS – Recent Literature
Handbook of Robotics
Handbook of Intelligent Vehicles
Intelligent Transportation Systems
ERCIM NEWS
Intelligent Cars
Some recent Books & Special issues
IEEE Technical Committee on "AGV & ITS"
Numerous Workshops & Special issues since 2002
C. LAUGIER – "Key Technologies for Addressing the Challenge of Autonomous Vehicles" – Keynote talk, Int. Conf. "Innovations for Next Generation Automobiles, Sendai (Oct. 2014)
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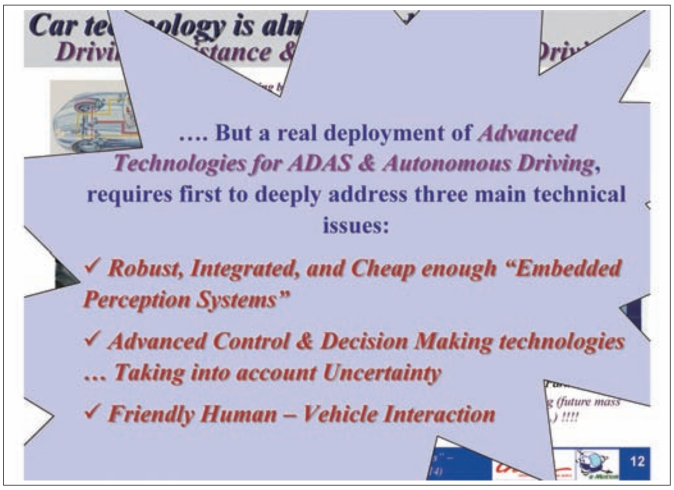
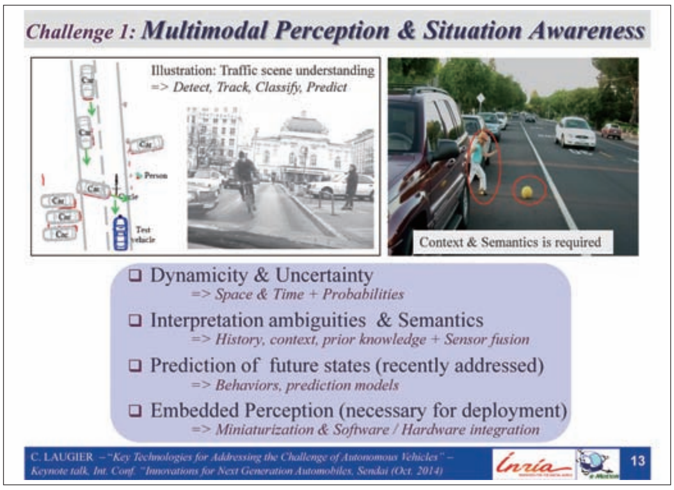
Intelligent Cars & ITS – Towards Driverless Cars ?
Horizon 2020-25 ?
Nissan promises a driverless car for 2020
LE FIGARO
Date : 29/08/2013
Google Car 2011
140 000 miles covered
Toyota
"Automated Highway Driving Assist"
(Demo Tokyo 2013, Product 2015)
Voitures sans conducteur : Nissan va mettre un robot dans votre moteur !
LA TRIBUNE
But also:
Tesla (90% Autonomous, => 2016),
Volvo, Mercedes Class S, BMW ...
Autonomous car: An industrial challenge for tomorrow !
The French Minister of Industry promotes driverless car
❖ Market Forecast : 8000 cars sold in 2020, about 95 millions in 2035
❖ Still some open questions: Why driverless cars ? Intelligent co-Pilot v/s Full Autonomy ? Acceptability ? Legal issue ? Driver / Co-Pilot Control transitions ?
C. LAUGIER – "Key Technologies for Addressing the Challenge of Autonomous Vehicles" – Keynote talk, Int. Conf. "Innovations for Next Generation Automobiles, Sendai (Oct. 2014)
10


Car technology is almost ready for
Driving Assistance & Fully Autonomous Driving
Steering by wire
Brake by wire
Shift by wire
Virtual dash-board
Modern "wheel" ....
Navigation systems
Driving assistance (speed, ABS, ESB ...)
Wireless Communication
Speech Recognition & Synthesis
... Towards connected cars
Radar, Cameras, Night Vision, Multiple sensors ..... but also
"Sensor based Active Driving Assistance" (e.g. Automatic Parking)
=> Cost decreasing & Efficiency increasing (future mass production, embedded systems, SoC ...) !
C. LAUGIER – "Key Technologies for Addressing the Challenge of Autonomous Vehicles" – Keynote talk, Int. Conf. "Innovations for Next Generation Automobiles, Sendai (Oct. 2014)
11


.... But a real deployment of Advanced Technologies for ADAS & Autonomous Driving, requires first to deeply address three main technical issues:
✓ Robust, Integrated, and Cheap enough "Embedded Perception Systems"
✓ Advanced Control & Decision Making technologies ... Taking into account Uncertainty
✓ Friendly Human – Vehicle Interaction
12


Challenge 1: Multimodal Perception & Situation Awareness
Illustration: Traffic scene understanding
=> Detect, Track, Classify, Predict
Context & Semantics is required
Dynamicity & Uncertainty
=> Space & Time + Probabilities
Interpretation ambiguities & Semantics
=> History, context, prior knowledge + Sensor fusion
Prediction of future states (recently addressed)
=> Behaviors, prediction models
Embedded Perception (necessary for deployment)
=> Miniaturization & Software / Hardware integration
C. LAUGIER – "Key Technologies for Addressing the Challenge of Autonomous Vehicles" –
Keynote talk, Int. Conf. "Innovations for Next Generation Automobiles, Sendai (Oct. 2014)
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Challenge 2: Human Aware Navigation & Interaction
Human beings are unbeatable in taking decisions in complex situations
Technology is better for "simple" but "fast" control decisions (ABS, ESP ...)
Share Control is mandatory !
.... But Driver inattention is still a major cause of accident !
Seat pressure
Steering actions
Pedal signals
Head /Eye Visual analysis
Driver Monitoring (using on-board Perception)
+
Safe & Socially Acceptable Human / Vehicle Interaction is necessary !
=> "Mutual Driver / Vehicle understanding"
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Key Technology 1:
"Bayesian Perception paradigm"
Bayesian Perception for Open & Dynamic Environments
Embedded Perception & Bayesian Sensor Fusion
C. LAUGIER – "Key Technologies for Addressing the Challenge of Autonomous Vehicles" –
Keynote talk, Int. Conf. "Innovations for Next Generation Automobiles, Sendai (Oct. 2014)
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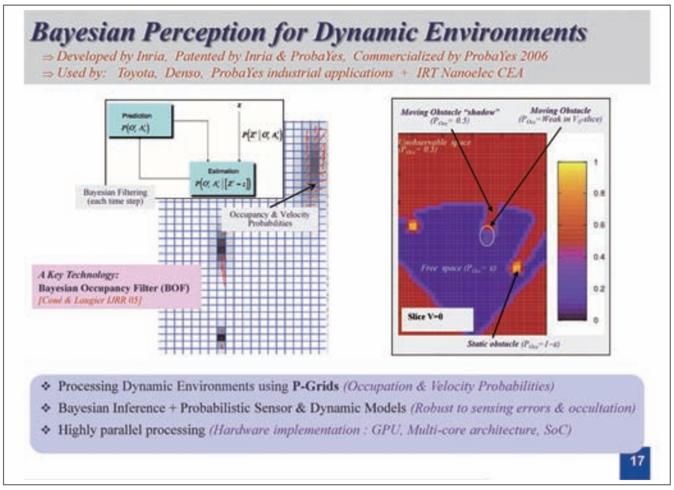
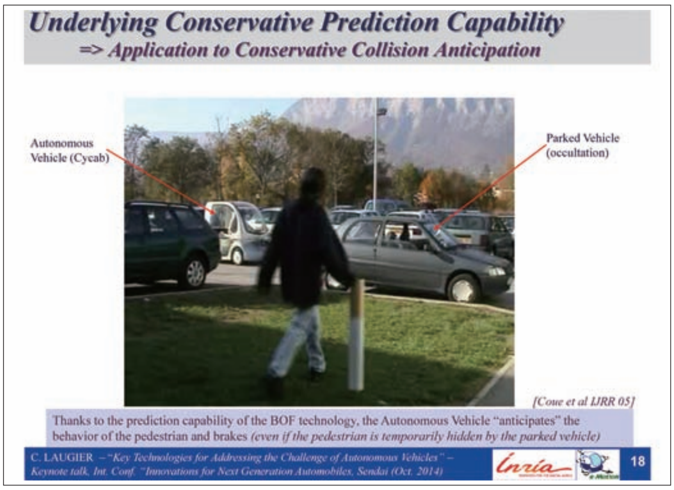

Bayesian Perception for Dynamic Environments
⇒ Developed by Inria, Patented by Inria & ProbaYes, Commercialized by ProbaYes 2006
⇒ Used by: Toyota, Denso, ProbaYes industrial applications + IRT Nanoelec CEA
Prediction
Estimation
Bayesian Filtering (each time step)
Occupancy & Velocity Probabilities
A Key Technology:
Bayesian Occupancy Filter (BOF)
[Coué & Laugier IJRR 05]
Moving Obstacle "shadow"
Moving Obstacle
Unobservable space
Free space
Slice V=0
Static obstacle
Processing Dynamic Environments using P-Grids (Occupation & Velocity Probabilities)
Bayesian Inference + Probabilistic Sensor & Dynamic Models (Robust to sensing errors & occultation)
Highly parallel processing (Hardware implementation : GPU, Multi-core architecture, SoC)
17


Underlying Conservative Prediction Capability
=> Application to Conservative Collision Anticipation
Autonomous Vehicle (Cycab)
Parked Vehicle (occultation)
[Coue et al IJRR 05]
Thanks to the prediction capability of the BOF technology, the Autonomous Vehicle "anticipates" the behavior of the pedestrian and brakes (even if the pedestrian is temporarily hidden by the parked vehicle)
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Keynote talk, Int. Conf. "Innovations for Next Generation Automobiles, Sendai (Oct. 2014)
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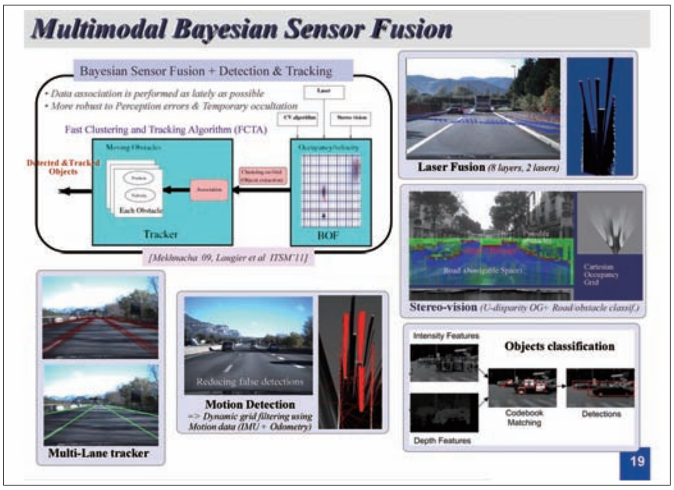
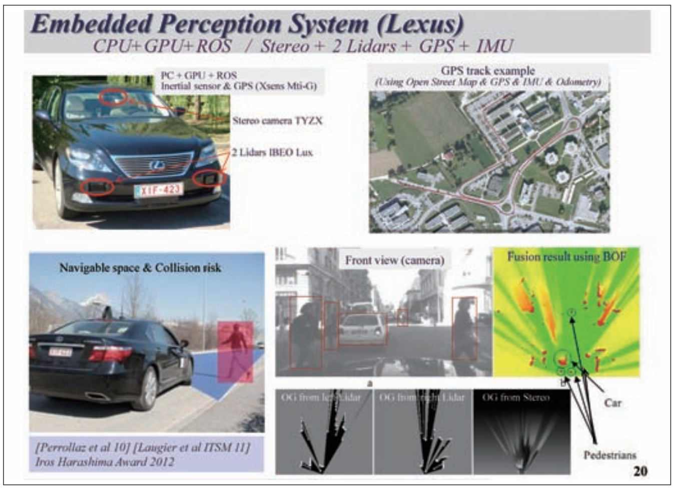
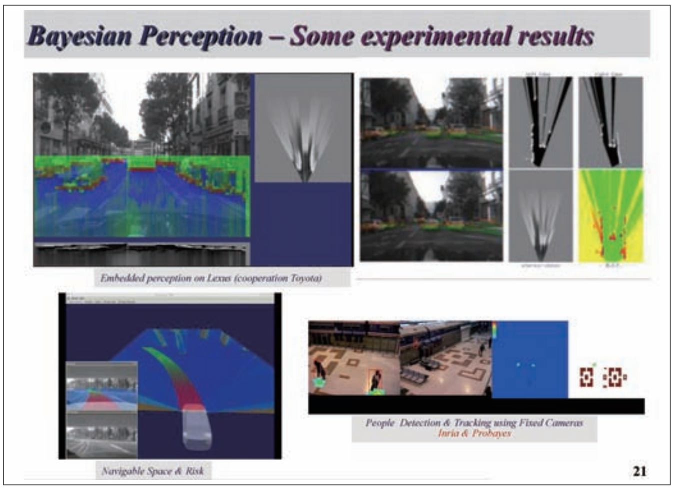
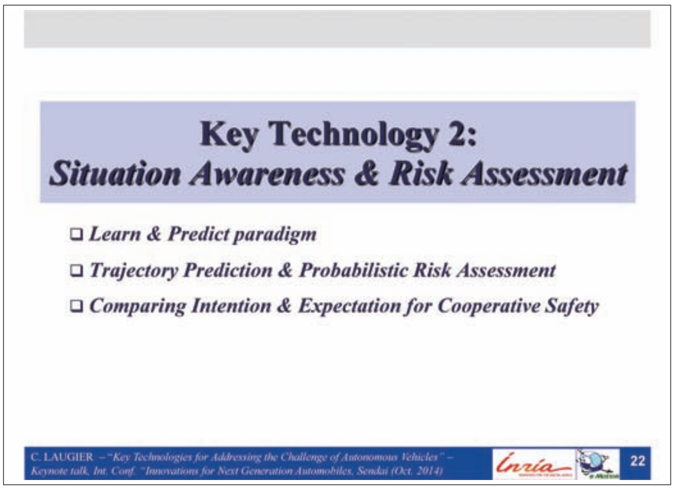

Multimodal Bayesian Sensor Fusion
Bayesian Sensor Fusion + Detection & Tracking
• Data association is performed as lately as possible
• More robust to Perception errors & Temporary occultation
Fast Clustering and Tracking Algorithm (FCTA)
Detected & Tracked Objects
Tracker
BOF
[Mekhnacha 09, Laugier et al ITSM'11]
Laser Fusion (8 layers, 2 lasers)
Stereo-vision (U-disparity OG+ Road/obstacle classif.)
Multi-Lane tracker
Reducing false detections
Motion Detection
=> Dynamic grid filtering using Motion data (IMU + Odometry)
Intensity Features
Objects classification
Codebook Matching
Detections
Depth Features
19


Embedded Perception System (Lexus)
CPU+GPU+ROS / Stereo + 2 Lidars + GPS + IMU
PC + GPU + ROS
Inertial sensor & GPS (Xsens Mti-G)
Stereo camera TYZX
2 Lidars IBEO Lux
GPS track example
(Using Open Street Map & GPS & IMU & Odometry)
Navigable space & Collision risk
Front view (camera)
Fusion result using BOF
OG from left Lidar
OG from right Lidar
OG from Stereo
Car
Pedestrians
[Perrollaz et al 10] [Laugier et al ITSM 11]
Iros Harashima Award 2012
20


Bayesian Perception – Some experimental results
Embedded perception on Lexus (cooperation Toyota)
People Detection & Tracking using Fixed Cameras
Inria & Probayes
Navigable Space & Risk
21


Key Technology 2:
Situation Awareness & Risk Assessment
❑ Learn & Predict paradigm
❑ Trajectory Prediction & Probabilistic Risk Assessment
❑ Comparing Intention & Expectation for Cooperative Safety
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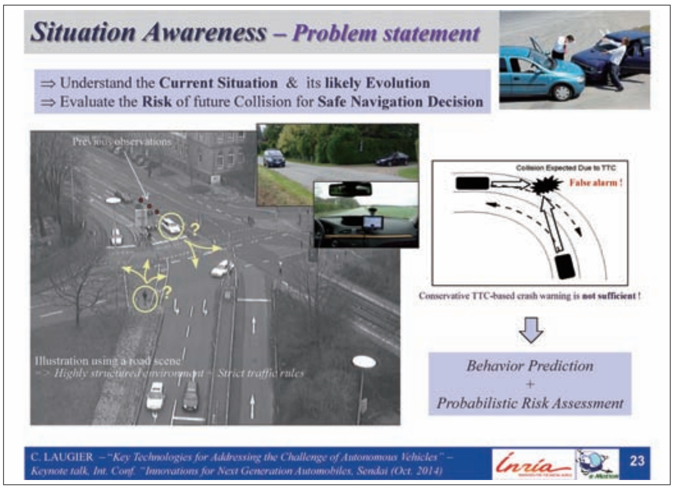
Situation Awareness – Problem statement
⇒ Understand the Current Situation & its likely Evolution
⇒ Evaluate the Risk of future Collision for Safe Navigation Decision
Previous observations
Illustration using a road scene
=> Highly structured environment + Strict traffic rules
Collision Expected Due to TTC
False alarm !
Conservative TTC-based crash warning is not sufficient !
Behavior Prediction
+
Probabilistic Risk Assessment
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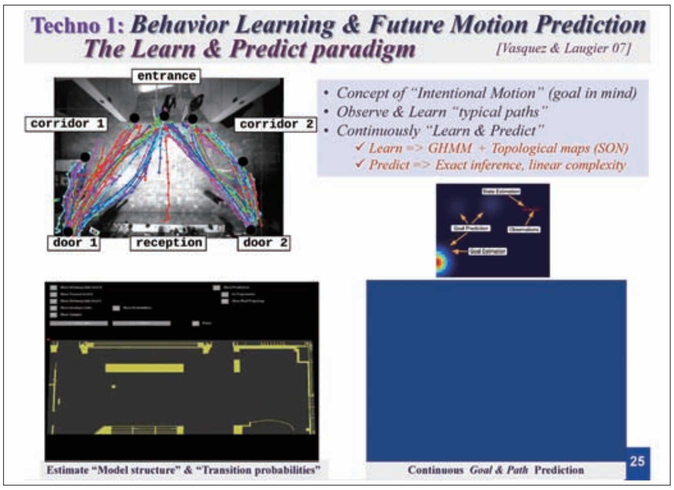
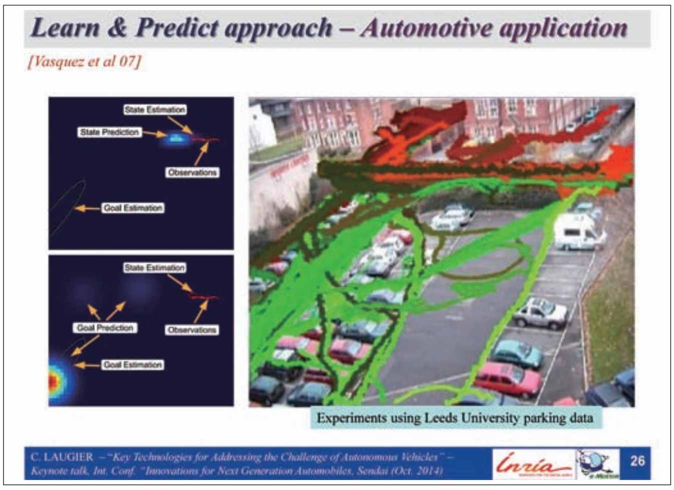
Situation Awareness – Pro
Behavior Prediction + Probabilistic
=> Consistent Prediction & Risk Assessment requires to reason about:
✓ History of obstacles Positions & Velocities
=> Perception (Datmo) or V2V Communications
✓ Obstacles expected Behaviors
=> Moving straight, turning, crossing, overtaking, stopping ...
✓ Space geometry / topology
=> Road lanes, curves, intersections ...
✓ Traffic rules
24


Techno 1: Behavior Learning & Future Motion Prediction
The Learn & Predict paradigm
[Vasquez & Laugier 07]
entrance
corridor 1
corridor 2
door 1
reception
door 2
• Concept of "Intentional Motion" (goal in mind)
• Observe & Learn "typical paths"
• Continuously "Learn & Predict"
✓ Learn => GHMM + Topological maps (SON)
✓ Predict => Exact inference, linear complexity
Estimate "Model structure" & "Transition probabilities"
Continuous Goal & Path Prediction
25


Learn & Predict approach – Automotive application
[Vasquez et al 07]
State Estimation
State Prediction
Observations
Goal Estimation
State Estimation
Goal Prediction
Observations
Goal Estimation
Experiments using Leeds University parking data
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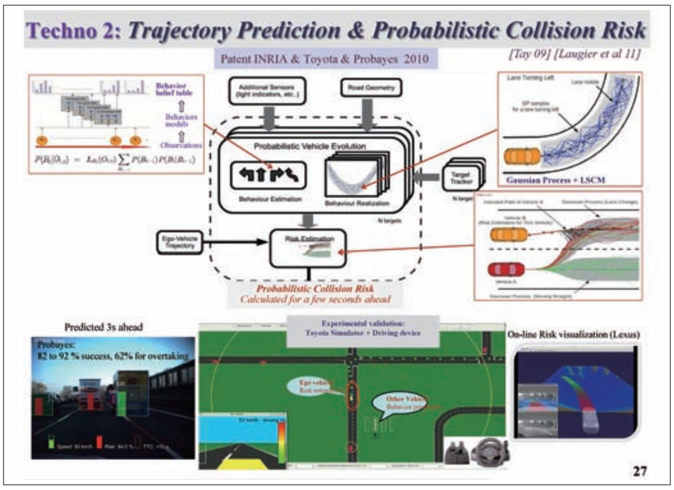
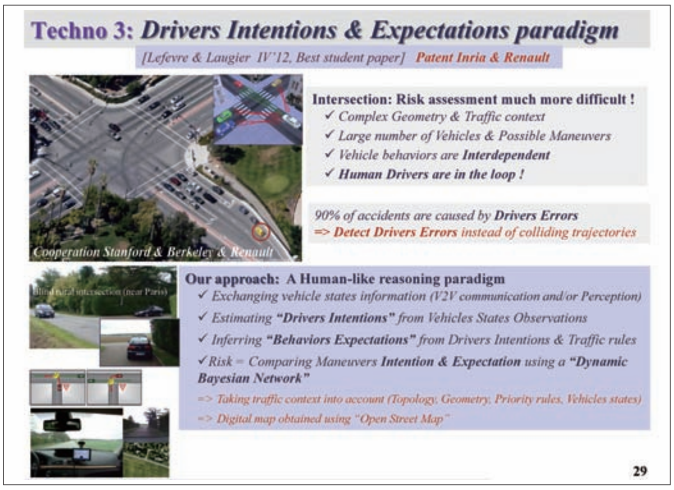
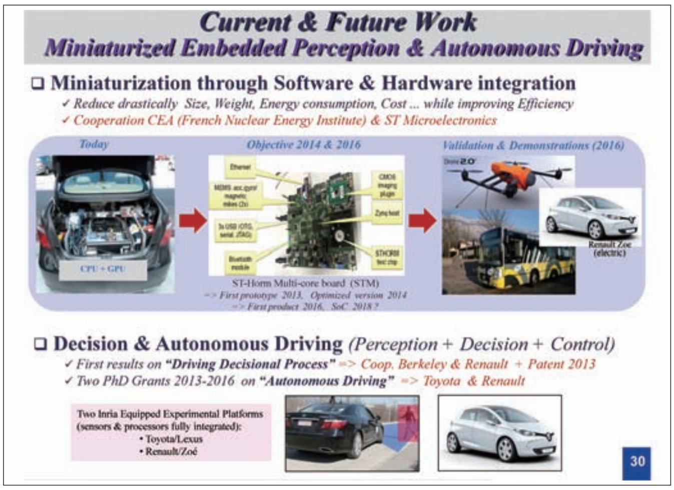
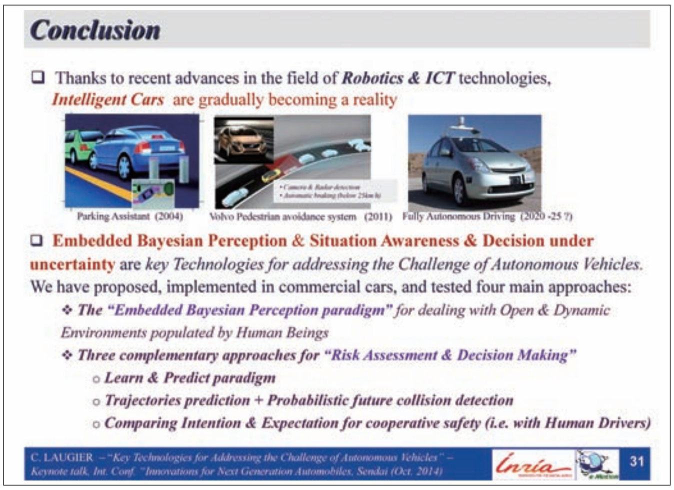

Techno 2: Trajectory Prediction & Probabilistic Collision Risk
Patent INRIA & Toyota & Probayes 2010
[Tay 09] [Laugier et al 11]
Behavior belief table
Behaviors models
Observations
Additional Sensors
Road Geometry
Probabilistic Vehicle Evolution
Behaviour Estimation
Behaviour Realization
Target Tracker
Ego-Vehicle Trajectory
Risk Estimation
Gaussian Process + LSCM
Probabilistic Collision Risk
Calculated for a few seconds ahead
Predicted 3s ahead
Probayes:
82 to 92 % success, 62% for overtaking
Experimental validation:
Toyota Simulator + Driving device
On-line Risk visualization (Lexus)
27


Trajectory Prediction & Risk – Experimental results
[Tay 09] [Laugier et al 11]
Speed: 96 km/h
Risk: 0.0 %
TTC: >10 s
Traffic participants behavior prediction & collision risk estimation
Probayes & TME
Navigable Space & Risk (using ROS)
28


Techno 3: Drivers Intentions & Expectations paradigm
[Lefevre & Laugier IV'12, Best student paper] Patent Inria & Renault
Intersection: Risk assessment much more difficult !
✓ Complex Geometry & Traffic context
✓ Large number of Vehicles & Possible Maneuvers
✓ Vehicle behaviors are Interdependent
✓ Human Drivers are in the loop !
90% of accidents are caused by Drivers Errors
=> Detect Drivers Errors instead of colliding trajectories
Cooperation Stanford & Berkeley & Renault
Our approach: A Human-like reasoning paradigm
✓ Exchanging vehicle states information (V2V communication and/or Perception)
✓ Estimating "Drivers Intentions" from Vehicles States Observations
✓ Inferring "Behaviors Expectations" from Drivers Intentions & Traffic rules
✓ Risk = Comparing Maneuvers Intention & Expectation using a "Dynamic Bayesian Network"
=> Taking traffic context into account (Topology, Geometry, Priority rules, Vehicles states)
=> Digital map obtained using "Open Street Map"
29


Current & Future Work
Miniaturized Embedded Perception & Autonomous Driving
❑ Miniaturization through Software & Hardware integration
✓ Reduce drastically Size, Weight, Energy consumption, Cost ... while improving Efficiency
✓ Cooperation CEA (French Nuclear Energy Institute) & ST Microelectronics
Today
Objective 2014 & 2016
Validation & Demonstrations (2016)
CPU + GPU
ST-Horm Multi-core board (STM)
=> First prototype 2013, Optimized version 2014
=> First product 2016, SoC 2018 ?
Renault Zoe (electric)
❑ Decision & Autonomous Driving (Perception + Decision + Control)
✓ First results on "Driving Decisional Process" => Coop. Berkeley & Renault + Patent 2013
✓ Two PhD Grants 2013-2016 on "Autonomous Driving" => Toyota & Renault
Two Inria Equipped Experimental Platforms (sensors & processors fully integrated):
• Toyota/Lexus
• Renault/Zoé
30


Conclusion
❑ Thanks to recent advances in the field of Robotics & ICT technologies,
Intelligent Cars are gradually becoming a reality
Parking Assistant (2004)
Volvo Pedestrian avoidance system (2011)
Fully Autonomous Driving (2020 -25 ?)
❑ Embedded Bayesian Perception & Situation Awareness & Decision under uncertainty are key Technologies for addressing the Challenge of Autonomous Vehicles.
We have proposed, implemented in commercial cars, and tested four main approaches:
❖ The "Embedded Bayesian Perception paradigm" for dealing with Open & Dynamic Environments populated by Human Beings
❖ Three complementary approaches for "Risk Assessment & Decision Making"
○ Learn & Predict paradigm
○ Trajectories prediction + Probabilistic future collision detection
○ Comparing Intention & Expectation for cooperative safety (i.e. with Human Drivers)
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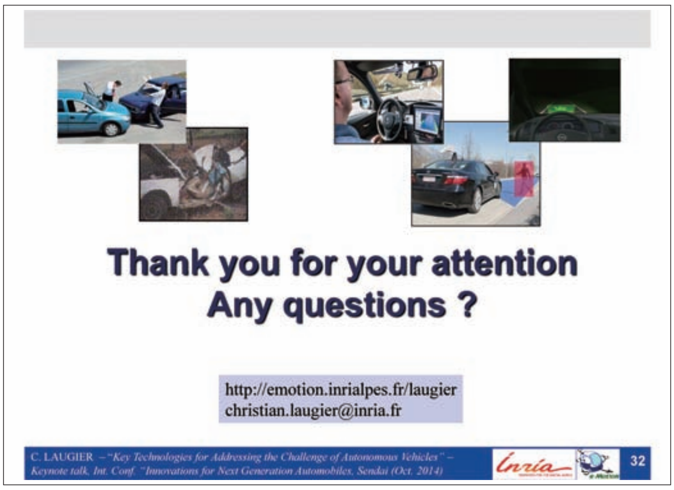
Thank you for your attention
Any questions ?
http://emotion.inrialpes.fr/laugier
christian.laugier@inria.fr
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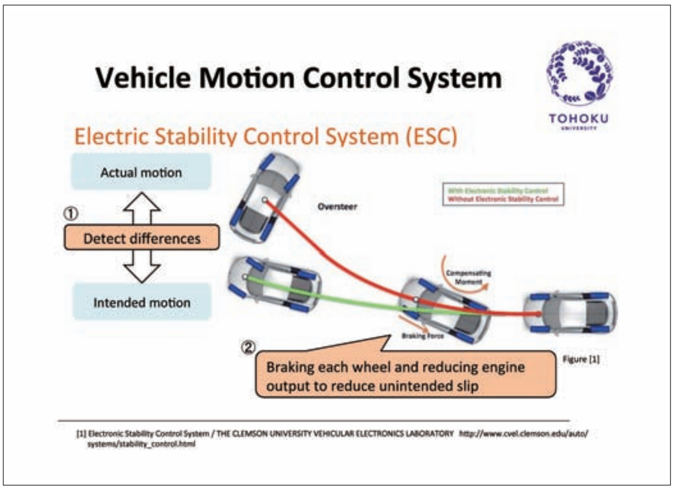
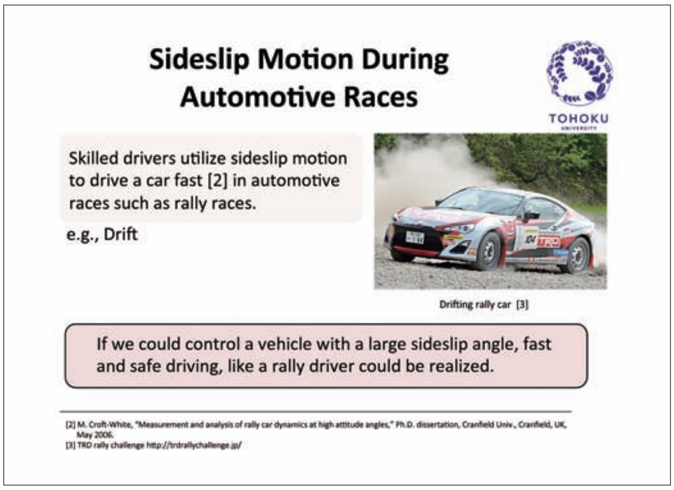
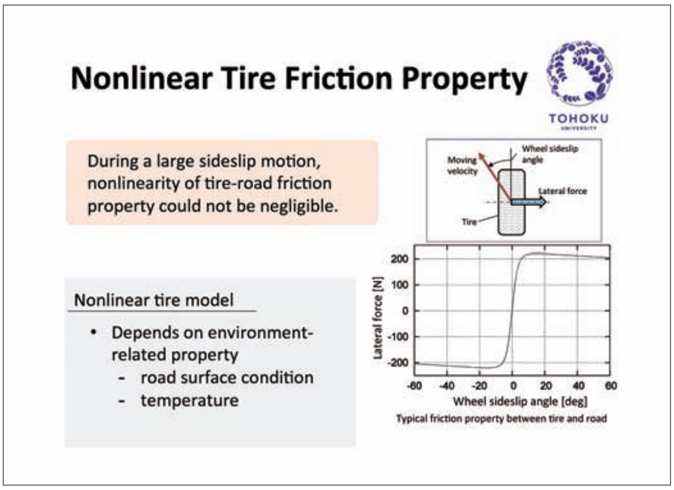
Dynamic Motion Control of a Vehicle with a Large Sideslip Angle

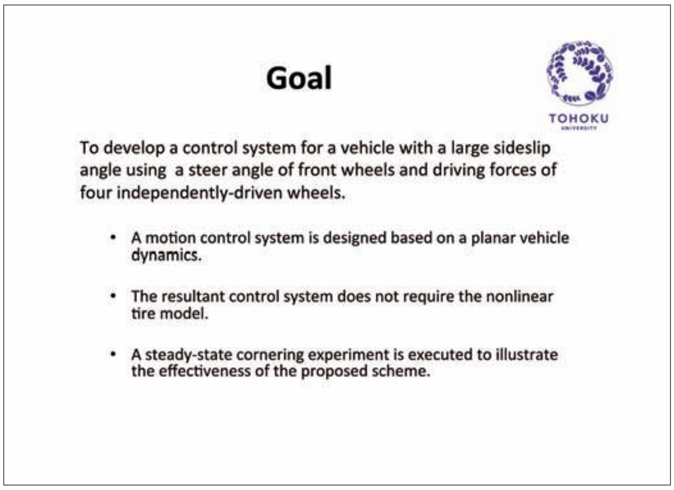
Kazuhiro Kosuge

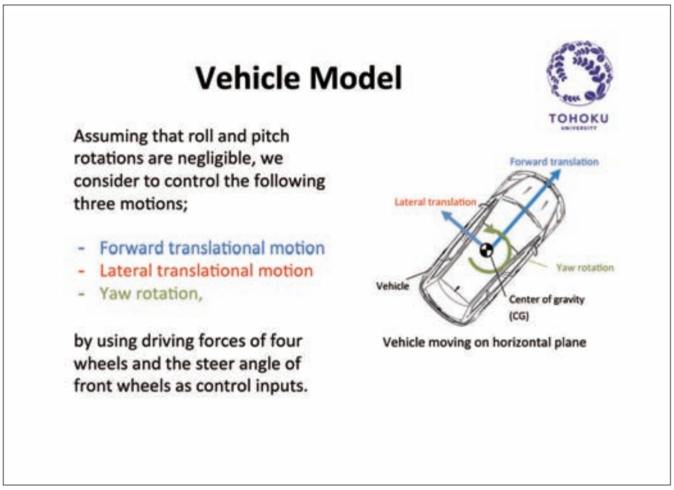
Professor, Bioengineering and Robotics Graduate School of Engineering, Tohoku University, Japan





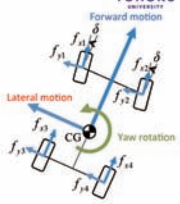






Controller Design

- Forward translational motion
  - Driving forces could be considered dominant force.
  - ➡ Controlled using Driving forces
- Lateral translational motion
  - Lateral forces could be considered dominant force.
  - ➡ Controlled using Lateral forces
- Yaw rotation
  - Motion are affected by driving forces and lateral forces.
  - ➡ Controlled using Driving forces



- Redundancy
- Easy to observe
- Generated actively

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Controller Design

Controller is designed in two steps.

- ☐ Controller for the forward translational motion & yaw rotation using driving forces as control inputs
- ☐ Controller for the lateral translational motion using the front-wheel steer angle as a control input

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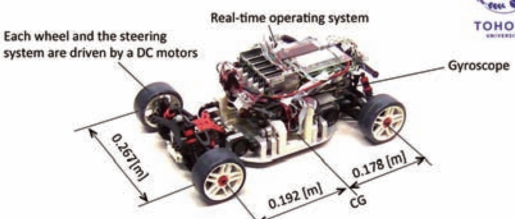
Experimental System



Vehicle mass:	5.77 [kg]
Yaw moment of inertia:	0.1043 [kgm²]
Wheel diameter:	0.097 [m]
Wheel polar moment of inertia:	0.156x10⁻³ [kgm²]
Control frequency:	1 [kHz]
Controller gain:	$[k_{Fx}\ k_{Fy}\ k_{\gamma}]=[10\ 30\ 10]$
Cornering stiffness:	$C_1+C_2=$ 40 [N/rad]

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Experiments

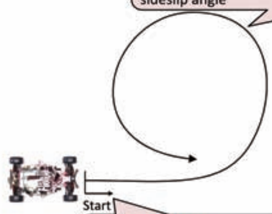
Steady-state cornering experiment

4 seconds after start
Increase the desired value of sideslip angle

Stopped state

⇩

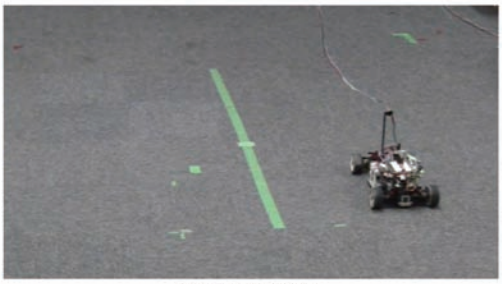
Desired state



Shortly after start
Increase the desired value of forward velocity & yaw rate

Experimental Results

Controller 1 Sideslip angle β = -20deg



Experimental Result

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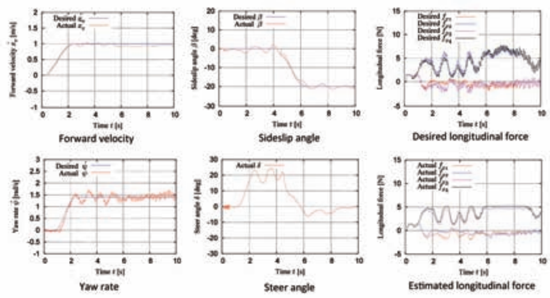
Experimental Results

Controller 1 Sideslip angle β = -20deg



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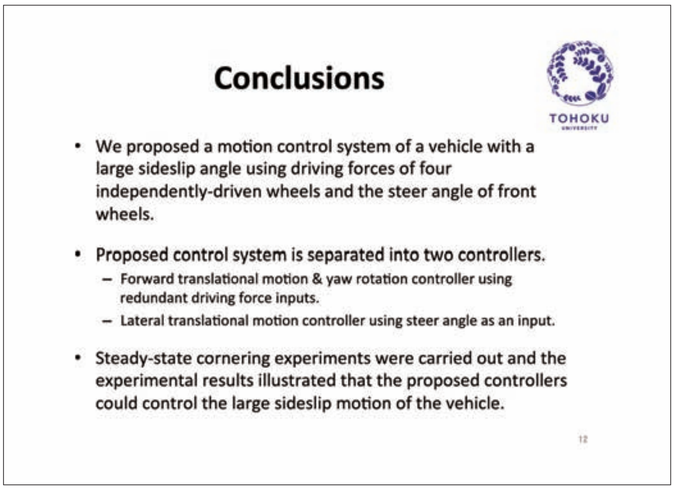
Conclusions
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UNIVERSITY
• We proposed a motion control system of a vehicle with a large sideslip angle using driving forces of four independently-driven wheels and the steer angle of front wheels.
• Proposed control system is separated into two controllers.
– Forward translational motion & yaw rotation controller using redundant driving force inputs.
– Lateral translational motion controller using steer angle as an input.
• Steady-state cornering experiments were carried out and the experimental results illustrated that the proposed controllers could control the large sideslip motion of the vehicle.
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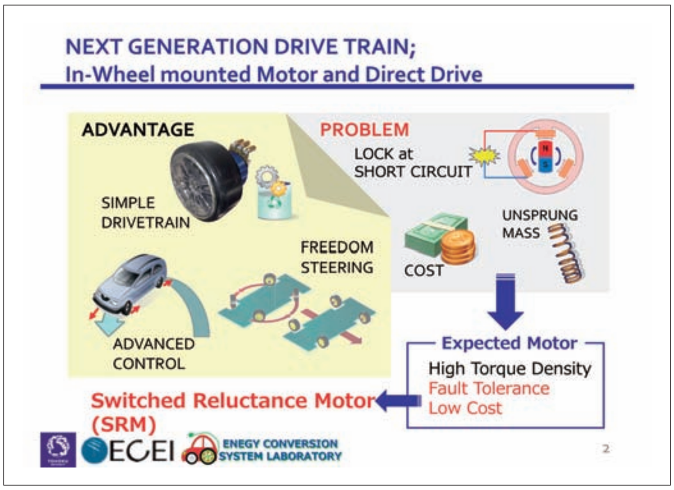
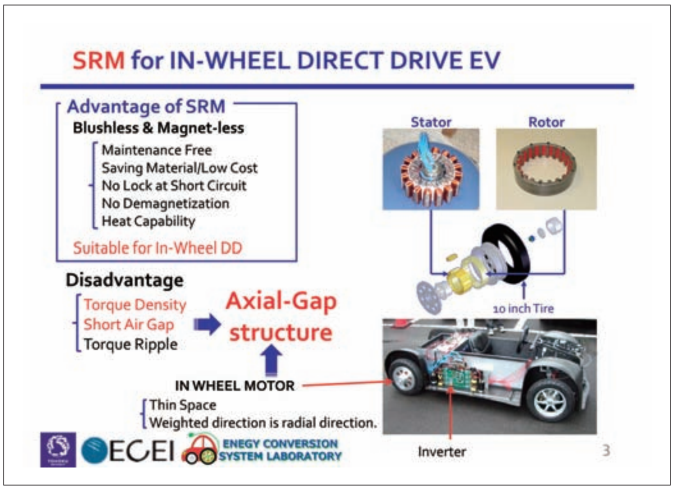
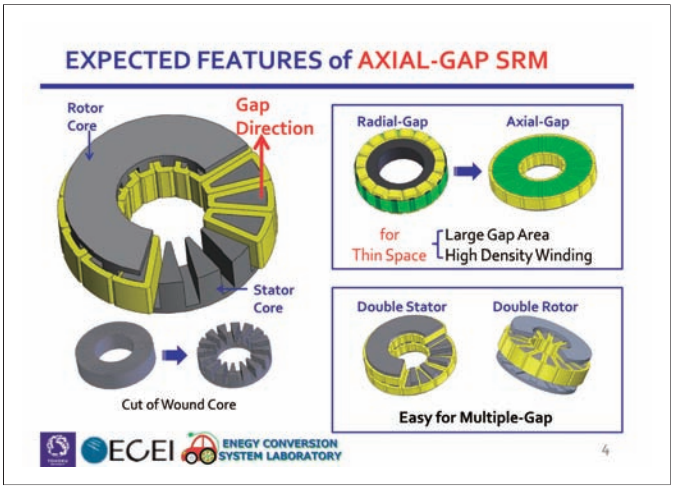
Development of High Torque Density Axial-gap Switched Reluctance Motor for Next Generation Automotive

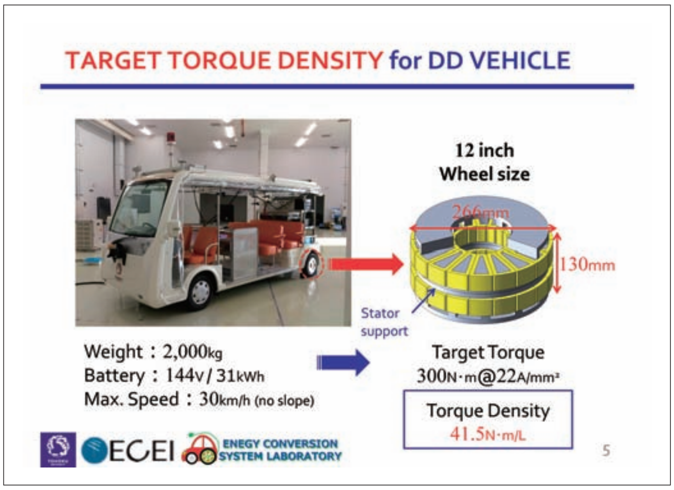
Hiroki Goto

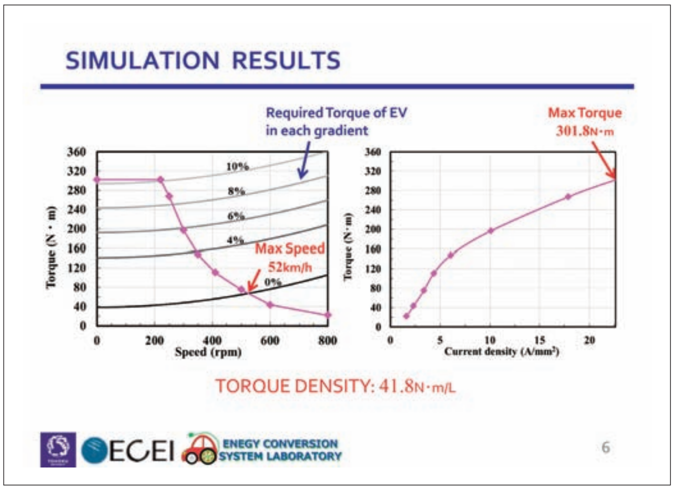
Assistant Professor, Applied Electromagnetic Energy, Tohoku University, Japan





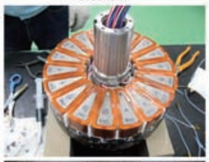






PROTO-TYPE MACHINE

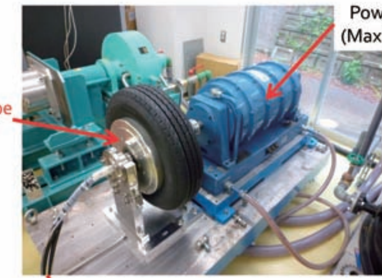
Stator



Rotor Core

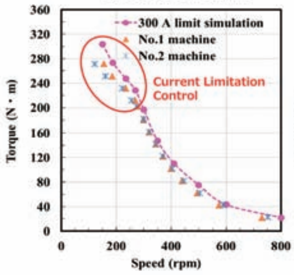
ECEI ENEGY CONVERSION SYSTEM LABORATORY 7

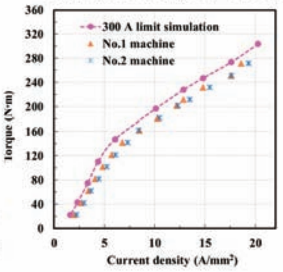
TEST BENCH



ECEI ENEGY CONVERSION SYSTEM LABORATORY 8

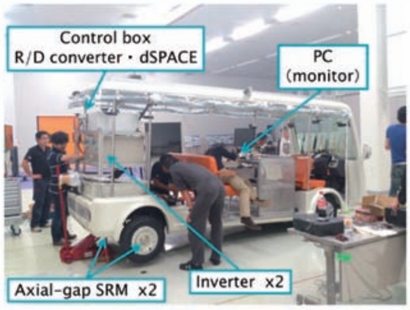
TEST RESULTS





ECEI ENEGY CONVERSION SYSTEM LABORATORY 9

VIEW OF VEHICLE WITH AXIAL-GAP SRM



ECEI ENEGY CONVERSION SYSTEM LABORATORY 10

CONCLUSIONS

AXIAL GAP SRM achieved HIGH TORQUE DENSITY.

➡ 39N・m/L(Measured) is comparable to Rare-Earth Magnet Motor.

Developing In-Wheel Direct-Drive EV with AXIAL GAP SRM and optimal drive system.

➡ Compact, Reliable, High Efficiency, Small Ripple

ACOUSTIC NOISE must be IMPROVED.

➡ Considering about Control Method and Mechanical Construction.

ECEI ENEGY CONVERSION SYSTEM LABORATORY 11

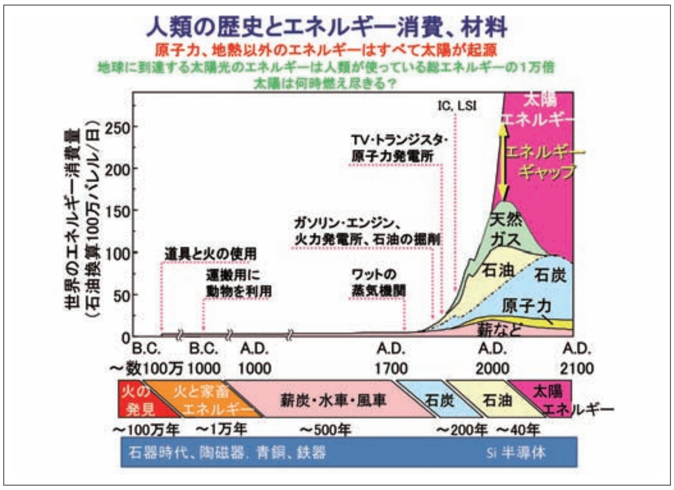
Thank you!

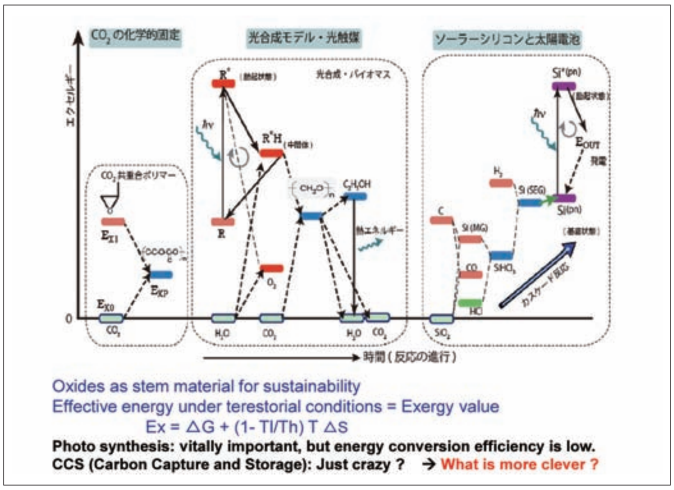
ECEI ENEGY CONVERSION SYSTEM LABORATORY 12

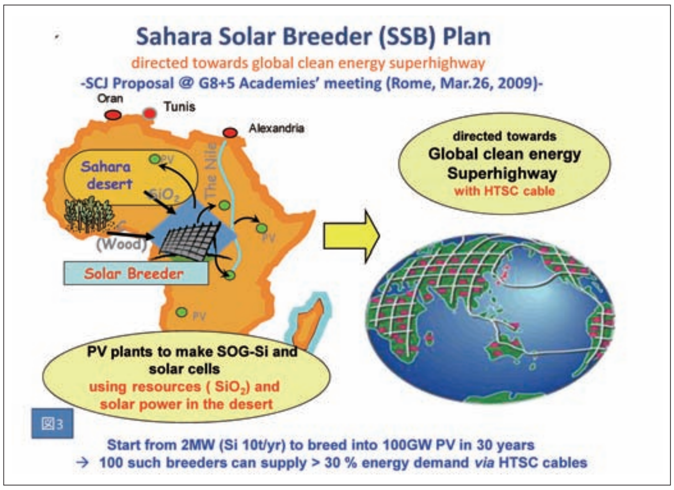
A new concept car for sustainable development and health

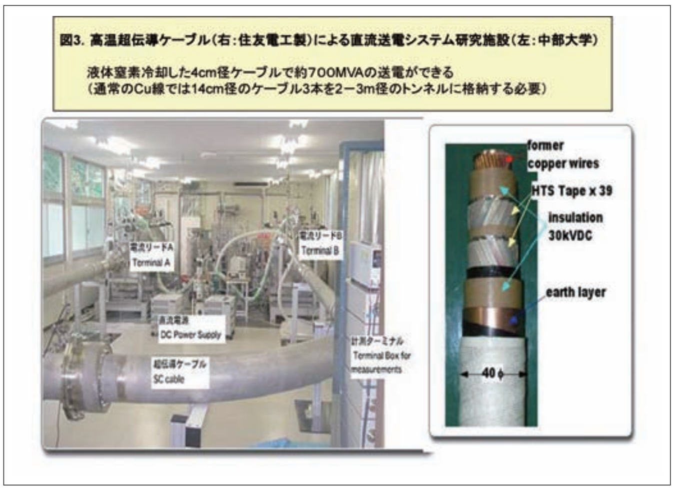
Hideomi Koinuma

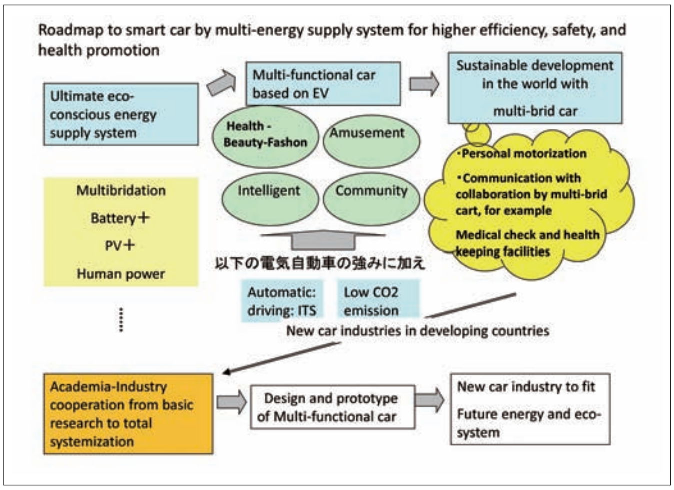
Visiting Professor, Tokyo University, Japan











○ Question:

-Can car keep a main player in future society, judging from life (health) , energy, environment and business ?

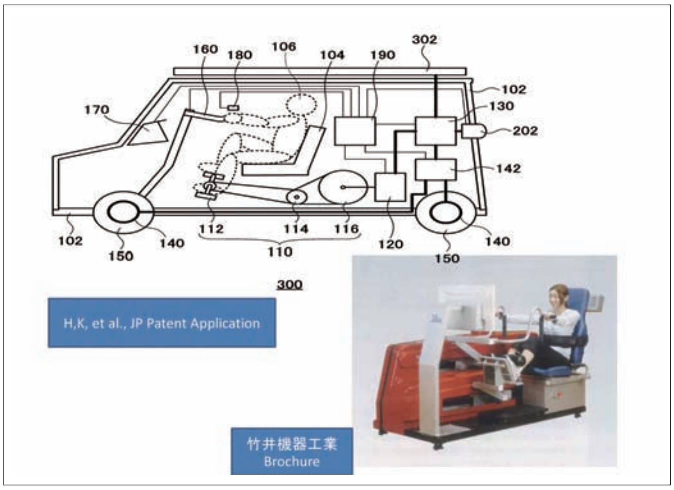
○ Basic concept

- What is a transporter superior to Hybrid, EV, and PHV cars ?
- How can we save money and time to compensate weight gain and muscle loss caused by constantly relying on car for trasportation ?
- Assist warming up from inside the body instead of energy consuming electric heater to overcome a serious weak point of EV in cold areas
- Heat is a lower grade energy, since it inevitably accompanies loss in conversion.

→ Multi-brid car assisted with man power

○ Design concept of car innovation

- Renewable energy
- Implementation of health care units with sensing devices and athletic functions that can work also at emergency
- Drive with hands only and let feet free for physical training: Add athletic room function to driving car.



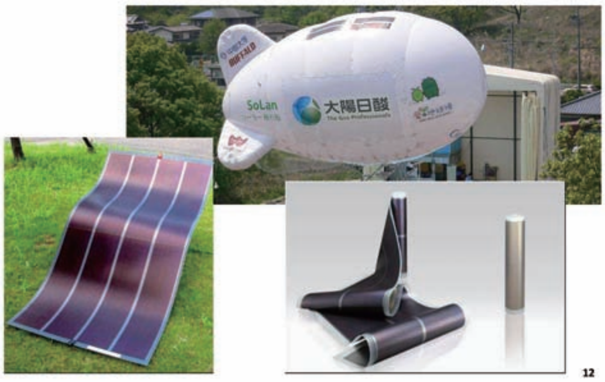
Multi-brid car (MBC)

** *New concept car equipped with health care and athletic gym function.***

Why ? EV has a serious weak point for deployment in cold local areas, if the air-conditioning, especially heating, is driven by the battery.
What is MBC ? Man power is not so big (100~600 W), but it can help not only battery charging but also warm up his body from inside.
How, who, where, and when ? Install bicycle-type electric power generator at driver's and passengers' seats. People can work and relax as they like under monitoring their health care sensors.
Thus, automobile can be an athletic room, in addition to transportation tool.

Fig. 1 Bicycle type human power electric generator : 200 ~600 W Prof. Hatta @ Kochi Inst. Tech

フレキシブル太陽電池モジュール



12

OVERVIEW OF RESEARCH ACTIVITIES

Shai Cohen

Research Assistant Professor, Center for Collision Safety and Analysis College of Science

George Mason University, USA

GEORGE MASON UNIVERSITY

OVERVIEW OF RESEARCH ACTIVITIES

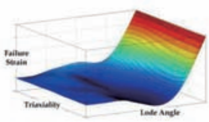
Center for Collision Safety and Analysis CCSA

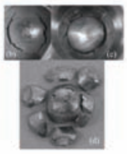
Introduction

Material Study (Metals & Composites)

- Development of Numerical Material Models
  - ⇨ Metals & Composites
    - Aluminum, Titanium, Inconel, Carbon-Fiber Reinforced Polymer (CFRP)
  - ⇨ Physical material test
    - New test condition
    - New specimen design

  - ⇨ New failure criteria
    - Stress-state
    - Rate dependent
    - Temperature dependent

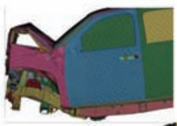




  - ⇨ New constitutive model
    - LS-DYNA materials: MAT224, MAT224_GYS, MAT224_Anisotropy

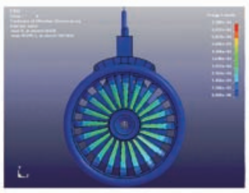
Composite Crashworthiness

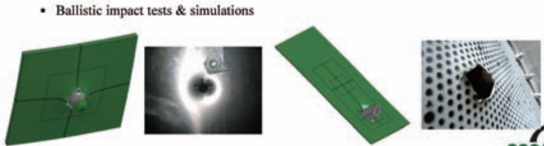
- Composites
  - ⇨ High SEA (Specific Energy Absorption) Material: Light-weight & high strength
  - ⇨ Application Barrier: Different material characterization from ferrous materials
- Automotive applications
  - ⇨ Mass Reduction to improve fuel efficiency
  - ⇨ Requirement: Keeping Compartment Integrity
  - ⇨ Demonstration of 32% weight reduction of ladder frame structure
    - 2007 Chevrolet Silverado pickup truck
    - Triaxial braided carbon-fiber thermoset composite



Failure Analysis

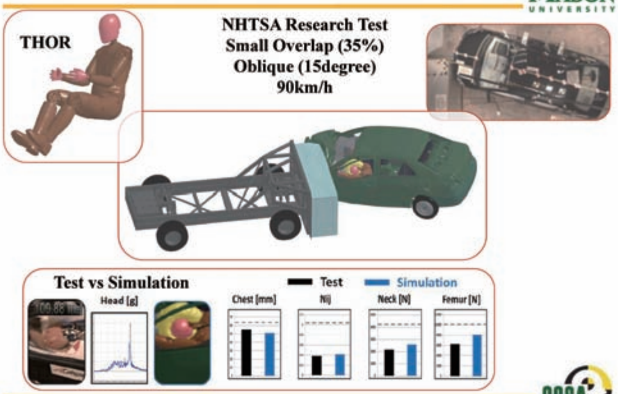
- Aircraft Safety
  - ⇨ Uncontained turbine engine failure
  - ⇨ Focus: Preventing Catastrophic Failure of Fuselage
- Failure Prediction
  - ⇨ Turbine engine failure simulation
  - ⇨ Prediction of ballistic impact speed to fuselage
    - Develop advanced plasticity material model
    - Ballistic impact tests & simulations





Rollover Simulation with THUMS

Oblique Frontal Impact with THOR



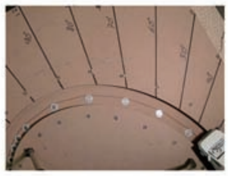
Animations

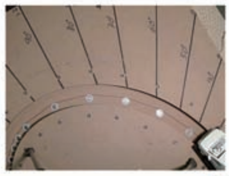
Testing Methodology Development

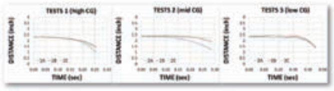
- Improve vehicle crash testing Methodology
- Create as near to Realistic test conditions as possible
- Advance the State of the Art
- Enhance the understanding of occupant injuries and mitigation methods
- Employ a combination of proven methods

Guided Rollover Test Device

- Longitudinal Accumulation of speed – occupants remain seated
- Vehicle performance driven initial conditions
- Excellent response to vehicle CG changes
- Highly repeatable testing results
- Enhance the understanding of occupant injuries and rollover mitigation methods







Suspension System Challenges

- The choice between solid-axle and independent suspension has never been easy; both provide great benefits however both also demonstrate limitations
- By incorporating one of each axle type into a single vehicle, manufacturers have only been able to achieve average dynamic performance characteristics
- Efforts to modernize suspension performance have concentrated on the electronic systems – addressing the symptoms, but not the fundamental mechanical limitation
- Current suspension design has not significantly reduced the number of rollovers resulting in fatalities

Independent Suspension

BENEFITS

- Low unsprung weight
- Traces flat or corrugated surfaces very efficiently even at high velocities
- Stable during high lateral accelerations

LIMITATIONS

- Only one degree of freedom per wheel
- Lower Ramp Travel Index results translate to lower off-road articulation capabilities
- Electronic systems compensate for low articulation and manage to stop floating wheels from spinning but do not put them on the ground – higher rollover propensity

Solid-Axle Suspension

BENEFITS

- Two degrees of freedom per wheel
- High Ramp Travel Index - higher articulation
- Performs well in low speed heavy applications and highly difficult off-road terrain (bolder and rock crawling)

LIMITATIONS

- High unsprung weight penalty
- Less stable in high speed corrugated surfaces resulting in hopping
- Excitations are transferred from one wheel to the other

Addressing the Design Challenge

WHAT IF WE…

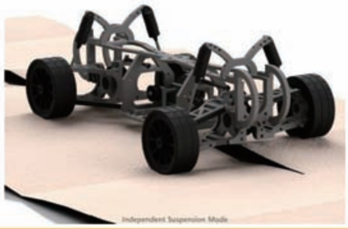
- Redefine the mechanical design of suspension systems to reduce an electronic compensation need
- Close the gap between solid and independent suspensions
- Enjoy the benefits of both suspension types and overcome their fundamental mechanical design limitations

The Dual-Suspension System

The Dual-suspension approach provides both solid-axle suspension and independent suspension. This gives automobiles the advantages of both systems and allows switching between them at will (U.S patent 8,480,106).

Independent-Suspension Mode

The center of the suspension is locked to the chassis, while the arms are free to move independently of each other, as shown below.



Solid-Axle Suspension Mode

The center of the suspension is unlocked from the chassis, while the arms are locked as one solid-axle, as shown below.

Testing

- Testing (1:10 scale) proved each mode maintains its advantages over the other
- Reliability is consistent with single-mode suspension

Realizing new automobile system and related products based on university studies

Katsuto Nakatsuka

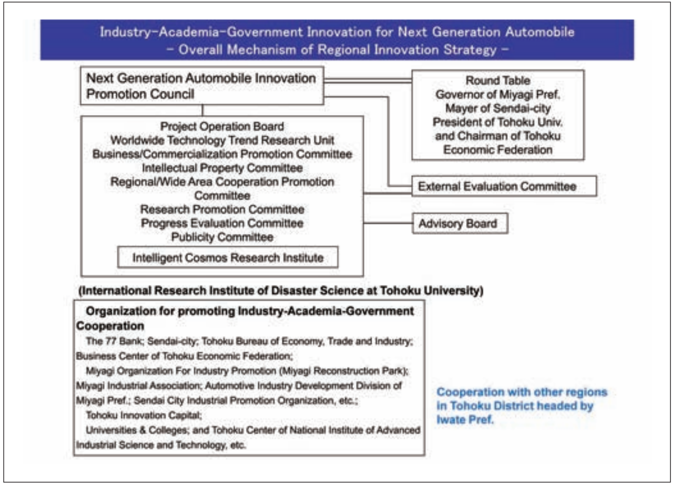
Project Director, Intelligent Cosmos Research Institute, Japan

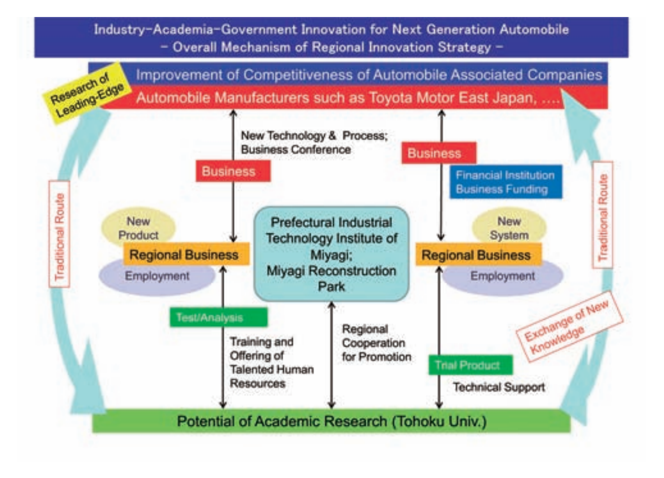
Regional Innovation Strategy Support Program Initiated by MEXT
Next Generation Automobiles ／Miyagi Area

Realizing new automobile system and related products based on university studies

Katsuto Nakatsuka*,Akira Miyamoto**, and Fumihiko Hasegawa**

*Intelligent Cosmos Research Institute(ICR)
Miyagi Reconstruction Park(within Sony Sendai Tec.)
3-4-1, Sakuragi,Tagajyo-shi, Miyagi, 985-8589 Japan
**New Industry Hatchery Center, Tohoku University
6-6-10, Aoba, Aramaki aoba-ku,Sendai 980-8579 Japan



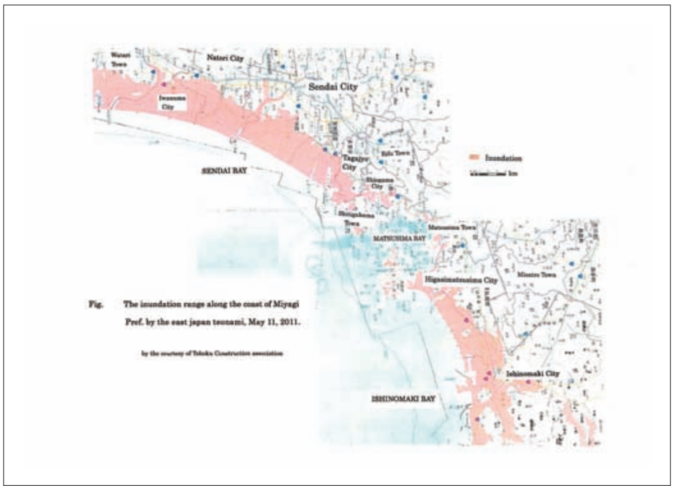


Next generation automobile

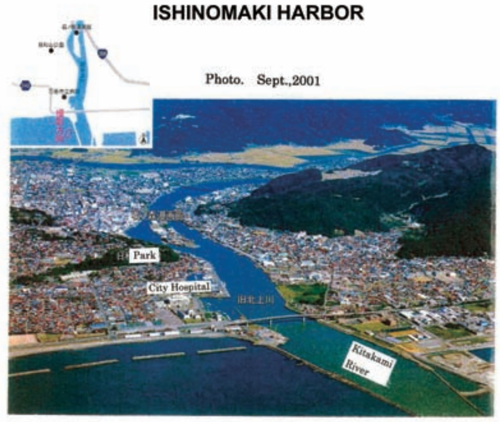
Automobile is a complex integration of machineries and equipment, basically 10 functions provided. Those are: generator, transmission, drive units, direction convertor, braking, wheeling, body structure, windows, meters and lamp light. Every equipment has been state-of-art product in its era, and improvement of them is still continuing..

On the other hand, the change of global subject in human society has recently actualized. Those are:

1. Population. The world population is rapidly increasing in growing country, and developed country is facing aging society. Japan is already「ultra-aging society」, where the number over 65 year old exceed 21% of national population. The number of automobile driver is decreasing in Japan.
2. Energy resources. Supply-demand balance for oil seems tilting toward the oil shortage. Is there a need that the present automobile divides its role to electric car , if possible ?
3. Appearance of aging society. Japan already belongs to "ultra-aging society". In order to alleviate the stagnation by aged people, the use of personal electric car which makes aged people be possible to move free will be useful . They will join to some social activities they hope, and this will be effective, because their long experience and knowledge is still important.



ISHINOMAKI HARBOR



ISHINOMAKI HARBOR

Photo. March 29, 2012

YURIAGE PORT

Record of Tsunami by earthquake in north-east Japan along Pacific Ocean (Magnitude ＞8.0)

Date	Name of Tsunami	Energy (Magnitude)	Interval (Years)
July. 13,869(AC)	Jyogan	M8.3	
Dec. 2 , 1611	Keichou –Sanriku	M8.1	742
Feb. 17, 1793	Miyagi offing	M8.0～8.4	182
June. 15, 1896	Meiji-Sanriku	M8.25	103
March. 3, 1933	Sanriku	M8.1	37
March. 11, 2011	East Japan	M9.0	78

BIG EARTHQUAKE (INDUCED TSUNAMI) in TOHOKU AREA, JAPAN

Basic principle of restoration from tsunami damage suggested by Prefectural governor

1. The industries which must inevitably operate seaside are rebuilt at the former place.
2. General residence, Areal commercial facilities, Educational facilities for children, Hospital, Resort facilities for aged people should be arranged on the hill or hillside.
3. For corresponding to the unpredictable tsunami, the system to escape from seaside to the hill or hillside should be designed.
4. The concrete measures and methods are decided by municipalities.

Electric car for personal mobility

Feature
- Small size ,
- Light weight(less than 300Kg)
- Simple operation control
- Small driving cost(less than 1／3 of gasoline)

Weakness
- Limited continuous distance(~50 km)
- Long charging time(being improved)

Significance in application

○Supplementary function for helping public transport, such as bus, subway, and trains.(Efficiency improvement of social infrastructure)

○New system to reinforce the reconstruction at tsunami affected areas. Offer of new transportation to support the industry activities at seaboard.

○Ensuring elderly activities and health by offering new personal mobility.

The impact of this project

Applicable to many cases at worldwide regions, especially for alleviating stagnation by aging in coming extremely- aging society.

Industry-Academia Collaboration

Toshio Kato

Regional Cooperation Coodinator, Intelligent Cosmos Research Institute, Japan

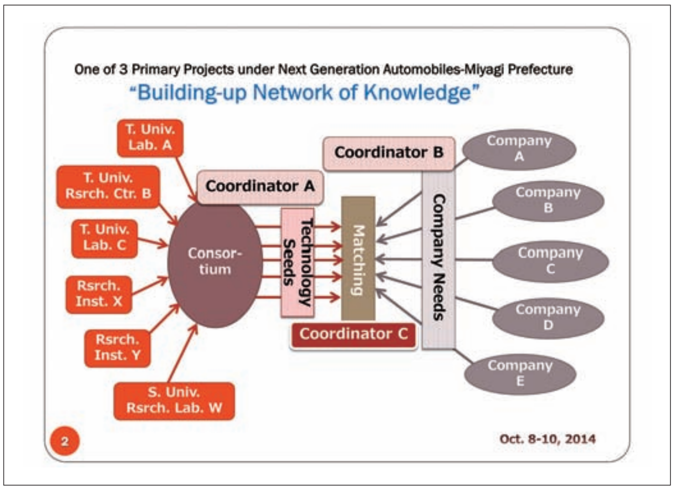
"Global/Local Innovations for Next Generation Automobiles"
General Lecture

Industry-Academia Collaboration

Toshio Kato

Regional Cooperation Coordinator
Next Generation Automobiles-Miyagi Prefecture

Intelligent Cosmos Research Institute
t-kato@icr-eq.co.jp



Things preventing effective collaborations between Regional Companies and Univ. Labs.

For "Local Innovation," collaborations between Regional Companies and Univ. Labs. are of essence.

In Miyagi pref.,

T.U. is one of Japan's most leading Univs.

- Highly advanced, leading-edge "science & technology"

↕

Many of Regional Companies are small-mid sized.

- Facing with day-to-day technological problems
- Need easy-to-practice, feasible techniques

Big gap between them

3 Oct. 8-10, 2014

Things preventing effective collaborations between Regional Companies and Univ. Labs.

Lack of communication

- Regional Companies do not know how to communicate with Univ. Labs.
- Regional Companies are wondering if Univ. Labs. have technologies that will help them.
- Because of their scientific level, Regional Companies are hesitant about knocking on Univ. Lab.'s doors.

Profs. are too busy.

- Univ. Lab.'s doors are always open but….
- Profs. are ready to welcome Regional Companies' visits but….
- Profs. are prepared to help Regional Companies but….

4 Oct. 8-10, 2014

For better collaboration for Local Innovation

Thus,

- Regional Companies do not need to hesitate to knock on Univ. Lab.'s doors.
- Because Profs. are busy, Regional Companies should think of sending their employees to Univ. Labs. to develop necessary technology with help of Profs.

Further,

- Regional Companies should appeal their unique technology to Univ. Labs.
- Jointly find-out areas for possible collaborative works

5 Oct. 8-10, 2014

Present Outcome of Regional Cooperation Coordination

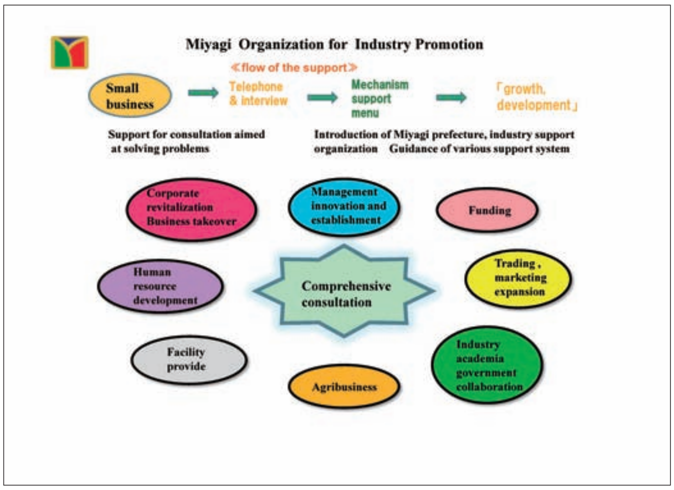
- Reduction drive system having magnetic planetary-gear mechanism
- Electro-magnetic brake
- Electro-magnetic clutch
- All solid Li-battery
- Hot-chamber die-casting machine
- Fine processing of die and mold
- Tools for CFRP processing
- Burr-less processing

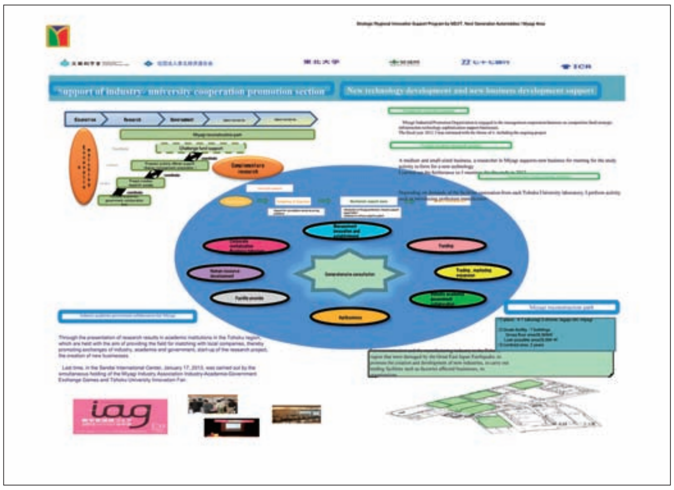
etc.

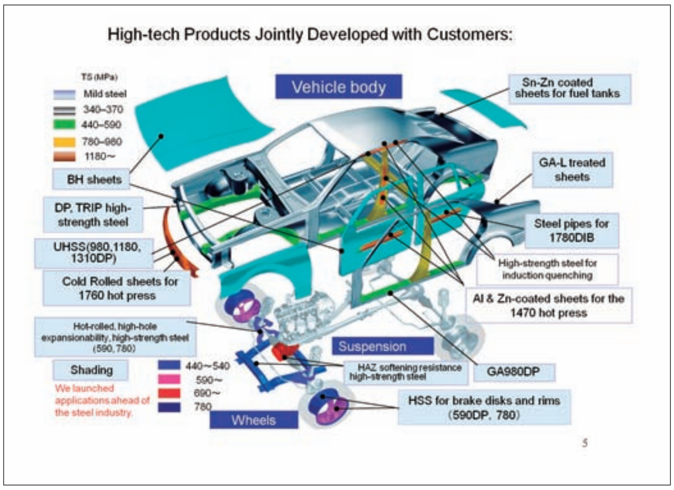
6 Oct. 8-10, 2014

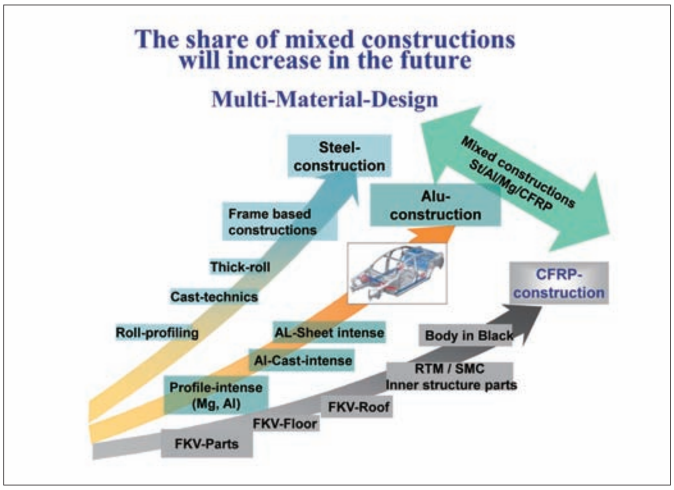
Materials for the Next Generation Automobile

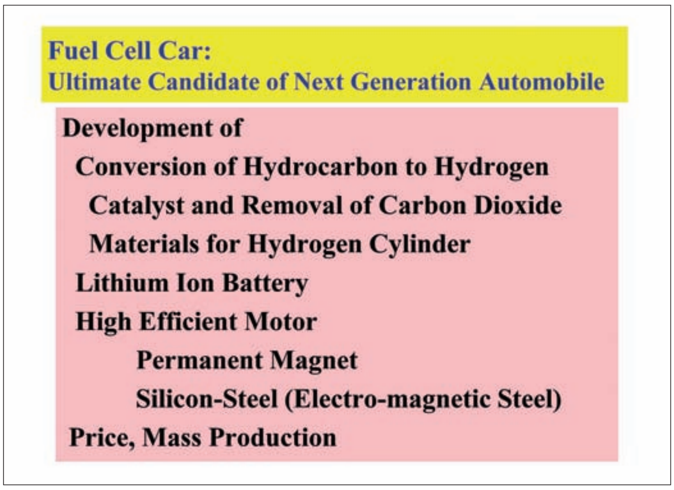
Yasutaka IGUCHI
Chairman, Board at Miyagi Organization for Industry Promotion, Japan

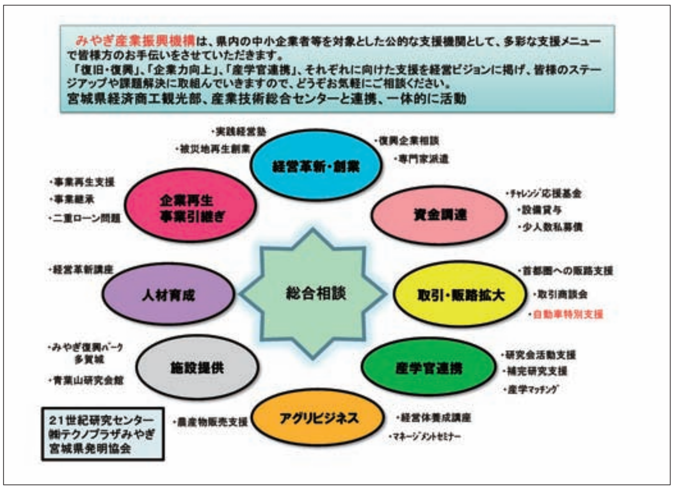








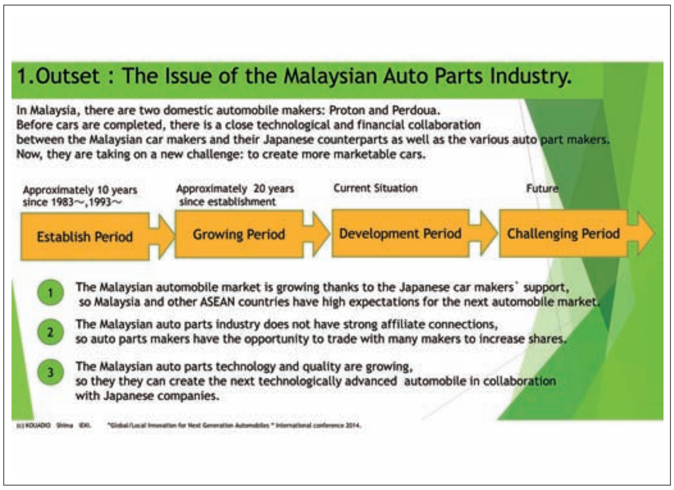

Fuel Cell Car:
Ultimate Candidate of Next Generation Automobile
Development of
Conversion of Hydrocarbon to Hydrogen
Catalyst and Removal of Carbon Dioxide
Materials for Hydrogen Cylinder
Lithium Ion Battery
High Efficient Motor
Permanent Magnet
Silicon-Steel (Electro-magnetic Steel)
Price, Mass Production

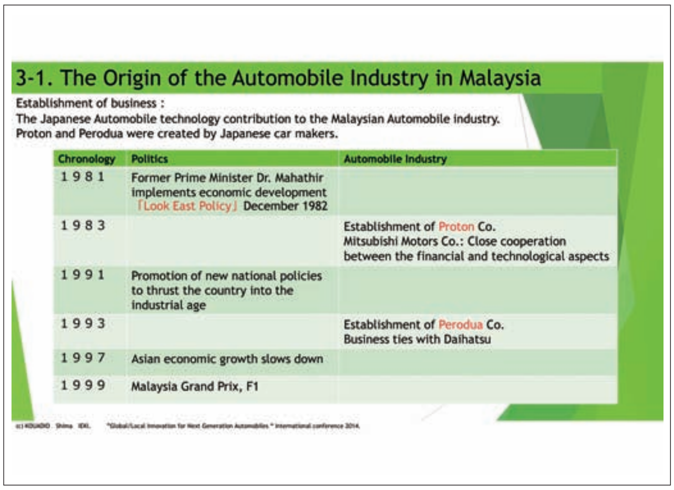

みやぎ産業振興機構は、県内の中小企業者等を対象とした公的な支援機関として、多彩な支援メニューで皆様方のお手伝いをさせていただきます。
「復旧・復興」、「企業力向上」、「産学官連携」、それぞれに向けた支援を経営ビジョンに掲げ、皆様のステージアップや課題解決に取組んでいきますので、どうぞお気軽にご相談ください。
宮城県経済商工観光部、産業技術総合センターと連携、一体的に活動
総合相談
経営革新・創業
・実践経営塾
・被災地再生創業
・復興企業相談
・専門家派遣
企業再生
事業引継ぎ
・事業再生支援
・事業継承
・二重ローン問題
資金調達
・ﾁｬﾚﾝｼﾞ応援基金
・設備貸与
・少人数私募債
人材育成
・経営革新講座
取引・販路拡大
・首都圏への販路支援
・取引商談会
・自動車特別支援
施設提供
・みやぎ復興ﾊﾟｰｸ
多賀城
・青葉山研究会館
産学官連携
・研究会活動支援
・補完研究支援
・産学ﾏｯﾁﾝｸﾞ
アグリビジネス
・農産物販売支援
・経営体養成講座
・ﾏﾈｰｼﾞﾒﾝﾄｾﾐﾅｰ
21世紀研究センター
㈱テクノプラザみやぎ
宮城県発明協会

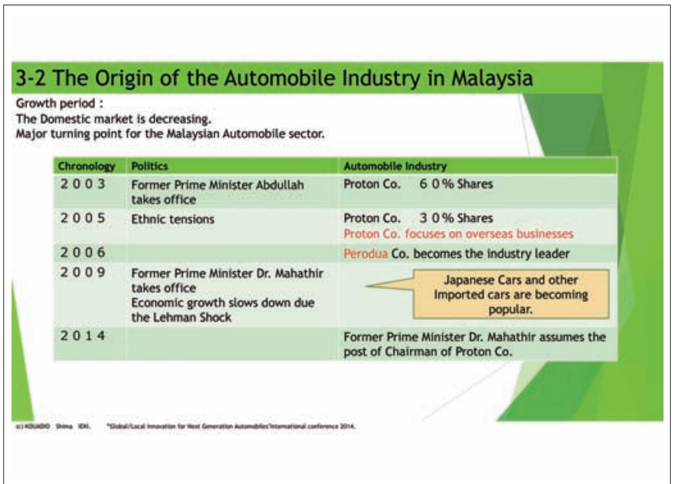
Case Study Oversea Business Automobile Sector (case of Malaysia)

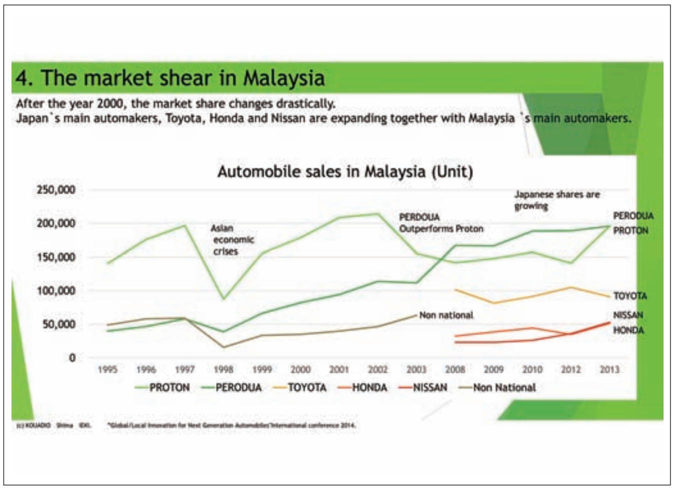
KOUADIO Shima IEKI

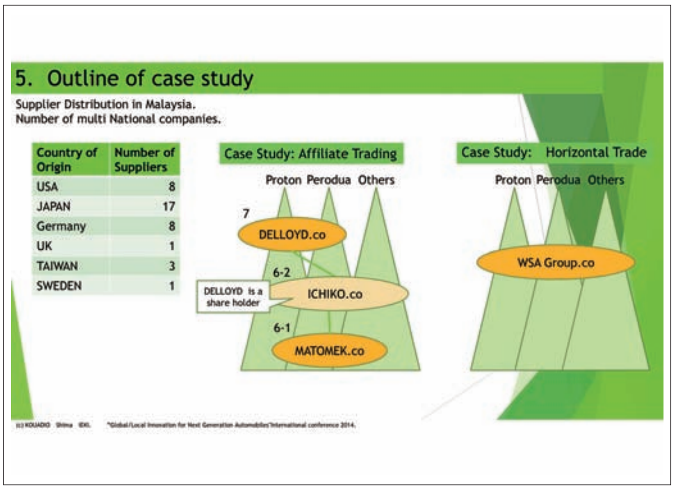
President, Kidskingdom International Inc., Japan





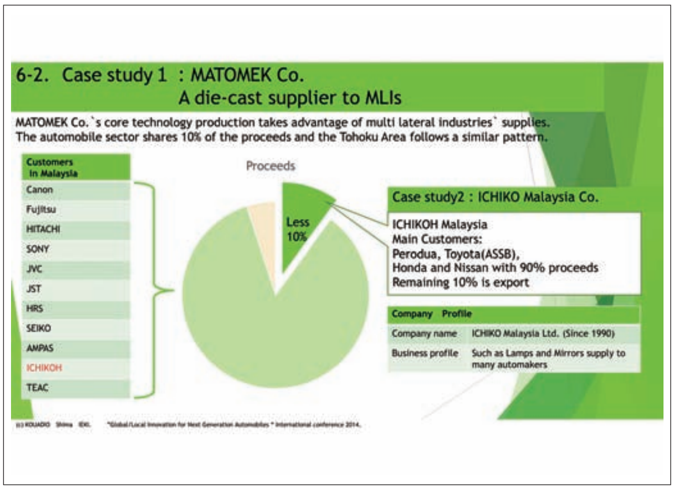




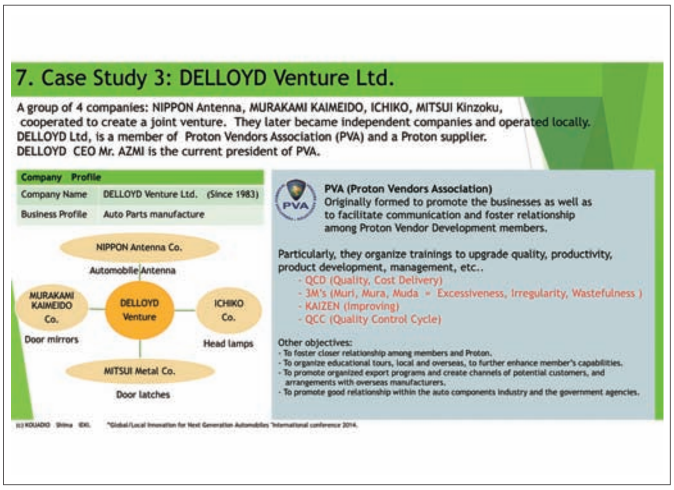


5. Outline of case study
Supplier Distribution in Malaysia.
Number of multi National companies.
Country of Origin | Number of Suppliers
USA 8
JAPAN 17
Germany 8
UK 1
TAIWAN 3
SWEDEN 1
Case Study: Affiliate Trading
Proton Perodua Others
7
DELLOYD.co
6-2
DELLOYD is a share holder
ICHIKO.co
6-1
MATOMEK.co
Case Study: Horizontal Trade
Proton Perodua Others
WSA Group.co

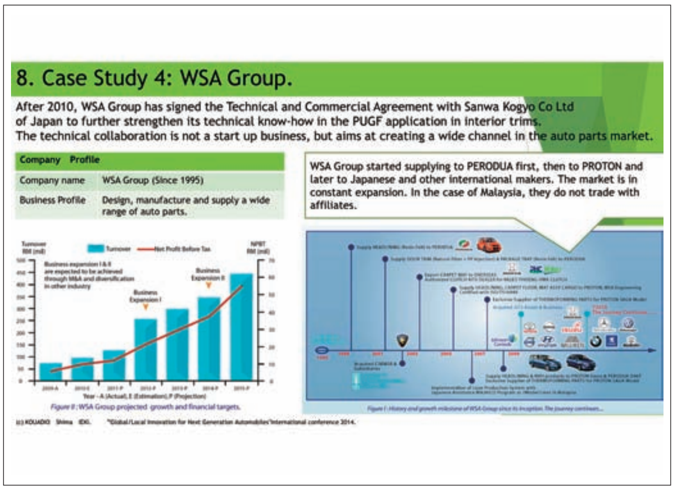
6-1. Case Study 1 : MATOMEK co.
An overseas business dealing with MLIs
MATMEK Co. is a small-scale precision metal mold maker. It supplies to various industries, has attained a high level of QCD, and the company receives many requests from Japanese corporations in Malaysia.
Company Profile
Company name MATOMEK PRECISION DIE SDN BHD
Region MALAYSIA
Date of Incorporation March 1991
Parent Company MATSUSHITA SEISAKUSHO Co. SAITAMA, Japan Since April, 1945
Quality:
All parts are inspected by hand
Detailed work



6-2. Case study 1 : MATOMEK Co.
A die-cast supplier to MLIs
MATOMEK Co.`s core technology production takes advantage of multi lateral industries` supplies.
The automobile sector shares 10% of the proceeds and the Tohoku Area follows a similar pattern.
Customers in Malaysia
Canon
Fujitsu
HITACHI
SONY
JVC
JST
HRS
SEIKO
AMPAS
ICHIKOH
TEAC
Proceeds
Less 10%
Case study2 : ICHIKO Malaysia Co.
ICHIKOH Malaysia
Main Customers:
Perodua, Toyota(ASSB),
Honda and Nissan with 90% proceeds
Remaining 10% is export
Company Profile
Company name ICHIKO Malaysia Ltd. (Since 1990)
Business profile Such as Lamps and Mirrors supply to many automakers



7. Case Study 3: DELLOYD Venture Ltd.
A group of 4 companies: NIPPON Antenna, MURAKAMI KAIMEIDO, ICHIKO, MITSUI Kinzoku, cooperated to create a joint venture. They later became independent companies and operated locally.
DELLOYD Ltd, is a member of Proton Vendors Association (PVA) and a Proton supplier.
DELLOYD CEO Mr. AZMI is the current president of PVA.
Company Profile
Company Name DELLOYD Venture Ltd. (Since 1983)
Business Profile Auto Parts manufacture
NIPPON Antenna Co.
Automobile Antenna
MURAKAMI KAIMEIDO Co.
Door mirrors
DELLOYD Venture
ICHIKO Co.
Head lamps
MITSUI Metal Co.
Door latches
PVA
PVA (Proton Vendors Association)
Originally formed to promote the businesses as well as to facilitate communication and foster relationship among Proton Vendor Development members.
Particularly, they organize trainings to upgrade quality, productivity, product development, management, etc..
- QCD (Quality, Cost Delivery)
- 3M's (Muri, Mura, Muda = Excessiveness, Irregularity, Wastefulness)
- KAIZEN (Improving)
- QCC (Quality Control Cycle)
Other objectives:
- To foster closer relationship among members and Proton.
- To organize educational tours, local and overseas, to further enhance member's capabilities.
- To promote organized export programs and create channels of potential customers, and arrangements with overseas manufacturers.
- To promote good relationship within the auto components industry and the government agencies.



8. Case Study 4: WSA Group.
After 2010, WSA Group has signed the Technical and Commercial Agreement with Sanwa Kogyo Co Ltd of Japan to further strengthen its technical know-how in the PUGF application in interior trims.
The technical collaboration is not a start up business, but aims at creating a wide channel in the auto parts market.
Company Profile
Company name WSA Group (Since 1995)
Business Profile Design, manufacture and supply a wide range of auto parts.
WSA Group started supplying to PERODUA first, then to PROTON and later to Japanese and other international makers. The market is in constant expansion. In the case of Malaysia, they do not trade with affiliates.
Turnover
Net Profit Before Tax
Business Expansion I
Business Expansion II

Heartfelt thanks to:
Mr. HAYASHI Kunihiko , Former DELLOYD Venture Co.
Mr. MATSUSHITA Kouichi , President MATOMEK Co.
Prof. OTAKI Seiichi , TOHOKU University Graduate School of Management and Economics
Reference:
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- The Development of the Automobile Industry and the Road Ahead. (Mohd. Uzir Mahidin and R. Kanageswary). 2004 Department of Statistic Malaysia.
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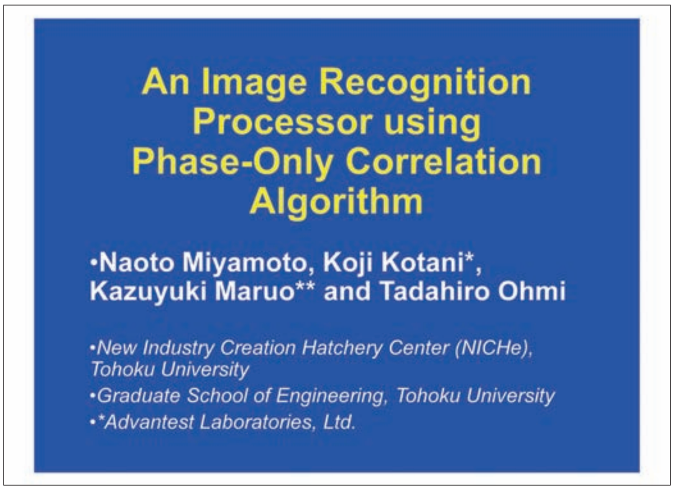
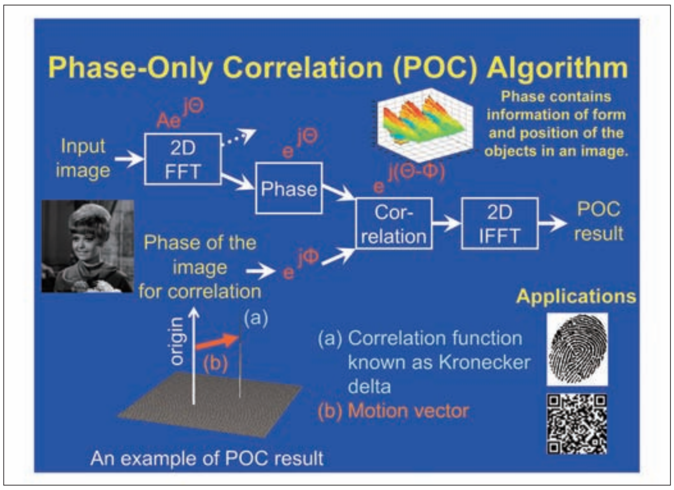
- http://www.proton.com/
- http://www.perodua.com.my/
- http://www.matomek.com/
- http://www.delloyd.com/
- http://www.ichikoh.com/
- http://www.wsacim.com/
- http://www.protonvendors.com/
- http://tsclub.com.my/about.asp
The PVA vendors attend the Proton Inspire match-making initiatives 2013 .
MATMEK Co. Interview on 8th August 2014. Mr. MATSUSHITA and KOUADIO.

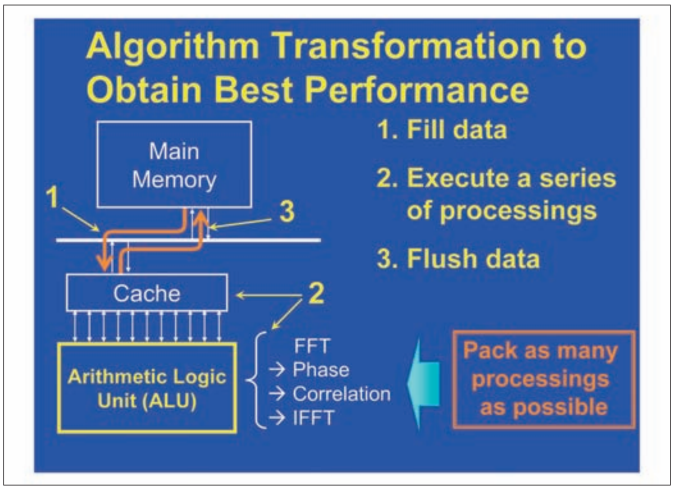
An Image Recognition Processor using Phase-Only Correlation Algorithm

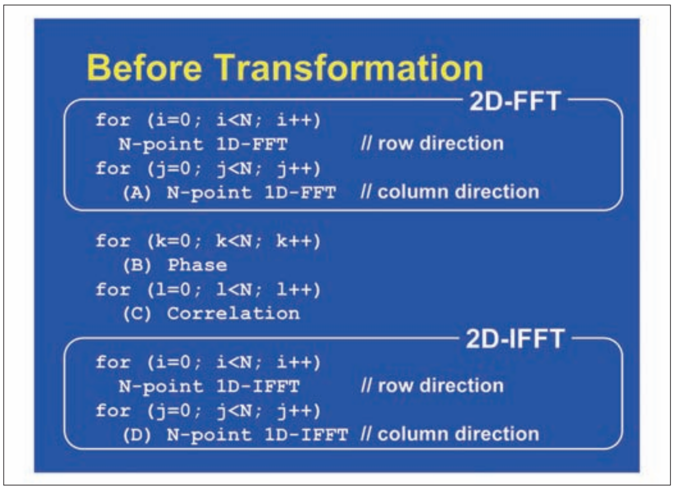
Naoto Miyamoto

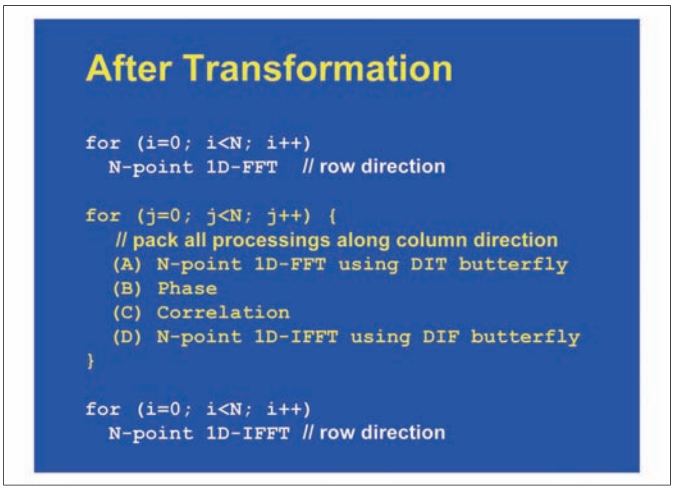
Associate Professor, New Industry Creation Hatchery Center, Tohoku University, Japan

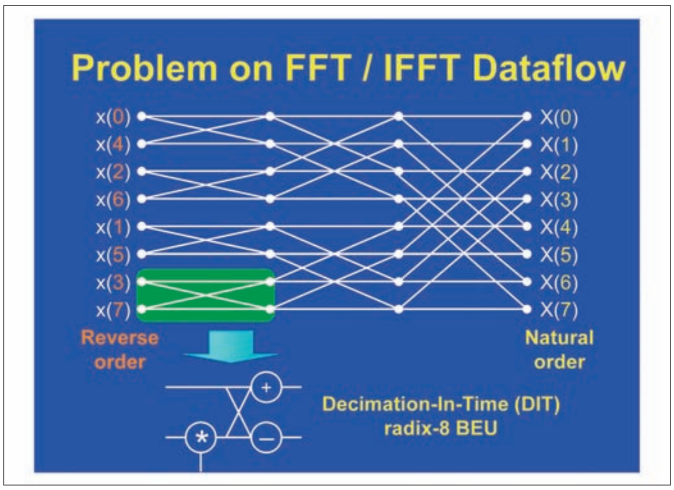


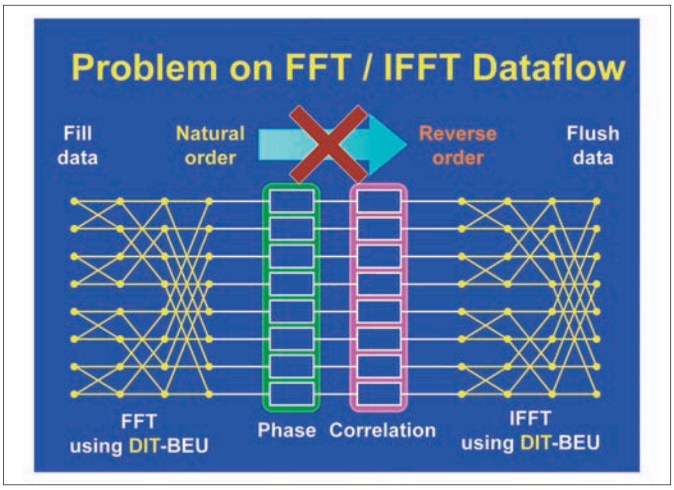


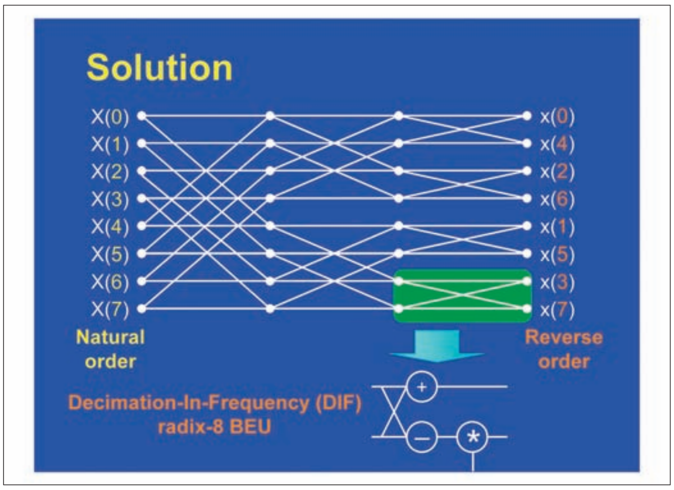


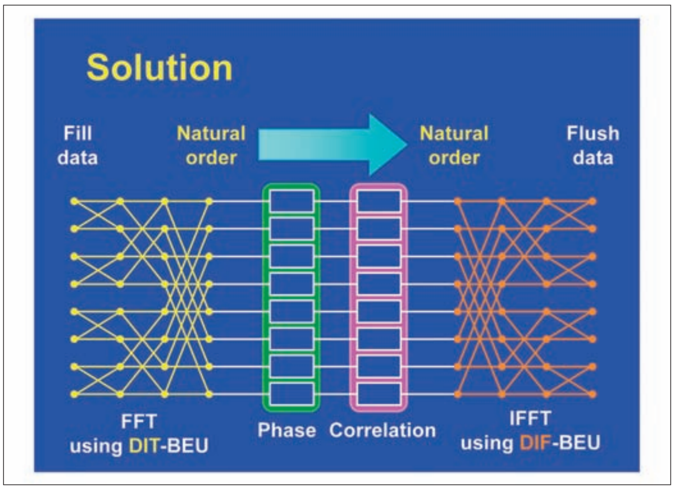


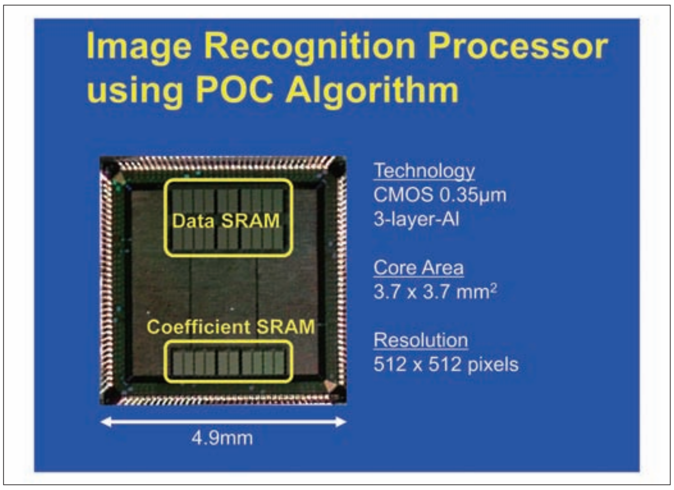












Chip Evaluation

	Proposed	Cinderella II*
Technology	0.35µm	0.35µm
Number of Transistors	Logic 400k SRAM 360k Total 760k	2000k
Clock Frequency	80MHz	100MHz
Power Consumption	310.9mW	3.5W
512x512 POC Execution Time	105.2msec	122.2msec (estimated)

*M. Morikawa, et al., "An image processor implementing algorithms using chara-cteristics of phase spectrum of two-dimensional Fourier transform," ISIE '99

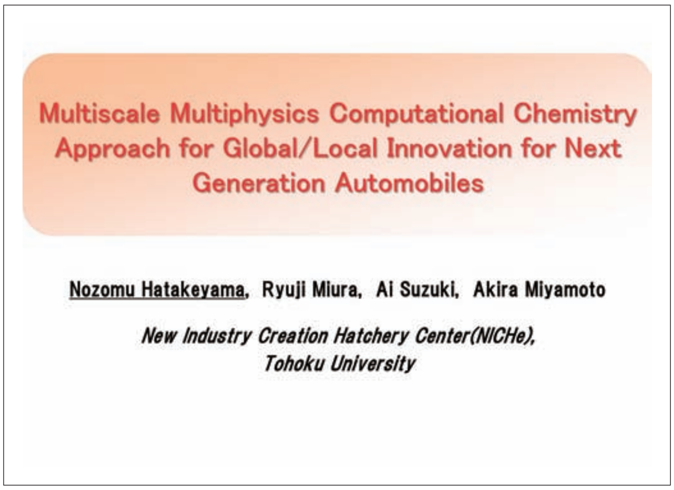
Conclusion

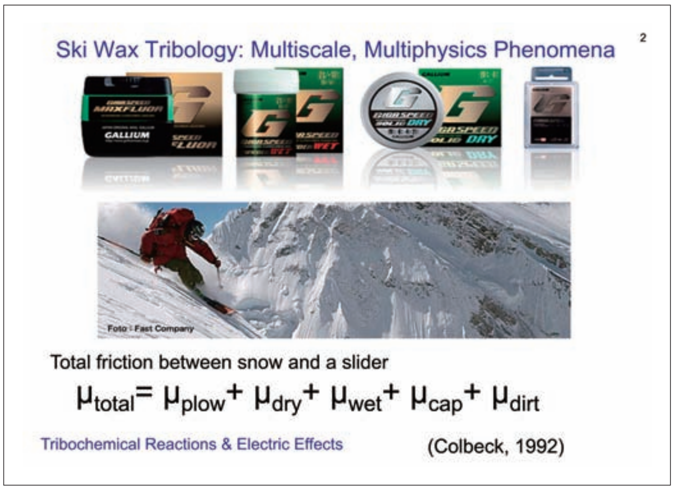
- An image recognition processor was proposed, which can execute 512x512 pixels POC in 105.2msec at 310.9mW in 3.7x3.7mm²
- The original POC algorithm was transformed to obtain the best performance, where all processings from 1D-FFT to 1D-IFFT are packed together so that the number of main memory access is minimized.
- By using the algorithm transformation, power consumption of the processor was reduced to 1/10 as compared to the conventional one.

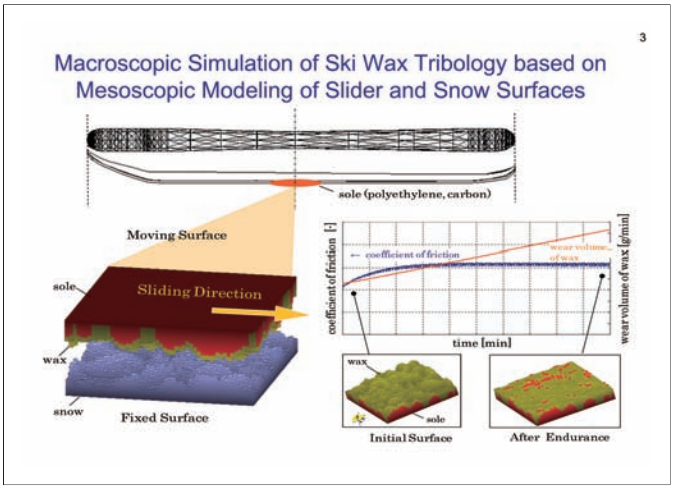
Multiscale Multiphysics Computational Chemistry Approach for Global/Local Innovation for Next Generation Automobiles

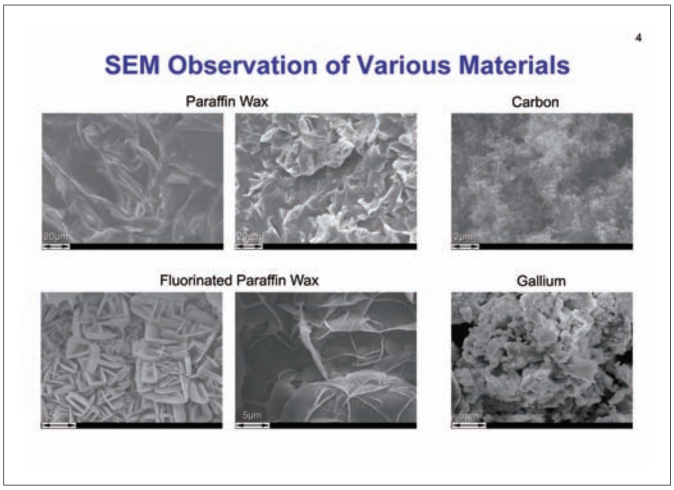
Nozomu Hatakeyama

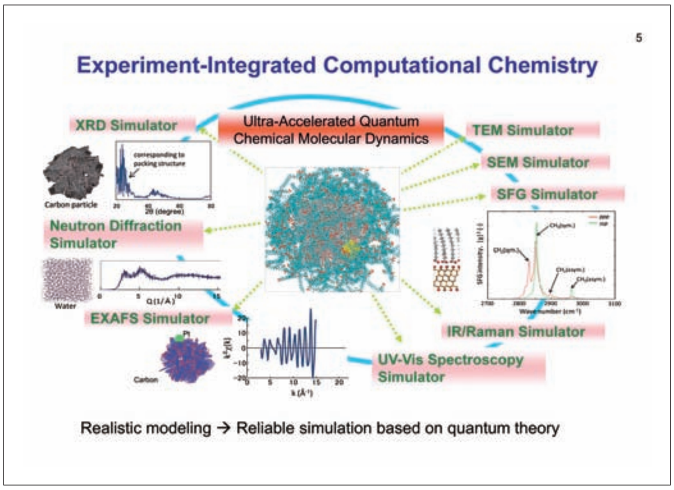
Associate Professor, New Industry Creation Hatchery Center, Tohoku University, Japan

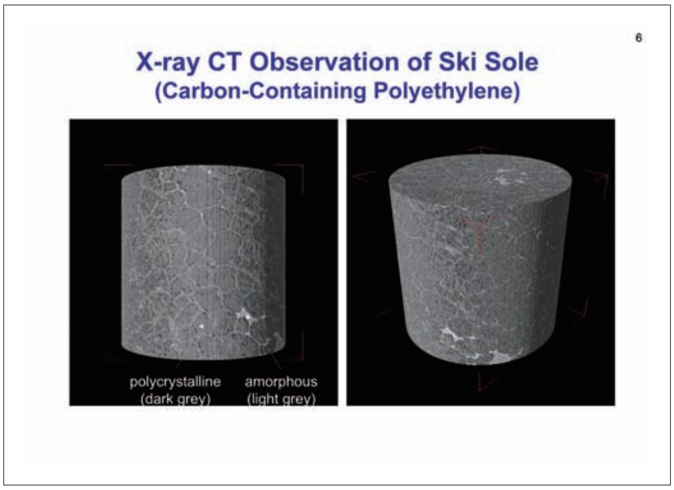


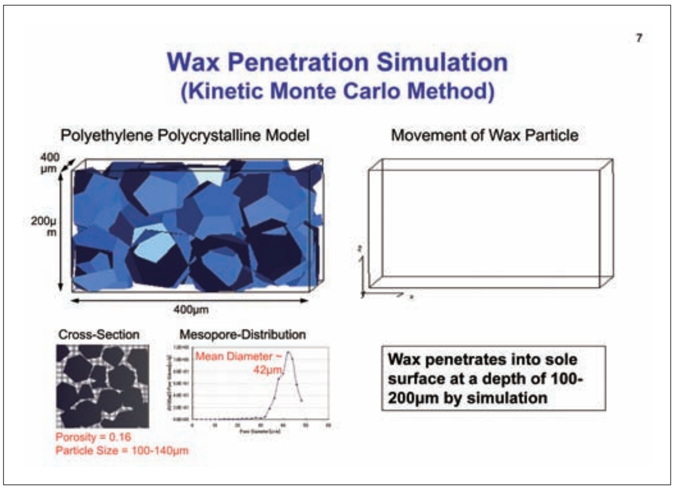


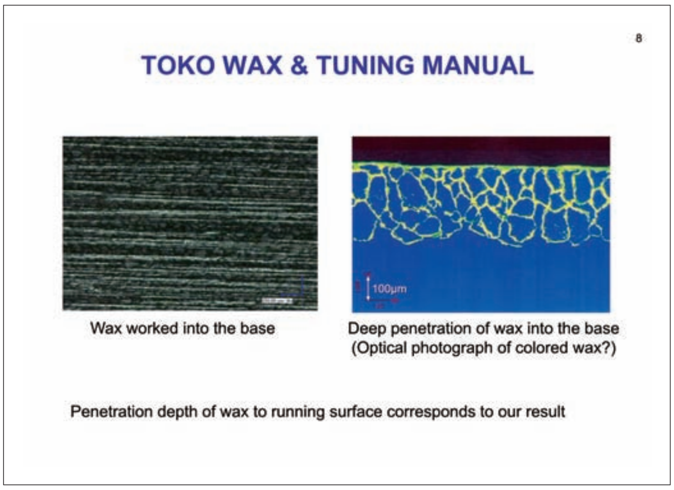









7
Wax Penetration Simulation
(Kinetic Monte Carlo Method)
Polyethylene Polycrystalline Model
Movement of Wax Particle
400 μm
200μm
400μm
Cross-Section
Mesopore-Distribution
Mean Diameter ~ 42μm
Porosity = 0.16
Particle Size = 100-140μm
Wax penetrates into sole surface at a depth of 100-200μm by simulation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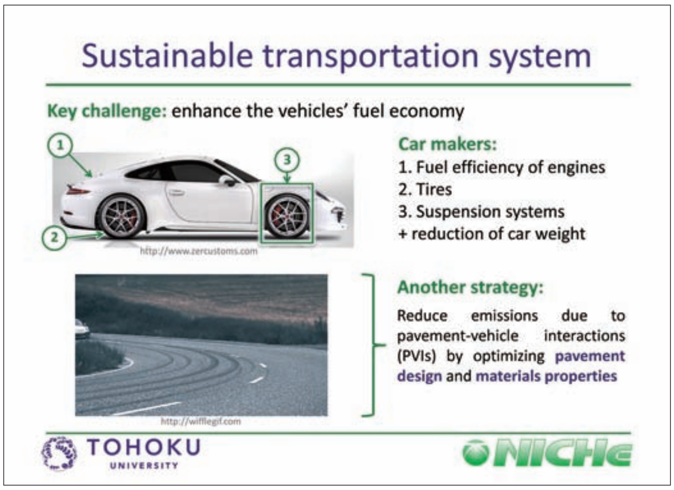
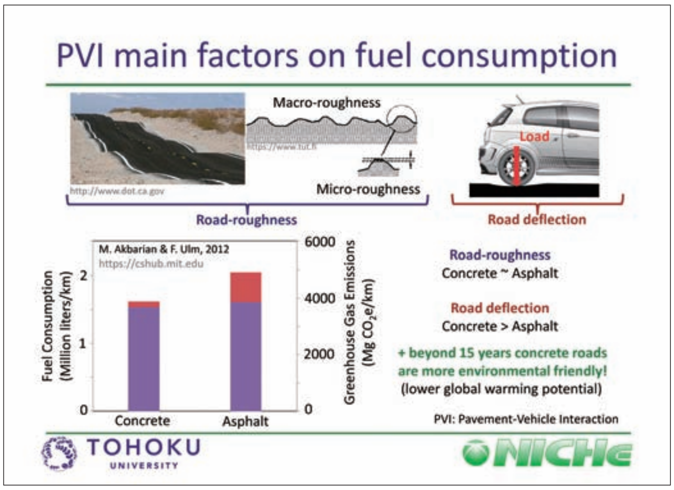
TOKO WAX & TUNING MANUAL
100μm
Wax worked into the base
Deep penetration of wax into the base
(Optical photograph of colored wax?)
Penetration depth of wax to running surface corresponds to our result

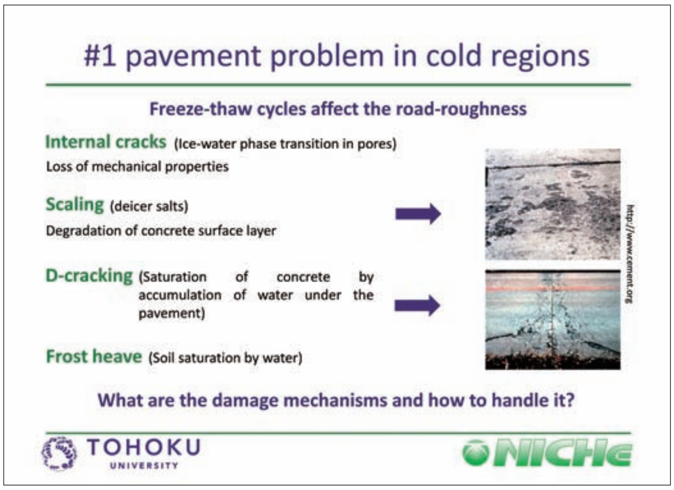
Concrete sustainability - Application to road pavements -

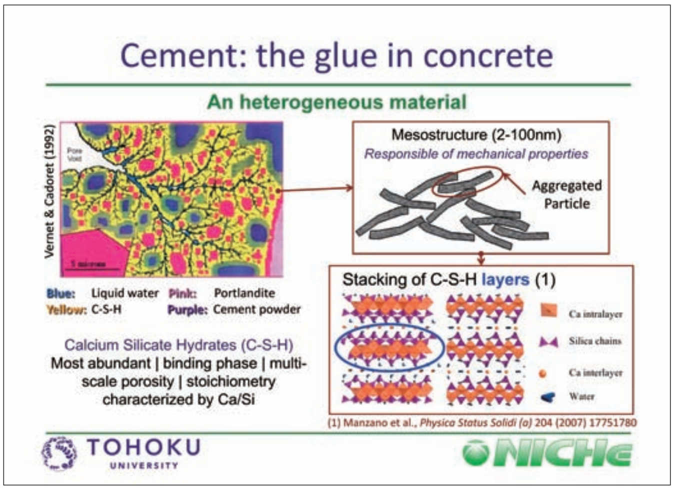
Patrick A. Bonnaud

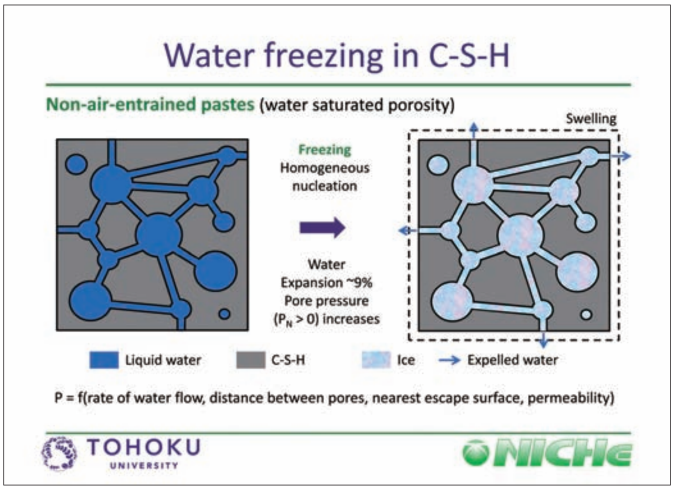
Researcher, New Industry Creation Hatchery Center, Tohoku University, Japan





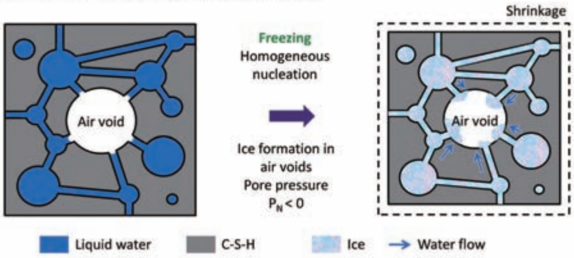






Water freezing in C-S-H

Air-entrained pastes (inclusion of air voids)



Air voids strongly reduce the effect of the hydraulic / crystallization pressure

Improve concrete resistance, but don't stop its deterioration!

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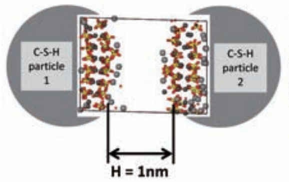
Problem statement

What's the origin of the disruptive pore pressure in the smallest nanopores upon freezing?

How to quantify it?

Molecular simulations between two C-S-H particles



Open porosity (exchange of water with a reservoir)

Effect of water densification (hydraulic pressure)

Closed porosity (fixed amount of water)

Effect of crystallization forces (crystallization pressure)

R. J.-M. Pellenq et al., *PNAS* 106 (2009) 16102.

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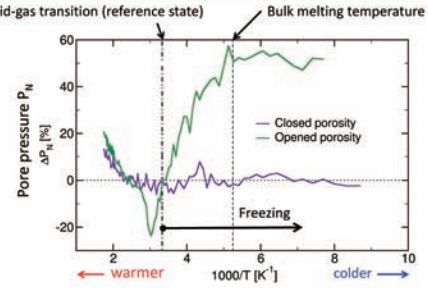
Pressure in a C-S-H nanopore



Water densification increases significantly the pore pressure (up to ~50%)

Crystallization forces barely affect the magnitude of the pore pressure

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Summary

- Road pavement design and materials properties play a role on fuel consumption of the overall transportation system
- Frost damages is the #1 problem for road pavement in cold regions
- Molecular scale simulations are valuable tools to improve concrete properties in such extreme conditions

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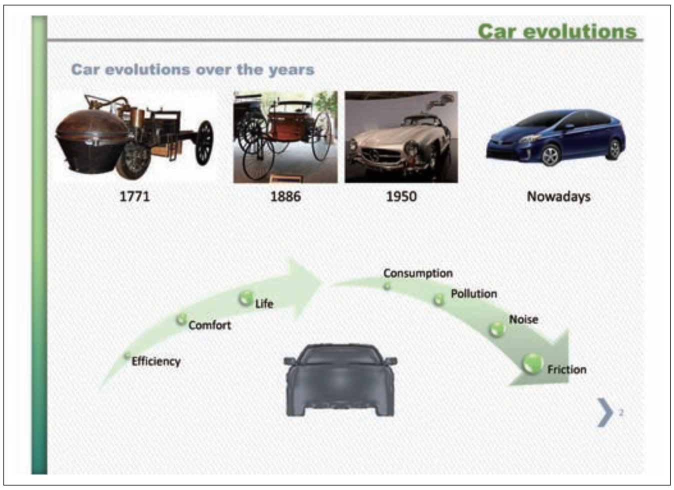
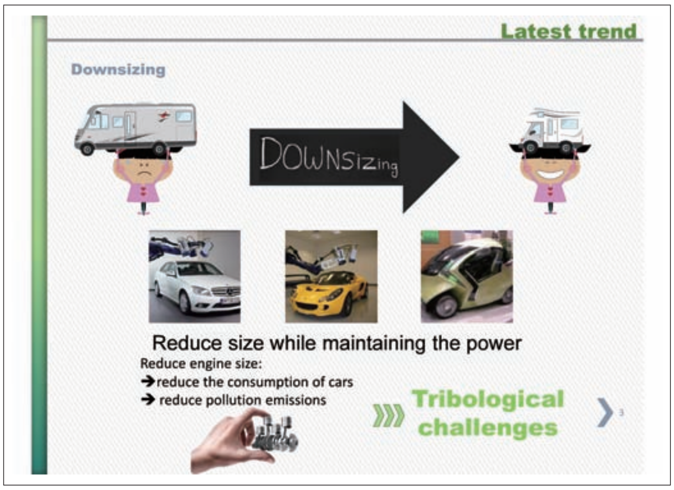
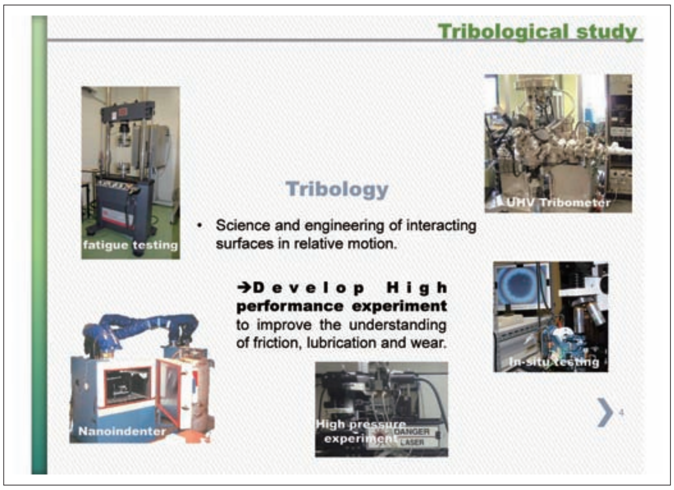
Innovations for Next Generation Automobiles: Contribution of tribology

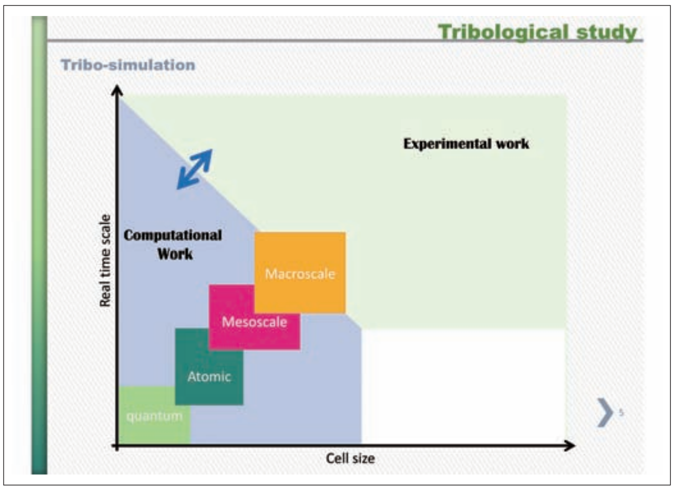
Sophia Berkani

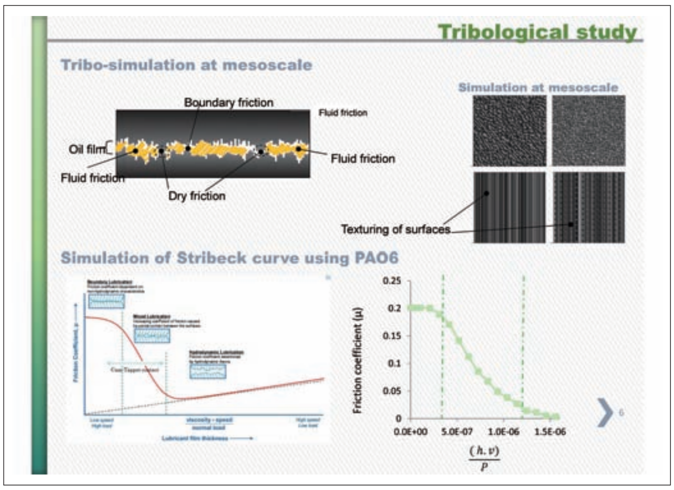
Researcher, Total Marketing & Services, Research Division - Solaize Research Center, France












Acknowledgments
Thank for your attention

Next Generation Vehicle Self-Drive Control Concepts and Safety Requirements: A Research Plan

Thomas Behling

Executive Director, CENTRA Technology Inc., USA

Next Generation Vehicle Self-Drive Control Concepts and Safety Requirements: A Research Plan

Colloquium Session CS3 Eleventh International Conference on Fluid Dynamics
October 8-10, 2014
Tohoku University

Thomas Behling

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Which Type of Self-Drive Vehicle Control Makes Sense, and Why?

- Autonomous
- Vehicle-to-Vehicle Cooperation
- Road Infrastructure-to-Vehicle Remote Control
- Human control
- Blend of capabilities

KEY ISSUES To RESOLVE:
1. Transition from few to many Self-Drive Vehicles
2. Self-Drive performance and safety standards

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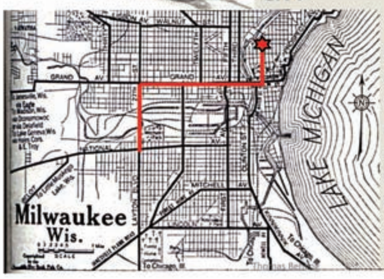
First, A Bit of History

Milwaukee Sentinel
Wednesday, December 8, 1926

PHANTOM AUTO WILL TOUR CITY



"Driverless, it will start its own motor, throw in its clutch, twist its steering wheel, and toot its horn…the "master mind" that will guide the machine will be a radio set in a car behind. "

Recent History

- 1960's – Ohio State University launches autonomous vehicle project--states roads will be ready in 15 years.
- 1980's - DARPA funds Autonomous-Land-Vehicle project using technologies from Carnegie Mellon University (CMU) and University of Michigan. Used laser radar and computer vision--driverless vehicle trailed lead car at 19 mph.
- 1995 – CMU develops "No Hands Across America" project—a 98.2% autonomous vehicle traversed 3,100 miles. Neural networking used to steer the vehicle, however, throttle and brake were operated by a human via remote control.

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Impact of DARPA Grand Challenges: Impetus for Self-Drive Vehicles

- Held in 2004, 2005, 2007
- 2005: Google, Volkswagen, and Stanford Engineers win 132 mile race with "Stanley"
- 2007: Carnegie Mellon University and General Motors win 60 mile urban race with "Boss"

'Boss' finishes

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Congressional Hearings on Self-Drive Automobiles

June 24, 2014: WASHINGTON - Transportation and Infrastructure Committee Chairman Bill Shuster (R-PA) welcomed Carnegie Mellon University and its self-drive vehicle for demonstrations

Shuster: "Autonomous vehicles … have significant potential to increase transportation safety and efficiency. The future of transportation is coming quickly, and it's important to provide policymakers with … better understanding of these kinds of innovations."

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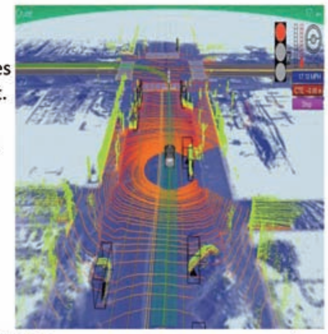
Autonomous Control

- Typical strategy is "sense-plan-act"
- Must deal with environment that includes :
  - Other vehicles on the road, each of which operates dynamically and independently
  - Other road users or on-road obstacles, such as pedestrians, cyclists, wildlife, and debris
  - Weather conditions, from sunny days to severe storms
  - Infrastructure conditions, including construction
  - Rough roads, poorly marked roads, and detours
  - Traffic events, such as congestion or crashes.

How does it work?

- **Google Car Example:**
  - Velodyne 64 beam laser, mounted of roof, generates a 3-D map of environment.
  - 4 radars mounted on the front and rear bumpers to navigate through high speed traffic.
  - Camera located on rear view mirror dedicated to reading traffic lights.
  - GPS



Google Car Concept of Operation

The Google car goes through six steps to make each decision on the road.

1. Locates itself with GPS and special maps embedded with detailed data the roadway. The value of maps was a key insight that emerged from the DARPA challenges. ***Maps are key—they give car a baseline expectation of its environment***

Source *The First Look at How Google's Self-Driving Car Handles City Streets* , Eric Jaffe in *CityLab*, 28 April 2014,

Google Car Concept of Operation, Continued

2. Next the car's sensors collect data on moving objects.
3. **Data is interpreted as actual objects that might have an impact on the car's route — other cars, pedestrians, cyclists, etc. — and to estimate their size, speed, and trajectory.**
4. **Interpreted data enters a probabilistic prediction model that considers what these objects have been doing and estimates what they will do next.**
5. Car software weighs those predictions against its own speed and trajectory and plans its next move.
6. The final step: turning the wheel, and braking or accelerating

Source *The First Look at How Google's Self-Driving Car Handles City Streets* , Eric Jaffe in *CityLab*, 28 April 2014,

US Department of Transportation Perspectives:

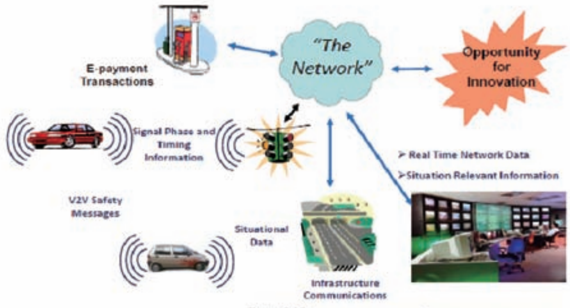
Vehicle to Vehicle and Vehicle to Infrastructure

History of VTV and VTI

- **Part of U.S. Department of Transportation's "Intelligent Transportation Systems" begun 1991**
- **Early concepts called for dedicated traffic lanes**
- **October 1999, the FCC allocated 75 megahertz of spectrum (5.850-5.925 GHz) for transportation services to improve highway safety and efficiency (Direct Short Range Communications)**
- **DSRC systems are being designed to provide short range, wireless link to transfer information between vehicles and roadside systems and other vehicles.**

Connected Vehicle Reference Implementation Architecture

Connectivity Between Vehicles and Central Operations Center



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Virginia Connected Vehicle Test Bed in Northern Virginia

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Current V2V Status

- August 2012: DOT launched Safety Pilot "model deployment" in Ann Arbor, Michigan
- 3,000 vehicles deployed with V2V technology—demonstrated feasibility
- Issues: security, liability, privacy, communication congestion, consumer acceptance

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Examples of Connected Vehicle Applications

Safety Applications

V2V

- Forward Collision Warning
- Emergency Electronic Brake Light
- Blind Spot Warning
- Left Turn Across Path

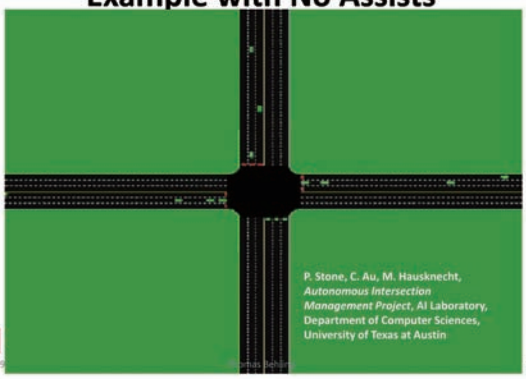
V2I

- Red Light Violation Warning
- Curve Speed Warning
- Stop Sign Violation
- Pedestrian Warning

Mobility and Evacuation Applications

- Intelligent Network Flow Optimization
- Emergency Communication, Staging and Evacuation
- Variable Speed Limits for Traffic in Bad Weather
- Motorist Advisories and Warnings
- Information and Routing Support for Evacuation and Emergency Responders

VTI Intersection Management: Example with No Assists



LINK

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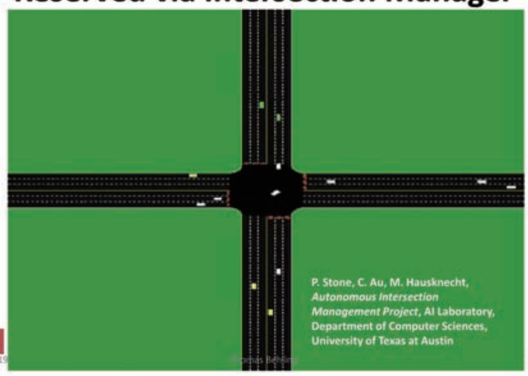
With VTI Management: Crossings Reserved via Intersection Manager



LINK

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Transition Issue: Vehicles Are Differently Equipped

- Cars "A" and "B" approach intersection
- You are passenger in Car A, which is self-drive
- What is the protocol for Car B?

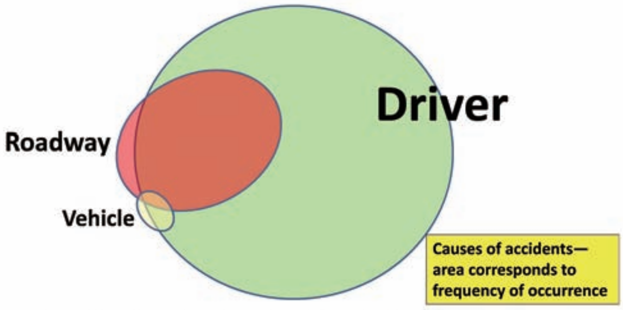
Car B Status	Car B systems OK	Car B has system fault
Driver in Car	Standard traffic rules	Standard traffic rules with alert
Driverless	Driverless traffic rules	Special conditions

Scenario 2

Scenario N

Some Observations on Safety Standards

Self-Drive Could Reduce Vehicle Accidents, Especially Driver Induced



K. Rumar, 1985, cited by Harry Lum and Jerry A. Reagan in "Interactive Highway Safety Design Model: Accident Predictive Module, Public Roads Magazine (Winter 1995) .

But Self-Drive Control Systems Must Deal with the Unexpected

- Control must be robust for individual vehicle and for cooperating vehicles
- Single Vehicle example: if a ball were to roll into the path of a vehicle, a driver would expect that a child could follow. Car based sensors and algorithms need to anticipate this event
- Many other examples

Real Example From Home: Pedestrian Crosses Against Traffic

Real Example From Home: Pedestrian Pauses in Median Strip

Self-Drive Vehicles Will Face Higher Safety Standards

- **Self-Drive can reduce human-caused crashes, especially fatalities**
- **But today's overall crash rates are already low**
- **In US, one crash (non-fatal) per 500,000 vehicle miles traveled (VMT)**
- **Google car has logged 700,000 accident-free miles (as of April 2014)**
- **Goal: much better than one crash per MVMT**

In US, 3 Trillion Vehicle Miles Traveled per year results in nearly 6 Million accidents. Compiled from US National Highway Traffic Safety Administration reports (Nov and Dec 2013)

How to Assess Control Concepts and Develop Transition Plan

Start with customer/driver needs, e.g.,:

- Reduce time driver is engaged in commuting (car acts like a train, giving driver time for other tasks)
- Add new functionality: operate car autonomously to pick up and deliver passengers
- Reduction in fatal and non-fatal crashes

Issues to be Worked

- How to measure effectiveness of control concepts?
- Can *performance* be improved by using patterns of driver behavior at detailed level?

Some First Steps

1. Assess utility of existing traffic models and data sets for applicability to key driver needs discussed above, e.g., do the models work only for freeway traffic? Can they handle dense urban traffic with pedestrians?
2. **Prepare plan for data gathering and model development**
   - **Break down exemplar needs into journey segments**
   - **Enhance existing data sets with data on traffic patterns in city neighborhoods gathered via automated means**
3. **Build data set of traffic behavior on an intersection-by-intersection and journey-segment basis, keyed to detailed maps**

LINK TO VEHICLE VIDEO

Vehicle Movement Automatically Registered by Time, Location, Direction, Speed

Some First Steps

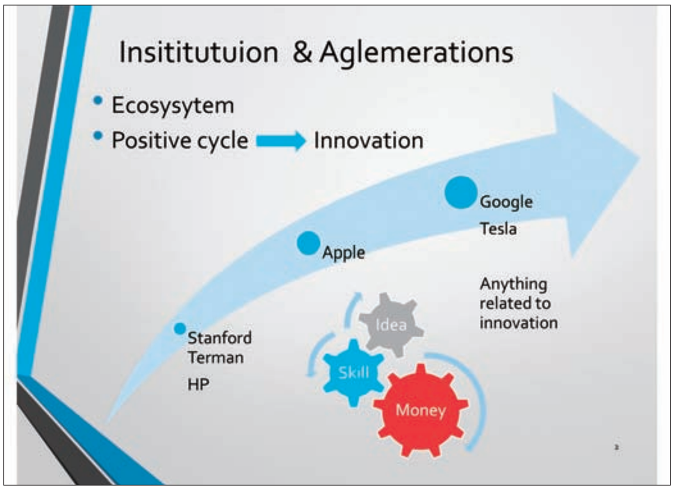
4. Use driver/pedestrian behavior data to create taxonomy and scripts for specific patterns of self-drive/driver and self-drive/pedestrian interactions (e.g., urban traffic behavior at intersections with traffic lights and heavy rain).
5. Develop standard set of reference scenarios based on combinations of scripts to assess vehicle interactions, V2V and I2V communication needs, safety, reliability, and resilience under adverse conditions
6. Assess effectiveness of vehicle control systems (self-drive with/without V2V or I2V coordination) for different on-road mixes of self-drive/driver vehicles
7. Develop crash rate data for reference scenarios for different mixes of human and self-drive vehicles

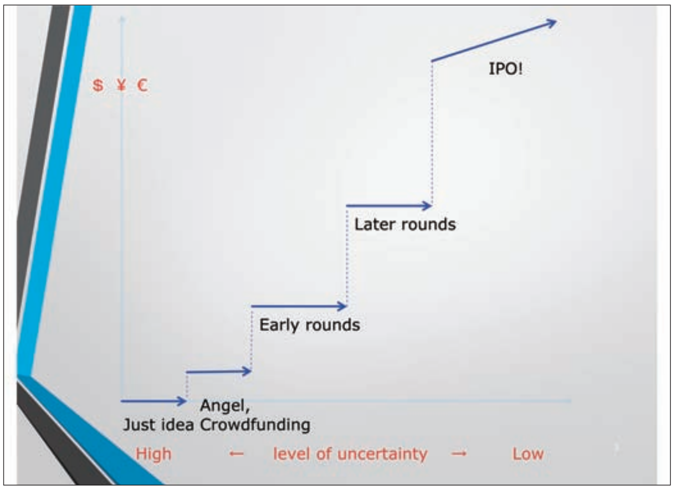
Final Thought: A Key Enabler for Transitioning to Self-Drive Vehicles

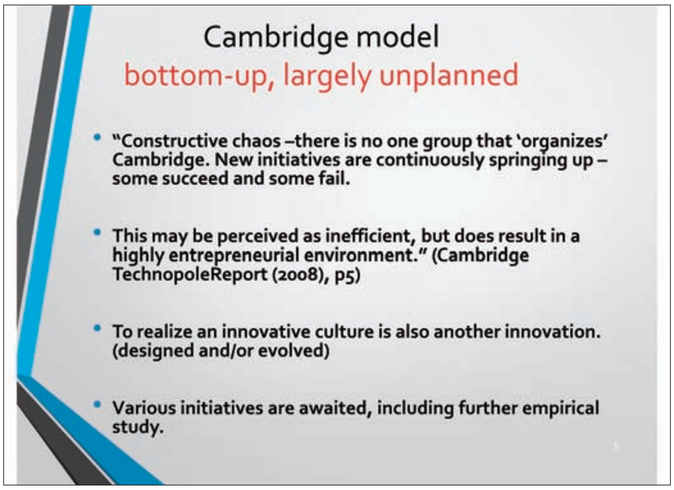
- Highly detailed, local maps of roadways are a key component of self-drive capabilities.
- In same manner, detailed scripts of driver and pedestrian behavior must be developed and keyed to specific locations.
- This gives self-drive car "expectation" of both the road environment and the likely actions of other moving objects

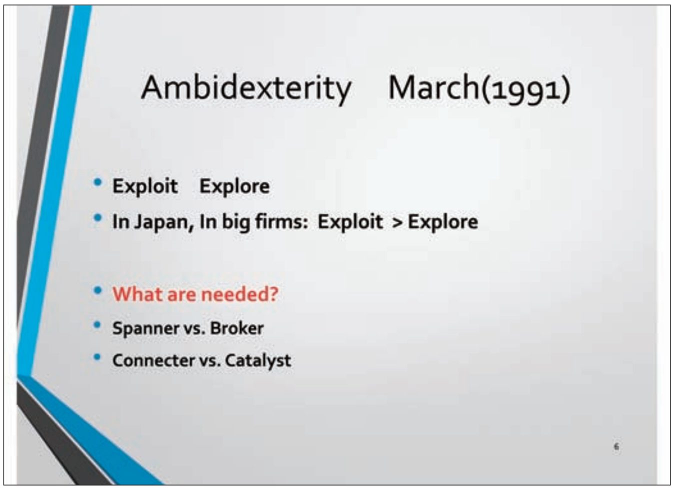
What determines the future?
- innovation, agglomeration and institutions -

Masato Hisatake
Visiting Professor, New Industry Creation Hatchery Center, Tohoku University, Japan





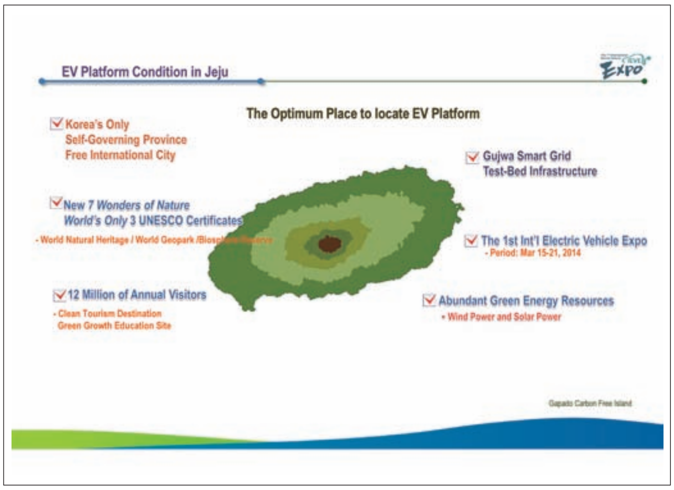


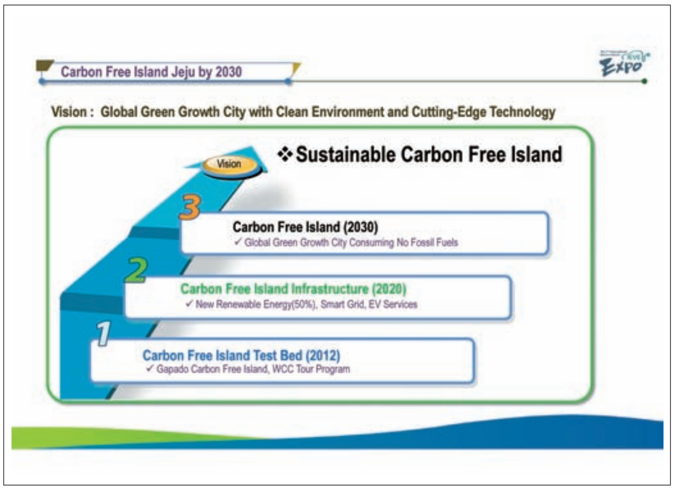


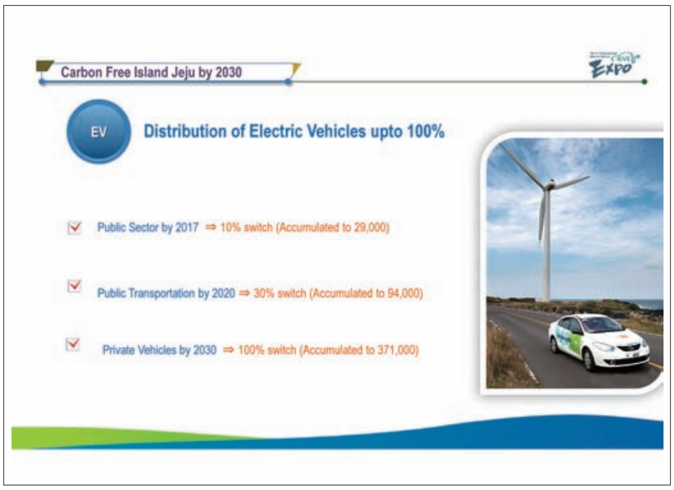
Global EV Platform in Jeju

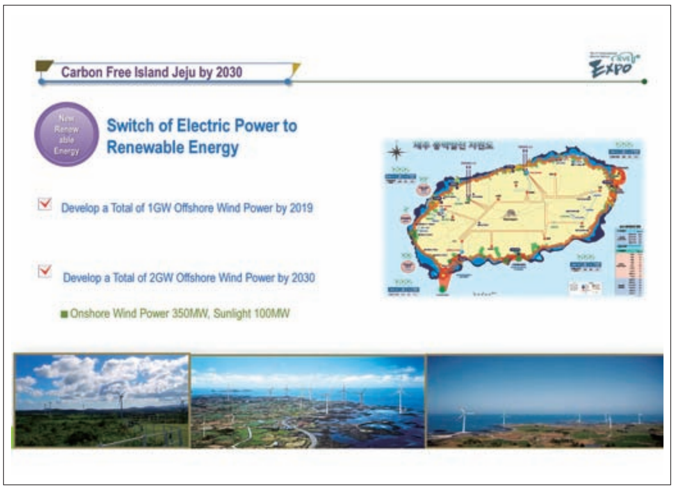
<u>Jae Chan Park</u>

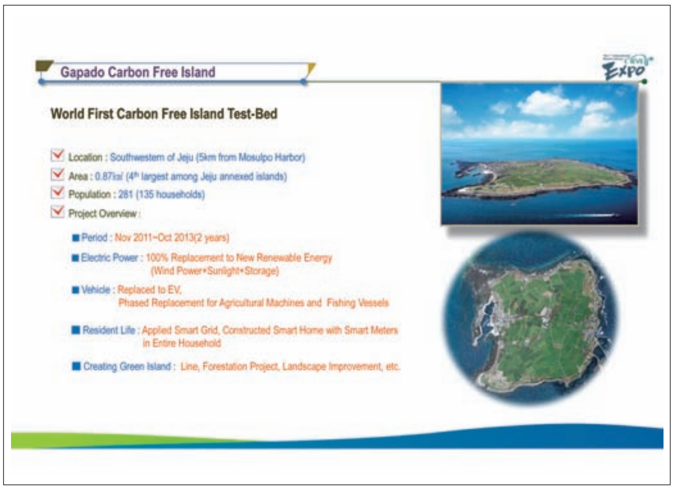
Secretary General, IEVE Organizing Committee



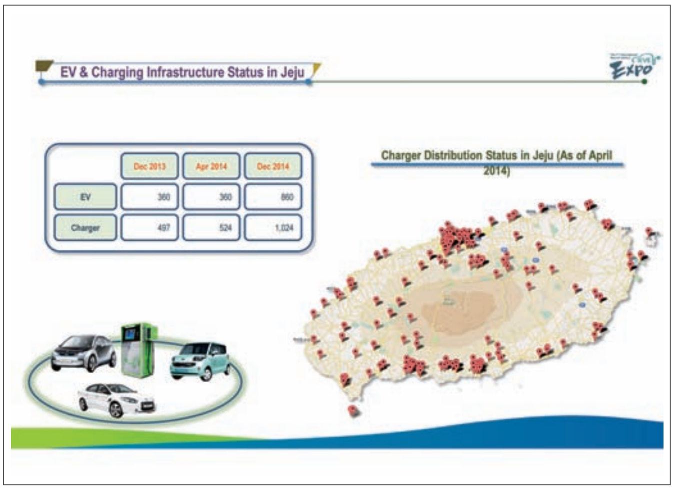





Carbon Free Island Jeju by 2030
Expo
New Renewable Energy
Switch of Electric Power to Renewable Energy
Develop a Total of 1GW Offshore Wind Power by 2019
Develop a Total of 2GW Offshore Wind Power by 2030
Onshore Wind Power 350MW, Sunlight 100MW


Gapado Carbon Free Island
Expo
World First Carbon Free Island Test-Bed
Location : Southwestern of Jeju (5km from Mosulpo Harbor)
Area : 0.87㎢ (4th largest among Jeju annexed islands)
Population : 281 (135 households)
Project Overview :
Period : Nov 2011~Oct 2013(2 years)
Electric Power : 100% Replacement to New Renewable Energy (Wind Power+Sunlight+Storage)
Vehicle : Replaced to EV, Phased Replacement for Agricultural Machines and Fishing Vessels
Resident Life : Applied Smart Grid, Constructed Smart Home with Smart Meters in Entire Household
Creating Green Island : Line, Forestation Project, Landscape Improvement, etc.

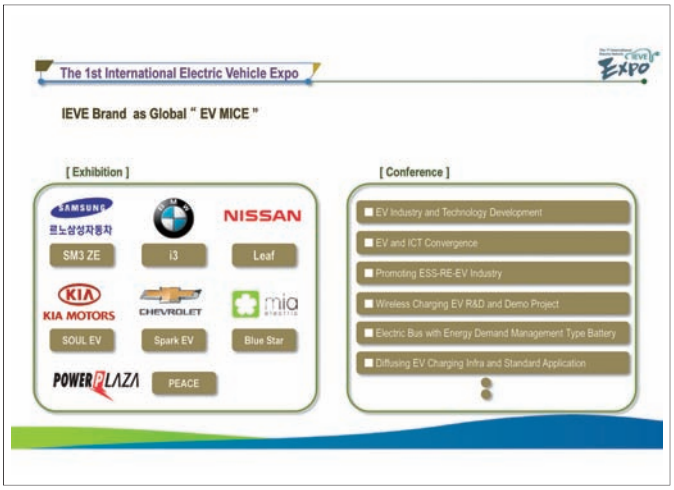

Gujwa Smart Grid Test Bed
Expo
Area : Gujwa-eup, Jeju (Northeastern Region of Jeju)
Scale : 5 sections / 2 substations / 4 distribution lines / 3,000 houses
Period : Dec 2009 ~ May 2013 (42 months)
Basic Stage: Dec 2009 ~ May 2011 : Constructing Infrastructure
Extended Stage : Jun 2011 ~ May 2013 : Operating Test-Bed
Participation : 12 Consortiums 168 Corporations
Budget : KRW 246.5 billion
Government 73.9 B(30%) KEPCO 23.9 B(10%) Private 148.7 B(60%)]
KEPCO
SK
posco
GS
LG
kt
CCS


EV & Charging Infrastructure Status in Jeju
Expo
Dec 2013
Apr 2014
Dec 2014
EV
360
360
860
Charger
497
524
1,024
Charger Distribution Status in Jeju (As of April 2014)


Jeju Electric Vehicle Service
Expo
The First Private EV Charging Infra Consortium in Korea
posco 포스코ICT
pmgrow
EVeryone
MEGA BESS
HABA
Jeju Electric Vehicle Service Consortium
[EV Infra Operation]
[EV Membership Service]
[Charger Manufacture & Maintenance]
[EV Call Center]


Jeju Electric Vehicle Service
EV & Charging Infra Management and Mobile Service in EV Infra Operation Center
EV인프라 운영 센터 EV Infra Operation Center
EVeryone


IEVE2014
The 1st International Electric Vehicle Expo
Theme: EV powered by wind
Period : Mar 15(Sat) ~ 21(Fri), 2014 [7 days]
Venue : Jeju International Convention Center (ICC Jeju)
Scale :
Exhibition : 8,591 ㎡ / 220 booths
Participant : About 40 EV Manufacturers and Related Industries
Visitors : 47,000 man-days
Organized by
Broadcasted by
Supported by
Hosted by
Participated by


The 1st International Electric Vehicle Expo
IEVE Brand as Global " EV MICE "
[Exhibition]
[Conference]
SAMSUNG
르노삼성자동차
NISSAN
SM3 ZE
i3
Leaf
KIA MOTORS
CHEVROLET
mia
SOUL EV
Spark EV
Blue Star
POWERPLAZA
PEACE
EV Industry and Technology Development
EV and ICT Convergence
Promoting ESS-RE-EV Industry
Wireless Charging EV R&D and Demo Project
Electric Bus with Energy Demand Management Type Battery
Diffusing EV Charging Infra and Standard Application


IEVE2015
Title : The 2nd International Electric Vehicle Expo
Period : Mar 06(Fri) ~ 15(Sun), 2015 [10 days]
Venue : Jeju International Convention Center (ICC Jeju)
Hosted by
Organized by


Carbon Free Island Jeju
by 2030
Global EV Platform in Jeju
THANK YOU