Connecting the Ground and the High Sky: Impact on Automobile/Mobility Industry of the Future

The New Mobility: Opportunities and Challenges
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Takahiro Fujimoto

Professor, Faculty of Economics, Tokyo University
Executive Director, Manufacturing Management Research Center (MMRC)
Executive Director, Monozukuri Kaizen Network (MKN)

John Paul MacDuffie

Professor, Management Dept, Wharton School, University of Pennsylvania
Executive Director, Program on Vehicle and Mobility Innovation (PVMI)
Mack Institute of Innovation Management

Basic Facts and Prospects

Quantity: 100M units of world production in 2020; 1.2B vehicles on earth;
Still growing worldwide despite the urban trend of "shared mobility"

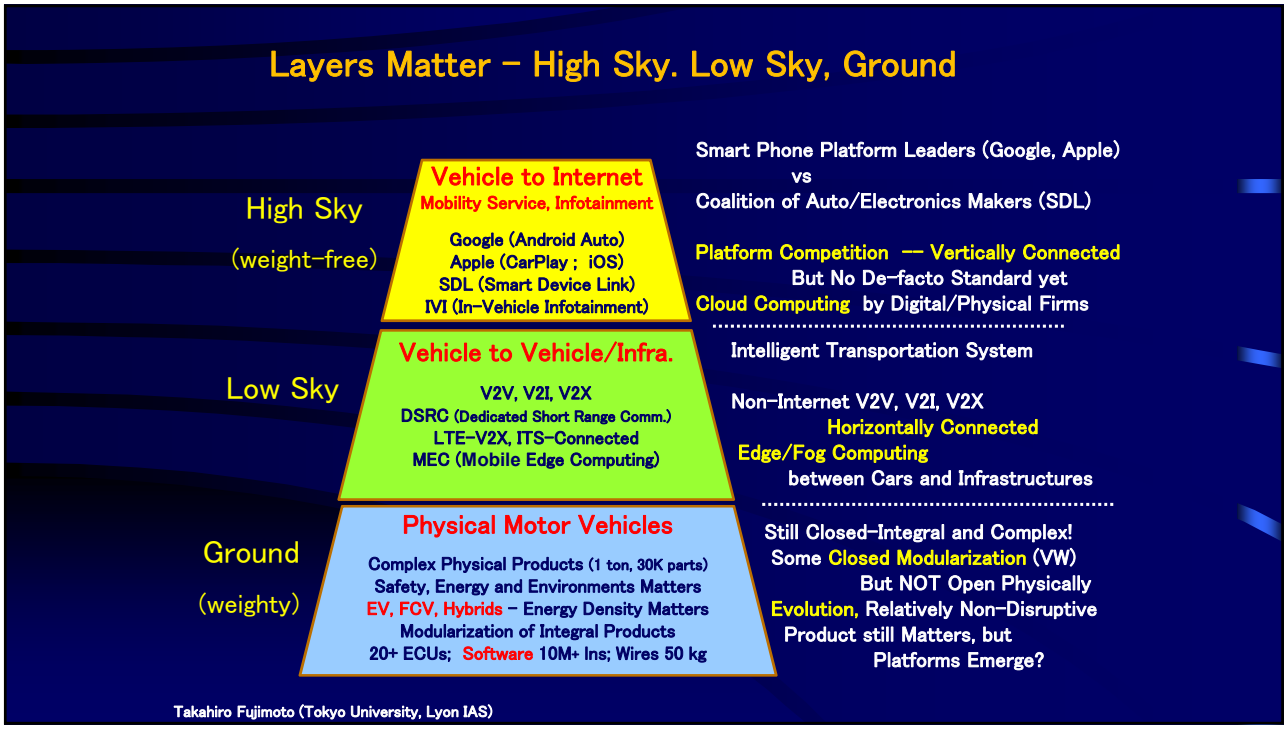
Mobility: 8Tkm trips on earth per year? Rapidly expanding – 15Tkm by 2030?
Low utilization (2% in time?) Passenger cars as "just-in-case" means to personal mobility

High Ticket Item: On average $20K+, despite some frugal innovations.
-- Demanding and complex functional requirements for motor vehicles.

Huge Industry Size: Manufacturing: $2T+; Mobility Service: $5T+
1% of the auto industry in larger than the current robot industry

Heavy and Fast Moving Object in Public Space
– Safety, Energy and Environments Matters (Original Sin)
Getting Complex, and Getting Heavier!

Leading Car Manufacturers: 10% Share or less in Units (VW, Toyota, etc.) – Big, but not dominating


Layers Matter – High Sky. Low Sky, Ground
High Sky
(weight-free)
Low Sky
Ground
(weighty)
Vehicle to Internet
Mobility Service, Infotainment
Google (Android Auto)
Apple (CarPlay ; iOS)
SDL (Smart Device Link)
IVI (In-Vehicle Infotainment)
Vehicle to Vehicle/Infra.
V2V, V2I, V2X
DSRC (Dedicated Short Range Comm.)
LTE-V2X, ITS-Connected
MEC (Mobile Edge Computing)
Physical Motor Vehicles
Complex Physical Products (1 ton, 30K parts)
Safety, Energy and Environments Matters
EV, FCV, Hybrids – Energy Density Matters
Modularization of Integral Products
20+ ECUs; Software 10M+ lns; Wires 50 kg
Smart Phone Platform Leaders (Google, Apple)
vs
Coalition of Auto/Electronics Makers (SDL)
Platform Competition -- Vertically Connected
But No De-facto Standard yet
Cloud Computing by Digital/Physical Firms
Intelligent Transportation System
Non-Internet V2V, V2I, V2X
Horizontally Connected
Edge/Fog Computing
between Cars and Infrastructures
Still Closed-Integral and Complex!
Some Closed Modularization (VW)
But NOT Open Physically
Evolution, Relatively Non-Disruptive
Product still Matters, but
Platforms Emerge?
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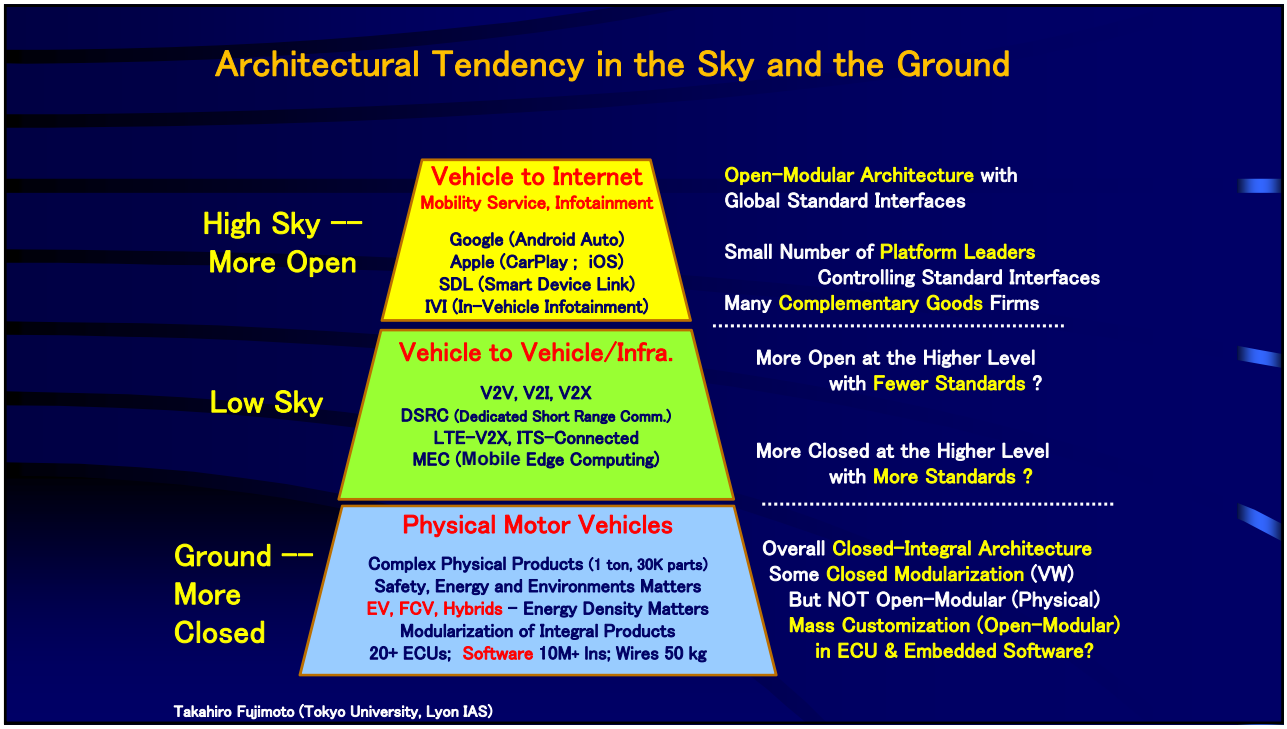
Architectural Tendency in the Sky and the Ground
High Sky --
More Open
Low Sky
Ground --
More
Closed
Vehicle to Internet
Mobility Service, Infotainment
Google (Android Auto)
Apple (CarPlay ; iOS)
SDL (Smart Device Link)
IVI (In-Vehicle Infotainment)
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Modularization of Integral Products
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Open-Modular Architecture with
Global Standard Interfaces
Small Number of Platform Leaders
Controlling Standard Interfaces
Many Complementary Goods Firms
More Open at the Higher Level
with Fewer Standards ?
More Closed at the Higher Level
with More Standards ?
Overall Closed-Integral Architecture
Some Closed Modularization (VW)
But NOT Open-Modular (Physical)
Mass Customization (Open-Modular)
in ECU & Embedded Software?
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Issues in Connected Cars and Automatic Driving

Basic Structure (High Sky, Low Sky, Ground) is Similar to IoT and Industrie 4.0 in Digital Manufacturing

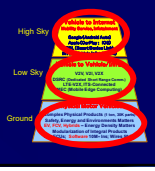
High Sky, Low Sky and Ground started to be Vertically and Horizontally Connected

High Sky: (e.g., Infotainment, Digital Mobility Service)
Platform Competition: Google (Android Auto), Apple (CarPlay)
versus SDI (by Alliance of Manufacturers – Toyota, Ford,—)
Mobility as service – directly connecting high sky to ground (vehicles with drivers)

Ground: Cars are getting more complex (10M lines of software, 30K physical parts) Standardization?
Difficult to design! — New Entrants Possible but NOT So Easy. Total disruption is not likely

Low Sky: Horizontal Connectivity (V2X)
Vehicle communication to both real things (radar, LIDAR, etc.) and to digital maps, 5G
Regional Difference Remains due to Environmental Variety
(US:DSRC; EU: LTE-V2X + DSRC; Japan: ITS-Connected + DSRC; China: LTE-V2X)

Infotainment: closer to High Sky; Digital Mobility as Service : High Sky and Ground;
Automatic Driving: Involving all layers (High Sky/Low Sky /Ground); EV: Closer to Ground)



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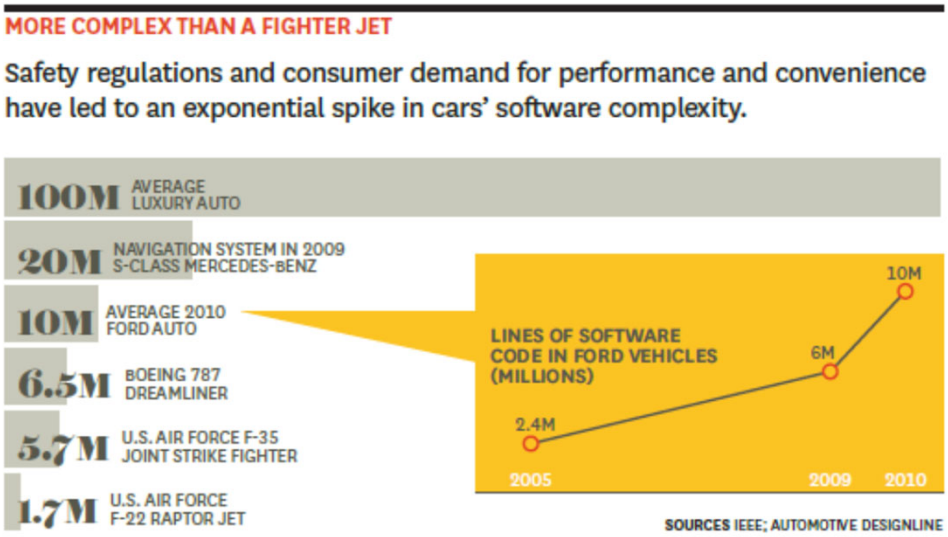
Background: Digitalization in Automotive Product Architecture

- Software became more important in automobile product architecture starting in 1990s – challenge for OEMs
- "Embedded software" – dedicated code for vehicle operations, relatively fixed (written to silicon), can be updated (via flash memory)
- Technical challenge – software control of physical things (digitalization of previously electro-mechanical controls)
- Organizational challenge – lack of software knowledge at OEMs
  - Start by training mechanical engineers to write code (lousy software)
  - Shift to hiring software engineers (no knowledge of hardware)
- Eventually a new division of labor – chipmakers do HW+SW, suppliers and OEMs add SW

PVMI PROGRAM *on* VEHICLE *and* MOBILITY INNOVATION

Software proliferation is one source of increased complexity



Dilemma: High Dependence on Integrated, Specialized Chips

- Soon, inside the vehicle: 20+ electronic control units (ECUs), 500 soft modules each, 10 million+ lines of code
- Increasingly specialized chips provide for multiple functions –– integration of physical design with proprietary software customized by chipmaker for specific OEM and vehicle requirements
- At the extreme, Renesas – Japanese firm with unique integration capabilities – has 60% market share of one critical ECU w/ highly integral chip architecture
- 3/11 Tohoku earthquake/tsunami shuts down Renesas factory in Sendai – loss of key ECU shuts down assembly plants worldwide
- OEMs try to reduce their reliance on highly integral ECU designs – and the suppliers who make them – but not easy to do

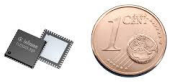
Connecting Ground and High Sky: Four Examples

1. Persistent integrality of new chip designs
2. Improving the driver interface in the dashboard/cockpit
3. Multiple layers of automotive data networks
4. Connectivity for V2X

PVMI PROGRAM on VEHICLE and MOBILITY INNOVATION

1. Persistent Integrality of New Chip Designs

- Incumbent automotive chip makers (e.g. NXP; Infineon; Renesas) keep making microcontrollers for traditional automotive features
  - OEMs preferring to use many cheap dedicated ECUs vs. one expensive chip



- But new applications pull chip design back towards integrated/integral – which shifts power towards the chip maker
  - Wireless modem chips connecting cars to the internet (Intel, Qualcomm)
  - Chips for the cameras and sensors that give a self-driving car "eyes" (Mobileye/Intel) – many cheap sensors, chip must provide "sensor fusion"
  - Microprocessing chips that serve as artificial intelligence "brains" in emerging AV OS (Intel and Nvidia – but Tesla, Waymo doing their own)

2. Improving the Driver Interface in the Dashboard/Cockpit: Ford Sync 3

- Ford's Sync 3 "offers voice recognition and an LCD touchscreen to give you connection to your phone: Alexa, music, navigation and more."
- Sync 3 is both "low sky" and important in recent Ford "wins" on quality
  - Highest rank in J.D. Power's IQS in 30 years
  - Winner of AutoPacific's 2017 "Most Ideal" brand plus 5 product segment winners
- "Low sky" interface issues, in particular, lie at the intersection of design capabilities, strategic positioning, and industry dynamics

Sync 3.0 at Ford: The Driver Interface Challenge

- Evolution of Ford Sync
  - Sync 1.0 - Infotainment interface developed with Microsoft (MyFordTouch)
  - Acquisition of Livio for link to outside apps via SmartDevice Link (SDL)
  - Many problems with MyFordTouch – lower JD Power scores, bad press
  - Microsoft dropped (continued role in cloud support for software updates)
  - Sync 3.0 switches to QNX (from Blackberry) OS w/ Panasonic as integrator
  - Toyota agrees to adopt Ford's App Link tools for next gen SDL (open-source)
  - Sync 3.0 ships with integration of Android Auto, Apple Car Play plus apps for Spotify, Pandora in all 2017 Ford models
- This example combines many "low sky" trends!
  - Partners outside auto industry (and changing those partners)
  - Acquisition of tech firm (Livio) for its platform software
  - Open source for new App Link & SDL; developing it with a competitor
  - Accepting that consumers want to use apps on their phone

Sync 3.0 at Ford: The Collaborative Challenge

- Establishing collaboration with Panasonic (for Sync), Microsoft (via Azure), and other potential "low sky" partners for software integration (e.g. IBM, Siemens)
- Achieving effective "coopetition" with Toyota in developing the SDL consortium and AppLink developer tools
- Providing continued integration with Apple CarPlay and Asteroid Auto (and now Amazon Alexa) without ceding too much control of the customer interface
- Gaining influence in the Automotive Grade Linux (AGL) and other key consortiums affecting "low sky" innovations
- Deciding whether to join 5G Automotive Alliance, a competing 5G coalition, or to back some other nearer-term standard for vehicle data communications
- Deciding which technologies to keep proprietary vs. to make open source

Sync3 at Ford: The Strategic Positioning Challenge

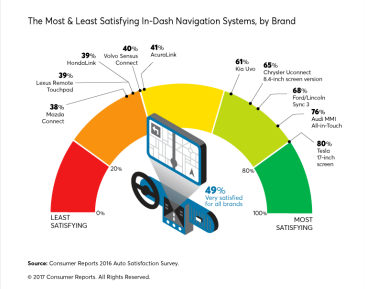
- Control:
  - OEMs believe that controlling the customer interface is crucial. *"The center stack … is prime real estate for OEMs to communicate their brand image." (*Sandy Lobenstein, VP of connected strategy, TMNA, *AutoNews*, 2/27/2017)
- Differentiation: How will Sync 3 provide a distinctly "Ford" customer experience as it offers access to more apps also available in other vehicles?
- Pace of innovation: Will upgrades happen quickly enough? *(+ over-the-air?)*
  - Quote from tech magazine review of 2017 Ford Fusion Energi "as a device":

  I just hope Ford rethinks how it wants to innovate as a technology company. Given how quickly new Alexa skills are added on the Echo, I'm more confident in Amazon's abilities to update Alexa for the car than in Ford to fine-tune SYNC 3. Self-driving vehicles and drone-launching delivery vans may seem like trends Ford thinks it needs to hop on, but above all that, it should start back inside the infotainment screen before getting lost in a futuristic fantasy. (The Verge, 5/1/2017)

Compare with Toyota's Entune

Goal: Maintain control, not give away the interface with the customer, no Apple CarPlay or Android Auto

"Toyota's concerns about privacy came from a report in 2015 which claimed that Google collected throttle position, coolant and oil temperature engine revs, as well as vehicle speed when Android Auto was in use. Though Google defended itself stating that it took privacy very seriously, it did not refute the claim that it kept data on the engine revs and speed. This is a major compromise for Toyota."



BACK TO THE DRAWING BOARD
(Consumer Reports review, October 2017)

Toyota Entune: 44 percent very satisfied
Toyota's system combines a touch screen and regular knobs and buttons, but the "whole thing is hit and miss," one owner says. Complaints include small screens and slow system response. The Entune app capability seems "clunky compared to phone apps."

3. Multiple Layers of Automotive Data Networks: From CAN to Automotive Ethernet

- Automotive networking standards now layer over each other, depending on application (i.e. all still in use)
  - CAN (developed by Bosch in 1980s) - ubiquitous, cheap, reliable; application: opening and closing windows, on-board diagnostics port
  - MOST (developed by Harman-Kardon and German OEMs in 1990s) – specialized to support data-intensive multi-media applications – poor fit to driving applications
  - FlexRay (developed by NXP and Freescale semiconductors + Bosch and German OEMs in 2000s) – fast-data rates for 'drive-by-wire' applications
- Automotive Ethernet is the newest data network standard (IEEE 802.3)
- Automotive Ethernet is already 10x faster than FlexRay, has advantages in protection against hacking but has a weakness in ***timing***
  - Ethernet was designed to send data, in packets, with a careful check to make sure "sent" and "received" packets match
  - Timing didn't matter as long as data eventually sent correctly
  - W/ physical processes, e.g. braking, steering, precise timing is **essential**

4. Connectivity Standards (or Lack Thereof) for Autonomy

vs.

- OEMs and transportation planners have worked on V2V (Vehicle-to-Vehicle) and V2I (Vehicle-to-Infrastructure) connectivity concepts for years

- Barriers to diffusion:
  - V2V needs interoperability and retrofitting
  - V2I needs government investment

- Meanwhile Google pioneers the self-sufficient AV, supported by high-resolution 3D mapping

- Fast progress with Google's approach because low interdependence with V2V & V2I complexity

- **May be impossible to get to 95-99% Level 4 autonomy without V2X connectivity**

What Standard for Connectivity?

- DSRC (Dedicated Short Range Communication)
  - U.S. government has dedicated portion of spectrum to it
  - Toyota saying it is actively experimenting with DSRC because it a well-understood and currently available communication standard
  - Most automakers believe it is too slow and can't handle the huge amounts of data and need for speed and responsiveness for AVs
  - Since DSRC has been used very sparingly, FCC may take it away!

- Many countries have DSRC… but also other region-specific standards
  (EU: LTE-V2X + DSRC; Japan: ITS-Connected + DSRC; China: LTE-V2X)
- 5G
  - Not here yet and won't be widely available for automotive use for some time
  - Big investment needed for comprehensive coverage in all locations
  - Could be a critical bottleneck that slows AV deployment and diffusion

Closing Thoughts

- Low Sky is area where neither "ground" nor "high sky" expertise is sufficient
- Automotive OEMs tried to do "low sky" themselves
- Now dependent on range of chip makers and "middleware" providers
- Need universal interoperable standard for connectivity to enable V2V & V2I
- Auto industry not accustomed to developing industry standards
- Even with agreement on a standard, big challenges with reliability testing, redundant systems for safety, availability of network in all locations, and need to retrofit both existing and new vehicles
- Low Sky may be a bottleneck; different firms from world of IoT will dominate (overlooked due to attention focused on "Ground" and "High Sky" firms)
- Both technical and organizational challenges always present for Low Sky