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The Incoming Wave of Innovation: Modular Interconnected Microsystems

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The rising visibility of microsystem technology is about to trigger a tsunami of wonder, curiosity, imagination, exploration and entrepreneurism.

When we look back at what's about to happen, one thing will certainly stand out: Motorola's "Project Ara" to create modular smartphones.

By teaming with 3D Systems to create a 3D printing production-platform and fulfillment system for Ara "Phonebloks," Motorola is signaling that microsystem "hardware apps" will soon join "software apps" in the public imagination as vital things to innovate, make, use and improve upon.

Those of us working in microsystems have seen bits and pieces of this coming for decades in an ever-widening array of innovations in microelectronics, MEMS and nanotechnology, micromachining, micropackaging and 3-D additive manufacturing.

However, the miniaturized results have been deeply embedded within OEM products such as PC's, smartphones, autos, aircraft, space satellites and other macroscale systems. Thus the underlying explosion of microsystem innovations has remained largely invisible, underappreciated and underexploited by the wider public.

That's all about to change as Ara smartphones become Lego-like, customizable, microhardware assemblages that can be partially reconfigured to meet individual and group requirements.

Suddenly, large numbers of product innovators will begin exploiting modular microscale building-blocks containing inertial, pressure, temperature and flow sensors, photoemitters, imagers and microcameras, actuators, strain gauges, linkages and more – along with their embedded microcontrollers and communication interfaces – to craft and exploit novel tiny-form-factor hardware apps that plug-n-play within macroscale systems.

Beginning in smartphones and tablets, modular interconnected microsystems will spread into wearable technology, automobiles, homes, environmental infrastructure and beyond. This will also trigger further innovations in functionality and componentry within micromanufacturing facilities – thus closing the loop and providing "intellectual gain" in the microsystem revolution.

But where will all the creative innovators come from?

Will 20th century engineering education, which mostly focused on narrow analysis and stove-piped optimizations of complex existing systems, provide the answer? I don't think so.

Fortunately, a wave of change is sweeping our universities. Leading engineering and business schools are increasingly exploring experiential learning, flipped courses, massive open online courses (MOOCs) and just-in-time learning – emphasizing entrepreneurial, multidisciplinary, user-centered problem-solving in exploratory team-project environments.

Faculty and students are increasingly learning about and sharing innovations via open-access academic journals and e-newsletters, and via emerging-industry wiki's, e-magazines, blogs and webinars – further enhancing the visibility and rate of exploration.

Many incoming engineering students have also gone to Lego Camps, used 3D printers and Raspberry Pi's, worked in FAB LABS and participated in robot competitions and Maker Faires. Such hands-on, DIY experiences are motivating increasing numbers of students towards real-world, user-engaged, team-problem-solving to create products and systems that truly meet deep human needs.

But what tools will incoming students use to explore, shape and build the future world? The answer: electronic design automation (EDA), rapid prototyping facilities, and related social-support infrastructure.

EDA companies such as Synopsys, Mentor Graphics and Cadence are providing innovators with increasingly effective intellectual "power-tools" for rapidly creating digitally-specified, manufacturable designs that reliably meet market requirements.

Such tools, along with the rapid development of digital design rules and open standards for new fabrication processes, are also enabling innovators to quickly exploit advances in manufacturing. For example, the rush is now on to exploit 2.5/3D MEMS and microcontroller chip-stacking using through-silicon-vias (TSVs) – a manufacturing technology that has kicked the door open to ever-tinier, increasingly-powerful, microhardware apps.

The wider world of EDA tools for user-engaged 3D product design, modeling, simulation and prototyping is also witnessing a revolution. Innovative environments such as Dassault Systems "3D Experience Platform" have arrived just in time to support participatory user/designer/fabricator explorations into how to embed microsystem functionality in a wide range of macroscale products.

Let's now look at what's coming from the perspective of the auto industry:

The need to embed rapidly-evolving information, communication, entertainment and environmental devices is already straining existing models of in-vehicle connectivity and parts-replacement, as are the increasing numbers of engine and drive-train sensors/actuators and safety-related components.

We've already seen a move from traditional wiring harnesses (and their 'give-aways') towards modular "KSK" harnesses that support subsets of user options. But even KSK methods will be strained as innovators of in-vehicle functional subsystems begin exploiting microsystems developed for non-auto markets. The rapid expansion of in-vehicle functionality will be further compounded by innovations in driver wearable-technology, and by intelligent vehicle and roadway systems.

The auto industry will thus stimulate and be affected by many new requirements and innovations – in areas such as wireless technologies and flexible and printable electronics – for signal and power connectivity among modular microsystems distributed within partially-customizable, upgradable products of all kinds.

We also glimpse, just over the horizon, an incoming paradigm shift in auto architecture towards low-drag "Very Light Cars" (VLCs), as exemplified by the pioneering work of the Edison2 team. Built upon high-tech, parameterized, lightweight axle-assemblies containing electric motors, regenerative brakes and wheel sets – such VLCs could be powered by battery modules and/or internal-combustion-engine/generator modules, depending upon national or regional energy markets and roadway infrastructure.

VLC outer shells and passenger compartments could be modularly fabricated by OEM's, by regional and local manufacturers, or by collaborative combinations of the above – enabling the targeting of widely varying international submarkets based upon local user needs, local driving conditions and local labor, material and energy costs.

In this way, interconnected microsystems will become embedded in and 'animate' all sorts of new modular 'product shells' (in clothing, home and office appliances, automobiles and structures).

In the process, the supply–chains for the electronics, information technology, clothing, automotive, appliance and building industries will begin to cross-couple and commingle.

Suddenly those with expertise in the manufacture of microsystem components won't be limited to selling into traditional, narrow-industry, tiered supply chains. They'll instead be able to connect in new ways with diverse communities of innovative designers, multiproduct supply-chains and emerging markets.

As a result, we'll see a shift beyond production of commodity parts aimed at mass-markets, into production of a vast range of high value-added, higher margin, specialty-market parts.

We'll also see a refactoring, reshoring, dispersal and democratization of many areas of manufacturing – leading to the rise of many novel types of specialized component-fabrication and subassembly shops – as user-community involvement, creative QTA partial customizations, and order-to-delivery times become vital market success factors.

But what about the complexity of the interactive-connections among multi-industry markets, investors, innovators, IP brokers, tool builders, fabricators, supply chains, system integrators, logistics systems and engaged users?

How will companies connect and thrive within this massive, rapidly-evolving, collaborative-competitive, industrial ecosystem?

The answer: the commingling of EDA and social-media is about to take us way beyond "design tools" into multi-technology "exploration infrastructure". The new infrastructure for user-engagement, interactive market research, crowdfunding, team design support, crowdsourcing, IP marketing and validation, agile project management and more, will enable all participants will to dramatically scale-up their connectivity and impact.

As the incoming wave of innovators, investors, students, social infrastructure, design tools, manufacturers, products and markets crests, it will trigger disruptive change. The microscale world will suddenly become widely visible, extensively explored and intensely exploited.

This revolution in human enterprise is technologically, economically, politically and socially inevitable, because the long term success of humanity depends upon sustainably providing ever-more functionality and empowerment per person, while consuming ever-less energy and material resources per person.

Connect the dots: the microworld 'gold-rush' has begun!

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