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The Incoming Wave of Innovation:
Embedding interconnected microsystems in almost everything

AKA: An adventurer's guide to exploring and making in the microworld.

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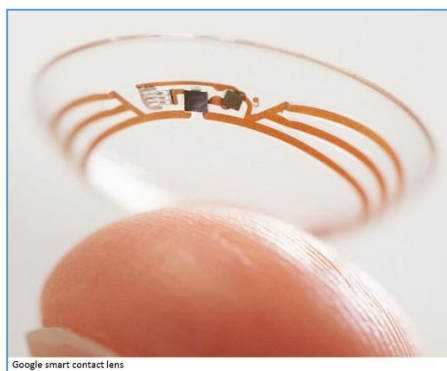
Google smart contact lens

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 conceptual milestone 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's Phonebloks, Motorola is signaling that microsystem mobile hardware apps will soon join mobile 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, nanotechnology, micromachining, micropackaging and 3-D additive manufacturing.

However, those micro-miniaturized results have been deeply embedded within final products such as PC's, smartphones, autos, aircraft, space satellites and other macroscale systems. Thus the underlying explosion of microsystem innovations has remained out-of-sight, underappreciated by the wider public and underexploited by entrepreneurial system-integrators.

That's all about to change as smart phones, watches and glasses 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 MEMS accelerometers, gyroscopes, pressure, temperature and flow sensors, microcameras, microactuators, microtransducers and more -- along with their embedded microcontrollers and interconnection interfaces -- to craft and exploit novel tiny-form-factor hardware apps that plug-n-play within macroscale systems.

Culturally diffusing via their wide-visibility in smart phones, watches and glasses, very-low-cost embedded modular interconnected microsystems will migrate into and greatly empower wearable technology, medical devices, personalized technology, automobiles and mobility technology, homes, robots, drones, environmental infrastructure and beyond. This will also trigger further innovations in functionality and componentry back within the micro-manufacturing technology itself, 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 and business education, which mostly focused on narrow analysis and stove-piped optimizations of existing systems, provide the answer? I don't think so.

http://ai.eecs.umich.edu/people/conway/Memoirs/Microworld/The_Incoming_Wave_of_Innovation.pdf
http://www.huffingtonpost.com/lynn-conway/the-incoming-wave-of-microsystems_b_4682105.html

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), small project online courses (SPOCs) and blended 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, e-newsletters, high-tech 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, done 3D scanning and open-source 3D printing, used Raspberry Pi's and Arduino, worked in FAB LABS and participated in robot competitions and the Maker movement. Such hands-on, do-it-yourself 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 microsystems 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 3-dimensional visualization, 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 drive-train axle-assemblies containing electric motors, regenerative brakes and wheel sets -- such VLCs could be powered either 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, homes and offices, automobiles and structures).

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

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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 microparts aimed at mass-markets, into production of a vast range of high value-added, higher margin, specialty-market componentry.

We'll also see a refactoring, reshoring, dispersal and market-democratization of many areas of manufacturing, leading to the rise of many novel types of specialized component-integration and subassembly shops -- with user-community involvements, creative quick-turnaround partial customizations, and order-to-delivery times becoming vital market success factors.

But what about the complexity of the interactive-connections among multi-industry markets, investors, innovators, designers, entrepreneurs, intellectual property (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 hybridization of EDA and social-media technologies is about to take us way beyond "design tools" into multi-technology "exploration infrastructure". The new infrastructure for user-engagement, interactive market development, user-driven technology evolution, collaborative learning, crowdfunding, crowdsourcing, meta-level team design support, IP marketing and validation, agile project methods and more, will enable all participants 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 microworld 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 infrastructural functionality and life empowerment per person, while consuming ever-less energy and material resources per person.

It can also move societies towards more diverse, egalitarian, inclusive and thriving futures, as ever more people migrate from being isolated consumers of mass-produced goods and entertainment towards being entrepreneurial and participatory customizers of their habitats and life experiences.

Connect the dots: The microworld "gold-rush" has begun!