

November 2013

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Defense Electronics: On the Pulse of the Current Dynamics

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This month, STRATeVU's Steve DeWaters demystifies the often complex world of military electronics and DoD spending, while Graphic Plc's Ashley Luxton demonstrates the utility of applications engineering to PCB design and manufacturing. Finally, Circuit Solutions' John Vaughan explores the intersection of unmanned vehicle systems and electronics technology.

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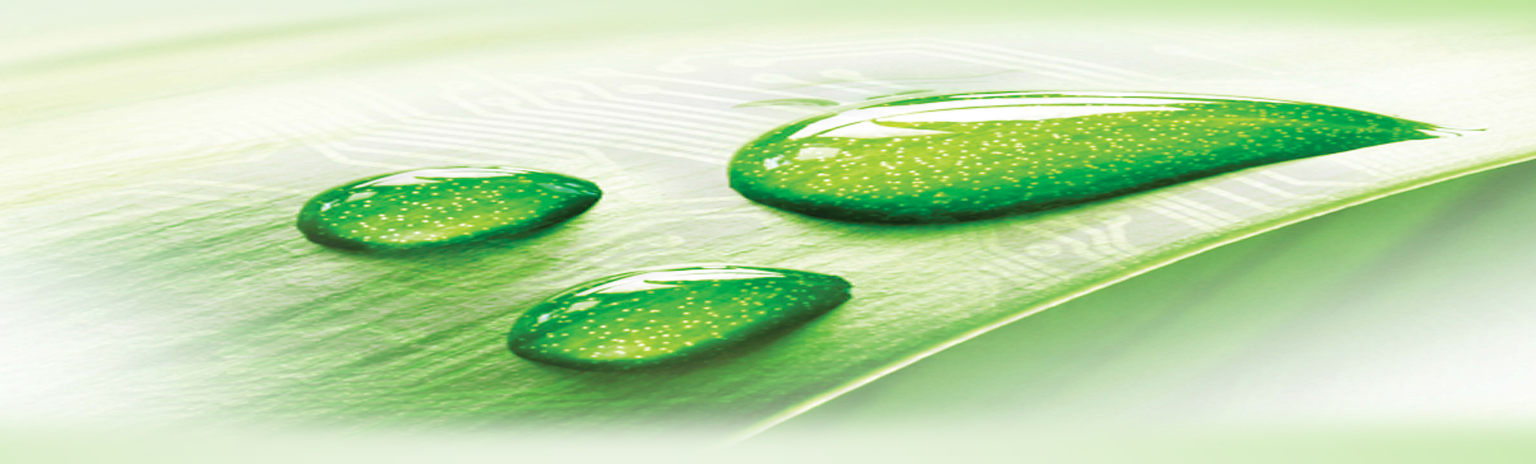


30 Applications Engineering for Military & Aerospace

by Ashley Luxton



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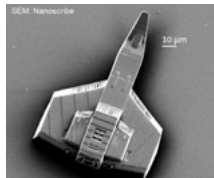
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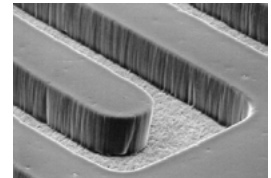


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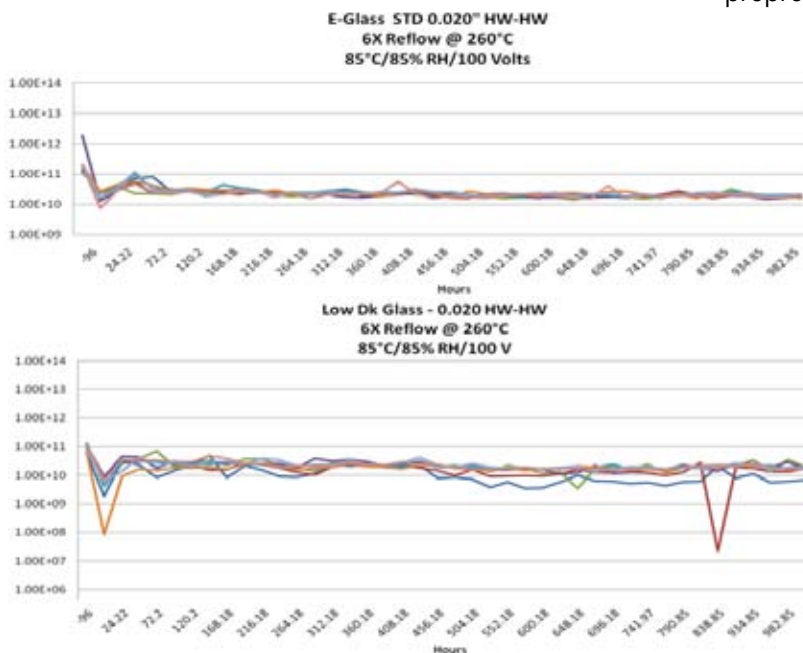
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The Summit

by Ray Rasmussen

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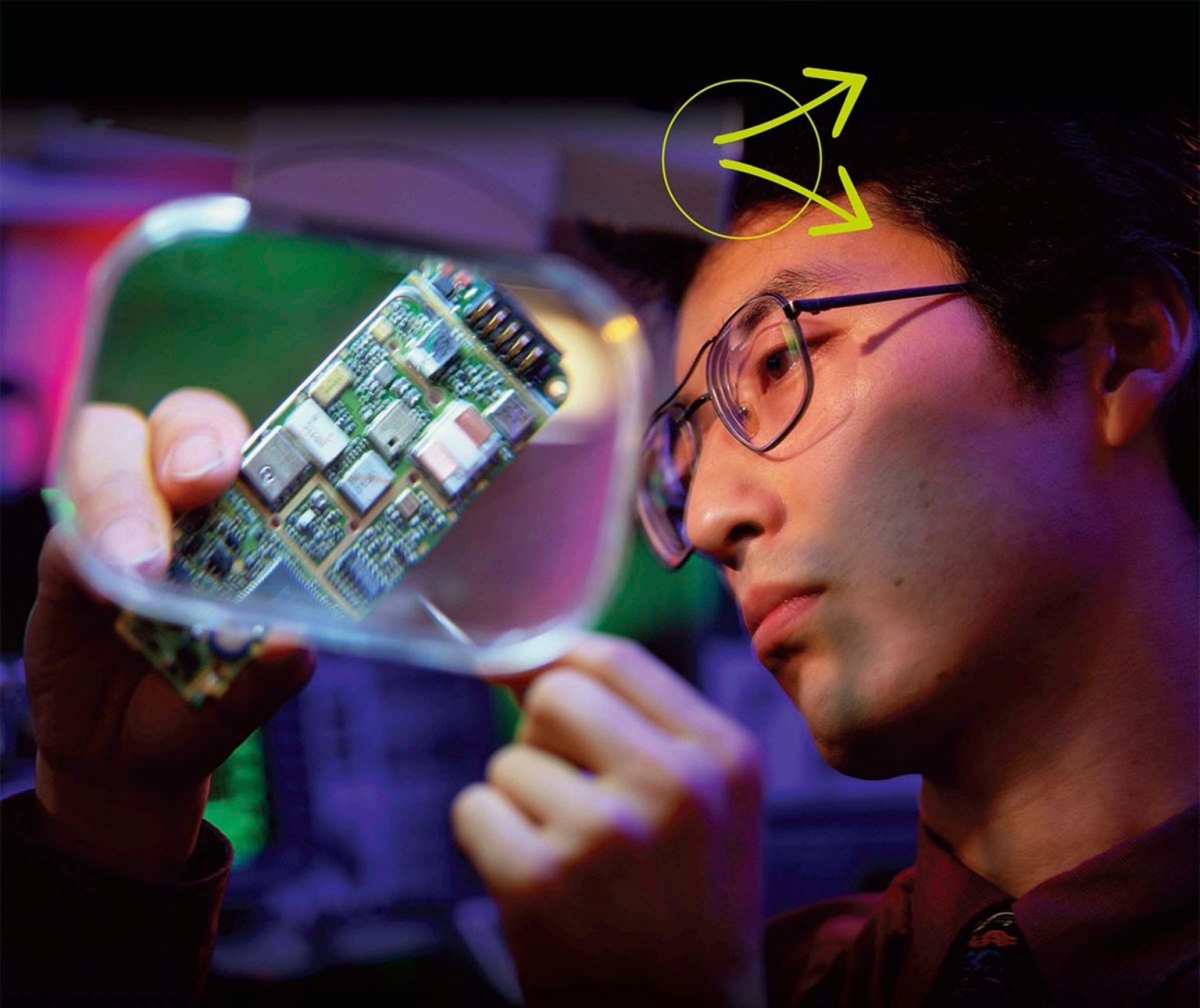
What's 20x more conductive than copper, 100–300x stronger than steel (depending on whom you ask) and possibly harder than diamond? What has great thermal conductivity, tremendous surface area and has researchers around the globe working day and night to develop the next generation of products? It's graphene.

Rediscovered in 2004 by physicists at the University of Manchester and the Institute for Microelectronics Technology, Chernogolovka, Russia, this amazing material has moved from labs around the world into volume production. Still in its infancy, graphene is being used for a whole host of products today and proposed and developed for myriad products of the future.

Did you know that a sheet of graphene as thin as a piece of plastic wrap could support the weight of an elephant? We learned this from a technologist who is working with this wonder material, MIT Professor Tomas Palacios, at IPC's recent TMRC meeting in Chicago. His presentation, along with a few conversations during the meeting, got me thinking about the possibilities.

On the PCB side of things, what's the biggest issue we face? After listening to a ton of presentations over the years, I'd say it revolves around laminates. The drive to thinner, lighter, more functionally capable laminates that won't come apart when wave soldered, is on everyone's list of requirements. How can we make





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much finer lines and spaces, get much thinner and still retain the electrical properties we need for today and tomorrow's products?

That's where I am with graphene. I've been reading about it since its discovery and we've published nearly 400 articles related specifically to this material over the years, so I've followed what's been developing.

The Next Generation of PCB Materials

I try to attend as many industry conferences as I can. I've noticed that everyone's making incremental changes to their materials or processes to improve the PCBs or assemblies we produce. No one's really seeking out that game-changing technology (save Joe Fjelstad's Occam Process) which would move the industry to another plateau. Not being a scientist or an engineer, I can only react to what I read from some really smart people. Maybe that's my advantage, or maybe I'm a bit naive. I don't know why it can't be done, so I only think of the possibilities.

As mentioned, graphene is highly electrically conductive, a great heat conductor (5000 W/MK), very strong and just one atom thick. Now, add in four-atom-thick nano-insulating materials that Palacios discussed in his presentation, along with carbon nanotube solder ([SAC 305 paste is already being made with carbon nanotubes](#)) and we may have a platform for next-generation electronics.

I don't know a lot about these new materials but I believe the following represents a few more of the characteristics.

- Fireproof (no need for flame retardants)
- Little or no moisture absorption
- CAF problem solved
- Resistance—smaller lines not a problem
- Giant heat sink

- Heat tolerant (won't delaminate)
- Nano insulating materials available
- Great surface area (good adhesion)
- Potential to be extremely thin
- Stretchable/bendable
- Lightweight
- Almost no CTE issues
- Highly durable solder joints that won't crack

Now, I'm sure there are some drawbacks. How will we make the circuits or vias on this new material? It's at least as hard as diamond and a lot stronger than steel. How will we solder to it (already being done in the lab)? I don't have all the answers, but that shouldn't hold us back. This material has way too many phenomenal characteristics, which address many of the pain points our customers have. I think it makes sense to take a look, think about and discuss the possibilities.

In order to not look too foolish before publishing this piece, I consulted a few industry experts to see if what I am suggesting makes sense. I queried my friend, Joe Fjelstad, who then suggested I get some feedback from Dr. Alan Rae. Here's what they both had to say.

Rae: There are definitely real opportunities for graphene in circuit board manufacture—in fact I had a conversation very recently with a board materials manufacturer. There is lots of work to do to get it to work. Graphene can be printed or chemical vapor deposition (CVD) on epoxy or other substrates, but will not etch easily. It will need an additive process. Good thermal and electrical conductivity in plane, and out of plane connections could be made with silver inks, for example (iimak is already making silver-graphene inks). So I can actually envision a system—even roll to roll—that might work well, but the board contacts and component attach details need a

“
I don't have all the answers, but that shouldn't hold us back. This material has way too many phenomenal characteristics, which address many of the pain points our customers have. I think it makes sense to take a look, think about and discuss the possibilities.”

lot of thought even before we start thinking about reliability.

Fjelstad: Thanks to you both for sharing your thoughts. This is the way we progress. Personally I am still ‘on the dock’ on this subject. Every sailboat needs a sail, a tiller, an anchor and a skilled sailor who (hopefully) knows the waters. Moreover, every journey of interest requires us to leave the safety of the harbor.

Academics often tend to be highly exuberant about their research. Which, extended to the metaphor, means they are often excellent sails but unfortunately they also often lack sailing skills and knowledge of the waters (experience on the manufacturing floor).

The result has often taken us off course (though, clearly we have visited places of future interest as a result). Presently, processing of graphene appears to be still a largely “uncharted sea.” It will be interesting to see what happens. One can only hope they don’t start selling a lot of tickets before they prove the journey is safely navigable.

The Graphene Summit

So, what do we do about this? We can watch the world race forward to develop new capabilities for industries around the globe and do nothing or we can grab hold of the opportunity this material offers and change our world. I do know that most of us prefer to let things evolve at their natural pace. If graphene has a place in the industry, it will come, someday. To borrow a term I love from Dr. Nakahara (Naka), I say, “bullshit nonsense.” There’s too much at stake to allow others to drive the future of our industry.

Please don’t take this the wrong way. I do believe that materials companies are working very hard, making tweaks to improve their products, producing laminates that are a bit thinner, a bit better heat conductors, a better conductor of electricity, etc. It’s an ongoing, never-ending introduction of material sets designed to offer solutions, but they never quite get to where they need to be. They make things better, but they don’t necessarily solve the problem since OEMs continue to push technologies to the limit to build the products of tomorrow. With graphene,

we might very well be able jump ahead of the curve and give them something they don’t expect: a new way to build their products entirely based on graphene PCB technology. Wouldn’t that be cool? We can give them the PCBs of tomorrow, today (or, as soon as we can develop the materials and processes needed).

Here’s what I propose: a summit in the form of a conference open to all. I hope it could be an IPC or iNEMi gig, but if not, I’d be willing to host it.

At the conference, we can at least talk about the possibilities of using this amazing material to provide the interconnection technology of the future. I know most suppliers are looking at and playing around with graphene in their labs, but we need a game-changing material which will give our customers, the OEMs, the solutions they’re looking for. After we meet, if it still makes sense to move forward, some task groups can be formed to explore the possibilities.

What I would hope to come away with after we’ve heard from the experts (research scientists, supplier CTOs, etc.) is whether graphene can truly be a game-changer for our industry. If it can, then we need to grab and run with it.

Speaking of conferences, I’ll be at [Graphene Live, Printed Electronics USA](#) later this month in Santa Clara. Drop me a note if you’d like to meet. **PCB**

Some additional reading on the topic:

- [Understanding Interface Properties of Graphene Paves Way for New Applications](#)
- [Researchers find chemical process for creating holes in graphene oxide](#)
- [Graphene Overview—Wikipedia](#)
- [“White graphene” halts rust in high temperatures](#)



Ray Rasmussen is the publisher and chief editor for I-Connect007 Publications. He has worked in the industry since 1978 and is the former publisher and chief editor of *CircuiTree Magazine*. To read past columns, or to contact Rasmussen, [click here](#).



Defense Electronics: On the Pulse of the Current Dynamics

by **Steve DeWaters**
STRATEVU, INC.

Summary: Through what lens can we look to see the opportunity landscape in defense electronics, and its likely program trajectories? And how do we make sure that we're using a telescope and not a kaleidoscope?

Through the lens of retrospect, the period roughly between the year 2000 and 2010 can be seen as something of an enormous clean-up and restoration process for the North American electronics industry. Heavily clotted inventory channels circa 2000, a 2008 financial meltdown, ongoing industry consolidations, and competitive pressures from overseas worked like force vectors to challenge nearly every business model. But, with the events of 9/11, it was also a period that launched a decided shift toward defense electronics as an attractive and parallel endeavor into high-reliability applications. However, that shift to defense has—for

the last 4–5 years—encountered contractions of its own, including: many of the defense service and program initiatives borne out of the 9/11 events now facing overwhelming budgetary constraints; exits from two prominent theaters of action; changing military doctrines; and juggled ideological priorities of the governing powers in Washington, D.C.

But there are still significant, although refined, opportunities for electronics companies to participate in and there likely will be for the foreseeable future, despite the headlines.

So, through what lens can we now look to see the opportunity landscape and likely program trajectories in defense electronics? And how do we make sure that we're using a telescope and not a kaleidoscope? First, let's examine some of the key budgetary requests, service priorities, and technological developments acting as guideposts for where and the how the most likely DoD expenditures will occur that will directly affect the electronics supply chain.

Budget Considerations

In April, the Congressional Budget Office (CBO) created a report entitled Long Term Implications of the 2013 Future Years Defense Program (FYDP). This report lays out, service-by-service, a breakdown of how and where requested funding will be applied during the five-year window of 2013–2018, with a slight nod as far out as 2030 for certain planned initiatives. The CBO applies its own rationale to the base budget requests by each service and attenuates the numbers (up or down) to reflect comparisons with the greater external considerations of the overall economy and other variables potentially impacting DoD budgeting.

Inside any DoD budget, the main areas of interest to electronics suppliers are the Procurement and RDT&E sections. Procurement has historically represented ~19% of the overall budget and RDT&E ~13%; the vast majority of each having significant electronics and optoelectronic content. Buried within these is a subsection of line items defined as the Communications, Electronics, Telecommunications, and Intelligence (CET&I) requests. The CET&I budget represents approximately 15% of the overall Procurement/RDT&E budgets and is the richest concentration of “pure” defense electronics.

With this budget refraction in mind, we can

look at the recent COB report and interpret a first level assumption about how much money is designated for electronics in the following way (see Figure 1).

The overall DoD Base Budget request was set at \$526B for 2013, plus another \$88B for Overseas Contingency Operations (OCO). Doing the math, the Procurement budget apportions at about \$116B and RDT&E at approximately \$79B, or \$195B, combined. The CET&I will wind up being in the neighborhood of \$17B. (Note: Some analysts consider the value of electronic content in the Procurement budget to be above 80%, mainly derived from considering the density of electronics at the platform level, so \$17B can be extrapolated to the neighborhood of \$90B very quickly.)

Now, if we dive a little deeper, we can look at the specific service budgets within Procurement/RDT&E and also take a look at the prioritized shopping lists within each. Figure 2 represents the three service budgets all-in.

Army's projections include vehicle modernization and upgrades to major platforms such as Abrams tanks, Bradleys and 155 mm howitzers. A new ground combat vehicle (GCV) will replace the carrier version of Bradleys, and an armored multipurpose vehicle (AMPV) will replace the M113 personnel carriers; a new light

Costs of DoD's Acquisition Plans

(Billions of 2013 dollars)

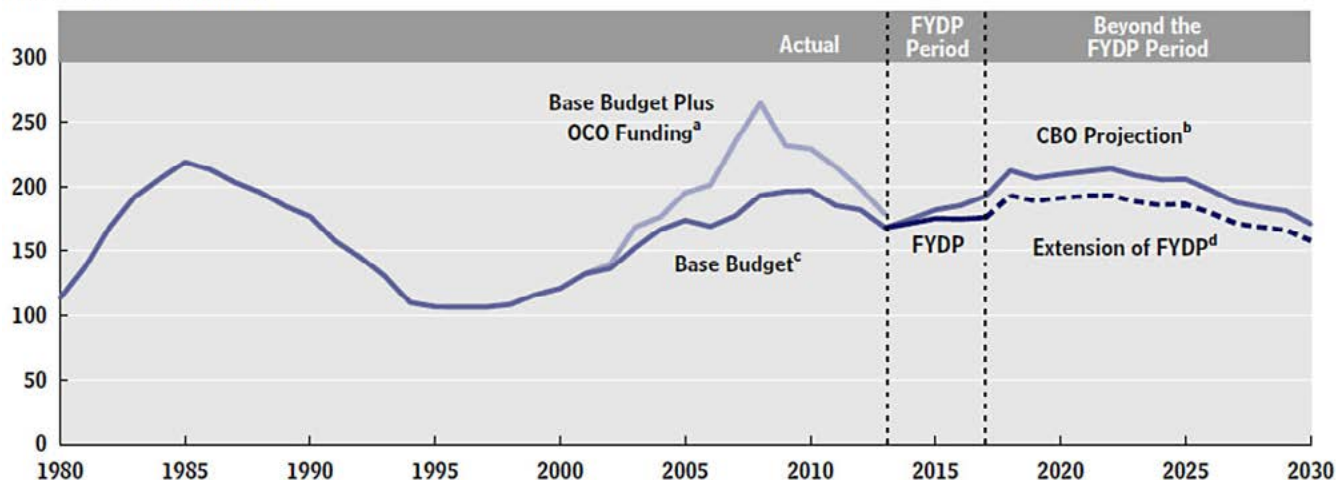


Figure 1.

Costs of DoD's Acquisition Plans, by Military Service

(Billions of 2013 dollars)

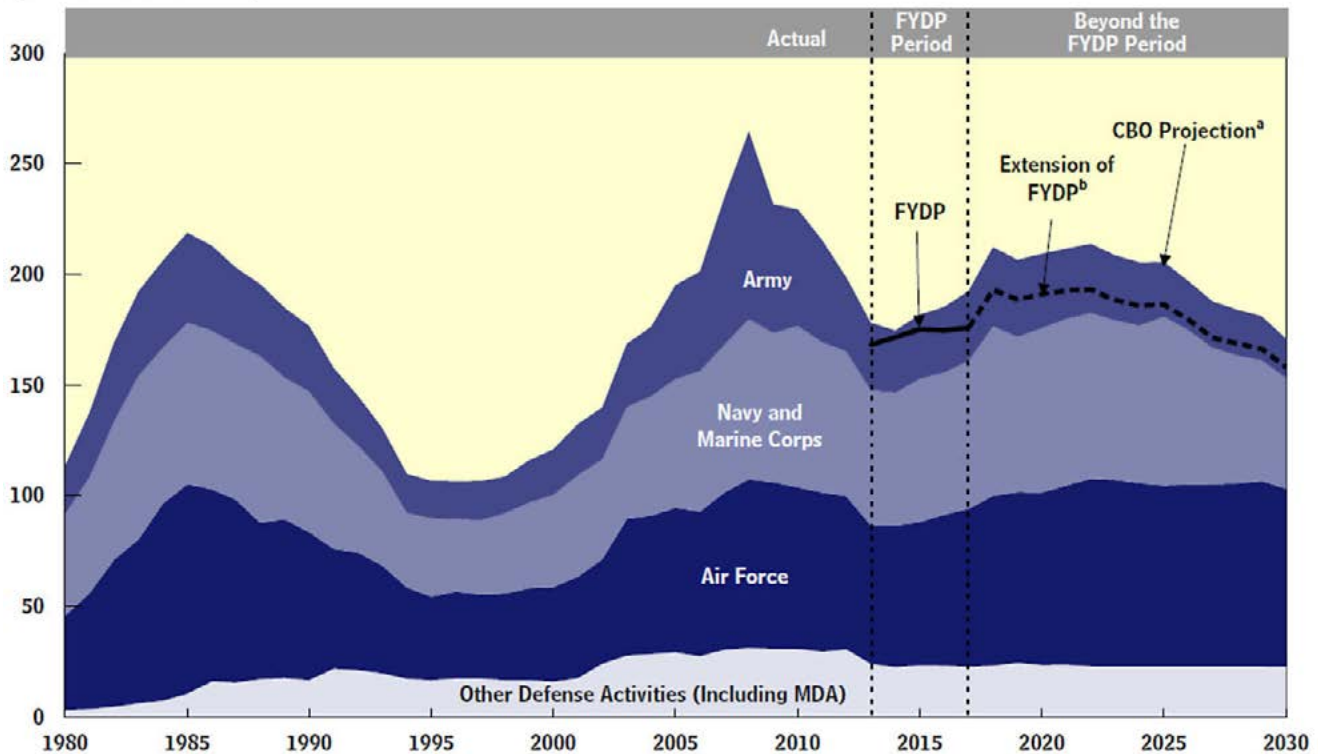


Figure 2: The three service budgets all-in. (Source CBO)

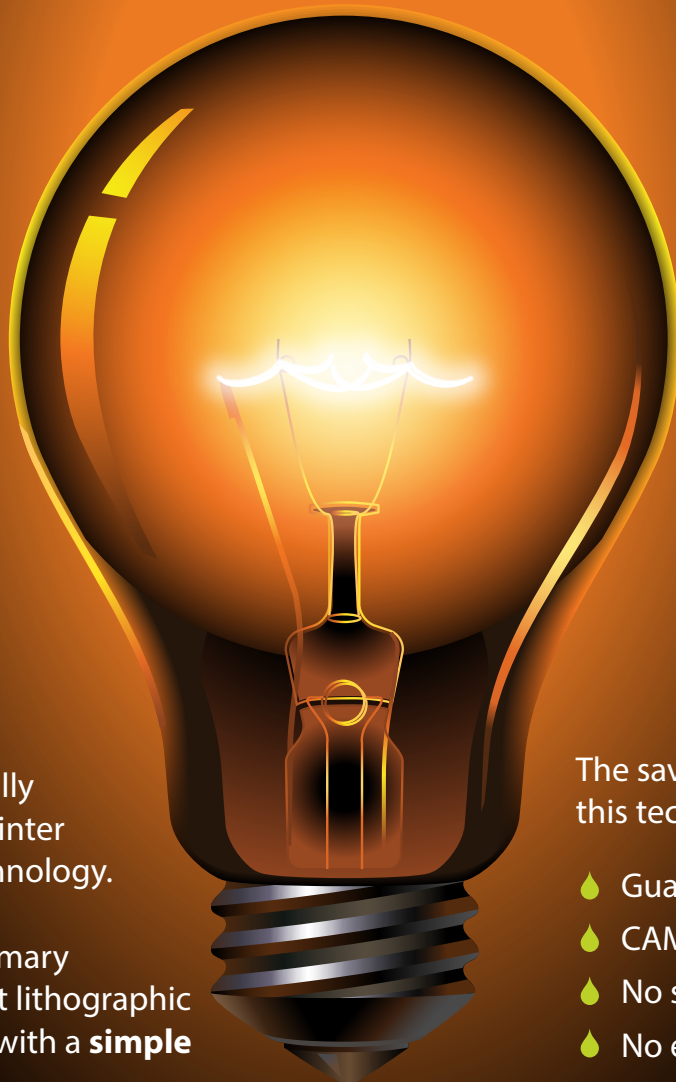
tactical vehicle is also on the menu for replacing 30% of the current HMMWV (Humvee) stock. In the C4ISR sector, Army will bias expenditures toward the Joint Tactical Radio (JTRS) and the Warfighter Information Network (WIN-T). Several types of unmanned aircraft and replacements for rotary and fixed-wing aircraft, and upgrades to Apache, Chinook and Blackhawk helicopters are also contemplated. The primary ordnance procurement will center on the Patriot Missile Segment Enhancement interceptor in quantities that essentially mimic the now-defunct MEADS program.

Navy's shopping list for ships will be centered in the surface combatant arena with emphasis on Littoral Combat Ships (LCS). The submarine force of the SSBN Ohio class will be replaced and the Nimitz class aircraft carriers are targeted for refueling and overhaul. In terms of aircraft, Navy will be spending a considerable chunk of its budget on F/A-18E/F, EA-18G and

the F-35 JSF, although the Joint Strike Fighter (JSF) has been delayed and quantities have been halved from initial procurement assumptions. There is also an expectation that a new design to replace the F/A-18E/F will enter the RDT&E phase by 2016. Significant numbers of air-launched and ship-launched weapons, including a substantial number of Tomahawk cruise missiles, are also part of CBO's projections.

Air Force has focused most of its budget assumptions on major modifications to existing aircraft, but also at increased production rates for the JSF and the KC-46A tanker. Of note, the UAV budget will see reductions due to the halt of production for the RG-4B Global Hawk and slowed production of the MQ-9 Reaper, but next-generation designs will emerge as the Reaper slows. A new long-range bomber is contemplated for downstream development and a new type of airborne troop transport is on the drawing table. The Minuteman III ICBM is due

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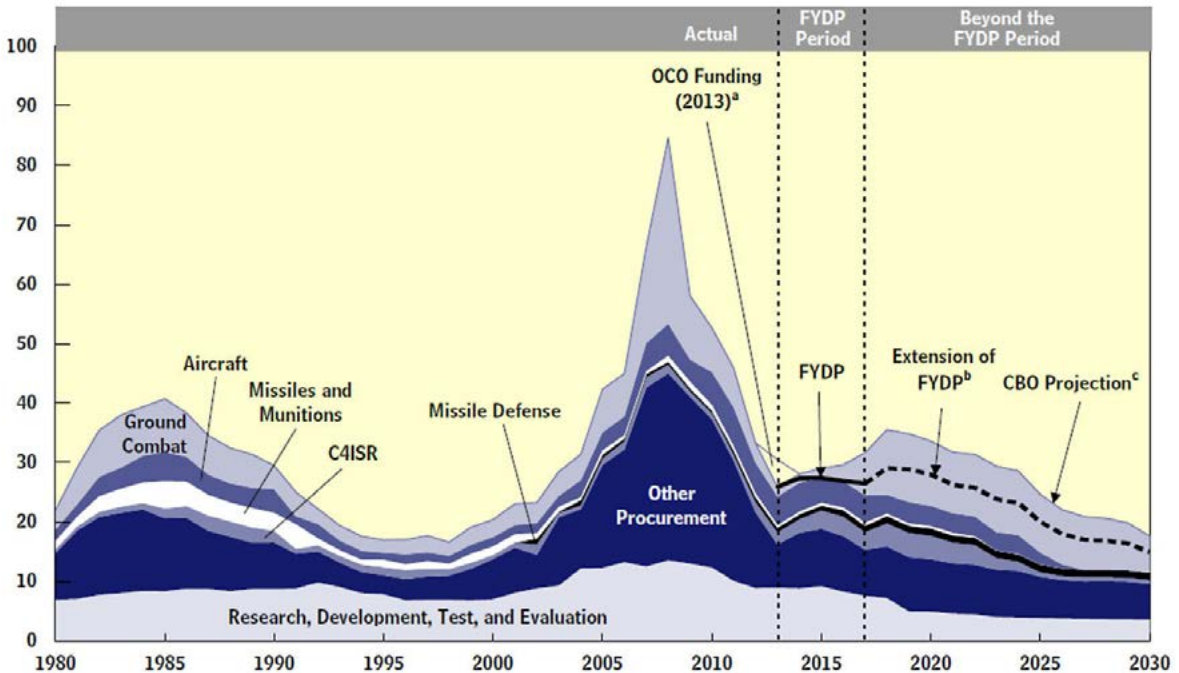
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Costs of the Army's Acquisition Plans

(Billions of 2013 dollars)



Figures 3–6: Each separate budget category. (Source: CBO)

Costs of the Navy and the Marine Corps' Acquisition Plans

(Billions of 2013 dollars)

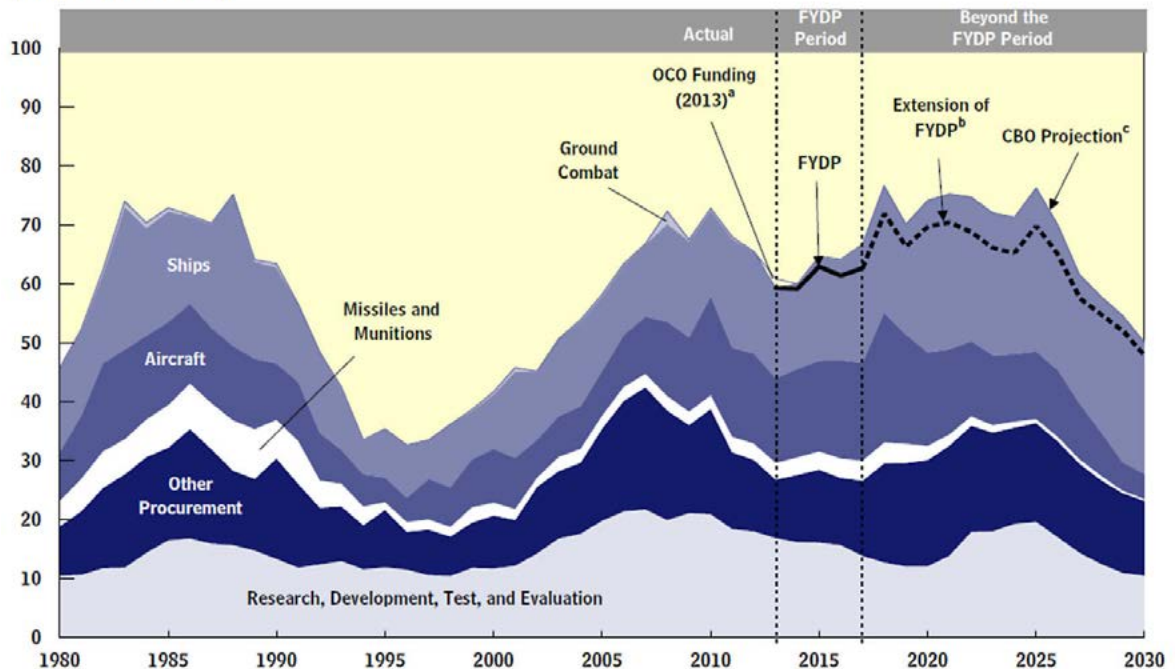


Figure 4.

Costs of the Air Force's Acquisition Plans

(Billions of 2013 dollars)

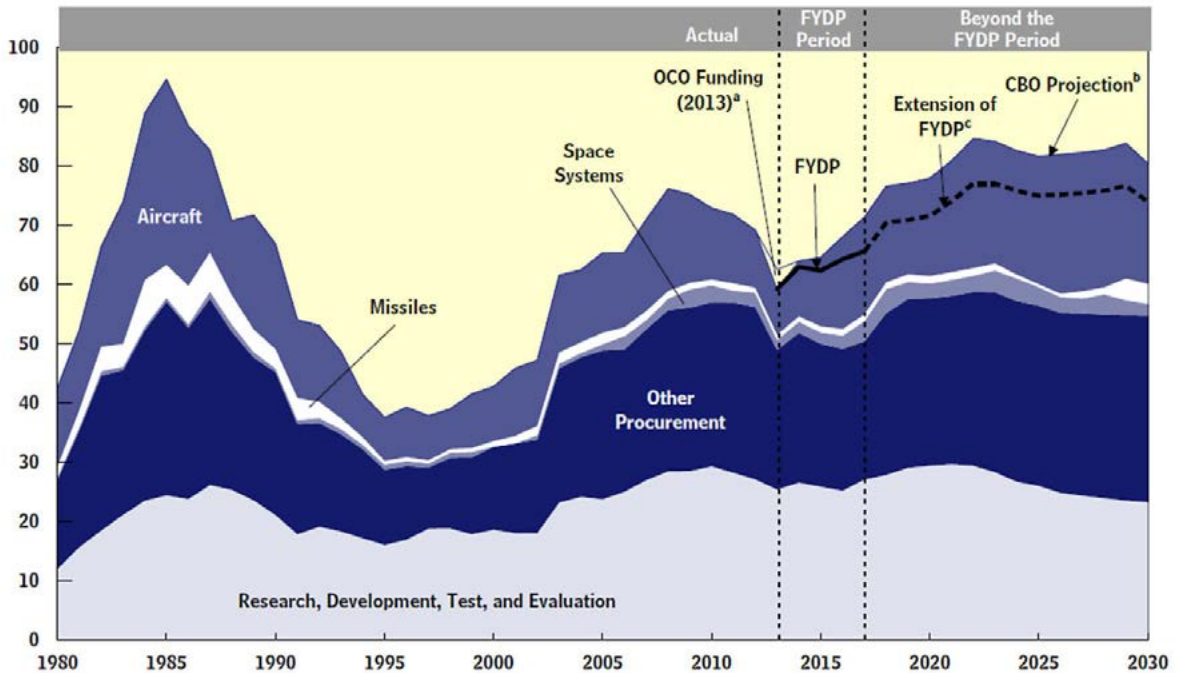


Figure 5.

Costs of DoD's Acquisition Plans Other Than Those for the Military Services

(Billions of 2013 dollars)

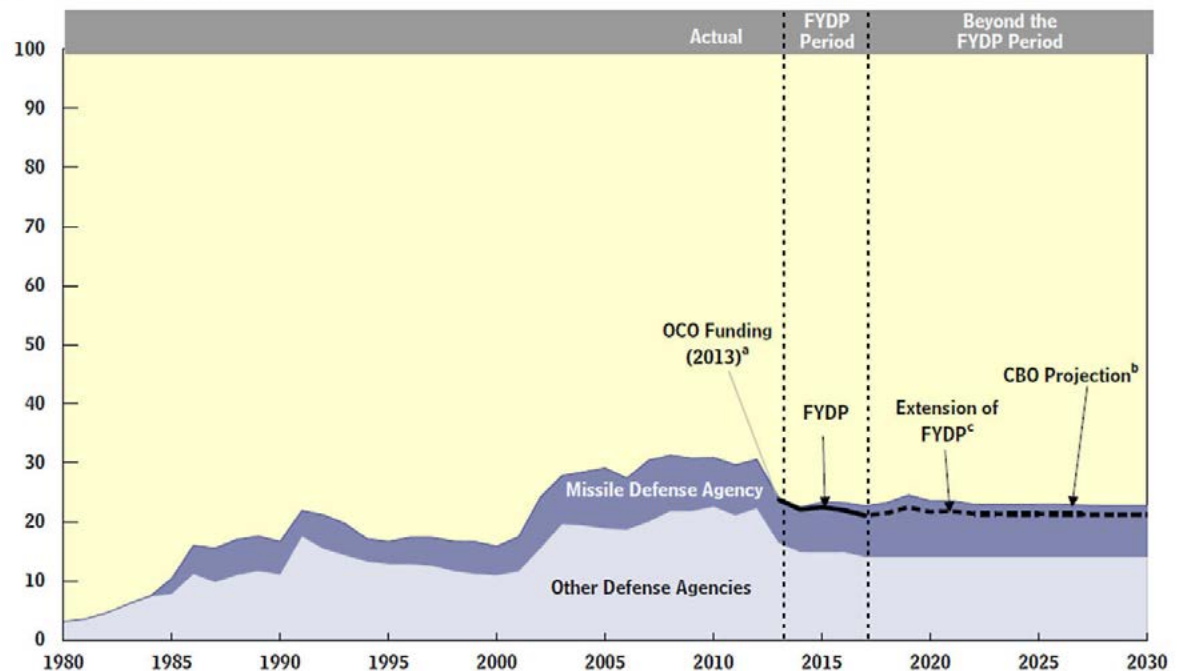


Figure 6.

to be replaced, as well as the nuclear-capable air-launched cruise missile. In space, the Advanced Extremely High-Frequency Satellites (AEHF) will see a block purchase of two satellites, as will the Space-Based Infrared System-High satellites.

The services and the platforms/programs mentioned above are chock-full of electronics and optoelectronics content. Note that these major programs are also accompanied by a whole range of other, unmentioned supporting programs and derivative devices buried deep within each service budget, albeit with a far more targeted cost and justification scheme tied to their development than a mere five years ago. But remember, there is still some \$195B in Procurement/RDT&E being spent, major portions of which are attributed to electronics and the dollars are certainly going somewhere. The key is discerning where they're being spent and how to qualify for involvement and to capture a share of those.

Supply Considerations

The aspect of sequestration, exiting Iraq and winding down Afghanistan, and economic pressures in general have conspired to assure that DoD priorities are now held under intense scrutiny for relevance, effectiveness, and, above all, cost. Defense is, however, also a major contributor of jobs by way of prime defense contractors and the supply bases they use for developing and manufacturing the myriad devices and platforms used by the armed services. So there is also a commensurate effort by Congressional members to preserve and foster job growth in their respective districts, which is often irrespective of a given platform's actual relevance. In this way, the Procurement budget has remained somewhat static as a percent of the overall DoD budget and seems quite likely to remain that way for the foreseeable future.

Of even more concern to the DoD is the preservation of the intrinsic industrial base of technology, manufacturing, qualification/certification, and primal knowledge banks that have allowed it to create and launch numerous systems that have provided the U.S. with strategic and tactical advantages in numerous conflicts. The prospect of losing those banks to arbitrary program closures, and administrative tourni-

quets applied to force readiness and projection, means that the DoD is also focused on creating ways to retain the talent and capabilities of indigenous U.S. suppliers. Adopting best commercial practices—ala the Perry Memo of 1994—is one of the ways the DoD is incorporating latest technologies and methods.

In addition, there is the potential for Foreign Military Sales (FMS) where certain countries and their Ministries of Defense (MoDs) may purchase designated platforms from the U.S. This holds the potential to keep manufacturing alive for some aging programs where foreign interest is high, but where our own interests are evolving to newer solutions.

All of these considerations paint a picture of refinement in the acquisition process in order to taper budget specificity, if not its overall size. But the need for ongoing supply of electronics can only grow in the face of trying to solve highly complex intelligence, surveillance, and reconnaissance demands. Couple those to the need for massive computing, IT, and cyber security, and it becomes an all but foregone conclusion that electrons and photons are quite simply the blood cells of the modern age of defense.

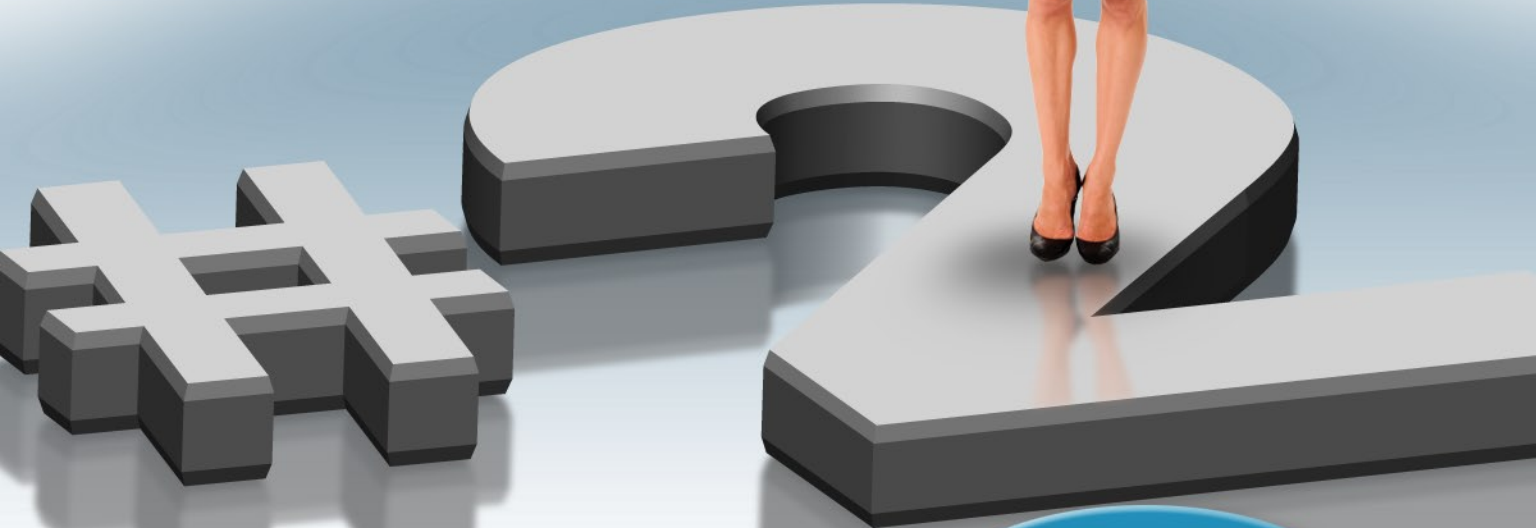
Technology and Doctrine Considerations

Moreover, it must be understood that the very nature of conflict and war is changing and the need for Normandy-like invasion forces with tens of thousands of vehicles and hundreds of thousands of personnel is largely a modern moot point. That requirement is slowly being displaced by technologies that have refracted large-scale—and expensive—campaigns into highly concentrated, SPECOPS-focused, rapid action, and intelligence-centric endeavors. (Witness the recent Delta Force capture of Anas al Libi or the Navy Seal operation against al Shabaab in Somalia, let alone the killing of Bin Laden.) Basically, large scale deployments are being offset by one-off incursions using super-trained professional military assets with increased precision, lethality, and surgically targeted operations.

The implications for these changes to the electronics/photonics industries harken to the need for accommodating data densities and data rates that manage at least the terascale,

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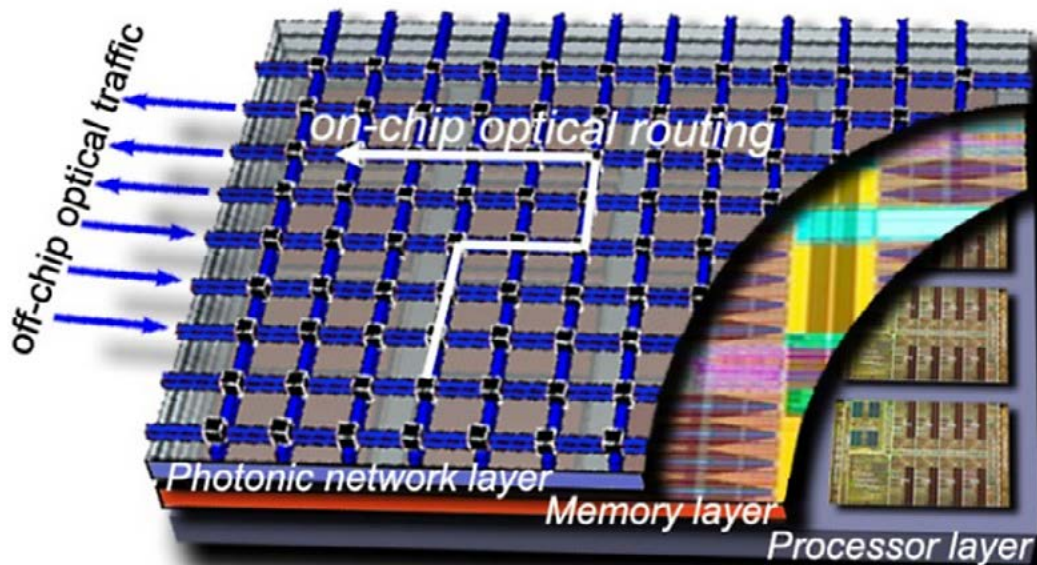


Figure 7: DARPA's E-PHI (electronic-photonic heterogeneous integration). (Source: IBM)

with emerging demands aimed at exascale performance. In a very few years, it will not be unusual to be reading of high-performance computing (HPC) applications involving up to 100 separate data channels operating at 10GHz–25GHz each and multiplexing data through wafer-level optical architectures and fanning out to the rest of the system through polymer waveguides in a circuit-board-like manifold.

There is no avoiding the absolute necessity to create, distribute, digest, interpret, and act-upon exponentially increasing demands for voice, data, image and video content. Whether between services, new and legacy platforms, or throughout the space-altitudes-ground-sub-surface layers of a battle space, it is the speed, quality and versatility of content flow that will determine the winners of the next generations of conflict.

Consider that DARPA's microsystems technology office continues to launch broad agency announcements aimed at developing ultra-low-noise lasers and optoelectronic signal sources at the semiconductor level. One such program, the E-PHI (electronic-photonic heterogeneous integration), involves developing a semiconductor incorporating a processor layer, a memory layer and an optical layer on the same chip due to the need to accommodate exascale computing.

In this way, there is—and will be—a place for problem-solving companies in the electronics industry that can tackle the so called big data problem. Whether it is at the component level, board level, assemblies, or integration level of any given platform or program, DoD money will be directed at those suppliers astute enough to proactively address the technological challenges while maintaining an affordable solution set. The best way to know if your company is suited to do either (or both) is to learn more about the drivers of the big data phenomena (also known as “More than Moore”) and engage the defense community with nothing more than a simple question: “How can we help?”

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Steve DeWaters is president of STRATEVU, Inc., a strategy and technology consulting firm specializing in the high-reliability electronics markets. He is a member of the Armed Forces Communications and Electronics Association (AFCEA), National Contract Management Association (NCMA), HANSCOM Air Force Base Representatives Association (HRA), and the National Defense Industrial Association (NDIA).



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The Intersection of Unmanned Vehicle Systems and Electronics Technology

by John Vaughan
CIRCUIT SOLUTIONS, LLC.

Summary: The attributes of flex and rigid-flex circuit technologies uniquely mesh with the size, weight and power (SWaP) and electronics packaging requirements and challenges of unmanned vehicle systems and robotics industries, which begs the question asked by AUVSI 2013: When the world of unmanned systems comes together, where will you be?

Widely recognized as the premier event for unmanned systems and robotics in the very near future, it was with great anticipation that I attended this year's [Association for Unmanned Vehicle Systems International \(AUVSI\) 2013](#)

event at the Walter E. Washington Convention Center in Washington, D.C.

With over 600 highly innovative companies exhibiting, it was an eye-opening view into an industry that is rapidly morphing and poised for tremendous growth. The technology being created, the potential markets, the myriad of applications and the momentum are all undeniable.

When most people think of unmanned systems, they think only of UAVs. The market is extraordinarily broader in scope than just UAVs, with a very large contingent of air, land and sea systems all on display at AUVSI, including: underwater vehicles and systems; unmanned ground cargo transport; snake cameras; robotic surveillance fish; bomb and mine defuse systems; shipwreck exploration systems; agricultural systems for crop surveillance; and



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search-and-rescue systems, among a multitude of other applications.

Leveraging existing technologies heavily, there is a very close and necessary marriage between unmanned systems and robotics, meaning the robotic paradigm of perception, processing and action is fully applied. This translates to a very high content of electronics being used not only in command and control of the unmanned systems, but also in: actuators; motors; sensors; vision systems; manipulation controllers; data acquisition cards; GPS systems; radar; LIDAR; video capture and processing; and inertial guidance systems. This is just a small sampling.

The question posed by AUVSI in their event advertising headline read, "When the world of unmanned systems comes together, where will you be?"

This is a very fitting question for manufacturers of flexible circuits, flexible heaters, rigid-flex circuitry, and electronics contract manufacturers. The attributes of flex and rigid-flex circuit technologies uniquely mesh with the size, weight and power (SWaP) and electronics packaging requirements and challenges of the unmanned systems and robotics industries:

- Flexible circuits and rigid-flex circuits allow unique designs which solve interconnect challenges
- The ability to fold and form flex and rigid-flex circuits enables a package size reduction
- Flex and rigid-flex circuits make installation and repair both practical and cost effective
- The number of levels of interconnection required in an electronics package is greatly reduced by utilizing flexible circuits and/or rigid-flex circuits
- A considerable weight reduction is achieved over wire harnesses and rigid circuit assemblies

- Flexible circuits dissipate heat at a better rate than any other dielectric materials

- The reduction in connectors and solder joints lowers costs and flexible circuits can be tested prior to assembly of components

The market potential for flex and rigid-flex circuit manufacturers to provide their products and services to the unmanned systems and robotics market was clearly noted by flex circuit and rigid-flex circuit industry leaders at the event, including: All Flex, Cirexx International, Eltek USA, PFC Flexible Circuits and Printed Circuits Inc. (PCI). All had a major presence at the event. Many of the event attendees were not familiar with flex and rigid-flex circuit technology, so there was a very steady stream of engineers asking detailed questions about the technology and expressing excitement at both the application potential and the extreme packaging configurations that could be attained with flexible and rigid-flex circuitry. (Note: Circuit Solutions, LLC. represents All Flex and PCI in the Washington military market.)

Equally impressive from my viewpoint is that the unmanned systems market is both invigorated and vibrant with youthful enthusiasm and entrepreneurship. I have been in the printed circuit board industry for more than 30 years and witnessed the decimation of the industry first-hand as U.S. shop after U.S. shop closed due to the offshoring of electronics manufacturing. This has all been well documented and I believe the cause and effect is well understood at this point. What is less well recognized is that with the offshoring of manufacturing (and subsequently much of the R&D), coupled with the closures, our industry has lost at least an entire generation of technologists, product development and new domestic manufacturing opportunities. Manufacturing lost both oppor-

Leveraging existing technologies heavily, there is a very close and necessary marriage between unmanned systems and robotics, meaning the robotic paradigm of perception, processing and action is fully applied.

tunity and its cool factor with our youth.

Helping to get the cool factor back into the equation, [The AUVSI Foundation Student Competition Pavilion](#) showcased student teams who compete in the Foundation's autonomous robotic competitions, including the International Aerial Robotics Competition (IARC), International Ground Vehicle Competition (IGVC), RoboBoat Competition, RoboSub competition, and the Student Unmanned Air Systems Competition (SUAS). This was a very high energy area and the technologies being developed and integrated by the student teams provided a further glimpse into the future of unmanned systems product development.

The pavilion also hosted a live demonstration of SeaPerch, the [AUVSI Foundation's Science, Technology, Engineering and Math \(STEM\) outreach program](#) for middle and high school students. Sponsored by the [Office of Naval Research](#) and managed by the AUVSI Foundation, the [SeaPerch Underwater Remote Operated Vehicle Program](#) is a fun and educational toolset for stimulating young minds about STEM through hands-on activities. Including a standard build curriculum for the vehicle and all necessary parts to fabricate the ROV, small underwater cameras and sensor suites may be integrated to capture video, measure and report underwater.

One perfect example of the potential resurgence in product development and manufacturing that exists in the unmanned systems market is embodied in three young men from North Carolina whom I met at AUVSI. Their company is [Bird Aerospace](#) and their product is the "Bird's Eye." Trevor Vita, 23; Matthew Most, 23; and the old man of the group, David Sanders, 24; have been friends since middle school. After high school, Vita and Sanders graduated from the University of California, Santa Barbara, with respective degrees in environmental science and software engineering. Most graduated from the University of California Los Angeles with a degree in mechanical engineering. These are bright young men with many career options. They are also young men who had an early interest in electronics and spent many hours as hobbyists tinkering with remote control aircraft, constructing and deconstructing



Figure 1: Bird's Eye launch.



Figure 2: Bird's Eye unmanned aerial system.

the crafts and their electronics, and like most young men of the era, at the joystick controls of PlayStation and X-Box.

Their background, education and entrepreneurial spirit create the perfect storm for prod-

uct development in the unmanned systems arena. After college, they also spent a combined seven years working hands-on in the military unmanned aerial systems (UAS) industry and realized that the existing systems were cumber-

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some to launch, difficult to maintain and insanely expensive. They set out to change all of that.

Their Bird's Eye UAS (Figure 1) is a revolutionary system that potentially puts very powerful technology into anyone's hands at an affordable cost. A, light-weight carbon fiber canister 12" in diameter and 2' in length houses the entire system. The Bird's Eye features a OneTouch deployment system which activates a small pyrotechnic charge that lifts the system to an altitude of 200–300 feet, where the canister splits in half and a 56" wing unfolds locking into a rigid airframe. Autonomously flowing, the operator simply uses a map/terrain overlay on a tablet or laptop to direct the aircraft on its mission. The total deployment time is 30 seconds and the operator needs only a clear view to the sky to launch. The Bird's Eye is deployable anywhere: forest, urban environment, at sea, from the air, from the desert, from high elevation and uneven terrain. With a set-up and deployment time of less than 30 seconds and a top speed of 120 mph, the Bird's Eye is potentially on the scene faster than any other small UAV to-date. Bird Aerospace's initial target markets are search and rescue operations, border patrol surveillance, agricultural surveys, forest fire management, and polar ice research/reconnaissance.

As with any emerging industry there are regulatory challenges. Setting aside the privacy issue for now, the UAS industry's key challenge is the integration of UAS technology into the National Airspace System (NAS). The Federal Aviation Administration (FAA) was tasked with solving this challenge in 2012.

To better understand the regulatory challenges, the timing, the wide variety of unmanned systems applications, the markets and the economic impact of UAS, I would suggest

downloading the AUVSI's March 2013 report, titled [The Economic Impact of Unmanned Aircraft Systems Integration in the United States](#).

Clearly, the unmanned systems and robotics market provides an excellent business opportunity for manufacturers of flexible circuits, rigid-flex circuitry and electronic contract manufacturers for the foreseeable future. There is already wide-scale adoption of some of the unmanned ground and sea systems and the robotics. As regards the integration of the UASs into the NAS, the issue is not whether these products will be adopted, but simply at what rates they will be adopted.

Just as importantly, as the care holders of the industry that has perfected these amazing circuit fabrication technologies, we have an outstanding opportunity and a responsibility to both guide and contribute to its rapid growth. Through sharing our acquired knowledge with the new generation of technologists that is evolving in concert with the development of many of the unmanned platforms, we can provide interconnect and packaging solutions, provide a manufacturing knowledge base, grow our own businesses, and most importantly, support job growth and economic growth in the USA. **PCB**

The total deployment time is 30 seconds and the operator needs only a clear view to the sky to launch. The Bird's Eye is deployable anywhere: forest, urban environment, at sea, from the air, from the desert, from high elevation and uneven terrain.



John Vaughan is president of Circuit Solutions LLC., based in the Washington D.C. metro military market and provider of integrated supply chain and program management solutions to the military C4ISR, Unmanned Systems and IED detect and defeat communities. Vaughan may be reached at john@circuit-solutions.com.

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Applications Engineering for Military & Aerospace

by **Ashley Luxton**
GRAPHIC PLC

Summary: Current functionality demands mean that designers and engineers no longer have the luxury of keeping designs simple and sticking with known technology; in fact, increasingly more designers are now among the first to try new technology, and become innovators rather than followers. Applications engineering services help bridge the safest, most cost-effective designs possible with performance requirements.

Military/Aerospace Requirements

When designing PCBs for the mil/aero segment, some specific, and often unique, requirements need to be considered.

Operating environments can be harsh, with conditions and temperatures ranging from desert to arctic. Humidity levels may also vary, as well as levels of vibration—either from the platform in which the PCB is installed, or from handling. And rather than being able to design the PCB to handle a particular environment, it must be designed to cope with the full range of these conditions throughout its life.

Additionally, it's quite possible that the assembled unit could sit on a shelf for months, or even years, in any one of these environments, and then be expected to perform perfectly—at a moment's notice, and continue performing for years.

The key aspect of mil/aero is, of course, reliability. Many systems will be life critical—either in terms of keeping an aircraft in the air, or ensuring that a missile hits its intended target (and doesn't detonate before or during launch). This, in contrast to consumer electronics, which will generally operate in a benign environment and have a comparatively short life expectancy, with the consequence of failure being little more than inconvenience.



The environment for industrial electronics may be a little more demanding, with vibration and temperature perhaps coming into play, and a board failure could result in significant financial loss, but even this doesn't compare with the long-term reliability requirements of the military and aerospace industry.

The Importance of Applications Engineering

In the past, where high reliability was required, the circuit board would have been designed with minimum complexity. High-reliability industries would have been reluctant to embrace new technologies until they had been well proven in the field.

Today, demands for functionality mean that designers and engineers no longer have the luxury of keeping their designs simple and sticking with technology that has been tried and tested over many years. In fact, the pace of change means that increasingly more designers

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are now among the first to try new technology, and become innovators rather than followers.

With the increase in board technology and complexity comes an increased need to ensure that it is designed with manufacture in mind. Applications engineering services must specifically help designers produce the safest, most cost-effective designs possible, while achieving their performance requirements. This benefits both the customer and designer by ensuring that risks in manufacture, and in service and cost, are optimised. The two go very much together, since ensuring the lowest risk often requires additional processes, and hence, costs. However, these costs are well worth it when weighed against the potential cost of the board failing in the field due to the increased risk involved with a compromised process. The fabricator benefits too, by receiving designs that are optimised, allowing greater efficiency through both the front end and manufacturing processes, and resulting in optimised yields.

The customer again benefits via on-time delivery and cost control.

How it Works

This process is based on two-way dialogue between the designer and applications engineer at an early stage in the design process. This is important, as it is all too easy for a design to be started and a board structure set, which then turns out to be compromised, and unnecessary risks introduced simply because it would be too much work at a late stage in the design to go back and change it.

By engaging in this dialogue early in the process, the designer can be made fully aware of the fabricator's manufacturing capability, and design the board accordingly. This applies not just to the relatively simple things like track/gap/annular ring, etc. (this is usually available on a fabricator's website), but it's how these things work in combination with the overall proposed design, considering board type, material, via structure, power requirements, etc.

By incorporating best practice right from the beginning, there is no need to spend the time correcting a design later, which can lead to significant changes, excess paperwork, cost, and delays if the design has already been issued.

The Role of Applications Engineering

One of the most critical aspects of applications engineering is advising on drawing and documentation specification. This is partly with the aim of ensuring that information is clear and concise with no ambiguity so as to minimise the opportunities for error and misunderstanding, but also to advise on the relevant quality standards that should be called up.

There has been something of a move away from the traditional MIL specifications towards IPC. This has in no way made the quality requirements any more straightforward, as most of the requirements are on a par with MIL. In fact, in some ways it has made it more confusing because many people don't have a full understanding of IPC specifications. It is easy to specify IPC on a drawing, but for this to be really meaningful the design has to have been based around IPC from the start.

With quality systems like AS/EN9100 and NADCAP, there is even greater need for the drawings to be correctly specified, and all requirements fully understood.

In conjunction with advising on the quality standards and requirements, applications engineers also advise on the design rules required to ensure that those quality requirements are met. This can also be a difficult job since those that are fully aware of IPC are often happy to work to exactly what it says, without taking into account that IPC doesn't really allow for many of the more complex board technologies commonly in use in the military and aerospace industries these days. For example, IPC gives land size requirements based on three different producibility levels, but doesn't differentiate between a simple through-hole multilayer and a multiple sub-assembly SBU HDI design. These more complex constructions have a significant impact on registration and producibility, and hence this has to be allowed for in the land sizes at the outset.

IPC correctly states that the more difficult producibility levels should only be used where necessary, but this is often overlooked with the tightest possible feature sizes being used throughout the board. To ensure optimum yields, saving cost and improving delivery performance (which is in everyone's interest) fea-

ture sizes should be optimised and increased where there is room to do so. Minimum feature sizes are just that—minimums—and should not be the standard.

Applications engineering also includes advising on the materials to be used. This is partly driven by the customer's requirements, but the fabricator's experience should also be considered, where possible, using materials that are available to the fabricator and which they have good knowledge of. In theory they would be quite capable of using a material that the designer may have selected by researching on the web, but they may need to run process trials first—increasing lead-time, experiencing poor yields due to inexperience with the material, and possibly having to pay more for that material than an equivalent that they do have knowledge of simply because it is from an unfamiliar supplier.

With the fairly recent trend towards higher-speed materials, this experience is perhaps even more important. There is now a wide range of high-speed materials on the market, and the data sheet can only tell so much. A material that has very good electrical properties may not perform well from a reliability point of view when subjected to thermal stresses, particularly in more complex structures. Data sheets can give an indication of which materials may be better than others, but experience with the material is the only way to really know how it performs.

The most widely used aspect of applications engineering, and one of the most important, is providing constructions. The reason is because different fabricators may have different preferences for construction based on their experience and capability. There can also be differences in the way impedance is calculated, and generally speaking, the fabricator will calculate the impedance to give the most accurate results for their particular process. This may not tally with other calculators or other fabricator's calculations.

The construction is also important as it is very easy at this point to either build in unnecessary cost, or unnecessary risk by making the construction too complicated, or simply not suited to a fabricator's preferred manufacturing method.

As well as being fundamental to a fabricator's ability to manufacture a given board, the construction will also have a significant impact on the fabricator's ability to meet the various quality requirements; things like minimum dielectric separation are fairly obvious, whereas the impact on wrap plating and registration is not so obvious.

For these reasons input from the fabricator is vital at this point.

As mentioned earlier, it is important to have the controlled impedance calculated, or at least checked, by the fabricator. Their calculations will be tailored to their processes to give the most accurate results. Achieving the given impedance a requirement basically comes down to the stack-up and the line widths. It is important to achieve the impedance with minimal compromise to either as it is otherwise quite possible to

engineer a situation where the impedance tolerances can't realistically be achieved, or yields can be reduced by compromised registration, dielectric separation or track/gap definition.

Panelisation is, of course, essential to cost, but can also have an impact on manufacturability in the case of more complex constructions and it will also have an impact on the assembly of the boards. If the assembly is to be done by a CEM, there should be discussion with the board fabricator and the CEM to ensure that all requirements are met without compromising either the manufacturability, or the ease of assembly.

Historically, cost was less of an issue for the mil/aero industry, but in the current climate it is becoming more and more important. As discussed previously, it is very easy to build unnec-

“
Panelisation is, of course, essential to cost, but can also have an impact on manufacturability in the case of more complex constructions and it will also have an impact on the assembly of the boards.
”

essary cost into a board, and applications engineering can help to optimise this. Sometimes an increase in cost is needed to reduce risks, and this needs to be weighed against the cost of failure, or possibly the knock-on cost of a more complex assembly process.

Having involvement in the design from an early stage is absolutely the best way to ensure success, but it is always possible for something to be overlooked, or design rules compromised due to a misunderstanding. If the data has been formally issued it can be a time-consuming process to make changes if errors are picked up during the fabricator's front-end tooling process, as well as of course introducing delays in the lead-time. To try and reduce this risk another service that applications engineering offers is a review of the completed data set prior to formal data release and order placement. Often this review will not be as thorough as the full DRC analysis that takes place during front-end tooling, but it can help to pick up any key issues and allow these to be corrected more easily.

If issues with the way the data has been supplied occurs, in terms of the way the features are created in the data, this can also be fed back. The presentation of data, particularly in the case of plane data, can have a huge impact on the processing time at the fabricator. This is yet another aspect of applications engineering that can give benefits all around by improving efficiency and lead-times.

With applications engineering, Graphic PLC has been able to successfully bring these technologies to key military projects such as the European Fighter -Typhoon, Joint Strike Fighter-F35 and also key aviation programmes such as A380 and A350. **PCB**



Ashley Luxton is an applications engineer at Graphic Plc Group and 18-year veteran in the PCB manufacturing industry. He may be reached at aluxton@graphic.plc.uk.

VIDEO INTERVIEW

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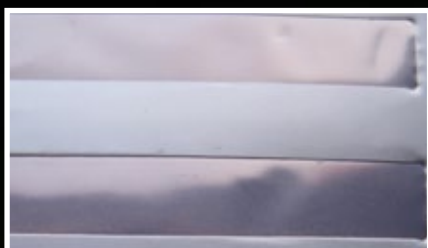


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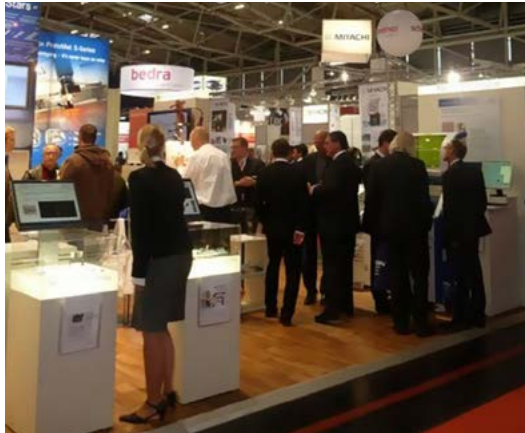
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Productronica 2013: Is it still needed?

by Michael Weinhold

TECHNICAL DIRECTOR, EUROPEAN
INSTITUTE OF PRINTED CIRCUITS



In 1975, productronica was created as a spinoff from electronica. Since then, the show has taken place in intervals of two years in Munich, Germany, despite the fact that most (more than 87%) of the global PCB fabrication market has since moved to Asia. My question is this: "Why is the largest show for electronic manufacturing technology and equipment held in an area that represents only about 5% of global PCB fabrication?"

The answer to this question is not simple. However, when we look at history, we will understand that manufacturing technology is engineering-driven. Here, Europe plays a major role in developing new products for automotive, medical, industrial, and military/avionic electronics. These advanced electronic devices require tools and chemistry in manufacturing that are well engineered. Without question, the European specialists have excellent engineering skills needed to manufacture the right tools (equipment) needed to build advanced PCBs and interconnect solutions (PCBAs). Here, the component assem-

bly technology and the technologies for cable processing as well as soldering and test/measurement are key items for quality assurance in the electronic field.

Companies like Atotech, Orbotech, Gebr. Schmid GmbH & Co., Dow, Schmolz, Huntsman and many others have their origin or R&D centre in Europe. In addition, large automotive manufacturers are also located in Europe as are the suppliers to this industry. To satisfy the needs of this industry in the global market, a strong innovation potential for the local electronics industry and the PCB fabricators and assemblers are needed.

During productronica 2013, visitors will learn what this and many other industry sectors require in terms of process technology, material and equipment to manufacture PCBs, hybrid components, LED devices and discrete components, production and processing software, production logistics and material-flow technology, electronic manufacturing services (EMS), photovoltaic manufacturing, battery and energy-storage manufacturing, organic and printed electronics as well as semiconductor and display manufacturing technologies.

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Viasystems Opens World-Class Factory in California



Figure 1: Viasystems' Anaheim facility.

by Ray Rasmussen
PUBLISHER, I-CONNECT007

On October 14, I joined Walt Custer and Dr. Hayao Nakahara (Naka) at the grand opening and factory tour of Viasystems' new HDI PCB facility in Anaheim, California.

The Technology

Before the tour began, Rajesh Kumar (Raj), VP of technology, presented on the capabilities of the new factory; it was impressive, to say the least. They've obviously been listening to their customers and incorporating the latest technologies to ensure they can deliver what's needed: LDI, small-hole capable mechanical drills, lasers, advanced plating systems, etc., along with all the processes you would expect in a high-end board facility. Kumar pointed out that what

really separates them from the competition is their "secret sauce," comprised of Flat-Wrap™, ThermalVia™, NextGen Sub-link™, and NextGen HDI-Link™ along with Ormet's sintering paste (with modifications), etc. Of course, the secret ingredients were alluded to, but not discussed.

The Tour

Plant Manager Ruben Zepeda led the tour, and his passion for this new facility was evident. He and his team had to build this factory while continuing to run the old one, a few blocks away. Although, I'm sure, there were a ton of headaches associated with this project, the pride that both he and his team felt was palpable as he walked us from process to process. Years behind schedule (the building required earthquake retrofits) and way over budget, it

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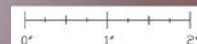
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looks like the new factory is finally ready to take on all comers.

Designed to consolidate the sprawl of 13 buildings that used to represent DDI's PCB business, the new factory is housed in an ex-MFLEX site and was constructed from scratch. This enables the company to service its very high-end customers, both military and commercial OEMs, who are looking for the latest in HDI, high-reliability PCBs for their products.

Of course, we were looking at a brand new factory, so everything was shiny and sparkling clean with new, rebuilt or fairly modern equipment transferred from their old factory down the street. Certainly, the cleanliness, the new equipment and the technical capabilities were impressive, but quite frankly, expected (you can't tout your commitment to the leading edge without them). What grabbed and held my attention, though, was the process flow. As Zepeda pointed out, they had worked hard to minimize the distance traveled by each and every panel. And since many of their boards require multiple laminations (less, now with the use of sintering paste) and plating steps, great care was taken in co-locating process steps, which need to be repeated to make the complex structures required. The linear process flow you might see in a Chinese megafactory won't work here. They're building very sophisticated boards requiring tons of engineering and technical knowledge.

Touring a factory with Custer and Nakahara was quite an experience as they shared their stories of past PCB adventures. Walt's perspective comes from his 30-40 years as a PCB supplier, while Naka, who began working at Photo Circuits in the '60s, represents the fabricator's viewpoint. Of course, Naka's understanding of the global PCB industry, continuously informed by visiting factories around the world, is unmatched and kept us all up-to-date on the latest developments. As a result, Naka's perspective was unique in that he's toured quite a few of the mile-long factories you come across in Asia. But after the tour, I believe it's safe to say that Naka was impressed, as were Walt and I. The first-class technical capabilities, process flow, engineering, waste treatment, and more importantly, people, provided a complete PCB package. It's all there.

The new factory is approximately the same size as the series of buildings a few blocks away, but has eliminated many of the headaches associated with that multiple building configuration, allowing for much tighter security (ITAR), better environmental controls over the boards as they travel through a single building, and flow improvements as product is moved as little as possible from process to process. The operational efficiencies have also increased capacity. Now, producing around 200 panels a day of complex, high-layer count HDI boards, Zepeda wasn't willing to share a specific number, but felt the factory could handle expected growth for the next



Figure 2: PAL electroless plating line.



Figure 3: IS Deburr line.



Figure 4: Chemcut etcher.

five years or more. I would suspect that doubling from 200 to 400 panels per day is possible.

Zepeda stated that they had spent about twice what they had originally estimated, but, as a result, there were no compromises in the final factory. It is the best they could make it. When asked about the investment, Viasystems CEO David Sindelar pointed out the PCB industry has stabilized over the last few years. What's left will remain, most likely here, and some segments will actually grow. For their commercial customers, factories like the new Anaheim facility will give them the R&D, ramp-up capabilities needed before they release volume production to Viasystems factories overseas. For the military, this ITAR plant will help customers develop the products of the future with security and confidence. And, as you would expect, this high-end factory has the potential to generate serious profits.

HDI Coming of Age

For years, Naka and Happy Holden have decried the fact that the U.S. was placing little or no effort into HDI boards. Happy continuously spoke at conference after conference espousing the benefits of HDI to the PCB design community and penned a 600-page technical book on the subject (www.hdihandbook.com). Naka's regular update on the number of lasers

located in Asian PCB facilities as compared to the U.S. seemed to always be a point of frustration for him. There were thousands in Asia and just a handful in the U.S. He could see the technology and the market continuing to elude many U.S. fabricators as Asian suppliers now had the tools to deliver the technology of the future. He felt that the U.S. fabricators would get further and further behind. Of course, the reason there aren't many lasers here is that the market for HDI was mostly overseas, driven by chip packaging

substrates and mobile devices. The U.S. market, dominated by industrial, military, and commercial OEMs hasn't been so interested in smaller, lighter, boards. They didn't want to pay the premium for HDI. But that's changing.

Now a big mil/aero supplier after its recent acquisitions of Merix and DDi, Viasystems is being pushed to the edge of HDI as lightweight, highly capable electronics drive military systems. Medical systems, too, are pushing the envelope as increasingly more electronics are being used inside the body. About one-third of Vias' Anaheim customers require class III boards. In both the military and medical cases, they need the boards to be highly reliable, capable, lightweight and small.

Viasystems' new factory complements its other U.S. manufacturing sites acting as not just a high-end production facility but as an R&D center to develop the next-gen PCBs. Kumar and his team are driving this effort.

Merix, DDi

Since we spent quite a bit of time with the execs of the company, I asked about the reasoning behind their U.S. acquisitions and expansion plans. They pretty much stuck to what's been said in the past: that they really needed a U.S. presence to support their volume manufacturing in Asia. Add to that the expansion

into new markets like military, aerospace, medical, etc., which Merix and DDi provided along with access to over 3000 new customers, and it seemed like a logical move. Of course, Vias' board thought Sindelar was crazy at the time, having spent the prior decade moving manufacturing out the U.S. and Europe, to China. Eventually, they came around.

When asked about what was next, it wasn't surprising to hear that China isn't as attractive as it once was. Sindelar's view of most other low-cost Asian locations wasn't all that positive, either. He didn't mention any specific plans for expansion, but it was interesting to hear his take on things. He didn't have much to say about new, exciting locations for future factories.

The Non-Value Added

One thing is for certain, Viasystems has made a very serious commitment to high-tech manufacturing in California and in the United States. And with that comes the higher cost of



Figure 6: Fume scrubber.

doing things right. A solid program for waste management is critical in California, though manufacturers didn't always tout their waste disposal capabilities as highly as their technical capabilities. Neither customers nor regulators turn a blind eye to pollution. It's a really big deal. As a result, they've made a significant investment to deal with wastewater as well as air quality. Emad Youssef, VP EHSS and Quality, showed us the state-of-the-art systems designed to keep

the company in compliance with the very strict rules required of manufacturers in California and especially in the Los Angeles basin. The wastewater treatment system is designed to return 50% of process effluent (30 million gallons of water per year) back to the factory floor, which provides them with some return on their investment. In fact, what's returning is DI water, which is actually cleaner than the original water, ultimately reducing the cost of process chemistries, as well, by extending bath life. It certainly isn't to the point where they're offsetting the cost of waste treatment, but reducing water usage certainly helps. Water's expensive in Southern California.



Figure 5: Water and chemistry.

Timing is Everything

I'm sure the recent bankruptcy of Endicott Interconnect Technologies didn't go unnoticed by the Viasystems team. Traveling in similar circles, the two companies competed for many of the same customers. With EIT out of the way, at least in the short term, Via has time to ramp up their new facility to take advantage of the opportunity. To hit the ground running just about the same time one of your major competitors closes its doors is pretty fortuitous. You can't plan something like that.

Let Bygones be Bygones

When talking about Viasystems, if you've been around awhile, there's a tendency to want to revisit the past. Sindelar has been an exec with the company since it was founded and is quite aware of the missteps that led to the company's bankruptcy and rebirth, which I believe makes a leader and a company stronger. It sure seems like they've gotten their act together. They're also demonstrating their commitment

to the N.A. market again with this significant investment.

Crazy Like a Fox

But I have to say, from the outside looking in, it does seem a bit daft for any PCB company to be investing in the United States. North American OEMs haven't been very loyal to their U.S. suppliers. It's been a rough ride for those PCB fabricators who've survived the Chinese exodus. Building a state-of-the-art factory in the U.S. isn't what you would expect to see. What's more, they built it in California. And not just in California, but in Southern California, which is notorious for very strict environmental standards and significantly higher costs of doing business. How crazy is that? Time will tell.

All in all, it's an impressive factory. They've done a really good job and spared no expense. You can only hope that they will be rewarded by their customers for this commitment to not only them, but also the North American electronics industry. **PCB**

Synaptic Transistor Paves Way to New Kind of Artificial Intelligence

It doesn't take a Watson to realize that even the world's best supercomputers are staggeringly inefficient and energy-intensive machines.

Our brains have upwards of 86 billion neurons, connected by synapses that not only complete myriad logic circuits, but they continuously adapt to stimuli, strengthening some connections while weakening others. We call that process learning, and it enables the kind of rapid, highly efficient computational processes that put Siri and Blue Gene to shame.

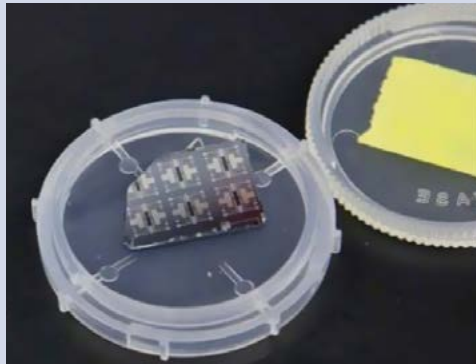
Materials scientists at the Harvard School of Engineering and Applied Sciences (SEAS) have now created a new type of transistor that mimics the behavior of a synapse. The novel device simultaneously modu-

lates the flow of information in a circuit and physically adapts to changing signals.

Exploiting unusual properties in modern materials, the synaptic transistor could mark the beginning of a new kind of artificial intelligence: one embedded not in smart algorithms but in the very architecture of a computer. The findings appear in *Nature Communications*.

"There's extraordinary interest in building energy-efficient electronics these days," says principal investigator Shriram Ramakrishnan, associate professor of materials science at

Harvard SEAS. "Historically, people have been focused on speed, but with speed comes the penalty of power dissipation. With electronics becoming increasingly powerful and ubiquitous, you could have a huge impact by cutting down the amount of energy they consume."



PCB007 Supplier/New Product News Highlights



[Isola Debuts TerraGreen Laminates and Prepreg Materials](#)

Isola Group S.à.r.l., a market leader in copper-clad laminates and dielectric prepreg materials used to fabricate advanced multilayer PCBs, has announced TerraGreen, the company's new halogen-free, ultra-low loss, RF/microwave/high-speed material.

[Ventec Debuts New Aluminum-based Thermal Dielectrics](#)

After the 2011 introduction of the moderately-flexible, yet highly-thermally-conductive VT4B3 at 3.0W/mK, Ventec engineers understood the need for a more flexible substrate to meet the demands of the latest 3D lighting designs while also seeing demand in the other direction—the high power needs of advanced lighting designs.

[Aismalibar's Flextherm Earns UL Certification](#)

Eduardo Benmayor, managing director, says, "3D designs with bendable insulated metal substrates are on the cutting edge of technology. Many leading OEMs and CMs are currently utilizing the capabilities of Flextherm to meet their thermal management objectives. We are extremely excited to continue working closely with design engineers to further develop their products."

[FabStream: PCB Library Expert Now Supports SoloPCB](#)

PCB Libraries has released a new free version of the Library Expert that creates IPC-7351-compliant footprints for FabStream's SoloPCB Design Software. The Library Expert is easy to use and requires a very short learning curve so PCB designers can use it effectively and quickly.

[American Standard Circuits Acquires First EIE Photoplotter](#)

Chicago-based circuit board manufacturer American Standard Circuits, Inc. (ASC) has announced the recent purchase a First EIE RP212+XT photo plotter. The new acquisition will allow the company to increase process capability as well as overall throughput.

[Rogers Recognized as Top CT Tech Company](#)

Rogers Corporation, a global technology leader in solutions for power electronics, advanced foams for cushioning and protective sealing, and high-frequency printed circuit materials, has been named one of the top 40 tech companies in Connecticut by the Marcum Tech Top 40.

[Atotech Marks Milestone with Sale of 750th Plater](#)

Atotech is celebrating the sale of its 750th plater. The jubilee plater is part of a Cu18 IP2, UTS-xs, with right-left process flow direction at 1.5 m/min and will be used for super-filling, BMV filling processes and conformal plating.

[FabStream, Eagle Circuits Form Partnership](#)

"We see our partnership with FabStream as a natural extension of our one source, end-to-end manufacturing solution," said Nilesh Naik, president of Eagle Circuits. "FabStream and the SoloPCB Design suite, including the extensive Digi-Key libraries, offer our customers a unique value added opportunity for rapid and low cost PCB prototyping."

[Career Selects Orbotech Paragon LDI System](#)

Commenting on the collaboration, Rick Wu, president of Career, said, "Utilizing Orbotech's advanced technology enables us to expand production capabilities to serve our most demanding customers as their requirements become more challenging. By partnering with Orbotech, we ensure the best production accuracy and cost of ownership."

[Interdyne Systems Releases K6 Line of Mechanical Drills](#)

The systems are replete with innovations that contribute to overall stability, increased productivity, and lowered operating costs. With an emphasis on stability as a guiding principle, the Flying Winga architecture is the central component of this novel approach to system design, which utilizes aerospace and aviation construction techniques.



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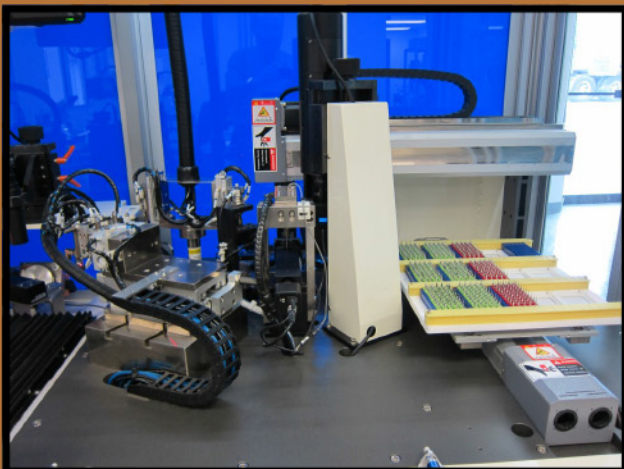
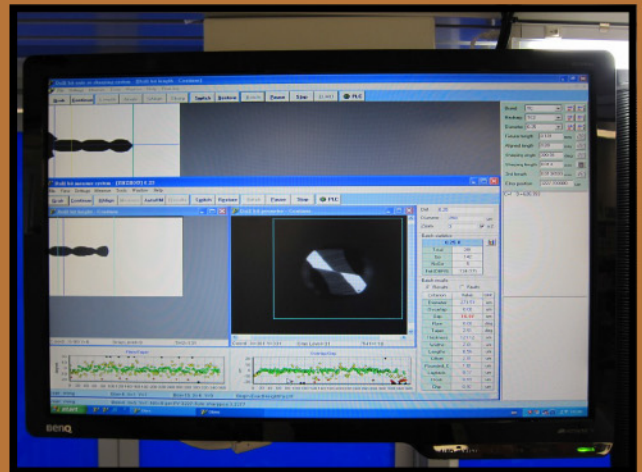
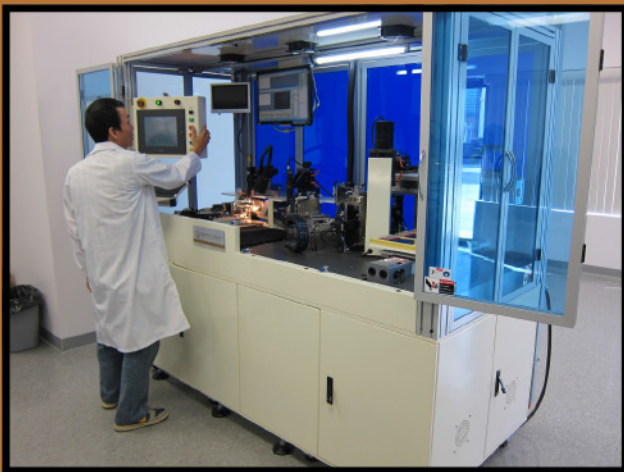
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Disruptive Technology: An Electronics Industry Perspective

by Dave Baron

ATOTECH DEUTSCHLAND GMBH

What is Disruptive Technology?

Disruptive technologies are, as their name suggests, technologies that create new markets by applying a different set of values. These unexpectedly and ultimately (over a few years or decades) overtake the existing market, thus shattering the status quo.

Disruptive technologies have been around for some time. Depending on your point of view this could be a few decades or even a few million years. The stone tools of Olduvai, made nearly two million years ago, are the first known technological inventions. They could be used to chop branches from trees, cut meat from large animals or smash bones for marrow fat—an essential part of the early human diet. They changed the status quo completely, helping our ancestors adapt to new environments and out-compete other animals.

In more recent times, the invention of the automobile was revolutionary, but it was not a disruptive innovation, because early automobiles were expensive luxury items that did not disrupt the market for horse-drawn vehicles. It wasn't until the introduction of the mass-pro-

duced and lower priced Ford Model T in 1908, that the transportation market changed.

The actual concept of disruptive technology is much more recent. The term was first used by Clayton M. Christensen, introduced in his 1995 article [Disruptive Technologies: Catching the Wave](#), which he co-wrote with Joseph Bower. Later, Christensen replaced “Disruptive Technology” with “Disruptive Innovation,” because he recognized that few technologies are intrinsically disruptive; rather, it is the business model forged with the technology that creates the disruption. He also went on to separate new technologies into two categories: sustaining and disruptive. Sustaining technology relies on incremental improvements to an already established technology. Disruptive technology lacks refinement, often has performance problems because it is new, appeals to a limited audience, and may not yet have a proven practical application.

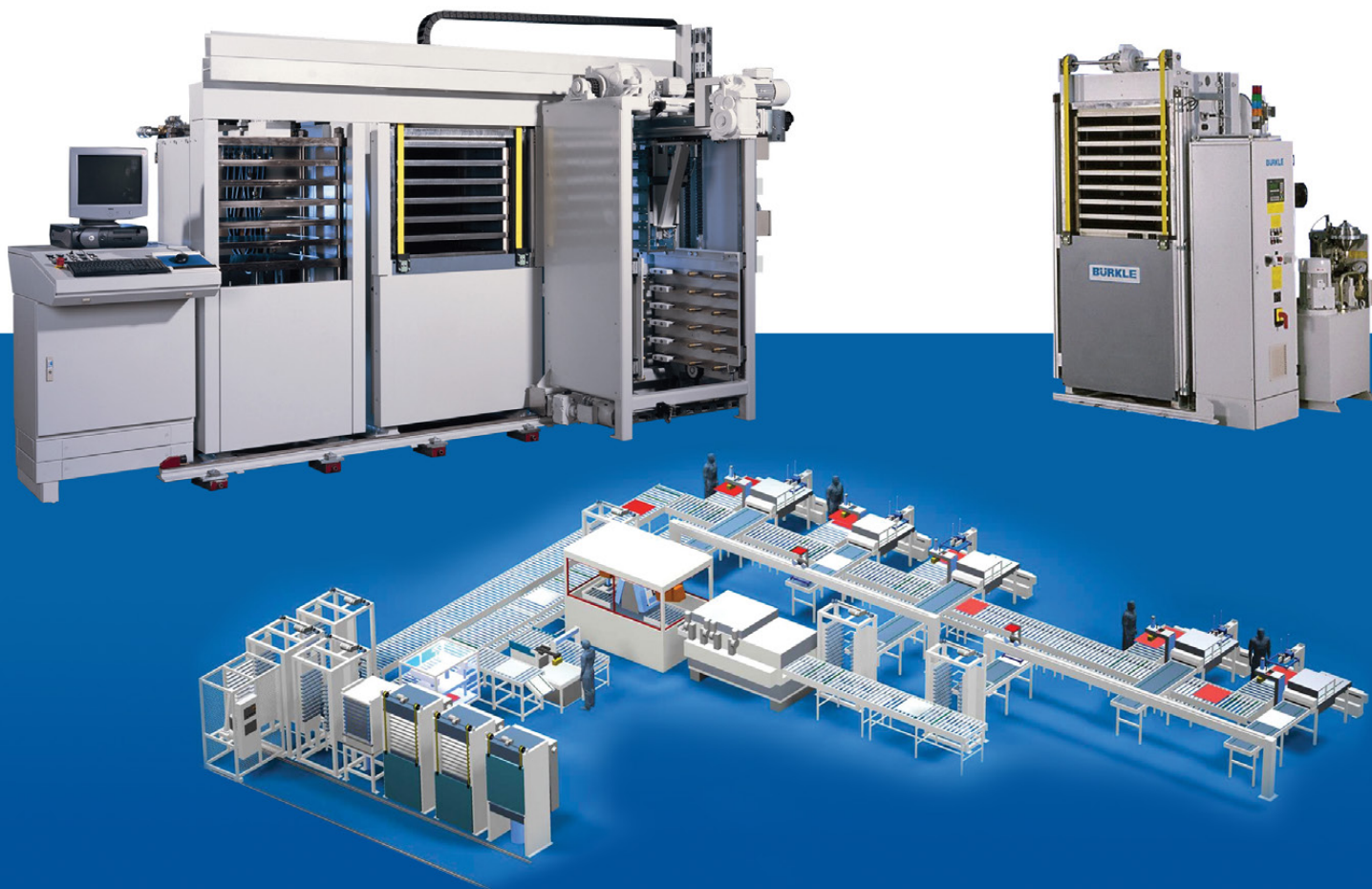
A good example of the points Christensen makes can be seen in the development of the laser in 1960 (and with it the ability to generate an intense, narrow beam of light of a single wavelength), which was initially met with complete indifference. Yet today, lasers are ubiquitous. They are used in a myriad of applications such as reading and writing DVDs and blue ray, guiding military weaponry, dental repairs,



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transmitting huge amounts of data down optical cables and machining a host of materials.

Examples of disruptive technology are too numerous to list in full. However, in no particular order, here are just a few examples of game-changing events: The internet; the jet engine; commercial flight; steam power in the industrial revolution; blast furnaces to produce steel; electrification; the computer; the telephone; digital photography; railways; the automobile; the silicon chip; plastics; LCDs; genomics, and antibiotics.

Disruptive technologies such as locomotives, assembly plants and airliners were notable due to their tangibility. The “connection revolution,” the latest in a chain of technological evolutions that began with the electric telegraph, may be harder to visualize than a steam engine, but promises to be as transformative as the industrial revolution.

Potential Disruptive Technologies

In May 2013 the McKinsey Global Institute released a report entitled “Disruptive technologies: Advances that will transform life, business, and the global economy,” which identifies 12 potentially disruptive technologies that could, or will, change our lives.

The authors of the report point out that the noise about the next big thing can make it difficult to identify which technologies truly matter. They attempt to sort through the many claims to determine the technologies with the greatest potential to drive substantial economic impact and disruption by 2025. Important technologies can come in any field or emerge from any scientific discipline, but they share four characteristics:

1. High rate of technology change
2. Broad potential scope of impact
3. Large economic value that could be affected
4. Substantial potential for disruptive economic impact

The following are some of the technologies identified by the McKinsey report, Audi’s Quarterly Tech Magazine, and Atotech’s own market assessments.

Cloud Computing: Outsourcing of computing services, via the internet, that provide flexible back-end services, rather than having all the services locally.

Internet of Things: Embedded microcontrollers are found in practically all machines, ranging from DVD players and power tools, to automobiles and MRI scanners. The IoT will link approximately 50 billion machines and devices by 2020, predicts Cisco Systems futurist Dave Evans.

Big Data: Any digital interaction, from a phone call to uploading a photo, creates a piece of data which can be used to gain insight about wider patterns of behavior. By mining huge sets of data, it is possible to spot trends.

Artificial Intelligence: Coined by computer scientist John McCarthy, artificial intelligence is “the science and engineering of making intelligent machines.” New algorithms for machine learning, lower prices for components, additive manufacturing and a growth in the “industrial internet” will enable the sci-fi concept of robots.

Mobile Technology: The transition of technology from fixed or desktop devices such as PCs, to mobile devices like smartphones and tablets.

Additive Manufacturing: More commonly known as 3D printing, additive manufacturing allows consumers to download designs and print them in their own homes layer by layer. In the manufacturing world this opens avenues for the creation of new and hitherto unobtainable structures and processes.

Autonomous Cars: Miniaturisation, integration and cost reduction of cameras, sensors, radar and GPS have enabled cars to communicate with each other and their environment, allowing the potential of self-driving vehicles.

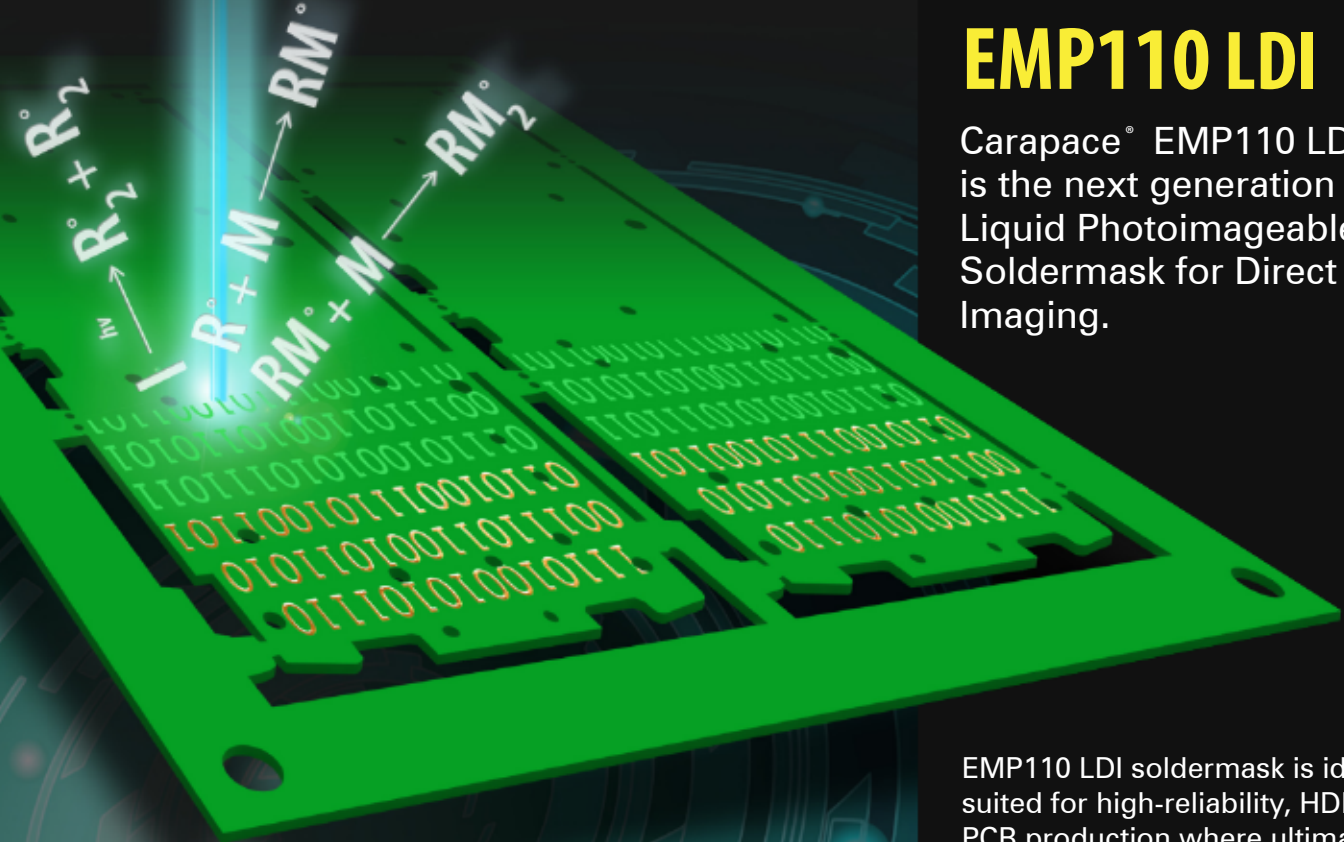
Genomics: The study of an organism’s genetic make-up. At the beginning of this work, it took approximately 10 years to produce a genetic breakdown; now, it can be achieved in a few days.

Energy Storage: At the electricity grid level, there is a need to store energy from intermittent generators like wind turbines and solar panels and release that energy when required by public demand. On the individual level there is

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With the possible exception of genomics and energy storage, all of the above rely on high-speed data management and electronics miniaturization.

Additive Manufacturing

Additive manufacturing techniques are not new; they have been around for a long time. Adding metal to another substrate to change the properties of that material has been practised for hundreds of years—more commonly known as plating. However, new methodologies combining the computer controlled deposition of nanoparticle based materials takes the manipulation of surface chemistry to a new level. Please refer to the image of 2-photon deposition as example of these new technologies.

High Speed Data Management

“Big Data,” “Cloud Computing” and the “Internet of Things” all have the same basic prerequisite—high-speed data management. Copper has been the electronics industry’s conductor material of choice for many years, because it provides acceptable performance at an acceptable cost. The obvious choice for the future would be optoelectronics or photonics, as the data rates are orders of magnitude greater than current electronic systems. However, cost has always been prohibitive for all but long distance transmission.

History has shown that conversion to optoelectronic or photonic systems is not so easy, as switching and connectors are notoriously difficult to achieve. New developments, though, show that these difficulties could be overcome

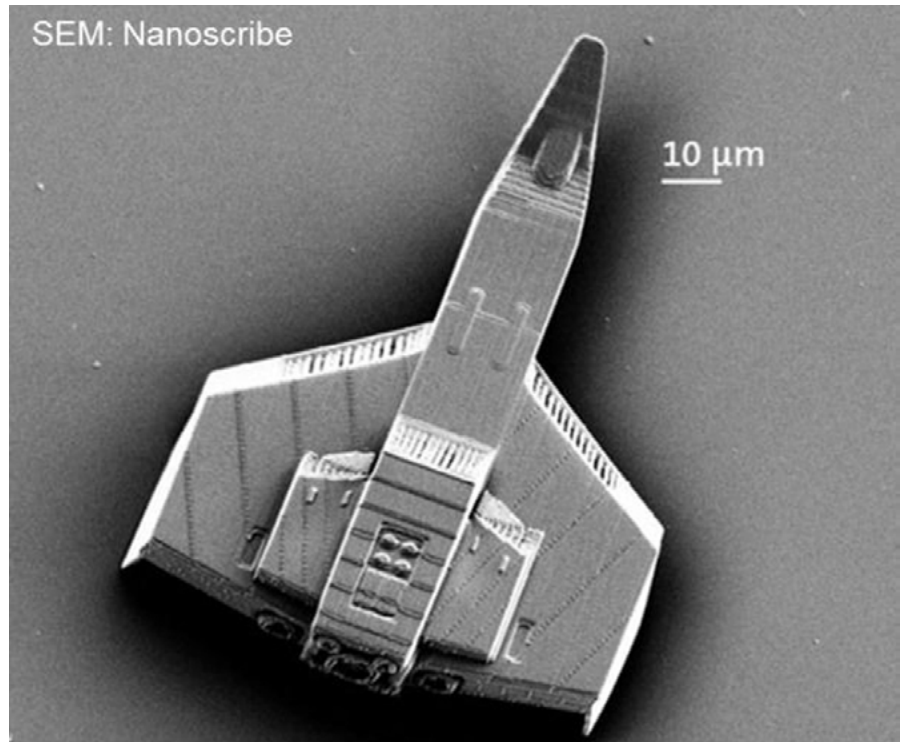


Figure 1: Real use of the 2-photon technology is in the area of photonics. Nanoscribe systems are used to print polymer waveguides reaching data transfer rates of more than five terabits per second. (Source: Nanoscribe)

and the many advantages of photonic transmission may be realized (Figure 2).

How Can Atotech Contribute?

More than 10 years ago, Atotech established a group of people whose prime function was, and still is, to look for alternative technologies. In some cases, the technologies investigated moved the electronics manufacturing industry forward a few steps, while in others a complete revolution may have to take place for the technology to be adopted.

Traditionally, the electronics industry, while very mobile, is quite conservative and is unlikely to make large-scale changes to its infrastructure, because of the cost-driven nature of the business (Figure 3). But it may be necessary for this conservative approach to change in the very near future. “Fortune favours the brave,” according to the Latin proverb first recorded in

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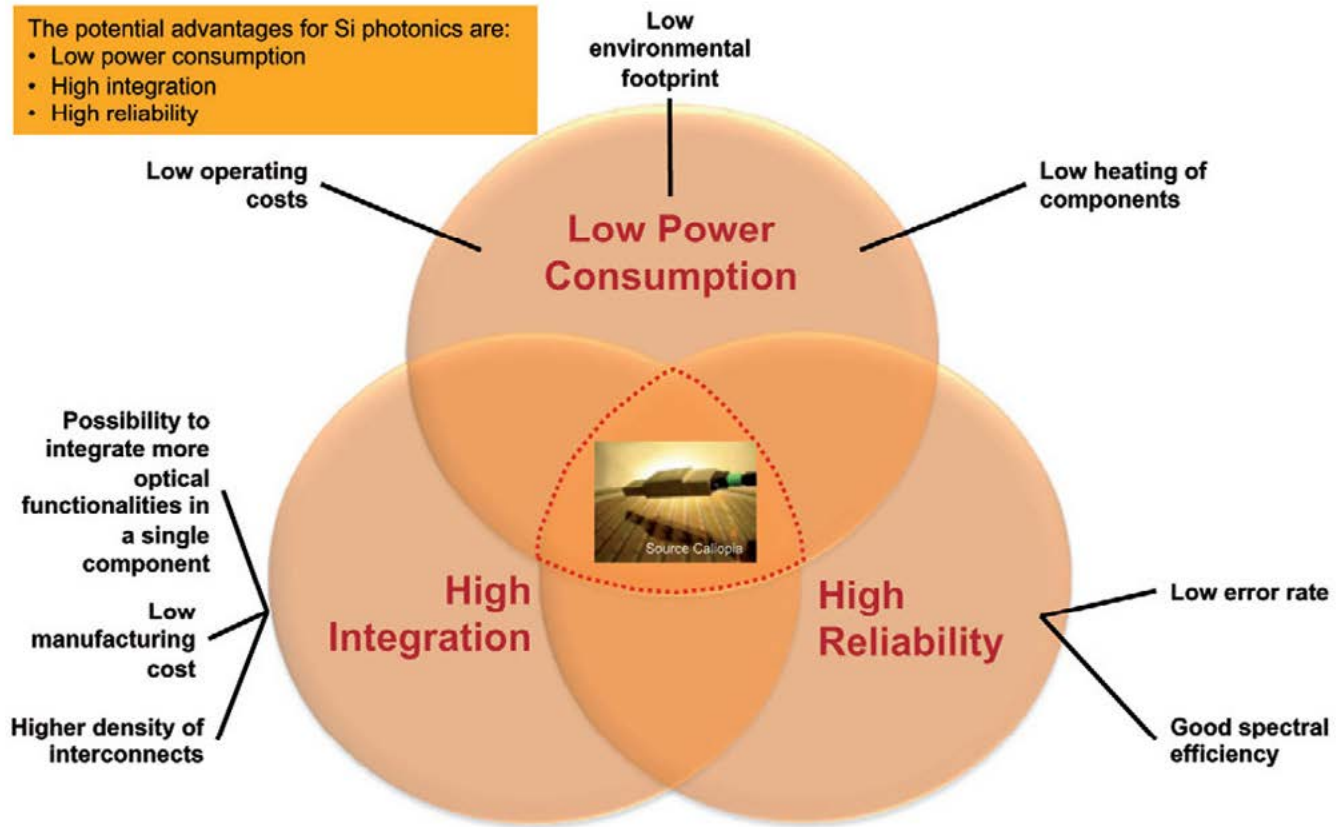


Figure 2: Potential advantages of photonics—still many challenges remain. (Source: Yole)

the play “Phormio” (161 B.C.) by the Roman playwright Publius Terentius Afer. And taking a risk may be absolutely necessary if we are to keep pace with the data explosion.

Current processes address the incremental changes necessary for business to progress on a day-to-day basis, including toxin-free chemical systems and fixes for immediate industry issues. On a longer term basis, however, revolutionary new processes that may significantly reduce the number of process steps



*Design costs include architecture, verification, physical, validation, prototype and software

Figure 3: Design costs by semiconductor node.

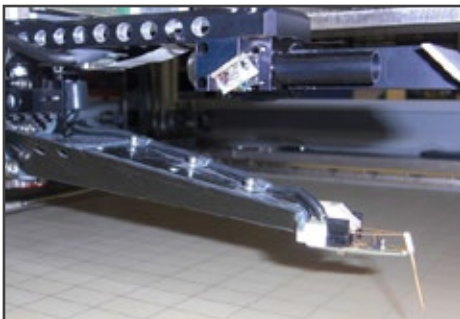
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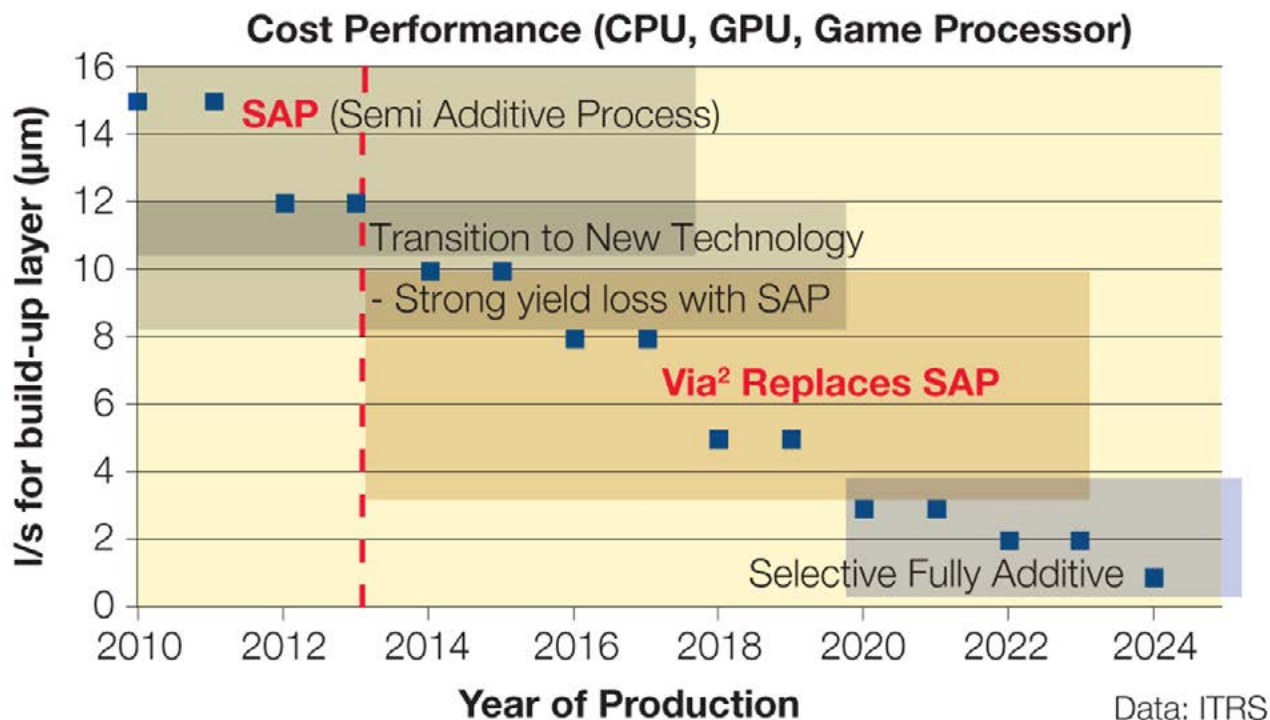


Figure 4: Technology segmentation by process type. Selective fully additive processing could be possible, because conductor thickness reduces along with other feature size reduction.

per metal layer deposited from multiples of ten to single digits are being investigated.

One such methodology is selective fully additive deposition, where direct write technology is used to deposit a circuit pattern that has bulk copper properties. Figure 4 shows when this technology is likely to be adopted and Figure 5 shows some early results from the test program.

The adoption of this technology could require the industry to look at its design rules and challenge the fundamentals of electronics and electrical design and things are done the way they are at present.

Similar technology (e.g., 3D printing, laser technology and refined traditional plating techniques) may also be used for the formation of board level photonics.

History has shown that disruptive technologies are actually few and far between. We have also learned that it is not necessarily the technology itself that is disruptive, but more the way it is sold to the marketplace. A real disruptive technology is one that changes everyone's life. **PCB**

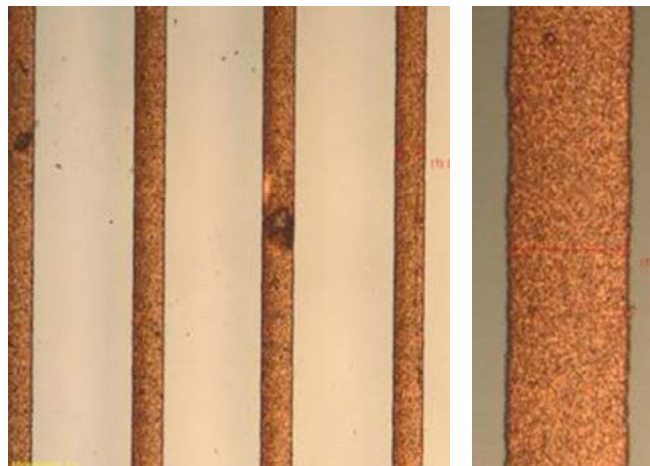


Figure 5: 60 μm conductors produced using selective fully additive deposition. (Source: Atotech)



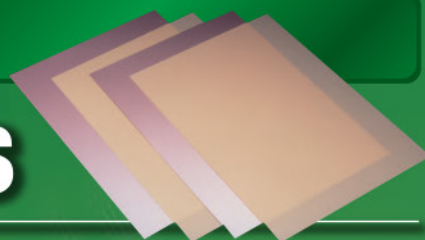
Dave Baron is director of technology strategy and strategic marketing at Atotech Deutschland GmbH. He may be reached at dave.baron@atotech.com.

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Mil/Aero007 News Highlights



Saline Lectronics Achieves Distinction with AS9100C Audit

The company has completed its AS9100 Certification for the fifth year in a row, and this year received a "Best-In-Class" distinction. Saline Lectronics is now certified to AS9100 Revision C, the fourth and latest release of the AS9100 standard, which takes in the revised requirements of ISO 9001:2008 and nearly 100 additional criteria specific to the aerospace industry.

SMTA Finalizes Counterfeit Electronic Parts West Program

SMTA and CALCE are pleased to announce that the program for the Counterfeit Electronic Parts and Electronic Supply Chain Symposium West is finalized and registration is open. This symposium will provide a forum to cover all aspects of changes in the electronic parts supply chain on how an organization performs part selection and management through the entire life cycle.

Conflict Minerals Issues Reach Far into Europe

Under pressure by U.S. laws, human rights campaigns, and guidance from the Organisation for Economic Co-operation and Development, European companies are already being asked by their customers to declare the use of conflict minerals.

U.S. DLA Program Mitigates Risks of Counterfeit Electronics

A little over a year ago, an initiative by the U.S. Defense Logistics Agency launched, aiming to sharply mitigate the risks of counterfeit electronic parts entering the military supply system. The effort featured SigNature DNA, an advanced anti-counterfeit technology platform. The initiative has already begun to pay off.

Cirtronics Achieves AS9100 RevC Certification

Cirtronics Corporation, a New England-based EMS provider, is proud to announce it has

achieved quality certification to AS9100 RevC. AS9100C certification is an internationally recognized quality management standard for the aviation, space, and defense industry.

Sanmina's Mexico Plants Earn Diebold Awards

Sanmina Corporation, a leading integrated manufacturing solutions company making some of the world's most complex and innovative optical, electronic, and mechanical products, has announced that its Guadalajara, Mexico operations are the recipient of Diebold, Incorporated's 2012 Gold and Silver awards for quality and performance.

Blackfox Debuts IPC Course Focused on Space Assemblies

Blackfox announces the latest addition to their IPC industry-developed and approved program curriculum, IPC/WHMA-A-620 Space Hardware Addendum. As a follow up to the IPC/WHMA-A-620B course, the space addendum provides additional requirements to ensure the performance of cable and wire harness assemblies that must survive in space.

Axis Electronics Hosts SC21 Best Practice Supplier Event

The event focused on the successful implementation of SC21 tools within Axis Electronics to drive business and service excellence, helping Axis customers deliver excellence to end customers.

Tin Whiskers Symposium Presented by IPC, CALCE

"IPC and CALCE share a common goal of helping to educate the industry on the latest information about tin whiskers theory and practice," says Sanjay Huprikar, IPC VP of member success. "This partnership has expanded the reach of both organizations, allowing us to develop a strong agenda with presenters who have deep knowledge of the complex technical challenges related to tin whiskers."

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Achieving Fine Lines and Spaces: Part 1

by Michael Carano

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Circuit designs with three-mil lines and spaces are increasingly becoming the norm for high layer multilayer fabrication and IC substrate technology. Regardless of one's technology level, optimizing the imaging process should be of paramount concern. Over the next few months, I will present the critical steps in the imaging process and again provide insight as to where potential yield reducing defects can occur and how to prevent them. This month I will first approach the all-important surface preparation step prior to resist lamination.

Getting Surface Preparation Right

Consider the job that the photoresist must accomplish. Besides the fact that it must provide the optimum photospeed and the highest resolution, the resist must adhere to the copper surface in order prevent resist lifting during the developing and etching steps. How does one accomplish this? First, we have to get the surface preparation prior to resist lamination. Figure 1 shows an example of what is possible with proper surface preparation, lamination, exposure, and development.

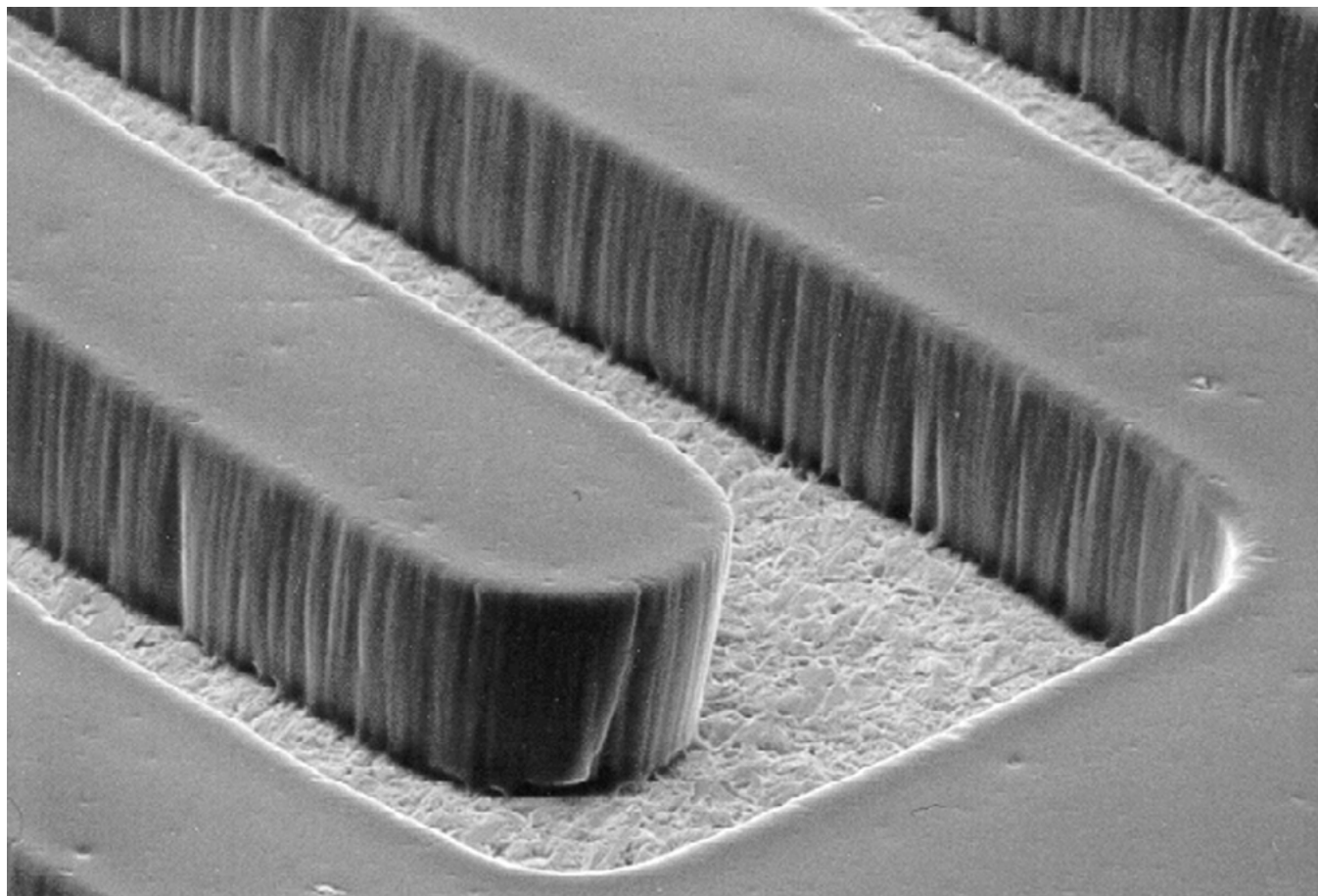


Figure 1: Fine lines and spaces—50 micron L/S.



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Now, consider the copper foil surface. For this particular column, we will focus on innerlayer copper foils rather than outer layers. For innerlayers, the fabricator must carefully prepare the copper surface in order to enhance the adhesion of the photoresist during the lamination process and prior to exposure and development. It is an accepted belief that resist adhesion to copper surface depends on two very critical factors:

- Overall cleanliness of the copper surface
- Film contact area

The copper surface must be free of soils, chromate anti-tarnish coatings and other materials that could interfere with resist adhesion. Film contact area is a function of several factors including overall copper foil surface topography, resist thickness, and lamination conditions such as lamination temperatures and pressures, lamination speed and the flow properties of the photoresist. If either of these two key factors is not optimized, there is a significant possibility of several defects related to the imaging process. These defects include:

- Resist lifting
- Etchouts/opens
- Interfacial voids
- Neck downs

Since poor adhesion of the resist to the copper surface is one key factor leading to defects, understanding the factors that impact adhesion is critical if one wants to avoid yield loss. First, consider the copper foil surface. Regardless of how pristine the copper appears as the material is brought to the lamination area, the surface itself has numerous contaminants that negatively impact photoresist adhesion. One of these contaminants is the chromate anti-tarnish. It is a misnomer to refer to the

chromate as a contaminant since the chromate is designed to prevent oxidation of the copper during storage. Over the years, copper foil producers developed improved anti-tarnish protection with a combination of chromium and zinc. This material is electrolytically coated by immersion in an aqueous electrolyte containing sodium hydroxide, zinc ions and chromium (VI) ions. The anti-tarnish coating consists of a co-deposited layer of zinc and chromium with a zinc-to-chromium ratio ranging from ~5:1 to ~12:1. The coating provides tarnish resistance at temperatures in excess of 190°C and is removable by immersion in sulfuric

acid or a combination of mineral acids such as phosphoric acid, nitric acid and sulfuric acid^[1]. More on this later.

While it is important to prevent oxidation of the copper foil, the circuit board fabricator must ensure that the anti-tarnish coating is readily removed. Generally, and as stated previously, strong mineral acids will remove the anti-tarnish. This is important since it is desirable to roughen the copper surface to enhance adhesion of the photoresist to the copper surface. If the anti-tarnish coating is not completely removed from the copper surface, the remaining coating will interfere with the overall surface roughening of the copper

surface by acting as an inhibitor to the surface roughening treating in those areas where the anti-tarnish remains.

“
If the anti-tarnish coating is not completely removed from the copper surface, the remaining coating will interfere with the overall surface roughening of the copper surface by acting as an inhibitor to the surface roughening treating in those areas where the anti-tarnish remains.
”

Achieving Optimal Results

After ensuring that the copper foil surface is free from the anti-tarnish layer, the fabricator is then able to “prepare” the surface to accept the photoresist. This is accomplished by treating the foil with either a mechanical or pumice scrub or a chemical cleaning process. The end goal is to provide a clean copper surface devoid



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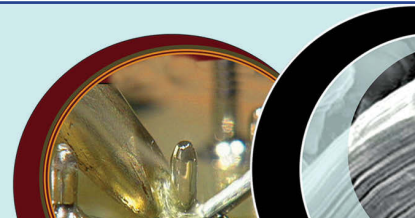
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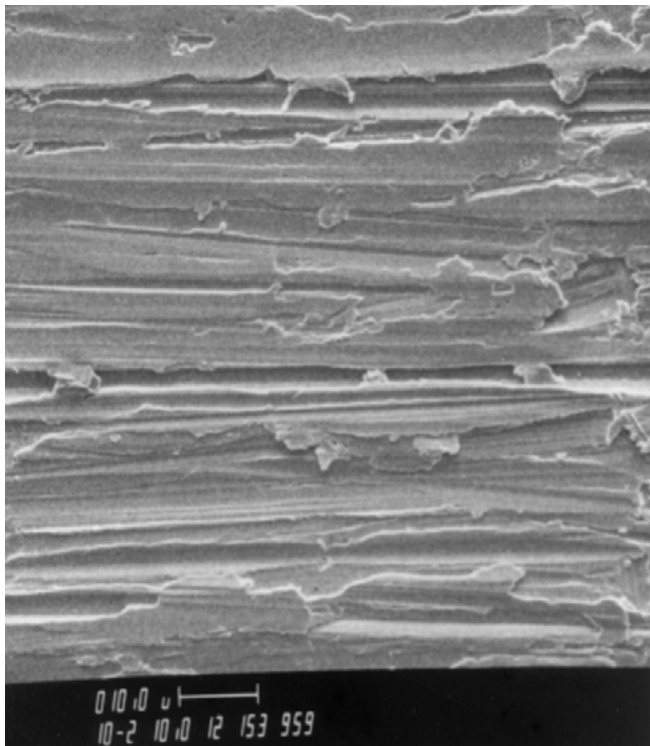


Figure 2: Mechanically brushed surface. Note the unidirectional nature of the scrub marks.

of oils, fingerprints, and anti-tarnish coatings, and of sufficient roughness or “topography” to provide adhesion of the resist. Keep in mind that the vendor copper foil used for multilayer fabrication is generally smooth with only minor roughness due to the glass weave styles in the material. So the importance of a prelamination surface prep must not be underestimated. A review of the various surface preparation options follows:

Mechanical Surface Preparation

This is my least favorite option for surface prep. While mechanical brush scrubbing does indeed change the topography of the vendor copper foil surface, this type of prelamination cleaning severely abrades and potentially stretches the copper. This can be particularly damaging to thin and ultra-thin copper foils. Since mechanical scrubbing via brush is quite harsh, copper foils can be smeared with organic residues that are on the copper if not removed in a pre-chemical clean step prior to brush scrub.

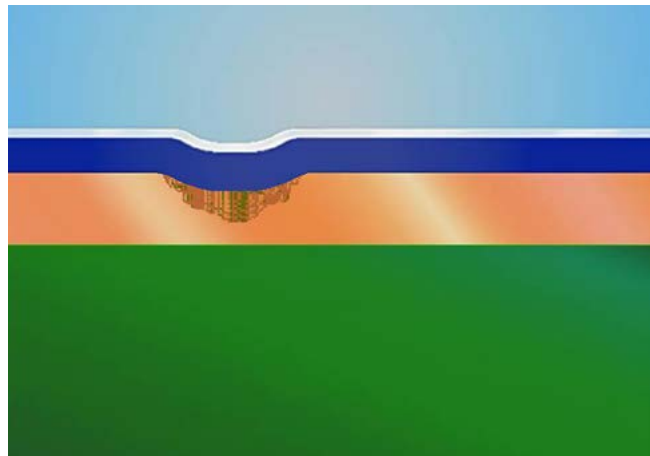


Figure 3: Photoresist unable to conform to deep gouge in the copper foil surface. (Source: IPC)

Secondly, the scrubbing action with bristle brushes is uni-directional (Figure 2).

Finally, there is always the concern that the operators will tighten down the brush pressure in such a way that deep gouges are introduced into the copper foil. One adverse consequence is that the laminated photoresist does not conform to the deep gouge area. If that occurs, it is possible that etching solutions in subsequent processing steps can etch away the copper that was designed to be protected (innerlayer) causing an open (Figure 3).

Again, there are several concerns with brush scrubbing including nylon brush smears, distortion of copper and thin foils and the extreme uni-directionality of the scrubbing action.

In next month’s column, I will further review pumice and chemicals cleaning. **PCB**

References

1. United States Patent #5,230,932.



Michael Carano is with OMG Electronic Chemicals, a developer and provider of processes and materials for the electronics industry supply chain. To read past columns, or to contact the author, [click here](#).

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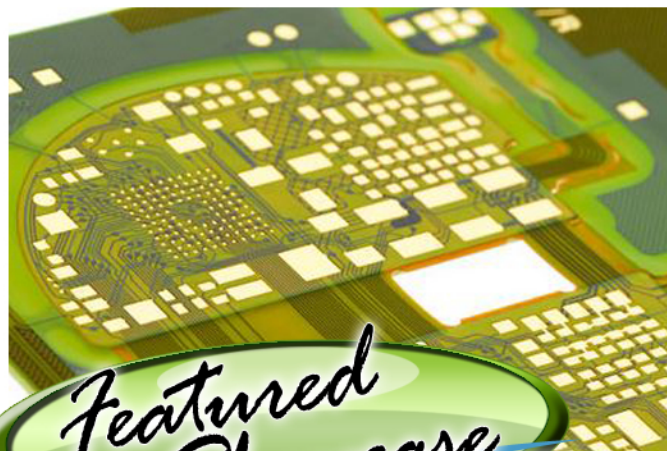
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The Value of a Strategic Consultant

by **Steve Williams**

STEVE WILLIAMS CONSULTING LLC

New blood, a fresh set of eyes or an outside perspective: No matter what you call it, the right consultant can add exponential value to any organization. How can you make sure you choose the right consultant and avoid the wrong one? Read on...

What is a Strategic Consultant?

This particular type of consultant is a professional who strategically analyzes businesses, creates solutions to problems, and helps organizations develop efficient plans for meeting their goals. As a business leader, you know your business better than anyone. But what happens when you need help or just want perspective on the direction the business is going? Anyone can offer general advice from the outside looking in, but to truly help you, they have to know your business very well—almost as well as you know it. That's what a strategic consultant does:

gets to know a business and then helps the business owner meet their goals.

Why Hire a Consultant?

A professional consultant brings many things to a business or a specific project, including:

- Accountability for results, schedule and costs to achieve a solution which translates into significant economies when compared to in-house efforts
- Proven, yet flexible, methodology appropriate for the assignment
- No cost of training or “experimenting” on how to complete the assignment: 100% focus on achieving results
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- Understanding of best practices drawn from a wide experience base
- “Color outside the lines” creativity

Now, this last point is one that is very close to my heart and stems from a memorable meeting I had early in my career with one of my all-time favorite strategic consultants: Tom Peters. While on a coffee break at a speaking engagement for his book *A Passion for Excellence*, Tom said, “Steve, if you are looking for an impact player, never hire a 4.0.” This was a major “aha” moment for me, and a lesson I have applied in each and every one of my hiring decisions ever since.

What Tom was getting at is that people that strive and obsess over achieving a 4.0 GPA will typically excel if you are looking for a solid, dependable, head-down performer that will always work “by the book.” Now, you probably don’t want to hire a 2.0, but most highly creative, critical thinkers tend to fall in the slightly less than 4.0 category. I am not talking about someone that takes reckless risks, but a person that is a creative, critical thinker who will look outside of the “because we have always done it this way” mindset.

Three Kinds of Consultants

I would propose that there are three general kinds of consultants: the Thinker, the Practitioner and the Strategist. There will be no problem finding a consultant that falls into one of the first two categories; these will usually be able to hit a single or perhaps an occasional double for the organization that hires them. However, while the strategic consultant will be much more difficult to find, this is the one you want if you are looking to consistently hit home runs. Here’s a breakdown of these three types:

- **The Thinker:** This consultant has vast knowledge in the theory of the services they offer, but not necessarily hands-on experience

in implementing and managing the aspect on which they are consulting. A lot of academics and Ph.D.s fall into this category.

- **The Practitioner:** This consultant has worked in the trenches and has “been there and done that.” They have excellent practical experience with the aspect they are consulting on, but do not have the theory and modeling experience to complement their experience.

- **The Strategist:** This consultant offers the best of both worlds and is the rarest of all the types of consultants, but also is the one you want to hire. The strategic consultant combines both theory and practical application to complete the equation. There are typically very few situations where they have not “seen that, solved that.” Consultants in this category often professionally teach the discipline on which they are consulting.

The Right Consultant Can Be a Game Changer

Beware of the consultant who comes in with a canned package and tries to force-fit a one-size-fits-all solution into the company; this is the wrong consultant and will generally result in failure and disappointment. The right consultant will leverage his expertise to work closely with the organization’s employees to teach, coach and facilitate a solution customized to the specific organization and project. Strategic consultants can be a tremendous resource to help companies drive operational excellence, and following these guidelines can ensure that you hire the right one for your organization. **PCB**



Steve Williams is the president of Steve Williams Consulting LLC (www.stevewilliamsconsulting.com) and the former strategic sourcing manager for Plexus Corp. He is the author of the books, [Quality 101 Handbook](#) and [Survival Is Not Mandatory: 10 Things Every CEO Should Know About Lean](#). To read past columns, or to contact Williams, [click here](#).

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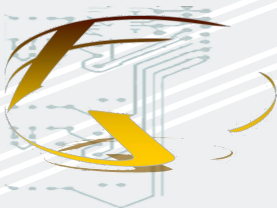
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How to Compute Your Plant's DAM Capacity

by Gray McQuarrie

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Do you know your plant's capacity? If your answer is, "Yes, because we have a scheduling department and an extensive scheduling system module built into our ERP," I would say "No, you don't." What is my reasoning? First, an answer like this doesn't really answer the question I asked; it doesn't tell me what the plant capacity is. Second, this answer doesn't tell me the process used to determine the plant's capacity. Third, this answer doesn't tell me how plant capacity estimates are verified and validated. Fourth, this answer doesn't tell me if their capacity is static (the same across all product types and product mix) or dynamic (different by product type and product mix).

We have all been obsessed with global labor costs in this industry, but what is hidden in terms of the cost of not understanding our plant's true capacity could make our plants so DAM profitable that we would not have to worry about global labor costs ever again. Yes, the opportunity could very well be that great.

Few of us are willing to admit we don't know our plant's capacity. It would be like a dentist not knowing how to brush teeth. Yet with our need to build advanced technology HDI boards with sequential lamination, figuring out our

plant capacity is a very difficult thing. Let me give you some examples that will more than pound this important point home. How much quick-turn work can you handle in your factory if it is a one-day, two-day, three-day, or four-day quick-turn? Is it 0%, 5%, 10%, and 20% by volume? What if you have a mixture of different quick-turn levels? How could you load your

shop or set your promise dates to ensure perfect on-time delivery? Let's compound the problem with HDI work with products that have two-eight lamination cycles. Based on the quick-turn commitments, how much plant capacity would you have left for regular 15-day orders? These are not questions that work well

on spreadsheets. If you don't believe me, try using a

spreadsheet to work out the different cycle times for each job in each scenario. The only way you can answer questions like these is with a model.

Model Behavior

Why is the model important? Because it allows you to see what will likely happen given an existing scenario, and allow you to play around or use a mathematical algorithm to optimize to a better alternative scenario.



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What is a model? One definition is an advanced calculator meant to compute a very specific set of things based on some logic structure. We use a model to predict the controlled impedance of our boards. Models range from simple to advanced. A more advanced model is able to simulate visual results so that we can play around with it in “what if” games, come up with decisions, and observe how they play out, without actually experimenting in the real world, which could be impossible or very expensive. An example of an advanced model that allows users to simulate results is the PCB registration software system sold by Xact PCB. I wrote about my early work in registration and how I modeled it using JMP data analysis software in [DAM Registration](#) (February 2013).

It's also important to describe what a model is not. For example, a database isn't a model. An equation that you derive from the data in the database is a model. An Oracle system or SAP system isn't a model, even if it has modules that claim modeling or simulation is happening behind the scenes. Anything that creates a dependency in which you have to accept on faith that it works and you don't understand how it works isn't a model. It would unfortunately be like HAL, which I discussed in [What is the DAM Problem with Scheduling?](#) (July 2013). When HAL is running the show, things tend to go from bad to terrible.

Note: Models aren't perfect and this often is why people often don't trust them. They are an abstraction of reality, not reality itself. For example, Newton's second law, $F = ma$, is an imperfect model that doesn't work well close to or at the speed of light. But we still use it. However, if a model is flawed in some way and doesn't represent reality perfectly, then why would we use it? Let me avoid answering this question for a moment and make another point. A model exposes our understanding of what we think is important and how we think things work. The problem with this is that it could prove what we thought was true is actually false: It could prove we are wrong. Who wants anything to do with that? Not me! I am perfect! I am right! We don't need models here! OK, let me calm down and take a few deep, meditative breaths. By the way, if you boil it down, my little fit was the rhetoric

of the dark ages, when they preferred mysticism over reason.

And now we have come full circle, back to our capacity problem. Can we use our best reasoning powers to determine the true capacity of our plant? Until now, there wasn't much available. Operations has always been confused about the problem: Is it people, who won't obediently do exactly as they are told (the dark ages when people existed as non-thinking slaves) or is it the management system being less than perfect (again, to admit to this as managers, we could be executed if it were the dark ages)? It is time to step into the light, and into the Age of Reason, using a model and the scientific method.

I have created a generic, imperfect model on which others can build better models, either working with me, or with others, or by themselves. You can see an example of how it functions by [clicking here](#).

The video shows the data entry tables such as the production specifications for product A, which is a 66-step sequential lamination HDI job, the production specifications for product B, which is a straightforward 29-step multilayer job, the specific plant capacities for each department, and so on. This example is very much simplified and in no way close to the limits of the model and the modeling software used to create it, which allows for hundreds of different jobs specified. However, the point in modeling is not to cover every single detail of the territory perfectly, but to make sure that the required territory is spanned to an adequate level of detail. So, as Lean theory tries to tell us, if we break our products up into logical families that cover the span in processing variations, this allows us to simplify what we need to know in order to know what our true plant capacity is, and it makes our modeling efforts easier and more productive.

In the training I received from Robin Clark of QMT Group to construct operational models over the last couple of years, I have repeatedly found people in my class from organizations as varied as the Mayo Clinic and Boeing. These companies have found that having a modeling capability within their organization is of strategic importance. Anyway, we were learning to

develop what is called discrete event models, or simulations. The model in the video link is a discrete event simulation.

Discrete Event Simulation

What's a discrete event simulation? If you think of your factory as a series of events that happen at specific times, such as, 10 panels go into the press, get laminated for 60 minutes, come out of the press, get broken down in 10 minutes, get stacked in two minutes, and then get moved to the next operation in five minutes, a discrete event simulation considers all of this detail, creates a huge multidimensional table, and updates it precisely to each event based on the parameters and inputs that you specify. It does this very quickly, typically many thousands of times, where it appears everything is happening simultaneously in one continuous flow. It is sort of like a movie, which really is a bunch of still pictures that change very quickly. So with the timing for the processes and the capacities specified for each department, which is all stuff we know about our factories (because of the sophisticated ways we handle our data), along with the logic that determines the priority of what is going to be worked on first, and so on, you can get a good dynamic simulated representation of your entire plant. A model (and the software behind it) can keep track of every single item (panel or job or sub-assembly or even worker and piece of equipment down to a drill bit if you desire) during a run (running the model to see the simulated result) and report back the statistics at any level of detail you desire.

So let's try a few things with this model and see what happens. In a month (five-week month with 560 hours of production time across two eight-hour shifts running seven days a week), can we build 2,000 panels of product

A and 2,000 panels of product B that have the same specifications for the products and the plant shown in the model in the video? Also, we want the average cycle time for the factory to be less than eight days; in order to achieve this we think we have to keep the total WIP of the factory down below 2,000 panels as best we can.

The first thing we have to determine is how we are going to start our jobs. Let's say we are going to start 40 panels of A and 40 panels of B at the beginning of each shift.

The most important concept about being Lean is takt time: the timing of work from start, through each department, all the way to packaging and shipping. If you don't have a clock on your wall in your plant keeping track of this, then you aren't Lean. What you are is unpredictable.

Figure 1 shows the result. We failed! Our average cycle time was 11.24 days. We were 1,000 panels short for our product A commitment and we were 400 panels short for our product B commitment. We could just end our analysis right here and say that we don't have the capacity. Our true capacity for product A (assuming no scrap) is 1,000 panels and our true capacity for product B is 1,600 panels. But we would be dead wrong. Why? It is because there is no such thing as a true static capacity for the type of plants we run in our industry. This fact will be the subject of future articles.

For now, let me make a provocative statement. I don't know of a single board shop that I have been in that is Lean. Yes, many that I have seen have done multiple Kaizen events, but that doesn't make them Lean. Let me explain. The most important concept about being Lean is takt time: the timing of work from start, through each department, all the way to packaging and shipping. If you don't have a clock on your wall in your plant keeping track of this, then you aren't Lean. What you are is unpredictable. In fact, you can see it in Figure 1, where so many processes appear to be the bottleneck—almost half the plant! If this describes your plant you aren't Lean. The good news is that you can be so much better.

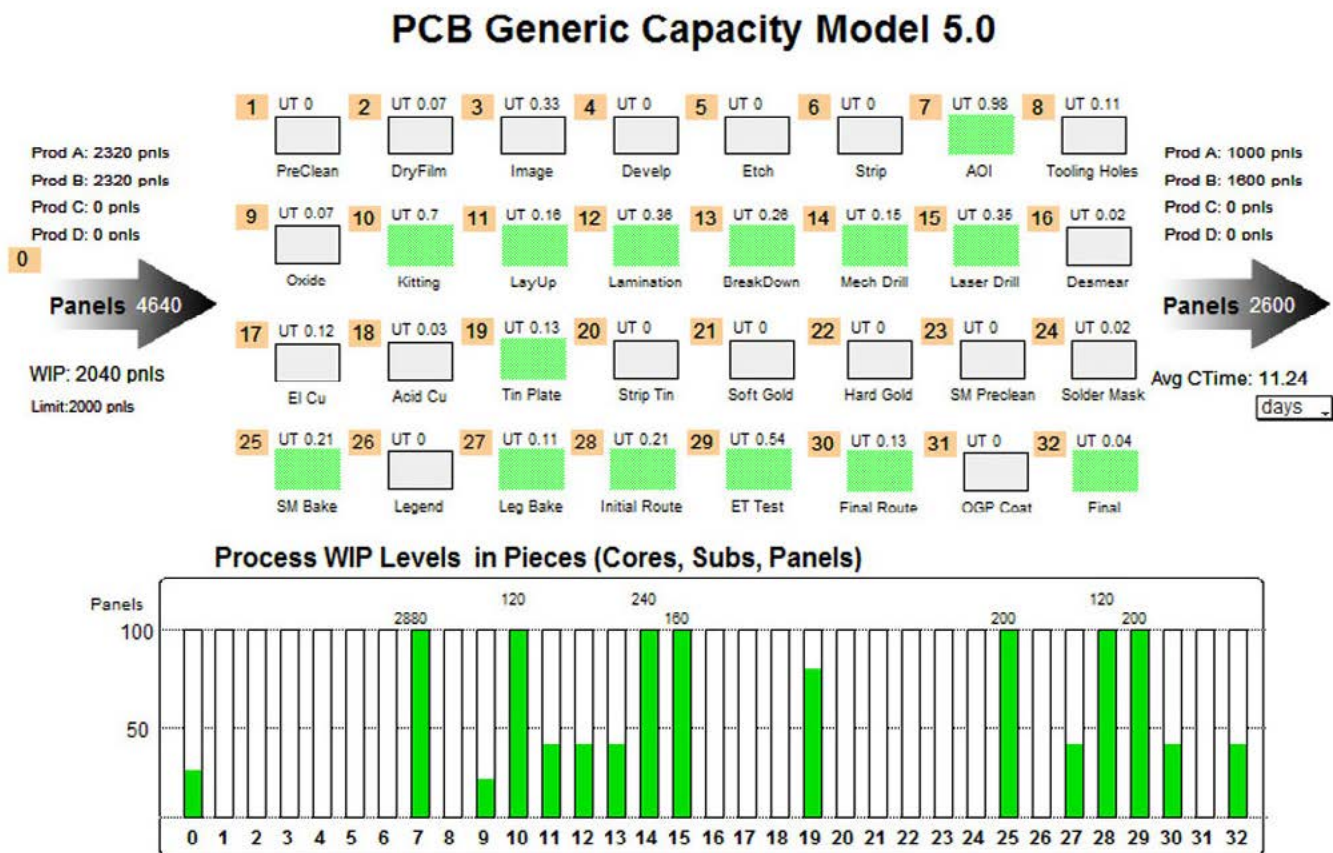


Figure 1: Capacity result with infrequent large lots. Each department is labeled and numbered. The numbers correspond to the number on the Process WIP levels graph. The green squares show which departments were processing panels at the end of the simulation and the green bars show the WIP levels, which can help to identify bottlenecks.

Let me give you an example. Many shops have been forced, for a number of reasons, to process small lot sizes and as a result, their cycle times and throughput have improved. But when they get that large volume, somewhat rare order (which is always exciting) they clump the lots as if they are one super lot and release them almost all at once on the floor. Before too long they have a WIP problem, delivery problem, and often higher scrap, too. Also, this chews up a lot of capacity. I talked about this in [Remove DAM Variation and Your Company Will Win!](#) (July 2012), where I explained the freeway analogy: If more cars are paced at the same speed and if more cars are sequenced to enter the freeway at precise intervals, the more cars you can have on the freeway. This means that how you pace and time your starts will remove or create

plant capacity! Is this in fact true?

Let's try out the model in this way and see. Let's start product precisely at two-hour intervals of 10 panels each of product A and product B. Figure 2 shows the result.

We have nearly doubled our throughput (plant capacity) and reduced the cycle time by 48%! If you got these results with your model, should you challenge them and test them to see if they are in fact true? Absolutely. The model doesn't think, we do. And only through challenge, observation, and inquiry can our thinking about how we run operations be improved. And if the model isn't making you smarter about how to run your business then you have an IT solution like HAL, and that isn't good.

Also notice in Figure 2 that there is one definitive bottleneck and that is AOI. This is re-



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PCB Generic Capacity Model 5.0

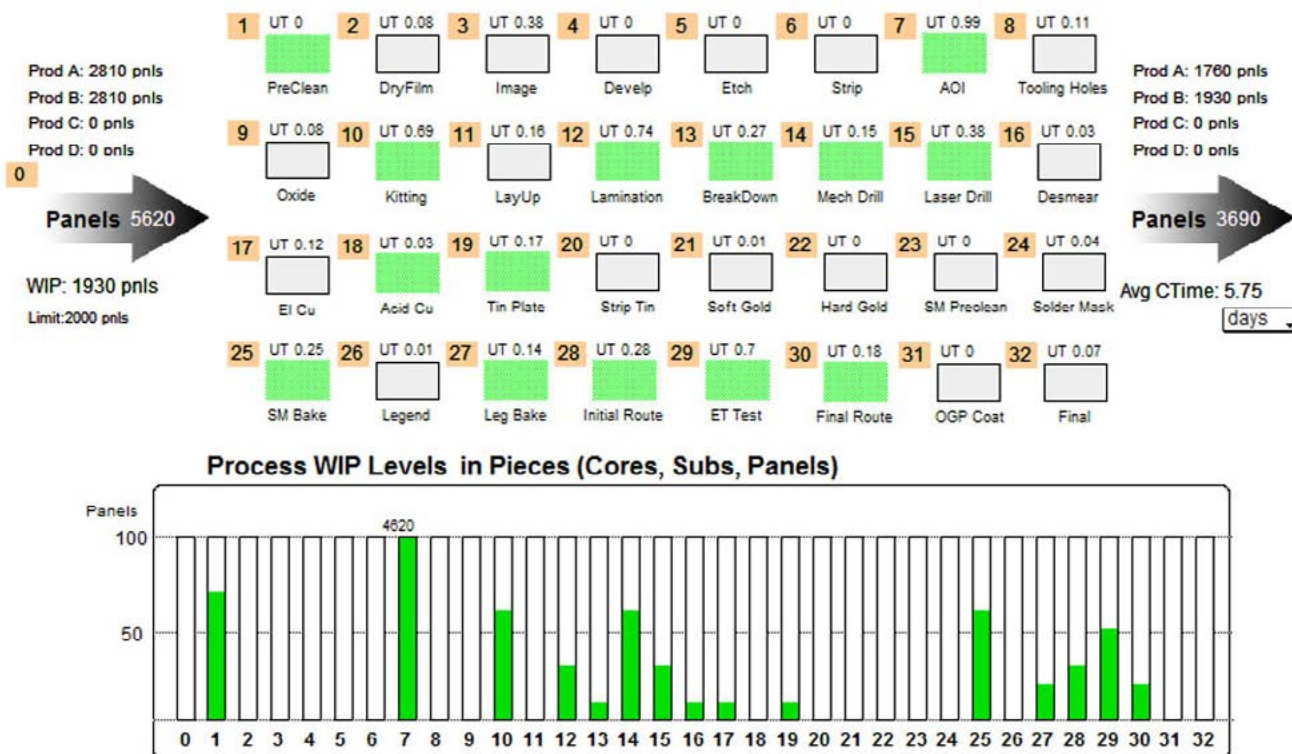


Figure 2: Capacity result with frequent small lots. Each department is labeled and numbered. The numbers correspond to the number on the Process WIP levels graph. The green squares show which departments were processing panels at the end of the simulation and the green bars show the WIP levels, which can help to identify bottlenecks.


ally amazing, because we have done nothing to change the structure of the plant and the equipment that is in it. We just changed how we start jobs. Now keep in mind this bottleneck is also a function of how we start and time jobs through the factory as well as the lot size we use, the size and scale of the equipment, and the product mix. So if you are thinking about arbitrarily increasing the frequency of your starts and decreasing the size of your lots just because of this article, this could be very hazardous to keeping your job if you do it without a good model and use a scientific approach.

The bottom line is that there is no such thing as a true static plant capacity in our industry. The plant capacity that we have on any particular day is a function of the decisions we make and how we manage our plant! Very little of this will be revealed in a spreadsheet analysis,

but very much of it will be revealed in a simulation model. Modeling will begin to infiltrate our industry and when it does it will happen quickly, just like Lean did. The question is, do you want to be the first to use this tool and get the gains now and pull away from your competitors, or do you want to wait until you must do something about it because you are so far behind? **PCB**



Gray McQuarrie is president of Grayrock & Associates, a team of experts dedicated to building collaborative team environments that make companies maximally effective. To read past columns, or to contact McQuarrie, [click here](#).



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Medical Electronics

SYMPOSIUM

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FEATURED EVENTS

Keynote Address — Tuesday, November 12, 2013

The Accelerating Technology Convergence in Medical Devices — Implications for the Future, Mark Kemp, President, Flextronics Medical

Panel Discussion — Wednesday, November 13, 2013

Key Issues Facing the Medical Electronics Industry — From the 2013 iNEMI Roadmap

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TOP TEN

PCB007
News

PCB007 News Highlights This Month

① **Natel Acquires EPIC Technologies**

"We are extremely pleased with the addition of EPIC because it strengthens and expands product solutions to include higher-level full system integration capabilities, as well as additional opportunities to reduce costs for our customers through the geographical distribution of our manufacturing locations," said Natel President and CEO Sudesh Arora.

② **Integrian Holdings Wins Bid for Endicott Interconnect**

The sale of Endicott Interconnect's assets to Integrian Holdings LLC was approved by a federal bankruptcy judge on Thursday, September 26, 2013.

③ **Bay Area Circuits Announces Silicon Valley Expansion**

The company has relocated to a 30,000 square foot manufacturing facility in Fremont, California. In addition to a significant increase in capacity, the additional manufacturing space will enable more in-house capabilities along with faster turnaround times.

④ **Falcon PCB Group Reveals Rebranding Effort**

A sustained period of investment both in plant and personnel has enabled the group to develop the high-technology rigid PCB facility, Merlin Circuit Technology Ltd. and the flex and flex-rigid facility, Merlin Flex-Ability Ltd., which have both been upgraded.

5 Printed Circuits Inc. Boosts PCB Manufacturing Capabilities

PCI has added a Uyemura ENIG/ENEPIG plating line to their wet process area, giving customers the ability to specify a traditional ENIG final finish on their circuit boards, or an option for the newer ENEPIG plating. ENEPIG allows PWB manufacturers single pass final finish, with high-reliability assembly yields on both wire-bondable and surface-mount components.

6 Candor Industries Develops New Selective Plating Process

The company, a Canadian-based high-technology PCB manufacturer, announces the development of an innovative selective plating process dubbed the "Partial Plating Process." This unique process allows designers to have a PCB with no plating on select areas of the surface, yet still have full plating within vias/through-holes located in those same areas.

7 IPC's PCB Industry Results for August: Stalled Growth

"Just as the North American PCB industry began showing signs of renewed growth, it was hit by some negative market developments, most notably reductions in U.S. military spending," said IPC's director of market research, Sharon Starr.

"This was especially evident in sales of rigid flexible circuits," she explained.

8 Aismalibar's Flextherm Earns UL Certification

Eduardo Benmayor, managing director, says, "3D designs with bendable insulated metal substrates are on the cutting edge of technology. Many leading OEMs and CMs are currently utilizing the capabilities of Flextherm to meet their thermal management objectives."

9 American Standard Circuits Acquires First EIE Photoplotter

Chicago-based circuit board manufacturer, American Standard Circuits, Inc. (ASC), has announced the recent purchase a First EIE RP212+XT photo plotter. The new acquisition will allow the company to increase process capability as well as overall throughput.

10 IPC Report: World PCB Market Grew 1.7% in 2012

"The report's estimates are developed through a consensus process involving leading analysts worldwide and the data is trusted within the industry," says Sharon Starr, IPC director of market research. "If you need to know what kinds of PCBs are being made where, the World PCB Production Report will tell you, in detail."

For the latest PCB news and information, visit: PCB007.com



EVENTS

For the IPC Calendar of Events, [click here](#).

For the SMTA Calendar of Events, [click here](#).

For the iNEMI Calendar of Events, [click here](#).

For a complete listing, check out
The PCB Magazine's full [events calendar](#).

International Wafer-Level Packaging Conference

November 4–7, 2013
San Jose, California, USA

LA/Orange County Expo & Tech Forum

November 5, 2013
Long Beach, California, USA

MEMS Executive Congress US 2013

November 7–8, 2013
Napa, California, USA

Gartner Symposium ITxpo 2013

November 10–14, 2013
Barcelona, Spain

productronica 2013

November 12–15
Munich, Germany

SMTA/iNEMI Medical Electronics Symposium - Tabletop Exhibition

November 12, 2013
Milipitas, California, USA

Aerospace & Defense Programs

November 13–14, 2013
Phoenix, Arizona, USA

MILCOM'13

November 18–20, 2013
San Diego, California, USA

Energy Harvesting & Storage USA 2013

November 20–21, 2013
Santa Clara, California, USA

Printed Electronics USA 2013

November 20–21, 2013
Santa Clara, California, USA

Graphene LIVE!

November 20–21, 2013
Santa Clara, California, USA

OLEDs LIVE!

November 20–21, 2013
Santa Clara, California, USA

Supercapacitors USA 2013

November 20–21, 2013
Santa Clara, California, USA

HKPCA & IPC Show

December 4–6, 2013
Shenzhen, China

Austin (CTEA) Expo and Tech Forum

December 5, 2013
Austin, Texas, USA



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Next Month in *The PCB Magazine:* The (PCB) World According to Our Columnists

In December, our hard-working columnists take center stage to explore their wide-ranging areas of expertise in the PCB industry, from PCB fabrication and processes to manufacturing disciplines, plant management and more. Don't miss their views on where the electronics industry is headed, where we've been in the past year, and most importantly, where we're at as an industry, domestically and globally.

See you in December!