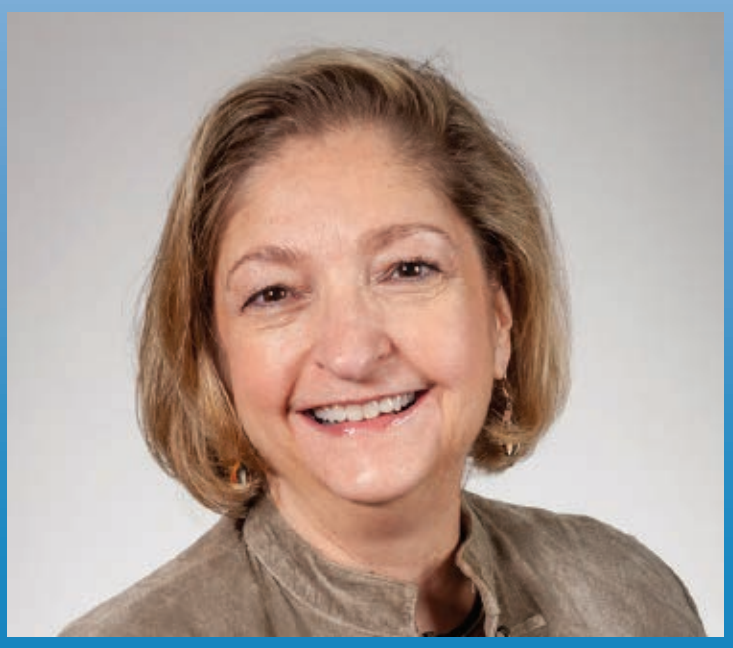
AN ADVERTISING SUPPLEMENT TO THE PITTSBURGH BUSINESS TIMES

TABLE *of* EXPERTS

ADDITIVE MANUFACTURING



Connie Palucka, NPDP
Managing Director, Regional Initiatives, Catalyst Connection

Vicki A. Barbur Ph.D.
Senior Vice President and Chief Technical Officer, Concurrent Technologies Corporation

Catalyst Connection

Connie Palucka is the Managing Director of Regional Initiatives at Catalyst Connection, an economic development organization dedicated to helping manufacturers in southwestern Pennsylvania improve their competitive performance. In this role, she leads a variety of new initiatives. They range from helping manufacturers adopt new technologies, such as Additive Manufacturing, to safeguarding their business by educating them about cyber security risks, to helping them stay abreast of megatrends in manufacturing, such as the Internet of Things.

Currently, Connie is leading an initiative funded by America Makes to support the emergence of an Additive Manufacturing cluster in this region. Key deliverables from this initiative will lead to a robust Additive Manufacturing value chain that will become a model for the nation.

Prior to joining Catalyst in 2005, Connie spent over 20 years in industry leading global sales, business development, and product development efforts. Her experience includes developing and executing global sales strategies, implementing a stage-gate product development program, and leading the execution of various strategic initiatives ranging from technology development and commercialization, internal process improvement, and building alliances to achieve strategic goals. Prior to joining Catalyst Connection, Ms. Palucka was employed by Callery Chemical Co., Zeton-Altamira, GE Reuter-Stokes, and Westinghouse.

Ms. Palucka is a certified New Product Development Professional. She holds a B.S. degree in Chemistry from the University of Tennessee and an M.B.A. from the Katz Graduate School of Business at the University of Pittsburgh.

Concurrent Technologies Corporation

Vicki A. Barbur, Ph.D. serves as Senior Vice President & Chief Technical Officer at Concurrent Technologies Corporation (CTC) and is a member of the Senior Executive Leadership Team. Dr. Barbur is responsible for setting the vision and strategic direction for CTC's scientific and technical capabilities.

02/2013

Her efforts focus on building and directing the company's technical capabilities, overseeing research and development activities, and maintaining a sound plan of technical organization. Dr. Barbur also leads the execution of technology strategy for technology offerings, partnerships, and external relationships, as well as providing visible leadership for CTC within the technical community. Dr. Barbur strives to ensure the sustainability of CTC's technical reputation and leadership in the competitive landscape while identifying new business opportunities.

Dr. Barbur earned a Ph.D. in physics from Imperial College, University of London, and a M.Sc. in applied statistics from the University of Oxford, both in the UK; an Executive MBA in global executive leadership from Amos Tuck Business School, Dartmouth College, Hanover, NH, USA; and a B.Sc. in physics from Imperial College, University of London.

Prior to joining CTC in 2013, Dr. Barbur served as Vice President of Research and Development for the medical segment at Cardinal Health, McGaw Park, IL. At Cardinal Health, she was responsible for the development of new products for several functional areas in the healthcare environment. She oversaw development platforms that utilize novel characteristics of materials and coatings to enhance barrier protection, improve strength, and increase absorbency. She had previously served as Technology Director at Kodak for research and development efforts, focused on specialty products that included nanomaterials.

Dr. Barbur is widely published in peer-reviewed journals and holds three U.S. and one European patent based on her work associated with applying novel statistical principles to processing methodologies.

She recently served on the board of directors for INDA, the Association of Nonwovens Fabric Industry in the USA, and the Sustainability 'Corporate Round Table' at the Chicago Botanic Gardens. Previously she has served on the executive board of The Color Group (Great Britain) and also on the board of directors for the Chamber of Commerce in Peabody, MA, USA.

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The Pittsburgh Business Times hosted a Table of Experts to discuss issues related to the additive manufacturing industry in our region on March 4. Panelists included: Connie Palucka, NPDP, Managing Director, Regional Initiatives, Catalyst Connection; and Vicki A. Barbur Ph.D., Senior Vice President and Chief Technical Officer, Concurrent Technologies Corporation.

Q: When should a manufacturer use additive manufacturing as opposed to a traditional manufacturing process?

Ms. Palucka: If manufacturers have parts or components where design complexity is an issue, then additive manufacturing could very well make sense. If they have a waste issue, additive manufacturing could possibly help in that particular respect as well.

Dr. Barbur: Moving from traditional manufacturing to additive manufacturing does require that you have a complex part or a complex object that you are trying to produce, because it would not make sense to make a solid object using additive manufacturing. The value comes from being able to address the challenges of complex geometry easily. If you are looking primarily for high volume production, at this stage of its maturity, you wouldn't be turning to additive manufacturing because it best serves a low volume operation. In short, additive manufacturing can best be used for high value, complex, customized parts at low volumes.

Ms. Palucka: I also think the capability to eliminate assembly steps is a big advantage that additive manufacturing could bring to the table. It's important to not only look at the individual parts themselves but also the assembly steps surrounding that part. With additive, there are instances where it could very well reduce the number of assembly steps to a single build step, which could have a significant impact in terms of time and cost reduction.

Dr. Barbur: One thing that we should stress is that if you are planning to install a machine, it's not a "plug and play" type situation. It could take between three and six months to ramp up in terms of the knowledge it would require. We have been working in this space for several years now and we are still learning every day.

Q: What are the primary applications of additive manufacturing today?

Ms. Palucka: Today, we are seeing additive manufacturing used in prototyping, tooling and finished parts in industries ranging from aerospace to medical devices to automotive, and even some consumer applications.

Dr. Barbur: I think the other place where additive manufacturing has a role to play is if you were in a situation where you didn't have a part, for example when it was obsolete. Then, in fact, additive manufacturing can be used because it's easier to make one part with additive manufacturing rather than have to tool up to make a whole series of parts, which would be redundant. The other place where additive manufacturing is used extensively is for repairs because sometimes you don't want to replace the whole part, but you just want to repair it. That also reduces waste because you aren't actually throwing a broken part away. That's not to say that every additive manufacturing process technology lends itself to every segment that we have talked about because there are specific process technologies that are more aligned with and more suited for certain applications.

Q: How do you see these applications of additive manufacturing changing in the future?

Connie Palucka, NPDP, Managing Director, Regional Initiatives, Catalyst Connection

Ms. Palucka: Right now, we see additive manufacturing being used for prototyping in consumer products. In situations where manufacturing and design engineering are in different geographic locations, designers benefit from the ability to use additive manufacturing to produce iterative prototypes. This can lead to more creative, value-added products as well as a faster time to market.
One product that bridges the consumer segment and medical device field is hearing aids. The production of hearing aids switched exclusively to additive manufacturing in less than a two-year period. Additive manufacturing took over because the custom aspect of hearing aid design and production is important. I think in the future we'll see consumers having their own additive manufacturing machines in their home. I think about my brother who is a double amputee and the prosthetic socket is something that has to be custom fitted. If he had a system in his home, he could produce the socket himself so that it's digitally designed to perfectly fit his leg shape. Also, in addition to the perfect fit, he could have this new socket, and the entire leg for that matter, in a matter of hours rather than the weeks or months it currently takes. I expect in the future we will see more of this type of thing.

Dr. Barbur: You have to consider the types of materials that we are discussing here too. At Concurrent Technologies Corporation, we are mostly interested in metal additive manufacturing so that definitely is to a large extent appropriate in orthopedic medical implants or in the aerospace or automotive industries. There are a variety of materials that one can use as part of an additive manufacturing process, be it metals, ceramics or plastics or polymers as they are known. There are different polymers, too, with varying characteristics that again allow them to be used in a range of applications. For example, you can use some polymers, which have very high temperature melting points, in prototyping, and some of those prototypes are used in the automotive area, in racecars, for example. Those parts are customized for the driver and effectively satisfy a need where the requirement for performance pertains to only one race. In aerospace, metal is routinely the material of choice currently, because if you are putting a part into a plane that is going to be operating for many months and that will be exposed to very aggressive environments, with high speed, high altitude and where people's lives are at stake, you will definitely be looking to use metal parts. You have to have the integrity and the robustness. If a hearing aid breaks, then I don't think that anyone's life is necessarily in danger, but if a part in an engine breaks, it's much more serious. Only simple applications in the consumer world would present the possibility of having an additive manufacturing system in one's home to create a device, a smartphone case, for example, as you need it. But I think some of those more industrial applications will never move into that fast maker space.

Q: What impact could additive manufacturing have on manufacturing operations?

Dr. Barbur: From a manufacturing point of view, it depends on whether it's a large manufacturer or a small manufacturer. I think that in the case of large manufacturers the companies are thinking about how they can optimize parts with geometries that were not possible previously using the standard traditional manufacturing processes. They have much broader technical availability of geometries that would potentially allow different dynamics to occur within the system, whereas the smaller manufacturers are using additive manufacturing to allow them to turn around new product concepts much more quickly. Smaller manufacturers are almost becoming like 3D printing shops to the extent that they can offer their services because they don't need to tool up in the way that they did previously. It's a digital process, which provides ready access to designs. You take the part that you want to reproduce and convert it to a digitized representation before printing; it's all computer driven. The digital file is effectively sent to the printer and the printer then produces it. The preciseness of the design is retained to a large extent throughout the conversion chain. There are some limitations, however, as we move into this digital space. We all know about security issues, and the larger manufacturers are probably going to have a very secure infrastructure. I think this issue is one of the major barriers that we see arising for small manufacturers. Are they aware of the potential barriers or the points of interruption in the digital thread that could impact the authenticity and the integrity of the part that they are producing?

Ms. Palucka: When we think of small manufacturers, I think additive gives them the opportunity to potentially add value to their product. It also gives them the opportunity to reconsider how they're producing their part. The example I have in my mind is GE, which is a large company, but they plan to produce 45,000 fuel nozzles a year using additive manufacturing. We've talked about additive manufacturing lending itself to small volumes, but 45,000 isn't really a small volume. In GE's case, they're using additive manufacturing because it allows them to eliminate 20 assembly steps with a single build thus reducing the production cost of that particular part by 75 percent. That's significant and that type of thinking applies to manufacturers of any size. As such, companies considering additive manufacturing should think creatively about the potential value that could be added to their products as well as about how their production process could be improved.

Dr. Barbur: The U.S. Navy, for example, is considering placing additive manufacturing on their ships. As you can imagine, when traveling long distances, parts do break and at this point in time their maintenance support can usually in one way or another, get them back to port. But you can imagine if they had one of these additive manufacturing machines on a ship, they then would have the ability to create a much more sophisticated part that would allow them to continue their mission without having to return immediately to port.

Ms. Palucka: There are many avenues of strategic thinking that manufacturers need to consider. Cyber security and intellectual property come to mind -- companies are going to have to rethink their intellectual property and patent strategy. That's because with additive manufacturing, intellectual property is no longer just related to the product itself but also to the digital designs. Manufacturers will have to determine how they control their digital designs. I think this is going to be an issue in the future.

Dr. Barbur: It's really important not to give anyone the impression that this new technology is a buy it, plug it in and it works kind of machine, so there's obviously the need for understanding and selecting the type of process that best fits your need in relation to the application and also the type of material. Additionally, you have to understand how to set up the machine and to have it actually deliver the performance characteristics that you expect or require in the part, because if not, you could have a great deal of waste that would actually not improve your business model.

Q: How would you characterize the current state-of-the-art in additive manufacturing in terms of the quality and complexity of structures and the finish it can produce?

Dr. Barbur: I think that at the moment the state of the art is still ramping up simply because additive manufacturing is in its early stages and there is some caution in terms of deploying it broadly into every possible application that you can see. When life and death are not an issue, it's going to be much easier to make such a decision. In orthopedics, where they are utilizing additive manufacturing to create customized implants, they are using it because they can obviously repair or replace the part again if anything happens. I think they are also using 3D printing in orthodontics to complement dental treatments because the parts are smaller, precise and because the usage environment is controlled. When you are making larger parts, say for automotive, or for aerospace, then you really have to think about the surface finish and quite often about which metals are more appropriate to use, it's not a one-step process. So quite often, in the industrial space, there are several steps in the sense that you have to print the part but then you also have to have a secondary treatment, perhaps a thermal process, in order to ensure that some of the potential deformations created as part of the printing process, are eliminated in the second treatment step.

Ms. Palucka: Currently there is still a lot of work to be done to bring additive

manufacturing up to the level that it could be. We lack quality standards at this point in time. There are other machining standards and processes that are not yet in place even though this particular technology has been around for more than 30 years. It's really only in the last four or five years, since the patents started expiring, that we've really seen a lot of development going on in this area. Much of it relates right now to the technology and the materials in the applications, but on the standards side there is still a lot of work to be done.

Q: We hear a great deal about additive manufacturing/3D printing; what materials can be used in these printing systems and why do we choose one over another?

Dr. Barbur: If you think about almost any product -- even the hearing aid -- something simple to which we can all relate -- it's not made of just one material. There might be a polymer as the outer-casing, and then obviously there'd be some metal, which includes the sensor, and then there is obviously some kind of wiring system that converts pulses to a signal that the brain can interpret. In any product that we have, there are going to be mixed material content. I think that ultimately, we will have the ability with the additive manufacturing machines that we install to cope with the variety of materials of which a product may consist. Ultimately, many of the parts that we create that include this increased complexity will not consist of just one metal. It could actually be a graded metal structure so one would need to mix the metals in the fabrication process in order to manipulate and manage the characteristics. That's why all these materials need to be investigated as well as the importance of thinking about what that end result is going to be, and where it is going to be deployed.

Vicki A. Barbur Ph.D., Senior Vice President and Chief Technical Officer, Concurrent Technologies Corporation

Q: What makes this methodology so different compared with the traditional manufacturing methods that have been in place for a number of years?

Ms. Palucka: It's in the name -- additive manufacturing -- we're literally building the part layer by layer by layer as opposed to a traditional subtractive type method. So imagine that you have a steel rod and you wanted to produce a shape -- with a subtractive process you would, for example, use a milling machine to remove material to get to the desired shape. This removed material is, in many cases, a waste product. This is one of the big differences with additive manufacturing. Because it's being built layer by layer, you don't have any of the waste generated.

Dr. Barbur: It's that additive manufacturing starts from the ground up; essentially you are creating a part additively and not subtractively. You start with something small and then you build up whereas in the subtractive process you start with a fairly large block of material and you end with a smaller part so it's essentially going in the other direction. While it can be considered a layer-by-layer process, it can also be a point-by-point system when you're actually using a laser sintering approach or an electron beam. In fact, at Concurrent Technologies Corporation, we've even developed a gaseous approach where we do lay the layers down onto a polymer pro-forma. If you have something that is a hollow core structure, then the gaseous approach has advantages. With the pro-forma, you layer on top of the structure, meaning that you can then extract the pro-forma leaving the hollow core shape that doesn't have any internal deformities, which may not be the case with the traditional additive processes.

Q: Why is the Pittsburgh area well positioned to be a leader in this field? What do we have that will help with recognition, expertise and positioning? What knowledge base can we leverage to our advantage?

Ms. Palucka: Pittsburgh, and this region, could really become our domestic center for additive manufacturing. For one thing, we have America Makes in our backyard. This is the national institute for additive manufacturing innovation located in Youngstown, Ohio, and their partner NCDMM (National Center for Defense Manufacturing and Machining), which for years has brought manufacturing innovations to the defense sector and its supply chain. We have leading universities like Carnegie Mellon and the University of Pittsburgh that have active research programs related to additive manufacturing materials, processes and applications. There are other facilities like the NETL (National Energy Technology Laboratory) and the McGowan Institute for Regenerative Medicine at UPMC, both of which are also conducting research in this area.
There are also a number of manufacturers such as GE, Mine Safety Appliances, Covestro, Kennemetal, Westinghouse Nuclear -- all of these companies are investing in additive manufacturing. They see this as the wave of the future to allow them to add more value to their

supply chain. We have one of the major system producers, ExOne, located in this region. We also have a vibrant maker and incubator environment supported by organizations such as TechShop, Innovation Works, AlphaLab Gear and the Pittsburgh Life Sciences Greenhouse. All of this is activity is coalescing and it makes our region unique. We are positioned to be a strong regional cluster and possibly become the leading region for additive manufacturing in the U.S. I've heard it said that we're at the tipping point related to additive manufacturing. I'm not ready to say that we are there yet, but we are very, very close. This is one of the reasons Catalyst Connection partnered with many of these organizations last fall for a technical conference, Additive Manufacturing for Small Manufacturers. We are currently working with America Makes and NCDMM to build a network of experts and resources to help manufacturing companies of all sizes successfully transition into additive manufacturing. Ultimately, we want to build a strong, vibrant additive manufacturing cluster in this region.

Dr. Barbur: One thing that makes this area so prominent in the metal additive manufacturing space is our history in steel. This is an industry that the region had as its foundation. As the area continues to revitalize itself, additive manufacturing has been a natural extension to some extent because there is the history and the heritage. I think another company to call out is Alcoa, and also I think in terms of ExOne and the University of Pittsburgh -- and Dr. Howard Kuhn, who is actually one of the founding fathers of additive manufacturing. Dr. Kuhn also helped establish Concurrent Technologies Corporation when it was founded in 1987.

Ms. Palucka: And I didn't mention Concurrent Technologies and the work they are doing in the additive manufacturing space and Ansys, which is working on modeling technology as well.

Dr. Barbur: We have talked about other areas that can use additive, but when you think about the number of parts that the U.S. Army, the Navy and the Air Force use, and the fact that they have to move them all over the world for different missions, the defense industry is very important. Additive is actually designed to minimize the amount of inventory that you need so that you can have the part captured as a digital file and you can essentially make it wherever you would like to use it. You don't have to ship the part, simply the digital file for printing. You don't have to store the part either. So from a military perspective it does allow them to think about how they manage their supply chain and their needs in the future.

Q: What is the future of additive manufacturing?

Dr. Barbur: Really the sky is the limit. We've been talking a great deal about small parts, engines, metals and medical devices, but architects are using additive manufacturing to build structures, including houses in China and Japan for instance. I've heard of people using additive manufacturing to replace the Great Barrier Reef. As you know, the Great Barrier Reef is disappearing and to keep the habitat around it, they are looking at how they use these different polymers to create a relevant structure to promote the habitat's survival into the future.

Ms. Palucka: Right now they are using additive manufacturing to create drones with 100-foot wingspans, but going even larger than that, they are looking at how to use this to produce fighter jets.

Q: As additive manufacturing improves, where do you think we will see the biggest impact?

Dr. Barbur: I hope that we see the biggest impact in our ability to define the standards so that we can use additive manufacturing to create critical parts. I think the biggest challenge right now is to have those standards in place, and agreed upon, so that large and small manufacturers can begin to use additive manufacturing more ubiquitously.

Ms. Palucka: Additive manufacturing has the potential to change how companies think about themselves. If a company has additive manufacturing capability, they could be producing parts for aerospace this week, manufacturing different parts for the medical sector next week and then producing something completely different the week after that. So, if I'm a machine shop owner with additive manufacturing capability, I may rethink how I position myself -- Is my company just a machine shop or are we something else?

Q: What advice would you give to organizations considering incorporating an additive manufacturing process into their production?

Ms. Palucka: Take small steps and think strategically about how they want to introduce additive manufacturing. Partner with an expert, whether that's a university or a consultant or a system builder, because there is a tremendous amount of expertise that goes into not only selecting the right machine and the right materials, but also the design of the part and the structure that it's going to be built on. Also, a company needs to think strategically about how they will introduce additive manufacturing into their particular production process. Are they going to start with a high-end part that has a lot of complexity and that's sold to a customer base that's not very price sensitive? Are they going to focus on a specific project, in essence start small and gain expertise over time? Or are they going start with a part that's used in multiple product families so they can gain a wider experience base throughout the company at a faster rate?

Dr. Barbur: I would say that people considering moving into this space should not be afraid to ask others who have been there before so that they can learn from experience and have a support structure in place. There needs to be some understanding before starting to produce parts using additive manufacturing to help reduce risk and avoid liability. You must fully understand how to build the digital conversion process flow as you move the information around -- whether it's related to the material characteristics or the design -- so that there is confidence in the process and that what you think you are producing is really what you're producing. It is important to ensure you don't have any breaches in the digital chain. It's also important to be aware of what you don't know, and sometimes that's hard for people to admit.

Ms. Palucka: Finding an expert to work with is so important. Catalyst Connection can help companies find an appropriate partner. Concurrent Technologies Corporation may be able to actually be that expert.

Dr. Barbur: We are both nonprofit organizations and we can help those interested in this new manufacturing process to identify the right technology and the right partner.