ZETON 35 1986-2021

REALIZE THE FUTURE

TECHNOLOGY HORIZONS

A publication by Zeton, the pilot plant specialists

SPRING 2021

IN THIS ISSUE

Horizons is also available on our website at **zeton.com**

BTG Bioliquids Plant for Green Fuel Nordic in Lieksa, Finland

CELEBRATING ZETON'S 35TH ANNIVERSARY

Welcome to a special 35th anniversary edition of Technology Horizons. To kick things off, a retrospective and forward-looking lead article written by David Beckman, Director of Zeton International.

Since 1986, Zeton has been working with customers to help develop, scale up and commercialize new process technologies. In many cases we have supplied customers with the initial lab scale system, followed by pilot and demonstration plants, and first modular production plants. It is interesting to look back at the wide range of process technologies that Zeton has helped advance over the years.

In the first 15 years, projects included applications for heavy oil upgrading, coal conversion technologies, catalyst testing for petroleum processing and chemical production, testing new families of polymer catalysts and new polymer products, specialty electronic chemicals, and environmental applications. Towards the end of this period the desire for cleaner fuels led to many different gas-to-liquids projects.

The past 20 years has seen a shift towards the development of sustainable technologies and green chemistry. Some of the processes we have helped advance include biomass conversion to liquid fuels, biopolymers and bio-chemicals, biodiesel production from waste fats, waste plastics conversion to chemicals, new sustainable processes to produce bio-rubber, carbon black, and other chemicals, conversion of CO_2 to natural gas, and most recently the production of sustainable jet fuel from biomass-derived feedstocks.

More recently, Zeton has been working with pharmaceutical companies to develop continuous flow chemistry processes. This collaboration has led to significant innovation in modular, plug-and-play designs specifically for pharmaceutical applications, and the development of first-of-their-kind modular flow chemistry API production plants. The development of sustainable technologies, and innovation in modular flow chemistry applications, are expected to continue into the foreseeable future.

Zeton is proud to have played an important role in the development of each of these technologies.

It's the knowledge and expertise passed from one generation of engineers and craft technicians to the next that has given Zeton the confidence to tackle new industries and applications, like energy storage and flow batteries, for example, as they emerge. This, along with our emphasis on quality and the goal of unquestioned customer satisfaction, has been key to our longevity and success.

Chemical Design, Inc. (CDI) of Lockport, NY joined the Zeton Group of Companies in 2019.

President Jim Ibaugh is in conversation with David Edwards

Jim Ibaugh, President,
Chemical Design, Inc.

David: "Jim, how did the company get started?"

Jim: "The origin of CDI dates back to the invention of molecular sieves, or zeolites, by the Linde Division of Union Carbide in Tonawanda, New York in the late 1950's. Linde did a lot of research on how they worked, and how you can separate different molecules at the molecular level based on size. But Linde didn't want to sell complete plants, so Walter Schmid and Jim Meyers started Chemical Design, Inc. in 1959, and one of the main goals was to use these molecular sieves and other adsorbents to remove impurities on a commercial scale. Most of the early plants were new applications that advanced the state of the art to the current technology."

David: "What were some of the early challenges?"

Jim: "The goal was always to supply complete systems, but modular skidded systems were in their infancy in the late 50's, early 60's. So with new process technology, and a new project delivery approach, it took about 3 years for sales to finally take off. The first systems were built in an old cookie factory in Lockport, NY, and they had to be disassembled to get them out of the building."

David: "What were some of the first applications for molecular sieves?"

Jim: "Mr. Schmidt was very good at applying these molecular sieves and other adsorbents to new industries. In 1964, we were the first company to use molecular sieves to remove water and CO_2 from air for the air separation industry. Before that they used reversing heat exchangers, where one would freeze out water and CO_2 for four minutes while the other one was defrosting, and any hydrocarbons in the air would invariably end up concentrating in the liquid oxygen stream, a major safety issue. Molecular sieves solved this quite elegantly by removing the hydrocarbons along with the water and CO_2. This approach is still the industry standard, and it is also used for removing water and CO_2 from natural gas before it is liquefied."

David: "Was CDI focused on Temperature Swing Adsorption (TSA) rather than Pressure Swing Adsorption (PSA)?"

Jim: "Yes, those early plants were always TSA. PSA is good for bulk removal of impurities down to 200 PPM (parts per million) or so. Below that, PSA can begin to slip. TSA allows you to get much lower, less than 1 PPM or even lower. In the electronics industry, they like to see less than 0.1 PPM of impurities, and for that you need TSA."

David: "What are some of the more recent innovations?"

Jim: "An important one would be cryogenic hydrogen purification. At very cold temperatures molecular sieves can remove just about anything from a hydrogen stream, which is very useful for the electronics industry.

"Secondly, we started adding catalyst beds in order to react some compounds out and then follow that with adsorbents to remove whatever products were formed in the reaction. An example is removing oxygen from argon by reacting the oxygen with hydrogen to make water and then use a dryer bed afterwards to remove the water.

"Thirdly, in the 1970's, CDI supplied the first polysilicon vent gas recovery units, to purify and recycle unreacted chemicals from the silicon reactor vents using a combination of different technologies including adsorption, compression, absorption and distillation.

"Finally, we've been active in chlor-alkali electrolysis plants for many years, supplying H_2 deoxo dryers to remove anywhere from 200 vppm to 1.5 mol% O_2 from H_2 streams of 1,000 to 25,000 Nm3/hr.

"There are many other applications for our reaction and adsorption technologies, some of which involve the nuclear industry."

David: "What synergies do you see between CDI and Zeton?"

Jim: "We both have a similar product, completely assembled plants, shipped on skids, shipped directly to site and reassembled quickly. One difference is that CDI uses its own process know-how, and because of that we are finding that Zeton plants can often use CDI's purification technology. We are able to integrate these with the rest of the Zeton project, which is a benefit to the customer."

David: "CDI supplies fully-automated control systems with its plants. Why is that, and how has that changed?"

Jim: "From the very first plant we have supplied the control systems. The early units used timers, a series of relays, and something that looks like a player piano drum - a step drum it was called. I joined CDI in 1987 and was able to see the last of step drums go out, and the first projects where PLCs were used. In 62 years, you learn a few tricks about how to do things safely, and we've got interlocks and safety protocols that are programmed into the control logic, to ensure our plants operate safely."

David: "Most of CDI's employees live in the Lockport, NY area?"

Jim: "Yes, local people, with a short commute. As a small company with 15 employees, we have a design team that really knows what they're doing, and can do it quickly and efficiently. They are very capable at working around the edges of whatever is the highest priority each day." ■

Future trends in modular pharmaceutical plants.

Herman Bottenberg, Marketing and Sales Manager at Zeton B.V. is in conversation with Esther Schröder

Herman Bottenberg, Marketing and Sales Manager, Zeton B.V.

Esther: "In this feature we'd like to give Zeton's perspective on the future of the pharmaceutical industry. Is there a specific trend that is driving change in this industry?"

Herman:"In the past year especially, the pharmaceutical industry has proven to be a crucial factor in the everyday life we all enjoy. In less than a year, vaccines had to be developed, and the technologies for this had to be rolled out globally to multiple locations and production facilities. Speed of execution and flexibility are key, and more important than ever.

"Along with this we recognise a trend towards independency, and local production in smaller quantities. More and more, continuous manufacturing will be chosen as the preferred route.

"Looking ahead, wouldn't it be great to develop a new technology which is better suited for future products, their control and required quality, independent of location, and one that is quickly scalable at the right moment?"

Esther: "What is the current status of this change in operation in the pharmaceutical industry?"

Herman: "The trend towards continuous, smaller production, and unknown future products, requires flexible solutions. And for rapid deployment, bottlenecks have to be removed. There are various initiatives, like Namur and VDI in Germany, acting on this, developing guidelines and standardisation on new modularisation technologies in anticipation of this."

Esther: "Does this future outlook influence how an engineering firm has to act? What is expected by our customers?"

Herman: "We have identified a focus on modularisation of production, to develop standardised functional process modules, which can be used for multipurpose processing. The overall process is divided into smaller process sections, with each operating as its own process unit. A selection of these modules together will form a complete process plant. By including automation in each module, we create predefined and pre-validated systems, eliminating a significant amount of validation when introducing new process modules for the next product or production run.

"The challenge is to understand the overall process required to produce this future product in such a newly configured system, and this goes beyond the process hardware to include a robust automation solution. Future industry developments can use Module Type Packages (MTP) to achieve fast integration of process modules. And we believe module-to-module communication will also be required to achieve maximum advantage in speed and flexibility. Zeton has successfully applied this latter functionality to several recent projects.

"An engineering firm realizing these processes should have excellent knowledge on the individual unit operations/functional modules, understand overall process design/operation and provide a modular automation solution."

Esther: "How did Zeton approach this?"

Herman: "When designing and building modular plants for various pharmaceutical customers in the last decade, standardization towards a modular concept has always been a key topic. We have developed a suite of standard process modules, ranging from simple pump and flow modules up to highly complex reaction and separation modules. These modules were delivered as single module assemblies and combined to form small molecules pharmaceutical and biopharma processing lines.

"A key philosophy is not changing process technologies between pilot and production scale. The modular design can then minimise time loss between those phases. Furthermore, being standalone systems, these process modules can easily be exchanged to facilitate maintenance while the production plant remains in operation."

Esther: "What is the pharma industry's benefit of embracing this modular concept?"

Herman: "As the modular concept is flexible and, to a degree, independent of the process, it will be a primary tool for any future product to be developed and produced. Working with standardized process modules also ensures industry-wide alignment between production sites; the scale-up and technology transfer challenges associated with traditional processing methods are largely avoided.

"Furthermore, a backbone can be integrated into Zeton's modular plant concept, to simplifies integration at site. Feeds and utilities are run in advance to the edge of the backbone, and connected to each module through a standardized connection system, saving significant time and effort. The modular automation will also reduce the time required for process and automation validation.

"Overall, this approach offers the flexibility and speed required by our customers."

Esther: "How does someone start implementing the modular concept? Can you start small?"

Herman: "Yes, one approach is to start small; this is the beauty of the modular concept. The process modules can be combined in the lab in a simple configuration to start with. We have had customers buying two pump modules and a reactor module, for example. Then they expand later by adding additional downstream processing modules, or parallel reaction modules. The backbone grows with the future expansion, since it is designed in a modular fashion as well.

"As an alternative to a simple starter set, we can also integrate new systems into existing facilities, and deliver complete, multi-step GMP/GAMP facilities for dedicated processes. They are fully-integrated with the site and the customer's process control system, also referred to as Process Orchestration Layer (POL). Although we standardise the process modules, the requirements of the process, together with our customer's specifications, defines the project scope. Zeton then tailors the modular plant solution for each customer using our established project-oriented approach." ■

Celebrating Zeton's last five years (2016-2021) A Graphic Illustration

January 14, 2017
The Zeton Zoomers freeze out the Burlington Dirty Devils 3-0 at the 40th annual Al Reid Memorial Oldtimers hockey tournament

April 25, 2017
Zeton Inc. celebrates the opening of our Michigan Drive facility in Oakville, ON

January 2018
Zeton Inc. ships the first of several plants built in the new clean bay

February 28, 2018
Leisl becomes President of Zeton Inc.

September 10, 2019
Zeton purchases CDI of Lockport, NY, a company specializing in innovative techniques for separation and purification applications

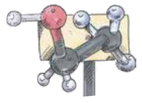
Winter 2019
Zeton B.V. celebrates the fundraising efforts of Mieke Padberg[1] and her colleagues, who together raised money for charity for a third consecutive year

December 2019
Zeton B.V. delivers the smallest hydrotreater units built to date

January 2020
Zeton launches its new AODA WCAG 2.0 Level AA compliant website

June 2020
Zeton B.V. purchases Marssteden 210 to provide a dedicated facility for lab, pilot and pharmaceutical industry equipment manufacture

September 2020
Zeton Inc. delivers the largest and heaviest modules in its history to the Port of Hamilton



September 2020
LanzaJet awards the EPC contract to Zeton for a 10 million gallon per year sustainable aviation fuel production plant, the largest project in the company's history

January 2021
Delivery of a continuous manufacturing facility represents a new milestone in Zeton's modular concept for pharmaceutical and fine chemical production

February 10, 2021
This milestone acknowledges the employees with 30+ years' service at Zeton Inc., Zeton B.V. and CDI:

John Grieve
Gary Chu
George Hart
Roland Haghuis
Johan ter Harmsel

Michel Koebrugge
Henk Naber
James Ibaugh
Darren Wildt
Steven Logar

Future trends in CO_2 utilisation.

Han van de Riet, Operations Manager at Zeton B.V. is in conversation with Esther Schröder

Han van de Riet, Operations Manager, Zeton B.V.

Esther: "The last few years in media communications, we've seen buzz words like "circular economy", "sustainable industry", "CO_2 footprint" and "eco-friendly products". Is this something Zeton sees in practice?"

Han: "Due to public and governmental pressure to reduce CO_2 emissions to the atmosphere, we see several initiatives in the chemical process industry to develop new technologies. The traditional multinationals are investing in this field, and also several start-up companies are active, working to make their technology viable. Pilot and demo plants are needed to convince stakeholders that the technologies work in the real world."

Esther: "How do you expect these global ambitions will impact the chemical industry?"

Han: "The chemical industry must set a goal to reduce the amount of CO_2 emitted. This is to be achieved by new technologies, reducing energy consumption, bio-based feedstocks and shifting to sustainable power sources for their chemical processes. Reducing CO_2 in the atmosphere can also be achieved by using CO_2 as base chemical for processes i.e. CO_2 utilisation. In this way, CO_2 can be partly made circular to reduce or eliminate the use of fossil-based raw materials."

Esther: "Zeton is active in supporting customers in scaling up their processes. Did you see a change in the past years in the types of projects that we see due to trends like sustainable manufacturing and CO_2 utilisation?"

Han: "A growing percentage of our projects are related to sustainable manufacturing and CO_2 reduction or utilisation. Even the more traditional processes are optimized in relation to these goals. For example, we have recently seen pilot plants for polymers focus on the use of CO_2 as building blocks for the polymer."

Esther: "Specifically, what value does Zeton bring to these types of projects?"

Han: "Start-up companies have more difficulty securing the required investments to bring their ideas through to a commercial plant, but they move a lot faster than larger, more established companies. Zeton's flexibility and experience can be of added value to help these companies realize their scale-up goals, in an affordable and expedited way. Our engineers are very good at translating the ideas of technology developers into real world plants, and they offer support through all stages of development for these new, innovative technologies."

Esther: "Do you think CO_2 utilisation and reduction will become a normal aspect of existing chemical industries, like, for example, safety and protection of the environment?"

Han: "Yes, I do. The first indication is that traditional energy and oil and gas companies are switching to greener feedstocks and processes. The political will to decarbonise energy-intensive industries is there, the funding is there and, increasingly, the public commitment of multinational chemicals producer executives is there."

Esther: "Might future plants employing CO_2 utilisation or reduction be smaller than their traditional ancestors?"

Han: "Some technologies like biofuels are suitable for a specific throughput that matches the feedstock availability or market size of the product locally. This is called distributed manufacturing. These production plants are smaller in size, and fit very well with the scale-specific project approach for modular skid-mounted plants that Zeton focuses on. A photo of such a plant features on the front cover of this edition of Horizons."

Esther: "What are some other examples of projects Zeton has completed in this emerging technology area?"

Han: "Zeton has built plants for the direct use of electricity - generated by wind and solar - in processes and factories where CO_2 is used as a feedstock to produce fuels and chemicals. An example where CO_2 is used to make a valuable product can be found on pages 8 and 9. Another example of CO_2 utilisation is the direct use of CO_2 in a fermentation process to convert CO_2 into a fuel, and Zeton has delivered plants for that too."

Esther: "What makes these projects unique and special?"

Han: "Oftentimes, new processes are operated under more extreme conditions, or require the use of exotic material of construction, for example. Identifying scale-specific solutions for the equipment in these processes, and delivering on the process and mechanical design challenges they present, are key to our customers proving their new technology in the real world, before they scale up to production scale."

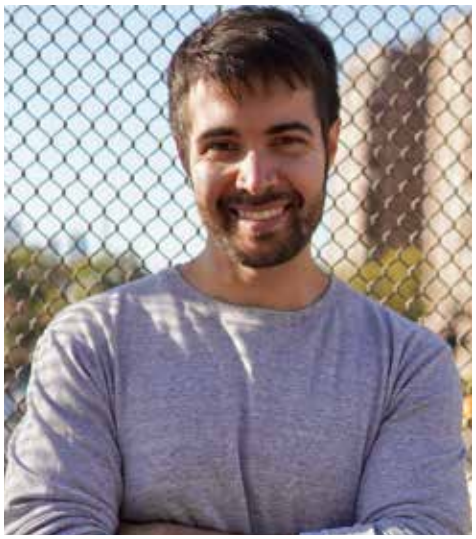
Esther: "How does Zeton's commercial offering compare to engineering companies active in this field?"

Han: "The scale of pilot and demonstration plants used in CO_2 utilisation project fits very well within Zeton's modular design-build approach. Several technologies in the carbon capture and utilisation (CCU) field use syngas-based technologies to convert CO_2 into chemicals and fuels, which Zeton has extensive experience with from our gas-to-liquids project portfolio. Also, Zeton is technology independent, so we are free to work with any customer, and any technology, and we do."

Esther: "What are Zeton's hopes and ambitions with respect to CO_2 utilisation?"

Han: "With over 35 years of experience in helping customers scale-up their process technology, Zeton is uniquely placed to play a part in the fight against global warming. We can best do this by actively supporting the development of new CO_2 utilisation technologies through the delivery of state-of-the-art pilot and demonstration plants to customers who are active in this area." ■

Dr. Stafford Sheehan discusses Air Company's origins, recent projects and future plans in conversation with David Edwards



Staff Sheehan, CTO,
Air Company

David: "The origins of Air Company date back to 2017. How did the company get started?"

Staff: "My co-founder Gregory Constantine and I met that same year at a bar in Israel over whisky. We were both on the Forbes 30 under 30 list and were there at an event hosted by Forbes. He was an executive at Diageo, the largest liquor company in the world, and I was focused on carbon dioxide conversion, trying to find ways to use carbon dioxide conversion technology commercially. We became friends, stayed in touch, and after several months started Concord Spirits, which became Air Company."

David: "Can you describe Air Company's innovative carbon dioxide to ethanol technology?"

Staff: "We capture CO_2 from a variety of sources; in Brooklyn from post-fermentation, in Calgary from the flue gas of an 860 megawatt natural gas fired power plant, and we're developing our own technology to capture it from air as well. We take that captured CO_2 and combine it with hydrogen that's generated in a water electrolyser using renewable electricity. In Brooklyn, we use a mix that's over 90% wind with the remainder being solar. The CO_2 and H_2 are fed into a reactor where they're exposed to catalysts. My Ph.D. was in catalysis, and our catalyst is a proprietary, in-house development that we produce in our laboratory. We end up with a mixture of alcohols in water, methanol, ethanol, n-propanol, that we distill to remove everything but the ethanol. The result is the ultra-high purity ethanol that we use to make Air Vodka."

David: "Commercially, what's your plan for the by-products?"

Staff: "The water we can reuse; it's actually pure enough to drink. The n-propanol is a valuable commodity chemical, but with a high legacy greenhouse gas impact; our n-propanol can make applications like pharmaceuticals greener. As for methanol, we're working on several partnerships, across different industries; industrially, it's one of the most widely used chemical intermediates. Methanol is also a target chemical intermediate for in-situ resource utilization on space stations, and on Mars."

David: "Air Company first approached Zeton in late 2017, and we completed our first project together in 2019. What was it, and how did it come about?"

Staff: "The first project we did together was the pilot plant in Brooklyn, NY, which is a fixed bed flow reactor. The project was partially funded by a grant under the Solutions 2030 Challenge from Ontario Centre of Innovation (OCI). I was initially introduced to Adam Whalley through one of our company's advisors. We had a CSTR in our laboratory, and we needed to scale it up into a flow reactor. We went to many different engineering firms to try to get advice on how to how to do it correctly. Through Adam, I was introduced to Chris Brown. I remember my first call with Chris. I was standing outside of Chelsea Market in New York City. We were reviewing the work that a lot of these engineering companies had done, and Chris knew exactly all the things they were doing right, and what they were doing wrong. He was able to sort out the best way to build this pilot plant, in the most economical way. And then over the course of the next year we designed and built it. It's fully operational in Brooklyn and serves both as a pilot and production plant."

The Brooklyn Pilot Plant

David: "So the scale-specific experience that Chris and Zeton contributed was key to helping this project take the next step and get built?"

Staff: "Yes, it was. Chris' experience was really helpful in keeping us within budget and we couldn't have asked for a better engineer. Even after retiring from Zeton, Chris and I have kept in touch and I really value his advice and mentorship. He got the first bottle of Air Vodka in Canada."

David: "Zeton just delivered a second plant to Air Company, and we've started design work on a third. What do these projects entail?"

Staff: "The second plant was developed as a 10x scale up of our Brooklyn pilot plant. It was built with a larger budget, so we could make performance upgrades to several components, for example, temperature control around the reactor. This was a custom-designed solution for our catalyst, and process, and it's made a world of

difference. We learned a lot from operating the first plant, and these improvements are included in the 10x scale-up. The third plant will be a continuous distillation system incorporating patent-pending IP for efficiency and impurity removal."

David: "What are the advantages in working with one company to scale your process technology?"

Staff: "One advantage is as you scale, you learn a lot of lessons at each step, and having an engineering partner that knows those lessons, and that they were hard-earned, helps to make sure that the same mistakes aren't made again. If we had a larger team of engineers, internally, then I think it might be different; we'd have more institutional knowledge within Air Company, but we're a 20-person company. So, as a technology developer, we're a small handful of people. Working with one developer - one EPC - ensures that the institutional memory is retained between our organizations as we scale up, which is good."

David: "Are there advantages in working with a company like Zeton that builds what they design, as opposed to working with an engineering company to do the design, and then shopping it around to different fab shops?"

Staff:"Yes, a lot of times we've learned that the as-designed system doesn't always work; what you design on paper doesn't always manifest perfectly in real life. Being able to iterate and modify the design, using the same people that develop the design initially, has been really helpful. So that's a big yes. For small businesses like ours, and at the scale we're operating at, I feel it's a much better decision to use the same firm for design and build. Big companies with their own engineering departments have options using their own internal resources, but for companies like Air Company that don't have a 500-person engineering department, I feel it's much better."

David: "The United States Government has announced ambitious plans to build a clean energy economy. How will Air Company contribute to this effort?"

Staff: "Well, we're already contributing to it. Our goal is to replace consumer products with products that are carbon negative, and higher quality. What we're showing is that you can have a product that is the highest quality, and the greenest, with our vodka, and with our sanitizer. Our vodka has won three gold medals in blind taste tests at the three largest spirits competitions in the world - blind, so they didn't even know it's made from CO_2. That's where we fit into the clean energy future the United States; we're going to make products greener and we're going to make them better."

David: "How would you categorize Air Company? A beverage company? A fine chemicals company?"

Staff: "We're a technology innovator. Eventually, we're going to want to license our technology, because the more people that use it, the more impact it can have toward removing greenhouse gases. But we're always going to have our own brands, which we build as we scale our technology. These brands are going to be made by us so that we can have tight quality control so that customers know they're getting the best product."

David: "One last question. Can you talk a little about your work with NASA?"

Staff: "Definitely. One of our projects, which we codename Air Stellar, relates to applications for CO_2 conversion on space stations in Earth's orbit and on Mars. It's gradually becoming a solid part of our business, especially as the space industry has skyrocketed in the last six months. The big one is Mars; with an atmosphere containing 95% CO_2, if you want to make anything on Mars, you better know how to convert CO_2. And there's water in the form of ice there. You use electrolysis powered by the sun and photovoltaics to make hydrogen and oxygen, and then our technology fits perfectly alongside that. We've done work for NASA's CO_2 conversion challenge, and to date I believe we're the only CO_2 conversion company that's been on the front page of nasa.gov." ■

The 10x Scale Up Pilot Plant

IN BRIEF

HIGHLIGHTING RECENT AND COMPLETED PROJECTS AND ENGINEERING STUDIES

- A CO_2 to chemicals pilot plant
- A bio-oil production plant
- A chemical batch reactor pilot plant
- A distillation system for the electronic chemicals industry
- A membrane system for a petrochemical industry application
- Two DCR FCC pilot plants
- A control system upgrade for a DCR pilot plant
- A custom gas-liquid contactor for a University research application
- An engineering study for a sulphuric acid leaching pilot plant

A modular pharmaceutical production platform

A separation skid in a biofuels industry application

A reagent dosing skid in a pharmaceutical industry application

A 3D render of a 10 million gallon per year sustainable aviation fuel biorefinery

CONTACT US

TO DISCUSS YOUR PROJECT REQUIREMENTS, OR ITEMS IN THIS ISSUE OF HORIZONS, PLEASE CONTACT:

ZETON INC.

740 Oval Court
Burlington, Ontario
Canada L7L 6A9

455 Michigan Drive
Oakville, Ontario
Canada L6L 0G4

Phone: +1 905 632 3123
E-mail: info@zeton.com

David Edwards
Ravin Davè
Catalina Bayona Velez
Pratik Bhishikar

ZETON B.V.

Marssteden 206
7547 TD Enschede
The Netherlands

Marssteden 210
7547 TD Enschede
The Netherlands

Phone: +31 (0)53 428 4100
E-mail: info@zeton.nl

Herman Bottenberg
Robert-Jan Zwiers
Thomas Ladrak

Visit us online at www.zeton.com