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US technology and R&D tour

16th – 30th October 2007

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1 Introduction

During the period of 16th to 30th of October 2007 a tour across the United States took place, where a group of six people from different companies (three representatives from Australian plants, two of a New Zealand technology provider, an MLA representative and one from an Australian technology company) visited multiple organizations, with a focus on new technologies, trends and cutting edge research applicable to the red meat industry.

The idea behind this trip was to understand which technologies are being developed in the U.S, in order to learn from different trends and explore new avenues to progress in the development and application of new technologies to provide a sustainable competitive advantage to the Australian red meat industry.

In the middle of that tour, the group attended AMI 2007, a renowned food processing trade show held in Chicago every couple of years.

This report is a summary of the observations and learnings taken from that tour.

2 University of California, Berkeley. Berkeley Robotics Laboratory (Berkeley, CA, 17 Oct 2007)

The first stop in our U.S. tour was the Berkeley Robotics Laboratory, run by professor Hami Kazerooni. Their research activities are focused on the design and control of a class of robotic systems worn or operated by humans to augment human mechanical strength, while the wearer's intellect remains the central control system for manipulating the robot. Human power extenders can be used to maneuver heavy loads with great dexterity, speed, and precision, in factories, shipyards, airports, construction sites, and warehouses.

The design and control of human power extenders are different from the design and control of conventional robots because they interface with the human on a physical level. The human transfers his/her commands to the extender via the contact forces between the human and the extender, eliminating the need for a joystick, pushbutton, or keyboard to transfer such commands. In this unique configuration, the human body, in physical contact with the extender, exchanges both power and information signals with the extender. Because of this unique interface, the human becomes an integral part of the robot and "feels" the load that the power extender is carrying. The hypothesis is that these machines when worn by workers to maneouver loads, prevent back injuries in workers. When the worker uses the extender to touch and manipulate a load, the extender transfers to her/his arm, as natural feedback, a scaled-down value of the actual load weight which the extender is manipulating: the human "feels" the load weight in the manipulations. In this way, the extender prevents back injuries to workers maneuvering loads.

This group has focused its work in two areas:

- lower extremities aid
- upper extremities aid

Lower extremities aid

The Berkeley Lower Extremity Exoskeleton or BLEEX project was originated from a U.S. defence need to help troops to carry heavy loads for extended periods of time. This group has gained funding from DARPA (Defense Advanced Research Projects Agency), and it is waiting for further funding to progress and take the technology to a full commercial stage.

We had the opportunity to witness a demonstration of the system, with a light framed researcher wearing the exoskeleton and carrying up several tens of kilos without major effort. The group is working on several versions, with the top end allowing the individual wearing it to carry more than his/her own weight, in sessions of 8 hours a day, during three days without the batteries needing a recharge. The expected price of a system like that would be between US$10-20k, but the entry versions should be below US$10k.

Some of the researchers under this team have founded a start-up called Berkeley Bionics to commercialize these systems.

Another demonstration we witnessed was an intelligent prosthetic leg for amputees capable replicating the natural movements of ankles and knees for people missing those joints. Despite being a prototype, the results were really impressive and most probably products based on that technology will reach the market soon.

Upper extremities aid

The other area where this group has done some work is in similar systems to aid workers in boxes or loads lifting. This application has been developed already into commercial systems to aid workers in lifting loads but an interesting new area is the design of machines to assist tasks like boning. Professor Kazerooni claims the skills developed under their Berkeley Bionics start-up have given them rapid prototyping capabilities very useful to quickly design and build a first system to aid boners on a selected task.

We agreed to provide them with a video of the typical tasks performed in a meat processing plant to see if they can come up with ideas to develop a system aimed at assisting meat workers in their everyday duties. We have already initiated this path with Northwestern University in Evanston, Illinois, but exposing other research organizations to our problems will always help us to find solutions more quickly.

3 IMTEC Corporation (Loa Alamos, NM, 18 Oct 2007)

We visited IMTEC in their Los Alamos facility in New Mexico. IMTEC Corporation is the result of the merger of Hytec and Imtec in 2006. The facility we visited was Hytec before the merger and it also serves as the R&D center of the company, specialised in industrial CT (Computed Tomography) but working also in other high tech engineering projects like highly stable structures, composite materials design and analysis, systems development and integration, etc.

The other half, the original IMTEC, is based in Ardmore, Oklahoma, where their star product is manufactured, which is ILUMA the head CT scanner for dental applications. They also manufacture dental implants in that facility.

IMTEC currently has close to 250 employees and a combined annual revenue of US$50M. Apart from their main facilities in Los Alamos and Ardmore, they also have a smaller office in Colorado where most of the software development is done. They also own other smaller companies in Holland and Australia dedicated to market their dental products.

IMTEC has 5 major product lines:

- Engineering services (Los Alamos).

  Their main customers are large science programs needing of expertise in highly stable structures, composite materials, etc.

- Industrial X-ray Imaging (Los Alamos).

  One of IMTEC’s core competencies is industrial CT scanning for non destructive testing and similar applications. All their products are built on their FlashCT platform.

- ILUMA (Ardmore).

  This is the commercial name for a whole head CT scanner conceived and developed for dentists, orthodontists and oral surgeons.

- Digital Dentistry (Los Alamos and Ardmore, with commercial agents in Holland and Australia).

  Digital orthodontic study models (OrthoProof, Align) and orthodontic/dental aids manufactured from digital models.

- Implants (Ardmore).

  Dental implants and related products.

The tour to Los Alamos facility helped us to understand IMTEC’s R&D capabilities, as this is the place where new products are developed, particularly in the CT scanning field.

FlashCT industrial systems

We saw several CT systems being assembled and tested and we had the opportunity to see the model IMTEC is planning to adapt for meat processing applications. The FlashCT platform is based in what is called Cone Beam CT, which makes possible collecting all the data with only one circular scan, versus the traditional CT approach of following a spiral path to cover properly the whole part or body to be analysed. This technique reduces significantly processing time.

After the walk through the facilities we reconvene at the main meeting room where we witnessed an impressive demonstration of the post-processing software they have developed in-house to analyse CT scans and extract and differentiate the different layers of information like bones, fat, muscles, etc. The demonstration was remotely run in real time by their team in Colorado, making use of a remote terminal network technology. The demonstration was really impressive, starting with the 3D image of a patient head, with layers progressively removed, with the skin and fat first, going through the muscles to end up with the bare skull, teeth and bones.

CT scan image

Overall, the demonstration was really useful for all the participants to understand better the potential of the technology, and how the data that was visualised could be used to define a comprehensive 3D map of an animal carcass, as well as determine accurately fat and lean content, and even size and weight of each particular cut.

The only issue raised by the tour participants was how the system could be modified to make it capable of enduring the rough environment typical from meat processing plants.

Currently MLA is working with IMTEC to set up a first project to evaluate the technology for red meat applications under MLA's Objective Carcass Measurement initiative.

4 Georgia Tech, (Atlanta, GA, 19 Oct 2007)

The Georgia Institute of Technology is a big research university located in Atlanta, Georgia, where more than 18,000 undergraduate and graduate students receive a technologically based education.

Georgia Tech has 6 major units:

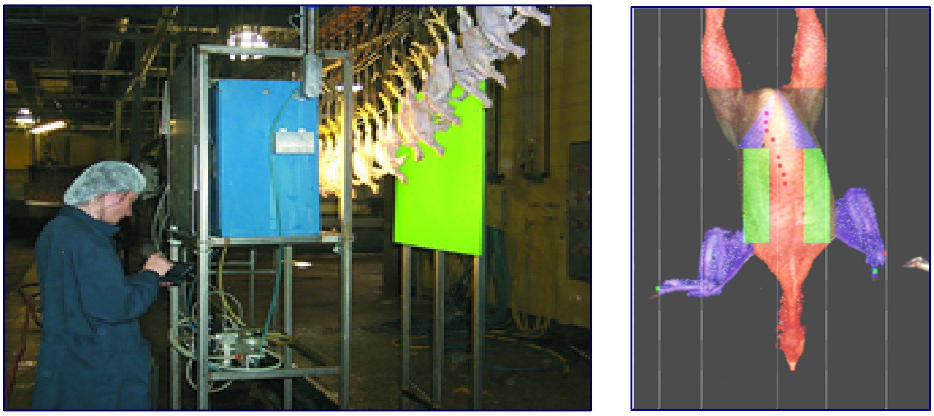
- Georgia Tech Research Institute (GTRI)
- Economic Development
- Degree Granting Colleges
- Distance Learning and Professional Education
- Interdisciplinary Centers
- President's Office

Our visit focused on the Georgia Tech Research Institute or GTRI, and in particular in the Food Processing Technology Division. Their mission statement is to conduct basic and applied technology research for the food industry, generating commercial outlets through which systems and developments can be transferred from research programs. Their major research areas are:

- Vision Technology
- Robotic systems
- Intelligent processing systems
- Flexible Computing and Information Systems
- Environmental Technologies
- Food Safety Systems
- Worker Safety Systems

Traditionally their research work has been more visible in the poultry industry, where their massive throughputs (there are plants processing up to 400,000 birds per day) justify high levels of automation. However they work also in other areas like vegetables, bakery, etc. and they are open to additional sectors like red meat.

A group of Georgia Tech researchers, led by Craig Wyvill, the Food Processing Technology Division chief, gave to the Australian party a comprehensive presentation of all the relevant areas of research they are active in. They started with an introduction to computer vision technology and their applications to grading and defect detection. For instance, they have developed systems to detect fan bones (very soft bone, close to cartilage) as well as foreign objects in poultry meat using superficial colour techniques. They have also done work in 3D imaging systems, including stereo imaging and laser profiling, as well thermal imaging.



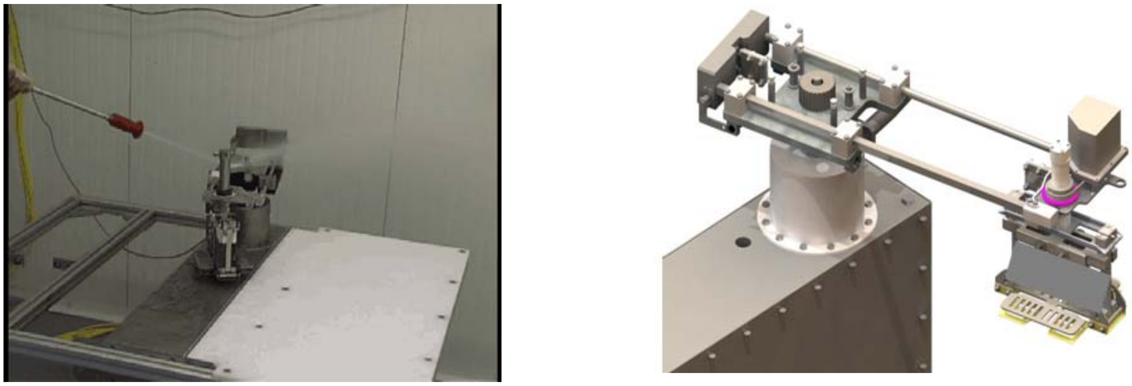
Poultry Imaging Cell

Grapefruit Screening system

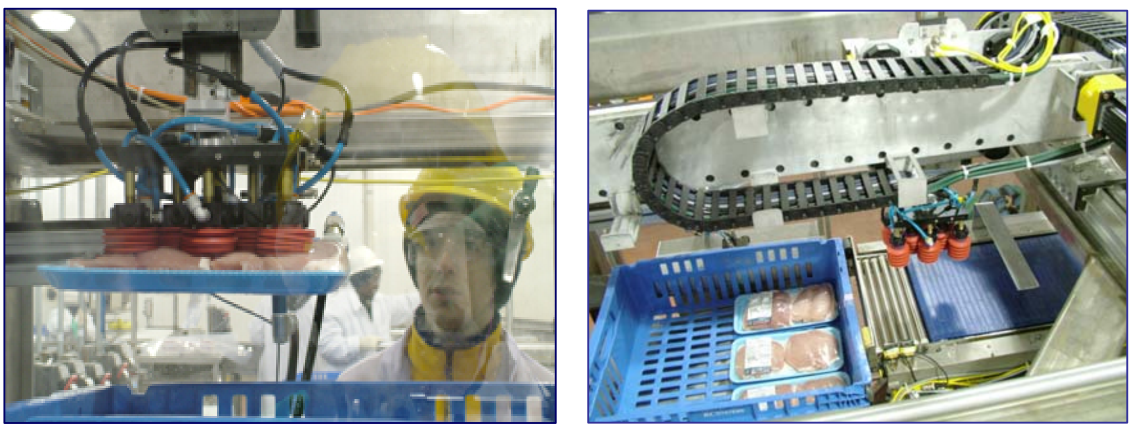
Poultry. Fan bone detection cell.

Bun screening system

Georgia Tech has been very active in robotics research. Some of their significant achievements are the development of a robotic case packer or a washdown robot for tray loading.

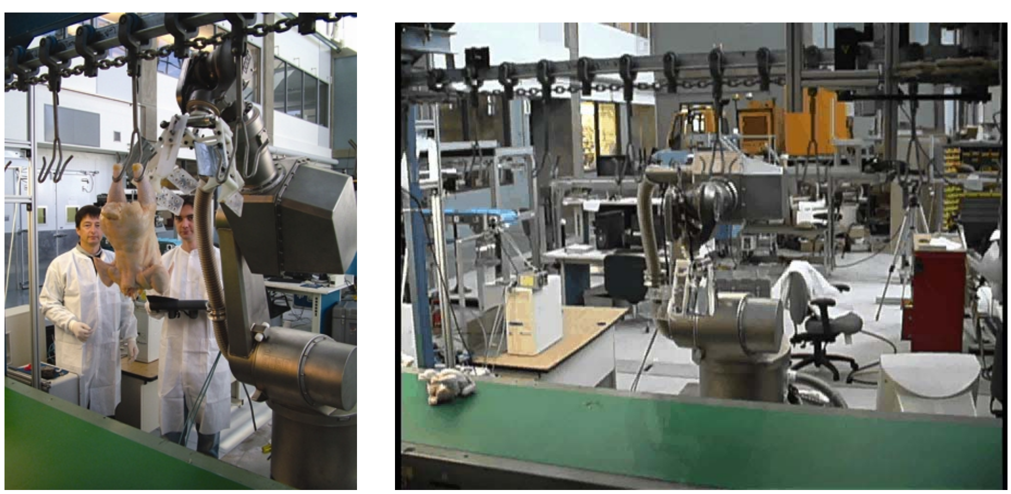


Washdown robot for tray loading



Casepacker robot

Other lines of work in robotics are intelligent cutting robots, in particular to cut chicken shoulder, or a system to load and unload birds in gambrels (automatic shackle loader).



Automatic shackle loader

Intelligent de-boning system

More advanced research is also being done in visual servoing with real time feedback. The speed at which the system can handle movements is still reduced, but the whole concept is very promising, as only through real time feedback the automation of complex boning tasks will be possible.

GTRI is also doing research in food safety, like the development of food safety sensors to detect avian influenza as well as advanced Ultra Violet disinfection technology.

Worker safety systems is another area where GTRI is active, by applying the technology developed by a Canadian company to monitor worker movements and reduce back injuries by optimising postures.

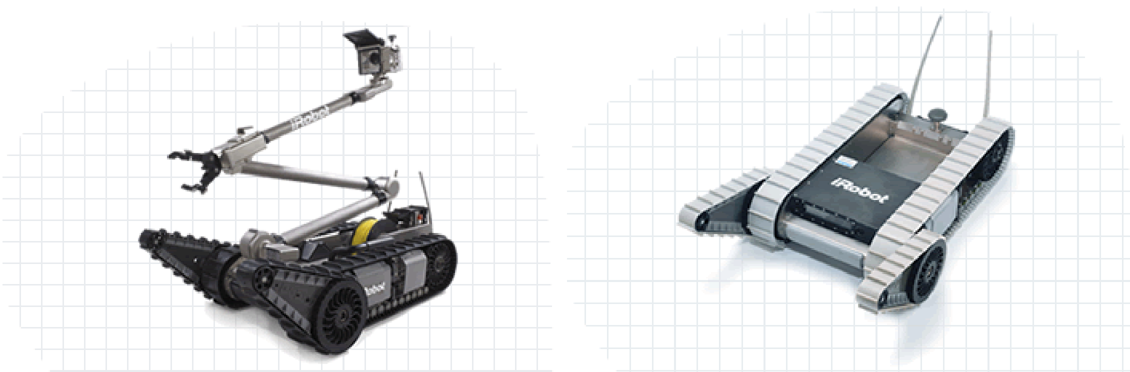
The day was concluded with a last presentation dedicated to biofuels and the work GTRI is doing to find a way to produce fuel chemically identical to petrol based fuel, and thus avoid issues like clogging point. Although with a different method and approach, the final goal of that research is finding a 2nd generation biofuel, similar to what North State University (our last visit of the tour) and also similar to what Tyson Foods and Syntroleum have partnered for.

5 iRobot (Burlington, Ma, 22 Oct 2007)

iRobot is a commercial company traded in the stock market that was founded in 1990 by roboticists from the Massachusetts Institute of Technology, or MIT. One of their founders is Rodney Brooks, an Australian robotics professor who is in charge of the MIT CSAIL (Computer Science and Artificial Intelligence Laboratory) and who facilitated this visit and the visit to MIT-CSAIL.

The company designs behaviour-based, artificially intelligent robots. They have broadly commercialised and sold in big numbers several home robots (more than 2.5 million up to date), in particular vacuuming robots, though they have a whole family of cleaning robots for home floors, swimming pools and gutters.

The other robot product line developed and commercialised by this company is the Government and Industrial robots line. iRobot has developed multiple models for surveillance, reconnaissance, bomb disposal and identification, route clearance, sniper detection, perimeter patrol, resupply, structure mapping, etc. The most successful platform is called PackBot, and some of them have been deployed in Iraq and Afghanistan in the last years for real missions.



Packbot platform

iRobot is trying to follow a modular approach, encouraging other companies to attach and integrate their systems into iRobot's platforms. They claim their technologies in conjunction with other advances have helped to reduce the urban warfare exchange ratio to 1/18, i.e. one soldier down per 18 enemies abated.

There are 3 different ways in which their systems can be controlled: manual mode, tele operation and autonomously. Their current line of research is focusing on autonomous operations (either by providing full autonomy from humans or reducing the human supervision to one operator for many robots) and collaborative unmanned systems, capable of working with other unmanned systems.

6 MIT CSAIL (Cambridge, Ma, 22 Oct 2007)

The CSAIL (Computer Science and Artificial Intelligence Laboratory) is a department of the Massachusetts Institute of Technology (MIT) dedicated to robotics and artificial intelligence, with more than 100 researchers. Professor Rodney Brooks is in charge of this department and is responsible for all the lines of research undertaken here. Professor Brooks took us on a little tour and showed us the CSAIL. We also attended several presentations with some of the most relevant lines of research for our industry.

The first presentation, given by Daniela Rus, a professor and director of CSAIL, talked about a project to set up virtual fences and paddocks to control cattle herds and graze them without human intervention. The technology is based on a sensor box or collar attached to cattle heads that register the position of each animal wearing it thanks to a GPS, and that uses sounds and electrical stimuli to deter animals from walking into ‘forbidden’ zones. The trials so far have actually taken place in Australia during a period of 6 months with encouraging results.

Cattle head with collar

The second presentation, given by professor Nicholas Roy, focused on what was called Model-uncertainty planning or robust planning, that is planning and controlling systems (mechanisms, robots, etc.) in a world in which we have limited knowledge of the state. This approach is followed, for instance, to provide navigational guidance to autonomous systems in unknown environments where there is partial or total uncertainty of the surrounding world.

We saw several interesting examples in some videos they showed us, like the one of a mechanical quadruped walking across areas full of uncharted obstacles.

Quadriped getting across an unmapped territory

A direct application of these technologies to the meat processing industry could be the tracking in real time of anatomical features like limbs, cuts, etc. in order to automate tasks needing from real time feedback like stunning, shackling or complex boning tasks, where all the required information cannot be modelled in advance but must be sensed, detected and processed simultaneously with the action to be performed.

Russ Tedrake, an assistant professor in CSAIL, talked next about control and movement dynamics for autonomous vehicles improved through machine learning, and after that professor Lozano-Perez showed how the behaviour of robots can be improved by experience, again emphasizing machine learning and planning in the presence of uncertainty.

Last, Rodney Brooks discussed with the Australian party his vision to use cheap robots in manufacturing where expensive components are substituted by computer power, and program those robots for more than 95% of the possible situations, so that they can handle most of the cases of a given production task in manufacturing, leaving 2-3% of the cases (misses) to human workers to fix, significantly increasing productivity but without 100% reliability.

In general, Rod Brooks and his team showed very open to work with the Australian red meat industry and to apply their research to solve our problems. A suggested approach would be for us to identify a visioning or sensing problem that seems really complex for us but doable for CSAIL, and through a short secondment of Australian engineers for a period of a few months, locate them in MIT so that the researchers at MIT can have direct Australian input about the issue to solve, and the seconded engineers working in the red meat industry can embrace the technology and influence it to produce a practical solution to the problem.

7 NorthWestern University (Evanston Il, 13 Oct 2007)

Michael Peshkin and Ed Colgate, two professors at NorthWestern University in Evanston, a town north from Chicago, have become renowned researchers in the field of interaction between humans and machines. They were contracted last year with support from the OH&S AMPC committee to develop a system to aid boners in the some of the most strenuous and arduous tasks, aitch boning and knuckle pulling. This stop in our tour served to get more familiar with their lines of research, but also to monitor the progress of the MLA/AMPC industry funded project.

During the first day we visited the labs of the department of mechanical engineering, with professor Michael Peshkin showing us their different active lines of research. In particular, we saw the work they are doing to develop a prosthetic leg, similar to what we witnessed in Berkeley though less advanced.

We also saw the first devices designed to prove what eventually became the Cobotics concept. Cobotics is now a trademark of Stanley Assembly Technologies, the company who owns now the license to commercialise some of the applications developed by Peshkin and Colgate. Those devices were used to show the concept of virtually constrained movements and virtual surfaces, but eventually evolved into the force amplification and inertia reduction characteristic of the 'cobotics philosophy'. Ed Colgate defined these intelligent assisted devices as computer controlled, servodriven tools that enable workers to lift, move and position heavy loads more precisely, quickly and safely than conventional powered assisted tools.

Another interesting application of their research is surface simulation with a piezoelectric material that vibrates very rapidly in a certain mode, according to the position and movement of the finger in touch with it, providing a simulated rugosity perception. The researchers envision applications for this technology in the consumer electronics field, for instance to control iPods and similar devices.

Peshkin and Colgate have done extensive work for the automotive industry and developed some applications for GM. They developed the concept of IADs or Intelligent Assist Devices by combining intent sensors, software and actuators into intuitive and fast powered devices with human-tuned control.

The first commercial examples were sold to Stanley Assembly, which currently commercialises dedicated systems like instrument panel handling and cockpit installs for automobile assembly, but also generic handling systems to lift and move heavy boxes, parts and components.

IAD devices commercialised by Stanley Assembly Technologies

After that, Peshkin and Colgate have kept on working towards the application of the same philosophy to other problems, like for instance mechanical aids for physiotherapy professionals to help them handle and support impaired people in need of rehabilitation. They identified several clinical needs and come up with a system, KineAssist, particularly designed to assist physical therapists to carry out rehabilitation tasks for patients who have suffered a stroke.

KineAssist system

In early 2007 Peshkin and Colgate visited first meat processing plants in Colorado, and then travelled to Australia to see how meat is processed here, and even practised themselves with a few cuts. As part of the MLA/AMPC project, the aitch boning / knuckle pulling task was identified as the one with most potential to take advantage of their technology. In a few months they developed two prototypes which we had the opportunity to evaluate in the facilities of Kinea Design, the company set up by the professors to develop diverse applications for the IAD concept.

8 Kinea Design (Evanston Il, 24 Oct 2007)

After our visit to NorthWestern University, we headed off to Kinea Design, the entity under which Peshkin, Colgate and their team are developing the boning prototypes for the MLA/AMPC project. We evaluated two prototypes:

- A rigid arm prototype, with force amplification in the vertical direction
- A cable prototype, with only a pulling force where the amplification takes place

Rigid arm prototype

Cable prototype

One of the members of the Australian party with boning skills, John Hughes, tested both systems with a beef hindquarter ready for the occasion. After that, the other members of the group had the chance to make cuts with the assistance of the device.

The general opinion of the people testing the device was very positive. In particular, John Hughes who tested both machines more intensively and who could compare with the unassisted way of performing the same operations, found the prototypes very responsive to all his moves, and considered the technology could be of great help to boners.

John Hughes boning a beef hindquarter with the rigid arm prototype

On the last day, all the party and the people from NorthWestern and Kinea involved in the project have a discussion about what to do next in this project. Andrew Arnold from Scott Technologies gave a little presentation to show their approach to this problem and how they have developed a prototype that has been already tested in a meat processing plant in New Zealand.

The overall impression of the group is that the prototypes shown in this visit have much better responsiveness and are more intuitive than the Scott system, with better control and smoother interaction with the user. But the Scott solution is closer to a rugged system capable of enduring the harsh conditions of meat processing plants.

In any case, the outcome of the evaluation of both prototypes is that the IAD or 'cobotics' approach has great potential to become a platform for a suite of assisted devices capable of making the life of boners and other meat workers much easier. It could even allow other workers that because of age, gender or physical condition cannot currently perform the most arduous tasks, be employed on those jobs, and help plants in getting access to a wider labour force, relieving in some way the constant shortage of people the Australian industry has to deal with.

9 Worldwide Food Expo, AMI 2007 (Chicago, Il, 24-27 Oct 2007)

Between the 24th and the 27th of October, the 2007 Worldwide Food Expo, a biannual trade show, took place in Chicago's exhibition center. There were two massive sections, one dedicated to food, dairy and beverages, and another for meat , poultry and seafood. The majority of the most important suppliers in the world of meat processing equipment were there, with several companies showing their progress in automated systems. It was a very comprehensive exhibition where we had the opportunity to contact and meet representatives from many companies.

Most of those companies and their activities were already known to us. Particularly worth mentioning is the first open robotic initiative from Jarvis, with a hog head dropper based on an industrial robot presented in the show.

In a different area, we met Blue Glacier Technology, a company with an interesting and novel product, Blue Glacier Tubes, containing an endotermic reactive solution that removes heat and moisture from chillers and other cold storage facilities to maintain a constant colder temperature, reduce energy costs and improve product quality. Representatives from this company claim that they can achieve energy savings close to 25% and we have initiated contacts to evaluate the technology in Australia.

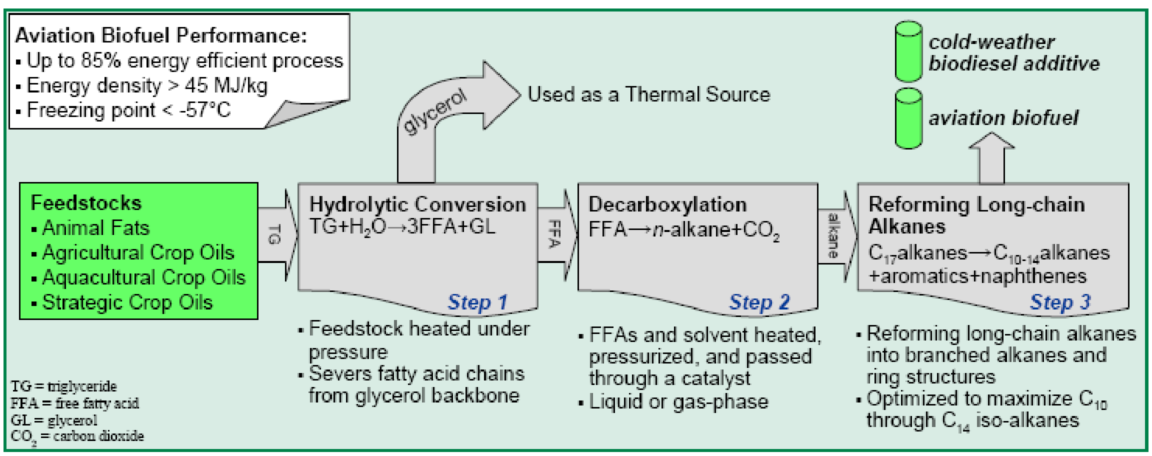
Blue glacier tubes

10 NC State University (Raleigh, NC, 27 Oct 2007)

Our last visit of the tour took a turn towards R&D in bio fuels. NC State University (NCSU) is a recognized leader in bioenergy and they have worked for decades in the field. Recently they have partnered with Diversified Energy Corporation (DEC) to develop and test a patent-pending technology for converting oils derived from any lipidic compound (like animal fats) to high-value fuels. The technology, termed Centia™ (a derivation of "green power" in Latin), integrates a sequence of three thermalcatalytic-reforming processes as shown in the figure below. These steps are either extensions of current commercial processes or based on recent laboratory breakthroughs by the DEC-NCSU team.

One of the most significant differences compared to conventional manufacturing of bio diesel is the fact Centia replicates with its manufacturing process the chemical composition of petrol derived fuels. Initially, NCSU has focused in the manufacturing of high value fuels, in particular aviation fuel for jet engines (Jet A and JP 8), but the same process can be used to manufacture bio gasoline and bio diesel, but without all the issues associated to current manufacturing techniques.

Another significant difference is the initial conversion of triglycerides into Free Fatty Acids (FFA), and then the conversion of FFAs into n-alkanes. This is step 2 in the figure below and the big breakthrough achieved by NCSU, as the other two steps are already commercial processes. This is a major difference from the conventional bio diesel manufacturing methods where the presence of FFA is not desirable, and only tallow with low FFA can be converted into fuel.
In other words, what conventional technologies are forced to avoid, tallows with high FFA content, at a high price (the lower the FFA content, the higher the price of the tallow), Centia can deal with, and even benefits from.



3 step Centia Biofuels process

In summary, the advantages claimed by NCSU and DEC are:

• Feedstock Flexibility – the first Centia™ step is designed to accommodate any lipidic compound without technical or operational modifications to the production process. As such, the process has the flexibility to accommodate oils (or a mix of oils) deemed the most available and cost-effective at any given time or geographic location.
• Fuel Output Flexibility – the third Centia™ step produces fuels capable of meeting strict aviation specifications and acting as a biodiesel additive for cold weather operations. In addition, the basic process may also be extendable to produce any other hydrocarbon fuel, including conventional gasoline.
• High Efficiency – the process will demonstrate an end-to-end energy efficiency of up to 85% and utilize roughly one-half the external energy of other conventional biofuel processes. In

particular, the glycerol produced in the first step is used as a heat source for the process, as long as it is burned at high temperatures (>500C) to avoid toxic emissions. This translates into higher yields and lower costs, an imperative for commercial viability and broad market adoption.

• "100% Green" Solution – Centia™ does not require the addition of any form of fossil fuel as a component of the biofuel produced. In fact, the production process itself can be designed to operate without consuming fossil fuels as a heat source.

• Maturity – process steps one and three are direct extensions from the commercial marketplace, step two builds upon recent NCSU-DEC laboratory results validating the science. Centia™ is ready for an end-to-end demonstration and commercialization.

• Scalability – nothing inherent in the Centia™ approach will prevent scaling to large commercial volumes, ranging from 10M – 50M+ gallons/year. Scalability has been a central driver in the design and engineering of the system.

• Affordability – assuming animal fats as a feedstock and no government incentives, preliminary analysis shows aviation biofuels could be produced profitably for ~US$2 per gallon range.

In our visit we met, among others, Bill Roberts, the NCSU professor leading the research, and Tim Turner, the Phd student who developed the original concept. They showed us the experimental reactor with which they had manufactured the first jet fuel samples, and that they plan to scale up to manufacture gallons, compared to the tea spoons they have produced so far. From our conversations with NCSU and DEC (no representative from DEC was present in this occasion), it seems NCSU has developed the basic science and DEC is taking care of securing funding, scaling up the technology and commercialising it, with DEC holding the licensing rights in exchange for royalties.

Initially DEC have suggested a next phase to prove they can scale up production, with a cost around $6-7M. After conversations with them it seems they could structure the next steps into smaller projects, with a preliminary trial for US$750k. Right now we are discussing whether MLA should co-fund this initiative.