Mathematical Conversations

LUI Pao Chuen: Of Science in Defense >>>

LUI Pao Chuen

Interview of LUI Pao Chuen by Y.K. Leong

LUI Pao Chuen played a pioneering and pivotal role in the establishment and development of the scientific and engineering capabilities of the Singapore Armed Forces (SAF) and the Ministry of Defense (Mindef).

Leaving behind his original dream of becoming a university lecturer after getting his bachelor's degree in physics from the then University of Singapore in 1965, he had a short stint at a radio and space research station before becoming one of the first scientists to join Mindef in 1966. Starting as a captain in the Logistics Division, he rose to the rank of colonel in 1978 in the course of a long and illustrious career in helping to build up, practically from scratch, the defense capability of a small nation that had to fend for itself economically, politically and militarily overnight. When he officially retired from SAF in 1986, he became the country's first Chief Defense Scientist. He went on in his typical tireless and visionary way to promote and coordinate research in science, engineering and technology in Mindef and SAF and to tap the resources of the universities and national research institutes in areas such as information and signal processing, remote sensing, experimental hydrodynamic studies, high performance computing, computational mechanics and biomedical research.

In 1973 he obtained a Masters degree in operations research and systems analysis from the US Naval Postgraduate School (NPS). While contributing much to defense science, he came back, in a full circle, to his original aim of teaching in the university when National University of Singapore appointed him as Adjunct Professor in Industrial and Systems Engineering in 1990. His contributions earned him professional recognition as Fellow of the Institution of Electrical Engineers (UK), Chartered Electrical Engineer of the UK Engineering Council and Senior Fellow of NPS. He was awarded the Commander of the Royal Order of the Polar Star by Sweden, NPS's Distinguished Alumni Award, induction into NPS Hall of Fame and the 2002 Singapore National Science and Technology Award. In addition to being appointed to leading positions in many national bodies such as Defense Science Organization, Defense Science and Technology Agency, National Research Foundation and Temasek Laboratories, he has been a member of the IMS Scientific Advisory Board that chartered the Institute's direction right from the beginning in 2000. Though he has recently relinquished his post of Chief Defense Scientist in 2008, he continues as a consultant to Mindef.

On 3 January 2007, he was interviewed by Y.K. Leong on behalf of *Imprints*. The following is an edited and vetted version of the interview in which he gave us an insight into an unusual and distinguished career in defense science and how his scientific team questioned conventional wisdom encapsulated in the safety codes of the US Department of Defense and introduced new codes that are now scientifically accepted.

Imprints: You started schooling in Singapore at a rather late age after your family moved from China and Hong Kong. What is your most memorable impression of education (whether in school or university) in those days?

LUI Pao Chuen: I moved to Singapore in 1954 when I was 8 eight years old. In school I had to catch up with the rest of my cohort. I needed to move much faster and the school was very kind to me. My first school was Balestier Road Boys' School (for a year) and after a double promotion, I went to St Patrick's .The school was quite different in those days. In 1962, I was a boarder in St Patrick's and had a chance to be away from my family. We were boys of 8 years old staying together in a very disciplined type of environment. Every morning we attended classes and after studies, we played games in the afternoon. We had a lot of freedom and I enjoyed doing things in the Scout Movement. I also spent a lot of time in the library reading mathematics. When I entered university [University of Singapore] I had one clear objective – to graduate, get a scholarship and come back with a PhD. Unfortunately I didn't do well enough in my final exams. I didn't get a First Class Honors and I could not get a scholarship to go to Cambridge. That was when I decided to start working.

I: You could have gone to some other university for graduate studies.

L: I set my mind to do something. When I couldn't get it, I would do something else.

I: What did you do after that?

Continued on page 13

Continued from page 12

L: The UK Science Research Council had a Radio and Space Research Station in Singapore. It had two sets of facilities, one at the Bukit Timah campus, next to the Students' Union House, with equipment to measure the ionosphere and the other was at the Sembawang Air Base where they were tracking the UK1 and UK2 satellites and gathering data from satellites passing over Singapore. I was employed by the UK Science Research Council to work at both facilities. After one year, I found that the Singapore Armed Forces had opportunities for me to contribute to Singapore, and so I switched.

I: Your initial training was in physics, but your career was more in engineering or at least technology. Did you ever consider doing an engineering degree in the first place?

L: Our family finances did not allow me to study engineering. At that time you had to go to KL [Kuala Lumpur] to do engineering. The engineering faculty was in MU [University of Malaya]. At that time, SU [University of Singapore] was part of MU, and they [MU] did not have a medical faculty while SU did not have an engineering faculty. To do engineering, you had to go to KL or do it at the polytechnic [Singapore Polytechnic], but it was only a diploma course, not a degree course. Reason number two is that engineering was a four-year course, whereas for physics, you could do it in 3 years by going directly into the second year as a "super-fresh" student.

I: After you were appointed as the Chief Defense Scientist in 1986, your work seems to move more towards research capabilities in science and technology.

L: Before that, I was running special projects. My last assignment was as a project director for Mindef and SAF. One major capability development is in science and technology capability in SAF and Mindef and to develop international relations.

I: Do the research capabilities have to be connected to defense?

L: Most of the capabilities we do must add value to our defense capability, including the R&D [research and development].

I: What is your latest research initiative?

L: I'm more involved in the management of research and development rather than doing research myself. For example, we have a problem of space in storing a large amount of ammunition in Singapore. Can you find a way where you require less land? There is so much land required if you store it on the surface. If you were to go underground, below the rocks, the current codes say that you require 240 hectares. But we looked deeper into it and found that actually those codes were not based on science but on empirical considerations. We did research and development on the ground shock behavior of explosives when they explode and we came out with a code that requires much less land than that. We embarked on a very large technology development program. Firstly, you must understand the physics, do the modeling of how explosives detonate and study their detonation patterns. Originally, we assume that explosives detonate as point masses, but we realize that's not the case in real life. They cannot be point masses, they are distributed in storage. When they explode in storage, they can go off together provided they detonate together. But would the peak pressure be the same as a point mass? We then did some computer simulations and found that the pressure is very slow if you assume that they are distributed and you have a very simple assumption that they detonate at the same time, which is a contradictory type of assumption. So then what else are there? We know that the ammunition is axially distributed. We looked at a number of critical parameters. First, the ground shock: will the buildings nearby collapse? You also need to know the structural behavior through soil, through layers of rock and so on. We thought that there must have been some research done in those things. The very interesting thing is that in the US Department of Defense, for safety codes, there were two formulas used to determine ground shock. So we put in the amount of explosives that we intended to store into the formula. One formula came up with an answer of 60 meters and our formula came up with something else. We went back to the Department of Defense and there was a big meeting. We had two sets of formulas and two different answers; so one of them must be wrong. Unless we have the scientific basis, we cannot persuade you to accept our findings. So we went back to the mathematical formulation, computer simulation, small scale testing and finally large scale testing. We built a tunnel in Sweden to verify our model. After that, the results were presented to the experts in NATO. They looked at our results and found that there was a scientific basis for us to write a new code based on our findings. What does that mean?

The normal way of storing ammunition above ground requires 1000 hectares of land. If you were to go below the rocks, in the caverns, making use of the present safety codes, the land required is 240 hectares. We found that these are empirical codes without any scientific basis to it. We went back to the scientific basis of the effects of the explosions – the theory, modeling, small-scale testing and large-scale testing – and found that the amount of land required is 100 hectares. This new code is now embodied into the safety codes of the US and NATO.

Continued on page 14

Continued from page 13

I: Is it implemented in Singapore?

L: Yes, of course. Why would we want to spend 12 million [Singapore] dollars on R&D to find that out?

I: In some countries, there is a perception among some academics that research sponsored by defense agencies tends to be geared towards military objectives and therefore not "peaceful" in nature. What is your view about this?

L: In Singapore it is very clear. If there is no defense, there will be no Singapore. The economic well being of the country depends on the perception of investors that Singapore is a safe place to invest their money in. In order to convince investors that Singapore is a safe place, national security must be given top priority by the Government. With national security comes development, next economic development, then social development. National security is fundamental to the well being of Singapore. NUS defense technology is a strategic thrust of the university and is important for our defense.

I: Has NUS been given any grants by Mindef?

L: Mindef identifies some research which can be done by researchers in the universities and accordingly funds the researchers to do this research. In order for results to be able to be fed into DSO [Defense Science Organization] they must create systems that are of high mutual value.

I: Does Mindef approach individual academics to do the research?

L: It started more than ten years ago with road shows that we conduct every year with briefings of what we are doing to academics to see whether they have any interest. Therefore it is a two-way thing.

I: Could you tell us what is defense systems engineering? What is the role of mathematics in this discipline?

L: Systems engineering ensures that all the components of an enterprise are blocked together in such a way that they will achieve the objective of that enterprise, by looking at the topologies and components of the subsystems, and in particular, defense systems engineering as it pertains to defense systems. The role of mathematics is fundamental. In anything that we do, it provides the tools for a scientific basis.

I: Is any of the research done by scientists in DSO considered to be "classified" and hence not published in the public domain? If so, would that be contrary to the spirit of free inquiry that is so dearly cherished by creative scientists?

L: There is protected work done by DSO. One is the development of capability that is normally systems specific and that is classified. They are creating capability that is of high value and that you cannot buy. These are the things that are classified and we will not tell people what we are doing until we know that the value of that information is no more relevant. But in the case of research, like lasers and mathematics, it is publishable. Some of the researchers are adjunct professors in the universities. There are research intensive type of publications. There is work on developing capabilities and we don't publish them. There are two parts of DSO: the open part dealing with more fundamental and basic research, and the second systems part of DSO.

I: Do you have people working on both types?

L: Yes, they can work on both.

I: Has "biological warfare" been seriously considered a potentially lethal option to be countered in defense science and are there any effective measures against such options?

L: More than 10 years ago, we established a biomedical initiative and one of the areas of focus was to study how biological agents could be spread in a densely populated place like Singapore and how we can respond. Biological activity has been a threat and continues to be a threat. Therefore the defense, medical and environmental research institutes play a part in total defense and have a responsibility to do research in the solution of this problem.

I: Is there any collaboration between DSO and biological scientists?

L: Our capacity is very limited. That is the reason why the billing in the BMRI [Biomedical Research Institute] in the medical faculty is for scientists in DSO to clap hands with the medical faculty.

I: Is there some kind of biological initiative initiated by DSO or Mindef?

L: I wouldn't say biological initiative. Perhaps research in defenses against biological agents.

I: You mentioned that there are people in DSO who do more publishable research. Are they free to choose their kind of research problems?

L: Most of their research is in common areas of interest

Continued on page 15

Continued from page 14

rather than in the areas of interest of the investigators. The investigators know the ultimate areas of interest to defense science and therefore, if they want to publish in astrophysics say, then probably they are not going to get much financial support from Mindef or DSO.

I: What are some of the "pure" areas relevant to DSO?

L: Electromagnetics. There was one book on electromagnetics. What I mean is information theory – or rather information security, especially with computer systems. We have a number of mathematicians working on how to protect information and how to understand information that could be extracted from noise.

I: Are computer scientists involved?

L: We have a sizable group of computer scientists working in defense.

I: Are there many of our graduates working in DSO?

L: One thousand something.

I: What are some of the achievements that you would like to be remembered for?

L: The things that are very interesting I can't tell you because they are classified, and the things that I can tell you are quite mundane. One thing I would like to be associated with is the build up of the core of engineering capability in SAF. When I joined the Logistics Division, there were only a handful of us with some science background. Now we have up to 3,000 science and engineering graduates. It takes a considerable effort to build, equip and train first rate engineers and then develop them into an organization. I'm quite proud to be associated with the people and organization that will be able to provide that depth in science and technology that allows them to have the confidence in pressing beyond world class caliber.

I: Do you think of retiring?

L: I'll be retiring in March 2008.

I: In spite of your heavy administrative involvement in many companies and committees, you have found time to teach in the engineering faculty of NUS for about ten years. What is the greatest satisfaction that this has given you?

L: More than 10 years. I started teaching in 1990 because the engineering faculty thought a minor in development systems would add value to the faculty. I teach one module a year on large scale systems engineering. I feel that it is important for the older generation to share their knowledge with the younger generation through teaching. The way I teach is through story-telling and case studies and to relate it back to some of the theory that are all there. I find that when the students meet me after 10 years, they still remember. It's not the theory but the stories and the lessons learnt.