Transcript of Public Lecture by Michael Steer

November 14, 2013

1. Thank you for the introduction.
    a. I want to talk to you about ideas.
    b. Where do they come from?
    c. Well, I am sure that ideas do not arise the same way for everyone but I am going to tell you about how they come to me. I think that I have been very prolific with ideas and I want to tell you about some of the good ideas I have, and about the best ideas I have now.
    d. Ideas from nothing.
    e. What you need is inspiration; you need to think differently; you need something that makes you think differently.
    f. How can you make yourself have ideas? How can you force them?
    g. There are no overnight successful ideas. Ideas take a long time to develop, to synthesize. It is hard work.
    h. Using biology for inspiration is itself a great idea.
        i. A little secret is that we do not need to be accurate; we just need to think differently.
        ii. For now we are seeing biology as a powerful mechanism for thinking differently.
    i. So, I am going to talk about biologically inspired system engineering, Ideas from nothing.
2. Here is what I want to talk about today. <READ>
3. I grew up in the southern hemisphere.
    a. This is the milky way, a part of the milky way that you cannot see from the northern hemisphere. The Milky Way is much brighter in the southern hemisphere.
    b. When there is a new moon and no clouds, it is almost as bright as if there was a full moon.
    c. I was listening to National Public Radio one day and a female reporter was interviewing an Australian Astronomer.
        i. She asked him why the sky was so much brighter in the southern hemisphere.
        ii. He replied, “It is like this mate, we are looking right into the guts of the Milky Way.”
        iii. In the Northern Hemisphere we are looking the other way, out of the Milky way.
    d. In the Southern Hemisphere you can also see other galaxies with the naked high.
    e. Here the Milky Way Galaxy is the bright diagonal.
    f. That little stripe on the right, just below half way up is the Large Magellanic Cloud
    g. In the bottom right hand corner is the Small Magellanic Cloud.
4. I grew up in Australia on the Gold Coast, just south of Brisbane .
    a. It is on the east coast, about in the middle where Australia sticks out the most.

5. The Gold Coast has many towns which were separate villages once, but are now connected.
    a. This is a picture of Surfer's Paradise.
    b. I spent my teenage years living in Surfers Paradise and that is still what I regard as my Australian home.
    c. <CLICK> The climate is great, the surfing is great. The Southern Hemisphere has a much milder climate than the Northern Hemisphere, the extremes of weather and temperature are much less. That is to do with the way the earth tilts when it goes around the sun.
        i. That is my brother surfing at Surfer's. The board just gets longer as you get older. What a great wave.
    d. <CLICK> There is an area on the Gold Coast where wild parrots land on you (as long as you have some food). They do not do it anywhere else.
6. The most important work I have done in my academic career is related to roadside bombs.
    a. This image is from a training exercise and no one was hurt. I would not want to use a real image where someone could have been killed.
    b. Since 9/11 we have all be confronted with terrorism which shook as to the core.
    c. Most of us recall the absolute shock. Let's hope we never forget.
    d. From 9/11 + 1 day I was committed to doing something that would address this problem.
    e. My biggest problem was that I did not know what to do. What problem could I work on?
7. I knew I was good at some things.
    a. I had a very good understanding of how electromagnetic fields and circuits interacted. I kind-of-knew how these would interact with systems.
    b. I had the inkling of an idea, a problem set worth working on. How can we locate all electronics in our environment. But there was not enough to address the problem.
    c. Well, when the US forces entered South West Asia and encountered Improvised Explosive Devices (IEDs), I knew then that I had a problem to work on.
    d. I was going to find a way to locate electronics and stop electronics from working.
    e. The good news is that I had a problem to work on but I needed ideas. Ideas from nothing. That is what I am going to talk about. Creating ideas, the key ideas I had, and these are still my best ideas ,and the ideas that drive me now. The best thing I ever did in this whole IED space was making people think differently. That is what made the difference.

8. One of the technical highlights from the work done 5 to 10 years ago is that we developed the ability to measure smaller signals than anyone else could. In particular we developed techniques for measuring small radio signals that are very close in frequency to other radio signals.
    a. If you have two radios next to each other and one is transmitting, it can be quite difficult for the neighboring radio to listen. The listening radio is trying to respond to very small signals but the transmitting radio is sending out very large signals.
    b. With cell phones this problem is solved by separating the frequencies of the transmitted signal and the received signal by a very large amount. We use devices called filters.
    c. But there are situations where you need to transmit and receive very close in frequency.
    d. We can do that 1,000 times better than anyone else. We have told companies and defense labs how to do it.
    e. This is technology transfer. When we built something and delivered the technology, that is applied research and technology transfer.
    f. However this was fundamental research as well as it enabled us to understand how electromagnetic fields and electronics interacted, work that led to the 2010 Microwave Prize for the best paper on microwave engineering in any IEEE publication.
    g. We were doing work that was very applied, but it was very fundamental at the same time. In fact our experience has taught us that fundamental research, applied research, technology transfer, and extension are all much the same thing.
9. Here is an example of a result no one could look at before.
    a. This is a measurement of the electrical signals on a vibrating antenna.
    b. This could be an antenna on an aircraft that is vibrating tremendously.
    c. Here we are transmitting a very large signal, yet we are “receiving” these other signals.
    d. These other signals are coming from the vibrating antenna.
    e. We have shown that this is a relativistic effect. Kind of like the Doppler effect.
    f. Previously these small signals could not be measured. However in a radio receiver they would create interference.
10. As well as working with electromagnetic fields and circuits, we also do a lot of acoustics work.
    a. This is a high power speaker that can blow eardrums out at 100 meters.
    b. We use this to shake objects and then we can use a laser or a radar system to measure how much something vibrates.
11. If you know how much an object vibrates, and how it vibrates, you can tell objects apart.
    a. You could tell if you have a fiberglass shell (on the top left). Something you could put over an outside faucet, or perhaps you could hide something inside it.
    b. You could separate that from concrete on the top right.
    c. Or identify a fake rock, on the bottom left. This could be used to hide an improvised explosive device. It looks like concrete doesn’t it. But it is dry concrete over foam.
    d. You also need to know if what you are looking at is just a rock.
12. What we really did that was most significant is that we developed ideas.

13. And this led to an Army medal.
    a. Over the years I have worked on many research projects primarily funded by the US Army Research Office, NSF, and the Office of Naval Research.
14. However I have done projects for many agencies. I have been lucky, I guess, as 85% of the proposals I have written have been funded for a total of about $34M. I think that may be because my proposals are much more than a work description. The proposals are rich with ideas. With a broader impact. A big idea that I hope to achieve. Yes there are technical specifics identified, but it is the broader impact that captures people's imaginations.
15. Five of my PhD students in the last decade began six start-up companies.
    a. and I am going to talk about three of them.
    b. Greenwave Scientific, started by Mark Buff in 2008, makes military antennas.
16. Vadum, started in 2004 by Aaron Walker in 2004, works on Electronic Warfare.
    a. Look at one of their press releases from October 2013. This says that they just received a $9.8M contract for Research and Development in Electronic Warfare.
    b. This is the most direct outcome of the work that we did here at NC State after 9/11. It is tremendous the difference being made.
17. Mohu, started by Mark Buff in 2010, is the leading manufacturer of HD TV antennas.
    a. They employ 60 people in North Raleigh and that is where they do all of their manufacturing.
    b. Their products initially were the commercialization of military antenna technology.
18. Currently my team is very interested in energy localization.
    a. This is a model of a homemade explosive.
    b. The explosive consists of explosive crystals embedded in a medium, the plastic in plastic explosive.
    c. Here we directed an electromagnetic wave, a radar signal if you like, into the block from the bottom. The red areas are where energy localizes.
    d. The reason we are interested in localizing energy is that if the conditions are right the explosive will burn and melt rather than explode.
    e. If there is a possible suicide bomber coming towards me I would much rather direct a beam at them and for the vest to burn and melt rather than explode. Evidence indicates that a short high power radio pulse has very little effect on people as long as they do not have pacemakers etc.
    f. How do you create a computer model of an explosive.
        i. You turn it into a computer game
19. These are crystals being poured into a container.
20. I have become rather passionate about national security.

21. As promised I am going to give you my best ideas.
    a. The first is about the Theories of Mind.
22. What a great painting.
    a. Why do we like paintings like this so much?
    b. I am going to have a go.
    c. I am going to be very different from the classic art critic.
    d. That's ok, I don't care.
    e. I do think that this is a great inspiration for ideas.
23. Another great painting.
    a. This is Jackson Pollack's NO. 11, also known as Blue Poles.
24. So what?
25. These paintings tug the internal workings of the brain, but in two different ways.
    a. Both provide great biologically-inspired ideas.
    b. They tell us a lot about how the brain works.
26. An Idea of how the brain works is called a "Theories of Mind"
    a. <READ>
    b. President Obama is a very smart man. He did not say this but I think he could have.
    c. TO prove that he is a smart man I need to introduce you to the secret handshake that electrical engineers use.
27. This is called Fleming's right-hand rule of electromagnetism.
    a. I want all of you to do this.
    b. Take you right hand and arrange it like this.
    c. Point your thumb in the direction of the electric field, your index finger in the direction of the magnetic field and the middle finger is the direction that the electromagnetic wave travels.
    d. SO hold it there.
    e. This is our secret handshake, so you learnt something new today.
    f. When you are walking down the street you just go, "Hi Bro"
    g. If he is electrical enigeer he will, "Yeah You Get It," and "Electrons are Green"
    h. Keep your hands fixed in Fleming's rule.
28. Here is my proof that President Obama is a smart man. He he is teaching locals how to use Fleming's rule of electromagnetism.
    a. Don't put your hands away
    b. You need to me careful where you use the right-hand rule.
29. Thus young engineer used the right-hand rule in public.
    a. And she looked like an idiot in front of her friends.
    b. You can put you right hand away now, remember to straighten out your fingers.
30. Here is another idea..
    a. We really do not know how hearing works, but that is not going to stop me.

31. Listen to this, I am going to ask you what I said.
    a. <WAIT> What did I say?
    b. Initially when we only had audio input we heard ba-ba-ba.
    c. With additional visual input we heard da-da-da. The audio still was ba-ba-ba, but I put that audio over me mouthing da-da-da.
    d. Or perhaps some of you heard sheep all the time.
32. An idea, a Theories of Mind, is that the brain is always fitting models
    a. Here the x's are inputs
    b. And the output is meaning.
33. A theories of mind is that the brain is fitting perhaps 10,000 models to our experiences all the time. <CLICK>
    a. Always pruning, refining and updating. With more input the models are better.
    b. Ten thousand models!
    c. Gosh, that is an idea. Perhaps when we solve our engineering problems we should not try to come up with one answer, perhaps we should come up with the best 10 or 100 answers.
34. Another idea is Surrogate Modeling, but these ideas are all related.
35. Here is the Warragamba dam, Sydney's water supply.
    a. Engineer's need to model the dam and be able to predict water levels for example.
36. Here are our inputs and outputs
    a. <READ inputs> These are our x's
    b. <READ Output> These are our y's
37. Here is our real dam with inputs and outputs.
38. An accurate engineering model can be called a fine model.
    a. Lots of equations and computation
    b. And lots of effort goes into tweaking the parameters of the model until it is as accurate as can be.
39. Here is a coarse model of the dam. Not very accurate but it is kind of right.
    a. It is not very accurate but it gets the trends right.
    b. More importantly, it gets the majority of the nonlinear relationships right.
40. Still it is not a good enough model to use on its own.

41. It only takes a little tweaking of the input parameters to enable us to get accurate results from our coarse model.
    a. The input mapping is key.
    b. This idea was developed by Dr. John Bandler of McGill University, in 1994.
    c. The reason this works is
        i. The coarse model has the key dependencies.
        ii. In fitting this surrogate model, the coarse model with the input space mapping, only the parameters of the input mapping need to be adjusted.
        iii. This is a simple task as there is little inter-relationship of the input parameters, they have weak correlation.
        iv. We can use this to help us optimize designs with an enormously large number of unknown.
        v. A former PhD student of mine who I co-chaired with Paul Franzon is now using these ideas in a large semiconductor company to optimize design of a system with 140 variables. Something that would be unthinkable without the surrogate modeling concept.
    d. The bottom line is that I think that the brain uses surrogate modeling.
42. Let's get back to our dancers.
    a. This is a non-abstract picture of dancers.
43. This is our abstract view.
    a. This is close to our coarse model.
    b. I claim that this, and much of abstract art, appeals to use because it jumps into the middle of our surrogate modeling process. It reveals our inner workings.
    c. It tickles our cerebral senses.
    d. We do not need to solve problems to the fraction of a percent. Yet the way we engineer (and model) now, most of what we do in our interim calculations requires incredible precision.
44. You can apply surrogate modeling to many different types of engineering problems as well.
    a. Abstract art meets circuits.
    b. It is a big continuum.
45. If president Obama had made comments about Theories of Mind I think that this si what he would say.
    a. <READ>

46. Surrogate modeling is closely related to associative thinking.
    a. <READ>
47. Another idea is self similarity
48. Back to No. 11.
    a. This painting has self similarity.
49. As we zoom in we see much the same patterns as we saw before.
    a. It appeals to us because this is the way the brain works.
    b. We are short-circuiting our inner workings.
    c. It tickles our cerebral senses, but in a different way from the painting of dancing ladies.
    d. I am going to show you something else which has a self similarity.
50. But first look at this. This is Newton's cradle.
    a. The pattern is repeating once every two seconds and so we say that it has a frequency of 0.5 hertz.
    b. This is well behaved. A nice repetitive response. But this is an animation.
51. Here is a circuit that has a nice expected behavior
    a. This is a 7^{th} order filter. This circuit, perhaps constructed another way, is on the other side of the antenna of every cell phone.
    b. The input on the left is a pulse of sinewaves, there are 275 here.
    c. The output on the right looks much the same as the input, we see a little bit of ringing, but all in all, much what we would expect.
    d. The input here is varying at about 1 billion hertz, a bit faster than the balls in Newton's cradle.
    e. It is useful to plot the level of the output as the frequency varies.
52. And that is what is shown here. This response is the transmission of the filter versus frequency.
    a. So signals get through if they have the right frequency, but they do not otherwise.
    b. This is how we separate different communication signals.
53. Let's get back to Newton's Cradle
    a. That animation is not exactly what happens.
54. Look at this.
    a. This is the real response
    b. Things behave a bit chaotically, not nearly as neat as we saw in the animation.
    c. What is going wrong? Why does it behave chaotically?
    d. Perhaps we should send this back and get another one. But we will have similar result.
    e. This is chaotic behavior. It is how the world works, and how the brain works, and how all circuits really have to work.

55. Just in case you have forgotten about the bandpass filter.
    a. Here is the response we expect from a filter.
    b. I call this the steady-state view
    c. That is how we analyze and in the end design our radio frequency circuits.
    d. But in reality circuits do not work that way.
        i. That is a bit of heresy, but if we open our minds we can understand many things that confuse us now.
        ii. How noise arises in circuits.
        iii. How electromagnetic fields and circuits interact, sometimes.
    e. Again this is the nice neat response, but let's look at what actually happens at the output.
56. We do not get just one pulse of sinewaves coming out, we get what looks like echoes.
    a. It looks like a chaotic mess.
    b. These are simulated responses
    c. We have done measurements as well and the behavior is much the same. It is very difficult to do these measurements and that is why we others have not looked for this.
    d. Why would you look, you only expect one RF pulse at the output.
    e. The interesting thing here is that this response is the deterministic response of a 14^{th} order differential equation.
    f. This looks unusual to us as our internal models, what we think, must be a reduced-order abstraction of the real world.
    g. Another conversation, and too deep for today, is that this behavior is behind flicker noise, or 1 over f noise, something we see throughout nature.
57. Jackson Pollack captured that.
    a. Chaos
    b. One over f behavior
    c. Self similarity.
    d. He tapped into the way the brain works
    e. It ties into our cerebral sensibilities.
    f. I believe that what I have just talked about could really change what we do engineering. As engineers we developed reduced-order abstractions of the real world. This is my greatest idea.

58. Where do ideas come from
59. As engineers we
    a. <READ>
60. Many people, especially lay people, see fundamental research as a path to a goal.
61. Some see it has climbing a mountain.
62. And when we get there we have finished.
63. But fundamental research is more like digging a hole.
    a. Where the ground is soft we keep digging.
    b. If it is hard we move on.
64. We nearly always need to dig lots of holes.
65. Research is really like shooting first and then drawing the target.
66. Do not get stuck in the rut of looking at just one approach.
67. As in everything, diversity is essential.
68. You must travel.
69. Confer.
70. Read, read a lot, and think.
71. Look at things from different perspectives.
72. .
73. You need to take risks
    a. But not all of them work out.
74. You need to be exposed to lots of ideas
75. Do not compartmentalize those ideas that you pick up.
76. You need to think and let the ideas ferment.
77. Let ideas come together.
78. New ideas are the synthesis of other ideas. This is not an original concept. Many people will say the same thing. New ideas are mostly (perhaps always) the synthesis of ideas you have been exposed to. You need to be exposed to and absorb many.

79. I want to share with you some of my academic history.
80. I received by bachelor's degree from the University of Queensland in 1976.
81. This is University of Queensland, with 48,000 students.
    a. This is the most beautiful campus in Australia.
82. I received my PhD in 1983. Now a PhD is not a natural state of being. It changes the way you think and tackle problems. With rare exception you need to be apprenticed to gain the necessary skills.
    a. My advisor was Peter Khan
    b. And he, and I, are descended from a long line of academics.
83. Which brings me to the story of a rabbit who was doing a project. The title of the project was "The Rabbit is Smarter than the Coyote, the Wolf, and the Fox combined."
84. The rabbit was outside his burrow eating grass and in turn came along a coyote, a wolf, and a fox.
    a. When the coyote came along, the coyote said "I am going to eat you"
    b. But the rabbit said, "No you cannot eat me. I have almost finished my project on how the rabbit is smarter than the coyote, the wolf, and the fox combined."
    c. And the coyote said "That is stupid. How could that possibly be so."
    d. And the rabbit said: "No, it is true, it is true. Let me go and show you."
    e. The coyote said: "Well I'm curious, and I am hungry, but I will let you show me and then I will eat you for my lunch."
    f. The rabbit and the coyote disappear down the burrow, and a little while later the rabbit is outside again munching on grass, a beautiful day, a beautiful sunny day.
    g. And along comes a wolf.
    h. And the wolf says "I've got you now, I am going to have you for lunch."
    i. And the rabbit said: "No you can't do that. I've almost finished my project on why the Rabbit is smarter than the Coyote, the Wolf, and the Fox combined.
    j. And the wolf says, "rrrf, that's rubbish."
    k. And the rabbit said: "Let me prove it to you."
    l. And the wolf said: "Ok, but then I will eat you for my lunch."
    m. The rabbit and the wolf disappear down the borrow, and a little while later the rabbit is outside, eating grass on a bright sunny day.
    n. And along comes a fox.
    o. The fox grabs the rabbit. And the rabbit says "stop, don't eat me now, don't eat me. I have almost finished my project on how the rabbit is smarter than the coyote, the wolf, and the fox combined."
    p. And the fox said "No way."
    q. And the rabbit says "let me prove it to you. Come down, to my study, and I will show you."
    r. And the fox says "alright, but then I am going to eat you for lunch."
    s. The rabbit and the fox disappeared, and a little while latter, the rabbit is outside munching on grass.
    t. A little while latter, the rabbit is outside again eating grass.
85. And along comes his friend the bunny.

a. And the bunny says to the rabbit “Mr Rabbit, aren’t you afraid to be outside eating in the open, what if a fox came along.”
b. And the rabbit said “No that’s ok, I just explain that I am working on my project that “The Rabbit is Smarter than the Coyote, the Wolf, and the Fox combined.”
c. And the bunny says, “Well Mr. Rabbit, I know you are really smart but I don’t think that’s right.”
d. And the rabbit says “well let me prove it to you.”
e. So down go down to the burrow.

86. And as their eyes adjusted to the dark, they see a pile of bones. …
    a. And the bunny says to the rabbit “Mr. Rabbit, who’s that?”
    b. And the rabbit says “That’s my advisor.”.
87. The moral of the story is <READ>
88. When we teach we want to train our students to think.
    a. To do that we, as faculty, must be thinking one or two steps beyond where we want our students to be.
    b. That is one reason we do fundamental research
    c. But we must also be good stewards of the resources invested in us.
        i. We are in a special position to solving societal problems
89. I wrote a textbook to capture many of the ideas I had. I could not think of a better way to spread the broad knowledge I have acquired over the years.
90. <READ>
91. I feel that life has come at me so fast. There is so little time to do it all.
    a. I am humbled by the honor you have bestowed on me
    b. I hope that I can continue to be
        i. A good educator
        ii. A good researcher
        iii. And continue to contribute to our nation’s and the world’s security
92. I leave you with my most powerful ideas.