Engineering a Learning Healthcare System: A Look at the Future - Day 1
Institute of Medicine of the National Academies
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MICHAEL MCGINNIS: Well good morning folks. I am Michael McGinnis and I am not going to do the welcome because you will have the two focal points for the Institute of Medicine and the National Academy of Engineering welcoming you officially in just a moment but I am going to go through some housekeeping and orientation elements.

First, just a note on the briefing books that you have to make sure that you have done your assignments and are all primed for the day's discussions. We should have a very interesting couple of days. This is an activity sponsored by the Institute of Medicine's Roundtable and Evidence-Based Medicine in collaboration with the National Academy of Engineering and you see in the briefing book the charter of the roundtable, the agenda for the meeting as well as the indication that the proceedings today are going to be web cast by the Kaiser Family Foundation.

So you are all on television. Please be on your good behavior. All cell phones off. We do not want to disturb the audio component of the web cast. Also in the briefing book are background materials on previous activities between the Institute of Medicine and the National Academy of Engineering and some general background on the work and status of the work of the roundtable.

If we can first turn to the agenda itself just to point out a few things. The first thing you see on the agenda is that this is one of the learning healthcare system series of workshops. The learning healthcare system is the concept under which the roundtable on evidence-based medicine is carrying forward its examination of key issues – issues like the clinical effectiveness research paradigm, the data availability and access, standards of evidence that are used, and of course, the whole notion of how the system of healthcare can be changed in order to ensure optimal function in each of those component activities.

Secondly, you see that this is sponsored in collaboration with the National Academy of Engineering. We view this as a vital partnership and a learning opportunity in itself.

Thirdly, you will see a little box with the issues that motivate the conversation and the discussions over the next couple of days and if you have time, I would encourage you to take a look at those because they will help shape some of the perspectives that will be engaged throughout the presentations.

You will also notice that day one, today, is going to be focusing on what the health challenges are and the elements that might characterize various components of healthcare systems and secondly what engineering might have to offer as we consider those health challenges and then tomorrow, day two, the drilling down on how the insights that are identified today might be applied to the betterment of our healthcare system and also too assessing some of the policy issues that need to be engaged if we are going to take advantage of those lessons.

The last item I will mention with reference to the agenda is among the most important and that is you see the planning committee, which has actually brought this meeting to you and we have the chair of the planning committee, Bill Rouse, who will be welcoming you in just a second. In addition to Dr. Rouse, we have Dr. James who you will be hearing from later on; Helen Kim, who was at the time, at the Gordon and Betty Moore Foundation, which is represented here today I should say; Cato Laurencin – Dr. Laurencin, you will also hear from – a member of the roundtable in a few minutes and the Honorable Paul O'Neill. And finally, Jerry Grossman – Dr. Grossman you will see a dedication to, he unfortunately passed away suddenly three weeks ago but was a very important member of this committee and we wanted to dedicate the meeting to Jerry.

The other introductions I would like to do just briefly – I will not ask anybody to stand and be embarrassed in that fashion but I would like to point out that we will have throughout the course of the meeting, several members of the roundtable including Dr. Denis Cortese, the chair of the roundtable; Helen Darling, the President of the National Business Group on Health; Carmen Hucarodo [misspelled?] from the Millback Memorial Fund; Cato Laurencin I mentioned already from the University of Virginia and Don Stein who is actually from Johns Hopkins University.

We also have, in the audience, a number of roundtable sponsors or those who are from roundtable sponsors, in particular as I have already mentioned, Gordon and Betty Moore Foundation, which is the principle sponsor of this workshop, in addition, American's Health Insurance Plans, the Agency for Healthcare Research and Quality, AstraZeneca, Burrows Welcome Fund, Centers for Medicare/Medicaid Services, FDA, Johnson & Johnson, NIH, Sanofi-Aventis, and the Department of Veterans Affairs. All of these are participants and supporters of the roundtable activity and, of course, we are very grateful to them for that involvement.

I should also mention, most importantly, the staff who have really put this activity together are in the room or outside the room. I will mention them briefly. We have Sara Brancho [misspelled?], Sarah Jane Brown, Rachel Passman, and Matt Spiro I think are not in the room so I will not ask them to wave their hands but we do have Catherine Baufner [misspelled?] over here and Dan O'Neill next to her there and over here, LeAnn Olsen, and we have also Alex Gulpe [misspelled?] who is the team coordinator for putting this workshop together and finally, we have Karen Gupta over here.

Karen has taken time off this week from her studies at Harvard Medical School to come here, is doing the duty with the timekeeping. We thought it was wise to put the person in charge of the timekeeping who lived the farthest away so that if she angers too many of our speakers, she will have a quick getaway.

Well, befitting the fact that this is a collaborative effort between IOM and the National Academy of Engineering, it is now my pleasure to turn the podium over to Dr. Denis Cortese, who is the CEO of the Mayo Clinic, as an IOM member and chair of the Roundtable on Evidence-Based Medicine and to Bill Rouse, the Executive Director of the Tennenbaum Institute at the Georgia Institute of Technology and a member of the National Academy of Engineering and the chair of the planning committee. Denis?

DENIS CORTESE, MD: Good morning everyone. It is a real pleasure to have you all here and I thank you for coming. I thank you for having the interest in this topic of how engineering science interacts with medical practice. It is really what we are here to talk about and what can we learn from that process.

The group we have today on your agenda, if you look in the book, the agenda has an outstanding group of people today and tomorrow and we are all going to learn a tremendous amount through these two days. I certainly know speaking on behalf of myself and my institution, we have learned a heck of a lot through these processes and we have brought them in to our own institution, even though at Mayo Clinic, we have had enrolled system engineers in our practice since 1901, the first system engineer hired at Mayo Clinic was a Dr. Henry Plumer who developed the unified paper record in Mayo Clinic in 1907.

So it has been over a hundred years where we have known the value. We really have not recognized the value but we knew there was a value to integrated data, integrated information, and then using that information to help generate new knowledge and it has been a powerful, powerful tool for our organization but what we have learned through this process of learning more about engineering shows that there is tremendous potential, tremendous reality if you apply the engineering principles.

Saying that, I would like to take a minute to pay tribute to Jerry Grossman, who has been a proponent physician and an engineer and he has been a very strong proponent of the systematic approach trying to integrate practice with the other sciences that are available that allow us to create connections when we are dealing with complex interdependent systems that really need to be brought together - how do we connect people with each other as well as building teams so that we can get the best results we can for patient care. The lack of coordinated care for patients drove Jerry Grossman crazy and those of you who know Jerry know what I mean.

He was a dedicated individual to this concept. Jerry, I think, set a very high standard for all of us. I feel free to talk about some of his problems now, now that I know that he would like you to – well he probably would not like you to know what he went through the last five years of his life but he was extremely productive the last five years. The most recent book with Clay Christiansen, Dr. Wong, is coming out, I think in May or June of this year about the innovator’s prescription for healthcare.

Jerry spent the last couple of years working with Clay Christiansen and others on that book. Jerry had suffered from cancer for five years. He had ten operations in five years, major operations in five years and I bet none of you had any idea who knew Jerry. He got up after each of those surgeries and he was working on his books in the intensive care units. I would go in and see him – powerful, powerful dedicated individual who just lived his life as though there was nothing else going on. He challenged us to turn his cancer into a chronic illness basically and we worked as hard as we could to do that and I would say he really taught us a lesson about how to live, how to be dedicated, and how to be focused.

And I think, as we embark on this meeting and we talk about this idea of what engineering could do for healthcare, we recognize at least on the physician side and I think many of the engineers recognize it too, there are huge barriers to this, huge barriers from culture, from the medical profession, from the payments, from everybody. You go to Congress – they do not have any idea what we are talking about with engineering and changing the delivery system.

They think you just get an insurance card and we solve the problem. It does not solve a single thing. It does not even get close to solving the problem. So on behalf of Jerry, we have a big uphill fight to do here. This meeting is just sort of moving it in the direction. It is one of the series of workshops through the Evidence-Based Medicine Roundtable and we plan to carry this further because we have to overcome the barriers that are out there so that we can change the delivery system.

So in that idea that we really like to dedicate this meeting. It is one of the series of workshops but I think this idea of engineering is the key workshop. It is the key effort to really how do we integrate all of the new knowledge we are going to be generating, establish it in practice but then how do we change the way we practice to get it to the patient, to get it right there.

It is delivered. How do we improve the delivery system? We have got many active ingredients but how do we deliver better care to those patients and the whole purpose for doing this is integrating the practice, bringing coordination, and to improve value and Jerry's definition of value is lower costs with better outcomes, better safety, and better service. That is the definition of value that we use and I will finish by leaving you with one additional challenge.

We have had - one additional concept – we have had one of our – at Mayo Clinic – one of our very strong benefactors is a gentleman who started a company called Cutters Insect Spray and I will just tell you a quick story. Some of you have heard it but it always is a good one. It has made a difference in my campus, a two-minute story that changed our whole campus. That is when he started the business, he had the product and here was the bottle and inside that bottle was the active ingredient.

It was 0.001-percent of the material in the bottle. That was dissolved in a hydrocarbon solvent and the hydrocarbon solvent was needed because that was the delivery system to get the active ingredient on to the skin and the most toxic component of his product was the delivery system that irritated the skin. It was greasy and it was the most expensive component.

Now is there a parallel there somewhere? The delivery system is the most toxic and the most expensive component to have the active ingredient. So he set about – how do we improve our product? How do we get better value? How do we get better outcomes, do it safer, at lower costs? How do we do that? Well every competitor was doing basic research to improve the active ingredient. He said forget the active ingredient. We have already got that.

So he hired somebody to come up with a new solvent. He shifted to an aqueous solvent in a matter of three to six months and the toxicity completely went away and the price was one tenth of what it was before, very powerful message and it took an outside person to tell it to our staff and one of our folks are here because of that. We started a whole program around this in our institution.

So that is what this is all about. How do we get better care to the patients? So thank you all for joining us today and tomorrow and I look forward to an exciting set of presentations. Bill, can I turn it to you? [Applause]

WILLIAM ROUSE, PhD: Well good morning. It is a real honor to be standing here and to be continuing the line of work that Dale Compton and Jerry Grossman started in 2004 with the interaction with IOM and NAE and hopefully contribute to a next step. It is a very important area and one of the nice things about this area, as an engineer, is everyone seems to agree it has to change as opposed to being tremendous reluctance through change. Now the question, of course, is how does it have to change?

One question is do we just try to get better in what we are doing already, trying to incrementally get those things better or should we do something really different and of course, we are going to hear a lot about that in the next two days. One of the sayings is one of my favorites and I think it is from Peter Drucker and it was – you should never try to get really good at something you should not be doing at all and maybe we will find some things here that we could really change the way we are doing things.

It is my honor to get to introduce Brent James. He is the Executive Director of the Institute of Healthcare Research and Vice President of Medical Research and Continuing Medical education at Intermountain Healthcare. Before I talk a bit about his accomplishments, one thing that is interesting, he is on the faculty at the University of Utah, Harvard Medical School Harvard School of Public Health, Tulane University, and the University of Sydney.

As an engineer, I quickly calculated that he is actually on the faculty in one sixth of the world's time zones but his claim to fame is not that. it is that he has, since 1991 I think, been educating medical professionals in safety, quality, improvement, et cetera and I heard of this morning, he has 3,100 graduates of the program in that 17 years – very impressive impact on the healthcare system. So Brent, it is all yours. [Applause]

BRENT JAMES, MD: The thing that Bill did not mention is that I actually received my original training in electrical engineering, financed my way through medical school, and through much of my residency program, on the side – building engineering systems. So in that regard, I thought something I might just show you to kick the thing off – it is my job to set framework after all – so let us see if this is going to work and the sound will come up. Our first test.

[TAPE PLAYED]

Well given – as a physician for many years, been working in medicine we are kind of asking engineering for consultation and I thought I would start out with showing a consultation from engineering seeking medicine's help just to balance things out.

My job is to establish a framework and I have thought of it as very quickly five major areas. Can I apologize in advance so – there is a massive body of literature behind this, truly massive.

When I am running the advanced training program, I would take two days and drag people through the literature. You are going to get the 100,000-foot view, very, very rapidly. Well I guess I should not apologize too much. Most of you are familiar with it but I am going to do a quick summary of the background science and I thought to cover five areas' deep background, we need to understand how the modern structure of healthcare delivery emerged.

Number two, to quote Ed Deming [misspelled?], aim defines the system. What is the aim of the American healthcare delivery system?. In that context, I would like to think of them not as failures really but as opportunities. It turns out that current healthcare falls short in five very specific ways. It has emerged within this field of research. I wanted to outline those – oh, we know why and I would like to quickly discuss the reasons for that failure and then finally talk about early solutions, emerging frameworks, and refined challenges as a – really a way of just putting this in context for the rest of the presentations for the next two days.

As long as there have been human beings, the healing professions have played a central role in human society. The earliest written record we have of human society – about 6,000 years ago talks about clinical practice. More than that, if you go back to the Stone Age societies, pre-literate societies, we find artifacts indicating that the healing role was central in those societies too but the vast majority at that time though was as physicians, as nurses, we were really limited in what we could accomplish. We could do two things.

Somebody would come to us with a problem – well we had seen it before. We could explain what was happening to them. We could explain the present. More important, having seen it before, we knew where it led next. We could predict the future. That was pretty much the limits of it. The reason that the healing professions were so tightly associated with religious societies is almost certainly that if any healing were going on, it was kind of spiritual healing – a shoulder to lean on, a listening ear, coming to some sort of balance, acceptance, closure you see.

We had very little that we could offer to change a patient’s future, very little. In fact as late as 1900, the most common treatment offered by physicians in the United States to patients was still bloodletting. We had advanced to the kinder, gentler form of bloodletting, which was leeching. In fact, physicians were often called leeches because we used them so frequently.

Number two therapy, purgadose [misspelled?] chemically induced vomiting and diarrhea. Now nobody measured it carefully at a population level but those who wrote about it, the educated class, routinely opined that if you were seriously ill and sought the attentions of a typical physicians, your chances of survival went down and that was almost certainly true. Hospitals were where people went to die.

Well wait a minute – that is not accurate. Hospitals were where the poor went to die. If you had any resources at all, you did not go to a hospital, of course. Well the point – that all changed. It started in the mid-1800s. I like to date it to people like Florence Nightingale and nursing – a British nurse. Her commentary on the Crimean War - still classic epidemiologic studies of the role of infectious disease in a large body of fighting men, more people dying from infection than from combat for example.

She was an advisor to the United States government during the American Civil War where you really start to see these new ideas begin to emerge. My favorite example, Sir William Oscler, Canadian physician practicing at Johns Hopkins, the father of internal medicine – well a long story short, they did four main things.

They first established a new standard for clinical education. It started with a report in 1902 from the American

Medical Association. That led, in 1910, to Andrew Carnegie hiring a high school teacher named Abner Flexner, to evaluate clinical education. As a direct result of the Flexner report, more than half of all purported medical schools in the United States shut down – medical schools. The average course of study was four months.

I mean how much time does it take to learn bloodletting, purgadose, and the humeral theory of disease where the human body was regarded to consist of four basic humors identified by colors and the disease of the result of imbalance in those tumors. This put some real teeth in professional licensing. Suddenly those laws exist just in passing to protect the guild of medicine from external competitions, but they took on a whole new meaning, once we had a new educational foundation against which to push. This is where we first adopt the scientific method as a basis for how we know what we know, the allopathic healing professions, well, shifted to a germ theory of disease and science as a basis for clinical knowledge.

So it is our first example of evidence-based medicine really on a broad scale, then a new internal organizational structure for hospitals. When that happened, the healing professions moved on to a fundamentally new trajectory. You can see it in population level health. This just illustrates longevity at birth.

A child born in the United States in 1900 had a life expectancy of 49 years. A child born one hundred years later, 77 years; 28-year gain in life expectancy during that century against a 49-year baseline. It is an amazing success story. Now, the orange part of the line corresponds to what we call the public health era. It was associated with control of epidemic infectious disease.

So those cholera epidemics, smallpox epidemics that would literally kill thousands in the past – eliminated. Number one killer in human history is typhus fever. It does not get the press that the Black Death Plague got because it was constant, flea-borne illness associated with unsanitary living conditions. We just do not hear about it in the modern society anymore. It was with sanitation you see - or the big killer.

In the 1900s, somewhere between one in five and one in three children died before reaching the age of five years from common pediatric infectious disease – diphtheria, pertussis, measles, mumps, polio. Well immunizations have eliminated that.

During this time period, life expectancy increased by three and a half years with each passing decade and it was a brand new thing in all of human experience.

Now an interesting thing happens in about 1950 to 1960 time zone – right at the end of World War II, we had pretty much tapped out the public health gains, at least that we had been able to easily achieve but another new phenomenon appears. For the first time in human history, you can show a population level benefit from what we do in hospitals and clinics from treatment. All right.

The interesting is before then, you really cannot. Oh we can set bones. We could deal with some forms of trauma but the big killer is we did not have any way to really help a patient. Think of it as a hundred years of science, massive improvement in understanding of the human organism in health and disease and literally thousands of ways that we could intervene to change a patient's future and change the model. We can still explain the present and predict the future but for the first time in human history, to treatment, we could change a patient's future.

Now the rate of increases attenuated a bit. It is about one in three-quarters, you are gaining life expectancy with each passing decade but it is still, against the backdrop of human history, amazing progress – truly amazing progress. Maybe the most amazing thing has happened within my lifetime. I was born in 1950. It is that new – a brand new part of human experience you see. Well in that context, this idea that we routinely achieve miracles.

We really do just illustrate the number one killer in any modern industrialized nation is ischemic heart disease. Since 1960, the age-adjusted mortality for that condition has climbed by 56-percent. Denis got it right when he talked about cancer. We made it a chronic disease. Instead of rapidly fatal, well where we do not cure it outright is we go in many pediatric leukemias particularly, we are talking about extending life to five, ten years as a chronic disease you see.

Number three on the list, stroke – 70-percent decline, massive improvements. Well in that context, what is the most important thing that determines a person's total health? Yes, this comes from the work of Mike McGinnis and with apologies to Mike but I did talk to you about it first, I rounded off to make a nice metal pneumonic [misspelled] that is easy to remember. About 40-percent of a person's total health are behavior is behaviorally based.

I have listed the big three challenges by which we take away our own health. Tobacco is still number one. A very close second is alcohol and other recreational drugs – about two-thirds of the effects is alcohol. It is not just alcoholism roadway accidents that kill people. It is about 70-percent of all violent crime is associated with alcohol use, about 75-

percent of all domestic abuse, about 60-percent of all fatal accidents outside of the highways associated with alcohol use and the list goes on.

Number three, Joann Drawdy [misspelled?] the head of bioengineering at the University of Utah calls it MBD, movement deficit disorder. I suffer from it personally. I would much rather claim this medicalized condition than admit that I am just too dang fat – obesity. The list goes on from there.

Number four on the list is sexually transmitted diseases including AIDS. Number five is unwed teenage pregnancy. Number six is suicide and violence particularly among young men and so on down the list. That is about 40-percent of a person's total health. About 30-percent, how wise you were in choosing your parents – genetics. We are starting to make some scientific inroads into this field but there is still relatively small – I think we are still – I do not know – 20-30 years out from making major interventions where we can offer treatments on a broad scale around genetic factors.

About 20-percent – public health. It turns out that only about, liberally – very liberally, ten-percent of a person's total health comes from healthcare delivery system, from treatment. In fact the best estimates say about three and a half years, three and a half to seven years, five to ten-percent. A fellow named Bill Dawsky [misspelled?] wrote about this extensively way back in 1977.

He called it the great equation. It is the belief that health equals medical care and that medical care means access to care. It turns out that – that common belief is fundamentally false, just not true. In fact, there are some very good studies out there that show that you can achieve more total health by investing in general education, more high school graduates, more college graduates than you can get by putting the same money into healthcare delivery just to get it in perspective.

Well I guess the other key part of that perspective is healthcare spending. You are familiar with these numbers. Basically they show that healthcare spending is increasing as a-percent of gross domestic product. the yellow lines are up through actual measured experience. The white dots are projections for the future. This is the HMO effect.

It dropped the total cost of healthcare delivery in the United States by 14-percent of this peak without damaging clinical outcomes. More important is the line at the bottom that shows spend per capita. In 2006 in the United States, we spent about $7,100 per person in the United States on healthcare delivery. That means for the prototypical family of four, they spent more on healthcare delivery than on owning a home.

It is more than the cost of home ownership. Over 50-percent of it comes through taxation just in passing. It is hidden from us through taxes. Most of the rest of it comes from employment-based health insurance.

Yes, the trouble is when we compare the United States to other countries. Here is the per capita spending in the United States rising rapidly. Here are just some other selected countries from the free world. My favorite – Sweden who has a reputation of having the finest socialized medicine system in the world.

They spend less than half of what we spend per capita. This shows that it is a-percent of gross domestic product. Interestingly, they spend less than half and they get a better health outcome. This shows life expectancy at birth. They have about three more years' life expectancy than does a citizen of the United States for example.

Another way of looking at it is infant mortality rates, another very common way to compare countries. We have all been improving significantly. The United States was roughly twice as high in infant mortality rates than Sweden.

So is this not a direct representation of the healthcare delivery system? Longevity, infant mortality rates?

Well wait a minute. Yes, we have to remember this back here and arguably, that is where the real differences lie just as one example. if you risk adjust the infant mortality rate for gestational age, the Swedish advantage disappears. They are about the same.

It turns out it is definitional in terms of how they define a pre-term birth, whether it is a salvageable infant that we put in our newborn ICU and invest massive quantities in attempting to save or if we treat them as stillbirth and in Sweden, it is much more likely to be classified as a stillbirth – just risk adjusted data and you will see the effects of that difference in definition popping out.

Here is the trick though. Even if we are the same, how do we justify twice as much expense within the United States? Twice as much to get the same result? Again, what are we getting for all that money? It turns out there are three possible aims and we have been talking about the first. The first one is total health, all right?

Compared to other countries, the United States spends massively more, roughly twice as much as other modern first world nations per capita as a-percent of gross domestic product and it is petty clear that we do not achieve more total health.

There is a second possible aim. I am going to call it high touch, when you carefully ask patients if they value their relationship with the caring clinician more than any other factor in the healthcare delivery system. It tops the list clearly. I found a great quote. It ties us back to that history where I started. There have been many of these, by the way.

You see, in 1910, we shifted our focus from caring – a shoulder to lean on. We shifted it to curing and it came at some cost. Well just read with me. A man stricken with disease today is assaulted by the same fears and finds himself searching for the same helping hand as his ancestors did five or 10,000 years ago.

He has been told about the clever tools of modern medicine and somewhat vaguely, he expects that, by and by, he will probably profit by them but in his hour of trial, his desperate want is for someone who is personally committed to him, who has taken up his cause and who is willing to go to trouble for him. This is the idea of caring, high touch, directly drives satisfaction within a healthcare delivery system. Patients translate their medical results through that relationship. Oh, it turns out that primary care is the main way to get a high touch system where people easy access to some sort of an expert. Compared to other countries, we do relatively poorly.

There is a third area though. It is called rapid response for the rule of rescue. The rule of rescue came from a fellow named Johnston in 1986. He defined it as the imperative that people feel to rescue identifiable individuals facing suffering or death. Later commentators pointed out that the interventions we apply do not have to be effective. It is the do something Jim, she is dying – phenomenon and there are many, many examples of it. We just lived through Crandal Mine disaster.

Those six men in that coal mine probably all died in the initial collapse. We spent literally tens of millions of dollars and killed three more men trying to rescue them on the chance that they might be alive, classic rule of rescue response. Now for rule of rescue to apply, it has to be a name and a face. It has to be someone with whom you can emotionally link, an empathic response right? And then we tend to pull out all the stops.

Now yes. If you take a look at rule of rescue, the United States tops the world. We are easily the best healthcare delivery system in the world in terms of rescue care. Look at major trauma, mortality rates were half of what Europe is. Heart attack mortality rates are two-thirds of what Europe is. This shows mortality rates for neonates less then 1,500 grams were half of what the rest of the free world is.

Renal dialysis per 100,000 – it is not because the Swedes do not have a need, they just have a different level of criteria for using this life extending technology, right? Liver transplants per 100,000; kidney transplants per 100,000 – I am just giving you a brief summary of a massive body of literature. So when people say the U.S. has the best healthcare delivery system in the world, they are correct in one area. We do rescue care better than anybody. So if you need primary care, Sweden is a great option. Great Britain will do very well for you well, but if you are in a major accident, you want to be right here in the United States.

Now having said that, there is another factor you need to know. Rescue care does not produce major changes at the population level. Just to illustrate, this is a little study that came out of World Health Organization – mortality amenable to healthcare. It turns out that real life extenders happen as preventative care and a primary care setting on average, all right.

So we fare relatively poorly when compared to other nations at that level. Do not get me wrong though, Americans have a huge interest in that rescue response you see. People value it. People are willing to pay for it. People want it but three possible aims – total health, high touch, rescue. Yes, on a macro basis, many countries outperform the U.S., primarily attributable to healthier behaviors, better public health, heavy emphasis on easily accessible primary care. We do significantly better on rescue care, better access to technology, less explicit and implicit rationing, easier access to subspecialists but just to get it in context.

Now Pete's number two behind this. If we would do a Medline search right now today in major articles on variation in care delivery in peer-reviewed journals published in the last 40 years, you will roll out about 40,000 articles. This is the entry point for understanding how the current system fails. I need to be very careful in how I state this. So it is how we fail compared to our theoretic potential.

You ill not find better care anywhere else on the face of the planet or during any previous generation. So I do not know, maybe it is improper to call them failures. Maybe they represent opportunities to be better. Five major areas. Probably the best example of massive variation is Wenberg's [misspelled?] work, [inaudible], I am not sure if you are familiar with it. Variation from one community to the next in the United States is so great that it is physically impossible that all Americans are getting good care when they have full access to care. That is the first thing.

The second thing people studied inappropriate care is the means of explaining the variation rates. It is maybe high utilization communities are treating patients where the medical benefit of the treatment is outweighed by its inherent medical risk. That is how they defined inappropriate. He showed two things.

The first is – is that inappropriate care does not explain the variation in rates. On average, high utilization communities have about the same amount of care judged to be inappropriate as low utilization communities – more on that in a minute.

Number two thing they showed though, for some medical treatments in hospitals, for some surgical procedures – as much as 30-percent of all care delivered judged to be inappropriate by one's professional peers on careful review where the risk to the patient outweighed any potential benefit and we did it anyway under the rule of rescue. This among professions who hold as our first tenet, first do no harm and the idea that for some treatments, 30-percent of the time we are putting people actively in harm's way – simply unacceptable.

The third factor – unacceptable rates of preventative care associated injury, and death – November 30, 1999 – from this group, the Institute of Medicine, we published errors human, estimating somewhere between 44,000, 98,000 preventable deaths per year from care delivered in hospitals. Oh that makes American hospitals somewhere between the fourth and sixth most common cause of preventable death in the United States of America, this kind of has karmic balance, the idea of a hospital as a major public health problem because they are – that definition.

Oh number four – people started to measure how well we did when we had hard evidence of best practice, how well we did in applying it consistently. Perhaps the best study was Beth Levin’s work out of Rand, 2003 New England Journal of Medicine – you have got it right 55-percent of the time. Numbers two and four actually balance each other.

Two is overuse, four is underuse. It turns out we are equal opportunity screw-ups. We are just as likely to undertreat as to overtreat roughly and that is probably why these studies did not show an association between inappropriate care and variation in rates is because you are only looking at half the problem.

Finally, huge amounts of waste and spiraling prices. We just completed a study for HRQ in which we estimated a minimum of 50-percent of all resource expenditures in healthcare delivery today is waste – nonvalue adding waste using a lean model, TPS lean model. Believe it or not, we were trying to be conservative. It is almost certainly larger.

Well five major areas of opportunity but I think that is a fairly accurate summary of that massive literature, 40 years of research on the topic. Yes, why? We know why. It is a head-on collision of two factors. The first is something called the craft of medicine. It is the idea of physicians and nurses and other health professionals as stand alone experts. In some sense along to yourself, honoring an ethical trust to the patients, a fiduciary trust, to put the patients' healthcare needs before any other end or goal, brought on this massive knowledge base gain from formal education experience.

Well we call it a craft because it is a cottage industry. The idea is that the physician/patient relationship – you start largely with raw materials, create a unique diagnostic and therapeutic experience one patient at a time and the promise we made, as a profession, is that this guarantees best possible medical outcomes to a patient. That was really consolidated back in 1910 when we transitioned into the modern healthcare delivery system. What it came up against was a hundred years of science.

So to briefly summarize another 40 years of research, we call it clinical uncertainty. The full list has about 70 items. These are the top four in terms of course and frequency and citation. Number one, lack of valid clinical knowledge – that is actually the whole reason for the roundtable. It turns out that we have evidence of best practice, about ten to 20-percent of the time, level one, two, or three evidence.

Level one is randomized controlled trial. Level two are observational designs. Level three is expert consensus from a group of respected authorities using formal methods. You see, most of the research we are generating shows that a particular treatment is better than nothing but relative to care [inaudible] that is not the pertinent question. Imagine that I have a patient who comes to me with a major illness and I have four treatment alternatives.

For each one, I have efficacy information that they are better than nothing. How often can I tell which one is best for this individual because a degree of health or harm could be massively different even though they are all better than nothing. See that idea? Well yes, we have evidence for best treatment ten to 20-percent of the time. Number two, the rate of increase of new medical knowledge.

Many of us got the same thing if you went through clinical training. The first day of medical school, somebody stood in front of us and told us that half of what they were going to teach us was going to be wrong and they did not know which half. Hence, you probably got that one too. They were really trying to emphasize our ethical commitment to continue to learn over time.

Yes, it was the new research efforts. The doubling time for medical knowledge in 1974 was about 30 years. So I could expect about half of my knowledge base to be replaced by new knowledge and of course, they did not know which half, as the research machine continued to chew ahead. Well wait a minute – what is the doubling time for new medical knowledge today?

Best estimates shorten to about eight years. That means that – that new internist coming into practice today is going to have to learn and unlearn and relearn half of her medical knowledge base five times. Janny Felt's [misspelled?] the main author addressing the topic it is physically impossible. How would you construct a system where every health professional basically was in lifelong residency?

So instead of placing the burden of that continual learning on the individual by attending meetings, reading journals, physically impossible task by the way, how would I organize so that the information was being pushed out in appropriate implementable ways.

Oh and number three, continued reliance on subjective judgment are actually three lines of evidence here. One has to do – we know how the expert human mind works. They are pattern matchers. We match patterns, subcompartmentalize and pattern match. The trouble is – is that so many of the problems we face in clinical medicine are not pattern matching problems.

They are statistical summarization problems. We are summarizing experiences over groups across time. Well it turns out the expert human mind is extremely poor about that. That is where the other two bodies of evidence come in empiric measures of how well we do. Short version – we misestimate measurable parameters by 20 to 50-percent consistently, when we rely upon subjective recall but the current system is built around subjective recall for independent experts you see.

Finally, another body of evidence that probably the finest variation analysis ever done, we have been able to prove significant variation within a single physician and a single patient literally morning to night on the same patient and outpatient settings and inpatient settings has to do with just plain old complexity. Yes, the seminal article was published in 1956 by a guy named Miller.

He talked about the magic number seven plus or minus two. Five to nine factors that the expert mind can consider at one time to make a clinical decision and we just started to count how many factors you should consider. The initial study was ventilator settings in patients with acute respiratory distress syndrome in an ICU, about 40. It turns out that if we just assume that every time the physician was seeing the patient, they were subconsciously and by their own evaluation at random, selecting six or seven factors to optimize, you could completely explain the variation.

Well take that complexity, run it head-on with this idea of the craft of medicine, stand alone experts. What you get is massive variation, high rates of inappropriate care, unacceptable rates of care-associated injury and death, striking in ability to consistently apply new research findings on a broad scale, and huge amounts of waste. So that is the basic fast diagnosis of the problem.

You need to know one last thing. we found some proven solutions. Technically they are a form of lean, the idea of a mass customization environment. Imagine that we called together a team, now organizational level care is what I am talking about, a team of health professionals – representatives of the physicians, the nurses, the pharmacists, the therapists, the technicians; even the administrators and we hammer out an evidence-based best practice protocol.

We do that fully understanding we have good evidence that you cannot write a protocol that perfectly fits any patient. The humans that come to us for care are just too variable – different genetics, different physiology and anatomy, different response to a pathogen, different expression of disease, different response to treatment, different personal preferences, circumstances.

Yes, we call them shared baselines. You build the thing and it is not just that you allow or even you encourage – you demand that your health professionals are going to adjust to individual patient needs. We have about 45 of these running right now inside Intermountain – measure them. I can tell you that you will end up changing 95-percent confidence interval about five to 15-percent of the shared baseline to meet the needs of a particular patient.

That is an emerging new approach, huge implications to the professional involved. It makes them massively more productive. They get to spend their time on the fun part of medicine where that expert mind, your most important resource, could make a real difference, huge implications for a care delivery system in terms of efficiencies of that system.

Well, today we come to you as the medical profession asking our colleagues on the engineering professions to share your learning with us. You have been at this a long time too. As we shift from a craft-based practice into a profession-based practice, this idea of care delivered as a team, an organized system of care delivery as opposed to a loose conglomeration of poorly coordinated parts, what do we need to know to do that right?

How should we be thinking about it? What can we learn from the path that you have walked to help us do it better? Yes, I threw in a few examples just to show it happening but how might we address clinical complexity? How do we build knowledge management into a learning system as part of care delivery? How do we think about care delivery through groups as opposed to stand-alone experts? Most important, how do we think of healthcare design as a coordinated system of production, a major new transition as we prepare for the next century. With that let me say thanks for your time and attention. [Applause]

MALE SPEAKER: We have time for any questions for…Just a couple of quick questions? Are there any questions or comments that anyone has for Brent? Another one of his usual extremely interesting and very knowledgeable presentations. Any comments or questions? Yes stunned into silence. He has challenged you all. Any comments? Yes sir?

MALE SPEAKER: [Inaudible]

MALE SPEAKER: Come back. Would you repeat the question as you understand it?

BRENT JAMES, MD: The point was is that eliminating variation while responding to individual patient needs seems to be highly dependent upon a robust information system and you are exactly correct. In fact, I skipped passed it, I can make a compelling argument, given enough time, that the reason that electronic medical records are starting to take off is because these shared baseline approaches.

Speaking broadly – other people use different names for them, they are putting enough structure into clinical practice that well proven data automation techniques from other industries are starting to apply in healthcare and you could make a pretty good case for that but it is a hand in glove relationship. Yes on the one hand, it makes EMRs a very, very productive tool for healthcare.

On the other hand, when you start to implement these shared baselines, you probably cannot do it on a broad scale without a good data system. We have done it manually but the biggest number we have ever been able to get running in one place at one time is four before the paper shuffling completely overwhelmed us and four was probably not sustainable – maybe three. The trouble is in a primary care setting, our analysis suggests I need about 40 running at one time and the only way that we have been able to even think about that is a good electronic medical record and the data system.

MALE SPEAKER: Back?

MALE SPEAKER: [Inaudible]

BRENT JAMES, MD: Yes, the question had to do with measuring and monitoring, managing the patient's experience of care and variation in that. This one takes some careful thought and I do not have a short answer is the problem. On the one hand, we believe in patient-centered care very, very heavily. For example I can show that with chronic diseases, the first line of defense is an engaged patient caring for their own condition, right.

You have to deeply respect the principal autonomy that people ought to be able to control their own circumstances.

There is a thing that makes medicine fairly unique though and I think it really does make us different from most other industries. It is the idea that clinician/patient relationship – there is good evidence that patients really value that relationship.

They use it to interpret their experience and it actually increases the level that you have to think about this. The point is – is that you always manage patients' expectations in every healthcare delivery setting. Sometimes we do it very poorly. Sometimes we do it well but just as with the care delivery, it requires an organized system to do it well and you think of – what is an organized system? It is just more systems theory in terms of that.

DENIS CORTESE, MD: That should do it. I think we have to move on here. Thank you. [Applause] Those of you who are engineers in the audience and you listen to what Brent is talking about maybe wondering gosh, this sounds like it really is clean cut and should be easy to do and are physicians not integrated, coordinated working together and he comes from a unique institution where the physicians that work there have already sort of naturally selected themselves to be willing and actually relish working in a group practice where they work in team care.

That is a unique talent today in the United States medical profession. I would say maybe, if we are lucky, 20-percent of physicians practice in that kind of an environment. So the more common environment, one of the things we have to tackle is the loose confederation of physicians that might be distributed in the city or they may or may not coordinate with each other even if they are in the same building.

How do we make that happen and how do they link to the hospitals in given cities? There are pockets of groups that practice integrated fashion. You can actually do what Brent is saying relatively easily. That is a – the term is a relative term because even there, there are significant hurdles. So as you think about ways to solve that problem, it is also thinking about how to do it in a distributed model, almost in a virtual type of environment where physicians can actually collaborate, interact with each other and interact with their patients wherever those patients are in the world. I mean this is the opportunity we have got in front of us.

Now to solve that, we have got Dale Compton who is going to tell us how to do all of this from an engineering perspective. I would point out the nature of your book. The descriptions of the individuals who are presenting, their CVs are in the book and also behind the yellow section here there is “Building the Better Delivery System” with additional commentary under the blue sections in the publication called "The Bridge."

The engineering document was published, I think, in 2004 with regard to healthcare. Dale Compton and Jerry Grossman were the co-chairs of that committee that did that work. Proctor Reed is with us, I think, today who was one of the editors and Benning [misspelled?] was one of the editors. I do not know if he is here today either but we have some people who were involved with that earlier work.

In addition, Dale is a Professor, named Professor emeritus at Purdue. He works in nanocrystal studies interested in metals but it is the engineering principles that he brings to the table and helping provide some expertise in the medical profession in his role as a board of director and involved with the quality chair of a hospital where he lives and in addition, he has served with distinction in the Institution for Healthcare Improvement, IHI. So with that I would like to turn the chair over to Dale. [Applause]

DALE COMPTON: Thank you very much Denis. That was a great talk. I want to focus my remarks not looking at what the content of the future healthcare delivery system will be but to think seriously about how do we get from here to there. How do we change these big organizations that we have? How do we bring about the transformation of our healthcare delivery from what it is today to what we want it to be?

And then about the role of learning about new circumstances that influences a need for these changes. Not an easy process. There are many challenges for large organizations, many of which are intentional, many of which are incidental. Let us hear some of them.

Well there organizational structural challenges, that is the problem with setting common objectives. There is fairness of the evaluation of performance of individuals and groups, and there is the issues of fairness of the reward system and these lead to the silos of large organizations – also very common. Well if these are some of the obstacles, how do we generally go about combating them?

We have some various tools. We move people about. We establish cross-departmental committees and then we reorganize even when it is not necessary.

It is all of an effort to try and get people in different areas working together thinking along common lines, committed to cooperation. Does it work? Not very well. We have all seen examples of that. So how can a large diffuse, diverse organization learn to do things differently in order to go in a very different direction?

I emphasize large diverse and diffuse advise [inaudible] that is really what our healthcare system looks like – big, diverse, virtual. Learning healthcare system really has two very distinct parts.

The clinical part that is the biologically targeted intervention processes and the delivery strategies are intended to support the clinical. And while many of you are responsible for delivering the clinical aspects of healthcare, you probably have been less responsible and perhaps even less concerned about the delivery system that supports these duties but improvements in the system of delivery can offer significant advantages in improving the efficiency of the system and reduce costs and as with this element, the organizational and structure of the delivery system for engineering can be of assistance.

Well how does one begin to think about the delivery aspects of healthcare? Well from an engineering perspective, we do ask questions like what are the system objectives? What determines present performance and what change would we like to accomplish? What are important points of controlling the system? Well fortunately the overall objectives of the healthcare system were well accepted. The system must be safe, effective, timely, patient-centered, efficient, and equitable.

Well it is interesting to note that cost is not one of those even though cost affects each of these objectives and is affected by each of them. This is becoming an increasingly important issue with healthcare.

It is with the larger system issues that I would like to discuss with you some of the issues this morning and while I fully recognize that there are many differences between the goals of the large, diverse, global company in the healthcare enterprise, I think as some experiences in large commercial product industries are particularly relevant. I emphasize that the important comparisons with commercial product industries where the success of the industry is determined by the acceptance of the consumer of the products.

While there are multiple participants in the consumer industry of healthcare, I tend to think of it as a consumer industry in which competition is at least somewhat subdued.

Well I would like to begin by sharing a few of my experiences relative to the way in which a large company faced the crisis of quality in the 1970s. I joined Ford Motor Company in 1970. My first experience with a corporate meeting attended by all management of the company dealt with quality. There was a lot of consensus during that meeting.

Everyone agreed that our product quality was lousy. Everyone agreed that something had to be done about it. The meeting ended. Everyone went back to work and continued doing the same thing they had done before with the result that quality was still lousy. Why? Well there was no real incentive. After all, our principle competitor was just across town and they had the same lousy product quality. So what changed?

Besides everyone thought that quality cost money and no one wanted to be the first to say that they had extra dollars laying around to spend on that problem but you all know what happened. A crisis occurred. There was an oil embargo. Vehicle fuel efficiency became more important than the big gas-guzzlers.

The public discovered that the Japanese manufacturers offered a smaller vehicle with better fuel economy and they flocked to buy it and then those customers discovered, strangely enough, that those vehicles had high quality and that was the beginning of the onslaught of the Japanese into the automotive market of the United States and you see where it is today.

In spite of what then Secretary of Commerce, Brock Adams, declared at the time, it was not technology that made the Japanese cars so attractive. It was that the Japanese had in place processes, processes that yield a product of high quality. Their better fuel economy is a direct result of being smaller and lighter in weight not of having a superior technology.

Now most of you are familiar with Chrysler's circumstances at the time, I am sure. Probably only a few of you though are aware that on one occasion, Ford was within a couple of days of running out of money. It was a grim situation. The Ford system was forced to change in order to survive. Quality had to be improved but how?

Well first it was recognized that it could be done on the short-term was to eliminate errors in the assembly of the vehicles. So the customers receive products that there are fewer problems and the company in fact did not lower warranty costs.

One plant was chosen. Top management of Ford brought the union management into the process of explaining why things needed to change and how to begin. The unions agreed with the strategy and fully supported it. Ford's upper management from the chief executive officer to the executive VPs and the other VPs were committed.

They were actively involved and very much served as salesmen of the need for change. It was a surprise to everyone was the spectacular progress that was made in a very short period of time in that plan. Quality improved by factors almost immediately. The changes were then spread to other plants by the workers – the workers in that first plant by teaching workers in other plants. So people who knew what the job was taught other people how to do it. For the company, quality became what was known as job one, the most important timing issue in the launch of a new product.

Now while the manufacturing system was being dramatically changed, product engineers put in place the process to improve the design of the next major Ford product. No longer was it designed by the engineers to be tossed over the wall to the manufacturing people and told now make this with the result often that in a period of a few weeks, it would be tossed back over the wall by the manufacturing people who said it cannot be manufactured with the facilities that we either have or going to have.

All of this lost time cost more money and ultimately led to a misunderstanding between the two groups - part of the silo system again - each of those acting as silos. So the concept of simultaneous engineering, which intends to reduce the silo mentality between the design engineers, the development engineers, the sales force, and so called parts activities that handles warranty problems was introduced.

Cooperation across boundaries became the operating rule. This led to the creation of one of the most successful products Ford has ever developed, the first Ford Taurus.

Now there are obvious differences between the Ford and the healthcare systems. There was a clear hierarchy setting the objectives for the Ford system. It was a single objective quality. It was a single objective that everyone could understand and rally around. Everyone in the Ford system could see the need for the objective and how they benefit and everyone came to believe that improving quality was not something that one could work toward and back to the old days.

It was also soon recognized by the Ford organization that it was necessary to adopt another important Japanese procedure – namely continuous improvement and while there are lots of steps in implementing this, I will mention only four.

First, how do you tell if you are improving? Well you must have data. Ford had lots of data. Its task was to create an organization to recognize the importance of letting individuals on the assembly line use those data and not have to go to some supervisor, get permission to try new ways of doing business. Continuous improvement in only work if the employees are empowered.

People at all levels have to be informed, trusted, and empowered. One important element of this was the introduction of some of the engineering tools that you will hear about this morning – such things as statistical process control where in the workers control and regularly document performance against operating objectives.

Well can the healthcare industry do the same? Let us ask a few questions about that. First is there crisis? I think Brent indicated those rather clearly, safety failures, knowledge, practice care, waste, and inefficiency, so forth. Clear answer is either yes or it is [inaudible]. So what are the next steps?

Well there are both short-term and long-term possibilities. In the short-term, you will hear later this morning about some of those alternatives - how to pick the low hanging fruit, what kinds of tools to use but the healthcare industry faces a problem that much of our manufacturing industry did not face, namely the positive good data, lots of data on the clinical side of the system, precious little on the delivery side. Let me offer you just one example.

I talked to a number of ambulatory clinics and hospitals who talked with us about how do you improve patient flow in the facility and if you can improve patient flow, how do you use that to improve your scheduling with the resources and people. What data do you need to get god patient flow? You need the arrival rate of patients at every station, every point that they stop. You need the average time that they spend there and you need the paths that they go through.

How is this normally done? Stopwatch and people writing down, following patients around. Well that is fine but then how do you move it from one facility to another? You have to do it all over again and as a result, very few facilities have those kind of data. Not that they cannot be in pain [misspelled?] but it cost money. It takes a lot of time to do it. So data is lacking and we have to find some way of making it available.

The second involves participation by all involved. Now I would like to quote from a recent publication by Paul Levy who is president and CEO of Beth Israel Deaconess Medical Center in Boston entitled “Adapting Process Improvement Techniques in an Academic Medical Center.” I will just sketch right through two or three.

Here is an example about ventilator-associated pneumonia, a problem relevant to anyone who has been or will be in an intensive care unit or will have a loved one in an ICU. A patient on a ventilator who contracts pneumonia has a 30-percent chance of dying, so pretty high mortality rate. He goes on to say it was academic physicians who read journals and other publications from around the world who instigated the changes.

After several of them had read the recent literature about preventing VAP, they decided that they would change the way the ICUs cared for patients but here is the key. They had to organize the 200 people who worked in the ICUs – respiratory therapists, nurses, and doctors all had to be changed to change the industrial process with no increase in staff and with basically no increase in resources, the doctors went to work and made a pact.

Many of the changes were not very complex. I watched the results of the changes and started posting them before they reached the 90-percent [inaudible]. At that point, the head of the group sent an email to his colleagues that read something like this. As you may have heard, Libby has a blog on which he is now posting our success rates with ventilator associated pneumonia prevention. Perhaps we should take this as an additional emphasis to do even better because people out there are watching.

Organizations of the system is also a very important aspect of allowing these changes to take place. For a complex system to be manageable, it must recognize that interaction takes place among the parts of this system and how actions by each element of the system affects the performance of the other parts. Seeking optimization of each of the parts does not guarantee the optimization of the whole.

Incidentally that can be proved mathematically quite conclusively except under very, very limited circumstances. One has to understand the details of the interaction of the various segments. Failure to recognize this as a truism is not unique to anyone in the industry. In manufacturing, we often talk about profit centers, the assumption being that you break up the companies into elements and let each worker optimize their own profits with the expectation that the total profit of the company will be optimized.

Where this becomes patently ludicrous is when one part of the company makes themselves products to another part of that same company. Well the amount of time and effort that is spent in trying to arrive at the proper transfer price between these two elements of the company is just unbelievable when, in fact, the company as a whole could care less, they're wooden nickels. What is the liaison, [misspelled?] break down the silos and as Paul Levy just described it that applies to all corporate objectives not just the profits.

The third issue that keeps appearing involves communication. The engineers and the healthcare professionals have a lot of work to do in creating the common understanding of problems and opportunities. You cannot achieve continuous improvement when people are not communicating. The committee that the late Jerry Grossman and I co-chaired that led to the report – Building a Better Delivery System – was well over a year late in publication not because of disagreements among the committee members of whom one of them was Denis Cortese you heard just a minute ago but because we had to rewrite the report several times in efforts to assure that both engineers and healthcare professionals would or could read it.

The language was important. I have seen similar communication difficulties at Purdue as we have launched the [inaudible] Industry Center for Healthcare Engineering. We do not have a common language. Simply put – most healthcare professionals do not know what questions to ask and what to do with the answers they receive and similarly most engineers have experience with healthcare only as patients.

Fourth, I mentioned earlier the need for good data. Not only do we need good data, we need good IT systems to collect, distribute, and analyze the data. The healthcare delivery system is well behind in having such a comprehensive system. There are a couple of relevant Bills at the various levels of treatment by the Congress. One of these is still in the House, it is a healthcare information enterprise integration initiative, $8 million for each of 2009 and 2010, a second one has been passed by the House and the Senate.

By 10,000 trained in 2011 in healthcare information, a $100 million between 2008 and 2011. Those are the good news. The bad news is that they are essentially settled with no action being taken at the moment but equally bad is the fact that the word engineer does not appear in either of those

Bills. Now I am strongly in favor of information technology and the need for it. I just regret that those two Bills could not have included the engineer so that we could make some progress with bringing kind of task time efforts that you are going to be hearing about today.

In the long-term, we need to create a [inaudible] of professional medical professionals – medical and engineering professionals who work together, who understand each other and who can collectively tackle some of these tough problems. In particular, the NAEIOM [misspelled?] Report recommended the creation of centers that would bring together members of the medical profession and engineering profession into a multidisciplinary environment where joint research would prosper, where the development of new tools would be undertaken for the demonstration of existing and new tools to healthcare providers would be shown, where new joint education of tools could be created, and where assistance could be provided to healthcare community to implement these tools.

We call for the establishment of 30 to 50 of these, each at a cost of about three and a $.5 million per year, which would apply between $100 and $150 million per year investment. It strikes me that that is a pretty small investment compared to the 150 billion we are currently wasting. These are aimed at long-term refocus of some of the educational aspects that both professions along with helping in the near-term with problem solving. Multidisciplinary research does not mean that one discipline works on the problem while the other just watches or simply consents to having the first one around.

I am worried that there is some possible [inaudible] about falling into this trap. The medical profession is becoming more open to letting engineers into their practices but they seem less frequently involved in joining in doing the actual research. Well we need the support of all of you in this audience and your colleagues to encourage our Congress and our officials to see the importance of investing not in the short-term but also in the long-term activities that can improve this system. I encourage your active participation in this.

If any of us could help, we are ready to do whatever is needed. For a huge diverse, diffuse system to learn and change requires the commitment of all people at all levels, the common understanding of where the system is going and what is needed and the tools to assist in that change. No wonder it is so hard for the healthcare delivery system to learn and change but individually and collectively, we could make it happen.

Ford learned. It changed, it survived, and it prospered. Then it went on to forget many little lessons that they have learned. We must be sure that the latter does not happen to healthcare. We have a responsibility that change occurs. We have the wherewithal to collectively make it happen. We must not let this opportunity stagnate or disappear. Thank you. [Applause]

MICHAEL MCGINNIS: Thank you very much Dale for that really very nice overview of the important lessons that we in healthcare can gain from you in engineering and the importance of engaging more specifically monitoring not just of clinical outcomes but of the nature of the processes involved, the empowering of the folks who are on the front line, and the need to focus constantly on the improvement process and embed it in every step of the enterprise. Are there any initial follow-up questions?

Actually because we are a little behind, if you could hold it for a second and catch Dale on the break, it is now my pleasure to introduce the moderator and chair of the next panel, Paul O'Neill. We will have a break in about a half an hour from now but we are going to move directly to the next panel and Paul will introduce the panel.

I think all of you are very familiar with the Honorable Paul O'Neill. He was not only an extremely valuable member of the planning committee but has been a leading exemplar of the practice of applying engineering and systematic principles to process improvement.

As you will hear throughout the course of the conference, Paul O'Neill was appointed by President George W. Bush as the 72nd Secretary of the U.S. Treasury and served in that position as Secretary of the Treasury for 2001-2002. He was previously the chairman of ALCOA for 12 years and engaged ALCOA in a number of leadership positions not just on the business side but the health side and he retired as chairman of ALCOA in the year 2000.

He is currently non-executive chairman of Value Capture and I guess there is an Indiana tie with our previous speaker in that you received your master's degree in public administration from Indiana University. Paul, thank you very much. Let me invite you to the podium. [Applause]

PAUL O'NEILL, MS, MPA: Thank you Michael. Brent said in his presentation that from his work and the studies he has done, he believes the opportunity value in health and medical care is 50-percent. Let me put a number on that. That means $1 trillion a year. It is a worthwhile enterprise we are engaged in here. I am going to be brief.

This session is devoted to the topic of engaging that complex system through engineering concepts and we would ask the question – how do the various engineering disciplines, for example, systems engineering, industrial engineering, operations research, human factors engineering, financial engineering, and risk analysis engage system complexity and how might this prospective inform and improve healthcare and what can we learn from the contrast. We have four speakers this morning. The first is Bill Rouse who you have already met.

Bill is the Executive Director of the Tennenbaum Institute at the Georgia Tech and Professor at the College of Computing and School of Industrial and Systems Engineering and he is going to offer general perspectives on the role of systems engineering in these circumstances. Dick Larson is the Founding Director of the Center for Engineering Systems Fundamentals at MIT and will speak to engineering systems analysis tools.

Jim Tien, formerly of Bell Labs and Rand, is a distinguished Professor and Dean of the College of Engineering at the University of Miami. He will speak on the topic of engineering systems design tools and Hal Sorenson is the founding faculty member of the University of California at San Diego and is currently a Professor of Mechanical and Aerospace Engineering at the Jacob School of Engineering. He will speak to the topic of engineering systems control tools.

After we hear from Bill and Dick, we will take a break so you will know where we are headed – maybe at 10:30 or 10:45 so that in that order of magnitude then we will hear from the other two speakers and then we will open ourselves up for our panel discussion questions.

So would the members please join up here and Bill Rouse, will you come to the podium. If the other panel members could come here if you will.

WILLIAM ROUSE, PhD: Good morning. I am going to start off and talk briefly of a contrast with science and engineering as I have been involved with healthcare intensely for the last year or so. I have really been involved for the last five years or so but intensely the last year or so, I have begun to understand some of the differences and perspectives and I want to briefly talk about that and then [inaudible] basically try to illustrate the engineering approach by taking one example and working on it at some length.

So science – we started off and we try to observe things and describe them and after we do that for a while, we will classify them and say there are some things are different than others and we may kind of get to the point of trying to predict that phenomenon. Engineering certainly is concerned with prediction also and building on science but engineering has this pension for trying to control the phenomena and then try to design it to work better.

By engineering here, I mean it not so much as a profession that is a verb of trying to predict control and design. So we feel that once we are good enough to predict something then we ought to be able to control it to do what we want it to do and once we understand how to do that, we try to design it to do better. So let us talk a little bit about that.

What do we mean by prediction? Well with randomized clinical trials, we would be fitting equations to data and trying to project outcomes for similar conditions in terms of health conditions for example. Engineering would be more likely to take a modeling approach and start with first principles – either first principles in physics or chemistry or mathematics, et cetera and to formulate models from that and try to computationally predict the outcomes of the experiments.

Now I know I have learned a little bit about the Archimedes Project where that approach has been taken to try to predict the outcome of randomized clinical trials. so there is a bit of convergence of the two approaches but as you will see in my example, I am going to take a phenomena that Brent outlined and see if we could creep up on it with some simple engineering models to try to understand what is going on.

So control – what do we mean by control? Well as Dale talked, we have to be able to measure system state and actually that requires we define what we mean by the system state. So if we say what is the state of the healthcare system – well what does that mean? If we are going to try to control it to achieve some desired outcome, we would have to be able to define it. Feedback means we take our predictions, we compare it to what actually happens, and then we try to correct the difference either by correcting our model or trying to influence the system to do something different. In compensation, we can add dynamic elements, for example, we have to counteract the fact that our information is delayed when we get it. So those are some elements of control.

For design, we try to understand input/output relationships including uncertainty. We try to design input/output relationships in say our processes in healthcare to achieve objectives. Then we have to worry about, of course, production. We have to build it, get it to work and then sustainment is creating mechanisms so that we will continue to meet objectives. So those are just the four elements of design but that is kind of abstract. So let us talk about a specific example.

The Congressional Budget Office issued a report in January that talked about the GDP for real healthcare costs has tripled in a 40-year period. It is actually a much bigger difference in numbers but adjusting for inflation, it has tripled and 50-percent of the growth is attributable to technological innovation and you maybe recall a few years ago, Peterson’s book, “Running on Empty,” that basically we are drowning in our success in terms of this technological innovation. So what I want to try to do is take that data and try to understand well what could we do about this and we are going to talk about three different models and this is just to present some elementary view of how an engineer would approach this.

So first of all, what is the phenomena and then we are going to go through three modeling levels. There is going to be a little algebra but that is not crucial in it but it is going to be there anyways. So what is the phenomena? So first of all, if you are going to work with engineers, you are going to see a lot of diagrams like this. An engineer, typically, you want to see if you can get this phenomena on a page and talk about it.

So up here we have – I guess I have got this pointer right? Okay. I would love to know how this one works too. Okay, so here we get technological innovation up here at the top. As we mature that technology, we get increased effectiveness. We have all experienced this on our desktop and we also get decreased risk in terms of say a medical intervention.

What happens with this increased effectiveness and decreased risk is we get increased use and it – interestingly in healthcare, we get increased use, we get increased care, so we get longer life. So we use it again. So we get to have more than two hip replacements. Over here, we get increased efficiency like in semiconductors and I will talk about how that efficiency happens in a minute. So that gets decreased cost per use, however, the increased use is growing so fast we get increased expenditures, which means we have to focus back on efficiency again.

So basically, what happens in the same way that we all now have cell phones, in fact, we just passed 50-percent of the people in the world having cell phones. In the same way we have that big success, we are also getting angioplasty and knee replacements and hip replacements and imaging, et cetera. So let us look at this phenomena because we have got this problem of tripling the cost of healthcare and we need to do something about it.

So here is our first model. Well okay, if the use is going to increase by some rate, we do not want the total to go up any faster than – say maybe this was the GDP growth – we do not want the total to go up any faster than the GDP. We want healthcare to track GDP but people keep on using this stuff more and more.

What are we going to do? Well we have got to decrease the cost per use somehow. So we do a little bit of calculation or algebra. Well we say we have got to get this alpha here to this rate if we are going to be able to afford this stuff. So let us look at what that means.

So here is the CDO data – annual growth of usage for angiography, angioplasty, et cetera These things are growing at ten to 15-percent per year for 40 years. Those are big numbers. Now it is the same thing as cell phones except we are happy about that of course because everybody buys their own cell phone but the technological innovation has been huge and this is what we have to do to reduce the cost of the use – per use in order to actually afford that.

Well we have got a problem with that model though. That model has a bit of a problem. First of all, there is no mechanism to achieve those cost reductions in the model. So where does it come from? We also got – we do not differentiate elements of the healthcare delivery process. It is not just decreasing costs in general but decrease them where? So let us make our model a little more complicated. One of the things we have found, I think it says it right here, and this is very well developed – this is why you have so much power on your desktop is the cost of something goes down as we do it more often.

That is why semiconductors, the way Intel makes so much money and other companies make so much money is they come down a learning curve at some rate and that learning is how they reduce the price of the product and still make a profit. So certainly maybe this can apply in healthcare. Maybe we can take this simple engineering model that has been around a long time and we could put some rate parameters in so what we would say – if we put this rate parameter in, we would say ok, after we double the number of times we do this procedure, the cost of doing it should only be 70-percent of what it was before.

That is what happens in semiconductors and a lot of manufacturing. I am sure Paul had learning rates at ALCOA. If you did not have these learning, you would not be making money. Learning is essential in whether it is for ALCOA or Intel. So let us apply this to our problem of trying to afford technological innovation in healthcare.

So let us say we try to – we go at a five-percent growth rate, five-percent increase in demand for these technologies and we try different learning curves. You could see what happens is the cost per use is going down. However, our demand is still going up significantly. This ten or 15-percent per year every, year decade after decade, the number gets very, very big. So we are having to fight the tide here.

So let us try what happens if it is ten-percent growth rate. Then see interestingly, the costs go down because we are just getting so much practice doing this but the demand is growing so fast that what we get is the following – financial growth and let us look at the bottom line here. So if we had a ten-percent growth rate, you can see that what originally costs a $100 per use is now $24. That is very impressive. However, we have quadrupled our spend on that.

Again it is just this exponential growth is compounding year after year after year that we are trying to deal with. Well this model has got a problem too because it does not seem like we can catch up with this. We get impressive cost learning but we do not see how and where we are going to get this learning. It does not reflect the fact that healthcare is more process oriented.

So let us go to a third model and say okay we actually have got a bunch of steps in the process and we have both labor and technology so let us see if we could find a way to deal with this problem that way. Now for technology learning curves, we have really good data from different industries and we can guess it is going to be a 70-percent to an 85-percent learning curve and that is what is happening. Medical devices are technology also but we have to look at – what about the labor?

So let us go on here. No we have got a much more complicated model. I will not take the whole thing but we have got cost of labor and cost of technology, which are learning at two different rates and we have got growth here and still our growth rate and demand – this is what it is going to be like if you work with engineers so okay. And so we now have our curve. Now this is kind of interesting. Let us say we only wanted healthcare to grow the GDP. That would be a reasonable goal. If we have a four-percent growth rate in GDP and only a five-percent increase in the use of the technology, you can see we need a learning curve of about 72-percent for labor.

Aggressive but doable. Other industries have done that. However, let us say we had a GDP growth of zero, so we want to keep healthcare constant and we had a 15-percent increase in growth rate. We need a 40-percent learning curve but no one has ever achieved that in anything. So and obviously that is our extreme and it could be someplace in between.

So the point is that the efficiency we would have to get in the system is rather substantial. So this is called the learning healthcare system. This really addresses the question well just how much learning do we need. Depending on your choice of parameters, we need a lot of learning to get control of this problem. How could we do that?

So what are our implications? In order to limit the growth, we need to kind of limit the growth of technology use. In other words, ration - only certain people get the innovations. We do not tend to like that in this society. We have got to limit the cost. Well it is going down pretty well. It just cannot keep up with the exponential growth or we have got to decrease the labor in the system. Overall savings to do the learning is key but we are asking for a learning rate that is very aggressive, aggressive enough that no one has ever achieved it before. SO how can we do that?

Well this is the standard set of things we could do. We could make labor more efficient. We could change the personnel mix, use lower – less expensive personnel for some of the aspects of the tasks, standardize things, et cetera but I have got a better step. The Commonwealth Fund came out with this last fall, I think, or early this year called bending the curve and they did an economic analysis of the different things we could do to actually cut costs out of the system and so this is not my list but I think it is a very interesting list. These are the ways we can approach to get that efficiency in this very nice report that is associated with this. I think you can get it off their website. Let us talk about this just to conclude now.

So successful technological innovation leads to growing markets and increased revenues. Yes, that is what our economy is about. For the innovator, it is great – a lot more revenue. However, when you have one payer especially for older people, it seems kind of daunting like Medicare having to deal with the costs. Such growth is viewed very favorably like cell phones – big success story, right?

Lots of things are big success stories because they are individual payers and we do not think about that. Other market-based mechanisms that control what is going on – maybe that is a good question. If we were going to focus on increasing system efficiency to assure this, their needed results are very substantial and to conclude, I just want to make one overall point.

I want to illustrate a little engineering and take a phenomena and what you will find working with engineers is you will first start off and there will be a real simple model and you will try that simple model and say well that is ok but these things are missing and then you will start to add things as I did and you start to get to hone in on what is the basis of the problem here? What is the phenomena we are trying to affect?

Here, the efficiency we need to get in the healthcare system to be able to actually afford healthcare – here affording means growing only the GDP, is very, very substantial. There are a lot of ways that could be done but nevertheless it is a really daunting task. Fortunately, my three colleagues are going to tell you more detail how to do that. I just wanted to lay out the yardstick here. Thank you. [Applause]

RICHARD LARSON, PhD: Good morning. My name is Dick Larson and I am a member of a global minority. I do not own a cell phone. [Laughter] Probably the only one in the audience that does not own a cell phone. Now let us see – it is working. Terrific. So we are off a Macintosh computer here. Some engineers think they are for – okay.

So if I go – I have been at MIT since age 18, life imprisonment at the same institution. I have not been able to figure out how to get out but sometimes I go to receptions. They say well what do you do? I say well I am into operations research and sometimes there might be some – the person who asks the question might have some affiliation with the medical profession and say, you know that is exactly what we need.

We need researchers in the operating room looking at those physicians doing those operations better and I would say well okay so and then their eyes roll up when I try to explain that what operations research is. So it may be early operations research in the early part of the 20th century where they are doing analysis of the OR and then gradually the OR has become more modern there and – but basically operations research is not doing research in operations other than some people tend to trivialize operations research and think that all it is – is an optimization and that these guys are basically an extension of tailorism from the 19 – teens.

We move widgets very efficiently from place to place and maybe the role of operations research really is in the operating rooms and we can best schedule the operating rooms and that is our role. So hopefully today I would like to give you some examples of where we can do more than that but I would like to go back to history and basics too and Phillip M. Morse is a physicist at MIT who is the founder of operations research in the U.S.

Basically in the late 1930s – early 40s there were other physicists who founded operations research and in Great Britain and if you go back to the first book, Morse and Kimble "Methods of Operations Research," operations research is an applied science utilizing all known scientific techniques and tools to solve a specific problem. Operations research uses mathematics but is not a branch of mathematics. I try to tell some of my OR friends these days that that is the case too and there is sometimes contention because the dominant mode in the OR silo has become more and more mathematical.

And then one of my favorites that often occurs at the major contribution of an OR worker, is to decide what the real problem is – namely to redefine the problem. The problem is not the way it was defined but it is something else and maybe quite simple to look at it that way.

So I guess at MIT, I am at the juncture of what is traditionally old fashioned operations research and a new emergent field called engineering systems and the way we do engineering systems at MIT, it is in the School of Engineering, but we tend to look at these complex systems problems and we try to put them in a box. We try to frame them in a way, which is compatible to include all other complexities.

So the complexity is traditional engineering, management issues, and not to be forgotten – social science issues and so we try to accept that we can embrace the full complexity at the then diagrammed intersection of those three and certainly the healthcare system, however you define it, has many, many such problems. So here are just some random photographs from the healthcare system as defined by a medical intervention and what is required?

Well if you go back again to the Phil Morse definition of OR, operations research, which I think is the engineering systems division idea of this then diagrammed intersection – we need multidisciplinary teams – not just teams representing one silo. We need to develop intimate knowledge of operations, the willingness and ability to invent new models, new methods, and we cannot pontificate from Ivy halls. We have to get boots on the ground, get down and dirty.

So there are some boots on the ground for you. So the way I view it, operations research of the 40s and 50s is the engineering systems of today and there are some nuances of difference but for today, let us not talk about it.

So I thought since I think 80-percent of you are from the medical community, healthcare community, 20-percent are engineers, let us talk about some applications in healthcare. For instance, there is a special issue of Operations Research, the flagship journal of the OR profession on healthcare. There is a book out, "Operations Research and Healthcare Handbook of Methods and Applications," and that has – I think 40 or 50 chapters on different applications of operations research in the healthcare sector and there are many celebrated success stories that might not be so widely known outside of operations research but these are success stories in the broader definition of the healthcare system. We like to think of the healthcare system as not only what happens when somebody gets sick but also how the – the prevention side.

So in a sense, the whole population is included. That symbol represents, by the way, the donation back of dirty needles to get a clean needle-needle exchange and Ed Kaplan who happens to be a member both of the NAE and the IOM, in 1992 was the Edelman Prize winner for his New Haven Health Department study on clean needle exchange. So unfortunately those who were addicted to heroin with using needles would often share the needles and if anyone in that group had HIV infection, the probability of getting HIV infection to others was rather high. Kaplan used fundamental operations research probabilistic modeling techniques, some of them from studying wildlife and applied it here that the equations were not fancy.

But the lateral thinking was very, very impressive and his results predicted that there be a substantial reduction in HIV/AIDS progression by the use of dirty needles if there were government-sponsored clean needle exchanges and that is the van, the initial van that was used in New Haven. This is now celebrated by Yale University and it is a major known study. Here is an example of where you go get down and dirty, get actually into the field. You talk to people who are involved in the system at all levels and then you apply some basic mathematical modeling techniques and that is what he did and he won some prestigious awards.

Much more recently, just a year ago, and I am sure Bill would like to see the Georgia Institute of Technology, Georgia Tech, is here. Eva Lee is one of the two co-winners of – in operations research and basically applied to certain aspects of cancer treatment and basically this was an Edelman Prize winner for the team device sophisticated optimization modeling technique. So yes, optimization is a tool of operations research and here they looked at three-dimensional depictions of cancerous tumors particularly prostate cancer.

And they figured out a way to put these seeds within the tumor and position them in 3D so that they have maximal positive effect and minimal negative effect and not only does this procedure save hundreds of millions of dollars per year but it improves the quality of life of those who are given this treatment.

So here is a major application of operations research – this optimization technique, for instance, Georgia Tech is well known for applying OR optimization techniques to airline crew scheduling and flight scheduling and here is a transition of that kind of methodology to a very important healthcare application. Even this year, an Edleman Prize finalist – by the way the Franz Edelman award in operations research is like the ultimate academy award worldwide in the application of these techniques to any area of practice and the fact that the healthcare has become more and more prevalent in the finalists in the nominations is quite interesting.

Here is one in Stockholm, Sweden. They did not win the award but they were a finalist. OR improves the quality and efficiency of social care and home care again, this is an issue of cost savings and improved service levels.

Ed Kaplan, I mentioned before, his colleague Larry Wine who is at Stanford used to be at MIT – have gotten national acclaim because of their papers on response to bioterrorism attacks. They have had Congressional testimony, et cetera and some of the work we have been doing recently at MIT deals with a low probability, high consequence event – the return of a pandemic influenza of the magnitude of 1918 and 1919, the so-called Spanish flu – had nothing to do with Spain.

As far as we could tell, it was born in Kansas and it killed, worldwide, about 50 million people – we will never know precisely but the probability of this depends on how basian you are, is anywhere between one-percent and five-percent on an annual basis – the probability of something like this coming back and if it is not – if we are not prepared for it worldwide, it has the potential to kill more people than a full nuclear exchange between two nuclear powers.

So therefore, it does make sense to look at this thing and the way we are looking at is we have these pictures here of Grand Central Station, New York, basically it is like any respiratory infectious disease, it is spread from person to person by face to face contact and touching contaminated pieces of metal and wood and other kinds of things.

The various states now have been given the responsibility and here we see just one day from a Google news alert for the flu pandemic where we see Alabama, Washington, Maine, Arizona, Wyoming, et cetera, et cetera all these states individually have to prepare their own pandemic flu plan and we have read them. We read them all and last week, in fact, at MIT we had a workshop with 12 states represented and imagine 50 hurricane Katrinas all happening at the same time and each state on their own, there is no federal aid to come.

So that is the way we like to think about this and what we are doing is we are trying to apply operations research – thinking, lateral thinking, some creative thinking to NPIs, non-pharmaceutical interventions.

These non-pharmaceutical interventions, there is strong evidence now can greatly reduce the probability that you and your loved ones and your co-workers will become infected should this disease hit the world. There is no way to cordon off boundaries. If it hits any place in Asia or any place else, the United States will get it with the probability of one minus tiny, tiny epsilon and so therefore, what can you do?

So we are looking at non-pharmaceutical interventions such as social distancing, which can be government mandated like closing schools, personal choice like telecommuting, or altering your shopping patterns and hygienic behavioral changes – very key – hand washing, 30 seconds minimum, hot water, lots of soap several times a day. Proper coughing and sneezing, face masks, avoiding crowds – that ladies and gentlemen, is an improper cough or a sneeze. That is an approved cough or sneeze into your elbow. It is funny – even when I go into medical facilities, I find how few workers in the medical facilities are aware of these things. They cough into their hands, which is not a good thing to do.

Another thing we are looking at, again using probability models of operations research, one of the most popular and fundamental figures – parameters in epidemiology are the R0 – the mean number of new infections generated by a typical newly infected person and a fully susceptible population.

The idea – it is very conducive to think of this thing of R0 is like two for instance, that means if I become infected with this disease before I am retired and isolated from the population, on average I will infect two more and then the next generation, there will be four and then after that, it is eight and 16. It is a doubling every generation. So the idea is if R0 is greater than one, you get an exponential increase.

If R0 is less than one, you get a geometric decay and that is all very well and good but the problem is many in the medical community treat R0 as a constant of nature. They will say a paper, well consider an infectious disease – respiratory infectious disease if R0 equals 2.6003724 and we will work from there. Well evidence recently suggests strongly that R0 can be decomposed into behavioral components and the behavioral components – I mean it gets more nuanced than the equation I have here – also from MIT – you have to see at least one Greek letter, so there is Lambda up there. That is Lambda.

So we are saying that R0 is the first order – P times Lambda where Lambda is the frequency of daily contacts and P is the probability of transmitting infection given contact. So again we can be more nuanced on this and actually there are vectors and matrices involved here but the idea is the frequency you can change. Recent research has indicated that about 15-percent of the population has four or fewer face-to-face contacts per day.

Another 15-percent of the population has a hundred more face-to-face contacts per day and most of us are in between those extremes and P represents the probability of giving it to somebody if – let us say if I am infected and I shake your hand, what is the probability of giving it to you – both Lambda and P are somewhat controllable by us, by our family members, by our co-workers and therefore, we can influence R0 as was done in 2003 in SARS in Hong Kong and elsewhere where the population drastically changed their behaviors.

So there are many roads forward and delighted that Paul O'Neill is here. His article in ORMS Today I think is required reading for all of us on why the U.S. healthcare system is so sick and what OR can do to cure it. That is available online, no charge, and there are lots of other areas in research that is related to OR that maybe in the ven diagram goes to social science, that is needed as well, for instance, physicians understanding and our own understanding of uncertainty.

Most people, including physicians, seem not to understand probability in risks the way they should. A nice little short read on this is that book, "Complications: A Surgeon's Notes on an Imperfect Science," and there is a picture of it there. I do not get any royalties if you buy it but it is a fascinating book and all the time, every day, physicians and healthcare providers have to make decisions based on a lot of confounding factors and they have to really calculate conditional probabilities and most of us, not just physicians, most of us are very bad at that.

There is additional research possibilities here and I know the red light is on so I will just show it to you and we could talk about it later if you want.

Going forward, most likely, the most transformative applications of operations research and engineering systems to healthcare have not yet been identified but we do need feet on the ground. We cannot pontificate from our offices and I think one of the key questions here in the whole area, imagine you or a loved on or a friend in a hospital, given hospital care, and the issue is who is the Harry Truman for any given patient in the hospital and that is the person who says the buck stops here.

Maybe the last thing I will say is we also need to get healthcare and preventive issues more and more into our popular culture and I will show my age here by showing my favorite example of this. I was feeling so bad I asked my family doctor just what I had. I said doctor, doctor, Mr. MD, can you tell me what is ailing me and anyway, you could see my age because I remember this song. This is from 1966. With that I will conclude. Thank you very much. [Applause]

PAUL O'NEILL, MS, MPA: We are running ok with time and I wonder if you have follow-up questions fro Bill or Dick before we take our break? I think we are going to take a break. Okay.

MALE SPEAKER: Twenty minutes, come back at five minutes to the hour. We will be all set. Thanks.

[END RECORDING]